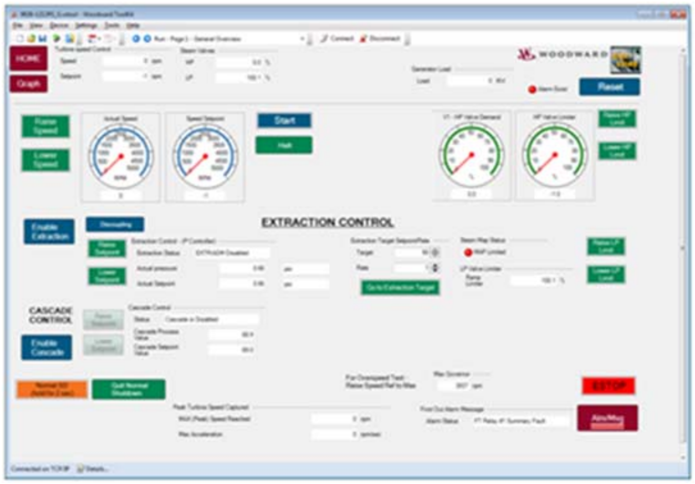
WOODWARD

Product Manual 26518V1
(Revision E, 4/2017)
Original Instructions



MicroNet TMR® 5009FT
Fault-Tolerant Steam Turbine Control

Operations Manual

Manual 26518 consists of 4 volumes (26518V1, 26518V2, 26518V3, 26518V4)

Volume 1

General Precautions	**Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.** **Practice all plant and safety instructions and precautions.** **Failure to follow instructions can cause personal injury and/or property damage.**

Revisions	**This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, check manual *26455*, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, on the *publications page* of the Woodward website:** **www.woodward.com/publications** **The latest version of most publications is available on the *publications page*. If your publication is not there, please contact your customer service representative to get the latest copy.**

Proper Use	**Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.**

Translated Publications	**If the cover of this publication states "Translation of the Original Instructions" please note:** **The original source of this publication may have been updated since this translation was made. Be sure to check manual *26455*, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.**

Revisions— A bold, black line alongside the text identifies changes in this publication since the last revision.

Contents

Illustrations and Tables

Warnings and Notices

Important Definitions

This is the safety alert symbol used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER** - Indicates a hazardous situation, which if not avoided, will result in death or serious injury.
- **WARNING** - Indicates a hazardous situation, which if not avoided, could result in death or serious injury.
- **CAUTION** - Indicates a hazardous situation, which if not avoided, could result in minor or moderate injury.
- **NOTICE** - Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT** - Designates an operating tip or maintenance suggestion.

WARNING Overspeed / Overtemperature / Overpressure	**The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.** **The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.**

WARNING Personal Protective Equipment	**The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:** • **Eye Protection** • **Hearing Protection** • **Hard Hat** • **Gloves** • **Safety Boots** • **Respirator** **Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.**

WARNING Start-up	**Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.**

Electrostatic Discharge Awareness

NOTICE **Electrostatic Precautions**	**Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:** • **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).** • **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.** • **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.** **To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual *82715*, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.**

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Chapter 1.
General Information

Introduction

The technical documentation for the 5009FT Control System consists of the following volumes:

Volume 1—provides information on system application, control functionality, fault tolerant logic, control logic, PID setting instructions, and system operation procedures.

Volume 2—provides hardware descriptions, mechanical and electrical installation instructions, hardware specifications, hardware troubleshooting help, and basic repair procedures.

Volume 3—provides installation procedures for the 5009FT control's personal computer based interface software program (CCT), information on all CCT features and modes (Configure, Service and Run).

Volume 4—provides details on installation and operation of the OpView™ operator control station, if provided with your system. It contains a list of the control's Modbus® * registers and tag names.

*—Modbus is a registered trademark of Schneider Automation Inc.

5009FT System part numbers covered in this manual are:

Control System Installation Procedure

1. Review all system manuals to gain an understanding of the control system.

2. Create a site-specific wiring diagram by referencing Volume 2's wiring diagrams, and then perform mechanical and electrical installation following Volume 2 instructions and the generated wiring diagram.

3. Apply power to 5009FT Control and reset all three CPU's by pressing the momentary reset button in the top/front of the module.

4. Connect a keyboard and mouse to the front panel CCT Panel. Configure the system using the CCT graphical interface screens (refer to Volume 3).

5. Perform a full system checkout; clear all system trips and alarms (refer to Volume 1, Chapter 6); adjust linkages and stroke actuators (refer to Volume 1, Chapter 6).

When ready to start the turbine, follow the operation instructions of Volume 1, Chapter 6. During initial start-up, the dynamics of each PID controller will need to be adjusted (refer to Volume 1, Chapter 6)

This volume provides control system description, and operation instructions for the Woodward MicroNet TMR® 5009FT Control System. It includes:
- General description of the control system
- Detailed functionality descriptions including I/O handling
- Control system operation
- Information on optional equipment
- Detailed functionality description of start-up procedures
- Detailed information on alarm and trip messages
- Detailed information on Modbus parameters

This manual applies to all 5009FT Control Systems but does not include information that is unique to your system. The 5009FT Control System can be provided in a number of hardware configurations and for steam turbine applications driving either a Generator or a Compressor as shown in Table 1-1. Because this manual addresses all configurations, many of the system software and hardware descriptions may not apply to your particular 5009FT System.

This manual does not contain instructions for the operation of the complete turbine system. For turbine or plant operating instructions, contact the plant- equipment manufacturer.

Table 1-2. Control Component Hardware

8262-1111	Control-- 5009FT Cabinet w/2 120 Vac/dc TMR PS
8262-1112	Control-- 5009FT Cabinet w/2 120 Vac/dc TMR PS + Integ Act Kit
8262-1113	Control-- 5009FT Cabinet w/2 120 Vac/dc TMR PS + Comp Cntrl Kit
8262-1114	Control-- 5009FT Cabinet w/2 120 Vac/dc TMR PS + Integ Act & Comp Cntrl Kit
8262-1115	Control-- 5009FT Cabinet w/2 220 Vac TMR PS
8262-1116	Control-- 5009FT Cabinet w/2 220 Vac TMR PS + Integ Act Kit
8262-1117	Control-- 5009FT Cabinet w/2 220 Vac TMR PS + Comp Cntrl Kit
8262-1118	Control-- 5009FT Cabinet w/2 220 Vac TMR PS + Integ Act & Comp Cntrl Kit
8262-1123	Control– 5009FT MicroNet w/2 24 Vdc TMR PS
8262-1124	Control– 5009FT MicroNet w/2 24 Vdc TMR PS+ Integ Act Kit
8262-1125	Control– 5009FT MicroNet w/2 24 Vdc TMR PS+ Comp Cntrl Kit
8262-1126	Control– 5009FT MicroNet w/2 24 Vdc TMR PS+ Integ Act & Comp Cntrl Kit
8262-1119*	Control-- 5009FT Cabinet w/2 120 Vac/dc TMR PS w/o CCT
8262-1120*	Control-- 5009FT Cabinet w/2 120 Vac/dc TMR PS + Integ Act Kit w/o CCT
8262-1121*	Control-- 5009FT Cabinet w/2 220 Vac TMR PS w/o CCT
8262-1122*	Control-- 5009FT Cabinet w/2 220 Vac TMR PS + Integ Act Kit w/o CCT

*CCT hardware not included as part of these P/Ns.

Chapter 2. Description

General

The 5009 Fault-Tolerant Control System is designed to control single valve, split- range valve, single controlled-extraction, single controlled-admission, or single controlled-extraction/admission steam turbines. The 5009 Control System is field programmable which allows a single design to be used in many different control applications and reduces both cost and delivery time. It uses a Windows-based computer program (CCT) to allow a user to configure the control, perform on-line program changes, perform on-line hardware tests, and alternatively operate the turbine. This control can be used as a stand-alone unit or in conjunction with a plant's Distributed Control System (DCS).

Control Fault Tolerance

The basis of this control's fault tolerance architecture is to detect control related faults, annunciate these faults, and allow on-line service/replacement of modules and/or transducers to correct these faults.

This control's architecture allows it to operate with any single point of failure, without shutting down the turbine. A CPU fault tolerance logic of 3-2-0 allows the control to function normally with any CPU module failed or removed. An analog I/O fault tolerance logic of 3-2-1-0 allows the control to function normally with any one or two analog modules failed or removed. A discrete I/O fault tolerance logic of 3-2-0 allows the control to function normally with any one discrete module failed or removed. A power supply fault tolerance logic of 2-1-0 allows the control to function normally with any one power supply failed or removed.

Three isolated kernel sections (A, B & C) each house a Kernel Power Supply module, CPU module, Analog Combo I/O module, and a Discrete I/O module. Optionally an Analog I/O module can be added to each kernel, and also an Actuator Controller module can be added to Kernels A and B. A single motherboard supplies nine electrically isolated data paths. Each CPU has a data path to its VME modules and two separate data paths, one to each of the other CPU modules. There is a total of six paths between CPUs allowing for redundancy and error checking.

All control inputs and outputs are Triple Modular Redundant (TMR); meaning that each individual analog and speed input is monitored by all three 5009 Control System kernels, then voted upon to ensure that the correct input value is used for control. Each input is split at one of the control's field termination module, and routed to the three kernels (A, B, C) via separate I/O cables; this allows on-line module replacement. Each control output signal is the sum of the three kernels outputs. Because the control monitors the health of each kernel's output signal, it can detect, alarm, and react to any system output fault.

The 5009 Control System allows redundancy to be extended beyond the control, by allowing multiple transducers to be used for any critical control parameter. Optionally the control can be configured to accept up to four speed sensor inputs, and three analog input signals (from separate transducers) for any single critical control parameter.

Table 2-1. System Module Layout

Woodward 5009FT MicroNet+ TMR Control System				
Main Chassis – MicroNet+ TMR P/N = 5453-279				
Chass/ Kernel/ Slot	**Module P/N**	**Module Description**	**Cable / Length (Qty)**	**FTM P/N (Qty)**
1/A/1	5466-1049	MicroNet Kernel Power Supply – 24 Vdc Input	—	—
1/A/2	5466-1047	CPU - PowerCCT5200 400 MHz	5417-393 / 7'	—
1/A/3	5466-1115	TMR High Density Analog Combo I/O	5417-026, -027 / 6-8'	5501-502 (1) 5501-372 (1)
1/A/4	5466-1051	TMR HD Discrete I/O (24 in / 12 out)	5417-172 / 8' (2)	5453-276 (4)
1/A/5	5466-257*	TMR High Density Analog I/O (24/8)	5417-172,-173 / 8-10'*	5501-372 (2)*
1/A/6	5501-432*	Actuator Controller Module (2 Chan)	5417-041 / 12'*	5437-672*
1/B/1	5466-1049	MicroNet Kernel Power Supply – 24 VDC Input	—	—
1/B/2	5466-1047	CPU - PowerCCT5200 400 MHz	5417-393 / 7'	—
1/B/3	5466-1115	TMR High Density Analog Combo I/O	5417-026, -027 / 6-8'	5501-502 (x) 5501-372 (x)
1/B/4	5466-1051	TMR HD Discrete I/O (24 in / 12 out)	5417-172 / 8' (2)	5453-276 (x)
1/B/5	5466-257*	TMR High Density Analog I/O (24/8)	5417-172,-173 / 8-10'*	5501-372 (2)*
1/B/6	5501-432*	Actuator Controller Module (2 Chan)	5417-041 / 12'*	5437-672
1/C/1	5466-1049	MicroNet Kernel Power Supply – 24 VDC Input	—	—
1/C/2	5466-1047	CPU - PowerCCT5200 400 MHz	5417-393 / 7'	—
1/C/3	5466-1115	TMR High Density Analog Combo I/O	5417-027 / 8 (2)	5501-502 (x) 5501-372 (x)
1/C/4	5466-1051	TMR HD Discrete I/O (24 in / 12 out)	5417-172 / 8' (2)	5453-276 (x)
1/C/5	5466-257*	TMR High Density Analog I/O (24/8)	5417-172,-173 / 8-10'*	5501-372 (2)*
1/C/6	3799-301	Blank	—	—

* Optional Item, See Volume 2, Appendix B

Each CPU module runs the identical software application as the other two. All inputs from each kernel are distributed to the other two kernels. Each CPU then compares the value it read, with the value the other two CPUs read, before outputting a signal to the application software. Depending on the configuration, a total of nine values for the same input parameter could be used in the voting logic to provide the best signal to the application software. Even if a data value has been corrupted along any one of the data paths shown in Figure 2-1, all CPUs use the same correct data for their application calculations. All CPUs use the same voted input signals in the same application calculations to generate the same outputs.

All output values are exchanged between kernels, the results are voted and the appropriate value is output from each kernel. Since the system can handle significant single errors, even multiple errors may not shutdown a kernel section. In the event of consistent errors from one of the kernel section, an alarm will be annunciated and that particular kernel will be shut down. Figure 2-1 shows the input to output structure of the MicroNet TMR®.

The 5009 Control System's redundancy architecture allows all control modules to be replaced one at a time while the turbine is on-line and operating at full power (sometimes referred to a Hot Replacement).

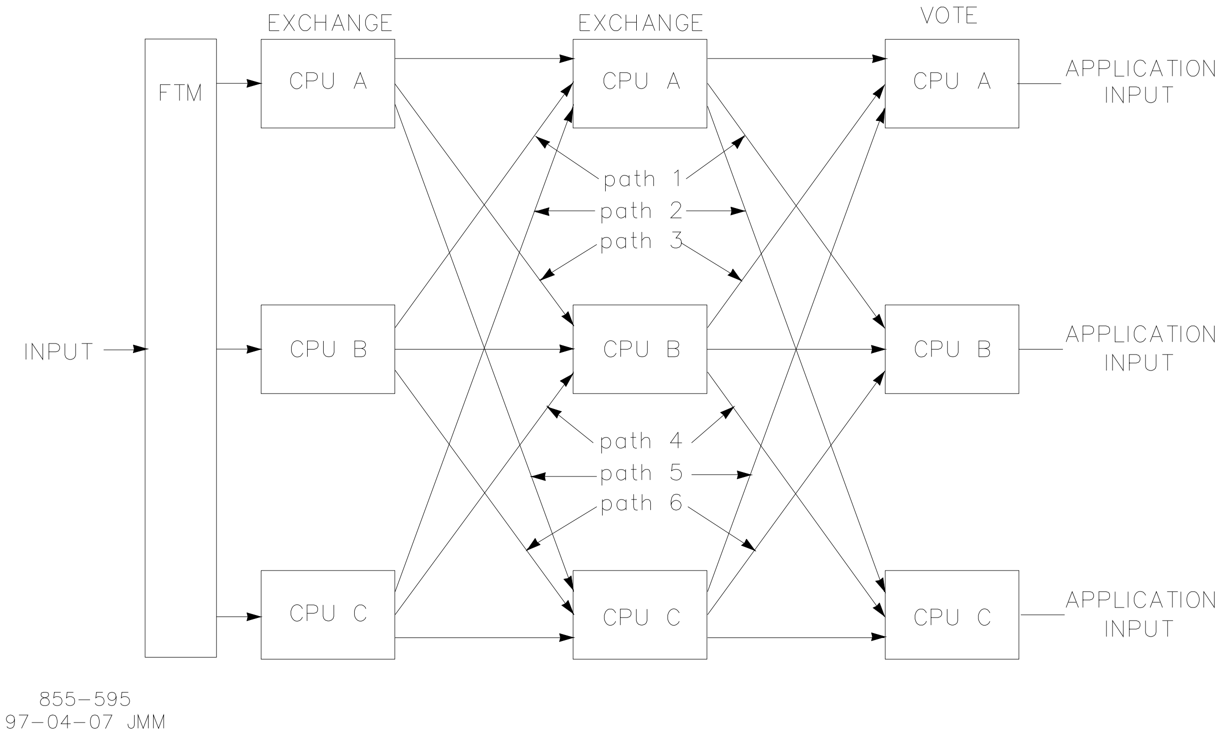


Figure 2-1. Double Exchange and Vote Structure

Speed Inputs

The control can accept one, two, three, or four speed inputs. Each speed input is monitored by all three kernels. With twelve possible speed signals from which to control with, the control can withstand multiple speed input failures with no loss of control functionality. Only one of the possible twelve inputs is required for speed control. The control can accept a 'slow speed' detect probe on channel 4 which can be unique or different from the other speed signals.

All speed inputs are connected to the control, via field termination modules (FTMs). An input's termination module is used to terminate customer control wiring and distribute each input signal to all three kernels. After the control's kernels double exchange their input values, and vote out any erroneous values, the Application Software Redundancy Manager then compares each kernel's voted result to select a value to be used within the application logic. Figure 2-2 is a graphical view of a control input's architecture. Table 2-2 displays the redundancy manager's input selection logic, for each possible input condition.

A speed input signal is determined to be faulty and is taken out of the input voting logic when it is below its "Speed Failure Level" setting. This failure level setting is common to all inputs and can be adjusted via the CCT program's Service mode. Refer to Volume 3 for all CCT program procedures.

An input deviation alarm is also used to annunciate if any of the four possible speed input channels is sensing a value that is different than the voted-good value used by the application. If an input channel's sensed value deviates from the voted-good signal value, by a greater margin than the speed control's "Max Deviation" setting, an input channel alarm will be issued. This type of annunciation can be used to indicate when an input channel or magnetic pickup unit is intermittently failing high or low. Max Deviation input settings are tunable via the CCT program's Service mode, and are defaulted to 1% (deviation range = .01 to 20%) of the "Overspeed Limit" setting. If a deviation alarm condition occurs, the alarmed input is not removed from the control's voting logic and still can be used to control with, in case all other channels fail.

The voting logic when more than one speed input (MPU or Prox. Probe) is used is as follows:

- With 4 good sensors, use the median 2 sensors
- With 3 good sensors, use the median value
- With 2 good sensors, use the higher value
- With 1 good sensor, use the good sensor's value

Analog Inputs

The control can accept one, two, or three transducer inputs for all critical parameters (ext/adm, aux, casc inputs). Only one input signal is accepted for non-critical functions (remote setpoint inputs). Each analog input can withstand up to two failures with no loss of control functionality. If any two of an analog input's three "legs" are failed, the control uses the third healthy leg's sensed input signal from which to control with.

All analog inputs are connected to the control, via field termination modules (FTMs). An input's termination module is used to terminate customer control wiring and distribute each input signal to all three kernels. After the control's kernels double exchange their input values, and vote out any erroneous values, the Application Software Redundancy Manager then compares each kernel's voted result to select a value to be used within the application logic. Figure 2-2 is a graphical view of a control's input architecture. Table 2-2 displays the redundancy manager's input selection logic, for each possible input condition.

Optionally, each leg of an input channel can be tested and its calibration verified through the CCT program's Service mode, by individually removing the other two input legs. Refer to Volume 3 for all CCT program mode procedures.

An analog input signal is determined to be faulty when it is below its "Fail Low Value" setting, or above its "Fail High Value" setting. These failure level settings can be adjusted via the CCT program's Service mode and are defaulted to values in engineering units which correspond to 2 mA and 22 mA respectively. If an input is determined to be failed, that input is removed from the control's voting logic.

Input deviation alarms are used to annunciate if any of the input channels or input legs are sensing a value that is different than the voted-good value used by the application. If an input channel's sensed value deviates from the voted-good value, by a greater margin than its "Max Deviation" setting, an input channel alarm will be issued. This type of annunciation can be used to indicate when an input channel or system transducer is going out of calibration. Max Deviation settings are tunable via the CCT program's Service mode, and are defaulted to 1% (deviation range = .1 to 10%) of the configured input range. If a deviation alarm condition occurs the alarmed input is not removed from the control's voting logic, and still can be used to control with, in case all other channels fail.

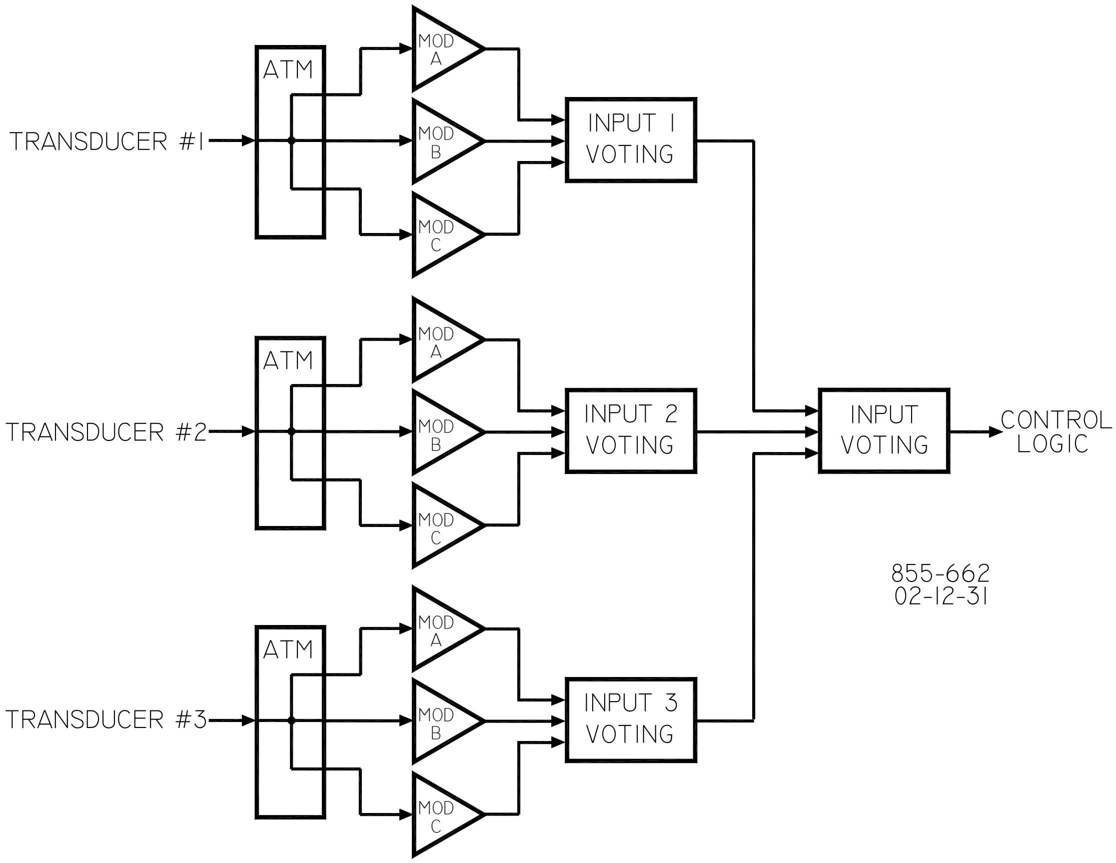


Figure 2-2. Fault Tolerant Analog Input

Table 2-2. Redundancy Manager Truth Table

A-FAULT	B-FAULT	C-FAULT	OUTPUT OF BLOCK (APPLICATION INPUT)
FALSE	FALSE	FALSE	MEDIAN OF A, B, & C-INPUT
FALSE	FALSE	TRUE	HSS* OF A & B-INPUT
FALSE	TRUE	FALSE	HSS* OF A & C-INPUT
FALSE	TRUE	TRUE	A-INPUT
TRUE	FALSE	FALSE	HSS* OF B & C-INPUT
TRUE	FALSE	TRUE	B-INPUT
TRUE	TRUE	FALSE	C-INPUT
TRUE	TRUE	TRUE	APPL. INPUT SET TO ZERO/FAULT SET TRUE

*HSS -> HIGH SIGNAL SELECT

855-594
97-04-07 JMM

Discrete Inputs
Each discrete input can withstand up to two failures with no loss of control functionality. If any two of a discrete input's three "legs" fail, the control uses the third healthy leg's sensed input signal from which to control with.

All discrete inputs are connected to the control via field termination modules (FTMs). A FTM is used to terminate customer control wiring and distribute each input signal to all three kernels. After the control's kernels double exchange their input values and vote out any erroneous inputs, the Application Software Redundancy Manager then compares each kernel's voted result to select a value to be used within the application logic. Figure 2-3 is a graphical view of the control's discrete input architecture.

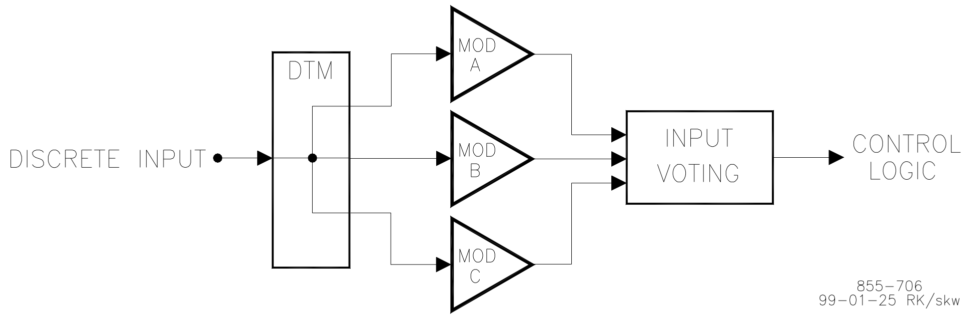


Figure 2-3. Fault Tolerant Discrete Input

A discrete input signal is determined to be faulty when it is determined to be different than the voted-good value used by the application. If an input is determined to be faulty, the input is removed from the control's voting logic and an input channel alarm is issued. Once the input fault is corrected the alarm condition can be reset by issuing a control "Reset" command.

Readouts (Analog Outputs)
Each control readout can withstand up to two failures with no loss of output functionality. Any leg of an output channel can drive a readout's full 4–20 mA current signal. After each CPU generates an analog output signal, the signals are exchanged between CPUs, voted on, and sent to the Redundancy Manager for output. The Redundancy Manager divides the output signal based on the number of known good output channels and distributes each portion of the signal to the respective output channel.

Precision resistors are used in each channel's readback circuitry to measure and verify the health of each output "leg". If a fault condition is detected, the faulty output leg is disabled, and the Redundancy Manager redistributes the output signal to the remaining legs. In a case where two failures are experienced at the same time within different legs, the single good channel (leg) will drive the entire output. Figure 2-4 shows a Fault Tolerant Analog Output's architecture. The Field Termination Module (FTM) combines each analog output signal from all three kernels into one signal at the FTM's terminal blocks.

An output is considered failed, and an alarm issued, if a channel's combined output or any leg of the output measures a difference of more than 10% from the output demand. Optionally, each leg of a readout channel can be tested and its calibration verified through the CCT program's Service mode, by individually removing the other two output legs. Refer to Volume 3 for all CCT program functionality.

With this output architecture, any single output driver failure results in the output signal only stepping to 66.66% of its original value. The time between when a failure is sensed and when the control corrects for it by redistributing current through the other drivers can be as long as 50 milliseconds.

Upon the correction of an output failure, and a "Control Reset" command, each failed output performs a continuity check though the its external load before current is again redistributed evenly between all output drivers. This continuity check entails, the failed driver to output a small amount of current through its output load, and compare that value with what is readback. The time between when a continuity check is performed and when the control redistributes current through the all drivers can be as long as 50 milliseconds.

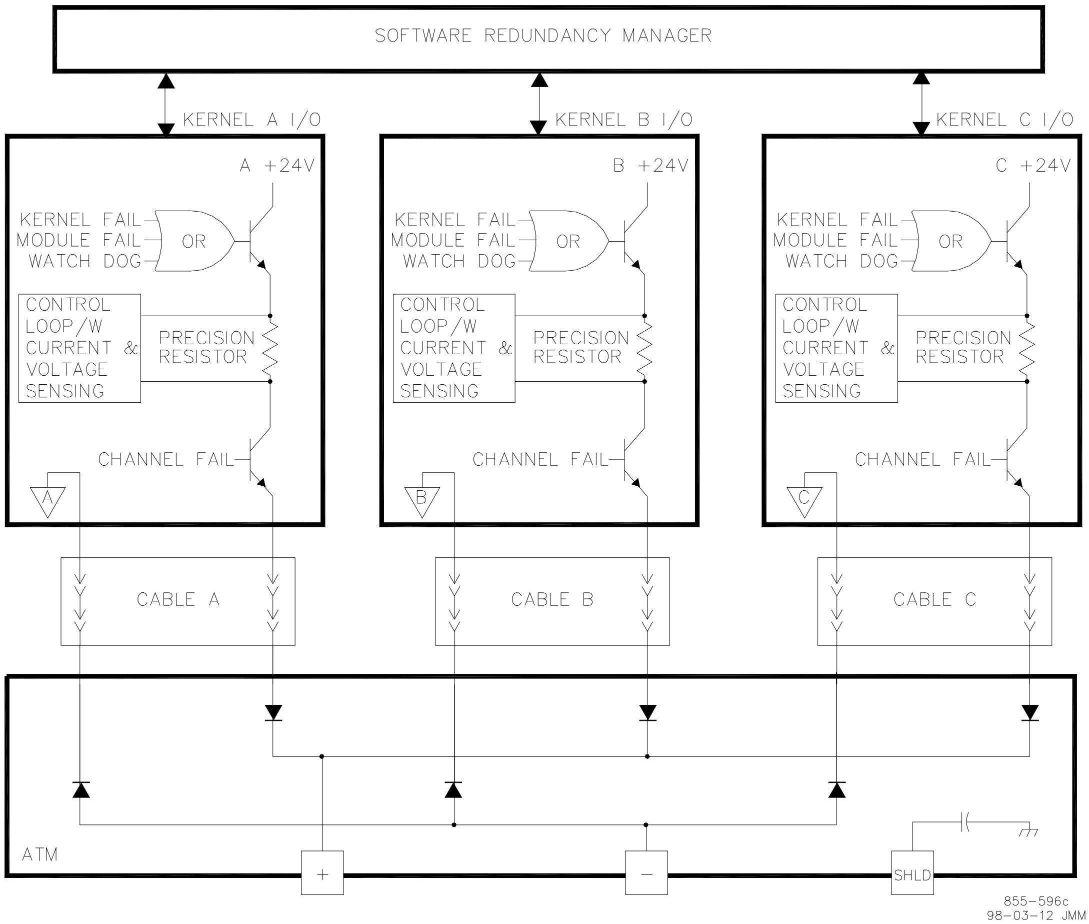


Figure 2-4. Fault Tolerant Analog Output

Actuator Outputs

Each actuator output can withstand up to two failures with no loss of output functionality. Any leg of an output channel can drive an output's full current signal (4–20 mA or 20-160 mA). After each CPU generates an actuator output signal, the signals are exchanged between CPUs, voted on, and sent to the Redundancy Manager for output. The Redundancy Manager divides the output signal based on the number of known good output channels and distributes each portion of the signal to the respective output channel.

Precision resistors are used in each channel's readback circuitry to measure and verify the health of each output "leg". If a fault condition is detected, the faulty output leg is disabled, and the Redundancy Manager redistributes the output signal to the remaining legs. In a case where two failures are experienced at the same time within different legs, the lone good channel (leg) will drive the entire output. Figures 2-5 and 2-6 show a Fault Tolerant Actuator Output's architecture. The Field Termination Module (FTM) combines each actuator output signal from all three kernels into one signal at the FTM's terminal blocks.

An output is considered failed, and an alarm issued, if a channel's combined output or any leg of the output measures a difference of more than 10% from the output demand. Optionally, each leg of a readout channel can be tested and its calibration verified through the CCT program's Service mode, by individually removing the other two output legs. Refer to Volume 3 for all CCT program functionality.

⚠WARNING	**Before calibrating or testing, the unit must be tripped and the steam supply removed. This is to ensure that opening the control valve(s) will not allow steam into the turbine. Overspeeding the turbine may cause damage to turbine and can cause severe injury or death to personnel. STEAM TO THE TURBINE MUST BE SHUT OFF BY OTHER MEANS DURING THIS PROCESS.**

Actuator outputs, or HP and LP valve outputs, are treated the same way as the other analog outputs, with the exception of an added precision resistor in the actuator output's return path. This resistor is used to measure and detect ground loops and coil shortages that are possible when interfacing to an actuator. If a single coil actuator is being driven, the dual coil terminal blocks are jumpered (wired) to the single coil terminal blocks and the redundancy manager shares the current equally between all three kernels. In the event of a fault, the Redundancy Manager will redistribute the load.

If the actuator connected to is a dual coil actuator, the Redundancy Manager shares half the current evenly between Kernels A & B outputs, and the other half comes from the Kernel C output. In the event of a fault, the Redundancy Manager redistributes load current.

With this output architecture, any single output driver failure results in the output signal only stepping to 66.66% of its original value (possibly 50% for dual coil applications). The time between when a failure is sensed and when the control corrects for it by redistributing current through the other drivers can be as long as 50 milliseconds.

Upon the correction of an output failure, and a "Control Reset" command, each failed output performs a continuity check though the actuator before current is again redistributed evenly between all output drivers. This continuity check entails, the failed driver to output a small amount of current through its output load, and compare that value with what is readback. The time between when a continuity check is performed and when the control redistributes current through the all drivers can be as long as 50 milliseconds.

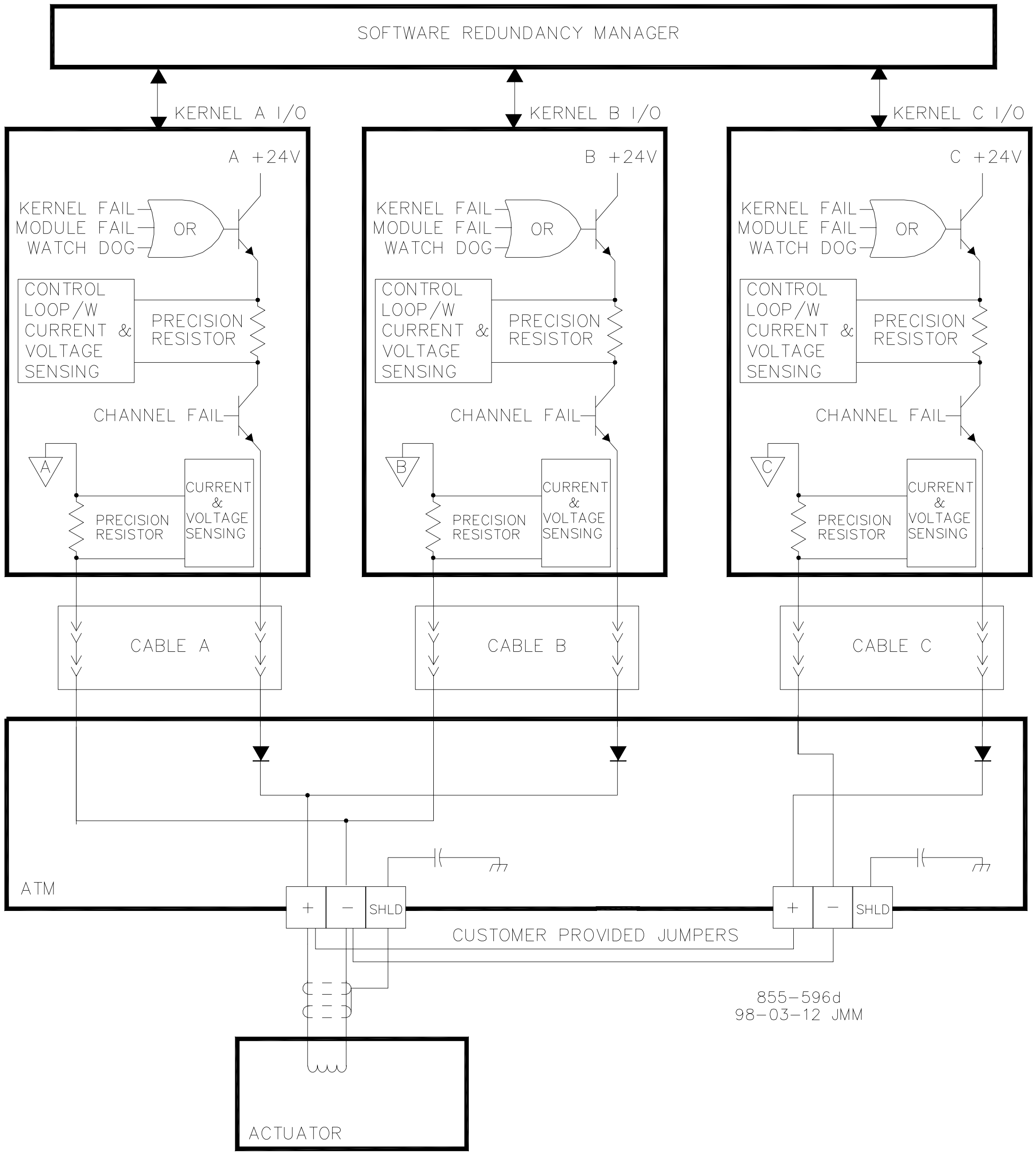


Figure 2-5. Fault Tolerant Single Coil Actuator Output

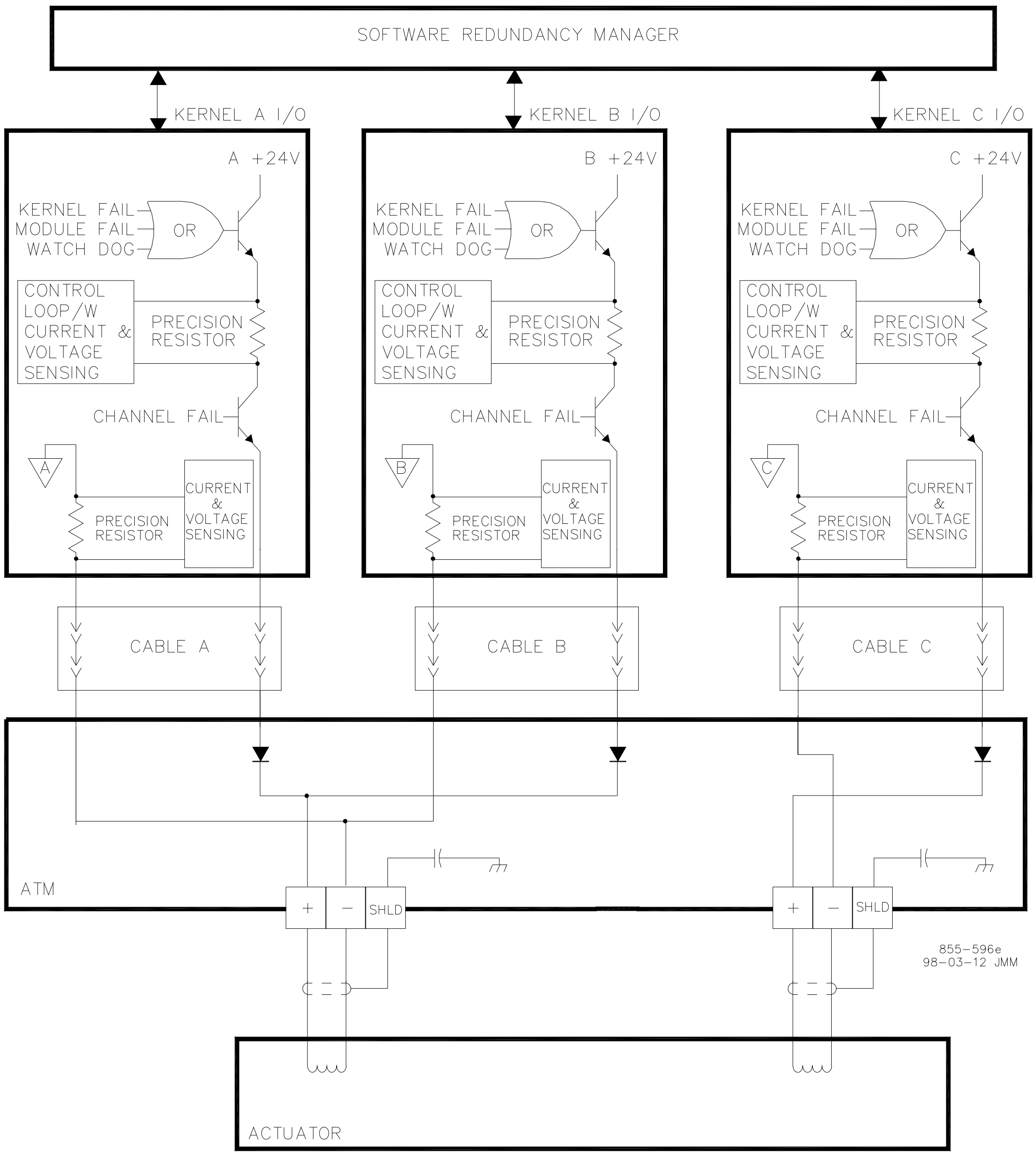


Figure 2-6. Fault Tolerant Dual Coil Actuator Output

Relay Outputs

Twelve fault tolerant relay outputs are provided with this control. With this control's architecture, a six relay configuration is used to form each fault tolerant relay output. When a relay output is closed, the contacts of all six relays are closed. Because of the series-parallel configuration that the relays are in, the failure of any individual relay will not cause the output to be open. This series- parallel configuration also allows any single relay of the six relay configuration to be removed and replaced "on-line" with no affect on the state of the fault tolerant relay output.

When a relay output is open, the contacts of all six relays are open. Because of the series-parallel configuration that the relays are in, the failure or removal of any one relay will not cause the output to be closed. The relay output would continue to be open.

Since this control's fault tolerant architecture can tolerate a single fault, it is possible for this fault to go undetected. This is called a latent fault. If a second fault occurs while a latent fault exists, the state of the fault tolerant relay output may be affected, possibly resulting in a shutdown condition. This is why it is important to detect and annunciate latent faults in a fault tolerant system.

Latent fault detection is provided with this control to detect any relay related failure without affecting the state of the overall relay output. Each individual relay output can be configured to use or not use latent fault detection. A latent fault detection test is performed periodically or on command through the CCT. The period of time between tests can be set from 1 to 3000 hours.

A relay output is tested by cycling the output's individual relays closed then open (or vice-versa depending on the output state), to ensure that they are in the correct state, and that they can change state. Position readback circuitry allows the state of each relay contact to be detected. Any failures are annunciated, and further testing is disabled without affecting the state of the relay output contact or control operation.

Each fault tolerant relay configuration consists of 6 relays, driven by two discrete outputs from each kernel (as shown in Figure 2-7). The relays are configured in three legs of two relays each. Customer circuit power is connected to one side of the resulting configuration, and customer load to the other side. Field selectable jumpers, located on system FTMs, are provided to allow each output's latent fault detection logic to be compatible with the circuit being interfaced to. Latent fault detection is used to monitor the actual contact positions of each of the six relays, and to momentarily change states of each relay one at a time. This verifies each relay's "normally open" or "normally closed" contacts.

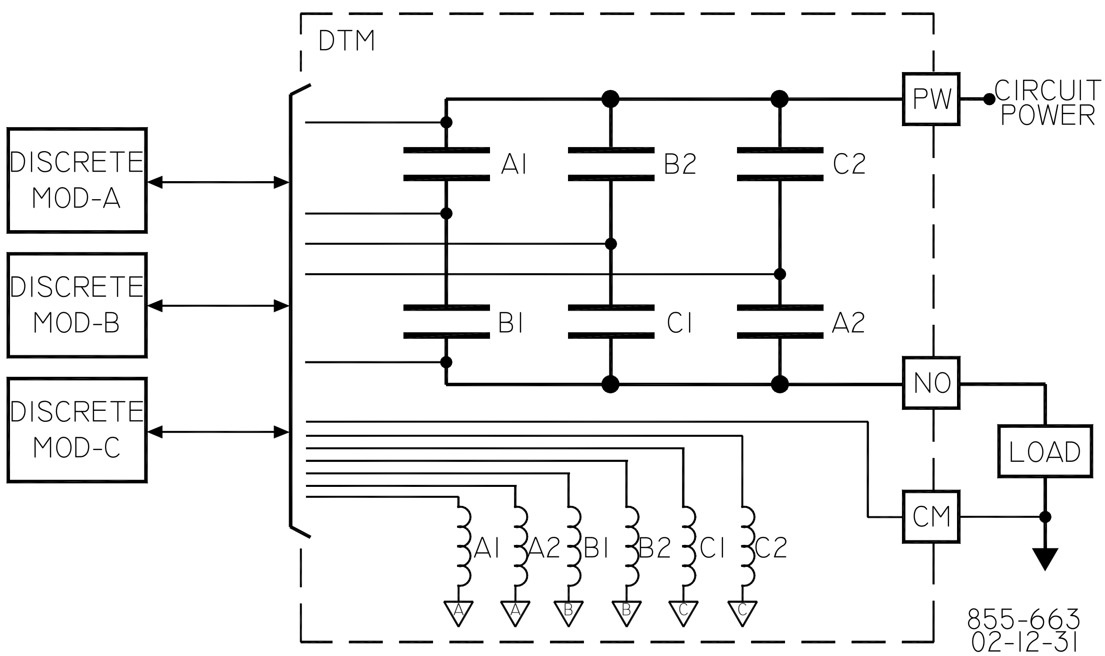


Figure 2-7. Fault Tolerant Discrete Output

Latent fault detection (LFD) is not usable with all applications or circuits. The control's LFD logic can only work with circuits using voltages between 18–32 Vdc, 100–150 Vdc, or 88–132 Vac. For latent fault detection to work, a small leakage current is passed through the circuit's load. Depending on the size of the load, the leakage current may be enough to cause a load to be on or active, when a relay contact is open. In this case, the individual relay's latent fault detection logic may be disabled, eliminating the leakage current, or a shunt resister can be used across the load to reduce the leakage current. Refer to Volume 2 of this manual to determine if Latent Fault Detection can be used with a circuit.

Servlink Communications

Each of the three CPU's supports Woodward's Servlink protocol to our service tools and provides a direct Woodward Servlink connection to the CCT through the provided network switch. All of the CCT service tools are defaulted to communicate to the first Ethernet RJ45 port (ETH1) on CPU-A. If Kernel A is not available for some reason, the service tools can easily be reconnected to a different CPU (a different TCP/IP address). Refer to Volume 3 for all CCT program functionality options.

All communication input values and commands from the CCT, including the saving of tunable/configuration settings are sent to all three CPU's.

Modbus Communication Ports

The 5009FT can be configured for Modbus Communications with a Woodward provided HMI offering, a distributed control system (DCS) or other operator control panel. The control can communicate via TCP, UDP, or serial to these other devices. To support various types of operator interface redundancy there are 2 Modbus blocks each with 2 communication links that are fully configurable. The first Modbus block also has an additional third link that can be used which is a view-only link.

The user can select the ability to enable or disable write commands from each link in the following manners:

Modbus View Only - NO Writes
Modbus Writes Always Enabled
Modbus Writes when Selected

The last choice allows the user to enable/disable the writes from the CCT or from a discrete input command (Remote/Local).

Internal control logic referred to as LOCAL/REMOTE functionality, permits Modbus ports to be temporarily disabled. This logic allows a user at one interface panel to lockout commands from other turbine/control interface panels. For safety reasons, the CCT (engineering workstation) ports are not affected by this logic. From the CCT, the user can put the control in CCT control only mode which will temporarily disable the Modbus commands.

The selection of the "Local" interface mode disables all ports so configured. The selection of the "Remote" interface mode enables all interfaces. Modbus port 1 and Modbus port 2 each have individual Local mode settings to allow a customer to configure the interface lockout functionality desired. Optionally the control can be configured such that all interfaces are enabled at all times.

All communication input values and commands from each port are double exchanged between all three CPUs and voted on to vote out any erroneous input values or commands before the application software is given the value or command. All communication output values or indications are also double exchanged between all three CPUs and voted on to vote out any erroneous output values or indications before the value or indication is output to the communications port.

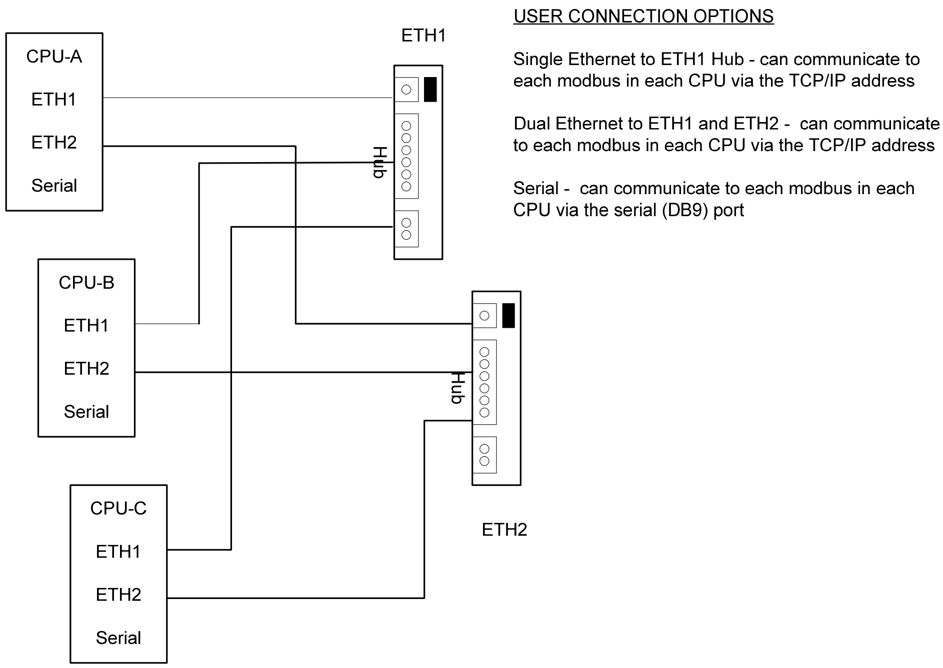


Figure 2-8. Fault Tolerant Modbus Communication Ports

5009 Control System Inputs and Outputs

Speed Sensor Inputs

Available Speed Sensor Inputs: 4

Of the four available fault-tolerant speed sensor inputs, one input is required for operation and the three additional inputs are optional for system redundancy. Each speed input can interface with a passive speed probe (magnetic pickup unit - MPU) or an active speed probe (proximity). Input #4 can be a unique sensor to bring a 'slow-speed' detection sensor into the control.
Refer to Volume 2 for input wiring and specifications.

Zero Speed Inputs

The Speed input #4 channel can be configured different from the others. Its range can be set for low speed detection. During start-up, this reading will be used by the control, up to the maximum range of this sensor.

A relay output configured for speed level will use this channel to increase the accuracy of the reading for very low speed.

Special protection features have been added for this channel, in conjunction with relay output configured for null speed detection.

The signal from channel #4 is compared with the other channels and an alarm will be initiated if a discrepancy is noticed. The null speed relay won't energize until the null speed detection function is re-armed, via a dedicated input (Modbus/hardware). Normal RESET won't re-arm this function.

When zero speed is reached, a delay can be applied before the "null speed" relay is energized.

To increase the zero speed detection safety, a contact input called "zero speed permissive" can be configured. If configured, the null speed relay will energize only if this contact is closed.

Analog Inputs

Available Analog Inputs: 8 **(Optional configurations provide additional 24)**

Any analog input can be configured to perform any of the listed control input functions (except the compressor control options, which must be on the optional additional Analog I/O module). This control only accepts 4–20 mA signals. These 4–20 mA inputs, however, can be configured to interface with loop-powered or self-powered transducers, through FTM input wiring. Refer to Volume 3 for a complete list of all possible analog input functions.

Time Stamping—The analog inputs have the capability of time stamping down to a five millisecond resolution on four setpoints. Two of these setpoints are the analog input failure high and low levels and two are the analog input high and low alarm levels. These setpoints are set to default values during the initial control configuration, and may be re-adjusted at any time.

Discrete Inputs

Available Discrete Inputs: 24

Of the 24 total discrete inputs, the first is dedicated and the next 23 are configurable, however the first three of those are defaulted to the following and should not be adjusted unless absolutely needed, they are:
DI #1 - Emergency Trip
DI #2 - Control Reset
DI #3 - Speed Setpoint Raise
DI #4 - Speed Setpoint Lower
If the control is configured for a generator application, a generator breaker discrete input and a utility tie breaker discrete input must be programmed. Only one discrete input may be programmed for any one listed option; more than one will result in a configuration error. Refer to Volume 3 for a complete list of all possible discrete input functions.

Time Stamping—All External Emergency Trip inputs, all External Alarm inputs, and the generator and utility tie breaker inputs have time stamping down to one millisecond resolution. By configuring multiple discrete inputs to function as external trips or alarms the control can function as a “First-Out” monitor to assist in system trouble shooting. The other discrete inputs are not time stamped.

Readouts—Analog Outputs

Available Readouts: 4 **(Optional configurations provide additional 8)**

Any readout can be configured to perform any of the listed control readout functions. These readouts only drive an output current of 4–20 mA. There are no configuration limitations on the analog output programming. For example, all four outputs could be configured to function as speed readouts, if desired. These outputs are not intended to function as actuator drivers. Refer to Volume 3 for a complete list of all possible readout functions.

Actuator Outputs

Available Actuator Outputs: 2 Proportional **(Optional configurations provide additional 2)**

Each proportional actuator output can be configured to output current ranges of 4–20 mA or 20-160 mA, and to interface with single or dual coil actuators. When a single-coil actuator is used, all three kernel output drivers are tied together and share current proportionally. When a dual-coil actuator is used all three also share output current, however, kernels A & B are tied directly together through the ATM to the coil #1 output and kernel C provides the coil #2 output.

An optional kit can be added to interface directly to integrating actuators (those using a Null current drive and position feedback signals from/to the control).

Integrating actuators utilize a null current, minimum current, and maximum current settings to position the valve based on a closed loop with position feedback. 0% demand does not correspond to minimum current nor does 100% demand correspond to maximum current. Changing the demand to the module will create an error between demand and feedback and the module will accordingly increase or decrease current to get a different position feedback and correct the error. In a forward acting controller, maintaining constant demand will output the null current and maintain the actuator position. Increasing demand will cause the module to increase current above the null and will increase actuator position. Decreasing demand will cause the module to decrease the current below the null setting and will decrease actuator position. The amount by which current increases above, or decreases below, the null current results from the magnitude of the demand – position error and along with the controller settings affects how fast the actuator reacts. Integrating actuators will only use the minimum output current, maximum output current and null current parameters during calibration.

The type chosen in the configuration tool (Figure 2-9) will be one of the following:
1 - Proportional (proportional)
2 - P (integrating)
3 - PI (integrating)
4 - PI Lag (integrating)
5 - PI Lead (integrating)

Following are further descriptions of each type.

<u>Proportional Actuator (Proportional or PROP):</u>

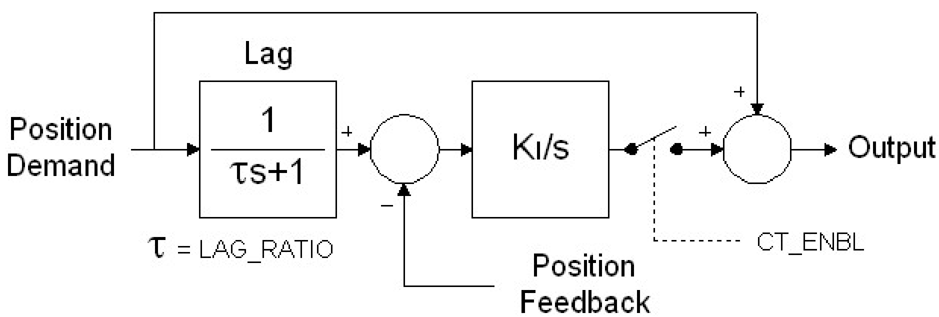


Figure 2-9. Proportional Controller Diagram

CTRL_TYPE = PROP
KP = N/A
KI = integral time constant
T_LEAD = N/A
LAG_RATIO = lag time constant

The proportional actuator controller uses a "command trim" scheme to reduce steady-state position errors. When the CT_ENBL input is false, the output equals the input. When CT_ENBL is true, the integrator trims the error between the position demand and the position feedback to zero. The output of the integrator is limited to 10% of the range defined by MA_AT_0 and MA_AT_100. The lag block reduces overshoot when the position demand changes faster than the actuator can respond. Ideally, the lag exactly matches the response of the actuator and therefore no change is required out of the Ki/s block.

Integrating Actuator (P):

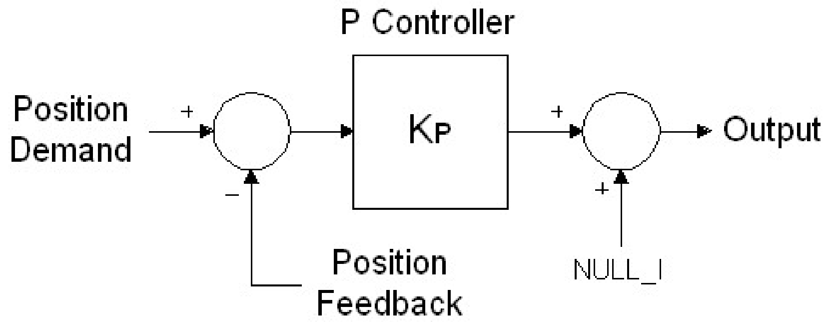


Figure 2-10. P Controller Diagram

CTRL_TYPE = P
KP = proportional gain
KI = N/A
T_LEAD = N/A
LAG_RATIO = N/A

The P controller is the simplest controller, is very robust, and works well for systems that are not very sensitive to position errors. Steady-state errors will exist if the NULL_I input value does not equal the actual null current of the actuator.

Tuning can be accomplished by increasing the gain until the actuator just starts to oscillate, then reducing the gain by a factor of two.

Integrating Actuator (PI):

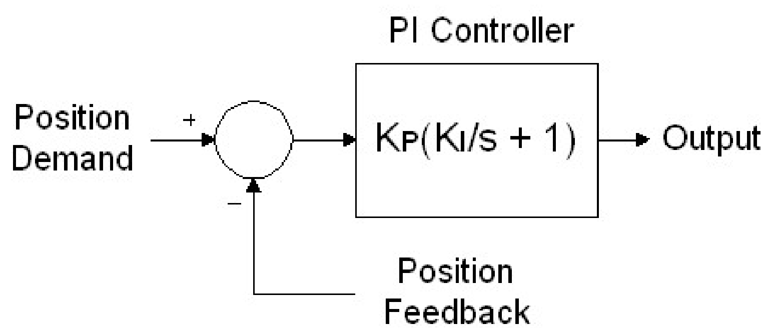


Figure 2-11. PI Controller Diagram

CTRL_TYPE = PI
KP = proportional gain
KI = integral gain
T_LEAD = N/A
LAG_RATIO = N/A

The PI controller is suitable for most applications. The following procedure may be used as a starting point to finding the optimal dynamic settings:

1. Adjust Ki to a minimum value.
2. Increase Kp until the actuator just starts to oscillate. Record the Period of the oscillation (Posc) and Kp (Kosc).
3. Set Kp = 0.45 * Kosc and I = 1.2/Posc.

This gives stable response. Test the actuator response and further refine the tuning until the desired performance is obtained.

Integrating Actuator (PI Lag or PI_LAG):

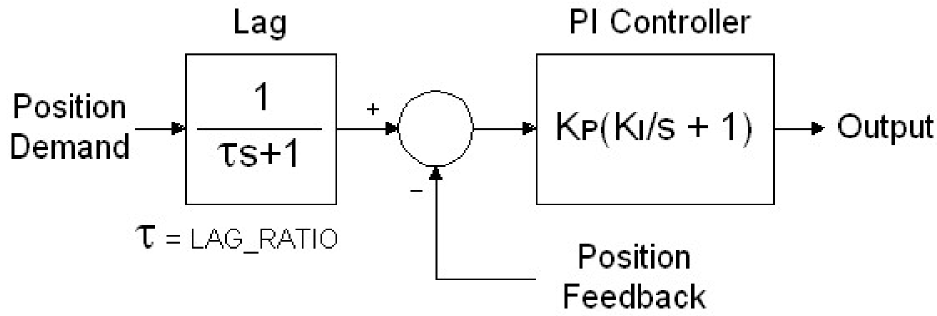


Figure 2-12. PI Lag Controller Diagram

CTRL_TYPE = PI_LAG
KP = proportional gain
KI = integral gain
T_LEAD = N/A
LAG_RATIO = lag time constant

The PI-Lag controller is a PI controller with a lag block conditioning the demand signal. The lag term may be used to cancel, or partially cancel, a zero in the closed-loop transfer function. Tuning of this control is exactly the same as the PI control. Use this control only if you have a critical process which cannot tolerate overshoots. This control will limit actuator response although the lag can be set to a very low value to avoid excessive delay.

Integrating Actuator (PI Lead or PI_LEADLAG):

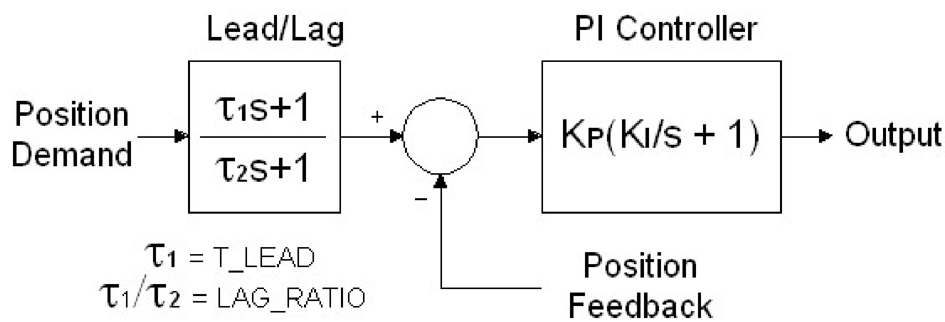


Figure 2-13. PI Lead Lag Controller Diagram

CTRL_TYPE = PI_LEADLAG
KP = proportional gain
KI = integral gain
T_LEAD = lead time constant
LAG_RATIO = lead/lag ratio

The PI-Lead/Lag controller is a PI controller with a lead/lag block conditioning the demand signal. The T_LEAD input sets the lead time constant. Note that the lag time constant is not entered directly. The LAG_RATIO input sets the lead/lag ratio. Tuning this control is the same as the PI control. The lead/lag term may be used to set the actuator response to some ideal value. The lead/lag may be used for increasing or decreasing the apparent bandwidth of the actuator thereby tailoring performance for the application. Of course, the control cannot force the actuator to exceed its physical limits, e.g., slew rate and dead time.

Command Trim Enable

Command trim enable is only available when actuator type is selected to be proportional. When command trim is disabled, the proportional controller acts as an open loop position demand. When enabled the proportional controller will still position based on milliamp at 0% and milliamp at 100% settings, but will also adjust demand to correct any error between it and % position feedback.

Actuator Direction

When Actuator Direction is selected to be FORWARD, then an increasing position demand will result in an increasing current output. When actuator direction is selected to be REVERSE then an increasing position demand will result in a decreasing current output.

Position Feedback Transducer Type

The position transducer must be an LVDT or an RVDT. The Position Feedback Transducer Type field determines how the signals from the transducer are interpreted. In the configuration tool enter:

- “None” if no position feedback will be used.
- "A" for devices with a single pair of return wires,
- "A–B" is for devices with two pairs of return wires that have a simple difference output.
- "(A–B)/(A+B)" is for devices with two pairs of return wires that have a difference/sum (also known as constant sum, or D/S) output.

For devices with two pairs of return wires, the device manufacturer's drawing should be consulted to determine if it is a difference type or difference/sum type.

Wiring methods for different transducer examples are shown below:

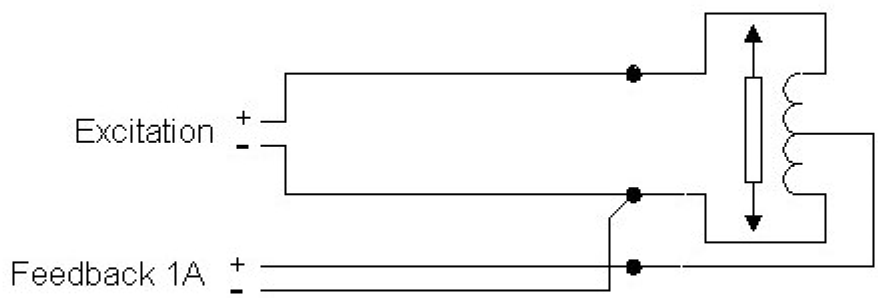


Figure 2-14. Three-Wire Transducer

The three-wire device has no primary-to-secondary isolation, which prevents the open-wire detection circuit from functioning properly. Under the tune menu of the configuration tool, uncheck the enable open circuit alarm checkbox to avoid nuisance feedback open and feedback failure alarms.

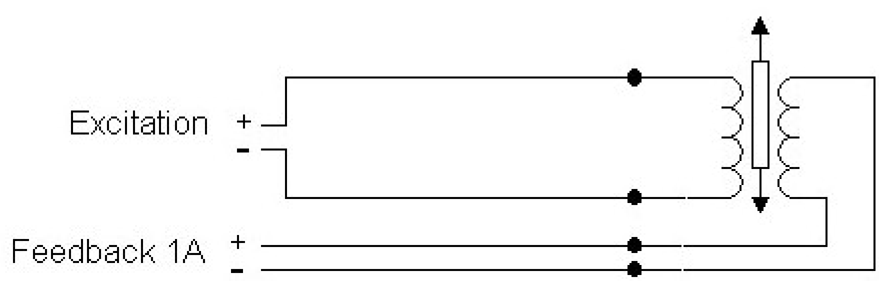


Figure 2-15. Four-Wire Transducer

The "+" and "-" designations shown here are arbitrary. Note: The output voltage of devices with a single pair of return wires must not pass through zero volts.

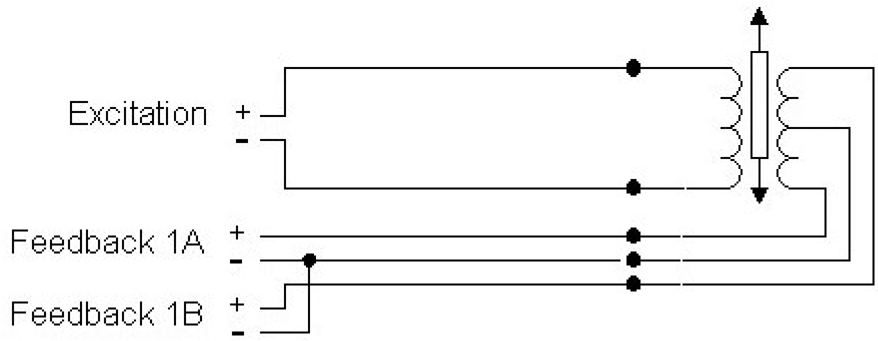


Figure 2-16. Five-Wire Transducer

The "+" and "-" designations for the exciter are arbitrary. The (-) side of feedbacks 1A and 1B should be tied to the output center tap as shown. This device could be a simple difference or difference/sum type. Consult manufacturer to determine if this is an “A–B” or “(A–B)/(A+B)” type transducer.

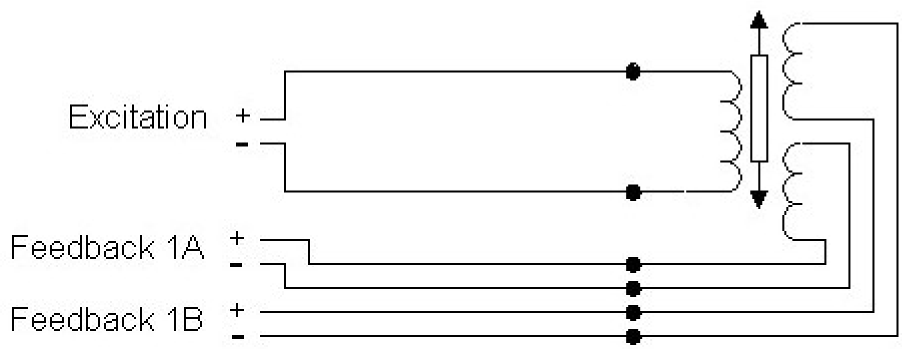


Figure 2-17. Six-Wire Transducer

The "+" and "-" designations shown here are arbitrary. This device could be a simple difference or difference/sum type. Consult manufacturer to determine if this is an “A–B” or “(A–B)/(A+B)” type transducer.

Excitation Amplitude
Consult the position transducer’s manufacturer for the ideal excitation amplitude.

Proportional Gain (KP)
Used for P, PI, PI Lag, PI Lead controller types. See Figures 2-1 to 2-17.

Integral Gain (KI)
Used for Proportional with command trim enable, PI, PI Lag, PI Lead controller types. See Figures 2-11, 2-12, 2-13.

Lag Time Constant (LAG_RATIO)
Used for PI Lag and PI Lead controller types. See Figures 2-12 and 2-13.

Lead Time Constant (T_LEAD)
Used for PI Lead controller types. See Figure 2-13.

Enable Open Circuit Alarm
Uses feedback open circuit detection. Generally will not work with a 3-wire transducer. See Figure 2-14.

LVDT Linearization

In some cases, after calibration (at zero and 100%), the LVDT position readouts at mid position may not match. This difference can result in a small “bump” in the valve position in case of failure of one of the LVDTs.

To compensate, it is possible in service mode (see Volume 3) to linearize the LVDT connected in kernel A (card A106), so that the position matches with the LVDT connected in kernel C (card C106).

For extraction and/or admission turbines, actuator driver #1 interfaces with the turbine’s High Pressure control valve actuator (HP) and actuator driver #2 interfaces with the turbine’s Low Pressure control valve actuator (LP). For non- extraction/admission turbines, actuator driver #2 can be used to control either a second actuator (with an offset) or it can be used as a readout.

Each actuator is configurable for a menu of functions – the default setting is that Proportional Actuator #1 is used to drive the High Pressure control valve actuator (HP). For extraction and/or admission turbines, the extraction valve is referred to as the turbine’s Low Pressure control valve actuator (LP).

Relay Outputs

Available Relay Outputs: 12

Of the 12 relay outputs, 2 are dedicated and 10 are configurable. The two dedicated outputs are Emergency Trip, and Alarm condition. There are no configuration limits on relay output programming. For example, all 10 of the programmable relays could be configured to function as a Speed PID In-Control indication, if desired.

Communication Ports

Each CPU has 2 Ethernet ports and 1 serial port that are available to the user. Each port on the CPUs is given a unique TCP/IP address. Each of the 2 Ethernet ports is connected to a separate LAN Switch in the cabinet to allow completely redundant communication paths to the user's external devices. To support this, the ETH1 and ETH2 of each CPU must be placed on different network domains. If the user is only connecting to the control from a single LAN network then connections should only be made to 1 of the LAN switches. See Volume 3 for the default settings of the Ethernet Ports in the 5009FT system. The following are the default IP addresses for a CPU ordered separately from the 5009FT:

Table 2-3. Default M5200 CPUTCP/IP Addresses

CPU IP	CPU Subnet Mask
ETH1 = 172.16.100.1	ETH1 = 255.255.0.0
ETH2 = 192.168.128.20	ETH2 = 255.255.255.0

The control’s CPU module communication ports are configurable for RS-232, RS-422 or RS-485 communications. RS-232 communications is limited to a distance of 50 feet. In cases where a device which is being interfaced to is located a distance of greater than 50 feet from the control, it is recommended that RS-422 or RS-485 be used.

Configuration & Commissioning Tools (CCT) Programs

The 5009 Control System is a field configurable steam turbine control that utilizes OCCT Windows-based CCT Interface programs to configure, operate, and service the 5009 Control.

The package includes two ToolKits:

- Configuration—allowing to configure the application
- Run and Service—allowing to operate the application.

Refer to Volume 3 for details on connecting to the control via the ToolKits.

The CCTs are a user interface programs. These interface programs have three levels of access (Configure, Service, Run). Each of these access levels has different levels of password security. These security levels allow only users who are qualified (and have access to the mode's password) access to perform changes in a specific interface mode.

Security levels:

- Configure Used to initially configure the control to the application—this mode is required in Configuration ToolKit to configure the application.
- Service Used to perform changes to the control's configuration, test control hardware, and calibrate control I/O, all while on-line at any operating level.
- Run Used to start the turbine, stop the turbine, and enable or disable any operating mode.

Service and run modes are recommended in Run and Service Toolkit to calibrate settings and to monitor the application.

All three CCT interface modes can be monitored at any time, however, changes cannot be made in the Configure mode unless the turbine is in a shutdown state and the correct password has been entered. The program's Limited Configuration, Service & Run modes do not require the unit to be shutdown. Refer to Volume 3 for details on the CCT program and its functionality.

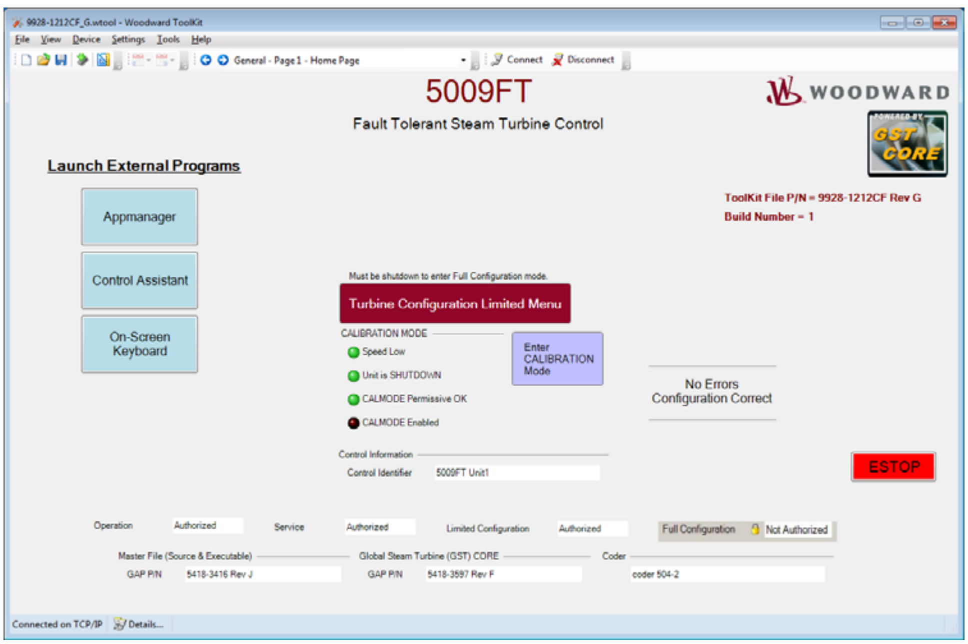


Figure 2-18. Configuration ToolKit Main Screen

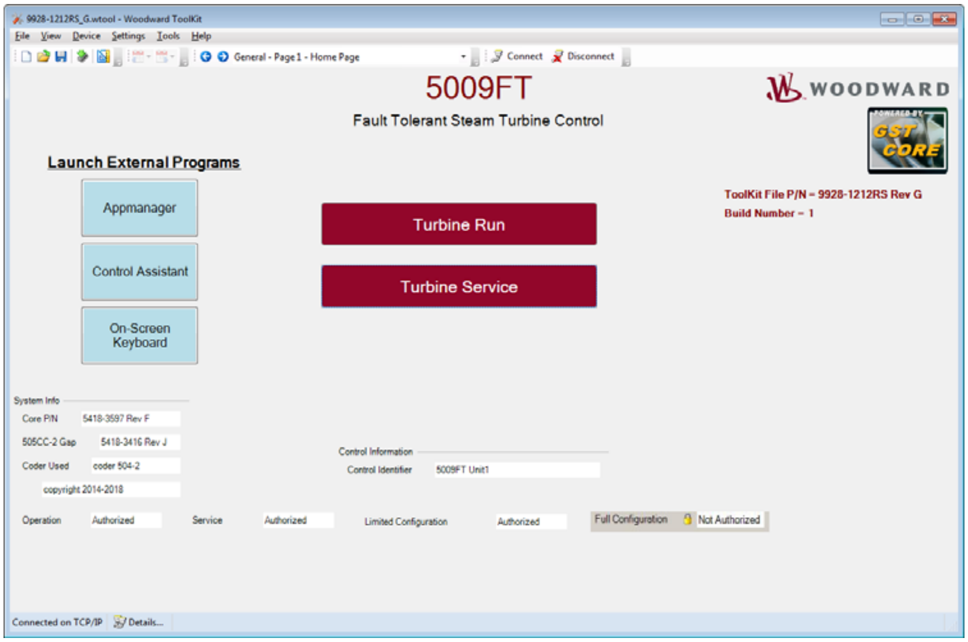


Figure 2-19. Run and Service ToolKit Main Screen

Chapter 3.
Control Functionality Overview

Control Overview

This control is designed to control single valve, split-range valve, single controlled-extraction, single controlled-admission, or single controlled-extraction/ admission steam turbines. Refer to the following turbine control descriptions and block diagrams to match the control's configuration to your type of turbine and application.

Single Valve or Split Range Valve Turbines

This control can be configured to control turbines with one or two turbine control valves (or valve racks) feeding into a single steam chest, or separate steam chests. With this type of configuration the control interfaces with the turbine control valve(s) to control one parameter at a time and limit an additional parameter if desired.

With this type of turbine, the one controlled parameter is typically speed (or load), however, the control could be utilized to control or limit: turbine inlet pressure or flow, exhaust (back) pressure or flow, first stage pressure, generator power output, plant import and/or export levels, compressor inlet or discharge pressure or flow, unit/plant frequency, process temperature, or any other turbine related process parameter. Refer to the following block diagrams for possible control configurations, and PID relationships.

When the control is configured for a split-range turbine type, actuator output #2 can be configured to begin opening at an offset value of actuator output #1 position. If this offset setting is 50%, then Valve #2 will begin opening when Valve #1 reaches 50%. The control will continue to open both valves to 100%, with a position difference of 50%.

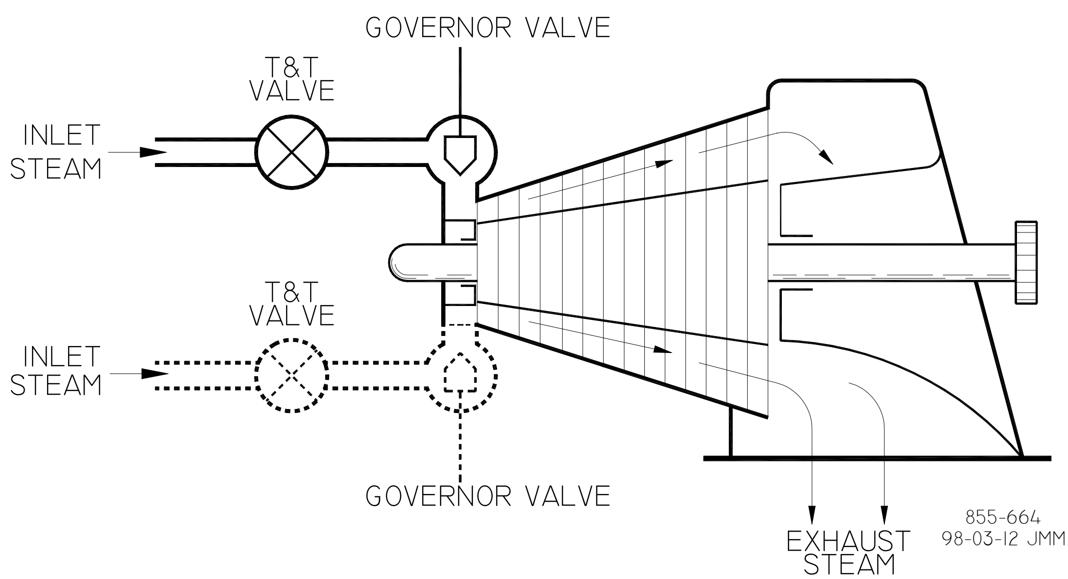


Figure 3-1. Typical Single Valve or Split Range Valve Steam Turbine

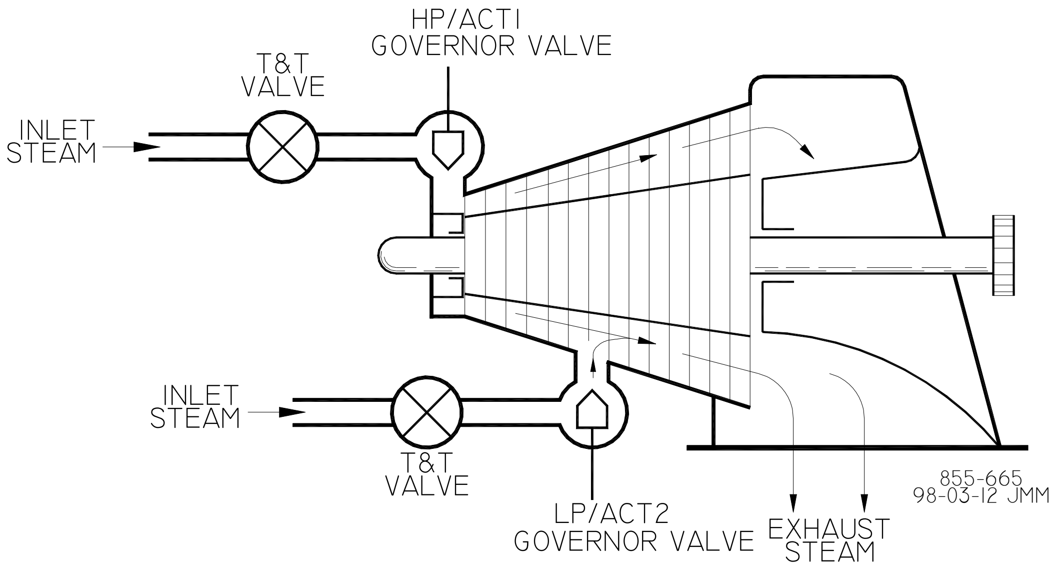


Figure 3-2. Split Range or Admission Type of Turbine Configuration
(depending on the parameters being controlled)

Extraction Turbines

When configured to operate single controlled-extraction steam turbines, the control, manages the interaction between the turbine's governor valve (HP) and extraction valve (LP) valve to control two turbine related parameters at the same time, while minimizing the affect each parameter has on the other.

Single controlled-extraction turbines have a high pressure stage and a low pressure stage, each controlled by a valve. Steam enters the turbine through the HP valve (see Figure 3-3). At the downstream end of the HP turbine stage and before the LP valve, steam can be extracted. The LP valve controls the entry of steam into the LP turbine stage, and the diverting of steam out the extraction line. As the LP valve is opened, more steam enters the LP stage and less is extracted.

When configured for an extraction type of turbine, this control uses Ratio/Limiter logic to control the interaction of the HP and LP valves. Due to a turbine's design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed/load (or Auxiliary or Cascade PID processes) and extraction pressure/flow levels. Because a single extraction turbine has only two control valves, only two parameters at a time can be controlled. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When system conditions cause a turbine to reach an operating limit (Min LP), only one process parameter can be controlled. The control's limiter logic allows the process parameter which has priority on that limit to be controlled by limiting the second parameter.

The interaction of both valves is automatically calculated by the 5009 Control System's ratio logic, based on entered turbine performance parameters. HP & LP valve decoupling modes are available, depending on the process parameters being controlled. Refer to the following block diagrams for possible control configurations, and PID relationships. Refer to the Ratio/Limiter section of this Volume for Ratio/limiter configuration options.

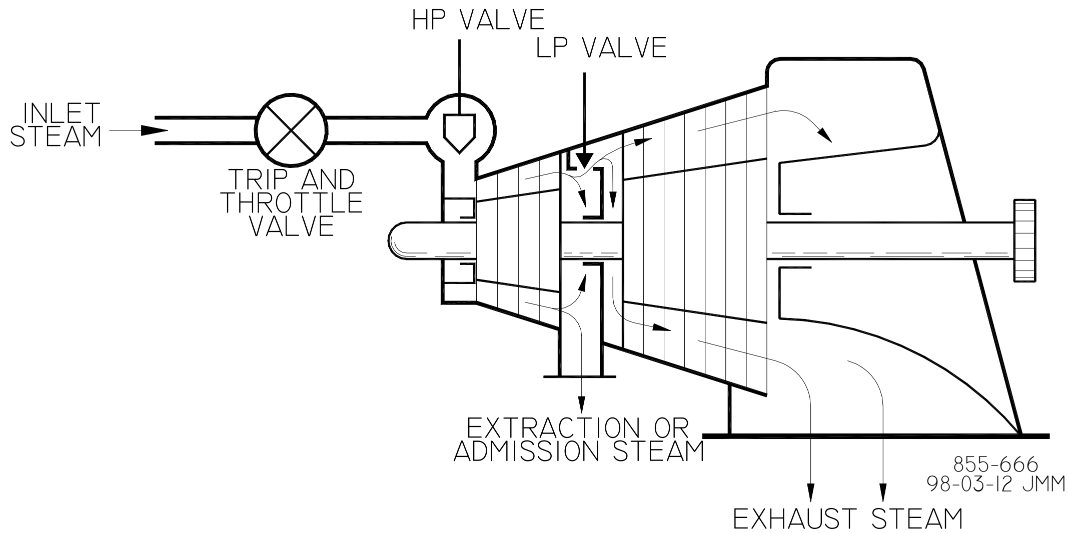


Figure 3-3. Extraction and/or Admission Steam Turbine

Admission Turbines

When configured to operate single controlled-admission steam turbines, the control, manages the interaction between the turbine's governor valve (HP) and extraction valve (LP) valve to control two turbine related parameters at the same time, while minimizing the affect each parameter has on the other.

Typical single automatic admission turbines have a high pressure stage and a low pressure stage, each controlled by a valve. Steam enters the turbine through the HP valve (see Figure 3-3) and at the downstream end of the HP turbine stage, before the LP valve. The LP valve controls the entry of steam into the LP turbine stage and through the admission line. As the LP valve is opened, more steam enters the LP stage.

When configured for an admission type of turbine, this control uses Ratio/Limiter logic to control the interaction of the HP and LP valves. Due to a turbine's design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed/load (or Auxiliary or Cascade PID processes) and admission pressure/flow levels. Because a single admission turbine has only two control valves, only two parameters at a time can be controlled. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When system conditions cause a turbine to reach an operating limit (Min LP), only one process parameter can be controlled. The control's limiter logic allows the process parameter which has priority on that limit to be controlled by limiting the second parameter.

The interaction of both valves is automatically calculated by the 5009 Control System's ratio logic, based on entered turbine performance parameters. HP & LP valve decoupling modes are available, depending on the process parameters being controlled. Refer to the following block diagrams for possible control configurations, and PID relationships. Refer to the Ratio/Limiter section of this Volume for Ratio/Limiter configuration options.

Extraction/ Admission Turbines

When configured to operate single controlled-extraction/admission steam turbines, the control, manages the interaction between the turbine's governor valve (HP) and ext/adm valve (LP) valve to control two turbine related parameters at the same time, while minimizing the affect each parameter has on the other.

Single automatic extraction/admission turbines have a high pressure stage and a low pressure stage, each controlled by a valve. Steam enters the turbine through the HP valve. At the downstream end of the HP turbine stage and before the LP valve, steam can either be extracted or admitted (inducted) into the LP turbine stage. The LP valve controls the entry of steam into the LP turbine stage. As the LP valve is opened, more steam enters the LP stage and less is extracted.

When configured for an ext/adm type of turbine, this control uses Ratio/Limiter logic to control the interaction of the HP and LP valves. Due to a turbine’s design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed/load (or Auxiliary or Cascade PID processes) and ext/adm pressure/flow levels. Because a single ext/adm turbine has only two control valves, only two parameters at a time can be controlled. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When system conditions cause a turbine to reach an operating limit (Min LP), only one process parameter can be controlled. The control’s limiter logic allows the process parameter which has priority on that limit to be controlled by limiting the second parameter.

The interaction of both valves is automatically calculated by the 5009 Control System’s ratio logic, based on entered turbine performance parameters. HP & LP valve decoupling modes are available, depending on the process parameters being controlled. Refer to the following block diagrams for possible control configurations, and PID relationships. Refer to the Ratio/Limiter section of this Volume for Ratio/Limiter configuration options.

Block Diagrams

Overviews of possible 5009 Control System configurations are shown in Figures 3-5 through 3-11. Use these block diagrams to match the control features to the site-specific application requirements. Figure 3-4 lists symbols and their respective explanations. The Cascade and Auxiliary PIDs are optional controllers, and are shown in the following diagrams for PID relationship purposes only. For more information on the functionality of the Ratio/Limiter block, refer to the Ratio/Limiter Section of this manual.

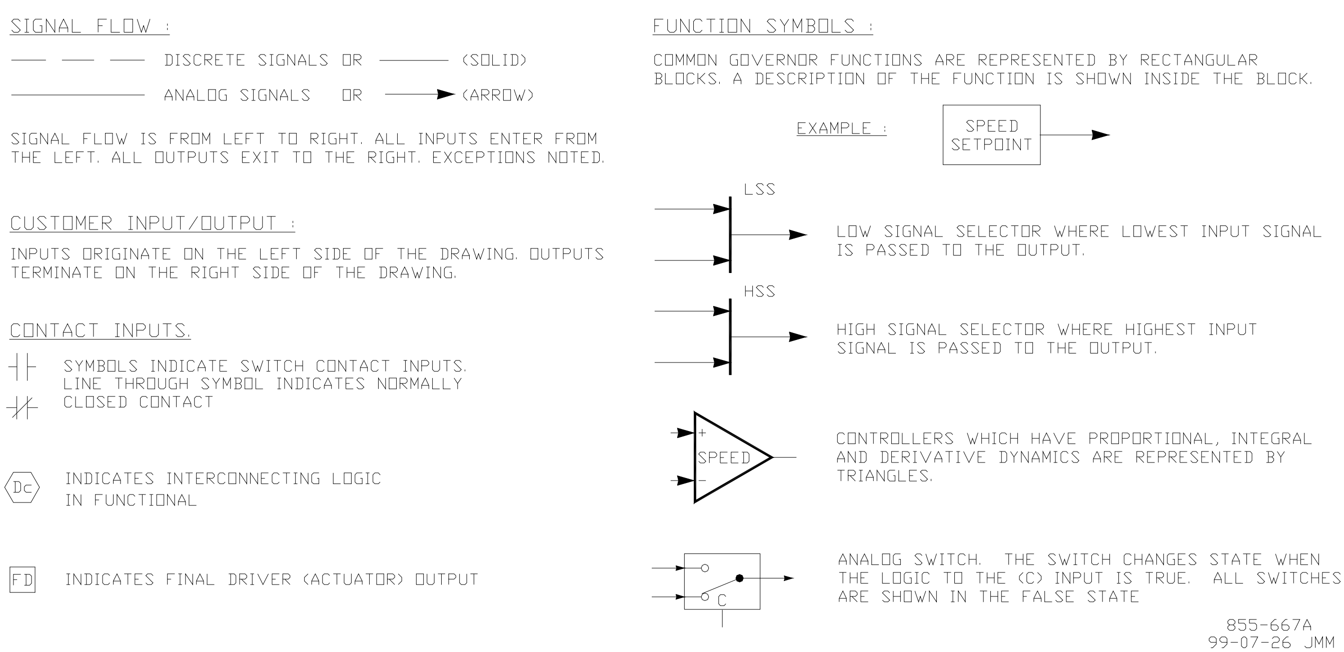


Figure 3-4. Overview of 5009 Control System Functionality Notes

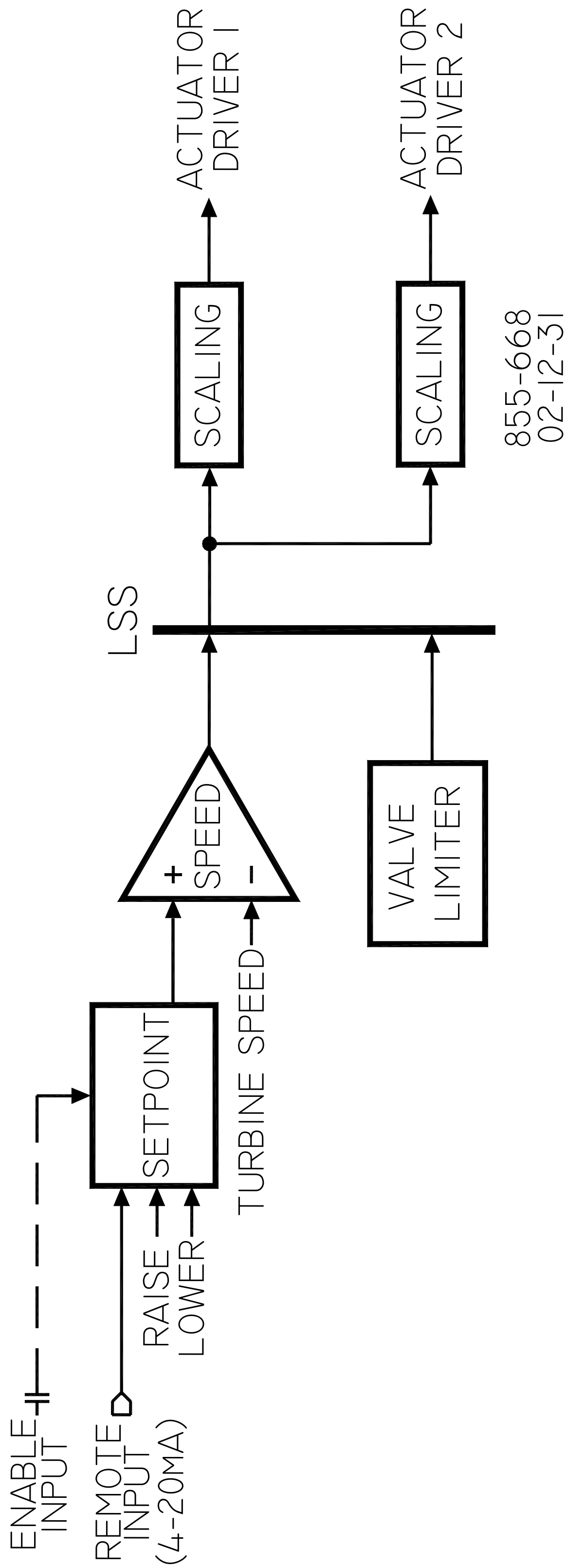


Figure 3-5. Single or Split-Range Turbine Configurations (Speed PID with Remote Setpoint)

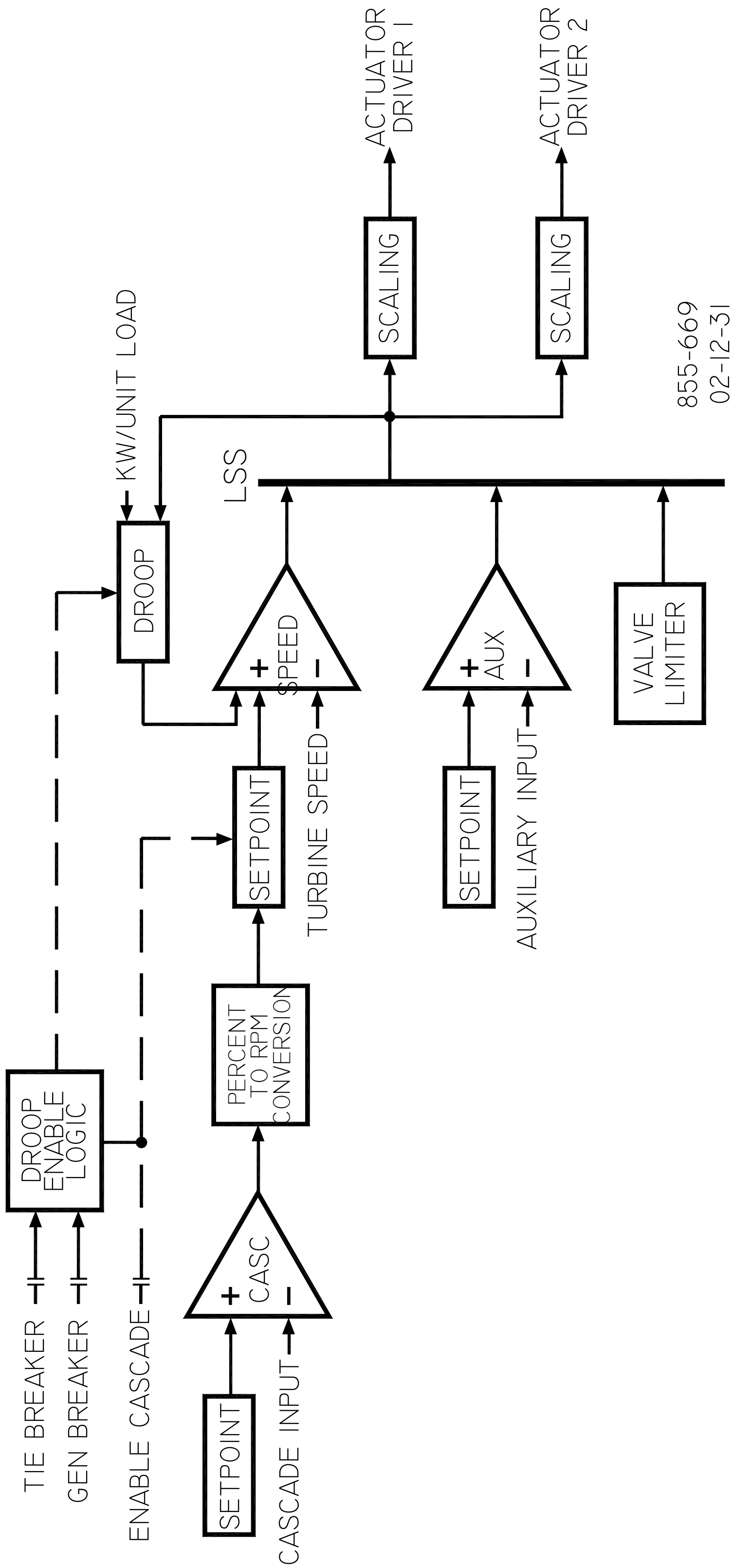


Figure 3-6. Single or Split-Range Turbine Configurations (Auxiliary PID Configured as a Limiter)

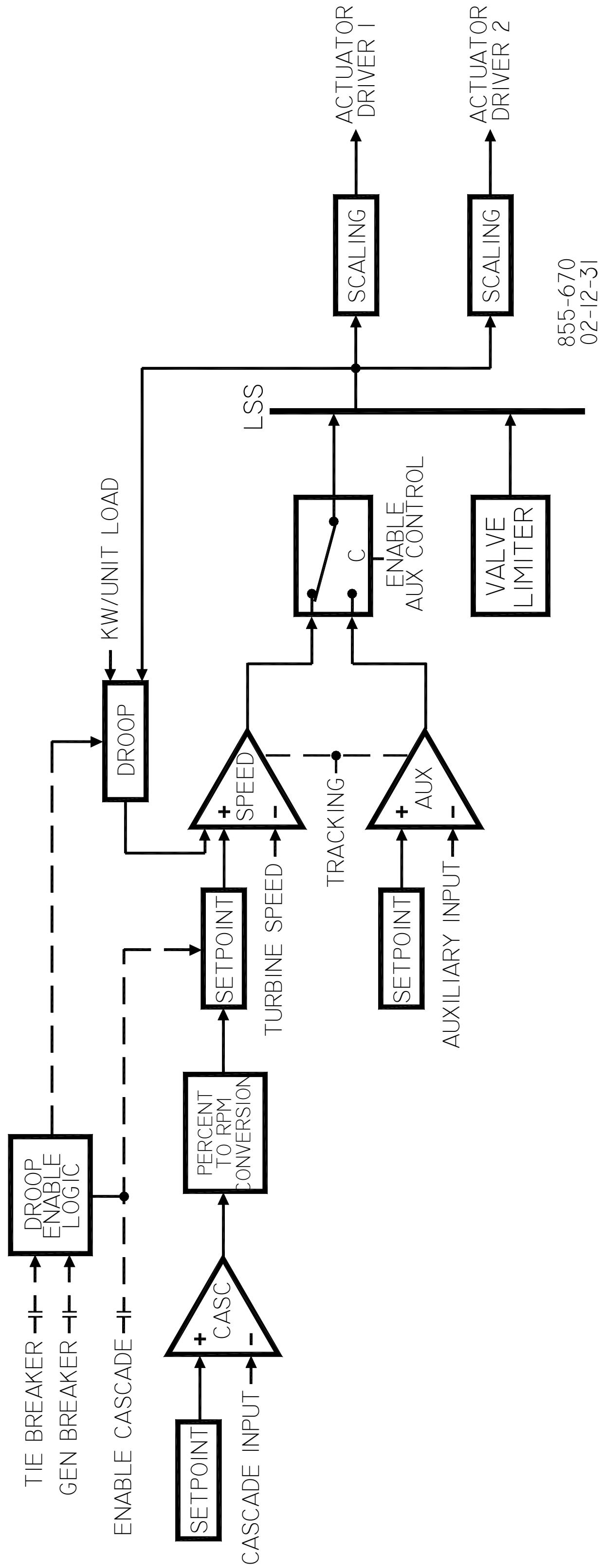


Figure 3-7. Single or Split-Range Turbine Configurations (Auxiliary PID Configured as a Controller)

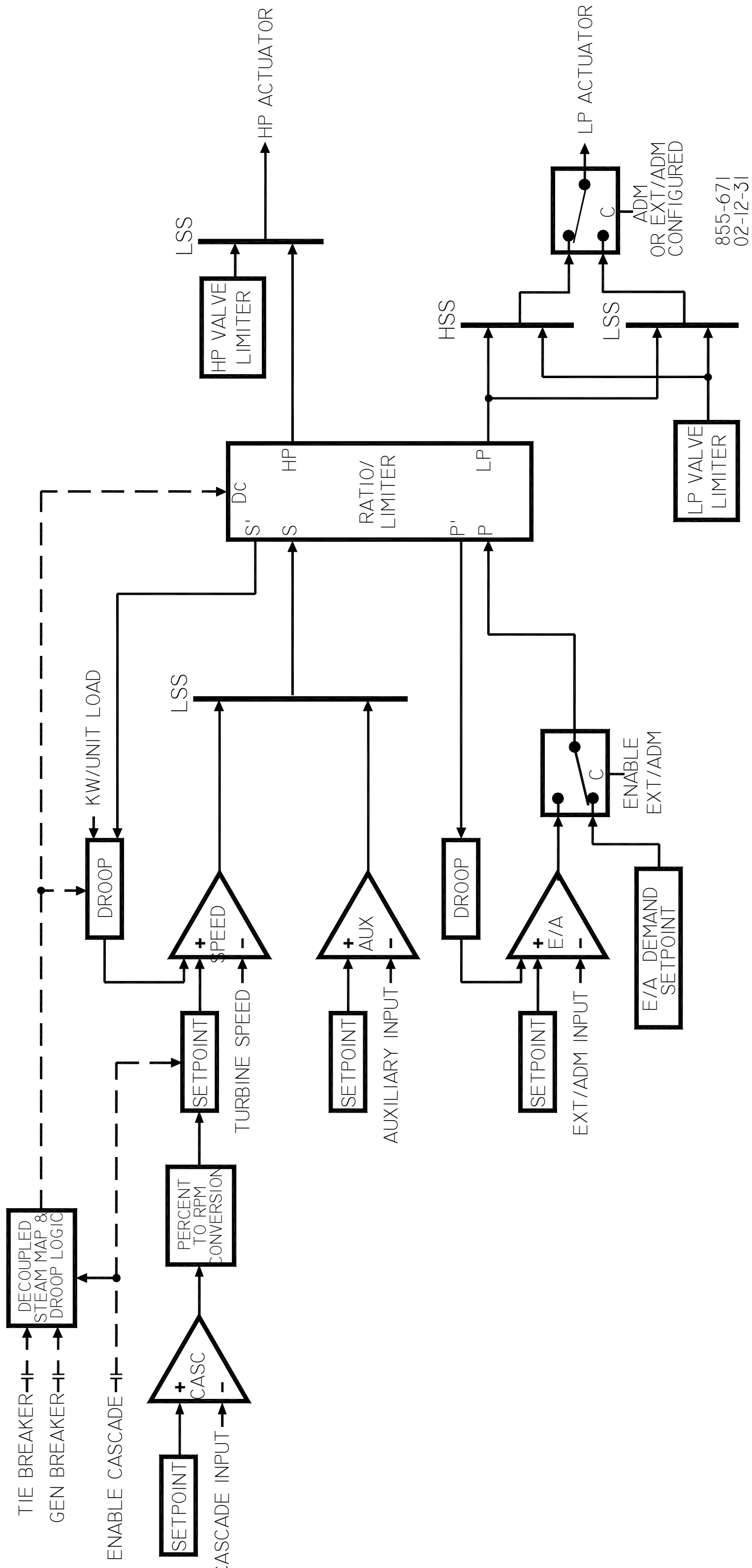


Figure 3-8. Extraction and/or Admission Turbine Configurations (Auxiliary Configured as a Limiter)

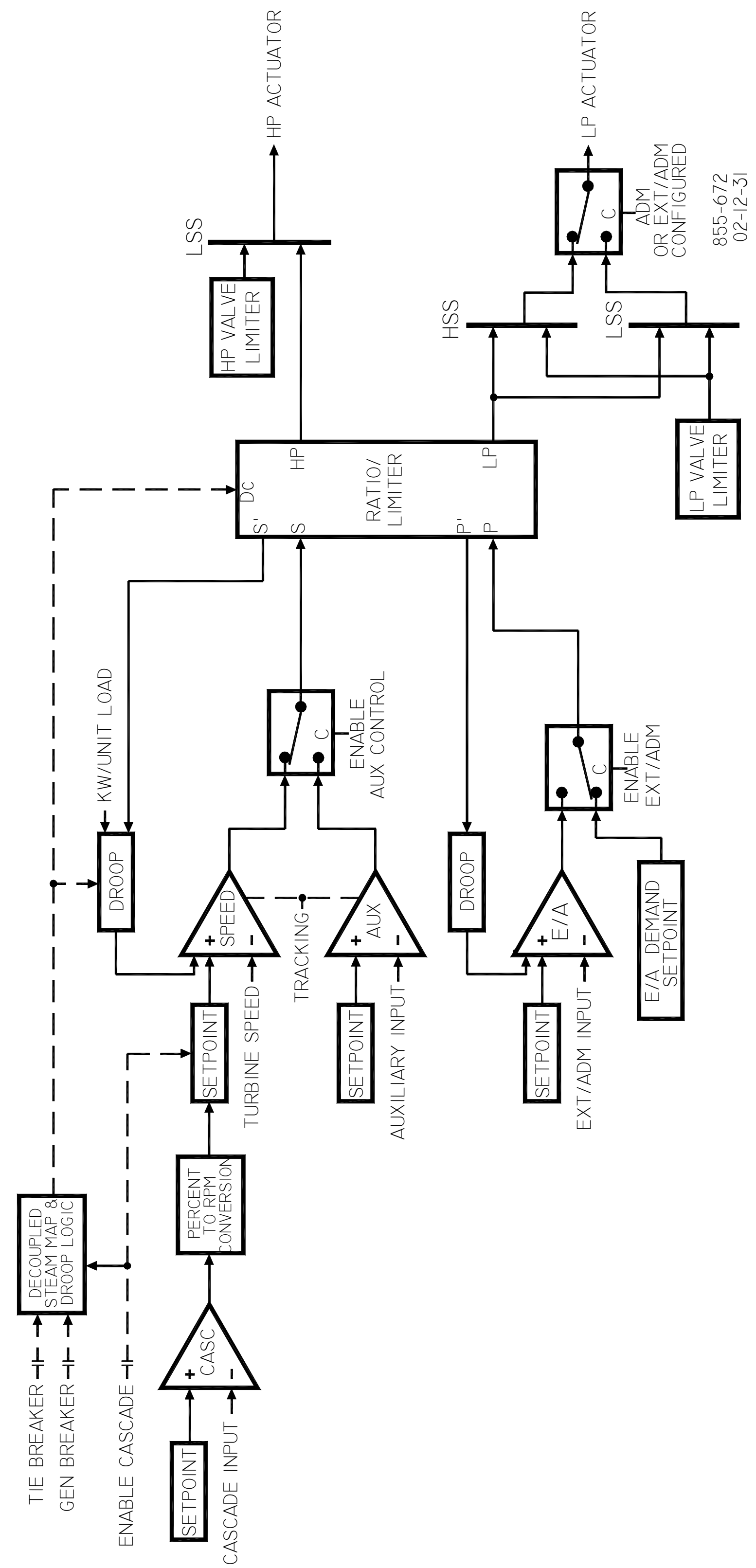


Figure 3-9. Extraction and/or Admission Turbine Configurations (Auxiliary Configured as a Controller)

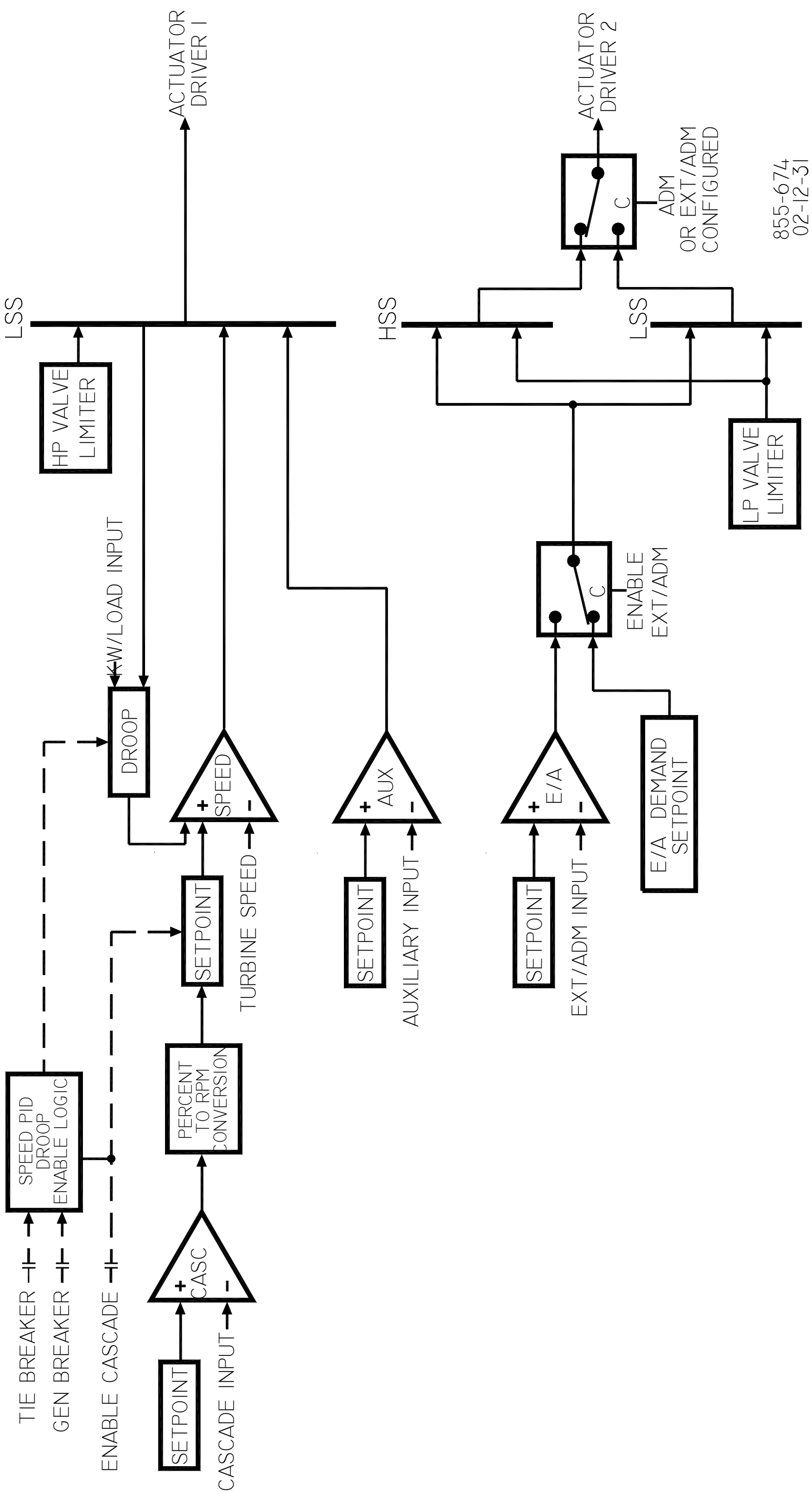


Figure 3-10. Extraction and/or Admission Turbine Configurations
(Decoupled HP & LP Ratio/Limiter, Auxiliary Configured as a Limiter)

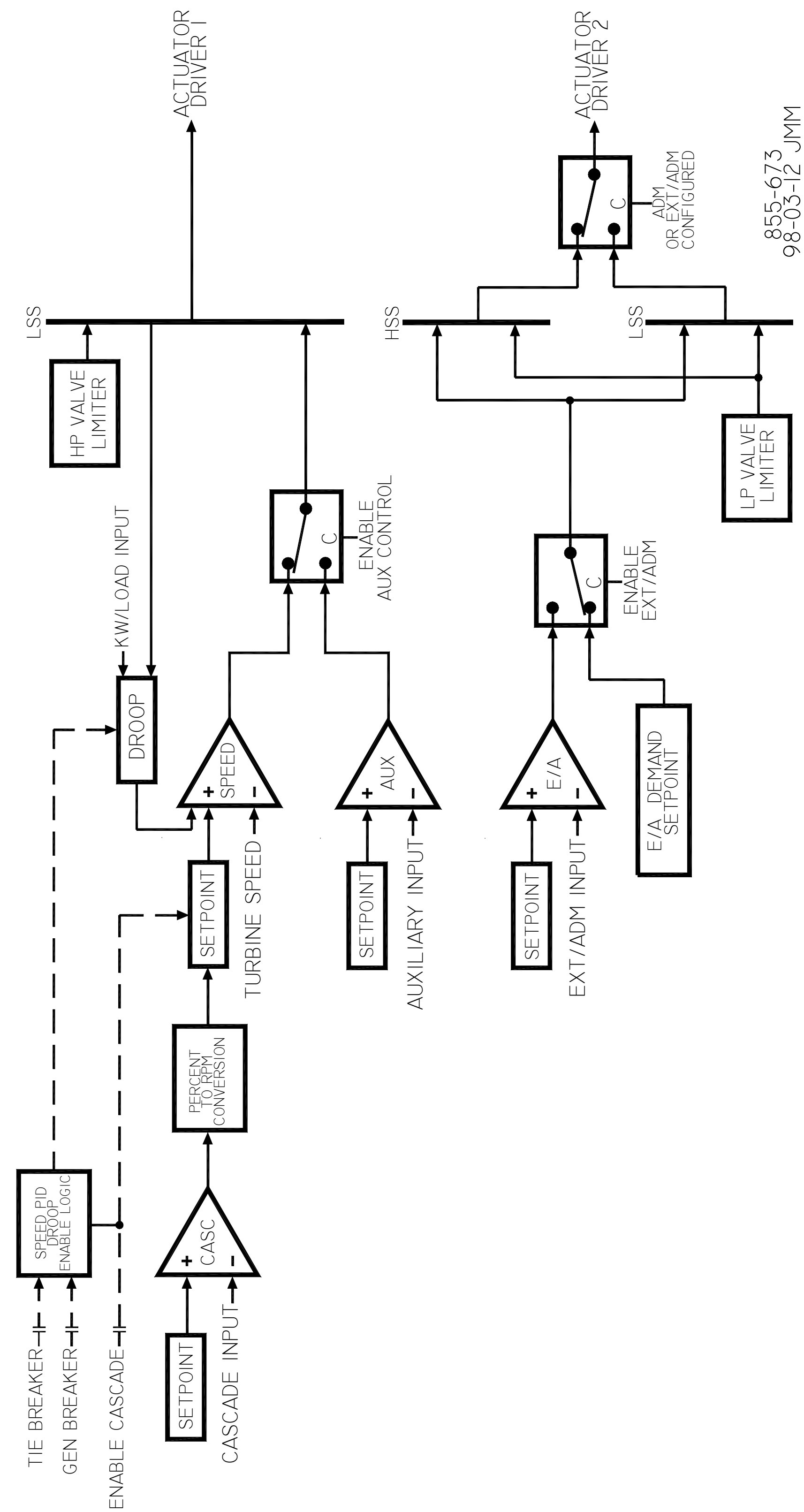


Figure 3-11. Extraction and/or Admission Turbine Configurations
(Decoupled HP & LP Ratio/Limiter, Auxiliary Configured as a Controller)

Chapter 4.
Application Notes

Overview

This chapter is provided to give users an idea of the 5009 Control System's capabilities and how to apply them to a system. Typical example applications are schematically shown and their functionality explained. In addition, programming and run mode notes are given for each example to assist programmers in configuring the 5009 Control System for their application. Basic peripheral device connections are shown in each application drawing to allow an understanding of how these devices interface to the 5009 Control System and expand system capabilities. Refer to Table 4-1.

Speed/Load PID

The Speed PID can control and limit:

- Unit Speed/Frequency
- Unit Load

The 5009 Control System's Speed PID can be used to control unit speed/ frequency when isolated and unit load when paralleled to an infinite bus (utility). The Speed PID can be programmed to sense unit load via its actuator output signal or a 4–20 mA analog input signal from a generator power sensor. When programmed to sense and control generator load via an analog input, true unit load is sensed and controlled. By using the generator load signal to control from, any turbine inlet or exhaust pressure variation is sensed and compensated for, thus providing true load control.

A combination of the Speed PID and its setpoint limits allow this PID to limit unit load. When used as a unit load limiter, it is recommended that the 5009 Control System be configured to sense and control only true generator load. If applying the 5009 System to a soft grid, where the utility frequency varies greatly, it is recommended that unit load limiting be performed by the Auxiliary PID - not the Speed PID.

If the 5009 Control System is controlling an extraction turbine the extraction PID's output is connected directly to the 5009 Control System ratio/limiter. Therefore, this PID directly positions one or both turbine throttle valves, depending on configuration, to control the above listed parameters.

EXTR/ADM PID (Extraction/ Admission Turbines Only)

The 5009 Control System's Extr/Adm PID can be programmed to control:

- Extraction and/or Admission Steam Pressure
- Extraction and/or Admission Steam Flow
- Turbine Exhaust Steam Pressure
- Turbine Exhaust Steam Flow

The 5009 Control System's Extr/Adm PID can be used to control any of the listed parameters. This PID can be enabled and disabled by commands given through the 5009 Control System's CCT Interface, contact inputs, or Modbus commands.

Since this PID's output is connected directly to the 5009 Control System's ratio/ limiter, it directly positions one or both turbine throttle valves, depending on configuration, to control the above listed parameters. Only when the 5009 Control System is configured for the "Decoupled HP & LP" mode, can the Extr/ Adm PID control turbine exhaust pressure or flow.

Auxiliary PID

The 5009 Control System's Auxiliary PID can be programmed to control (enabled/disabled on command) or limit:

- Turbine Inlet Steam Pressure
- Turbine Inlet Steam Flow
- Turbine Exhaust Steam Pressure
- Turbine Exhaust Steam Flow
- Generator Power Output
- Plant or Tie line Import/Export Power
- Process Temperature
- Compressor Suction Pressure
- Compressor Suction Flow
- Compressor Discharge Pressure
- Compressor Discharge Flow

Any process parameter related to unit load, inlet pressure, or exhaust pressure (depending on configuration)

When programmed as a limiter, this PID's output is low signal selected with the Speed PID's output. This configuration allows the Auxiliary PID to limit unit load based on the parameter being sensed.

When the Auxiliary PID is configured as a controller, it must be enabled and disabled by commands given through the 5009 Control System's CCT Interface, contact input, or Modbus commands. In this configuration, the Speed PID is disabled and tracks the Auxiliary PID's output when the Auxiliary PID is enabled.

To control or limit any of the listed parameters, the 5009 Control System must be programmed to accept an auxiliary analog input signal representing that parameter's level. The exception to this rule is when controlling or limiting generator load. The Auxiliary PID can be programmed to use and share the KW/ Unit load input with the Speed PID.

Cascade PID

The 5009 Control System's Cascade PID can be programmed to control:

- Turbine Inlet Steam Pressure
- Turbine Inlet Steam Flow
- Turbine Exhaust Steam Pressure
- Turbine Exhaust Steam Flow
- Generator Power output
- Plant or Tie Line Import/Export Power
- Process Temperature
- Compressor Suction Pressure
- Compressor Suction Flow
- Compressor Discharge Pressure
- Compressor Discharge Flow
- Any process parameter related to unit load, inlet pressure, or exhaust pressure (depending on the configuration)
-

This PID must be enabled and disabled by commands given through the 5009 Control's CCT Interface, contact input, or Modbus commands.

The Cascade PID is cascaded with the Speed PID to vary unit speed/load. By directly positioning the Speed PID's setpoint, the Cascade PID can vary unit speed/load to control its input parameter. This configuration allows for bumpless transfers between the two control modes (speed/load and cascade).

Example Applications

The example applications in this chapter do not show every possible control configuration or combination. These examples are provided as a reference to follow when applying any of the controlling combinations or parameters. To apply a desired control parameter, refer to one or more of the typical application configurations that are shown and resemble the control configuration desired, then substitute the shown control parameters with the required control parameters.

Example—To configure the 5009 Control System to perform a turbine exhaust pressure limiting function use the “Pump or Compressor Discharge Pressure Control with Turbine Inlet Pressure Limiting” application for reference. With this example substitute exhaust pressure for inlet pressure and disregard any program settings specified to control pump or compressor discharge pressure.

The examples shown in this section are summarized as follows:
Example 1—Pump or Compressor Discharge Pressure Control with Inlet Pressure Limiting
Example 2—Pump or Compressor Suction Pressure Control with Dual Coil Actuator.
Example 3—Exhaust Pressure Control with Generator Power Limiting and Plant Import/Export Limiting
Example 4—Plant Import/Export Power Control with DRFD Servo Interface and Dual Coil Actuator
Example 5—Plant Import/Export Power Control with DRFD Servo Interface
Example 6—Inlet Pressure Control with Isochronous Load Share Control in Island Mode
Example 7—Plant Import/Export Power Control with Isochronous Load Share Control in Island Mode
Example 8—Inlet Pressure Control and Exhaust Pressure Control with Generator Power Limiting
Example 9—Admission Steam Control with Bootstrap Start-up **Capability**
Example 10—Plant Load and Steam Pressure Control
Example 11—Induction Generator Control

The features and functionality shown in each example are summarized in Table 4- 1.

Table 4-1. Example Extraction Summary

	APPLICATION	1	2	3	4	5	6	7	8	9	10	11
Turbine Type	Mechanical Drive	X	X									
	Synchronous Gen. Drive			X	X	X	X	X	X	X	X	
	Induction Gen. Drive											X
	Dual Inlet			X								
	Extraction Control						X	X	X		X	
	Ext./Admission Control					X						
	Admission Control									X		
Control Channels	Auxiliary Limiting	X	X	X			X					
	Auxiliary Control				X	X						
	Cascade Control	X	X	X			X	X				
	Synchronizing			X	X	X	X	X	X	X		
	Loadsharing						X	X				
	Frequency Control				X	X	X					
	Extr/Adm Control					X	X	X		X		
Control Modes	Inlet Pressure Control		X				X		X			
	Min Inlet Pres. Limiting	X										
	KW / Load Control							X		X	X	
	KW / Load Limiting		X				X		X			
	Import/Export Load Cntrl				X	X		X			X	
	Import/Export Load Limtg			X								
	Ext/Adm Pressure Control					X	X	X			X	
	Adm Flow Control									X		
	Exhaust Pressure Control			X				X	X			
	Suction Pressure Control		X									
Map Coupling Mode	Coupled HP & LP					X				X		
	Decoupled Inlet (HP)						X					
	Decoupled Exhaust (LP)							X				
	Decoupled HP & LP								X			
Devices	Dig. Sync Ld Share (DSLC)			X	X	X	X	X	X	X	X	
	Mstr Sync Ld Share (MSLC)							X			X	
	Real Power Sensor (RPS)			X	X	X	X		X	X		
	Dig. Rmt Final Dvr (DRFD)				X	X						
	Redundant Sensors		X									
	Dual-Coil Actuator		X									

855-591
97-03-31 JMM

Example 1—Pump or Compressor Discharge Pressure Control with Turbine Inlet Pressure Limiting

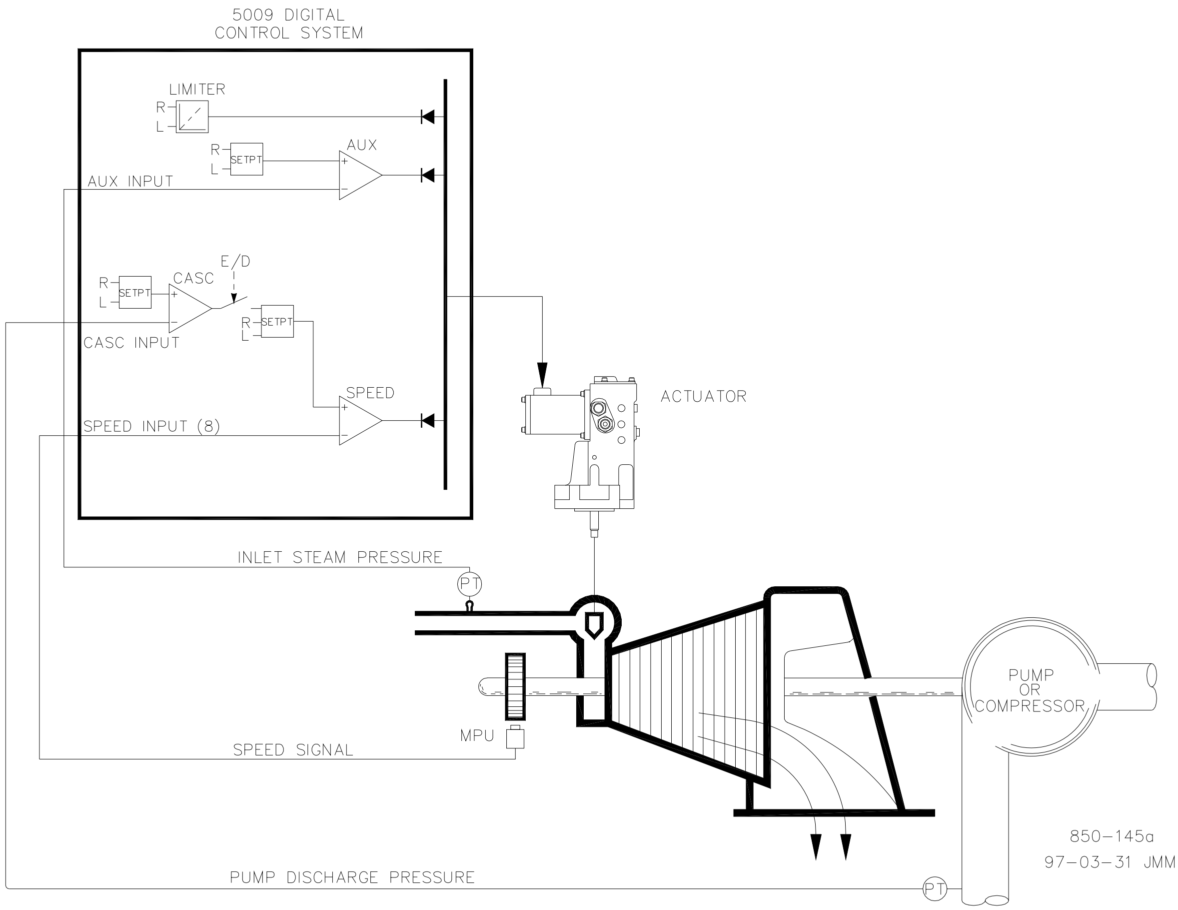


Figure 4-1. Pump or Compressor Discharge Pressure Control with Turbine Inlet Pressure Limiting

This is an example of a typical pump or compressor application. In this application the 5009 Control System is configured to normally control pump/ compressor discharge pressure and limit governor valve position based on low turbine inlet steam pressure. Both the auxiliary and cascade modes were used for this example application. Other applications may or may not use all the functionality shown in Figure 4-1 and described below.

With this application pump/compressor discharge pressure control is performed within the 5009 Control System through the Cascade Controller. Because the discharge pressure being controlled typically affects many other plant processes, a plant Distributed Control System (DCS) may be used to monitor plant process conditions and set the cascade setpoint. This can be performed through Modbus commands, discrete raise and lower commands, an analog setpoint signal or through the CCT Interface.

For this application a limiting type of control function was required to help preserve inlet header pressure in case of system header problems. Because the Auxiliary PID is the only controller that has this capability, it is used to sense turbine inlet pressure and limit governor valve position based on a low inlet pressure setting.

If a DCS is used to sense and control a process by positioning the load of multiple pumps or compressors (load sharing), the DCS may interface directly to the 5009 Control’s Speed PID setpoint through a remote speed setpoint analog input. This allows a DCS to monitor and compensate for plant and system conditions by directly changing the speed of multiple pumps or compressors simultaneously.

All 5009 PID controller setpoints may be adjusted through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands or the CCT Interface.

The following list of notes is provided as a reference for application programmers to follow when configuring the 5009 Control to achieve any of the control and limiting actions shown in Figure 4-1.

Starting & Run Mode Notes for Example 1—Starting and ramping to an idle or minimum speed position can be performed automatically, semiautomatically, or manually. From this position, the Idle/Rated or Auto Start Sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position or an operator can give a raise command to manually increase turbine speed.

After the unit has been started and is controlling at a minimum/desired speed position, cascade control (pump/compressor discharge pressure) can be enabled through contacts, Modbus commands, or the CCT Interface. When cascade control is enabled, if actual discharge pressure does not match the setpoint, the control will automatically ramp turbine speed at the 'SPEED SETPOINT SLOW RATE' setting until the pump/compressor discharge pressure matches the setpoint.

With this application the auxiliary control is used as a limiter, thus it does not need to be enabled. If turbine inlet pressure decreases below the auxiliary setpoint at any time the Auxiliary PID will take control of the governor valve and lower it to help preserve inlet header pressure.

See the Service Mode section of this manual for information on related tunable values and rates.

Example 2— Pump or Compressor Suction Pressure Control with Turbine Inlet Pressure Limiting and Dual Coil Actuator

This is an example of a typical pump or compressor application. With this application the 5009 Control System is configured to normally control pump/ compressor suction pressure, and limit governor valve position based on low turbine inlet steam pressure. Both the auxiliary and cascade modes were used for this example application. Redundant signals are used for the MPUs and the cascade input. Other applications may or may not use all the functionality shown in Figure 4-2 and described below.

With this application pump/compressor suction pressure control is performed within the 5009 Control System through the Cascade Controller. The cascade inputs are from redundant pressure transducers. The I/O handling for redundant sensors is explained in Volume 1 of this manual.

Because the discharge pressure being controlled typically affects many other plant processes, a plant Distributed Control System (DCS) may be used to monitor plant process conditions and set the cascade setpoint position. This can be performed through Modbus commands, discrete raise and lower commands, with an analog setpoint signal or through the CCT Interface.

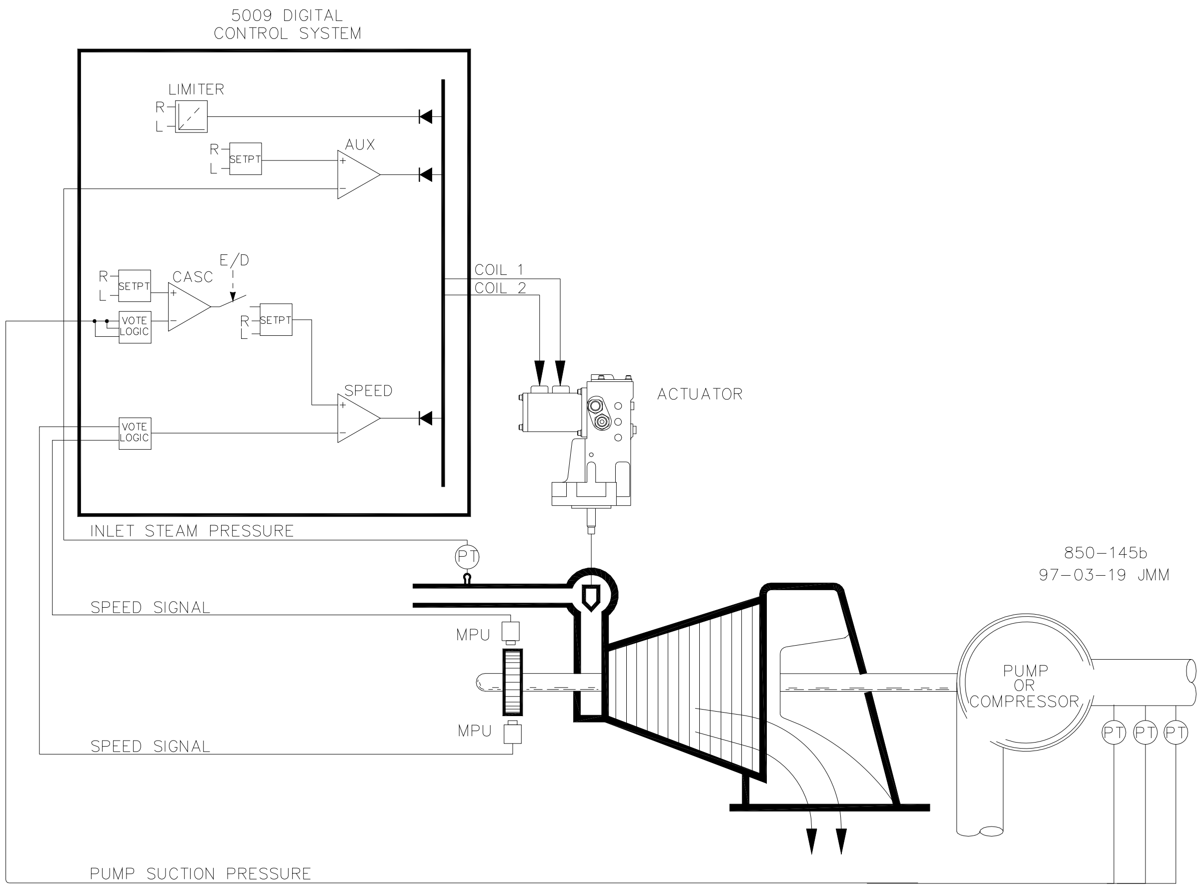


Figure 4-2. Pump or Compressor Suction Pressure Control with Turbine Inlet Pressure Limiting and Dual Coil Actuator

For this application a limiting type of control function was required to help preserve inlet header pressure in case of system header problems. Because the Auxiliary PID is the only controller that has this capability, it is used to sense turbine inlet pressure and limit governor valve position, based on a low inlet pressure setting.

If a DCS is used to sense and control a process by positioning the load of multiple pumps or compressors (load sharing), the DCS may interface directly to the 5009 Control's Speed PID setpoint through a programmed remote speed setpoint analog input. This allows a DCS to monitor and compensate for plant and system conditions by directly changing the speed of multiple pumps or compressors simultaneously.

All 5009 PID controller setpoints may be changed through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes is provided as a reference for application programmers to follow when configuring the 5009 Control System to achieve any of the control and limiting actions shown in Figure 4-2.

Starting & Run Mode Notes for Example 2—Starting and ramping to an idle or minimum speed position can be performed automatically, semiautomatically, or manually. From this position, the Idle/Rated or Auto Start Sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position or an operator can give a raise command to manually increase turbine speed.

After the unit has been started and is controlling at a minimum/desired speed position, cascade control (pump/compressor discharge pressure) can be enabled through contacts, Modbus commands, or the CCT Interface. When cascade control is enabled, if actual discharge pressure does not match the setpoint, the control will automatically ramp turbine speed at the 'SPEED SETPOINT SLOW RATE' setting until the pump/compressor discharge pressure matches the setpoint.

With this application the auxiliary control is used as a limiter, thus it does not need to be enabled. If turbine inlet pressure decreases below the auxiliary setpoint at any time, the Auxiliary PID will take control of the governor valve and lower it to help preserve inlet header pressure.

See the service mode section of this manual, for information on related tunable values and rates.

Example 3—Exhaust Pressure Control with Generator Power Limiting and Plant Import/Export Limiting

This is an example of a typical turbine generator application where plant process steam (turbine exhaust pressure) is desired to be controlled at a single pressure level. With this type of application, turbine load varies based on the plant process steam demand. Both the auxiliary and cascade modes were used for this example application. Other applications may or may not utilize all the functionality shown in Figure 4-3 and described below.

With this application turbine exhaust pressure control is performed within the 5009 Control through the Cascade PID controller. This is an ideal controller for this type of function because it can be enabled and disabled as desired by a system operator. This gives a system operator full authority of when to transfer process pressure control to or from a letdown station or turbine bypass valve.

Because turbine load may vary greatly with this application, a limiter is used to protect the generator from being over powered. In order to limit generator load, the 5009 Control must be able to sense generator load. As shown in Figure 4-3 generator load is being sensed with a Woodward Real Power Sensor (RPS) and supplied to the 5009 Control's KW droop input. Generator over-load protection is performed by a combination of the Speed PID and the speed setpoint maximum limit. By programming the speed setpoint maximum limit to that of rated speed plus the % droop value at 100% load, the speed setpoint cannot be taken over 100% load.

A limiting type of control function was required to limit the plant export power to zero. The plant does not get reimbursed for any power exported, and it is more economical to make power than purchase it from the utility, thus a zero plant import/export power level is desired. Because the Auxiliary PID is the only 5009 controller that has this limiting capability, it was used to sense tie line power and limit turbine/generator output based on a zero export limit setting.

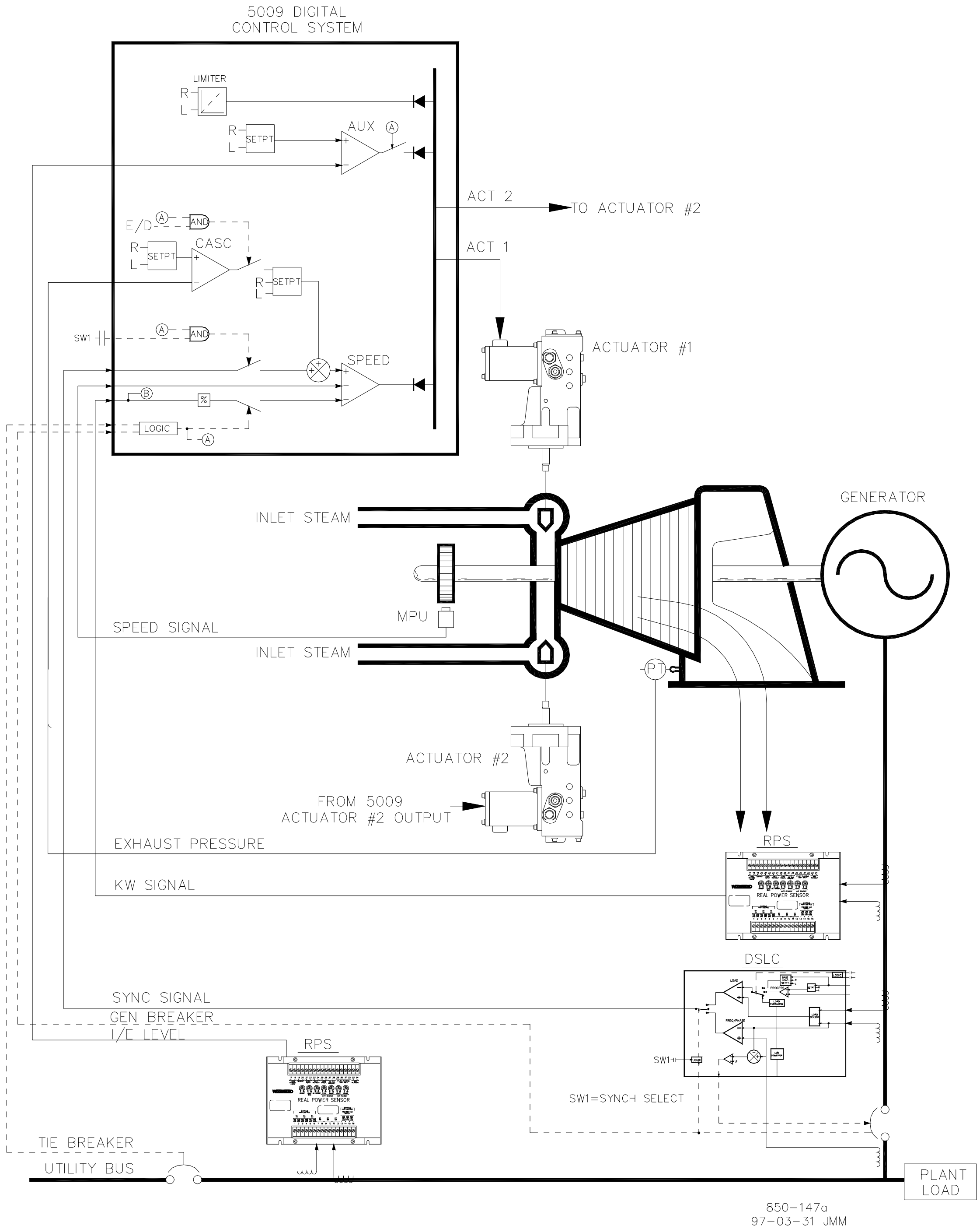


Figure 4-3. Exhaust Pressure Control with Generator Power Limiting and Plant Import/Export Limiting

A second RPS #8272-726 was used with this application to sense utility tie line power. This RPS senses –5 to +5 A CT current to allow its output to represent power flow in both the import and export directions. With this RPS 12 mA represents zero power flow. Because of this feature, the RPS #8272-726 cannot be used with the 5009 Control to sense generator load/power. Please check with a Woodward certified distributor or factory for the correct RPS to use as a generator load sensor.

This application uses a DSLC™ control for synchronization only. Because the DSLC interfaces to the 5009 Control through an analog signal, a 5009 Control analog input must be programmed. When a synchronizing input/function is programmed, the input can be enabled, through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-3 a panel mounted (DPST) switch is used with this application to select automatic synchronization in both the DSLC and 5009 Control.

This example uses split range valves. Both valves are driven from the same Low Signal Select (LSS) bus, however, actuator #2 does not begin to open until actuator #1 reaches the programmed offset %. After this point both actuators move proportionally. See Figure 4-3b.

All 5009 Control PID controller setpoints may be changed through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve the control and limiting actions shown in Figure 4-3.

Starting & Run Mode Notes for Example 3—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. From an idle or minimum speed position, the Idle/Rated or Auto Start Sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position. Alternatively, an operator can give a manual raise command to increase turbine speed as desired.

After the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized manually, or automatically. The system operator can select automatic synchronization through the auto-synch select switch (SW1 in Figure 4-3). When this switch is closed, the 5009 Control's synchronizing input is enabled and the DSLC control's automatic synchronizing function selected.

When the plant to utility tie line/breaker is closed, and the unit generator breaker closes, the 5009 Control steps the speed/load setpoint up to a minimum load level to reduce the chance of reverse powering or motoring the generator. This minimum load level is based on the speed/load setpoint and is defaulted to a "3%" step change of the speed/load setpoint. The defaulted value is adjustable through the 5009 Control's CCT Interface (**BREAKER LOGIC - MIN LOAD BIAS = 5 RPM**).

After synchronization the 5009 Control's load setpoint can be positioned through raise and lower speed/load setpoint contacts, a programmed 4–20 mA input, Modbus commands, or the CCT Interface.

Cascade control (turbine exhaust pressure) can be enabled at any time after the utility tie breaker and generator breaker input contacts are closed. Cascade control can be enabled through a programmed contact, Modbus command, or the CCT Interface. Exhaust pressure control can be transferred from a letdown station or turbine bypass valve in one of the following ways; enabling cascade control and backing down the letdown station's setpoint, or slowly increasing turbine load with the Speed PID's setpoint to allow the letdown station to close, then enable cascade control.

After exhaust pressure control has been transferred to the 5009 Control's Cascade PID, the letdown station or turbine bypass valve must be closed or in a manual control mode. This will stop the two controllers (5009 Control Cascade PID and system letdown station) from fighting for control of one parameter and causing system instability.

With this application the auxiliary control is programmed to be used as a limiter and be automatically enabled when both the utility tie and generator breakers are closed. When paralleled to the utility this 5009 and RPS combination allows the plant to import power from the utility, but not export power. If the utility-to-plant tie line power reaches a zero import/export level the Auxiliary PID will begin limiting generator output until plant conditions require power to be imported again.

Optionally the Auxiliary PID's setpoint can be varied to limit plant power to a different import or export power level.

Example 4—Plant Import/Export Control with SPC Interface

This is an example of a typical turbine generator application where plant import/ export control is desired when paralleled with the utility, and frequency control when isolated from the utility. When paralleled to the utility, turbine load varies based on the plant power demand. Other applications may or may not use all the functionality shown in Figure 4-4 and described below.

With this application plant import/export control is performed within the 5009 Control through the Auxiliary PID controller. Optionally the Cascade PID controller could have been used instead. For this application the Auxiliary PID is configured to be enabled and disabled on command instead of performing a limiting action. This gives a system operator full authority of when to enable or disable plant import/export control.

When programmed for this type of control action, the Speed PID is disabled when the Auxiliary PID is enabled and can only limit the 5009 Control’s valve output signal if unit load reaches 100%. Also, the auxiliary setpoint automatically tracks the PID’s input value when not in control.

A Real Power Sensor (RPS) #8272-726 was used with this application to sense utility tie line power flow. This RPS senses –5 to +5 A CT current to allow its output to represent power flow in both the import and export directions. With this RPS 12 mA represents zero power flow. Because of this feature the RPS #8272-726 cannot be used with the 5009 Control to sense generator load/power.

To save buying a second RPS for this application, unit load is sensed through turbine inlet valve position (5009 Control LSS bus), not a generator load signal. When the generator is paralleled to the utility, the Speed PID controls governor valve position instead of generator power. Thus 100% governor valve position is considered 100% unit load regardless of system conditions.

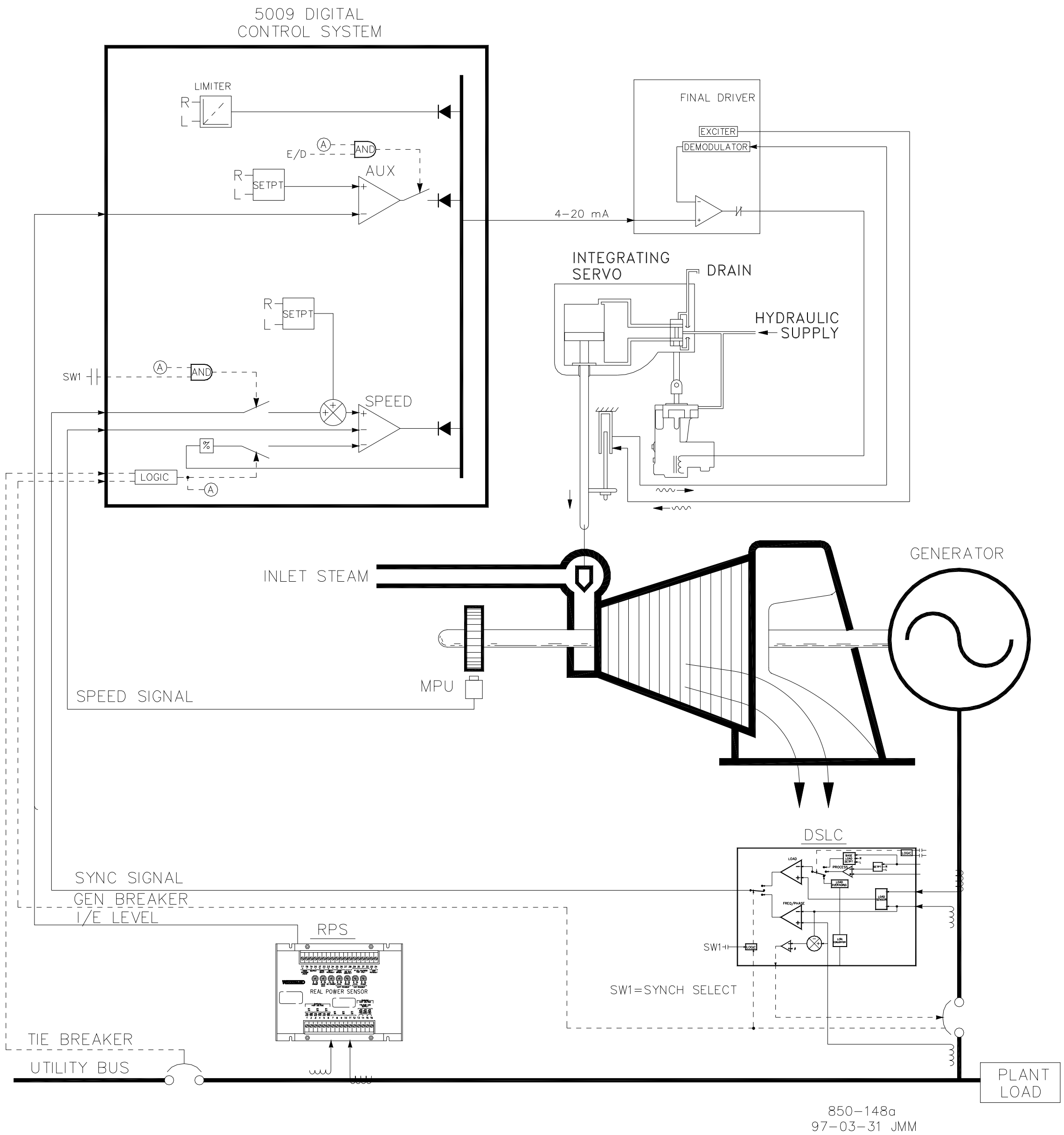


Figure 4-4. Plant Import/Export Control with DRFD Servo Interface

The DSLC is used for synchronization only. Because the DSLC interfaces to the 5009 Control through an analog signal, a 5009 Control analog input must be programmed. When a synchronizing input/function is programmed, the input can be enabled through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-4 a panel mounted (DPST) switch is used with this application to select automatic synchronization in both the DSLC and 5009 Control.

With this application the existing servo assembly had an actuator which required ±50 mA for pilot valve positioning and a LVDT mounted to the valve rack to feedback actual rack position. Because the 5009 Control does not have a bipolar drive circuit and cannot perform closed loop servo position control, a Woodward Servo Position Controller (SPC) was used to interface with the existing servo actuator. The integrating type of SPC used accepts a 4–20 mA valve demand signal from the 5009 Control, monitors actual valve position (through, LVDTs, MLDTs, or other DC position feedback devices), compares the two signals, and outputs a drive signal to the servo assembly's actuator accordingly. The SPC interfaces directly with an LVDT, (providing excitation and demodulation) thus no external converter was required.

Older 5009 installations utilize the Digital Remote Final Driver (DRFD), which is still a valid control solution. However, for new installations, the Servo Position Controller (SPC) should be used. Also, with the new 5009FT system, the option exists to interface the actuator and its feedback mechanisms directly to the 5009FT Actuator Controller card.

All 5009 Control PID controller setpoints may be changed through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve any control and limiting actions shown in Figure 4-4.

Starting & Run Mode Notes for Example 4—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. From an idle or minimum speed position, the Idle/Rated or Auto Start sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position. Alternatively, an operator can give a manual raise command to increase turbine speed as desired.

After the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized manually or automatically. The system operator can select automatic synchronization through the auto-synch select switch (SW1 in Figure 4-4). When this switch is closed the 5009 Control's synchronizing input is enabled and the DSLC control's automatic synchronizing function selected.

The DSLC provides either phase matching or slip frequency synchronizing, and ties into the unit automatic voltage regulator to match voltages before paralleling. It communicates over a LAN, using an Echelon network, with other plant DSLC controls to perform safe dead bus closing.

When the plant-to-utility tie line/breaker is closed and the unit generator breaker closes, the 5009 Control steps the speed/load setpoint up to a minimum load level to reduce the chance of reverse powering or motoring the generator. This minimum load level is based on the speed/load setpoint and is defaulted to a "3%" step change of the speed/load setpoint. The defaulted value is adjustable through the 5009 Control's Service mode (**BREAKER LOGIC - MIN LOAD BIAS = 5 RPM**).

After synchronization the 5009 Control's load setpoint can be positioned through raise and lower speed/load setpoint contacts, a programmed 4–20 mA input, Modbus commands, or the CCT Interface.

With this configuration, Import/Export control (Auxiliary PID) can be enabled at any time after the utility tie breaker and generator breaker input contacts are closed. Auxiliary control can be enabled through the programmed contact, a Modbus command, or the CCT Interface. Because the auxiliary setpoint tracks plant import/export power before being enabled, the transfer to auxiliary control is bumpless. Once enabled, the Auxiliary PID's setpoint can then be positioned to the desired import or export level.

Because of the 5009 Control's configuration, this unit will automatically switch to frequency control the plant-to-utility tie breaker is opened.

Example 5—Plant Import/Export Control with SPC Interface

(Adm or Extr/Adm Turbine, Coupled HP & LP mode)

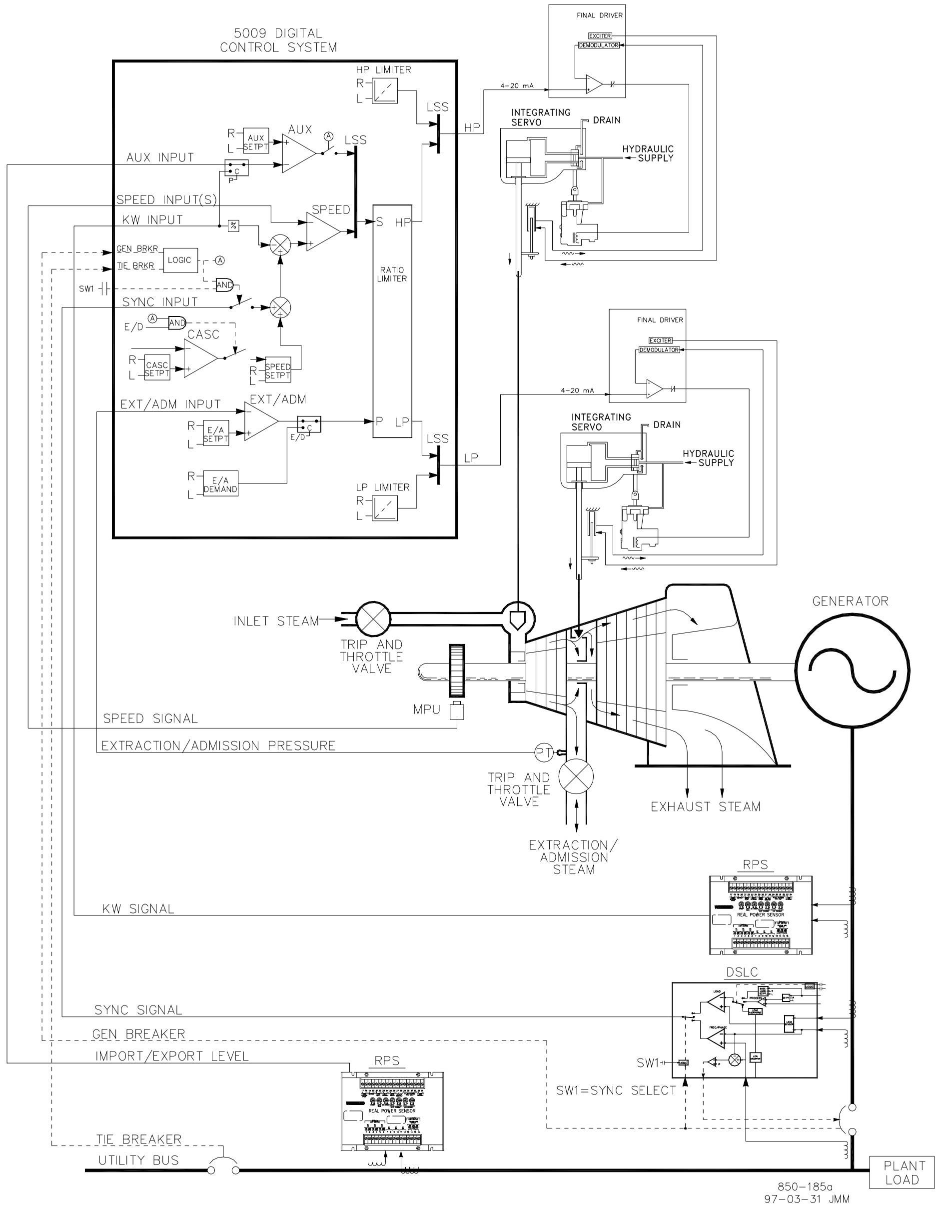


Figure 4-5. Plant Import/Export Control with DRFD Servo Interface

This is an example of a typical turbine generator application where plant import/ export control is desired when paralleled with the utility, and frequency control when isolated from the utility. When paralleled to the utility, turbine load varies based on the plant power demand. Other applications may or may not use all the functionality shown in Figure 4-5 and described below.

With this application, plant import/export control is performed within the 5009 Control through the Auxiliary PID controller. The Cascade PID controller could have been used instead. Also, the Auxiliary PID is configured to be enabled and disabled on command instead of performing a limiting action. This gives a system operator full authority of when to enable or disable plant import/export control. When programmed for this type of control action, the Speed PID is disabled when the Auxiliary PID is enabled and can only limit the 5009 Control's valve output signal if unit load reaches 100%. The auxiliary setpoint automatically tracks the Auxiliary PID's input value when not in control.

Two Real Power Sensors (RPS) were used with this application; one for sensing generator load to allow the 5009 Control Speed/load PID to control generator output, and one for sensing plant import/export tie line power to allow the 5009 Control Auxiliary PID to control plant import/export power.

A RPS #8272-726 was used with this application to sense utility tie line power flow. This RPS senses –5 to +5 A CT current to allow its output to represent power flow in both the import and export directions. With this RPS 12 mA represents zero power flow. Because of this feature, the RPS #8272-726 cannot be used with the 5009 Control to sense generator load/power.

Because of the similarities between the operation of admission (Adm) and extraction/admission (Extr/Adm) turbines, this example application will cover both types of turbines. In either case it is assumed that an external trip valve or trip-and-throttle valve is used to completely stop any admission steam from entering the turbine upon a system shutdown condition.

Adm or Extr/Adm pressure is controlled by the Extr/Adm PID. This PID must be manually enabled once the pressures on both sides of the admission trip-and - throttle (T&T) valve have been matched. A manual demand signal is available in the 5009 Control to allow an operator to match the pressures across the admission T&T valve before enabling the control loop. With this application the Extr/Adm setpoint is varied through the 5009 Control’s CCT Interface or Modbus commands.

This application uses a DSLC for synchronization only. Because the DSLC interfaces to the 5009 Control through an analog signal, an analog input must be programmed. When a synchronizing input/function is programmed, the input can be enabled through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-5, a panel mounted (DPST) switch is used with this application to select automatic synchronization in both the DSLC and the 5009 Control.

With this application the existing servo assembly had an actuator which required ±50 mA for pilot valve positioning and a LVDT mounted to the valve rack to feedback actual rack position. Because the 5009 Control does not have a bipolar drive circuit and cannot perform closed loop servo position control, a Woodward Servo Position Controller (SPC) was used to interface with the existing servo actuator. The integrating type of SPC used accepts a 4–20 mA valve demand signal from the 5009 Control, monitors actual valve position (through, LVDTs, MLDTs, or other DC position feedback devices), compares the two signals, and outputs a drive signal to the servo assemblies actuator accordingly. The SPC interfaces directly with an LVDT, (providing excitation and demodulation) thus no external converter was required.

Older 5009 installations utilize the Digital Remote Final Driver (DRFD), which is still a valid control solution. However, for new installations, the Servo Position Controller (SPC) should be used. Also, with the new 5009FT system, the option exists to interface the actuator and its feedback mechanisms directly to the 5009FT Actuator Controller card.

All 5009 Control PID controller setpoints may be changed through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve any control and limiting actions shown in Figure 4-5.

Starting & Run Mode Notes for Example 5—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. From an idle or minimum speed position, the Idle/ Rated or Auto Start sequence functions can be used to assist in ramping the control to a rated speed position. Alternatively, an operator can give a manual raise command to increase turbine speed as desired.

After the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized. This can be done manually or automatically. The system operator can select automatic synchronization through the Auto-Sync select switch (SW1 in Figure 4-5). When this switch is closed the 5009 Control’s Synchronizing input is enabled and the DSLC control’s automatic synchronizing function selected.

The DSLC provides either phase matching or slip frequency synchronizing and ties into the unit automatic voltage regulator to match voltages before paralleling. It communicates over a LAN, using an Echelon network, with other plant DSLC controls to perform safe dead bus closing.

When the plant-to-utility tie line/breaker is closed and the unit generator breaker closes, the 5009 Control steps the speed/load setpoint up to a minimum load level to reduce the chance of reverse powering or motoring the generator. This minimum load level is based on the speed/load setpoint and is defaulted to a “3%” step change of the speed/load setpoint. The defaulted value is adjustable through the 5009 Control’s CCT Interface (**BREAKER LOGIC, MIN LOAD BIAS = xxx RPM**).

After synchronization the 5009 Control’s load setpoint can be positioned through raise and lower speed/load setpoint contacts, a programmed 4–20 mA input, Modbus commands, or the CCT Interface.

Admission or Extr/Adm control can be enabled any time after the generator breaker is closed. To perform a bumpless transfer into Adm or Extr/Adm control the pressures on each side of the Adm Trip-&-Throttle (T&T) valve should be matched. The 5009 Control has a manual demand signal to allow operators to manually vary the pressure on the turbine side of the Adm T&T valve. Once these pressures are matched an operator can open the T&T valve and then issue an Extr/ Adm control enable command. The manual demand signal’s raise and lower and the Extr/Adm enable/disable commands can all be issued through the 5009 Control’s CCT Interface, contact inputs, or Modbus commands.

When a letdown station is used as a backup to the turbine extraction pressure controller, it is required that the letdown station’s setpoint be lower than that of the 5009 Extraction Control’s setpoint to prevent fighting and potential instability between the controllers.

With this configuration, import/export control (Auxiliary PID) can be enabled at any time after the utility tiebreaker and generator breaker input contacts are closed. Auxiliary control can be enabled through the programmed contact, a Modbus command, or the CCT Interface. Because the auxiliary setpoint tracks plant import/export power before being enabled, the transfer to auxiliary control is bumpless. Once enabled, the Auxiliary PID’s setpoint can then be positioned to the desired import or export level.

Because of the 5009 Control’s configuration, this unit will automatically switch to frequency control upon the opening of the plant-to-utility tie breaker.

Example 6—Inlet Pressure Control with Isochronous Load Sharing Control in Island Mode

(Extraction Turbine, Decoupled Inlet mode, Coupled HP & LP mode)

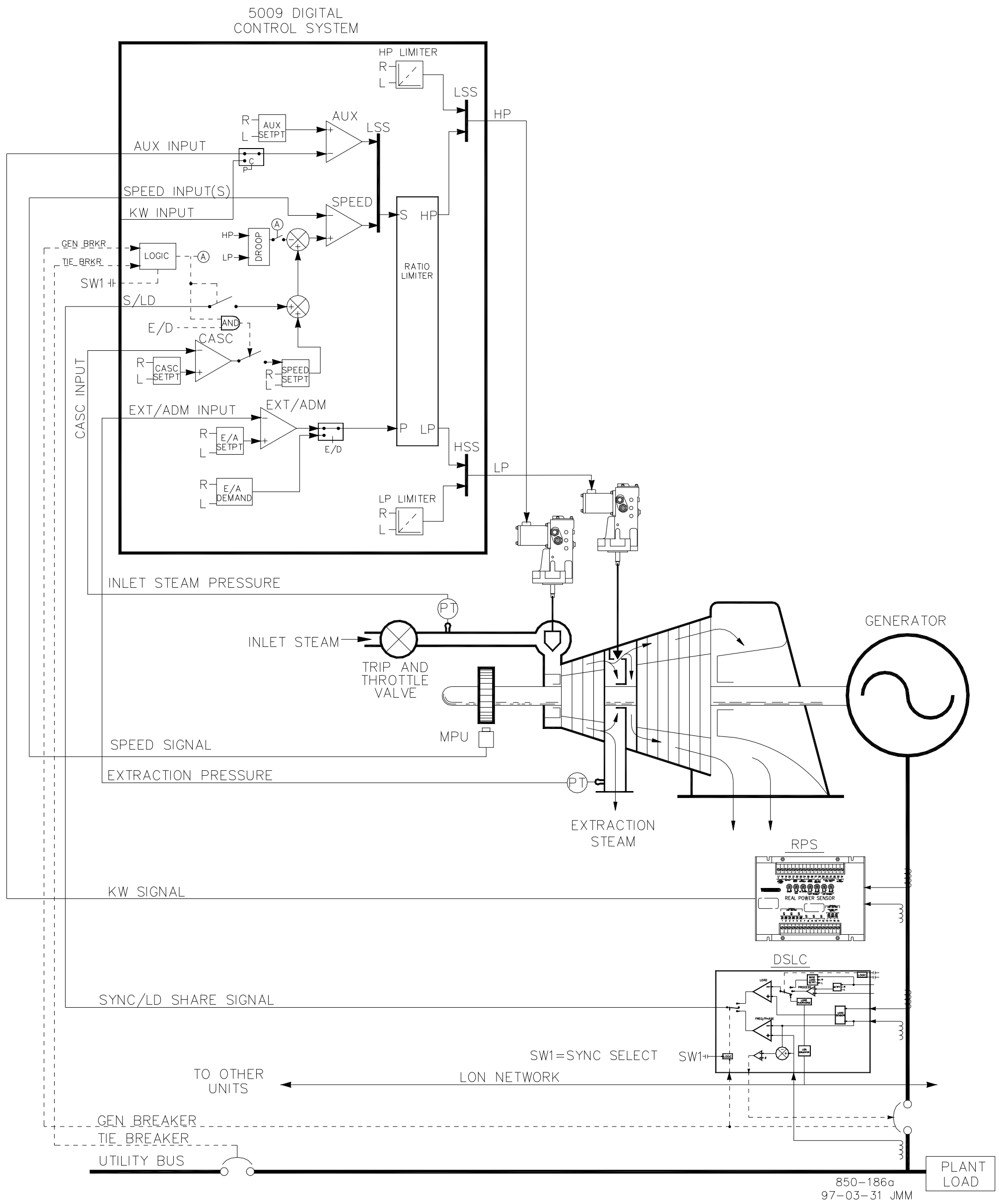


Figure 4-6. Inlet Pressure Control with Isochronous Load Sharing Control in Island Mode

For this application it is desired to control inlet pressure when paralleled to the utility, and plant frequency when isolated from the utility. With this type of application load varies based on plant process steam demand when paralleled to the utility. When isolated from the utility, unit load varies based on plant power demand. Other applications may or may not utilize all the functionality shown in Figure 4-6 and described below.

Turbine inlet header pressure control is performed within the 5009 Control through the Cascade PID controller. This is an ideal controller for this type of function because it can be enabled and disabled as desired by a system operator. This gives a system operator full authority of when to transfer process pressure control to or from a letdown station or turbine bypass valve.

Extraction pressure is controlled by the extraction PID. This PID controller can be enabled automatically or manually depending on configuration. In all cases, the 5009 Control starts up with the extraction PID disabled and the LP valve at its maximum open position. This allows a turbine to warm-up in a uniform manner. The extraction setpoint can be varied through the 5009 Control's CCT Interface, discrete inputs, a 4–20 mA signal, or Modbus commands.

During normal operation, unit load is determined by the Cascade PID which is controlling inlet header pressure. Because turbine load may vary greatly, a limiter is used to protect the generator from being over powered. This protection is performed by the Auxiliary PID configured as a limiter.

This application uses a DSLC for synchronization and isochronous load sharing. When the unit is paralleled to the utility, the DSLC is disabled and the 5009 Control's internal load setpoint or Cascade PID (inlet header pressure) is used to control/set unit load. When the plant becomes isolated from the utility (utility tie breaker opens), the DSLC is enabled, cascade control is disabled, and the 5009 Control is switched to a frequency control / load sharing mode.

The DSLC sends an analog input signal to the 5009 Control to set the Sync/Ld Share level. When a Sync/Ld Share analog input is programmed, the input is automatically enabled if the generator breaker input is closed and the utility tie breaker input is open.

Before the generator breaker is closed, the Sync/Ld Share input can be enabled to allow automatic synchronization by the DSLC. This synchronizing function/input can be enabled through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-6 a panel mounted (DPST) switch is used with this application to select automatic synchronization in both the DSLC and 5009 Control. Alternatively, this switch could come from a 5009 Control relay programmed to energize for a Modbus Command, CCT Interface Command, Sync Enabled, or a Speed Switch Level Reached condition.

All 5009 Control PID controller setpoints may be changed through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve any control and limiting actions shown in Figure 4-6.

Starting & Run Mode Notes for Example 6—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. From an idle or minimum speed position, the Idle/ Rated or Auto Start Sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position. Alternatively, an operator can give a manual raise command to increase turbine speed as desired.

When the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized. This can be done manually or automatically. The system operator can select automatic synchronization through the Auto-Sync select switch (SW1 in Figure 4-6). When this switch is closed the 5009 Control's Sync/Load Sharing input is enabled and the DSLC control's automatic synchronizing function is selected.

After synchronization, generator load is determined by the state of the utility tie breaker contact input. If the utility tie breaker contact is closed, generator load is determined by the 5009 Control's internal load setpoint or, when enabled, inlet header pressure control (cascade control). If the utility tie breaker contact is open, generator load is determined by the DSLC. The DSLC can be configured to operate in several different load control modes. For this application the DSLC is only used for isochronous load sharing, when the plant is isolated from the utility.

In this plant four generating units use DSLC controls and, upon the plant-to-utility tie breaker opening, they all switch to frequency control and communicate over a LAN, using an Echelon network, to share load. Thus plant frequency is controlled by all units and plant load is shared proportionally by all four units. With this configuration, plant frequency will be the average frequency of all units. The 5009 Control has a feature that resets its frequency setpoint to the 'RATED SPEED SETPOINT' setting upon the utility tie breaker opening, thus assuring that all units will be at synchronous speed. The DSLC control's frequency trimmer function may also be programmed to trim system frequency to a desired frequency.

Cascade control (turbine inlet header pressure) can be enabled at any time after the utility tie breaker and generator breakers are closed through a contact input, Modbus command or the CCT Interface. If the actual inlet header pressure does not match the cascade setpoint when cascade control is enabled, the control will automatically ramp turbine load at the “Speed Setpoint Slow Rate” setting until the inlet header pressure does match the setpoint. Once in control, the Cascade PID will no longer be limited by the “Speed Setpoint Slow Rate” setting. The 5009 Control’s ratio/limiter uses the coupled HP & LP mode when cascade control is disabled and the decoupled Inlet mode when cascade control is enabled.

Because the 5009 Control was programmed for the capability to automatically enable Extraction Control, the operator may choose to automatically or manually enable Extraction Control. To manually enable Extraction Control, the operator must issue a LP valve limiter lower command from the 5009 Control CCT Interface, a contact input, or through Modbus commands. The LP valve limiter must be taken to its minimum position to fully enable Extraction Control.

The enabling routine, which automatically lowers the LP valve limiter, may be issued from the 5009 Control’s CCT Interface, contact input, or through Modbus commands. This routine automatically ramps the LP valve to its minimum position and may be stopped at any time by momentarily issuing a LP valve limiter raise or lower command. Once the automatic enabling routine has been stopped it may be restarted/enabled at any time by issuing a disable command followed by an Extr/Adm control enable command or, once stopped, the operator may continue the routine manually. (Disabling of Exhaust control can also be performed manually or automatically.)

When a letdown station is used as a backup to the turbine extraction pressure controller, it is required that the letdown station’s setpoint be lower than that of the 5009 Control extraction control’s setpoint to prevent fighting and potential instability between the controllers.

With this application the Auxiliary Control is programmed to be used as a limiter and to be automatically enabled when both the utility tie and generator breakers are closed. When paralleled to the utility, if inlet header pressure demand and/or other system conditions try to force the generator to operate above its load limit setting, the Auxiliary PID will take control of the governor valve to limit generator load. Once system conditions demand unit load below that of the auxiliary setpoint, the Cascade/Speed PIDs will again take control of generator load.

Example 7—Import/Export Control or Exhaust Pressure Control with Isochronous Load Sharing in Island Mode

(Extraction Turbine, Decoupled Exhaust Mode, Coupled HP & LP Mode)

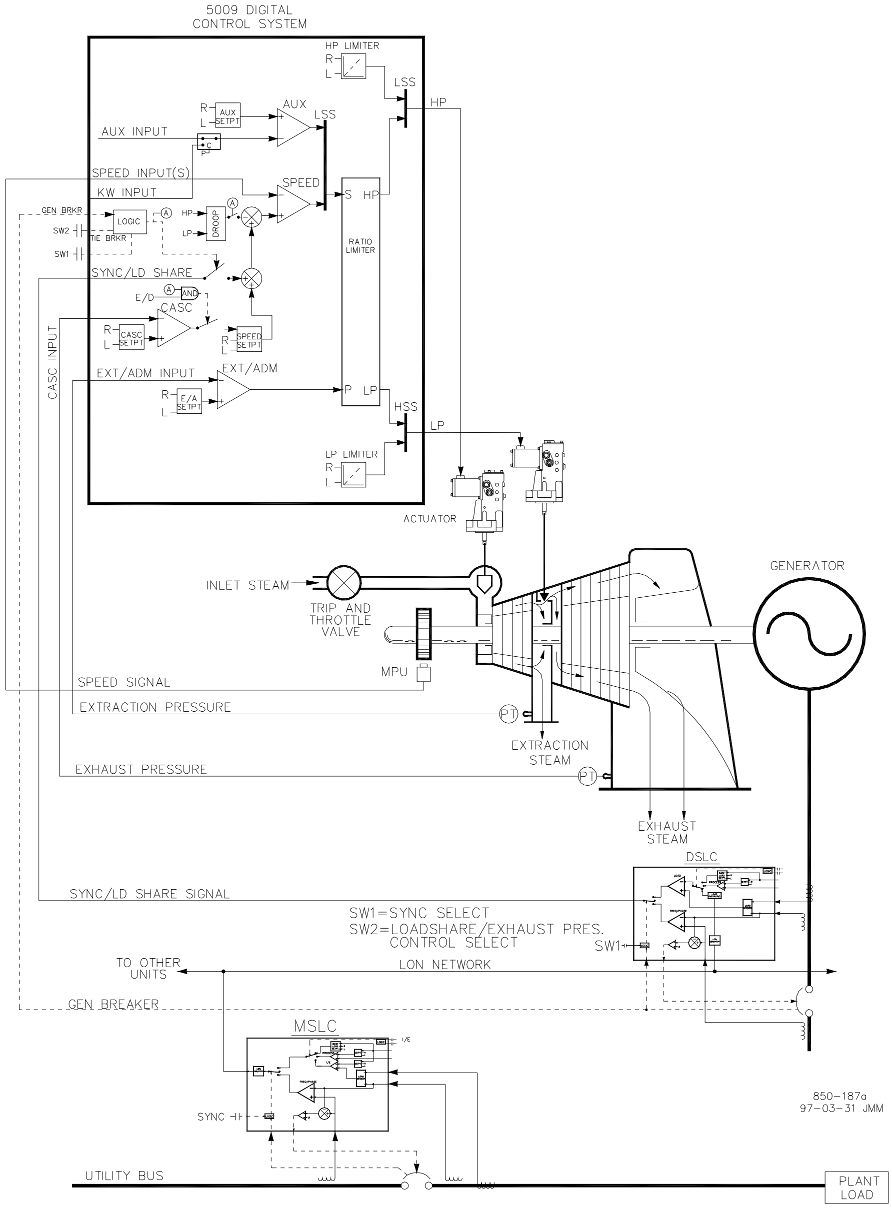


Figure 4-7. Import/Export Control or Exhaust Pressure Control with Isochronous Load Sharing in Island Mode

This example utilizes multiple turbine generators and requires that all units have the capability to control different plant parameters depending on the status of each unit. Normal operation is to have one unit control plant process steam (turbine exhaust pressure) and the other units be controlled based on plant import/export demand. Other applications may or may not utilize all the functionality shown in Figure 4-7 and described below.

Based on system health, only one unit at any time is used to control plant process steam. The other units are used to control a plant export power level of five MW.

Each unit control panel has a mode selection switch which allows an operator to place a unit in one of three different modes of operation. The three modes of operation are: manual load (used to manually load and unload a unit), plant process steam control (turbine exhaust pressure), and load sharing (used for plant import/export control or unit load sharing).

When a unit is switched to manual load control mode, its internal load setpoint determines unit load. This allows an operator to manually load or unload a unit to a set level if desired.

When a unit is switched to the plant process control mode, turbine exhaust pressure control is performed within the 5009 Control through the Cascade PID controller. This is an ideal controller for this type of function because it can be enabled and disabled as desired by a system operator. This gives a system operator full authority of when to transfer process pressure control to or from a letdown station or turbine bypass valve.

This application uses Woodward DSLC controls and an MSLC to allow all units to communicate, share plant load, and control plant export power. The DSLC is used on each unit for synchronization and load sharing. One Master Synchronizer & Load Control (MSLC) is used for plant synchronization and import/export power control. The MSLC, when enabled, sets the load setpoint of each unit DSLC (in the load sharing mode) to control a plant export level. When the plant- to-utility tie breaker is open, the MSLC is disabled, and each unit communicates with the other units in the load sharing mode via the DSLC control’s LON network to share plant load.

Extraction pressure is controlled by the Extr/Adm PID. This PID controller can be enabled automatically or manually depending on configuration. In all cases the 5009 Control starts up with the Extr/Adm PID disabled and the LP valve at its maximum open position. This allows a turbine to warm-up in a uniform manner. With this application the Extr/Adm setpoint is only varied through the 5009 Control’s CCT Interface or Modbus Commands. Optionally the 5009 Control could be programmed to have the Extr/Adm setpoint varied through discrete inputs or a 4–20 mA signal.

A DSLC control’s speed bias signal interfaces to a 5009 Control through an analog input signal. When a Sync/Ld Share analog input is programmed, the input is automatically enabled if the generator breaker input is closed and the utility tie breaker input is open.

Before the generator breaker is closed, the 5009 Control’s Sync/Ld Share analog input can be enabled to allow automatic synchronization by the DSLC. This synchronizing function/input can be enabled through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-7, a panel mounted (DPST) switch is used to select automatic synchronization in both the DSLC and 5009 Control. Alternatively, this switch could come from a 5009 Control relay programmed to energize for a Modbus command selected, sync enabled, or a speed switch level reached.

All 5009 Control PID controller setpoints may be changed through programmed raise and lower contacts, 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve any control and limiting actions shown in Figure 4-7.

Starting & Run Mode Notes for Example 7—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. From an idle or minimum speed position, the Idle/ Rated or Auto Start sequence functions can be used to assist in ramping the control to a rated speed position. Alternatively, an operator can give a manual raise command to increase turbine speed as desired.

After the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized. This can be done manually or automatically. The system operator can select automatic synchronization through the Auto-Sync select switch (SW1 in Figure 4-7). When this switch is closed the 5009 Control’s Synchronizing input is enabled and the DSLC control’s automatic synchronizing function selected.

In this mode, the operation of the system is dependent on SW2's position. When SW2 is not selecting the load sharing mode and the generator breaker is closed, unit load is set by the 5009 Control's internal speed/load setpoint, or the Cascade PID if enabled. Upon the generator breaker closing, the 5009 Control steps the speed/load setpoint up to a minimum load level to reduce the chance of reverse powering or motoring the generator. This minimum load level is based on the speed/load setpoint and is defaulted to a speed setpoint rpm value equal to "3%" turbine/generator load. The defaulted value is adjustable through the 5009 Control's CCT Interface or Modbus commands.

After synchronization the 5009 Control's load setpoint can be positioned through raise and lower speed/load setpoint contacts, a programmed 4–20 mA input, Modbus commands, or the CCT Interface.

Since decoupled exhaust was the ratio/limiter action programmed with this application, it is recommended that Extraction Control be enabled (the LP limiter lowered to min) before exhaust control (which uses the LP valve to control). It is also recommended that cascade control be disabled before Extraction Control is disabled (the LP limiter raised). By following these recommended procedures, each control mode can be bumplessly taken into and out of control. The 5009 Control's ratio/limiter uses the coupled HP & LP mode when cascade control is disabled and the decoupled exhaust mode when cascade control is enabled.

Because the 5009 Control was programmed for the capability to automatically enable Extraction Control, the operator may choose to automatically or manually enable Extraction Control. To manually enable Extraction Control the operator must issue a LP valve limiter lower command from the CCT Interface, a contact input, or through Modbus commands. The LP valve limiter must be taken to its minimum position to fully enable Extraction Control.

The enabling routine, which automatically lowers the LP valve limiter, may be issued from the 5009 Control's CCT Interface, contact input, or through Modbus commands. This routine automatically ramps the LP valve to its minimum position and may be stopped at any time by momentarily issuing a LP valve limiter raise or lower command. Once the automatic enabling routine has been stopped it may be restarted/enabled at any time by issuing a disable command followed by an Extr/Adm control enable command or, once stopped, the operator may continue the routine manually. (Disabling of Exhaust control can also be performed manually or automatically.)

Cascade control (turbine exhaust pressure) can be enabled at any time after the utility tie breaker and generator breaker input contacts are closed. Cascade control can be enabled through a programmed contact, Modbus command, or the CCT Interface. Exhaust pressure control can be transferred from a letdown station to 5009 Control Cascade Control in one of the following ways; enabling cascade control, and backing down the letdown station' s setpoint, or enabling cascade control and raising the cascade's setpoint. When a letdown station is used as a backup to the turbine pressure controller, it is required that the letdown station's setpoint be lower than that of the 5009 Control's setpoint to prevent fighting and potential instability between the controllers.

After exhaust pressure control has been transferred to the 5009FT's Cascade PID, the letdown station or turbine bypass valve must be closed or in a manual control mode. This will stop the two controllers (5009 Control Cascade PID and system letdown station) from fighting for control of one parameter and causing system instability. If both a turbine bypass valve and the turbine's flow are required to satisfy the header flow requirements, droop is required in one of the control loops for stability.

When SW2 is switched to select load sharing, the DSLC bumplessly ramps load to match the MSLC's load setpoint, or to a load setting determined by the DSLC control's load sharing circuitry, depending on utility-to-tie breaker position. The MSLC can be used to set all the units in the load sharing mode to a base load setting or to vary their load based on a plant import/export demand setting.

During normal operation, one unit is controlling plant process steam and the other units are in load sharing control mode. The units sharing load are loaded based on the MSLC plant load demand. If the plant should become isolated from the utility, the MSLC is disabled and the load sharing units will share plant load. When desired, the MSLC can be enabled to re-synchronize the plant bus to the utility bus and close the plant-to-utility tie breaker. After synchronization the MSLC will either ramp plant power to the desired export power level or ramp plant load to a base load setting, depending on the mode of operation selected.

Woodward DSLC controls can interface directly with a unit's automatic voltage regulator. This allows units with DSLC controls to share reactive power as well as real power. This configuration also allows the MSLC to control plant power factor when the utility-to-tie breaker is closed.

Example 8—Inlet Pressure Control & Exhaust Pressure Control with Generator Power Limiting

(Extraction Only Turbine, Decoupled HP & LP Mode)

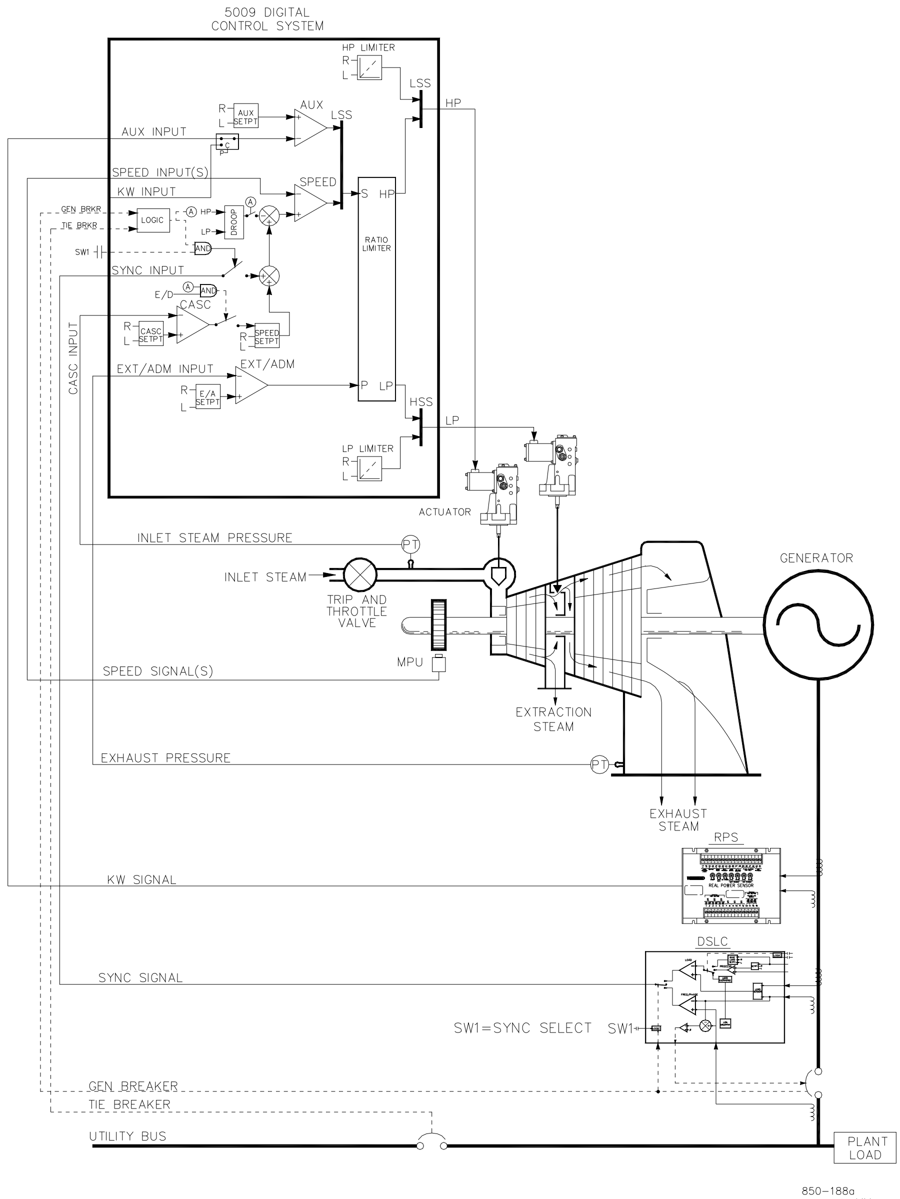


Figure 4-8. Inlet Pressure Control, Exhaust Pressure Control with Generator Power Limiting

This is an example of a typical turbine generator application where the turbine inlet and exhaust header pressures are desired to be controlled and the turbine's extraction header pressure is controlled by a system letdown station. With this type of application, turbine load varies based on the plant process steam demand. Both the auxiliary and cascade modes were used for this example application. Other applications may or may not utilize all the functionality shown in Figure 4- 8 and described below.

With this application, turbine inlet header pressure control is performed within the 5009 Control through the Cascade PID controller. This is an ideal controller for this type of function because it can be enabled and disabled as desired by a system operator. This gives a system operator full authority of when to transfer process pressure control to or from a letdown station or turbine bypass valve.

During normal operation unit load is determined by the Cascade PID controlling inlet header pressure. Because turbine load may vary greatly with this application, a limiter is used to protect the generator from being over powered. This protection is performed by the Auxiliary PID configured as a limiter. By configuring the Auxiliary PID as a limiter and using a Real Power Sensor's (RPS) output signal as the PID's controlling parameter, the maximum load the generator can operate at can be limited.

Turbine exhaust pressure is controlled by the Extraction PID. This PID controller can be enabled automatically or manually depending on configuration. In all cases the 5009 Control starts up with the Extraction PID disabled and the LP valve at its maximum open position. This allows a turbine to warm-up in a uniform manner. With this example the extraction setpoint is only varied through the 5009 Control's CCT Interface or Modbus commands. Optionally the 5009 Control could be programmed to have the Extr/Adm setpoint varied through discrete inputs, a 4- 20 mA signal.

This application uses a DSLC for synchronization only. Because the DSLC interfaces to the 5009 Control through an analog signal, a 5009 Control analog input must be programmed to receive the DSLC control's Speed Bias signal. When a synchronizing input/function is programmed, the input can be enabled through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-8 a panel mounted (DPST) switch is used with this application to select automatic synchronization in both the DSLC and 5009 Control. Alternatively, this switch could come from a 5009 Control relay programmed to energize for a Modbus Command Selected, Sync Enabled, or a Speed Switch Level Reached.

All 5009 Control PID controller setpoints may be changed through programmed raise and lower contacts, programmed 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve any of the control and limiting actions shown in Figure 4-8.

Starting & Run Mode Notes for Example 8—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. From an idle or minimum speed position, the Idle/ Rated or Auto Start sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position. Alternatively an operator can give a manual raise command to increase turbine speed as desired.

After the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized. This can be done manually or automatically. The system operator can select automatic synchronization through the Auto-Sync select switch (switch SW1 in Figure 4-8). When this switch is closed, the 5009 Control's Synchronizing input is enabled and the DSLC control's automatic synchronizing function is selected.

When the plant-to-utility tie-line breaker is closed and the unit generator breaker closes, the 5009 Control steps the speed/load setpoint up to a minimum load level to reduce the chance of reverse powering or motoring the generator. This minimum load level is based on the speed/load setpoint and is defaulted to a "3%" step change of the speed/load setpoint. The defaulted 3% minimum load value (stored as a setpoint "rpm" change) is adjustable through the 5009 Control's CCT Interface or Modbus commands. (Breaker Logic, Min Load Bias = X rpm).

After synchronization the 5009 Control's load setpoint can be positioned through raise and lower speed/load setpoint contacts, a programmed 4–20 mA input, Modbus commands, or the CCT Interface. This load control mode may be used to slowly increase turbine load, and take control away from a letdown station or turbine bypass valve.

Cascade control (turbine inlet header pressure) can be enabled at any time after the utility tie breaker and generator breakers are closed, through a contact input, Modbus command or the CCT Interface. When cascade control is enabled the cascade setpoint will match the inlet header pressure level at that time, thus a bumpless transfer to inlet header pressure control is accomplished. After the Cascade Controller has been enabled, the operator can increase or decrease the control setpoint as desired.

Because the 5009 Control was programmed for the capability to automatically enable Extraction Control, the operator may choose to automatically or manually enable Extraction Control. To manually enable Extraction Control, the operator must issue a LP valve limiter lower command from the CCT Interface, a contact input, or through Modbus commands. The LP valve limiter must be taken to its minimum position to fully enable Extraction (exhaust) Control.

The enable routine command may be issued from the 5009 Control's CCT Interface, contact input, or through Modbus commands. This routine automatically ramps the LP valve to its minimum position and may be stopped at any time by momentarily issuing a LP valve limiter raise or lower command. Once the automatic enabling routine has been stopped it may be restarted/enabled at any time by issuing a disable command followed by an Extr/Adm control enable command or, once stopped, the operator may continue the routine manually (disabling of exhaust control can also be performed manually or automatically).

When a letdown station is used as a backup to the turbine extraction pressure controller, it is required that the letdown station's setpoint be lower than that of the 5009 Extraction Control's setpoint to prevent fighting and potential instability between the controllers.

With this application the auxiliary control is programmed to be used as a limiter and to be automatically enabled when both the utility tie and generator breakers are closed. When paralleled to the utility, if inlet header pressure demand and/or other system conditions try to force the generator to operate above its load limit setting, the Auxiliary PID will take control of the HP governor valve to limit generator load. Once system conditions demand unit load below that of the auxiliary setpoint, the cascade/Speed PIDs will again take control of generator load.

Example 9—Admission Steam Turbine Control with Bootstrap Start-up

(Admission Turbine, Coupled HP & LP Mode)

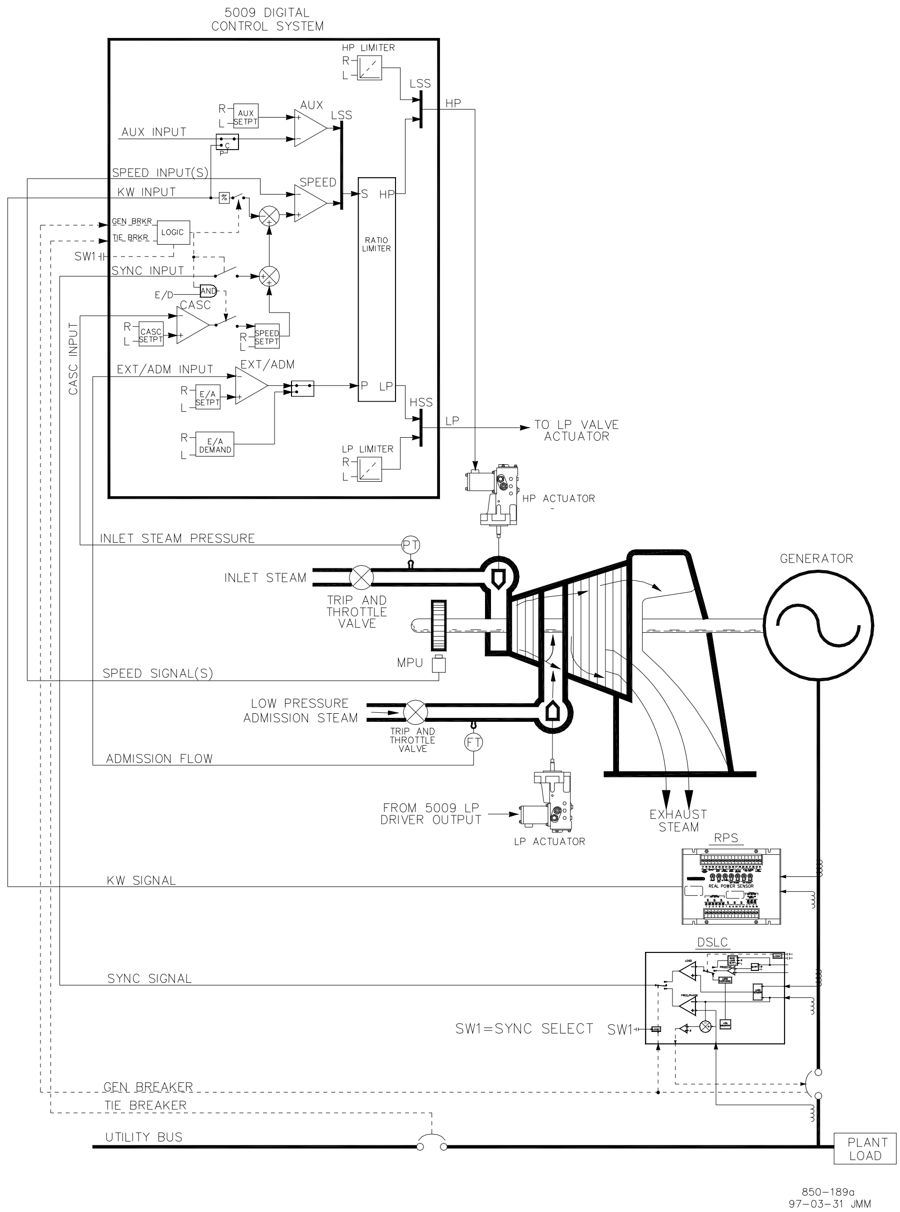


Figure 4-9. Admission Steam Turbine Control with Bootstrap Start-up

This is an example of a typical turbine generator application where turbine load and admission flow are controlled. However, this application requires that the turbine be started with low pressure admission steam until the refinery can be bootstrapped up to begin producing high pressure inlet steam. Other applications may or may not use all the functionality shown in Figure 4-9 and described below.

With this application, a Real Power Sensor (RPS) is used to sense generator load and allow the 5009 speed/load PID to control and limit generator load.

In this example, it is assumed that an external trip valve or trip-and-throttle valve is used to completely stop any admission steam from entering the turbine upon a system shutdown condition.

Admission pressure is controlled by the Admission PID. An operator uses a manual demand signal to match the pressures on both sides of the admission trip & throttle valve. After the pressures have been matched, the operator can enable admission. At this point the operator can vary the admission setpoint through the 5009 Control's CCT Interface or Modbus commands.

This application uses a DSLC for synchronization only. Because the DSLC interfaces to the 5009 Control through an analog signal, a 5009 Control analog input must be programmed to receive the DSLC control's speed bias signal. When a synchronizing input/function is programmed, the input can be enabled through a contact input, Modbus command, or the CCT Interface. As shown in Figure 4-9 a panel mounted (DPST) switch is used with this application to select automatic synchronization in both the DSLC and the 5009 Control.

All 5009 PID controller setpoints may be changed through programmed raise and lower contacts, programmed 4–20 mA inputs, Modbus commands, or the CCT Interface.

The following list of notes are provided as a reference for application programmers to follow when programming the 5009 Control to achieve any control and limiting actions shown in Figure 4-9.

Starting & Run Mode Notes for Example 9—Starting and ramping to an idle or minimum speed position can be performed automatically, semi automatically, or manually. With this type of configuration, a semiautomatic start requires that the LP valve limiter be manually lowered to 0% before the admission Trip-and-Throttle (T&T) valve is opened.

From an idle or minimum speed position, the Idle/Rated or Auto Start sequence functions, if programmed, can be used to assist in ramping the control to a rated speed position. Alternatively, an operator can give a manual raise command to increase turbine speed as desired.

After the unit has been started and is controlling at a rated speed position, the turbine generator can be synchronized. This can be done manually or automatically. The system operator can select automatic synchronization through the Auto-Sync select switch (SW1 in Figure 4-9). When this switch is closed the 5009 Control's synchronizing input is enabled and the DSLC control's automatic synchronizing function selected.

The DSLC provides phase matching or slip frequency synchronizing, and ties into the unit automatic voltage regulator to match voltages before paralleling. It communicates over a LAN, using an Echelon network, with other plant DSLC controls to perform safe dead bus closing.

When the plant-to-utility tie line/breaker is closed and the unit generator breaker closes, the 5009 Control steps the speed/load setpoint up to a minimum load level to reduce the chance of reverse powering or motoring the generator. This minimum load level is based on the speed/load setpoint and is defaulted to a "3%" load. The defaulted value is adjustable through the 5009 Control's CCT Interface or Modbus commands. (Breaker Logic, Min Load Bias = xxx).

After synchronization, the 5009 Control's load setpoint can be positioned through raise and lower speed/load setpoint contacts, a 4–20 mA input, Modbus commands, or the CCT Interface.

Once the inlet steam pressure is near rated levels, the HP T&T valve can be opened. As inlet steam capacity increases, the 5009 Control will reposition the control valves to hold a constant load level (true load control is capable only if KW droop is used).

Admission control can be enabled any time after the generator breaker is closed, the HP trip-&-throttle valve has been opened, and the inlet steam source has the capacity to provide the steam required to hold the turbine at its current load level.

To perform a bumpless transfer into admission control, the 5009's manual demand signal must be manually adjusted to match the signal to the admission's steam flow (in %). Once the manual demand signal matches the current percent admission steam flow, admission control can be enabled. The manual demand signal's raise/lower and the admission enable/disable commands can be issued through the 5009 Control's CCT Interface, contact inputs, or Modbus commands.

Example 10—Typical Plant Load and Steam Pressure Control Application

With this application a combination of 5009 Control System, DSLC controls, MSLCs, and a Single Loop PID controller allow the following plant parameters to be controlled:

- Plant Import and/or Export Power (Utility Tie breaker closed)
- Plant Inlet Header Pressure (Utility Tie breaker closed)
- Plant Power Factor or VARs (Utility Tie breaker closed)
- Plant Frequency with proportional load sharing (Utility Tie breaker open)
- Plant Power Factor Sharing (Utility Tie breaker open)
- Plant to Utility Frequency–Automatic Synchronizing (Utility Tie breaker open)
- Plant to Utility Phase–Automatic Synchronizing (Utility Tie breaker open)
- Plant to Utility Voltage–Automatic Synchronizing (Utility Tie breaker open)
- Plant Extraction Header Pressure (Utility Tie breaker open or closed)

This is an example of a typical plant application where multiple turbine generators are load and flow shared to control plant functions like import/export power or turbine inlet header pressure and extraction header pressure. When the plant is disconnected from a utility, this configuration allows all units to control plant frequency, load share, and continue flow sharing into the extraction header. Other applications may or may not use all the functionality shown in Figure 4-10 and described below.

With this application, each 5009 Control is paired with a Digital Synchronizer and Load Control (DSLC). When enabled each DSLC interfaces with its respective 5009 Control to determine the unit's load. Each DSLC, when in the isochronous load sharing mode, interfaces with all other plant DSLC controls and MSLCs via an Echelon Network. This digital network allows units to share load with each other or be controlled by a Master Synchronizer and Load Control (MSLC). Only one MSLC at a time can be on the Echelon network.

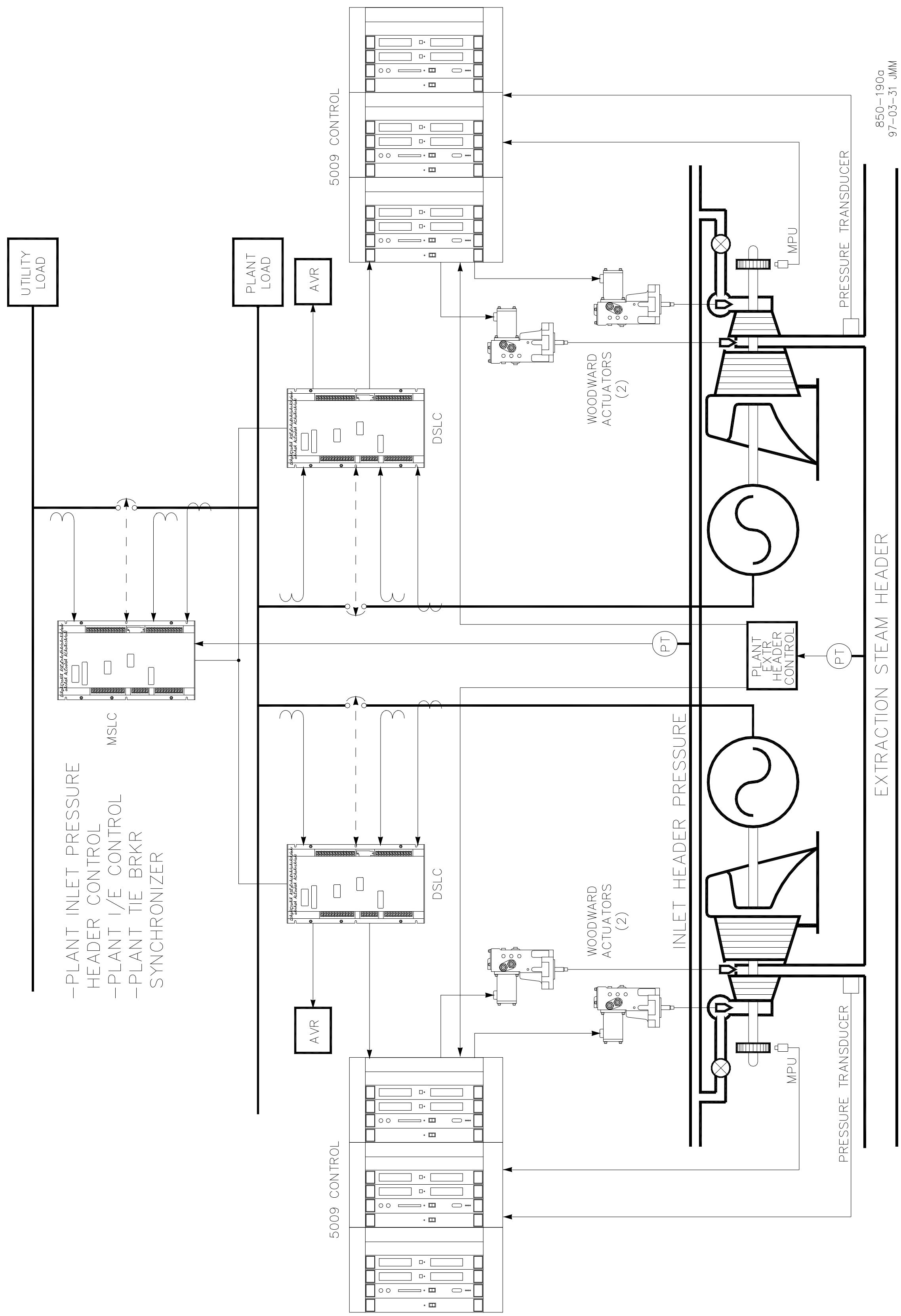


Figure 4-10. Plant Load and Steam Pressure Control Application

An MSLC, when enabled, can control the load of all units (via DSLC controls and 5009FTs) on the Echelon network to control a common parameter. To have its load level set by the MSLC, a DSLC must be in the isochronous load sharing mode. This allows an operator to determine which units will function together to control a common parameter (inlet header pressure, import/export power) and which units will function separately to control other parameters (exhaust pressure, unit load).

The MSLC senses plant import/export power and uses a “PI” controller to command any or all units on the Echelon network to control plant import/export power. The MSLC can also accept and control (with a “PI” controller) any process signal which is directly related to each unit’s load and which the units enabled all have in common (inlet header pressure, exhaust header pressure). All units share equally in the load because the MSLC sends the same demand signal to each DSLC.

When the utility tie breaker is open, the MSLC can be used to automatically synchronize the plant bus to the utility grid. The MSLC varies the frequency setting of all units, through the DSLC controls, which are on-line and enabled for synchronization. By connecting each DSLC to its respective generator’s automatic voltage regulator (AVR), the MSLC can also communicate with all the enabled DSLC controls to match plant voltage to that of the utility.

With each DSLC connected to its unit AVR, the MSLC can be used to control the plant power factor or reactive power level (VARs). This configuration also allows power factor sharing between units when the plant is disconnected from the utility.

The plant extraction header pressure controller used with this application is a stand-alone “PI” controller. This controller senses extraction header pressure and outputs identical signals to all unit extraction pressure controllers thus forcing allow all units to equally flow share. The controller’s output signal is used to drive each unit’s extraction pressure setpoint. Unlike the MSLC, this controller does not communicate over an Echelon network, thus the plant extraction header controller is required to have multiple outputs.

Because turbine extraction pressure is not a function of turbine load, the MSLC cannot be used to control this parameter. A “PI” controller was used with this application to allow all units to flow share. Alternatively, one unit could have been used to control any changes in plant demand and the other units could have been set to output a constant flow. The latter configuration, however, limits the amount of plant demand change the system can handle without an upset or an operator driven change.

Another benefit of this MSLC - DSLC configuration is that any prime mover that has a DSLC installed can be used to load share. Because each DSLC has an individual load sharing gain setting, the response differences between units can be compensated for.

Example 11—Induction Generator Applications

When the 5009 Control is configured for induction generator applications, there are typically only two differences in the programming of the 5009 Control versus programming for synchronous generator applications.

The induction generator’s slip frequency must be taken into account. This is achieved by compensating for the slip frequency with the 5009 Control’s maximum speed setpoint setting. The maximum speed setpoint must be equal to synchronous speed plus the droop percentage plus the full load slip frequency percentage.

1. **MAX CONTROL SETPOINT**= Sync Speed + (Sync Speed * Droop) + Max Slip RPM

2. The Generator Tie Breaker contact input is used in the Major Alarm Relay output to shutdown the turbine.

Chapter 5.
Control Functionality

Introduction

The 5009 Control System may be programmed to operate single valve, split-range valve, single extraction, single admission, or single extraction/admission turbines. For each of the extraction and/or admission turbine applications, the 5009 Control's Ratio/Limiter logic may be configured to allow the turbine's HP and LP valves interact differently depending on the turbine's function within a system. When there is no controlled-extraction, a Ratio/Limiter is not used. In that case, none of the extraction/admission logic is used either.

The relationship between Speed/Load PID and the Auxiliary PID is based on the Auxiliary PID configuration selected. If the Auxiliary PID is configured as a "Limiter" the Aux PID is always active, and the Speed and Auxiliary PID outputs are all low-signal-selected (LSS) to position the actuator output(s). In single valve compressor applications the AUX PID is always set to be a "Limiter" rather than a controller.

If the Auxiliary PID is configured as a "Controller", the Auxiliary PID is only active when enabled. Once the Auxiliary PID is enabled the Speed PID is disabled and tracks the Auxiliary PID's output. Refer to control block diagrams in Chapter 3 for PID relationships based on configuration.

IMPORTANT

In this manual the term "HP valve" refers to a non-extraction turbine's inlet control valve, or an extraction/admission turbine's High Pressure inlet control valve. If configuring the control for a non-extraction turbine, ignore all references to the LP valve, extraction control, and ratio/limiter.

Turbine Start Modes

This control can be configured for any of three possible turbine start modes (manual, semiautomatic or automatic). These start-up modes determine how the turbine is taken from a shutdown state to an idle or minimum turbine speed position. One of these start modes must be chosen and programmed to perform a system start-up.

Once a turbine is started and the control is controlling turbine speed, the configured "Turbine Start Routine" determines the control sequence used to bring the turbine from an idle speed up to the turbine's rated speed. Refer to the Turbine Start Routines section of this chapter for details.

Once a 'Start' command is issued, the valve limiter and speed setpoint are manipulated manually or automatically, depending on the start mode selected. After a turbine start has been completed, turbine speed will be controlled at a minimum controlling speed. The minimum controlling speed may be idle if idle/ rated is being used, low idle if the auto start sequence is used, or the speed setpoint's Min Control setting if neither idle/rated or auto start sequence is used.

A 'Start' command may be issued from the CCT program, an external contact, or through Modbus. If an External Start' contact is programmed, a 'Start' command is issued when the contact is closed. If the contact is closed prior to start-up it must be opened and re-closed to issue a 'Start' command.

If turbine speed is sensed when a 'Start' command is issued, the control will instantly set the speed setpoint to the sensed speed and hold for an operator command or continue towards the next highest idle speed setting, depending on the start mode selected. In the event the sensed turbine speed is greater than the minimum controlling speed setting, the speed setpoint will match this sensed speed, the Speed PID will control at this point, and the control will wait for further action to be taken by the operator.

If turbine speed is first sensed within a critical speed band, the control will take control of turbine speed, ramp the speed setpoint to the upper limit of the critical speed band setting, and wait for action to be taken by the operator.

Manual Start Mode

The Manual Start Mode can be used to allow an operator to start the turbine via a hand-operated throttle valve. With this mode, when a start command is issued the inlet HP valve will be raised to its maximum limit. For extraction turbines, this maximum limit depends on the steam map parameters entered, and may be less than 100%. When turbine speed increases to the minimum controlling speed (idle or min control speed), the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve. The following start-up procedure is employed when the **Manual start mode** is configured:

1. Issue a RESET command (to reset all alarms and shutdowns)
   - If programmed for an extraction-only turbine, the LP valve position will ramp to its maximum limit until extraction is enabled.
   - If programmed for admission or ext/adm turbines, the LP valve position will follow the turbine's steam map to try to maintain zero flow.

2. Issue a START command (verify Trip & Throttle (T&T) valve is closed before issuing)
   - At this point the control will ramp open the governor (HP) valve to its maximum position at the HP valve limiter rate.
   - The speed setpoint will ramp from zero to its lowest speed setting at the Rate-to-min rate.

3. Open HP T&T valve at a controlled rate
   - When turbine speed increases to the minimum controlling speed, the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve.

4. Open HP T&T valve to 100%
   - Speed will remain at the minimum controlling speed until action is taken by the operator or the auto start sequence, if programmed, will continue its sequence.

The HP valve limiter rate and the rate-to-min settings are tunable via the CCT program's Service mode.

WARNING

The HP trip-and-throttle valve must be closed before pushing the 'START' key in Manual Start mode. If a START command is given while the trip-and-throttle valve is open, there exists a possibility of turbine runaway with resultant serious injury or loss of life.

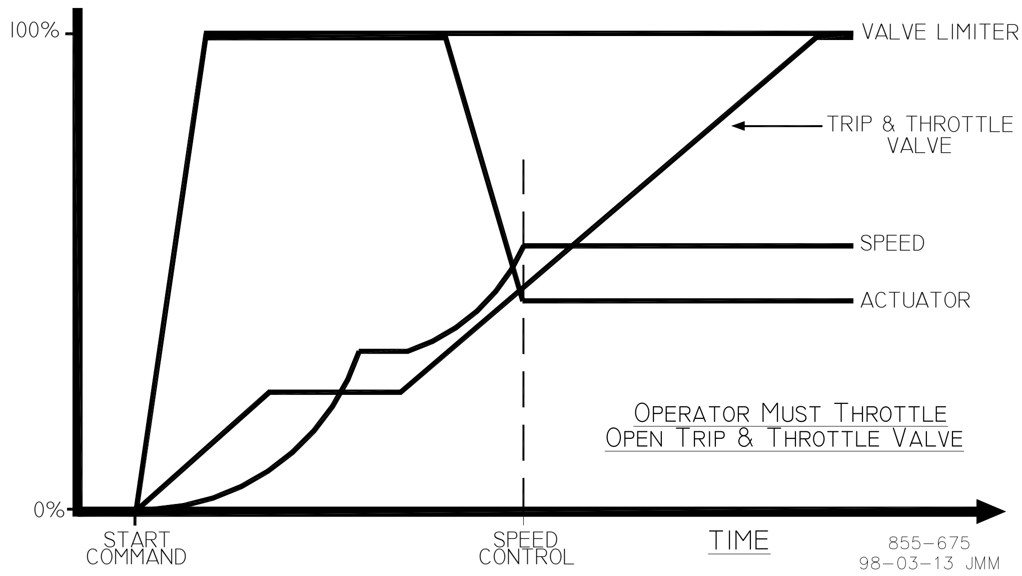


Figure 5-1. Manual Start Mode Example

V1 Initial Position

This option is only available when the control is configured to use the “Manual” start mode. If used this function sets the V1 valve (HP) limiter to an initial preset position upon a start command.

When using the “Manual” start mode, if this feature is not used the V1 (HP) valve will ramp to 100% upon a start command. When using the “Manual” start mode, with this feature configured, the V1 (HP) valve can be set to ramp to a specific position (0 - 100%) upon a start command. A feature like this may be desirable to increase the resolution of the Trip & Throttle valve, allowing an operator using the T&T valve to have better control of turbine speed during start-up.

The “V1 Init Position” programmed will be the percentage the inlet control (HP) valve limiter is initialized to when a Start command is given. From this position the limiter can be raised or lowered as desired. With this option, the HP Limiter will need to be raised to 100% after the unit is started.

Semiautomatic Start Mode

The Semiautomatic Start Mode can be used to allow an operator to open the unit Trip & Throttle valve (T&T valve), then start the turbine by manually increasing the control’s inlet HP valve limiter. With this mode, when a start command is issued the inlet HP valve will stay at 0% until the control’s inlet HP valve limiter is manually raised. The HP valve limiter can be raised, via CCT program, external contact, or Modbus commands. When turbine speed increases to the minimum controlling speed (idle or min control speed), the control’s Speed PID will take control of turbine speed through positioning the turbine’s inlet HP valve. The following start-up procedure is employed when the Semiautomatic Start mode is configured:

1. Issue a RESET command (to reset all alarms and shutdowns)
   - If programmed for an extraction-only turbine, the LP valve position will ramp to its maximum limit until extraction is enabled.
   - If programmed for admission or ext/adm turbines, the LP valve position will follow the turbine’s steam map to try to maintain zero flow.

2. Open the HP Trip & Throttle valve (verify that the turbine does not accelerate).

3. Issue a START command.
   - At this point the speed setpoint will ramp to its lowest speed setting at the Rate-to-min rate.

4. Raise the control's HP valve limiter at a controlled rate.
   - When turbine speed increases to the minimum controlling speed, the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve.

5. Raise the control's HP Valve Limiter to 100%.
   - Speed will remain at the minimum controlling speed until action is taken by the operator or the auto start sequence, if programmed, will continue its sequence.

The HP valve limiter will open at the HP valve limiter rate and may be moved via CCT, external contacts, or Modbus commands. The HP valve limiter rate and the rate-to-min settings are tunable via the CCT program's Service mode.

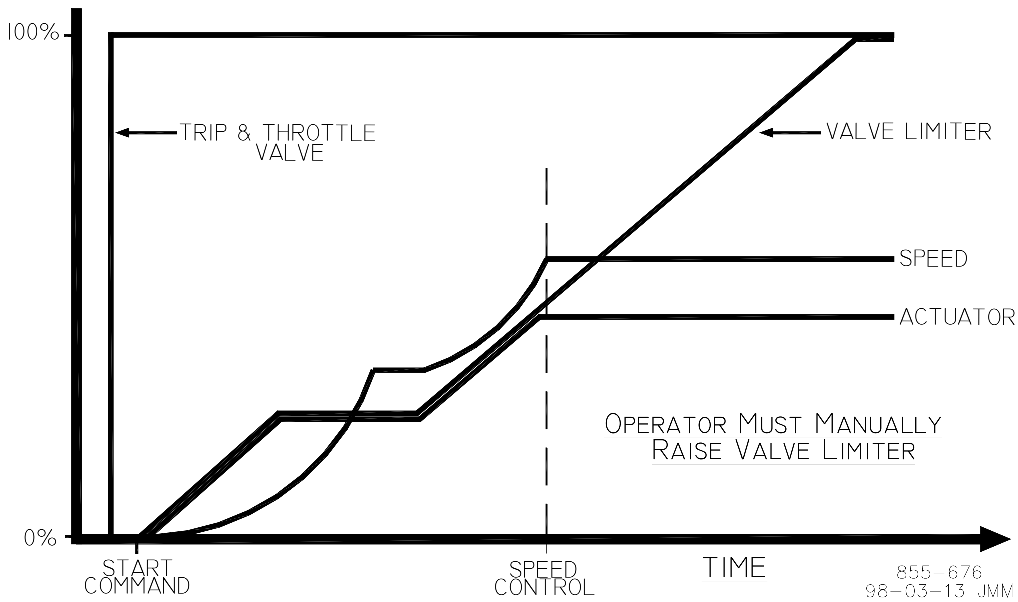


Figure 5-2. Semiautomatic Start Mode Example

Automatic Start Mode

The Automatic Start Mode can be used to allow an operator to open the unit Trip & Throttle valve (T&T valve), then start the turbine by issuing a Start command. With this mode, when a start command is issued the inlet HP valve will ramp from 0% towards 100% until the control's Speed PID takes control of the inlet HP valve. The HP valve limiter is used to ramp the HP valve open and can be halted at any time by momentarily issuing a HP valve limiter raise or lower command. When turbine speed increases to the minimum controlling speed (idle or min control speed), the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve. The following start-up procedure is employed when the Automatic start mode is configured:

1. Issue a RESET command (to reset all alarms and shutdowns)
   - If programmed for an extraction-only turbine, the LP valve position will ramp to its maximum limit until extraction is enabled.
   - If programmed for admission or ext/adm turbines, the LP valve position will follow the turbine's steam map to try to maintain zero flow.

2. Open the HP Trip & Throttle valve (verify that the turbine does not accelerate)

3. Issue a START command
   - At this point the 5009 Control will ramp open the HP valve limiter to its maximum position at the HP valve limiter rate setting.
   - The speed setpoint will ramp to its lowest speed setting at the Rate-to- min rate.
   - When turbine speed increases and matches the ramping speed setpoint, the control's Speed PID will take control of turbine speed through positioning the turbine inlet HP valve.
   - Speed will ramp up to and remain at the minimum controlling speed until action is taken by the operator or the auto start sequence, if programmed, will continue its sequence.

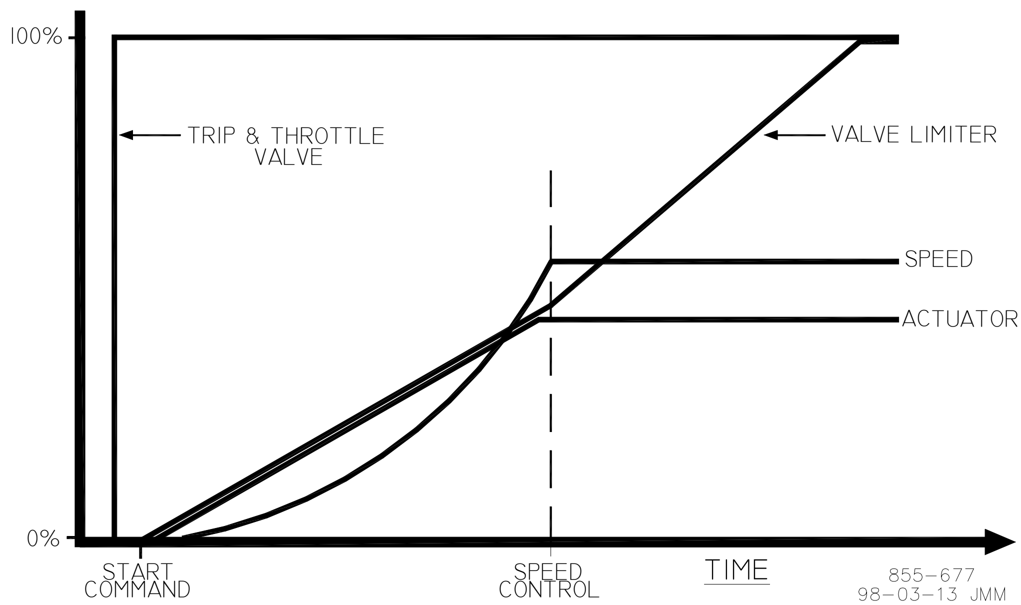


Figure 5-3. Automatic Start Mode Example

The automatic start routine may be aborted at any time by issuing a halt command, HP valve limiter raise or lower commands, speed raise or lower commands, or an Emergency Shutdown command. Once halted this routine can be continued by issuing a continue command. The HP valve limiter rate and the rate-to-min settings are tunable via the CCT program's Service mode.

The automatic start sequence can also be:

- Automatically enabled at shutdown: It will remain enabled as long as the engine is tripped.
- Automatically disabled at shutdown: It will remain disabled as long as the engine is tripped.
- Not affected by the shutdown condition: It can be enabled/Disabled at any time.

The selection is done in program mode and service mode under start settings folder (see Volume 3 for more details).

V1 Initial Position

This option is always available. If its use is not desired, V1 must be set to 100%.

- When a start command is issued, the V1 (HP) valve can be set to ramp to a specific position (0–100%) upon a start command.
- The "V1 Init Position" programmed will be the percentage the inlet control (HP) valve limiter is initialized to when a Start command is given. From this position, the HP limiter can be lowered as desired.
- When the 5009 is in control of the speed and speed is above low idle, HP ramp will automatically ramp to 100%.
- A feature like this may be desirable to increase the resolution of the Trip & Throttle valve, allowing an operator using the T&T valve to have better control of turbine speed during start-up.

If the option in the CCT software “SD if Rotor stuck” is set true (not available in manual mode), the engine will trip if the HP valve reaches V1 position and Low idle speed is not reached.

Max Speed Deviation Protection

- In the CCT software, a maximum speed deviation can be configured.
- Once Low Idle speed is reached, this protection will compare the actual speed and the actual speed reference.
- If the difference is greater than the max speed deviation authorized, during more than the Alarm delay, an alarm will be generated.
- If SD option is selected, ff the difference is greater than the max speed deviation authorized, during more than the SD delay, a shutdown will be generated.

Zero Speed Signal Override

The 5009 Control issues a shutdown if no speed signal is detected (magnetic pickup voltage less than 1 Vrms or speed is less than the ‘Failed Speed Level’). To allow the control to start with speed not being sensed, this shutdown logic must be overridden. The control can be configured to provide an automatic speed override, or allow a manual speed override. The status of the MPU override logic may be viewed in the CCT program’s Service mode or through Modbus communications. This override logic applies to both passive and active speed probes.

Automatic Speed Override—The control’s automatic speed override logic is used, if the “Override Speed Sensor Fault” contact is not programmed. This logic, overrides the “loss of speed detection circuit” when the turbine is being started, or when any other shutdown command is given. During a turbine start routine, this logic overrides the “loss of speed detection circuit” until the sensed turbine speed exceeds the programmed failed speed level setting + 250 rpm. Once turbine speed exceeds this level, the loss of speed detection circuit is enabled and the control will execute a system shutdown if sensed speed drops below the failed speed level setting.

Alternatively, an Override Timer can be configured (in the CCT program’s Service mode) as an extra level of protection. A sixty minute maximum time limit is applied to a manual override command (as defaulted in the Service Mode). This timer starts when the START command is initiated and re-arms the loss-of-speed detection logic when the time expires. The 5009 Control will execute a system shutdown if turbine speed is not above the ‘Failed Speed Level’ setting when the time expires.

Manual Speed Override—Manual Speed override functionality is selected by configuring an “Override Speed Sensor Fault” contact. If the ‘Override Speed Sensor Fault’ function is assigned to a contact input, the ‘loss-of-speed detection circuit’ is overridden as long as this contact is closed. Opening the assigned contact input, enables the ‘loss of speed detection circuit”, and the control will execute a system shutdown if sensed speed drops below the failed speed level setting.

Alternatively, an Override timer can be configured (in the CCT program’s Service mode) as an extra level of protection in the event the contact input is left closed. A sixty minute maximum time limit is applied to a manual override command (as defaulted in the Service Mode). This timer starts when a START command is initiated and enables the ‘loss of speed detection circuit’ when the time expires. The 5009 Control will execute a system shutdown if turbine speed is not above the ‘Failed Speed Level’ setting when the time expires.

Underspeed Configuration

When this option is selected from CCT Software, once the engine has reached min governor speed, this protection is activated.

If the speed PV becomes lower than the underspeed level, during more than the alarm delay, an alarm is generated, and, if configured a shutdown can be generated.

Start Permissible Contact

An external contact may be used as a turbine start-up permissive. When configured for this functionality, the contact input must be closed in order for a 'Start' command to be executed. Should the contact be open when a 'START' command is given, an alarm will be issued and the 5009 display will indicate that the start permissive was not met. The contact must be closed, before the 5009 Control will accept a 'START' command. After a 'START' command has been accepted, the start permissive contact has no effect on operation. If used, this input is typically connected to a Trip & Throttle valve's closed limit switch to verify that it is in the closed position before a turbine start-up is performed.

Valve Limiters

There are two valve limiters (HP & LP) available when the unit is programmed as an extraction turbine control and only one (inlet, HP) when used in a non- extraction control application. The HP and LP valve limiters are used to limit the HP and LP valve outputs to aid in starting and shutting down the turbine and in enabling of extraction control. In a non-extraction control, only the actuator #1 (HP) valve limiter is used. The limiters can be adjusted through the CCT program, external contact closures, or Modbus commands.

In a non-extraction application, the output of actuator #1 valve limiter is the output of the LSS bus. The lowest signal will control the actuator #1 valve position. Thus, the actuator #1 valve limiter limits the maximum actuator #1 valve position (and actuator #2 valve position, if configured).

In an extraction application, the output of the HP valve limiter is low-signal selected with the output of the ratio/limiter. The lowest signal will control the HP valve position. Thus, the HP valve limiter limits the maximum HP valve position.

The LP Limiter is only used when the unit is configured for extraction, admission, or extraction/admission type turbines. The output of the LP valve limiter is high- signal selected with the output of the ratio/limiter when configured for extraction steam turbines, and low-signal selected when configured for admission or extraction/admission steam turbines. Thus, the LP valve limiter limits the minimum or maximum LP valve position depending on the configuration selected.

Refer to the Starting Procedures section of this Volume for information on using the valve limiters during start-up. Valve limiters also can be used to troubleshoot system dynamic problems. If it is believed that the 5009 Control is the source of system instability, the valve limiters can be positioned to manually take over control of the valve positions. Care should be taken when using the valve limiters in this fashion, so as not to allow the system to reach a dangerous operating point.

The level of each valve limiter can be adjusted through the CCT program, contact inputs, or Modbus communications. When raise or lower commands are received, the respective limiter ramps up or down, at its programmed valve limiter rate. In all cases a limiter's range is defaulted to 0-100%. Each valve limiter's rate and maximum valve position setting can be adjusted via the CCT program's Service Mode.

When automatic start is selected, any R/L command on the HP valve limiter will stop the automatic ramp up. To re-initiate an automatic ramp-up, a START command must be given (even if the engine is already running).

V1 Initial Position

The "V1 Initial Position" option is available when the control is configured to use the "Manual" start mode. If used this function sets the V1 valve (HP) limiter to an initial preset position upon a start command. The "V1 Init Position" programmed will be the percentage the inlet control (HP) valve limiter is initialized to when a Start command is given. From this position, the limiter can be raised or lowered as desired. With this option, the HP Limiter will need to be raised to 100% after the unit is started.

Minimum HP and LP Lift Limiters

The minimum HP lift limiter is used with only Admission or Extraction applications to limit the HP valve's minimum position above 0% to ensure HP section cooling steam. This limiter prevents the Ratio/Limiter from taking the HP valve fully closed. Unless specified by the turbine manufacture, this setting should be set to zero. The minimum HP lift limiter is only active if the following conditions are true:

- Unit is programmed for Adm or Extr/Adm applications
- Ext/Adm control is enabled
- HP valve demand is above the Minimum HP lift limiter

The minimum LP lift limiter is used to limit the LP valve's minimum position. With the exception of shutdown conditions, this limiter is active at all times and prevents the Ratio/Limiter from taking the LP valve fully closed. During shutdown conditions the LP valve is taken fully closed. Unless specified by the turbine manufacture, this setting should be set to zero.

Turbine Start Routines (Idle to Rated)

Once a turbine is started and the control is controlling turbine speed, the Turbine Start Routine configured determines the control sequence used to bring the turbine from an idle speed up to the turbine's rated speed. The start routine configured and minimum governor controlling speed will depend on normal plant starting procedures and turbine manufacturer's recommendations. Refer to the Turbine Start Modes section of this chapter for details on this control's starting features.

The start routine allows the control to perform a hot start routine, cold start routine, or an in-between start routine depending on how long the turbine has been shutdown. With this routine, the turbine's starting ramp rates and idle speed hold times change depending on the length of time the unit was shut down. This routine may be used with any of the three start modes (manual, semiautomatic, automatic), and is initiated by a START command.

This routine uses three idle settings or hold points between zero and min governor speed, referred to as low idle, medium idle, and high idle. With this routine the Speed Set Point ramps to a low idle setpoint, holds at this setting for a duration (and until turbine speed is at or above this setting), ramps to a medium idle setpoint, holds at this setting for a duration, ramps to a high idle setpoint, holds at this setting for a duration, then ramps the Speed Set Point to a rated speed setting. All ramp rates and hold times are programmable for both hot start and cold start conditions.

- If either Medium or High Idle is desired, each can be configured using the CCT software.
- Disabling Low Idle will result in an IDLE/Rated start.

When a START command is given, the automatic start sequence logic determines what ramp rates and delay times (at the idle settings) to use during the start routine, based on the hours-since-trip timer. This timer starts when a shutdown has been executed and turbine speed has decreased below the low idle speed setting.

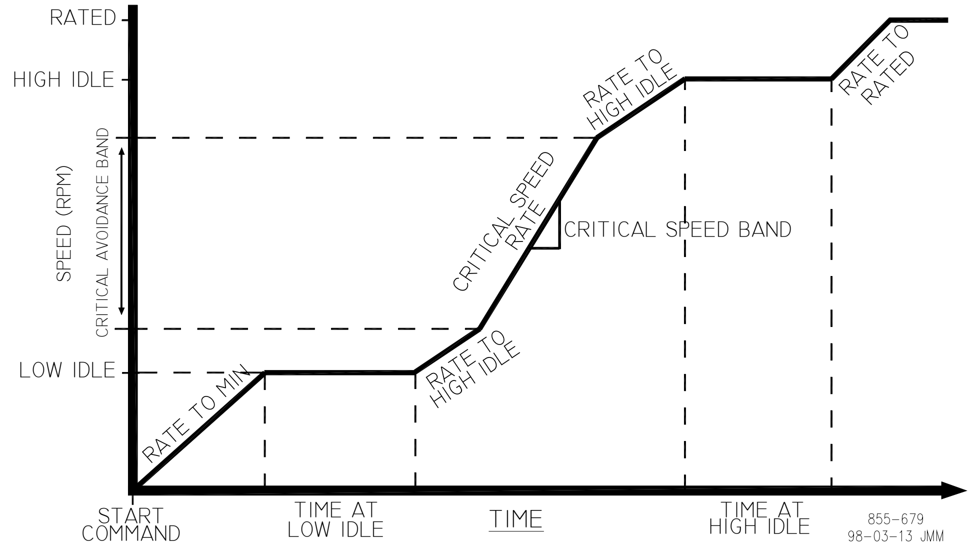


Figure 5-4. Automatic Start Sequence

With this sequence, a set of hot-start ramp rates and hold times is programmed for use when a START command is given and the turbine has been shut down for less than the programmed 'HOT START' time setting. A set of cold-start ramp rates and hold times is also programmed for use when a START command is given and the turbine has been shut down for longer than the programmed 'COLD START' time setting.

It is also possible to configure an Analog input called "remote HOT/COLD timer. In this case, the internal timer is by-passed, and the start-up logic will use this
4–20 mA signal to determine the start-up up curve to be used.

In case of failure of this signal, the internal timer is re-enabled.

However, if the speed reference is above the Idle level (manually raised), the autostart sequence will ramp to the next level, regardless to the hold timer.

If Low idle priority is selected in CCT, when Auto Start Sequence is halted from Modbus/CCT or contact input, the engine will ramp down to low idle.

This setting is only valid during start-up.

Note: If R/L speed is pressed, the Auto Start Sequence is halted, but the speed set point remains at its present position.

No Idle Used

If this routine is used, once a 'Start' command is issued, the speed setpoint ramps directly to the Speed setpoint's Min-Control-Speed setting at the "Speed Setpoint Rate to Min Speed" rate. The control's "Critical Speed avoidance" function cannot be used with this start routine.

Idle/Rated (Ramp)

This routine, upon command, ramps turbine speed from an idle speed setting to the turbine's rated speed setting at a configured rate. The ramp-to-rated command can be issued through the CCT program, an external contact closure, or Modbus communications.

The Idle/Rated function can be used with any start mode (manual, semiautomatic, automatic). When a START command is issued, the speed setpoint will ramp from zero rpm up to and hold at the idle speed setting. When a ramp-to-rated command is given, the speed setpoint ramps to the rated speed setting at the Idle/Rated rate setting. While ramping to rated speed, the setpoint can be stopped at any time by a issuing a raise or lower speed command or directly entering a valid speed setpoint.

The control will inhibit a ramp to idle speed or ramp to rated speed command if the generator breaker is closed, remote speed setpoint is enabled, Cascade PID is in control, or the Auxiliary PID is in control (as defaulted in the Service Mode, see Volume 3). Alternatively, the Idle/Rated routine's functionality can be changed via the Service Mode's Use Idle and "Idle has priority over Rmt Speed, Casc, Aux" selections. Refer to Volume 3 for details on these selections and how they can be used to change the Idle/Rated routine's functionality.

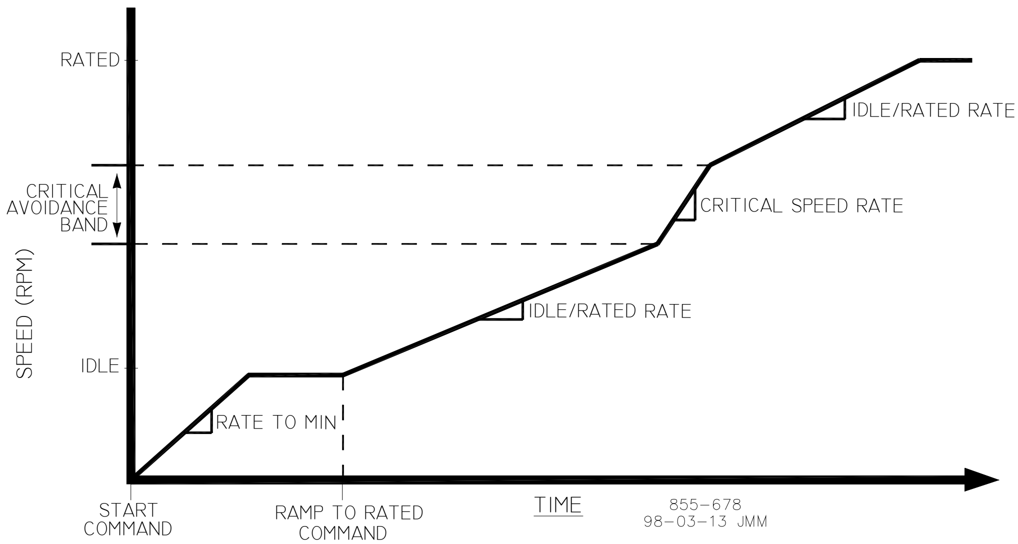


Figure 5-5. Idle / Rated Start

Ramp-to-rated and ramp-to-idle commands may be issued via the CCT, a contact input, or Modbus communications. The last command given from any of these sources dictates the function performed.

If a contact input is configured for the "Idle/Rated" function, idle speed is selected when the contact is open and rated speed is selected when it is closed. The Idle/ Rated contact can be either open or closed when all trip conditions are cleared. If the contact is open, it must be closed to initiate a Ramp-to-Rated command. If the contact is closed, it must be opened and re-closed to initiate a Ramp-to-Rated command.

When the turbine is used for mechanical drive applications, rated speed may be set at or above the minimum governor speed setting. When the turbine is used to drive a generator, the "rated speed" setpoint may be set at minimum governor speed, at synchronous speed, or at any intermediate speed setting. All pertinent Idle/ Rated parameters are available through Modbus communications.

Auto Start Sequence

This routine allows the control to perform a hot start routine, cold start routine, or an in-between start routine depending on how long the turbine has been shutdown. With this routine, the turbine's starting ramp rates and idle speed hold times change depending on the length of time the unit was shut down. This routine may be used with any of the three start modes (manual, semiautomatic, automatic), and is initiated by a START command.

This routine uses up to three idle settings or hold points between zero and rated speed, referred to as Low Idle, Medium Idle, and High Idle. With this routine, the speed setpoint ramps to a low idle setpoint and holds at this setting for a duration (and until turbine speed is at or above this setting). If configured, the Auto Start Sequence then ramps to a medium idle setpoint and holds there for the configured duration (and until turbine speed is at or above this setting). The control then ramps to a high idle setpoint if configured, holds at this setting for a duration (and until turbine speed is at or above this setting), then ramps the speed setpoint to a Rated speed setting. All ramp rates and hold times are programmable for both hot start and cold start conditions.

When a START command is given, the automatic start sequence logic determines what ramp rates and idle delay times to use during the start routine, based on the hours-since-trip timer. This timer starts when a shutdown has been executed and turbine speed has decreased below the low idle speed setting.

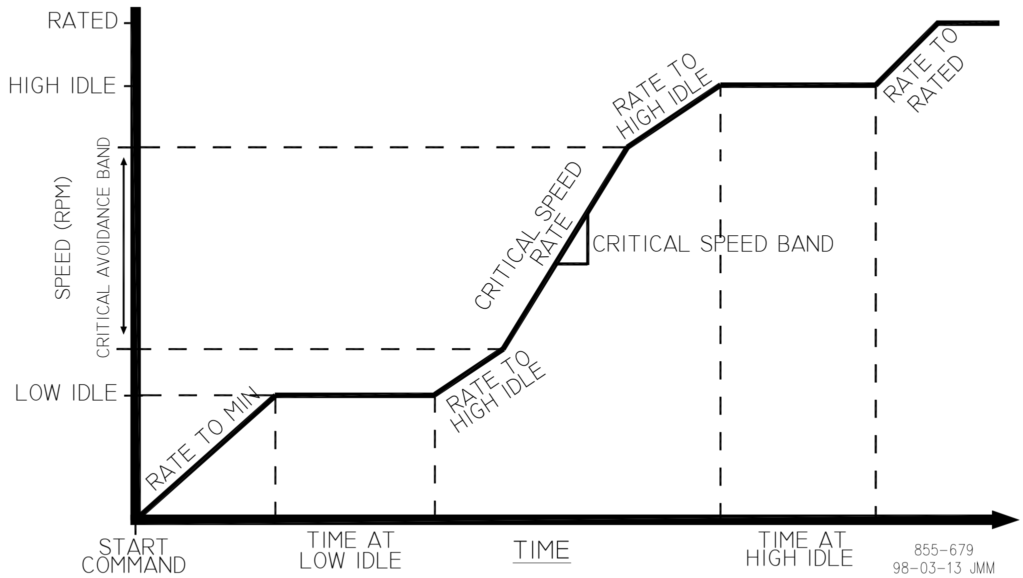


Figure 5-6. Automatic Start Sequence

With this sequence, a set of hot-start ramp rates and hold times is programmed for use when a START command is given and the turbine has been shut down for less than the programmed ‘HOT START’ time setting. A set of cold-start ramp rates and hold times is also programmed for use when a START command is given and the turbine has been shut down for longer than the programmed ‘COLD START’ time setting.

If a turbine START command is given when the length of time the system has been shutdown is between the ‘HOT START’ and ‘COLD START’ time settings, the control will interpolate between the hot and cold programmed start values to determine starting rates and hold times. For example, if the unit had the following automatic start sequence settings:

COLD START (> xx HRS)	=	22	HRS
HOT START (< xx HRS)	=	2	HRS
LOW IDLE SETPT	=	1000	RPM
LOW IDLE DELAY (COLD)	=	30	MINIMUM
LOW IDLE DELAY (HOT)	=	10	MINIMUM
HI IDLE SETPT	=	2000	RPM
RATE TO HI IDLE (COLD)	=	5	RPM/S
RATE TO HI IDLE (HOT)	=	15	RPM/S
HI IDLE DELAY TIME (COLD)	=	20	MINIMUM
HI IDLE DELAY TIME (HOT)	=	30	MINIMUM
RATE TO RATED (COLD)	=	10	RPM/S
RATE TO RATED (HOT)	=	20	RPM/S
RATED SETPT	=	3400	RPM

If the unit was tripped for 12 hours, the control would interpolate between the hot and cold parameters and use the following rates and delays (viewed in the Service Mode, see Volume 3):

LOW IDLE DELAY	=	20	MINIMUM
RATE TO HI IDLE	=	10	RPM/S
HI IDLE DELAY	=	10	MINIMUM
RATE TO RATED	=	15	RPM/S

Based on the example's configuration and trip time, the speed setpoint would ramp to 1000 rpm at the rate to minimum setting and hold for 20 minutes (turbine speed must also be at or above 1000 rpm), move to 2000 rpm at 10 rpm/s and hold there for 10 minutes, and lastly, move to 3400 rpm at 15 rpm/s. At 3400 rpm, the sequence would be completed. If the unit was tripped for 2 hours or less and restarted, the control would use the hot start parameters. If the unit was tripped for 22 hours or longer and restarted, the control would use the cold start parameters.

IMPORTANT

The control will automatically set the hours-since-trip timer to its maximum setting after a power up or upon exiting the Program mode. The hours-since-trip timer will reset only when a unit trip has occurred and turbine speed has decreased below the minimum governor speed setting.

The auto start sequence can be halted or continued at any time through the CCT, a contact input, or Modbus communications. The last command given from any of these three sources determines the mode of operation. The routine can be halted by a halt command, a raise or lower speed setpoint command, or by directly entering a valid speed setpoint.

When the sequence is halted, the delay timers do not stop if they have already started counting down. The sequence will resume when a continue command is issued. If there were 15 minutes remaining to hold at an idle speed and the halt command was issued for 10 minutes before a issuing a continue command, the sequence would remain at the idle speed for the remainder of the hold time, which is 5 minutes in this example.

Alternatively, this routine can be configured via the Service mode to halt at each idle setting until given a continue command. By selecting the "Automatically Halt at Idle Setpoints" option in the Service mode, the control will halt at each idle setting and wait for a continue command to be given by the operator. Optionally, a relay can be programmed to indicate when the auto start sequence is halted.

If a 5009 contact input is programmed to function as a halt/continue command, the sequence is halted when the contact is open and continued when the contact is closed. The halt/continue contact can be either open or closed when a reset command is given. If the contact is closed, it must be opened to allow the sequence to be halted. If the contact is open, it must be closed and reopened to halt.

Critical Speed Avoidance

In many turbines it is desirable to avoid certain speeds or speed ranges by passing through them as quickly as possible due to excessive turbine vibration or other factors. This control allows up to three critical speed ranges to be configured. The idle/rated or auto start sequence functions must be programmed to allow critical speed avoidance to be configured.

The speed setpoint cannot be stopped in the critical band. If a raise or lower speed setpoint command is issued while in a critical band, the speed setpoint will ramp up or down (depending on raise or lower command) until it is out of the critical range. Since the lower speed setpoint command has priority over a raise setpoint command, issuing a lower command while increasing through the band will reverse the setpoint direction and return it to the lower limit of the band. If a lower speed setpoint command is given while in a critical band, the turbine speed must reach the bottom of the band before another command can be executed.

A speed setpoint value cannot be directly entered within the programmed critical speed band settings. In the event this is attempted, an error message will appear over the Modbus ports. The speed setpoint can be directly entered via the CCT program's Start mode "SET" function, or through Modbus.

If the turbine cannot accelerate though a critical speed band within the configured length of time, a Stuck in Critical alarm will be issued and the speed setpoint will instantly return to idle.

Critical speed bands are defined in the Configure mode on the Start Settings page (see Volume 3). All critical speed band settings must be set between the idle speed and the minimum governor speed settings. A configuration error will occur if an idle setpoint is programmed within a critical speed band. The rate in which the speed setpoint moves through a critical speed band is set by the critical speed rate setting. The critical speed rate setting should be set no higher than the turbine's rated maximum acceleration rate.

Speed Control Overview

Turbine speed is sensed through one to four MPUs or proximity probes. The MPU gear ratio and the teeth seen by MPU settings are configured to allow the 5009 Control to calculate actual turbine speed. Any combination of MPUs and proximity probes can be used at the same time. However, they must be mounted on the same gear since the gear ratio and teeth seen by the MPU must be the same for all four inputs. The 5009 Control's Speed PID compares this speed signal to a setpoint to generate a speed/load demand signal to the Ratio/Limiter in an extraction and/or admission turbine, and to the low signal select bus for a non- extraction turbine.

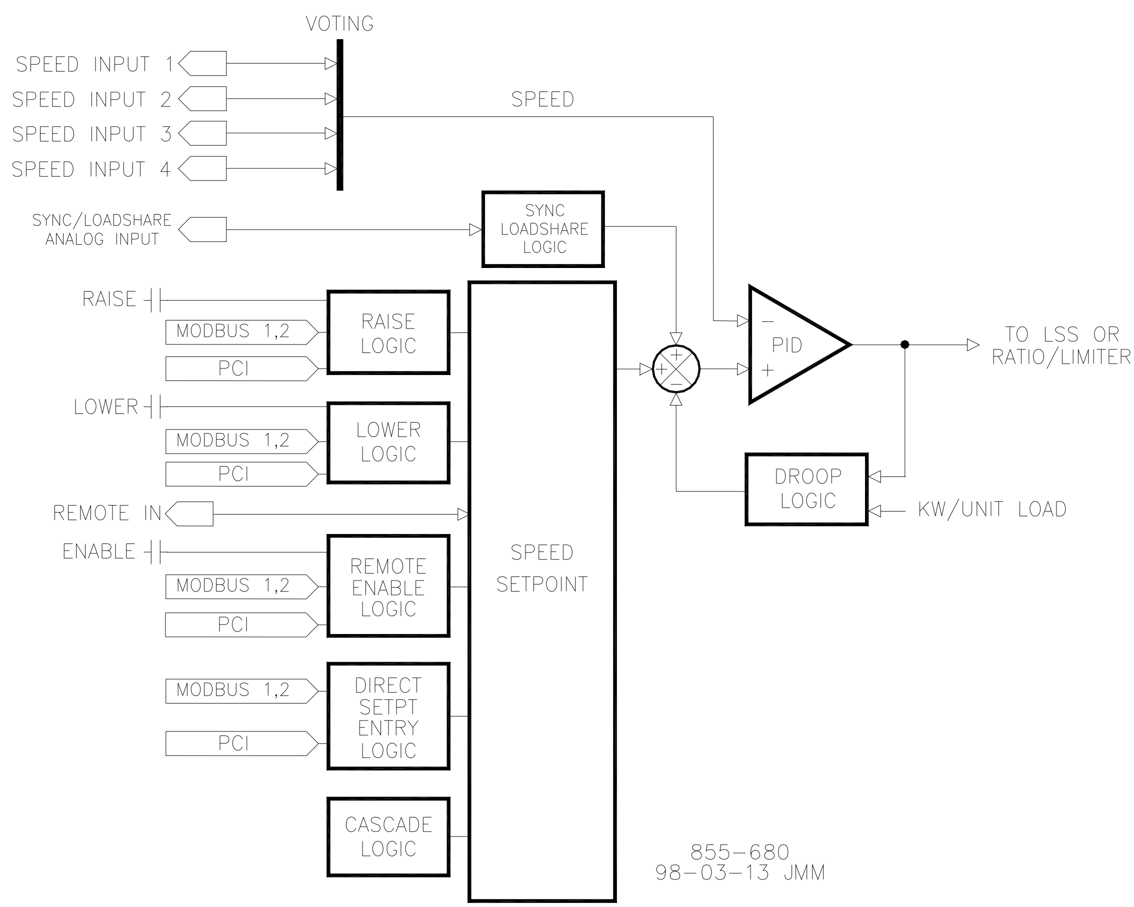


Figure 5-7. Speed Control Functional Diagram

Speed PID Operational Modes

The Speed PID operates in one of the following modes, depending on configuration and system conditions:

1. Speed Control
2. Frequency Control
3. Unit Load Control (droop)
    - Turbine HP and LP valve position control
    - Generator Load control

Speed Control

When not programmed for generator applications, the 5009 Control Speed PID operates in a Speed Control mode at all times. When programmed for generator applications, the state of the generator and utility tie breakers determine the operational mode of the Speed PID. If the generator breaker contact is open, the Speed PID operates in a Speed Control mode. If the generator breaker is closed and the utility tie breaker is open, the Frequency Control mode is selected. When both the generator and utility tie breakers are closed a unit load control mode is selected.

While in the Speed Control mode, the Speed PID will control a turbine at the same speed or frequency regardless of the load it is supplying (up to the unit's load capability). With this configuration, no form of droop or second controlling parameter is used by the PID for stability or control. Refer to Figure 5-8.

All pertinent Speed Control parameters are available through the 5009 Control CCT Interface and Modbus.

Speed Setpoint

The Speed PID's setpoint may be adjusted from the 5009 Control CCT Interface, contact inputs, Modbus, or through a 4–20 mA analog input. A specific setpoint setting can also be directly entered through the 5009 CCT Interface or Modbus communications. The Cascade PID also directly controls this setpoint when it is used.

The speed setpoint range must be defined in the program mode. The minimum and maximum governor speed setpoints define the normal operating speed range of the turbine. The speed setpoint cannot be raised above the maximum governor speed setpoint setting unless an overspeed test is performed. Once the speed setpoint is taken above the minimum governor speed setpoint, it cannot be varied below this setting again unless the Idle/Rated ramp to idle command is selected or a controlled stop is selected.

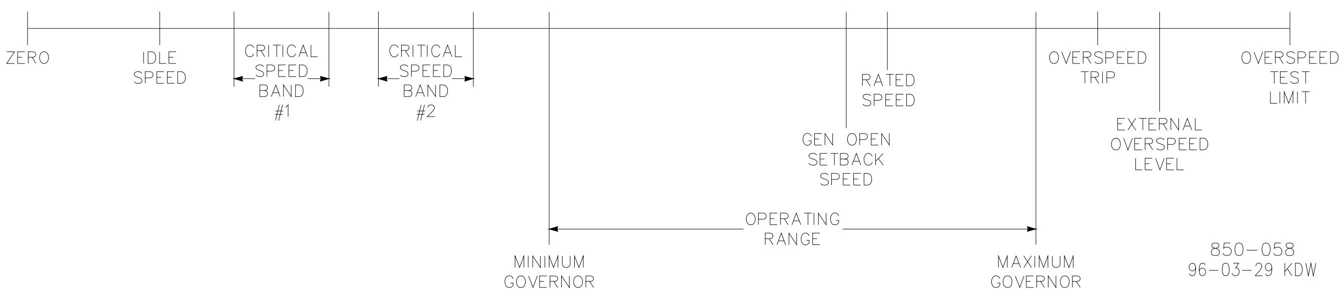


Figure 5-8. Speed Relationships

Once turbine speed is equal to or greater than the minimum governor speed setpoint, the speed setpoint may be adjusted through discrete raise and lower commands. When a raise or lower speed command is issued, the setpoint moves at the programmed speed setpoint slow rate. If a speed raise/lower command is selected for longer than three seconds, the speed setpoint will then move at a faster rate which is three times the speed setpoint slow rate. The speed setpoint slow rate, fast rate delay, and fast rate can all be adjusted in the Service Mode (see Volume 3).

The speed setpoint may be set to a specific level by entering a setpoint value through the 5009 CCT Interface or Modbus communications. After a valid setpoint value is entered and accepted, the setpoint will ramp at the speed setpoint slow rate (defaulted setting) to the newly entered setpoint value. This ramp rate may be changed from its defaulted value in the Service Mode.

When the 5009 Control is configured for a generator application, a special speed setpoint rate (sync window rate) is used to increase setpoint resolution around synchronous speed. This allows for tighter setpoint control to accommodate synchronizing manually or by an automatic synchronizer which interfaces to the 5009 Control discretely. This sync window rate is defaulted to two rpm/s and is only used when the generator breaker is open and the speed setpoint is within 10 rpm of rated speed. Both the synchronizing rate and the synchronizing window are tunable in the Service Mode.

When configured for generator applications a minimum load setpoint is used by the 5009 Control to reduce the chance of reverse powering a unit upon closing the generator breaker. With the utility tie breaker closed, when a generator breaker closed indication is received, the speed setpoint is stepped to the minimum load setting. The minimum load setting is defaulted to 3% above rated speed (tunable in the Service Mode). The minimum load setting can be disabled in the service mode.

Feed-Forward Control (for compressor units)

Normal Loop

In some case, while the engine is for example controlling the suction pressure of a compressor with Cascade, a coupling effect can be noticed between the Anti-surge controller (external) and the Cascade controller.

If the anti-surge valve opens to protect the compressor, the suction pressure will increase. The cascade controller will raise the speed. By raising the speed, the flow through the compressor will increase, and the anti-surge controller will close the anti-surge valve, resulting in a decrease of pressure etc. Stabilizing the process might be very difficult. The feed-forward should solve this problem when configured.

An analog Input must be configured as feed-forward. The signal should be the anti-surge valve demand. In the CCT software only, configuration parameters (range delay, etc) are available. When Min governor speed is reached, and when enabled via contact input or Modbus, this loop will be activated.

Based on the Feed-forward signal minus Feed-forward Lagged, the speed reference will be temporarily corrected, regardless of the internal reference. For protection, the speed reference cannot be lower than Min Governor nor higher than Max Governor in any case.

The filter time (LAG) must be set quite long (typically 120 seconds). When the anti-surge valve moves, the amount of speed correction should match with the expected speed variation needed to maintain the pressure.

Later, the speed correction will slowly ramp back to zero, based on the LAG time configured (typically 120 second). During this recovering, the cascade controller, (slow controller), should correct its outputs to perfectly maintain the pressure (see Volume 3 for more details).

⚠WARNING	**This loop should only be tuned by experienced people.**

Emergency Loop

An emergency feed-forward loop can also be activated. Different from the normal loop, its action time (LAG) should be equal or lower than the surge time loop, and will not correct the speed in normal operation.

In case of compressor surge, huge speed upset may occur, and recovery might be very difficult. When this even occurs, in order to decrease the amplitude of the speed oscillations, Emergency Feed-forward must act on the speed reference.

If the anti-surge valve opens very fast, the engine speed must be raised immediately even if the real speed is far higher due to the surge event. With this, any coupling effect will be limited.

The action of this loop must be limited the surge time loop. The trigger level must be tuned perfectly to avoid accidental activation of this loop (see Volume 3 for more details).

⚠WARNING	**This loop should only be tuned by experienced people.**

Direct action
When configured for direct action, the feed-forward loop will correct the speed directly, proportionally to its 4–20 mA calibration.

The direct action cannot be used the decrease speed below Min governor nor above Max Governor.

HP Pressure Compensation

This feature, when configured, is intended to compensate for the effect of any variation of the Inlet Steam pressure. During start-up, even in normal operation, the Inlet Steam pressure may deviate from its normal value, and speed PID settings might become too slow or too fast.

For extraction turbines, the steam map has been specified for a specific Inlet and extraction pressure. Estimated flow is calculated based of these standard pressures. Any variation of these pressures might generate an error in the calculation.

During turbine start, if the Inlet pressure is much lower than specified, the steam map limitation might limit the HP opening.

The pressure compensation calculation will directly correct the HP valve demand. The action level should be the square root of P standard/P actual. A curve is available in the CCT software, to determine the action level (range 0.1–2).

This action level will multiply the HP valve demand.

- If the Pressure is higher than standard pressure, the compensation should be lower than 1 (min value possible is 0.1).
- If the Pressure is lower than standard pressure, the compensation should be higher than 1 (max value possible is 2).
- To avoid interaction with the speed controller, the HP compensation signal should be Delayed (Lagged).

It is also possible to use the cascade input as a pressure compensation signal (configurable in the CCT).

LP Pressure Compensation

This new feature, when configured, is intended to compensate for the effect of any variation of the Extraction Steam pressure.

In normal operation, if the Extraction Steam pressure derivate from its normal value, speed PID settings and/or extraction PID settings might become too slow or too fast.

The steam map has been specified for a specific Inlet and extraction pressure. Estimated flow is calculated based of these standard pressures. Any variation of these pressures might generate an error in the calculation.

While running in decoupled mode Inlet & speed, the LP valve is controlling the speed. Extraction pressure must be controlled by an external device.

A coupling effect could be noticed between the LP valve movement and the extraction pressure control valve (external), resulting in oscillations. These oscillations might become critical in the case of a sudden loss of extraction steam.

The LP compensation will dump these oscillations. The pressure compensation calculation will directly correct the LP valve demand. The action level should be the square root of P standard/P actual.

A curve is available in the CCT software to determine the action level (range
0.1–2).

This action level will multiply the LP valve demand.
- If the Pressure is higher than standard pressure, the compensation should be lower than 1 (min value possible is 0.1).
- If the Pressure is lower than standard pressure, the compensation should be higher than 1 (max value possible is 2).
- To avoid interaction with the speed controller, the LP compensation signal should be lagged.

It is possible to use the Extraction input or another signal configured has "LP compensation" as a pressure compensation signal (configurable in the CCT).

Frequency Control (for Generator Units)
The following Frequency Control mode descriptions are based on the 5009 program's default settings. For information on how to change the 5009 Control's defaulted breaker logic, refer to Volume 3 of this manual.

The Speed PID operates in a Frequency Control mode when the generator breaker is closed and the utility tie breaker is open. In this mode the unit will operate at the same speed or frequency regardless of the load it is supplying (up to the unit's load capability). Refer to Figure 5-8.

When breaker positions result in the Speed PID switching to Frequency Control, the speed setpoint is instantly stepped to the last turbine speed (frequency) sensed before Frequency Control was selected. This allows a bumpless transfer between modes. If the last speed sensed was not at the Rated Speed (synchronous speed) setting, the speed setpoint will ramp to the Rated Speed setting at a default rate of 1 rpm/s (tunable through the Service mode; see Volume 3).

In the Frequency Control mode the speed setpoint can be varied with the speed setpoint raise/lower commands, as desired, to allow manual synchronization across a tie breaker to an infinite bus. See the synchronization section in this Chapter.

For indication purposes, a relay can be programmed to energize when the unit is in Frequency Control.

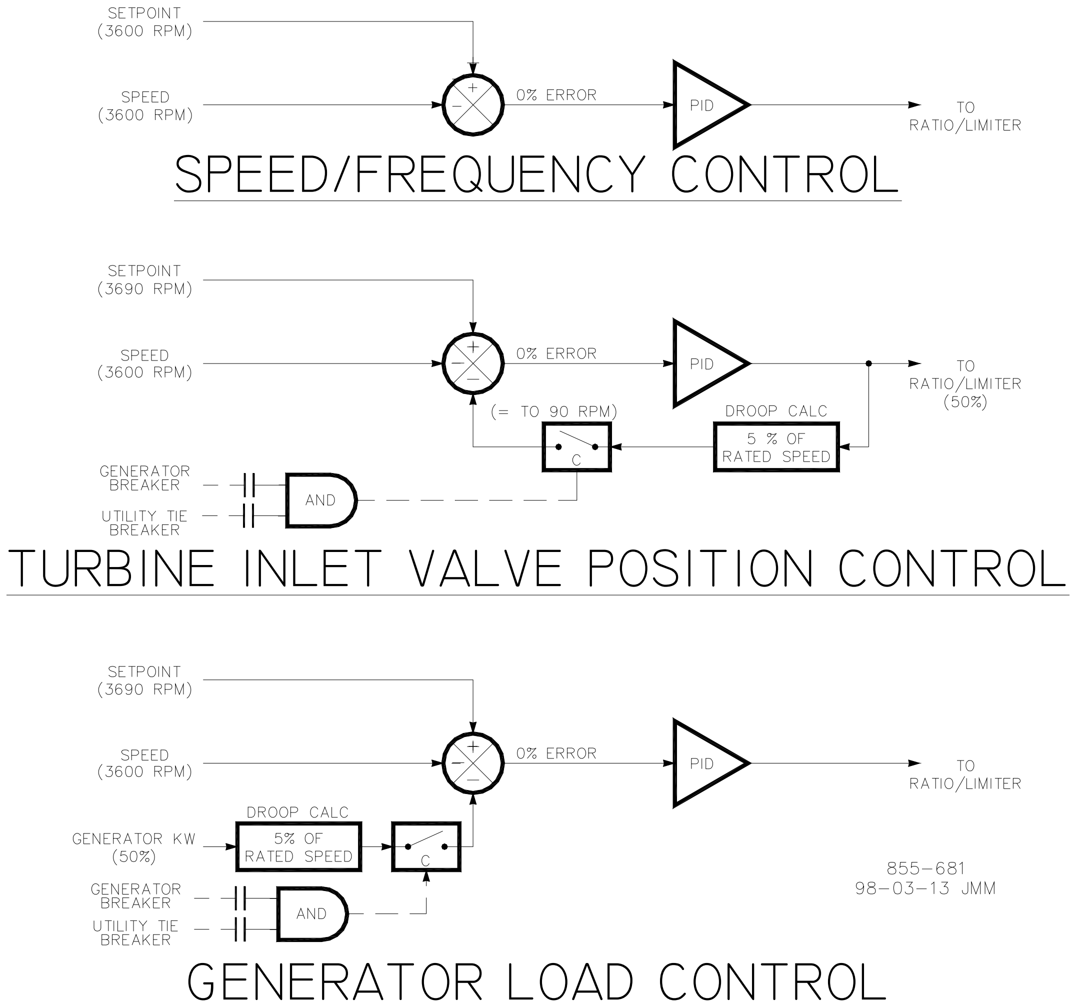


Figure 5-9. Speed PID Control Modes

Unit Load Control (for generator units)

The 5009 Control's Speed PID can control two independent parameters when the generator breaker is closed: frequency when the generator is isolated and unit load when the generator is paralleled with an infinite bus. When the 5009 Control's generator and utility tie breaker inputs are both closed, the Speed PID operates in a unit load mode. This method of allowing a PID to control a second parameter is referred to as droop.

Giving the Speed PID two parameters to control allows it to control unit load and act as a stabilizing effect for any change in bus frequency. With this configuration, when bus frequency decreases or increases, unit load increases and decreases respectively, based on the unit's droop setting. The net effect is a more stable bus. See Figure 5-10 for a frequency and load relationship diagram.

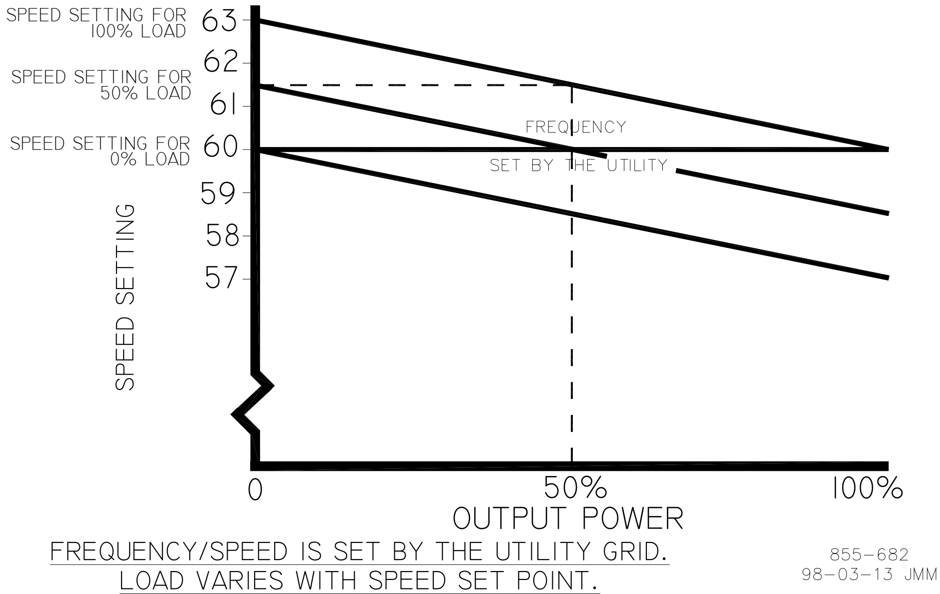


Figure 5-10. Frequency and Unit Load Relationship

The term "droop" was derived from an isolated unit's speed reaction to an increase in load when another parameter (unit load) is fed back to a Speed PID's summing junction. The droop term, as used throughout this manual, refers to a PID's second controlling parameter. A second parameter representing unit load is fed back into the 5009 Control's Speed PID to allow it to control two parameters; speed when operating in an isolated mode and unit load when paralleled to an infinite bus (see Figure 5-10).

Because the 5009 Control's Speed PID and setpoint are used to control turbine speed and a second parameter, this second parameter (unit load) is normalized to allow all three terms (speed, setpoint, unit load) to be summed together within the PID summing junction. This normalization is based on a percentage of rated speed and creates a direct relationship between unit load and the Speed PID's setpoint. Once unit load (0-100%) is represented as a percent of rated speed, the speed setpoint can be varied by this percent, above rated speed, to increase load from 0–100% when paralleled to the utility. Unit load is converted to a percentage of rated speed as shown in the following example calculation:

DROOP % x (gen load or valve positions-%) x rated speed = setpoint change in rpm

Example: 5% x 100% x 3600 rpm = 180 rpm

For this example when paralleled to a utility bus, the speed setpoint can be adjusted from 3600 rpm to 3780 rpm to vary unit load from 0 to 100%.

Droop feedback allows the Speed PID to control unit load (generator power or HP & LP valve positions) once it is paralleled with a utility bus or other generating systems which do not have droop or load sharing capability. When a turbine generator set is paralleled with a utility bus, the utility determines the unit frequency/speed, thus the 5009 Control must control another parameter.

The 5009 Control senses unit load through the turbine HP and LP valve positions or an analog input from a watt transducer sensing generator load. HP and LP valve positions are sensed by their respective 0-100% actuator drive currents. Thus the calibration of drive current to actual valve position is very critical, and should be adjusted as close as possible.

Recommend a Woodward Real Power Sensor (RPS) or equivalent watt transducer be used to sense generator load and feed it back to the 5009 Control's KW input for KW droop control. However, if KW droop is not used or programmed, the 5009 Control uses a calculated load value based off turbine's HP and LP valve positions when paralleled with an infinite bus. If, while controlling generator load, the KW input signal fails, the 5009 Control will issue an alarm and revert to its internal calculated load value.

IMPORTANT

When using one of the Ratio/Limiter's decoupled modes it is recommended that KW droop not be used. Since unit power is affected by the position of both valves, using KW droop would reduce the desired decoupling action.

If the 5009 Control is programmed to control unit load using turbine valve positions, the 5009 Control calculates load based on the valve positions at the time the generator breaker is closed. The valve positions at this point are considered to be zero load. In a typical application, where inlet and exhaust pressures are at rated levels when the generator breaker is closed, this zero load calculation allows unit load to be accurately sensed and controlled.

Frequency Arm/Disarm (for generator units)

The frequency arm/disarm feature may be used when multiple generator sets are on a common isolated bus and no other type of load sharing is used. With this feature, one unit on a multiple unit isolated bus controls frequency and the other units operate in a unit-load mode. The unit controlling frequency is referred to as the "Swing Machine" because its load will swing (vary) depending on the load of the plant. Caution should be taken with this configuration to not allow the "Swing Machine" to be overloaded or reverse powered.

This feature allows an operator to select one unit out of all the units on an isolated bus to function as the swing machine and to change the operating swing machine while in operation. The other units on the bus then operate in a drooped or base load mode. Frequency Control can be armed or disarmed while connected to an isolated or infinite bus, however, when armed, a unit will switch to Frequency Control if the plant to utility tie breaker opens. When disarmed, a unit will stay in a unit-load control mode when the plant-to-utility tie breaker opens.

To use this feature, frequency arm/disarm must be programmed, the sync/load sharing mode cannot be programmed, and a discrete command must be programmed. The frequency arm/disarm mode can be selected from a programmed contact input, CCT Interface, or Modbus. When the programmed contact input is closed, the unit's Frequency Control mode is armed. When the programmed contact input is open, the unit's Frequency Control mode is disarmed.

Depending on a unit's size and running status, an operator may select which unit is designated as the plant Frequency Control unit should the plant-to-utility tie breaker open. Frequency Control can be armed at any time, but it will only go into control when the generator breaker is closed and the utility tie breaker is open.

NOTICE

Only one unit at a time should have its Frequency Control mode armed. If multiple units try to control plant frequency at the same time they may fight and cause system instability, with the potential of damage to the equipment due to overloading or reverse powering a machine.

If the frequency arm/disarm function is disabled, Frequency Control is always armed and the unit will go into Frequency Control when the utility tie contact is open. If the frequency arm/disarm function is enabled then Frequency Control must first be armed before the unit will switch into Frequency Control when the utility tie contact is open.

Dual Speed Dynamics

The Speed PID has two sets of dynamics; Off-Line and On-Line. When a system has variable response times, do to changing system conditions, these dynamic variables allow the Speed PID to be tuned for optimal response.

When the 5009 Control is configured for a generator application, the utility tie and generator breakers determine which set of dynamics is used by the Speed PID. The Speed PID's Off-Line dynamics are selected when either the utility tie or generator breakers are open. The Speed PID's On-Line dynamics are selected if both breakers are closed (see Table 5-1).

When not configured for a generator application, the 5009 Control uses the programmed minimum governor speed setpoint setting to determine which set of dynamic values are used by the Speed PID. The Speed PID's off-line dynamics are selected when turbine speed is below the minimum governor speed setpoint. The Speed PID's On-Line dynamics are selected when turbine speed is above the minimum governor speed setpoint. (see Table 5-1).

Optionally, a contact input may be programmed to chose between on and off line dynamics. When this contact input is programmed, the switching of the Speed PID's dynamics is dependent only on the state of the programmed contact. The utility tie and generator breaker positions (generator applications), and the minimum speed setting status (non-generator applications) do not effect dynamics selection. When the programmed contact input is open, Off-Line dynamics are selected. When the programmed contact input is closed, On-Line dynamics are selected.

A relay can be programmed to indicate which dynamics are selected.

Dynamic values are defined in the Program Mode and tunable at any time. Refer to the Dynamic Adjustments section in this manual.

Table 5-1. On-Line / Off-Line Dynamics Selection

CONFIGURATION	ON-LINE DYNAMICS SELECTED	OFF-LINE DYNAMICS SELECTED
GENERATOR SET	BOTH BREAKERS CLOSED	EITHER BREAKER OPEN
NOT A GEN SET	SPEED > MINIMUM GOV SETTING	SPEED< MINIMUM GOV SETTING
*CONTACT INPUT	CLOSED	OPEN

* When programmed, the contact input option has priority.

Remote Speed Setpoint

The speed setpoint can be positioned remotely through an analog signal by programming the Remote Speed Setpoint (RSS) analog input. This allows the speed setpoint to be set remotely by a process control or distributed plant control system.

The RSS range is determined by the programmed analog input's 4 mA and 20 mA settings. The RSS range is tunable in the Service Mode, but cannot control outside of the minimum and maximum governor speed setpoints.

Since RSS is a secondary speed setting function, the Speed PID must be in-control of the 5009 Control's LSS bus to allow the RSS to position the actuator. When configured as a generator application, the RSS will not take control unless both breakers are closed and the Speed PID is in control. When configured as a non- generator application, turbine speed setpoint must reach minimum governor before the RSS can take control. The cascade and auxiliary (if configured to be enabled/ disabled) controls are automatically disabled if RSS is enabled.

The RSS may be enabled or disabled from the 5009 CCT Interface, external contact or Modbus. The last command given from any of these three sources dictates the enabled/disabled state.

A contact input can be programmed to perform as an external RSS enable. When this programmed contact is open the RSS is disabled, and when it is closed the RSS is enabled. The contact may be either open or closed when a trip condition is cleared. If the contact is open it must be closed to enable the RSS. If the contact is closed it must be opened and re-closed to enable the RSS.

If the milliamp signal to the RSS is out of range (below 2 mA or above 22 mA) an alarm will occur and the RSS will be inhibited until the input signal is corrected and the alarm is cleared.

Remote Speed Setpoint Status Messages

The RSS may be in one of the following states (5009 CCT Interface status messages):

- **Disabled**—The RSS function is not enabled and will have no effect on the speed setpoint.
- **Enabled**—RSS control has been enabled.
- **Active**—RSS is in control of the speed setpoint, but the Speed PID is not in control of the actuator output.
- **In Control**—RSS is in control of the speed setpoint and the Speed PID is in control of the actuator output.
- **Inhibited**—RSS cannot be enabled. The input signal has failed, a controlled stop is selected, the unit is shut down, or RSS is not programmed.

If, when enabled, the RSS does not match the speed setpoint value, the speed setpoint will ramp to the RSS at the “RSS Not-Matched-Rate. Once the RSS function is “in control” of the speed setpoint, the speed setpoint will move at the same rate as analog input value, up to the “Rmt Sept Max Rate setting” rate. (If the RSS maximum rate was set at 10 rpm/s and the RSS instantly moved from 3600 rpm to 3700 rpm, the speed setpoint will move to 3700 rpm at 10 rpm/s.)

Refer to Volume 3 of this manual for information on related Service Mode tunables.

All pertinent RSS parameters are available through Modbus.

Synchronization (for Generator Units)

Automatic generator synchronization can be performed through a Woodward Digital Synchronizer & Load Control (DSLC™). The DSLC connects to a 5009 Control analog input to bias the 5009’s speed setpoint directly to vary generator speed, frequency and phase. Optionally the DSLC can interface with the unit voltage regulator to match system voltage across a generator breaker.

When the 5009 Control is configured for a generator application, a special speed setpoint rate (synchronizer window rate) is used to increase setpoint resolution around synchronous speed. This allows for tighter setpoint control to accommodate synchronizing manually or by an automatic synchronizer which interfaces to the 5009 Control discretely. This rate is only used when the generator breaker is open and the speed setpoint is within 10 rpm of rated speed (tunable through the Service mode).

The DSLC can be used as a synchronizer only or as a synchronizer and load control. When the DSLC is used as a synchronizer only, the 5009 Control must be configured to accept the DSLC control’s analog speed bias signal and have this input enabled. To configure the 5009 Control to utilize a DSLC as a synchronizer-only, assign the “Synchronizing Input” function to an analog input. The Synchronizer Input has preset range and gain settings that are tunable only in the Service Mode. Thus the 4 mA and 20 mA Program Mode settings for the synchronizing input are irrelevant.

Alternatively the “Sync Enable” function can be assigned to a contact input for external synchronizer selection. The synchronizer enable command becomes disabled when the generator breaker closes. To re-enable this input the synchronizer enable contact must be opened and re-closed. Typically a double pole single throw (DPST) switch is used on a site’s synchronizer control panel to select automatic synchronizing by enabling both the DSLC sync mode and 5009 Control’s Sync Enable function at the same time.

The Sync Enable function can be performed through the CCT program, an external contact (as described above), or Modbus communications. See Volume 3 of this manual or Woodward manual 02007 for more information on applying the DSLC.

Synchronization Status Messages (for Generator Units)

- **Disabled**—The synchronizing input is disabled and will have no effect on the speed setpoint.
- **Enabled**—The synchronizing input has been enabled.
- **In Control**—The synchronizing input is biasing the speed setpoint.
- **Inhibited**—The synchronizing input is inhibited and cannot be enabled. Input signal is failed, both the utility tie and generator breakers are closed, the turbine is shut down, a controlled shutdown is being performed, or synchronizing control is not programmed.

Synchronization / Load Sharing (for Generator Units)

A Woodward Digital Synchronizer & Load Control (DSLC) is used with a 5009 Control to allow automatic generator synchronization to a bus and the sharing of load with other units (using DSLC controls on the same bus). The DSLC is a microprocessor based generator load control designed for use on three-phase AC generators with Woodward Speed Controls and automatic voltage regulators.

A DSLC with VAR/Power Factor control, allows all units with DSLC controls to reactive load share as well as real power load share. The DSLC senses unit load through generator PTs & CTs and system load through the DSLC LON network (a combination of all units on the network). The DSLC uses an Echelon network to communicate with other DSLC controls on the same bus.

When used as a synchronizer and load control, the DSLC performs automatic synchronization and controls unit load based on an internal base-load setting, a system average load setting, a process loop's control setting, or a Master Synchronizer & Load Control's (MSLC) demand setting.

After synchronization, unit load can be controlled by the DSLC (through the sync/ load share input) or by the 5009 Control's internal speed/load setpoint. The utility tie breaker contact is used to select which of these units controls and determines unit load. When the Utility Tie contact input is closed, the 5009 Control's internal load control is selected and the Speed PID setpoint is used to control unit load. In this mode, the Cascade or Auxiliary Control PIDs may be used to set unit load based on another system parameter. When the Utility Tie contact input is open, the "Sync/Load Share" bias input is selected, and the DSLC determines unit load via its Speed bias output.

To configure the 5009 Control to utilize a DSLC for generator synchronizing and/ or load sharing the "Sync/Load Share" function must be assigned to an analog input. Alternatively the "Sync Enable" function can be assigned to a contact input for external synchronizer selection only. The sync/load share input has preset range and gain settings that are tunable only in the Service Mode (see Volume 3). Thus the 4 mA and 20 mA Program Mode settings for the Synchronizing input are irrelevant.

The Sync Enable function can be performed through the CCT program, an external contact (as described above), or Modbus communications. See Volume 3 of this manual or Woodward manual 02007 for more information on applying the DSLC.

A combination of the utility tie breaker contact, generator breaker contact, and sync/load share enable contact define the state of the 5009 Control's synchronizing and load sharing operating modes (See Table 5-2).

The utility tie breaker contact input is used to enable and disable load sharing when the generator breaker is closed. If the utility tie contact is open, load sharing is enabled, and the 5009 Control's internal Speed PID droop, cascade, and auxiliary modes are disabled (as defaulted in Service Mode). If the utility tie contact is closed load sharing is disabled and the 5009 Control's Speed PID droop, cascade, and auxiliary modes are enabled.

The generator breaker contact input is used in conjunction with the utility tie contact to activate load sharing.

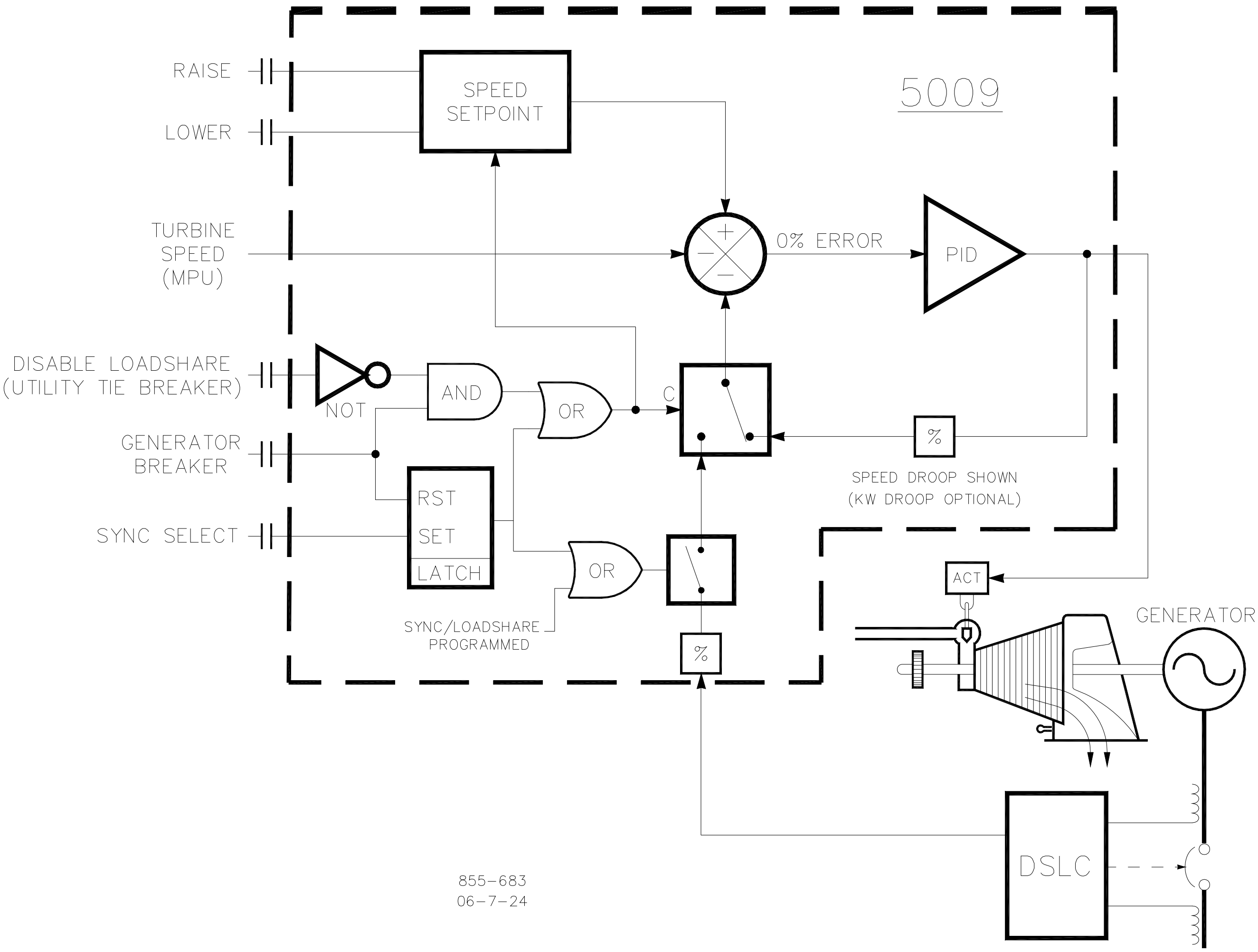


Figure 5-11. Load Sharing Logic

Table 5-2. Load Sharing Logic

TIE BREAKER CONTACT	GEN BREAKER CONTACT	SYNC ENABLE CONTACT	SELECTED SPEED CONTROL MODE	SELECTED CASC & AUX MODES
CLOSED	OPEN	OPEN	SPEED	DISABLED (DFLT)
CLOSED	CLOSED	OPN or CLSD	UNIT LOAD	ALLOWED (DFLT)
OPEN	OPEN	OPEN	SPEED	DISABLED (DFLT)
OPEN	OPEN	CLOSED	SYNCHRONIZING W/DSLC	DISABLED (DFLT)
OPEN	CLOSED	OPN or CLSD	LOADSHARE W/DSLC	DISABLED (DFLT)

855-684
98-03-13 JMM

The sync/load share enable contact input option is used to enable the sync/load share analog input before the generator breaker is closed. This discrete enable/ disable function is ignored after the generator breaker is closed, and must be re- selected after the generator breaker opens. Typically a double pole single throw (DPST) switch is used on a site's synchronizer control panel to select automatic synchronizing by enabling both the DSLC sync mode and 5009 analog input at the same time.

Sync/Load Share Status Messages (for generator units)

- **Disabled**—The sync/load share input is disabled and will have no effect on the speed setpoint.
- **Enabled**—The sync/load share input has been enabled.
- **In Control**—The sync/load share input is biasing the speed setpoint.
- **Inhibited**—The sync/load share input cannot be enabled. The input signal is failed, the turbine is shut down, a controlled shutdown is being performed, or the sync/load share feature is not programmed.

All pertinent synchronizing and load sharing parameters are available through Modbus.

Extraction, Admission, or Extr/Adm Turbine Control

The control (extraction, admission, or extraction/admission) can receive up to three input (4–20 mA) signals from pressure or flow transducers. The Ext/Adm PID controller then compares the voted good input signal to its setpoint to generate an output signal to the Ratio/Limiter. The Ratio/Limiter receives input signals from the Speed/Aux LSS bus and the Ext/Adm PID. The ratio logic ratios these signals based on the turbine performance parameters to produce two output signals, one to control the HP valve and one to control the LP valve. The limiter logic keeps the outputs to the valves within the boundaries of the turbine steam map.

Extraction-Only Turbine Control

When configured to operate single controlled extraction steam turbines, the control manages the interaction between the turbine's governor valve (HP) and extraction valve (LP) valve to control two turbine related parameters at the same time. With this type of configuration, the control's LP valve limiter is high signal selected with LP Valve demand output, allowing an operator to manually limit extraction flow if desired.

During turbine start-up the LP valve limiter (and LP Valve) is held at 100% to allow the inlet steam to pass non-restricted through the turbine's front and back- sections. After a shutdown, and before a turbine start, the LP valve limiter is ramped to its 100% position upon issuing a reset command to the control. This allows the turbine to warm up and expand evenly before starting. Upon a shutdown condition, the LP valve limiter is taken to 0%.

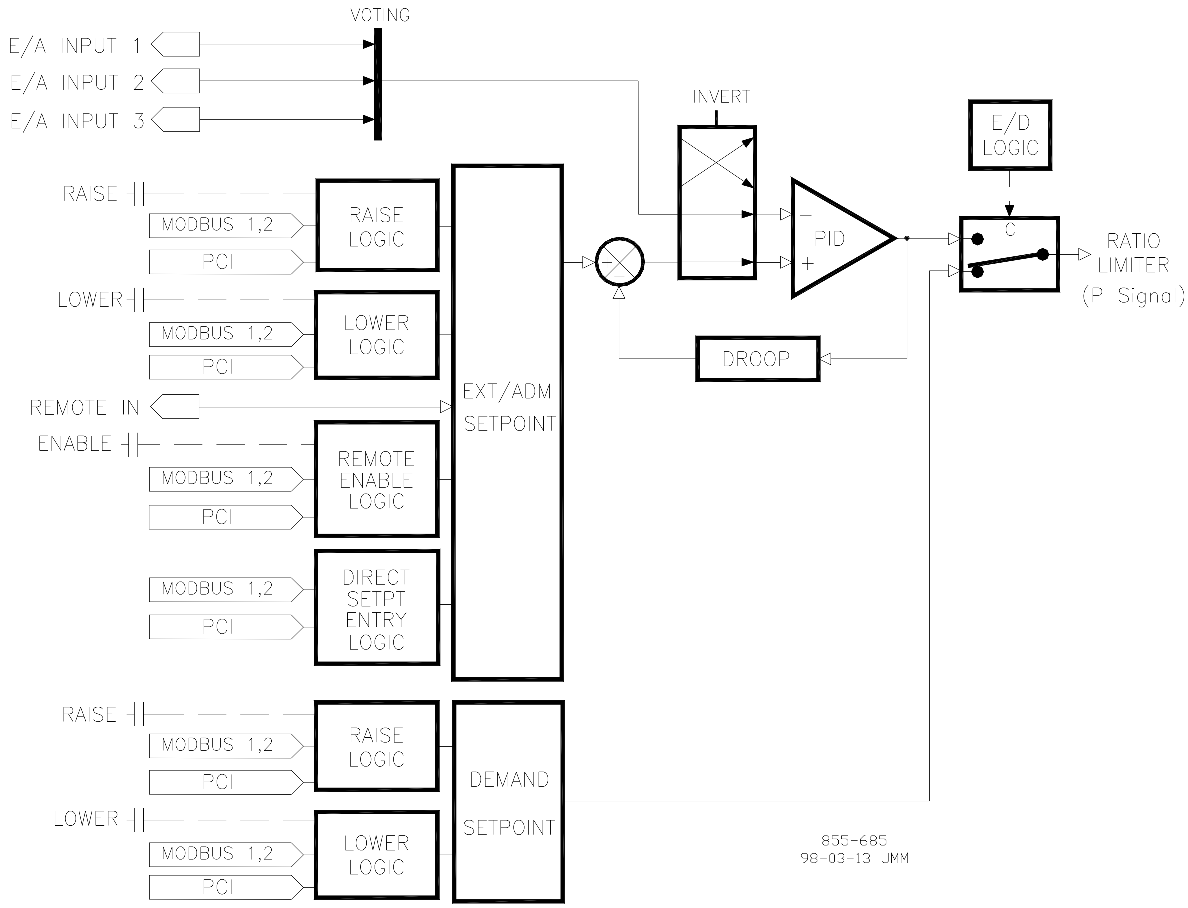


Figure 5-12. Ext/Adm Control Diagram

The Extraction PID can be enabled automatically or manually. Extraction control is enabled by lowering the LP valve limiter to its 0% position. After a start-up, the HP and LP valve limiters should normally both be fully open. If the HP valve limiter is not fully opened, it will act as a speed/load limiter and will interfere with automatic governor operation. Typically, a turbine is controlled at a rated speed setting or loaded to a minimum load point before Extraction Control is enabled. All related Extraction permissives must be met before the 5009 Control will allow the Extraction PID to take control of a process. The enable permissives are:

- Ext/Adm input not failed
- Turbine speed above programmed permissive speed
- Generator breaker closed (if configured)
- Tie breaker closed (if configured)

Manual Enable/Disable—To manually enable Extraction Control slowly lower the LP valve limiter until the Extraction PID takes control of its process, then continue running the LP valve limiter to its minimum (closed) position. If the LP valve limiter is not fully closed, it will act as an Extraction limiter and will interfere with automatic governor operation. All related Extraction permissives must be met and Extraction Control enabled before the 5009 Control will allow the LP valve limiter to be lowered.

To disable Extraction Control slowly raise the LP valve limiter until the Extraction PID loses control of its respective process. Continue running the LP valve limiter to its maximum (open) position.

Automatic Enable/Disable—If the “Use Automatic Enable” function is selected, the LP valve can be lowered automatically by issuing an “Ext/Adm Control Enable” command. After receiving an enable command, the 5009 Control will automatically lower the LP valve limiter at the LP valve limiter rate. Once the Extraction PID takes control of its process, the LP valve limiter will continue lowering to its minimum (closed) position.

The LP valve limiter may be stopped at any time during the automatic enabling routine by momentarily issuing a LP limiter raise or lower command (or by entering a valid setpoint). Upon stopping the automatic enabling routine from lowering the LP valve limiter, the Extraction PIDs output will still continue to be enabled. This allows an operator to continue the enabling routine manually as desired. By re-issuing an enable command, the enable routine will continue lowering the LP valve limiter. If a contact is programmed for this function it will have to be opened and re-closed to re-issue an enable command.

The 5009 Control only accepts an Extraction enable command if all related permissives are met (see above list). An enable/disable command may be issued through the CCT, a contact input, or Modbus. The last command given from any of these three sources dictates the state of the Extraction Control.

When a contact input is programmed to function as an “Ext/Adm Control Enable” command, a closed state represents an enable command and an open state represents a disable command. This contact can either be open or closed when a 5009 Control trip condition is cleared. If the contact is open it must be closed to issue an enable command. If the contact is closed, it must be opened and re-closed to issue an enable command.

Upon receiving a disable command the 5009 Control will instantly step the LP valve limiter to the LP valve’s current position and then raise the LP limiter to its maximum (open) position at the LP valve limiter rate. At some point, depending on system conditions, the Extraction PID will lose control of its process.

The LP valve limiter may be stopped at any time during the automatic disabling routine by momentarily issuing an LP limiter raise or lower command. Once stopped, an operator can continue to manually adjust the valve limiter as desired or issue a disable command. By issuing a disable command the disable routine will continue raising the LP valve limiter to its maximum (open) position. With automatic Extraction enabling programmed, an operator can also enable and disable extraction control manually if desired.

Admission-Only or Extraction/ Admission Turbine Control

The procedure for enabling the Ext/Adm PID with admission or extraction/ admission applications is the same. In all cases it is assumed that an external trip valve or a trip-and-throttle valve is used to completely stop any admission steam from entering the turbine upon a system shutdown condition.

Admission or Extraction/Admission Control can be enabled and performed after one of the three starts has been performed. After a start-up, the HP and LP valve limiters should normally both be fully open. If either limiter is not fully opened, it will interfere with automatic governor operation.

Demand Setpoint—To perform a bumpless transfer into Ext/Adm Control the pressures on each side of the admission trip valve or T&T valve should be matched, before control is enabled. The Ext/Adm Demand setpoint is used to manually change a unit’s flow demand, thus the turbine’s internal pressure at the admission header’s inlet. An operator must manually vary the Ext/Adm Demand setpoint to manually match the turbine’s internal pressure to that of the pressure on the plant side of the Ext/Adm T&T valve.

The Demand setpoint is a manual admission or ext/adm flow demand, and allows an operator to manually change the turbine’s adm or ext/adm flow. When the Ext/ Adm PID is not enabled, this flow setpoint is the “P” term input into the control’s Ratio/Limiter. This flow demand setpoint is defaulted to 100% for Admission turbines, and to a calculated zero ext/adm flow point for Extr/Adm turbines. All default settings can be changed via the CCT program’s Service mode.

The following procedure allows a bumpless transfer into Admission or Extraction/ Admission Control to be performed. The Admission or Extraction/Admission enabling procedure is:

1. Verify that all Ext/Adm enable permissives are met.

2. Match the Ext/Adm setpoint to that of the pressure on the plant side of the Ext/Adm T&T valve. (Skip this step if setpoint tracking is used).

3. Vary the Ext/Adm Demand setpoint to match the turbine’s internal Ext/Adm pressure to the pressure on the plant side of the Ext/Adm T&T valve.

4. Open the Ext/Adm T&T valve.

5. Issue an Adm or Ext/Adm Control Enable command.

All functions required to bumplessly enable and disable Adm or Ext/Adm Control can be performed through the CCT program, contact inputs, or Modbus. The control only accepts an enable command if all related permissives are met. An enable/disable command may be issued through the CCT program, a contact input, or Modbus. The last command given from any of these three sources dictates the state of the Adm or Ext/Adm Control.

When a contact input is programmed to function as an “Ext/Adm Control Enable” command, a closed state represents an enable command and an open state represents a disable command. This contact can either be open or closed when a 5009 Control trip condition is cleared. If the contact is open it must be closed to issue an enable command. If the contact is closed, it must be opened and re-closed to issue an enable command. The following procedure allows Adm or Ext/Adm Control to be disabled in a controlled manner:

1. Issue a Disable Adm or Ext/Adm Control command. At this point the Ext/ Adm Demand setpoint will step to the Extraction PID’s last position, take control of the process from the PID, then ramp back to the default flow demand setting.

2. If necessary manually adjust the ext/adm demand setpoint to reach zero extraction/admission flow.

3. Close the extraction/admission Trip-and-Throttle valve.

EXT/ADM Control Status Messages

- **Disabled**—Ext/Adm Control is not enabled and will have no effect.
- **Enabled**—Ext/Adm has been enabled but is not active or in control. Permissives have not been met (speed < ext/adm enable speed or generator or tie breaker open).
- **Active / Not in Control**—Ext/Adm has been enabled but the turbine is on a operating limit with speed priority selected or the LP valve limiter is limiting the Ext/Adm PID output.
- **In Control**—Ext/Adm PID is in control of its process.
- **Active With Remote Setpoint**—Ext/Adm has been enabled and the remote Ext/Adm setpoint is in control of the setpoint, but the turbine is on a operating limit with speed priority selected or the LP valve limiter is limiting Ext/Adm PID output.
- **Control w/Remote Setpoint**—Ext/Adm is in control and the remote Ext/ Adm setpoint is positioning the Ext/Adm setpoint.
- **Inhibited**—Ext/Adm cannot be enabled. The Ext/Adm input signal has failed, a controlled stop is selected, or the unit is shut down.

EXT/ADM Input

Depending on the control action required, the Ext/Adm PID’s input signal can be inverted. When used with a typical Ext/Adm and/or admission turbine application this input should not require inverting. Upon loss of the Ext/Adm input signal during operation, the control can be programmed ramp the LP valve to its open limit, ramp the LP valve to its closed limit, hold the LP valve at its last position, or trip the turbine.

If configured to ramp the LP valve on loss of the Ext/Adm input, the LP valve limiter steps to the LP valve’s last position, then ramps the actuator output at a 1% per second rate to its minimum or maximum limit, depending on the programmed settings. The control senses an input failure and issues an alarm if the 4–20 mA Ext/Adm input signal goes < 2 mA or > 22 mA.

Refer to Chapter 2 of this Volume for details on input fault tolerant logic.

PID Dynamics

The Ext/Adm PID uses its own set of dynamic settings. These values are programmable and may be tuned at any time from CCT Interface or Modbus. Refer to Chapter 5 of this manual for information on PID dynamic adjustments.

EXT/ADM Droop

When sharing control of a parameter with another external controller, the Ext/ Adm PID can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the Ext/Adm PID's output, or the back-calculated Ratio/Limiter "P" term, depending on configuration. By including this second parameter into the control loop, the Ext/Adm PID does not fight with the other external controller over the shared parameter. If Ext/Adm droop is used, the Ext/Adm input signal will not match the Ext/Adm setpoint when in control. The difference will depend on the amount (%) of droop programmed and the output of the Ext/Adm PID. The droop value fed back to the Ext/Adm PID is equal to the following defaulted settings:

PID OUTPUT % x 'EXT/ADM DROOP %' x 'RATED EXT/ADM SETPOINT' x 0.0001

Example: 25% x 5% x 600 psi (4137 kPa) x 0.0001 = 7.5 psi (51.71 kPa)

The rated Ext/Adm setpoint is defaulted as the maximum Ext/Adm setpoint and is adjustable in the Service Mode. The Ext/Adm droop % and the maximum Ext/ Adm setpoint values are set in the Program Mode and the PID output is determined by the Ext/Adm demand. Refer to Volume 3 of this manual for information on related Service Mode tunables.

Setpoint

The Ext/Adm setpoint may be adjusted from the 5009 CCT Interface, external contacts, Modbus, or through a 4–20 mA analog input signal. A specific setting can also be directly entered from the 5009 CCT Interface or through Modbus. The Ext/ Adm setpoint range must be defined in the program mode. The minimum Ext/ Adm setpoint and the maximum Ext/Adm setpoint define the range of the Ext/ Adm setpoint and control.

When a raise or lower Ext/Adm setpoint command is issued, the setpoint moves at the programmed Ext/Adm setpoint rate. If an Ext/Adm raise or lower command is selected for longer than three seconds, the Ext/Adm setpoint will move at the fast rate which is three times the Ext/Adm setpoint rate. The Ext/Adm setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

A specific setpoint may also be directly entered through the 5009 CCT Interface or Modbus communications. When this is performed, the setpoint will ramp at the Ext/Adm setpoint rate. The setpoint can also me adjusted manually through the CCT Interface or Modbus.

Setpoint Tracking—This feature is programmable and usable only if the control is programmed for an Admission or Ext/Adm application. To reduce the number of steps required to smoothly enable Ext/Adm control the Ext/Adm setpoint can be programmed to track the Ext/Adm process input when control is disabled. This tracking feature causes the setpoint to be equal to the Ext/Adm input when Ext/ Adm control is enabled. After Ext/Adm control is enabled, its setpoint can be moved to another setting.

Setpoint with No Tracking—If the Ext/Adm control is programmed not to use the setpoint tracking feature, the setpoint will remain at its last setting (running or shutdown). With this configuration, when Ext/Adm control is enabled and the sensed process signal does not match setpoint, the Ext/Adm control will ramp the Ext/Adm process up or down to match the process and setpoint. When the 5009 Control is powered-up, the setpoint is reset to the setpoint initial value. With this configuration, if one of the permissives is lost or Ext/Adm control is disabled, the Ext/Adm setpoint will remain at its last setting until adjusted. Refer to Volume 3 of this manual for further information on Service Mode and On-Line tunables. All pertinent Ext/Adm control parameters are available through the Modbus links.

Remote EXT/ADM Setpoint

One of the 5009 Control's analog inputs can be programmed to set the Ext/Adm PID setpoint. This allows the Ext/Adm setpoint to be positioned remotely by a process control or distributed plant control system.

The remote Ext/Adm setpoint range is determined by the programmed analog input's 4 mA and 20 mA settings. The remote Ext/Adm setpoint range is tunable in the Service Mode.

When enabled, the remote setpoint may not match the Ext/Adm setpoint. In this case, the Ext/Adm setpoint will ramp to the remote setpoint at the "Remote E/A Not-Matched Rate" (adjustable via the Service mode, and defaulted to the Ext/ Adm Slow setpoint setting). Once matched, the Ext/Adm setpoint moves at the same rate the remote setpoint input moves up to the "Rmt Sept Max Rate" setting. If the remote Ext/Adm setpoint maximum rate were set at 10 and the remote setpoint analog input instantly moved from 0 units to 1000 units, the Ext/Adm setpoint will move to 1000 units at 10 units/s.

If the milliamp signal to the remote Ext/Adm setpoint input is out of range (< 2 mA or > 22 mA) an alarm will occur and the remote Ext/Adm setpoint will be inhibited until the input signal is corrected and the alarm is cleared.

Remote Ext/Adm Setpoint Messages—The remote Ext/Adm setpoint may be in one of the following states:

- **Disabled**—The remote setpoint function is disabled and will have no effect on the Ext/Adm setpoint.
- **Enabled**—The remote setpoint has been enabled, but permissives are not met.
- **Active**—The remote setpoint has been enabled and permissives are met, but the Ext/Adm PID is not in control.
- **In Control**—The remote setpoint is in control of the Ext/Adm setpoint and the Ext/Adm PID is in control.
- **Inhibited**—The remote setpoint cannot be enabled. The remote setpoint input signal is failed, Ext/Adm input signal is failed or a controlled stop is selected.

Remote Ext/Adm Setpoint Enable Logic—There are three different options for enabling remote Ext/Adm setpoint and Ext/Adm control via external contacts. They are as follows:

- Only a Remote Ext/Adm Setpoint Enable contact input configured.
- Both the Ext/Adm Control Enable and Remote Ext/Adm Setpoint Enable contacts configured.
- No enable contact inputs configured.

If the remote Ext/Adm setpoint enable function is configured, and an Ext/Adm enable contact is not configured, closing the remote Ext/Adm setpoint contact will enable both Ext/Adm control and remote Ext/Adm setpoint input. This configuration allows both functions to be enabled with one command. If the contact is opened, both control modes are disabled.

When both Remote Ext/Adm Setpoint enable and Ext/Adm Control enable contact inputs are programmed, each function is enabled by its respective contact. If Remote Ext/Adm Setpoint enable is selected, only the remote Ext/Adm setpoint will be enabled. If Ext/Adm control enable is selected, only Ext/Adm control will be enabled. If remote Ext/Adm disable is selected, only the remote Ext/Adm setpoint will be disabled. If Ext/Adm control disable is selected, both remote Ext/ Adm Setpoint input and Ext/Adm control will be disabled.

If no external contact input is programmed for either Ext/Adm control or Remote Ext/Adm Setpoint control these functions can be enabled through the CCT program or Modbus communications. Since the CCT program and Modbus provide both remote Ext/Adm and Ext/Adm control enable commands, they will operate in the same manner as programming both enables. Refer to Volume 3 of this manual for information on related Service Mode tunables. All pertinent Remote Ext/Adm Setpoint parameters are available through Modbus.

Ratio/Limiter

The control's Ratio/Limiter logic is only used with extraction, admission, and extraction/admission type turbines. The Ratio/Limiter receives input signals from the speed (or aux) and ext/adm PIDs. The ratio logic uses these signals, and based on the turbine performance parameters, produces two output signals, one to control the HP actuator and one to control the LP actuator. The limiter logic keeps the actuator outputs within the boundaries of the turbine steam map.

Because a single ext/adm turbine has only two control valves, only two parameters at a time can be controlled. Due to a turbine's design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed/load (or Auxiliary or Cascade PID processes) and ext/adm pressure/flow levels. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process. When system conditions cause a turbine to reach an operating limit, the limiter logic limits the HP or LP valves to maintain speed/load or ext/adm levels depending on the priority selected.

When correcting for a system demand change in one process it may be desirable to have the control move both turbine valves at the same time in order to reduce or stop the interaction of one process on the other. For this reason the Ratio/Limiter logic can be configured in the following operational modes depending on the parameters being controlled and the turbine's function within the system.

Ratio/Limiter Configurations:

- No Ratio/Limiter
- Coupled HP & LP
- Decoupled INLET (HP)
- Decoupled EXHAUST (LP)
- Decoupled HP & LP

No Ratio/Limiter

When configured for single actuator or split-range actuator type of turbines, ext/ adm and Ratio/Limiter logic is not used. The Speed/Load Controller, Auxiliary Controller, and HP Valve Limiter are all low-signal-selected or command selected, in the case of Aux Enable/Disable, to position the actuator output(s). Refer to Figures 3-5, 3-6, and 3-7.

Coupled HP & LP

This mode is typically used when the two controlled parameters during normal operation are turbine speed/load and ext/adm pressure (or flow).

In this operating mode the turbine's HP and LP valve actions are coupled (ratioed) together to control both processes without the two processes interacting with each other. Turbine load and ext/adm pressure are controlled by moving both the HP and LP valves simultaneously. For a change in either process both valves are repositioned to create a net effect of no change (pressure, flow or power) on the other process.

In most cases, the operator of an ext/adm turbine needs to maintain both turbine speed/load and ext/adm pressure/flow at constant levels. Changing the position of either the HP valve or the LP valve affects both turbine speed/load and extraction/ admission. If either the load on the turbine or the ext/adm demand changes, both the HP valve position and the LP valve position must be changed to maintain speed/load and extraction/admission. The movement of both valves is automatically calculated by the 5009 Control's ratio logic based on the programmed turbine performance parameters to minimize valve/process interaction.

Refer to Figure 5-13 for details on the Coupled HP&LP mode logic.

Decoupled Inlet

For Compressor Units – Decoupled Inlet and Speed
For Generator Units – Decoupled Inlet and Speed or Ext/Adm Pressure

This mode is typically used when the two controlled parameters during normal operation are turbine inlet pressure and speed (for a compressor unit) or ext/adm pressure (for a generator unit).

In this operating mode the turbine's HP and LP valve actions are de-coupled to allow control of a turbine's inlet pressure without interaction from ext/adm flow changes. With this mode of operation, turbine speed (or ext/adm pressure) is controlled by only moving the LP valve. Although turbine load is not controlled with this configuration, it is limited based on the turbine operating limits programmed.

The turbine's HP and LP valve actions are still coupled to control turbine speed (or ext/adm pressure/flow) without interaction from turbine inlet pressure or flow changes. Turbine inlet pressure is controlled by moving both the HP and LP valves simultaneously, thus no change in speed (ext/adm pressure) is created. For a change in either process the valves are repositioned to create a net effect of no pressure or flow change on the other process. Refer to Figure 5-14 for details on the Decoupled Inlet mode logic.

With this mode of operation:

- Turbine inlet pressure can be controlled through either the 5009 Control's Auxiliary or Cascade PIDs.
- (Compressor) Speed is controlled via speed PID and cascade if enabled.
- (Generator) Ext/adm pressure/flow can only be controlled through the 5009 Control's Ext/adm PID.

The decoupling mode can be Enabled/disable via external contact if configured, CCT software or Modbus commands.

This mode can be activated only when extraction has been enabled (manual or automatic control)

The decoupling PID can be configured to use up to three decoupling inputs.

A remote Decoupling setpoint can also be configured. It will be enabled when a configured contact Enable remote decoupling is closed, or via CCT or Modbus.

Like the extraction PID, the decoupling PID can be put in manual mode via external contact, CCT or Modbus commands. In this case, R/L demand can be use to open/close the HP valve. These commands can be the same external contacts use to R/L the extraction demand, or they can come from CCT or Modbus. In case of failure of the decoupling inputs, the control can be configured to automatically put the decoupling PID in manual mode.

Decoupled Exhaust

For Compressor Units – Decoupled Exhaust and Speed

For Generator Units – Decoupled Exhaust and Speed or Ext/Adm Press

This mode is typically used when the two controlled parameters during normal operation are turbine speed (or ext/adm pressure) and exhaust pressure.

In this operating mode the turbine's HP and LP valve actions are de-coupled to allow control of a turbine's exhaust pressure without interaction from speed (or ext/adm flow) changes. With this mode of operation, turbine speed (or ext/adm pressure) is controlled by only moving the HP valve.

The turbine's HP and LP valve actions are still coupled to control turbine speed (or ext/adm pressure) without interaction from turbine exhaust pressure or flow changes. Turbine exhaust pressure is controlled by moving both the HP and LP valves simultaneously, thus no change in speed (or ext/adm pressure) is created. For a change in either process the valves are repositioned to create a net effect of no pressure or flow change on the other process. Refer to Figure 5-15 for details on the Decoupled Exhaust mode logic.

With this mode of operation:

- Turbine exhaust pressure can be controlled through either the 5009 Control's Auxiliary or Cascade PIDs.
- (Compressor) Speed is controlled via speed PID and cascade if enabled.
- (Generator) Ext/adm pressure can only be controlled through the 5009 Control's Ext/ adm PID.

Decoupled HP & LP

This mode is typically used when the two controlled parameters during normal operation are turbine inlet pressure and exhaust pressure.

In this operating mode the turbine's HP and LP valve actions are fully de-coupled. The HP valve can be positioned by the 5009 Control's Speed, Cascade, or Auxiliary PIDs. The LP valve can only be positioned by the 5009 Control's Ext/ Adm PID. This configuration allows control of a turbine's inlet pressure without interaction from exhaust flow changes. With this mode of operation, turbine exhaust pressure is controlled by only moving the LP valve.

The turbine's HP and LP valve actions are also decoupled to control turbine exhaust pressure/flow without interaction from turbine inlet pressure or flow changes. Turbine inlet pressure is controlled by only moving the HP valve, thus no change in exhaust pressure/flow is created. For a change in either process the respective valves are repositioned for a net effect of no pressure or flow change on the other process.

With this mode of operation, turbine inlet pressure can be controlled through either the 5009 Control's Auxiliary or Cascade PIDs and turbine exhaust pressure is controlled through the Ext/Adm PID. Although turbine load is not controlled with this configuration, it is recommended to use the Auxiliary PID as a load limiter for unit protection. Refer to Figure 5-16 for details on the Decoupled HP&LP mode logic.

Block Diagram Description—The block diagrams displayed below provide a detailed view of each Ratio/Limiter configuration, and the relationship between the ratio/limiter's input and output signals.

The "S" input signal originates from the Speed/Auxiliary LSS bus and represents Speed, Load, Aux PID, or Casc PID demand (refer to Figures 3-8 and 3-9 for information on where this input originates). The "P" input signal originates from the Ext/Adm PID or the E/A demand setpoint, depending on selected modes, and represents Ext/Adm flow demand (refer to Figures 3-8 and 3-9 for information on where this input originates). The "A" input signal is a discrete signal that originates from the control's decoupling map logic, and goes to a true state when ratio/limiter decoupling is selected (refer to Figures 3-8 and 3-9 for information on where this input originates).

The "S" and "P" signals must pass through map limiters, depending on the priority selected, before they are used in the ratio equations. Only one parameter (S or P) at a time can be limited, thus if Speed priority is enabled only the P signal is limited. If Ext/Adm priority is selected only the S signal is limited. These limiters allow the valves to be correctly positioned on each turbine operating limit. To simplify the limiter logic, the Min (HSS bus) and Max (LSS bus) limiters are displayed as one limiter bus. Each possible turbine operating limit is labeled and displayed graphically. All limiters are based on the entered steam map values, and actual HP & LP valve positions (as derived from the control's actuator driver signals).

Once the "S" and "P" signals pass through their respective limiters, they are referred to as S' (S-prime), and P' (P-prime). When the turbine is not operating on a limit, the S' value equals the S input signal, and the P' value equals the P input signal.

If programmed for decoupled operation, digital ramps are used to transfer between Ratio/Limiters. During normal enabling and disabling of the decoupled ratio/limiter mode these ramps take 50 seconds to completely ramp from one ratio/limiter to the next. With generator applications, this transfer is made within 40 milliseconds when switching to frequency control (gen or tie breaker opens).

If configured for a decoupled ratio/limiter mode, the control starts by using the Coupled ratio/limiter, then switches to the Decoupled ratio/limiter when the Auxiliary or Cascade PIDs are enabled. The Auxiliary PID when configured as a limiter has no influence on the ratio/limiter selection. The control switches back to the Coupled ratio/limiter when the Auxiliary and/or Cascade PIDs are disabled.

The "HP" output signal represents HP valve demand, and is connected to the control's HP LSS bus (refer to Figures 3-8 and 3-9 for signal interconnections). The "LP" output signal represents LP valve demand, and is connected to the control's LP LSS bus (refer to Figures 3-8 and 3-9 for signal interconnections).

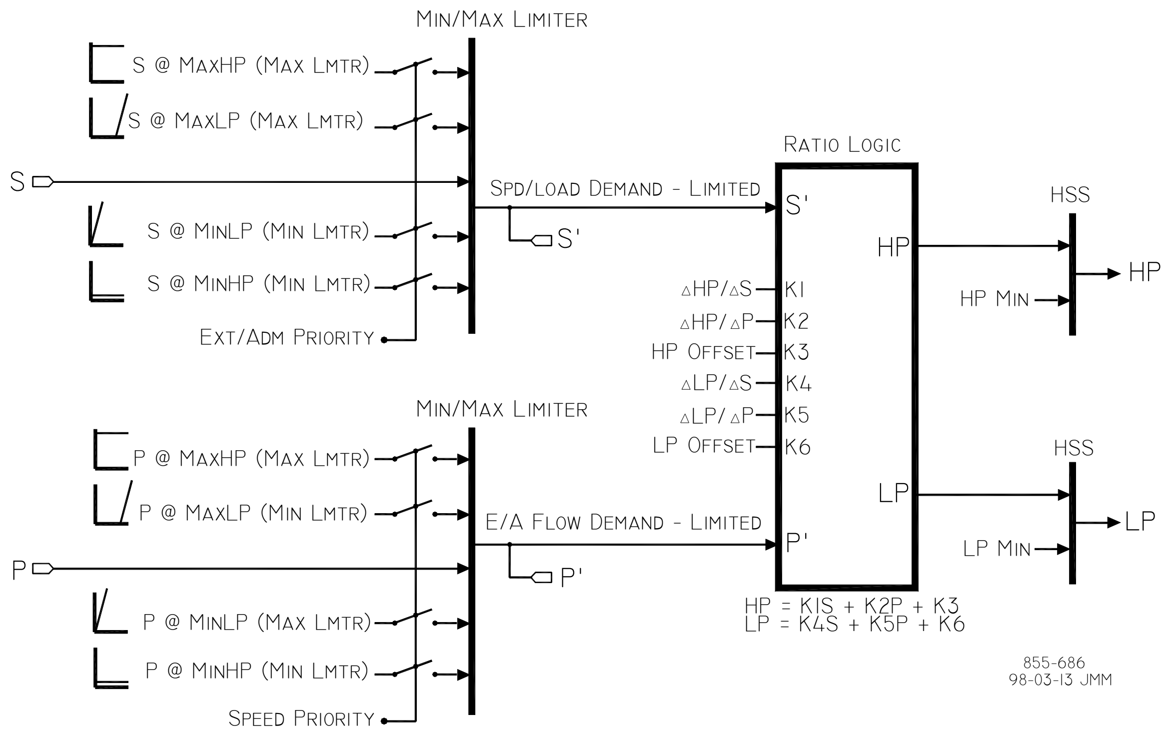


Figure 5-13. Coupled HP & LP Mode

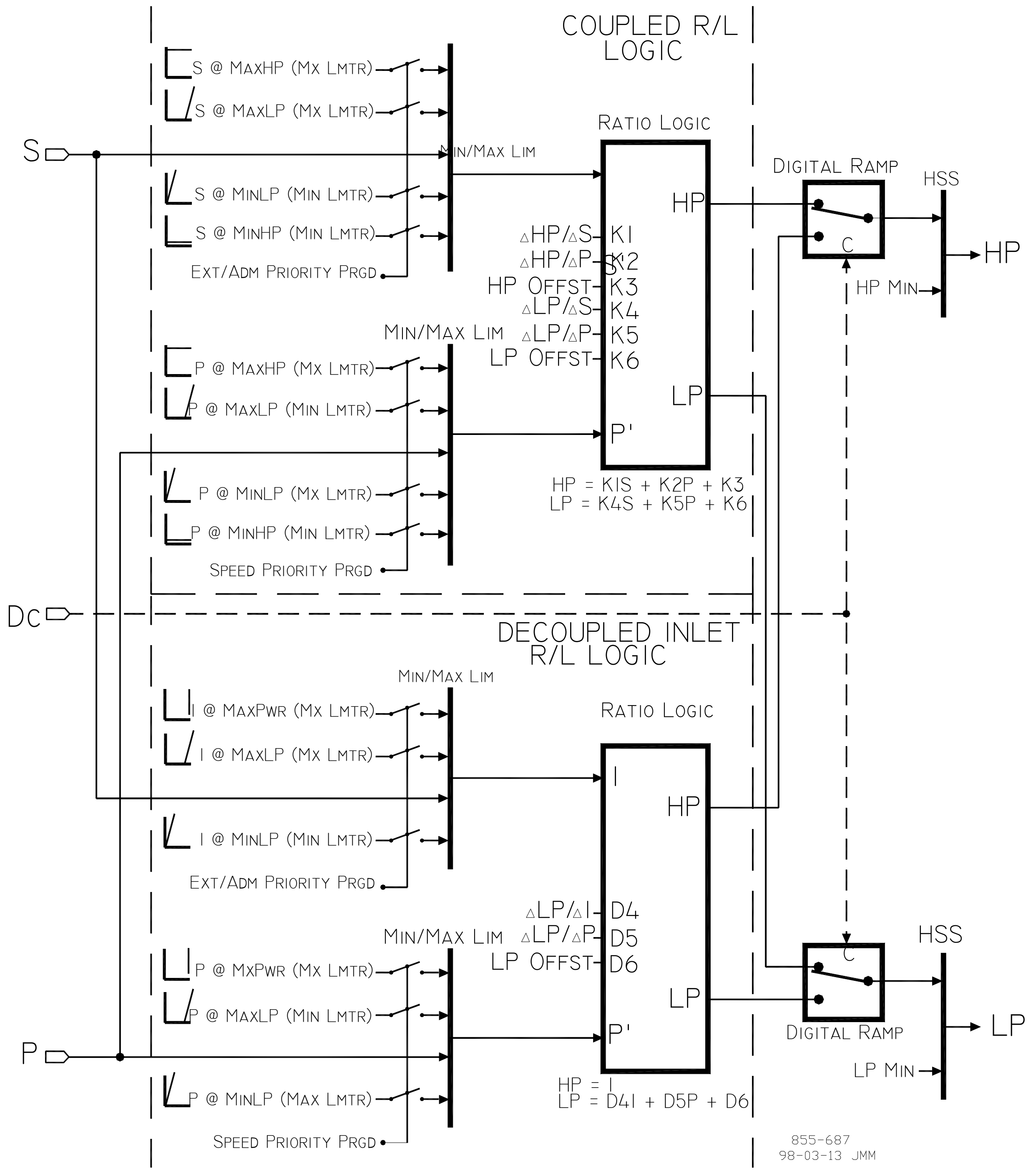


Figure 5-14. Decoupled Inlet (HP) Mode

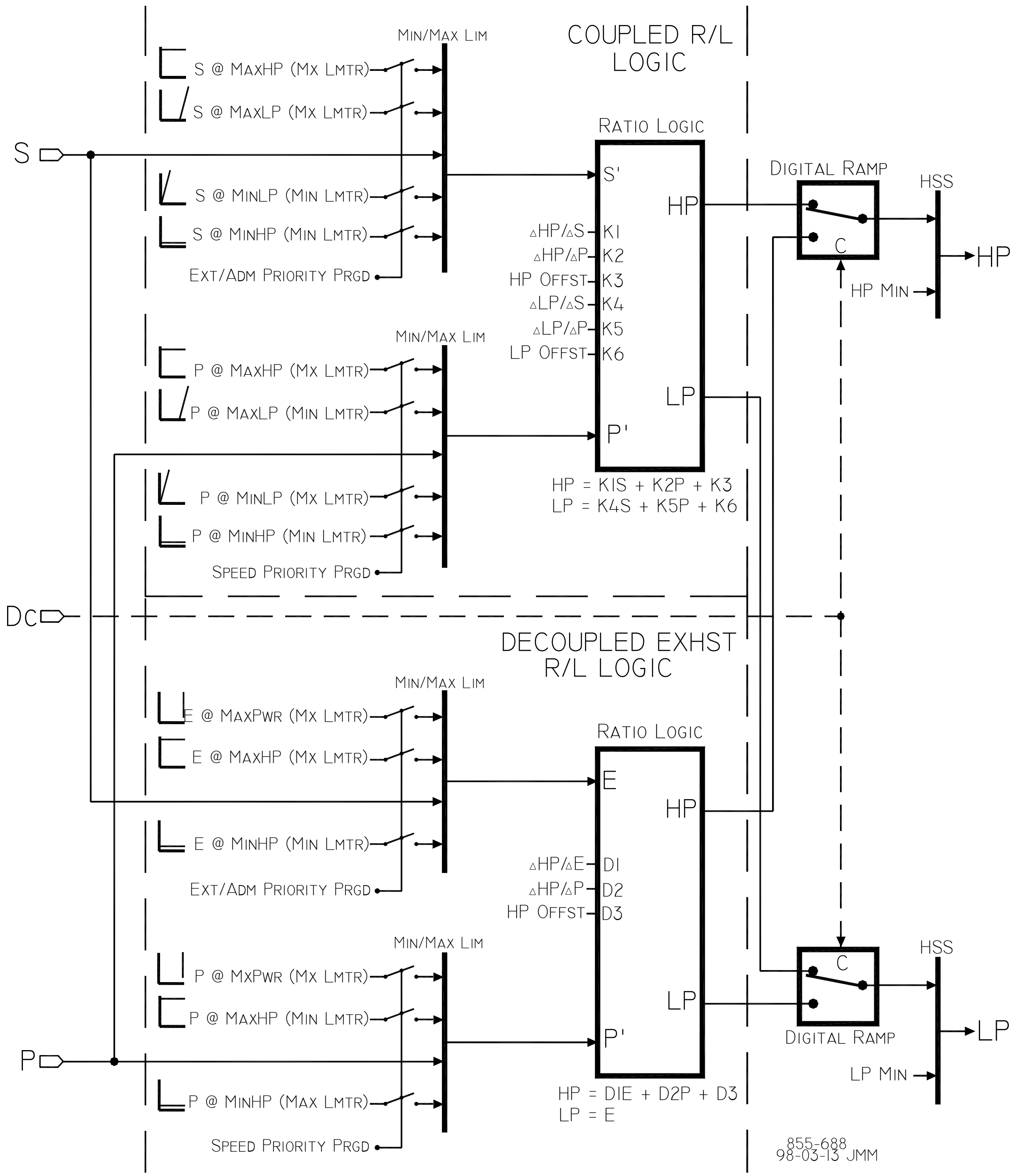


Figure 5-15. Decoupled Exhaust (LP) Mode

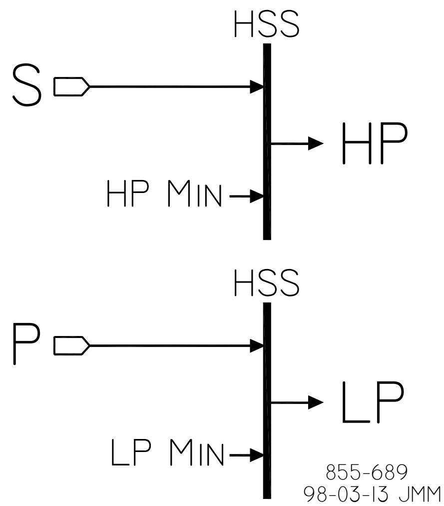


Figure 5-16. Decoupled HP&LP Mode

Speed vs. EXT/ADM Priority

Because an extraction and/or admission turbine has two control valves, it can only control two parameters at a time. If the turbine reaches an operating limit, (a valve fully open or closed) the result is only one free moving valve to control with, thus the 5009 Control can only control one parameter. It is at these turbine limits that the control can be programmed to select which one parameter will remain in control, or has priority over the other parameter.

If speed priority is programmed, the 5009 Control will only control turbine speed/ load (Cascade PID process if used, or the Auxiliary PID process if used) when the turbine reaches an operating limit. When programmed for speed priority, the control will maintain speed/load (or cascade or auxiliary) and sacrifice ext/adm control. With this configuration the Ext/Adm PID is forced to lose control of its process until system conditions change to allow the turbine to move off of an operating limit.

In Compressor Units—
In a compressor (mechanical drive) unit speed must be controlled at all times, so in most cases speed should always be set to have priority.

LP max priority:
Once the steam Map brings the LP valve to 100%, it might be necessary to limit the load of the engine, in order to avoid overheating. In this case, if Extraction at LP max priority is selected, Extraction/decoupling pressure will have priority over the speed controller. When limit is reached, the Speed reference cannot be raised (even via cascade) as long as this limit is reached.

If not selected, the extraction/admission will be Limited when this limit is reached.

If the 5009 Control is programmed for speed priority only it will be in speed priority at all times. If it is programmed for speed priority with ext/adm priority on the LP maximum limiter, speed priority will be selected at all times except when the LP valve is at its maximum (open) position.

In Generator Units—

Auto Priority Enabling—If the 5009 Control is programmed for ext/adm priority, speed priority is initially selected and ext/adm priority can be programmed for automatic or manual selection. When auto switch E/A priority is true, the unit is programmed for automatic selection of ext/adm priority and will automatically switch priorities when the following conditions are met:

- LP valve limiter at 0.00 position (programmed for Ext/adm only control)
- Ext/adm Control is enabled (programmed for Adm or Ext/adm control)
- Ext/adm PID is In-Control

Speed priority is selected if any of the above conditions are false.

Manual Priority Enabling—The 5009 Control only accepts an ext/adm priority select command if all related permissives are met (see enable permissive list above). An ext/adm priority enable command may be given from the 5009 CCT Interface, a contact input, or through Modbus. The last command given from any of these three sources dictates the priority selected.

When a contact input is programmed to function as an ext/adm priority enable command a closed state represents ext/adm priority and an open state represents speed priority. This contact can either be open or closed when a 5009 Control 'Start' command is given. If the contact is open it must be closed to select ext/adm priority. If the contact is closed when a trip condition is cleared, it must be opened and re-closed to select ext/adm priority. The priority selected can be viewed on the CCT Interface or through Modbus. Optionally a relay can be programmed to externally indicate the priority selected.

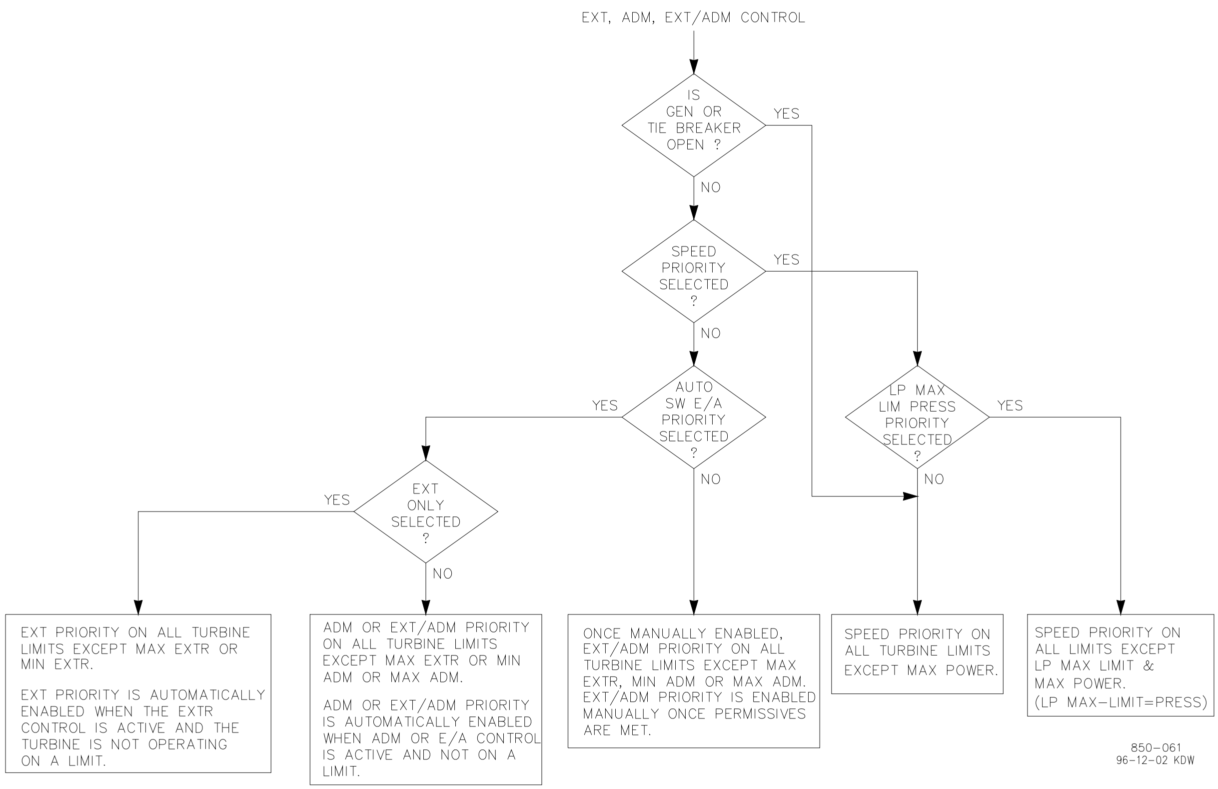


Figure 5-17. Priority Flow Diagram

Auxiliary Control

The Auxiliary PID can be used to limit or control generator power, plant import/ export power, turbine inlet pressure, turbine exhaust pressure, pump/compressor discharge pressure, or any other auxiliary parameters directly related to turbine speed/load. The auxiliary input is a 4 - 20 mA current signal. The PID control amplifier compares this input signal with the auxiliary setpoint to produce a control output to the digital LSS (low-signal select) bus. The LSS bus sends the lowest signal to the Ratio/Limiter circuitry.

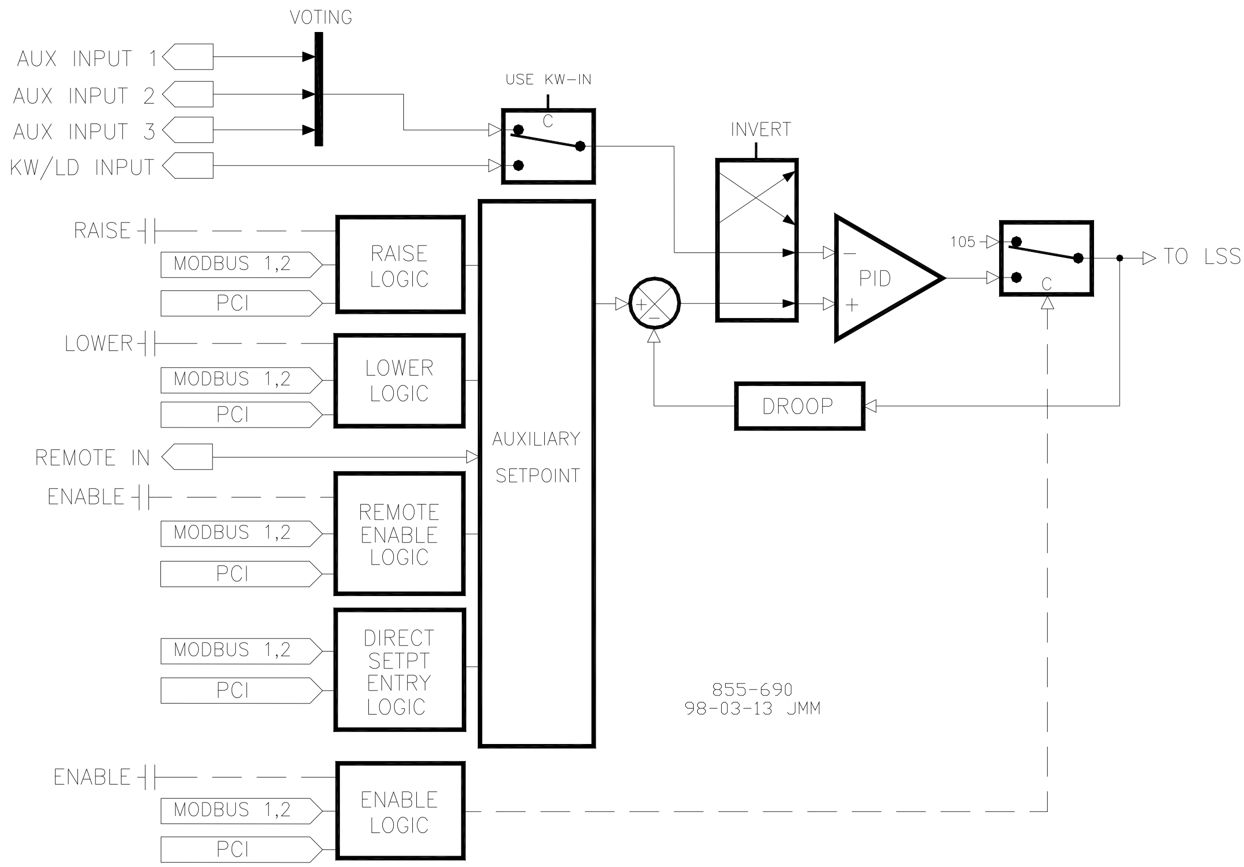


Figure 5-18. Auxiliary Control Overview

Auxiliary as a Limiter

When configured as a limiter, the Auxiliary PID is low signal selected (LSS) with the Speed PID, allowing it to limit on any process including or directly related to turbine speed/load.

When auxiliary is configured to act as a limiter, the Auxiliary PID will 'limit' the LSS bus when the input reaches the setpoint. For any programmed Ratio/Limiter mode of operation the Auxiliary Control is always capable of limiting turbine load.

The auxiliary setpoint initializes to the programmed setpoint initial value on a power-up-reset. This setpoint may be adjusted at any time and will remain at the last setting (running or shutdown), provided a power-up-reset did not occur. Depending on configuration and system conditions, the Auxiliary Limiter may be in one of the following states:

- **Auxiliary is Enabled**—Auxiliary has been enabled but the generator and utility tie breaker permissives have not been met (generator applications only).
- **Auxiliary Active / Not Limiting**—Auxiliary is configured as a limiter but is not limiting the LSS bus.
- **Auxiliary Active With Remote Setpoint**—Auxiliary is not in control of the LSS bus and the remote auxiliary input is in command of the setpoint.

- **Auxiliary Control With Remote Setpoint**—Auxiliary is limiting the LSS bus and the remote auxiliary analog input is in command of the setpoint.
- **Auxiliary is Inhibited**—Auxiliary cannot be enabled because the input signal has failed.

For generator applications, Auxiliary Control can be configured to be disabled when the generator and/or utility tie breakers are open.

If the unit is not configured for a generator application, the utility tie and generator breaker inputs do not affect Auxiliary Limiter status, and the limiter will be active at all times.

Auxiliary as a Controller

When configured as a controller, the Auxiliary PID may be enabled and disabled on command. When Auxiliary Control is enabled it instantly takes full control of the LSS bus and the Speed PID is switched to a tracking mode. When Auxiliary Control is disabled the Speed PID instantly takes control of the LSS bus. When the Auxiliary PID is disabled, its setpoint tracks the Auxiliary PID's process signal.

The Speed PID will only track the Auxiliary PID LSS bus signal up to 100% speed/load. Thus if turbine speed/load reaches 100%, the Speed PID will protect the unit by limiting unit speed/load to less than or equal to 100%. Depending on the configuration and system conditions, the Auxiliary PID may be in one of the following states:

- **Auxiliary is Disabled**—Auxiliary is disabled and will have no effect on the LSS bus.
- **Auxiliary is Enabled**—Auxiliary has been enabled but the generator and utility tie breaker permissives have not been met (generator applications only).
- **Auxiliary Active / Not in Control**—Auxiliary has been enabled, permissives met, but is not in control of the LSS bus.
- **Auxiliary Active With Remote Setpoint**—Auxiliary has been enabled but is not in control of the LSS bus and the remote auxiliary input is controlling the setpoint.
- **Auxiliary in Control**—Auxiliary is in control of the LSS bus.
- **Auxiliary Control With Remote Setpoint**—Auxiliary is in control of the LSS bus and the remote auxiliary analog input is in control of the setpoint.
- **Auxiliary is Inhibited**—Auxiliary cannot be enabled because the input signal is failed, the 5009 Control System is in Frequency Control, controlled shutdown is selected, unit is shut down or Auxiliary Control is not programmed.

For generator applications, Auxiliary Control can be configured to be disabled when the generator and/or utility tie breakers are open. If the unit is not configured for a generator application, the utility tie and generator breaker inputs do not affect Auxiliary Control status, and the controller will be active at all times (capable of being enabled).

Auxiliary Control may be enabled from the 5009 CCT Interface, remote contacts, or Modbus communications. The last command given from any of these three sources dictates the state of Auxiliary Control. If an external auxiliary enable contact is programmed, disable is selected when the contact is open and enable is selected when it is closed. The contact can be either open or closed when a trip condition is cleared. If the contact is open, it must be closed to enable. If the contact is closed, it must be opened and re-closed to enable.

When configured as enable/disable controller, the Auxiliary Control will automatically be disabled upon a shutdown condition. Auxiliary Control will be disabled and inhibited when the 5009 Control is in Frequency Control. If the auxiliary milliamp input signal is out of range (below 2 mA or above 22 mA) an alarm will occur and Auxiliary Control will be inhibited until the input signal is corrected and the alarm is cleared. Optionally the unit can be programmed to issue a shutdown on a loss of the auxiliary input signal.

Auxiliary Dynamics
The Auxiliary PID control uses its own set of dynamic settings. These values are programmable and may be tuned at any time from the CCT Interface or via Modbus. Refer to the PID Dynamic Adjustments section in Chapter 6.

Generator Load Limiter/Control
On generator applications, the Auxiliary PID may be programmed to use the KW/ unit load input signal instead of the auxiliary input signal for limiting or control. This is the same input signal (KW/unit load input) used by the Speed PID for KW droop. This configuration allows the Auxiliary PID to limit or control generator power.

Auxiliary Droop
When sharing control of a parameter with another external controller, the Auxiliary Control amplifier can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the LSS bus (control valve position). By including this second parameter into the control loop, the Auxiliary PID becomes satisfied, and does not fight with the other external controller over the shared parameter. The droop % fed back to the Auxiliary PID is equal to the following defaulted settings:

LSS BUS OUTPUT % x ‘AUX DROOP %’ x ‘MAX AUX SETPOINT’ x 0.0001
Example: 25% x 5% x 600 psi (4137 kPa) x 0.0001 = 7.5 psi (51.71 kPa)

The ‘AUXILIARY DROOP %’ and ‘MAXIMUM AUX SETPOINT’ values are set in the Program Mode and the ‘LSS bus output %’ is determined by the auxiliary demand.

Invert Auxiliary Input
Depending on the control action required, the Auxiliary PID’s input signal can be inverted. An example of this control action would be when the Auxiliary PID is configured to control turbine inlet steam pressure. To increase turbine inlet steam pressure, HP control valve position must be decreased.

Auxiliary Setpoint
The auxiliary setpoint can be adjusted from the 5009 CCT Interface, external contacts, Modbus, or through a 4–20 mA analog input. A specific setting can also be directly entered from the 5009 CCT Interface or through Modbus.

The auxiliary setpoint range must be defined in the Program Mode. Program settings minimum auxiliary setpoint and maximum auxiliary setpoint define the range of the auxiliary setpoint and control.

When a raise or lower auxiliary setpoint command is issued, the setpoint moves at the auxiliary setpoint rate. If an auxiliary raise or lower command is selected for longer than three seconds, the auxiliary setpoint will move at the fast rate which is three times the auxiliary setpoint rate. The auxiliary setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

A specific setpoint may also be directly entered from the 5009 CCT Interface or through Modbus communications. When this is performed, the setpoint will ramp at the auxiliary setpoint rate.

Refer to Volume 3 of this manual for further information on Service mode and On-Line tunables. All pertinent Auxiliary Control parameters are available through Modbus.

Remote Auxiliary Setpoint
The Remote Auxiliary Setpoint (RAS) can be positioned through an analog signal. This allows the RAS to be positioned remotely by a process control or distributed plant control system.

The RAS range is determined by the analog input’s 4 mA and 20 mA settings. The remote auxiliary setpoint range is tunable in the Service Mode.

When enabled, the remote setpoint may not match the auxiliary setpoint. In this case, the auxiliary setpoint will ramp to the remote setpoint's value at the auxiliary setpoint rate (as set in the Service Mode). Once in control, the fastest the remote setpoint will adjust the auxiliary setpoint is limited to the remote auxiliary setpoint maximum rate. If the remote auxiliary setpoint maximum rate was set at 10 and the remote auxiliary setpoint analog input instantly moved from 0 units to 1000 units, the auxiliary setpoint will move to 1000 units at 10 units/s.

If the milliamp signal to the remote setpoint input is out of range (below 2 mA or above 22 mA) an alarm will occur and the remote setpoint function will be inhibited until the input signal is corrected and the alarm is cleared. Depending on configuration and system conditions, the remote auxiliary setpoint may be in one of the following states (5009 CCT Interface screen messages):

- **Disabled**—The remote setpoint function is disabled and will have no effect on the auxiliary setpoint.
- **Enabled**—The remote setpoint has been enabled, but permissives are not met.
- **Active**—The remote setpoint has been enabled, permissives are met, but the Auxiliary PID is not in control of the LSS bus.
- **In Control**—The remote setpoint is in control of the auxiliary setpoint, and the Auxiliary PID is in control of the LSS bus.
- **Inhibited**—Remote setpoint cannot be enabled. The remote setpoint input signal is failed, Auxiliary Control is inhibited, or the remote auxiliary setpoint is not programmed.

Remote Auxiliary Enable Logic

The RAS input may be enabled from the 5009 CCT Interface, contact input, or Modbus communications. The last command given from any of these three sources dictates the state of the RAS input. A contact input can be programmed to enable and disable the RAS input/function. When this contact is open the RAS is disabled, and when it is closed the RAS is enabled. The contact can be either open or closed when a trip condition is cleared. If the contact is open, it must be closed to enable the RAS input. If the contact is closed, it must be opened and re-closed to enable the RAS input.

When the Auxiliary PID is programmed to function as a limiter, the RAS may be enabled at any time when the 5009 Control is in the Start Mode.

When the Auxiliary PID is programmed as a controller (enabled/disabled), there are three different options for enabling RAS and Auxiliary Control as follows:

- One remote enable contact input is programmed.
- Both remote auxiliary enable and auxiliary enable are programmed.
- No enable commands are programmed.

When only the remote enable contact input command is programmed, selecting 'Enable' will enable both the RAS and Auxiliary Control. This configuration allows both functions to be enabled with one command.

When both RAS and Auxiliary Control are programmed, each function is enabled by its respective command selection. If RAS enable is selected, only the RAS will be enabled. If Auxiliary Control enable is selected, only Auxiliary Control will be enabled. If RAS disable is selected, only the RAS will be disabled. If Auxiliary Control disable is selected, both RAS and Auxiliary Control will be disabled. However, if before the Auxiliary PID was able to be 'In-control' an Auxiliary Control disable command is given, only Auxiliary Control will be disabled.

If no external contact input is programmed for the enable commands, Auxiliary Control and RAS must be enabled from either the CCT Interface or from Modbus. Since the CCT Interface and Modbus provide RAS enable and Auxiliary Control enable commands, they will operate in the same manner as both enables programmed.

Refer to Volume 3 of this manual for information on related Service Mode tunables. All pertinent Remote Auxiliary Setpoint parameters are available through Modbus.

Cascade Control

The Cascade Control can be configured to control any system process, related to or affected by turbine speed or load. Typically, this controller is configured and used as a turbine inlet or exhaust pressure controller.

Cascade Control is a PID controller that is cascaded with the Speed PID. The Cascade PID compares a 4–20 mA process signal with an internal setpoint to directly position the speed setpoint, thus changing turbine speed or load until the process signal and setpoint match. By cascading these two PIDs, a bumpless transfer between the two controlling parameters can be performed.

When enabled, the Cascade PID can move the speed setpoint at a variable rate up to the maximum speed setpoint rate, which is set in the Program Mode.

Since cascade is a secondary speed setting function, the Speed PID must be in control of the 5009 Control's LSS bus for cascade to take control. When the 5009 Control is configured for a generator application, both the utility tie and generator breakers must be closed before the Cascade PID can begin controlling a process. When not configured for a generator application, turbine speed must be greater than the minimum governor setpoint before the Cascade PID can begin controlling.

Cascade Control may be enabled and disabled from the 5009 CCT Interface, a contact input, or Modbus. The last command given from any of these three sources dictates the Cascade PID's control state.

If a contact input is programmed to function as a cascade enable contact, Cascade Control is disabled when the contact is open and enabled when it is closed. This contact can either be open or closed when a trip condition is cleared. If the contact is open it must be closed to enable Cascade Control. If the contact is closed it must be opened and re-closed to enable Cascade Control.

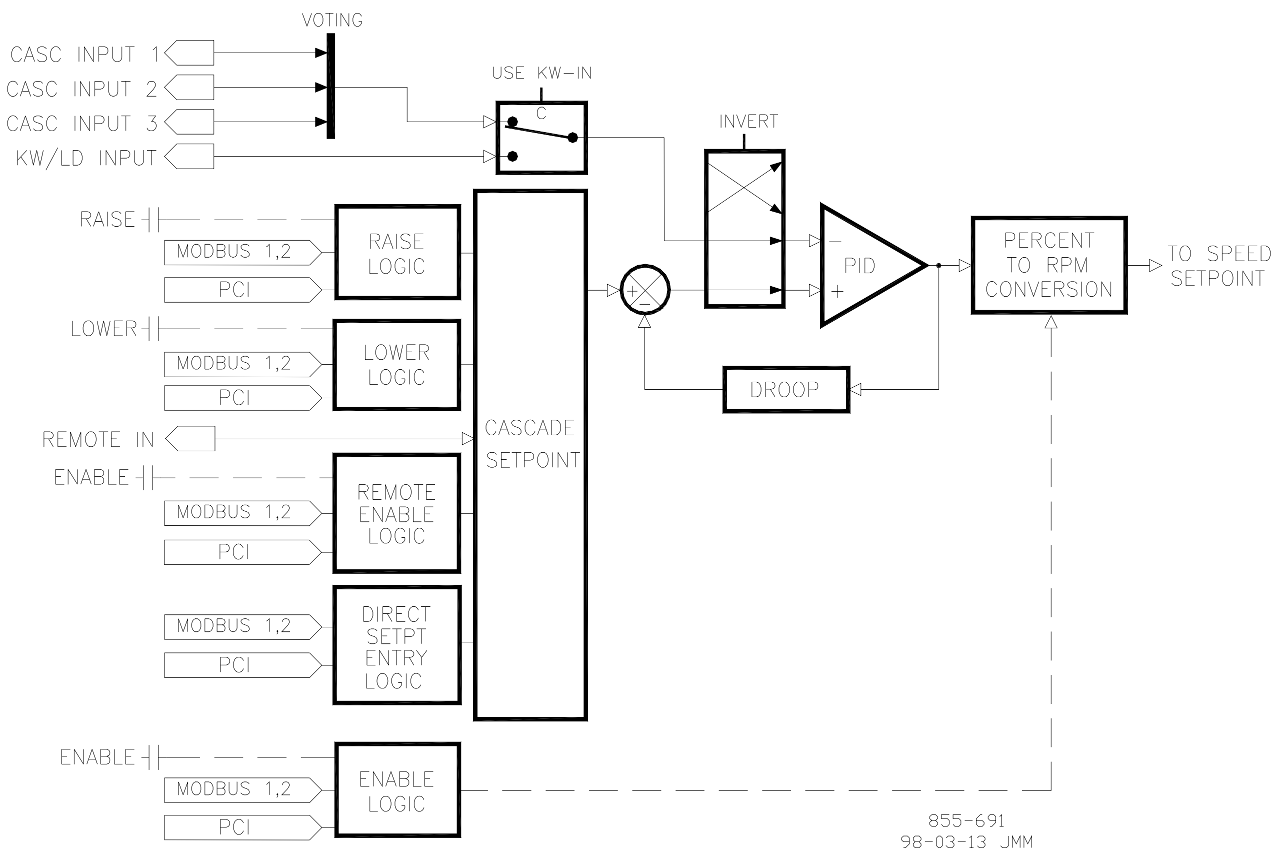


Figure 5-19. Cascade Functional Diagram

Cascade Control Status Messages

- **Cascade is Disabled**—Cascade Control is not enabled and will have no effect.
- **Cascade is Enabled**—Cascade has been enabled but is not active or in control. Permissives have not been met (speed < minimum governor or generator or tie breaker open).
- **Cascade Active / Not in Speed Control**—Cascade has been enabled but the Speed PID is not in control of the LSS bus (either auxiliary or valve limiter is in control).
- **Cascade Is In Control**—Cascade is in control of the LSS bus.
- **Cascade Active With Remote Setpoint**—Cascade has been enabled and the Remote Cascade Setpoint is in control of the setpoint, but the Speed PID is not in control of the LSS bus.
- **Cascade Control With Remote Setpoint**—Cascade is in control of the LSS bus and the Remote Cascade Setpoint is positioning the Cascade Setpoint.
- **Cascade is Inhibited**—Cascade cannot be enabled. The cascade input signal has failed, a controlled stop is selected, the unit is shut down, or Cascade Control is not programmed.

Cascade Control is automatically disabled on a shutdown condition and must be re-enabled after a successful system start-up. Cascade Control is disabled if the remote speed setpoint is enabled or auxiliary is configured as enable/disable is enabled. If another parameter on the LSS bus takes control of governor valve position from the Speed PID, Cascade Control will stay active and begin controlling again when the Speed PID is the lowest parameter on the LSS bus.

All pertinent Cascade Control parameters are available through Modbus.

Cascade Dynamics

The Cascade PID control uses its own set of dynamic settings. These values are programmable and may be tuned at any time from CCT Interface or Modbus. Refer to the PID Dynamic Adjustments section in Chapter 6.

Cascade Setpoint

The cascade setpoint can be adjusted from the 5009 CCT Interface, external contacts, Modbus, or through a 4–20 mA analog input. A specific setting can also be directly entered from the 5009 CCT Interface or through Modbus.

The cascade setpoint range must be defined in the Program Mode.

When a raise or lower cascade setpoint command is issued, the setpoint moves at the cascade setpoint rate. If a cascade raise or lower command is selected for longer than three seconds, the cascade setpoint will move at the fast rate which is three times the cascade setpoint rate. The cascade setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

A specific setpoint may also be directly entered from the 5009 CCT Interface or through Modbus communications. When this is performed, the setpoint will ramp at the cascade setpoint rate (set in the Service Mode).

Refer to Volume 3 of this manual for information on which programmed settings are tunable through the 5009 Control’s Service Mode. Service Mode values can be tuned/adjusted while the 5009 Control is shutdown or in the Start Mode.

Cascade Setpoint Tracking

To allow a bumpless transfer from turbine speed/load control to Cascade Control, the Cascade PID can be programmed to track its controlling process input when disabled. When this tracking feature is programmed, the Cascade PID will not cause a turbine speed or load correction to be performed. After the Cascade Control is enabled, its setpoint can be moved as required to another setting.

Cascade Setpoint with No Tracking

If the Cascade Control is programmed not to use the setpoint tracking feature, the setpoint will remain at its last setting (running or shutdown). When the 5009 Control is powered-up the setpoint is reset to the setpoint initial value. When Cascade Control is enabled and the sensed process signal does not match setpoint, the Cascade Control will ramp turbine speed/load to match the two signals at a controlled "not-matched" rate (set in the Service Mode).

If cascade is the controlling parameter and one of the permissives is lost or cascade is disabled, the speed setpoint will remain at the last setting until another parameter adjusts it.

Cascade Droop

When sharing control of a parameter with another external controller, the Cascade PID can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the Cascade PID's output. If cascade droop is used, the cascade input signal will not match the cascade setpoint when in control. The difference will depend on the amount (%) of droop programmed and the output of the Cascade PID. The droop value fed back to the Cascade PID is equal to the following defaulted settings:

PID OUTPUT % x 'CASCADE DROOP %' x 'MAX CASC SETPOINT' x 0.0001
Example: 25% x 5% x 600 psi (4137 kPa) x 0.0001 = 7.5 psi (51.71 kPa)

The 'CASCADE DROOP %' and 'MAXIMUM CASC SETPOINT' values are set in the Program Mode and the 'PID output %' is determined by the cascade demand.

Refer to Volume 3 of this manual for information on related Service Mode tunables.

Invert Cascade

Depending on the control action required, the cascade input signal can be inverted. If a decrease in HP governor valve position is required to increase the cascade process signal, program the cascade input to be inverted. As an example, when the Cascade PID is configured to control turbine inlet steam pressure the cascade input must be inverted. To increase turbine inlet steam pressure, the HP control valve position must be decreased.

Remote Cascade Setpoint

The cascade setpoint can be positioned through an analog signal. This allows the cascade setpoint to be positioned remotely by a process control or distributed plant control system.

The Remote Cascade Setpoint (RCS) range is set in the Program Mode and can be tuned in the Service Mode.

The RCS input may be enabled from the 5009 CCT Interface, contact input, or Modbus communications. The last command given from any of these three sources dictates enable/disable.

If the milliamp signal to the RCS is out of range (below 2 mA or above 22 mA) an alarm will occur and the RCS will be inhibited until the input signal is corrected and the alarm is cleared.

Remote Cascade Setpoint Messages

Depending on configuration and system conditions, the RCS may be in one of the following states:

- **Disabled**—The RCS is not enabled and will have no effect on the cascade setpoint.
- **Enabled**—The RCS has been enabled but Cascade Control is not active. The breakers are not closed, speed < minimum governor, or cascade has not taken control.
- **Active**—The RCS has been enabled but cascade is not in control. Cascade has been enabled and the RCS is in control of the setpoint, but the Speed PID is not in control of the LSS bus.
- **In Control**—Cascade is in control of the LSS bus and the RCS is positioning the cascade setpoint.
- **Inhibited**—RCS cannot be enabled. The RCS is failed, cascade input signal is failed, a controlled stop is selected, the unit is shut down, or the RCS is not programmed.

When enabled, the RCS may not match the cascade setpoint. In this case, the cascade setpoint will ramp to the RCS at the programmed cascade setpoint rate setting (set in the Service Mode). Once in control, the RCS will adjust the cascade setpoint at the programmed remote cascade maximum rate. If the remote cascade maximum rate was set at 10 and the RCS analog input instantly moved from 0 units to 1000 units, the RCS will move to 1000 units (at 10 units/s).

Remote Cascade Enable Logic

There are three different options for enabling RCS and Cascade Control as follows:

- Only a remote cascade enable contact input is programmed.
- Both remote cascade and cascade enable contact inputs are programmed.
- No enable commands are programmed.

When only a remote enable contact input command is programmed, closing the remote cascade enable contact input will enable both Cascade Control and remote Cascade Control. This configuration allows both functions to be enabled with one command.

When both remote cascade enable and Cascade Control enable commands are programmed, each function is enabled by their respective command selection. If remote cascade enable is selected, only the RCS will be enabled. If Cascade Control enable is selected, only Cascade Control will be enabled. If remote cascade disable is selected, only the RCS will be disabled. If Cascade Control disable is selected, both Remote Cascade Control and Cascade Control will be disabled. However, if before the Cascade PID was able to be ‘In-control’, a cascade disabled command is given, only Cascade Control will be disabled.

If no external contact input is programmed for the enable commands, Cascade Control and remote Cascade Control must be enabled from either the CCT Interface or from Modbus. Since the CCT Interface and Modbus provide both Remote cascade enable and Cascade Control enable commands, they will operate in the same manner as when both enables are programmed.

Refer to Volume 3 of this manual for information on related Service Mode tunables. All pertinent Remote Cascade Control parameters are available through Modbus.

Seal GAS PID Control

The Seal Gas PID Controller can be configured to control any system process. Typically this controller is configured and used to control seal gas pressure, but it can also be used for any type of PID loop.

The Seal Gas PID compares a 4–20 mA process signal with an internal setpoint to directly position an analog output configured as Seal Gas PID output.

The Seal Gas PID loop can be put in manual and automatic mode via dedicated contact input, Modbus commands or CCT tool.

If a contact input is programmed to function as a seal PID manual contact, Seal PID Control is in automatic mode when the contact is opened and in manual mode when it is closed. If a command is send via Modbus/CCT to put this PID in automatic mode, then the contact input must be closed/opened to bring back the manual mode.

Seal Gas PID Manual Mode

When the Seal gas PID is in manual mode, it is possible to manipulate its output directly using Raise/Lower demand commands. These commands are available via Modbus, CCT, or contact inputs configured as Seal Gas PID raise/lower demand.

In CCT software, it is possible to inhibit the manual mode selection. In this case, Seal Gas PID will be in manual mode only when its process value is lost. Should a Process value be lost, it is also possible to configure the 5009 to ramp the PID output up or down automatically.

Seal Gas PID Dynamics
The Seal Gas PID control uses its own set of dynamic settings. These values are programmable and may be tuned at any time from CCT Interface only.

Seal Gas Set Point
The Seal Gas setpoint can be adjusted from the 5009 CCT Interface, external contacts, or Modbus. The cascade setpoint range must be defined in the Program Mode.

When a raise or lower Seal PID setpoint command is issued, the setpoint moves at the Seal PID setpoint rate. If a Seal PID Set Point raise or lower command is selected for longer than three seconds, the setpoint will move at the fast rate, which is three times the cascade setpoint rate. The Seal Gas setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

Refer to Volume 3 of this manual for information on which programmed settings are tunable through the 5009 Control's Service Mode. Service Mode values can be tuned/adjusted while the 5009 Control is shutdown or in the Start Mode.

Seal GAS PID Droop
When sharing control of a parameter with another external controller, the Seal Gas PID can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the PID's output. If droop is used, the input signal will not match the setpoint when in control. The difference will depend on the amount (%) of droop programmed and the output of the PID. The droop value fed back to the PID is equal to the following defaulted settings:

PID OUTPUT % x 'SEAL DROOP %' x –0.01

Refer to Volume 3 of this manual for information on related Service Mode tunables.

Seal Gas PID Deadband
When a small fluctuation of PV must not affect the PID output, it is possible to set a deadband (% of seal PV range).

Invert Seal Gas PID
Depending on the control action required, the Seal Gas PV input signal can be inverted. If a decrease of PID output is required to increase the cascade process signal, program the input to be inverted.

Emergency Shutdown

When an Emergency Shutdown condition occurs, both valve output signals are stepped to zero percent demand, and the Shutdown Relay(s) de-energize(s). There is also an option to drive both valve output signals to zero milliamps in addition to setting the demand to zero.

First Out Indication—This control can be configured to accept up to ten individual External Trip inputs (contact inputs) to cause an Emergency Shutdown. By wiring trip conditions directly into the control, instead of a trip string, the control can pass a trip signal directly to its output relay (to trip the T&T valve), and also indicate the first trip condition sensed. All trip conditions are individually indicated through the control's CCT program and Modbus communications. Alternatively, up to ten alarm inputs (contact inputs) can also be configured to indicate system related alarm conditions.

The first trip indication is latched-in and can be viewed at any time after a trip. This control saves the last 20 trip conditions and displays them through the CCT alarm History page. Once latched-in, the first trip indication cannot be reset. This allows an operator to confirm what the trip condition was hours or days after the unit has been reset and restarted.

The "Trip Output Relay" (Relay #1) is intended to be connected to the unit trip-oil header solenoid, or trip logic. When another relay output is programmed as a Trip Relay, the respective relay will function like the dedicated Trip Relay (normally energized and de-energizes on a shutdown) to indicate the position of the dedicated Shutdown Relay.

The “Shutdown Condition” relay may be programmed to indicate a shutdown condition on a remote panel or to a plant DCS. The Shutdown Indication relay is normally de-energized. This relay will energize upon any shutdown condition and stay energized until all trips have been cleared. The reset clears trip function has no effect on the programmable Shutdown Indication Relay.

Controlled Shutdown

The Controlled Shutdown function is used to stop the turbine in a controlled manner, as opposed to an Emergency Trip. The controlled shutdown cannot be used if a manual start is selected and no idle speeds are programmed. When a STOP command (controlled shutdown) is issued the following sequence is performed:

1. All control PIDs and functions are disabled except the Speed and Extraction PIDs.
2. The Extraction Control is disabled (the LP limiter is raised to maximum for extraction applications).
3. If used, the ratio/limiter map is transferred to the coupled HP & LP map.
4. The speed setpoint is ramped to zero at a controlled rate.
5. The HP valve limiter is ramped to zero at a controlled rate.
6. The 5009 Control executes a Shutdown (Shutdown Relay de-energizes, actuator drive currents = zero).
7. A ‘Shutdown - Controlled Stop’ message is indicated.

IMPORTANT	**On generator applications, the 5009 Control does not automatically issue a generator breaker open command upon reaching a minimum load level.**

A controlled shutdown can be initiated or aborted from the 5009 CCT Interface, a programmed contact input, or either Modbus communication link. Verification of the shutdown request is not required if a controlled shutdown command is initiated by a programmed contact input or Modbus communication link.

The controlled shutdown sequence can be aborted at any time. Refer to Chapter 6 (Start/Operation) of this manual.

Closing a contact programmed for the Controlled Shutdown Sequence will initiate the shutdown. The shutdown sequence will go through the same steps described above, with the exception that verification of the shutdown sequence is not needed. Opening the contact will stop the sequence. Stopping and continuing the Modbus-initiated Controlled Shutdown Sequence requires two commands: one to start the sequence and the other to stop it.

See Volume 3 for all 5009 Control Service panel messages.

Synchronize Control Clock

This control has the capability of synchronizing its internal Real-Time clock to a network controlled system clock. This allows the control’s Real-Time clock to be aligned with a plant Distributed Control System, up to once a day. By synchronizing both systems’ Real-Time clocks, alarm data can be compared on a time basis between the two systems without the confusion of time offsets.

The “Synchronize Control Clock” function is selected by configuring a TCP/IP address of the network time sync clock in the CPU by using the AppManager service tool program. Refer to Volume 3 for details in configuring this feature.

Local / Remote Function

The 5009 Control's Local / Remote function allows an operator at the turbine skid or 5009 Control to disable any remote command (from a remote Control Room) that may put the system in a unsafe condition. This function is typically used during a system start-up or shutdown to allow only one operator to manipulate the 5009 control modes and settings.

The Local/Remote function must first be programmed before a Local or Remote mode can be selected by an operator (refer to Service Mode, CPU Comm Page, Port 3 'CPU' Settings). If this function is not programmed all contact inputs and Modbus commands (when Modbus is programmed) are active at all times. If the Local/Remote function is programmed, Local and Remote modes can be selected through a programmed contact input or the CCT program.

When Local mode is selected, the 5009 Control is defaulted to be operable from CCT program only. This mode disables all Modbus commands from any and all devices, it does not (as in previous designs), disable any hardwired signals.

The 5009 Control is defaulted to only allow control operation though its CCT Interface when the Local Mode is selected. If desired, this defaulted functionality can be changed through the 5009 Control's Service Mode. The 5009 Control can be modified to also allow operation through contacts inputs, and/or Modbus port #1, and/or Modbus port #2 when the Local mode is selected.

When the Remote Mode is selected, the 5009 Control can be operated through its CCT Interface, contact inputs, and/or all Modbus. When using a contact input to select between Local and Remote Modes, a closed contact input selects the Remote Mode and an open contact input selects the Local Mode.

All pertinent Local/Remote control parameters are available through the Modbus links.

Relays

The 5009 Control has twelve relay outputs available. Two of these relays are dedicated: one for a system shutdown/trip command from the 5009 Control and one for alarm indication. The other ten relays can be programmed for a variety of indications and system functions.

The dedicated Alarm Relay is normally de-energized. This relay will energize upon an alarm condition and stay energized until the alarm condition is cleared. Optionally this relay can be configured through the 5009 Control's Service Mode, to toggle on and off repeatedly when an alarm condition has occurred. With this configuration if a reset command is given and the alarm condition still exists, the relay will stop toggling and stay energized. The relay will start toggling again, upon a new alarm condition. This option can be used to inform the operator when another alarm condition has occurred.

Any of the other ten relays can be programmed to function as a level switch or a mode or condition indication. When programmed as a level switch the relay will change state when the selected parameter reaches the programmed level (energizes when value is higher the programmed level). Relays not used as level switches can be programmed to indicate control states. Except for the Trip relay, when programmed to indicate a state or event, relay will energize upon the respective state or event occurring.

The present relay state (energized / de-energized) and relay configuration is indicated through both Modbus communication links and through the CCT Interface.

Relay Clarifications

The Shutdown Condition relay may be programmed to indicate a shutdown condition on a remote panel or to a plant DCS. The Shutdown Indication relay is normally de-energized. This relay will energize upon any shutdown condition and stay energized until all trips have been cleared. The 'RESET CLEARS TRIP' function has no effect on the programmable Shutdown Indication relay.

When programmed as a Trip Relay, the respective relay will function like the dedicated Shutdown Relay (normally energized or normally de-energized, depending upon configuration) to indicate the position of the dedicated Shutdown Relay.

The Alarm Condition relay may be programmed to indicate an alarm condition on a remote control panel or to a DCS. The Alarm Indication relay is normally de- energized. This relay will energize upon any alarm condition and stay energized until all alarms have been cleared. If the 'BLINK ALARMS' option is 'YES' the programmable Alarm Condition relay will toggle on and off repeatedly when an alarm condition has occurred. With this configuration if a reset command is given and the alarm condition still exists, the relay will stop toggling and stay energized.

The Overspeed Test Enabled relay will energize when an Overspeed Test is performed. This relay toggles on and off when turbine speed is above the turbine Overspeed trip setting.

An Underspeed Switch function can be programmed to indicate a turbine underspeed or overpower condition. If the Underspeed option is configured, once turbine speed reaches a level above the minimum governor speed setting, then decreases 100 rpm below the minimum governor speed setting, the respective relay energizes (indicating an underspeed condition). The 'Underspeed setting' is adjustable through the Service Mode, under the 'Speed Values' header.

When the Sync Enabled function is programmed, the assigned relay energizes when a synchronize command is given. After the unit generator or utility tie breaker is closed this function becomes disabled and the relay de-energizes. The 5009 Control's Synchronization function can be used to synchronize across a generator breaker or utility tie breaker.

When the Sync / Load Shr Enabled function is programmed, the assigned relay energizes when a synchronize command is given or Load Sharing is selected. When both the generator and utility tie breaker inputs are closed (Load Sharing not selected) this function becomes disabled and the relay de-energizes.

When the Modbus function is programmed, the assigned relay energizes when the respective Modbus "Turn On Relay X" is issued, then de-energizes when the respective Modbus "Turn Off Relay X" is issued. This feature allows a 5009 Control relay to be driven directly from Modbus to control a system related function (synchronizing).

Chapter 6.
5009 Control System Operation

Introduction

The 5009 Control System is designed to interface with the provided CCT program, discrete and analog input/outputs, and devices communicating via Modbus (OpView). The 5009 Control's operating architecture is divided into two sections: Run Mode and Configure Mode. The Configure Mode is used to configure the 5009 Control for the specific application and set all operating parameters (Refer to Volume 3). The turbine must not be running to enter this mode as all outputs from the control will be disabled. The Run Mode is the normal turbine operation mode and is used to view operating parameters and run the turbine. A third mode called Service Mode is available while the turbine is running to allow access to control tuning, calibrations and other specific parameters. All operating parameters can be controlled from the CCT Interface program, Modbus commands (OpView), and/ or discrete and analog inputs to the 5009 Control.

⚠WARNING

Improperly calibrated devices can cause turbine damage and possible personnel injury or death. Before starting the turbine for the first time, and periodically thereafter, verify the calibration of all external input and output devices.

⚠WARNING

This manual does not contain instructions for the operation of the complete turbine system. For turbine or plant operating instructions, contact the plant-equipment manufacturer.

5009 System Power-up

The following procedure should be followed for the initial start up. Before power is applied, the control should be wired and installed as referenced in Volume 2. If at any time during this procedure the defined or expected result is not achieved, refer to Volume 2, and begin system troubleshooting.

1. Verify that the turbine is externally tripped (close the manual trip valve).

2. Verify that all modules are inserted firmly in the 5009 Control and that all cables connecting the modules to the FTMs are firmly in place.

3. Turn the power for one power supply on and verify that the power supply's green LED is the only power supply LED on.

4. Turn the power for second power supply on and verify that the power supply's green LED is the only power supply LED on.

5. The control will automatically perform Off-Line CPU diagnostics, start the application, synchronize each CPU and initialize the I/O. This may take up to 2 minutes to complete.

6. If the unit falls to initialize after this time - Momentarily press the RESET button (near the top of the module) on each Kernel CPU. This will re-initialize the control boot-up process.

When all CPUs have synchronized and completed their diagnostic tests, no red LEDs should be on, and the control will begin running the application program. The 5009 Control is now running. Before any Run Mode parameters or calibrations can be performed, it must be configured using the CCT Interface program described in Volume 3. Once site specific data has been configured into the control, the remaining operations functions can be performed.

Valve / Actuator Calibration & Test

Before initial operation or after a turbine overhaul where any actuator or valve travel may have been affected, the below Valve Calibration procedure should be followed to ensure that the 5009 Control is calibrated to both valves (HP & LP). The 5009 Control uses its actuator output currents to sense HP and LP valve positions. These valve positions are used by the 5009 Control to calculate internal turbine ratios and operating limits. Thus if the 5009 Control is not correctly calibrated to each control valve's actual travel, it will incorrectly calculate turbine operating limits. It is recommend that each valve be manually stroked after the 5009 Control's output has been calibrated to ensure that the 5009 Control and the actual valve position match as closely as possible.

After a valid program has been entered, the actuator and valve minimum and maximum positions can be adjusted and tested, if needed. Actuator and valve positions are determined by the drive current to the actuator. The maximum actuator current cannot be adjusted lower than the minimum actuator current (see Table 6-1 below). The minimum actuator current cannot be adjusted higher than the maximum actuator current. The driver current ranges are determined by the settings in the Configure Mode under Driver Configuration.

When adjusting or testing actuator and valve travel, verify that sufficient valve over travel at the minimum stop is achieved (1-2%). This ensures that each valve can fully close.

Table 6-1. Actuator Driver Limits

Driver Limits	20-160 mA Range	4–20 mA Range
Overcurrent	10% above maximum setting	10% above maximum setting
Under current	10% below minimum setting	10% below minimum setting
Max Output Current Range	8-196 mA	1.8-24 mA
Max Output Impedance	45 ohms	360 ohms
Min Stop Adjust Range	8-100 mA	1.8–12 mA
Max Stop Adjust Range	100-196 mA	12–24 mA

To ensure proper control to actuator resolution do not calibrate the span of the actuator output to be less than a range of 100 mA (for the 20-160 mA option) or 12 mA (for the 4–20 mA option). If necessary, the actuator to valve linkage may need to be adjusted to ensure proper 5009 to valve resolution.

The stroking option is only available when the 5009 Control is in a shutdown state. If the user has configured the unit to 'cut' the current to the actuator upon a Trip event (configured under the Turbine Protection page), then a reset will need to be issued after entering the CALMODE to stroke or calibrate the actuators of the 5009 Control. After enabling the stroke mode, there are options available to adjust the minimum and maximum stops and to manually stroke the output(s). The manual adjustment mode can be used to stroke the actuators and valves from 0 to 100% after the minimum and maximum positions have been adjusted. This allows both the actuator and valve to be tested for binding, play, resolution, linearity, and repeatability. The actuator and valve positions can be varied by using the CCT Interface program (Refer to Volume 3). Once calibrated, the user can stroke the valve via Modbus commands (OpView—see Volume 4). As a safety precaution, if turbine speed ever exceeds 400 rpm, the Valve/Actuator Calibration and Test will be automatically disabled and actuator currents taken to zero.

Valve Calibration / Stroking Procedure

⚠WARNING

Before calibrating or testing, the unit must be tripped and the steam supply removed. This is to ensure that opening the control valve(s) will not allow steam into the turbine. Internal Overspeed sensing and its relay are disabled during this process. Overspeeding the turbine may cause damage to turbine and can cause severe injury or death to personnel. STEAM TO THE TURBINE MUST BE SHUT OFF BY OTHER MEANS DURING THIS PROCESS.

1. The turbine must be shut down, and the 5009FT control should be placed into calibration mode via the CCT.

2. Execute a system RESET command.

3. **CCT**: Unlock the Start mode's security logic. If the Start mode's Security logic is locked the calibration settings can only be monitored. If the Start mode's Security logic is unlocked, the calibration settings can be monitored and changed. Refer to the Security Button section in Volume 3 for instructions on locking and unlocking the Start Mode's Security logic.

4. For Proportional actuators: In the CCT program, go to the Proportional Actuator Channel # 1 or 2 while in Service or Configure mode.

   To Manually Stroke the Valve: At the bottom of the page are handles to enter a manual demand, and a rate at which the valve will move to this demand when entered.

   To Calibrate the Valve: Click the Enter Channel Calibration button, use the toggle buttons to hold the valve at minimum or maximum, and adjust the corresponding currents in the Actuator Current Range section. Visually verify that the valve is at 0 or 100% during this process.

5. For Integrating Actuators: Go to the Integrating Actuator Channel #1 or 2 while in Service or Configure mode.

   To Manually Stroke the Valve: Use the FORCE Act # Output section to enter a demand position and a rate at which to move to this value.

   To Calibrate the Valve: Follow the step-by-step sequence from top to bottom. During this process, a calibration demand can be entered at the end of the routine to set up each of the redundant channels.

Turbine Start

Refer to the turbine manufacturer's operating procedures for complete information on turbine start up, and Chapter 5 of this manual for a step by step procedure, depending on the start mode selected. The following is a typical start- up procedure:

⚠WARNING

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

1. Initiate a control reset to clear all alarms and trips and (if an extraction unit) increase the LP Valve Limiter to 100%. If the 5009's 'RESET CLEARS TRIP' setting is programmed "YES" in the CCT Interface program, the 5009's shutdown relay will reset or energize upon initiating a control reset after a shutdown. If the 'RESET CLEARS TRIP' setting is programmed "NO", the 5009's shutdown relay will reset or energize upon initiating a control reset ONLY after all trip conditions are cleared.

2. Initiate a START command to begin the configured start-up mode. If a semiautomatic start mode is configured, the valve limiter must be manually increased to open the control valve.
    - A 'Start Perm Not Closed' alarm will be issued if the application is using a Start Permissive contact input and this contact input was not closed when the START command was issued.

3. After the selected start-up mode has been performed, the turbine will operate at the minimum or idle speed setting. The 5009's speed setpoint will move to minimum governor speed unless an idle speed is programmed. The Idle/Rated Manual R/L ONLY or Auto Start Sequence functions must be programmed for the turbine to control at idle speed. When using the Auto Start Sequence, the 5009 will begin stepping through its sequence once it gets to low idle. This sequence may be stopped, rated speed may be selected (if using idle/rated) or the operator may vary turbine speed with raise/lower speed commands through the external switches, or Modbus communication links (CCT, OpView).

The 'Start' and 'Reset' commands can be selected from contact input closures (if programmed), the CCT program, or Modbus communications links. In addition, the following indications are available through the Modbus links: Speed Setpt Moving to Min, Start Permissive Closed, Start Permissive Not Closed, etc.

Speed Screens

The CCT interface program and the OpView have Turbine Start screens that allow the user access to all of the parameters necessary to start the turbine. For a detailed description of the screens and access to those parameters, refer to Volume 3 for the CCT and Volume 4 for the OpView. If configured, contact inputs will perform the same functions in the 5009 Control.

Idle/Rated Start

For details on the idle/rated start-up procedure, refer to Chapter 4 of this manual. Upon receiving the Start command, the speed setpoint is instantly set to the actual turbine's speed. If at zero speed, the speed setpoint will ramp to the idle setting. To increase the speed to the programmed 'Rated Setpt' setting, select the Rated Speed command. A Rated command can be issued by closing the Idle/Rated contact (if programmed) or selecting a Go To Rated command from a Modbus communications link. When the speed setpoint is moving to the Rated Setpoint setting it can be stopped at any point that is not within a critical speed avoidance band by issuing a Speed Setpt Raise or Lower command. This can be done by closing a Speed Raise/Lower contact input or selecting Speed Raise or Lower from a Modbus communications link. The speed setpoint will again ramp to the Rated Speed setting if the Rated command is re-issued.

The speed setpoint will ramp to the Idle Speed setting upon start-up. However, the Idle Speed setting can be re-selected, when conditions allow, by opening the Idle/ Rated contact (if programmed), or selecting Go To Idle from a Modbus communications link.

Another feature of the Idle/Rated function is the 'Ramp to Rated' option which allows the speed setpoint to only move to the Rated Speed setting; Idle is not selectable. This feature is configurable in the Service Mode of the CCT only. When this feature is used with the Idle/Rated contact input, closing the contact results in the speed setpoint ramping to the Rated Speed setting, opening the contact stops the speed setpoint ramp - rather than selecting 'Go To Idle'. To continue ramping to the Rated Speed setting, re-close the contact or select 'Go To Rated' from a Modbus communications link.

The following indications are available through the Modbus links: Ramping to Idle, At Idle, Turbine in Critical Speed Band, Ramping to Rated, and At Rated. In addition to these indications, the Idle Speed Setpoint and Rated Speed Setpoint analog values are also available.

Auto Start Sequence

When a START command is issued the Speed setpoint is instantly set to the turbine's actual speed and the sequence will continue from this point. This sequence is automatic, however the sequence can be halted. Halting the Auto Start Sequence can be performed by opening the Halt/Continue contact (if programmed), selecting Halt from a Modbus communications link, or selecting Speed Setpoint Raise or Lower command. To provide feedback, a relay can be programmed to indicate the Auto Start Sequence is halted. The Sequence can be restarted again by closing the Halt/Continue contact, or selecting Continue from a Modbus communications link.

The following Auto Start Sequence indications are available through the Modbus links:

- Setpt Moving to Min
- Setpt at Low Idle
- Ramping to High Idle
- Setpt at High Idle
- Turbine in Critical Speed Band
- Ramping to Rated
- At Rated.

In addition to these indications, the following are also available providing comprehensive sequence information.

- Low Idle Speed Setpoint
- Low Idle Delay Time
- Time Remaining at Low Idle
- Low Idle to High Idle Rate
- High Idle Speed Setpoint
- High Idle Delay Time
- Time Remaining at High Idle
- High Idle to Rated Rate
- Rated Speed Setpoint
- Run Time (hours)
- Hours Since Trip analog values

Dynamic Adjustments

The Speed, Cascade, Extr/Adm, and Auxiliary control loops utilize PID controllers. The response of each control loop can be adjusted for optimum response, however it is important to understand what a PID controller is and the effect each controller adjustment has on the controller response. Proportional gain, integral gain (stability), and SDR (speed derivative ratio) are the adjustable and interacting parameters used to match the response of the control loop with the response of the system. They correspond to the P (proportional), I (integral), and D (derivative) terms, and are displayed by the 5009 Control as follows:

P = Proportional gain (%)
I = Integral gain (%)
D = Derivative (determined by DR and I)

Proportional Control

Proportional response is directly proportional to a process change. Analogy: Setting hand throttle to keep constant speed on a straight and level highway. Proportional control (using the same analogy) results in a certain speed as long as the car is not subjected to any load change such as a hill. If a throttle is set to any particular setting, the speed of the car will remain constant as long as the car remains straight and level. If the car goes up a hill, it will slow down. Of course, going down a hill the car would gain speed.

Integral Control

Integral compensates for process and setpoint load changes. Analogy: Cruise control maintains constant speed regardless of hills. Integral, sometimes called "reset", provides additional action to the original proportional response as long as the process variable remains away from the setpoint. Integral is a function of the magnitude and duration of the deviation. In this analogy the reset response would keep the car speed constant regardless of the terrain.

Derivative

Derivative provides a temporary over-correction to compensate for long transfer lags and reduce stabilization time on process upsets (momentary disturbances). Analogy: Accelerating into high speed lane with merging traffic. Derivative, sometimes called "preact" or "rate", is very difficult to draw an accurate analogy to, because the action takes place only when the process changes and is directly related to the speed at which the process changes. Merging into high speed traffic of a freeway from an "on" ramp is no easy task and requires accelerated correction (temporary overcorrection) in both increasing and decreasing directions. The application of brakes to fall behind the car in the first continuous lane or passing gear to get ahead of the car in the first continuous lane is derivative action.

Proportional Response

The amount of controller change is directly related to the process change and the Proportional Gain setting on the controller; Controller output change is Proportional to the process change. If there is no process change, there is no change in output from the controller (or valve change) regardless of the deviation. This results in an undesired offset between the original desired setpoint and the resulting drop in the Control Point.

Proportional Gain (Effect of Settings)

Figure 6-1 shows the effect of Proportional gain settings on control. Starting at the top of the graph a load change is introduced. With a small Proportional gain (meaning a large process change is required to produce full valve travel), stability is good but offset is very high. With a moderate gain setting (higher number setting) stability is still good - offset is still fairly high. With a high setting, offset is considerably smaller but the stability is poor. The 0.25 ratio affects a minimum area whereby the offset is reduced to a minimum while stability is in a decaying manner at 0.25% ratio. The decay ratio used (0.25%) means that if the second cycle is 1/4 of the first cycle, then each succeeding cycle will be 1/4 of the preceding cycle until the cycle is not visible.

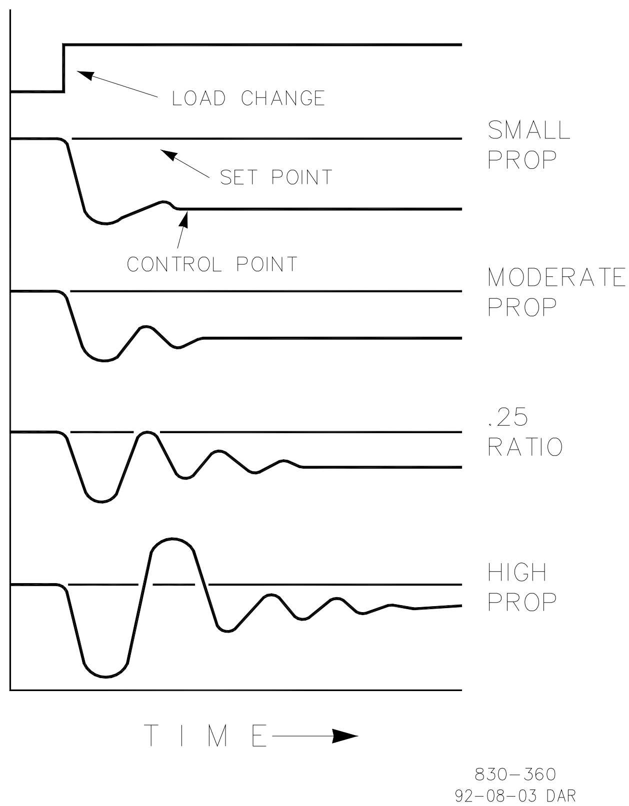


Figure 6-1. Proportional Gain Setting Effects

Since Proportional gain is adjusted to produce the proper stability of a process, continually increasing its effect will not correct offset conditions. The amount of stability and offset is directly related to the setting of the Proportional setting. Stability is of course also affected by the stability of the process. In essence, the amount of output from the controller due to the Proportional setting is from the error. If there is no error, then there is no Proportional effect.

Integral Response

Integral Gain as stated in the Woodward controls is repeats per minute (or Reset Rate). Therefore, a high amount of Integral gain (high number) would result in a large amount of Reset action. Conversely, a low Integral gain (low number) would result in a slower reset action.

Integral response is provided to eliminate the offset that resulted from straight Proportional control. Figure 6-2 shows how the controller action is Proportional to the measurement change, but as we saw earlier, this results in offset. The Integral (or Reset) action is a function of both time and magnitude of the deviation. As long as an offset condition (due to load changes) exists, Integral action is taking place.

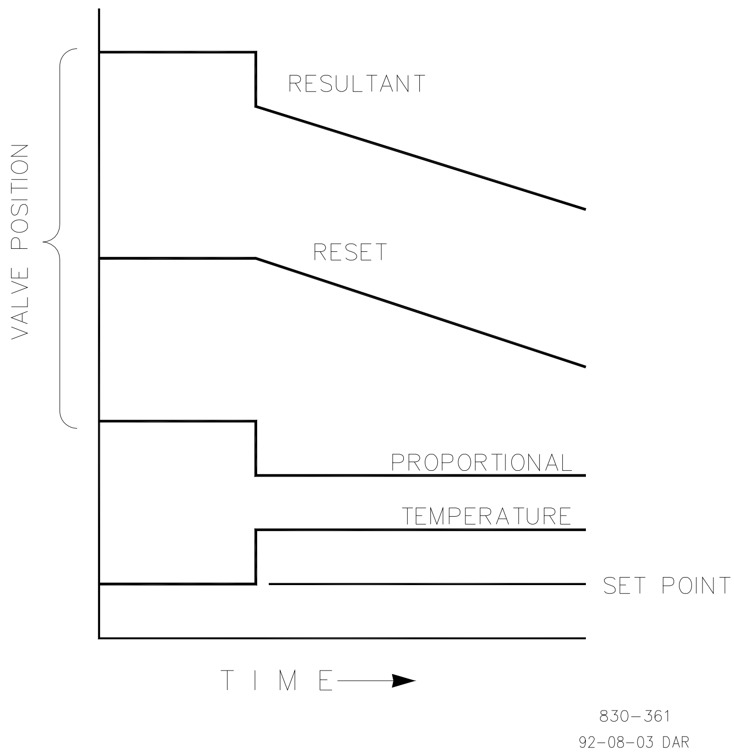


Figure 6-2. Open Loop Proportional and Integral Response

The amount of Integral action is a function of four things:

- The magnitude of the deviation.
- The duration of the deviation.
- The Proportional gain setting.
- The Integral setting.

In this Open Loop figure (5-2), the Integral response is shown increasing due to the offset condition existing between the temperature and the setpoint. The resultant action is the top curve showing the step Proportional response that ends as soon as the measurement stops changing. Then the Integral (or reset) action is added to the Proportional action in an amount equal to the Integral of the deviation. In other words, Reset action continues (in either or both directions) as long as there is a difference (deviation) between the setpoint and the process measurement. In this case, the deviation will never be eliminated (or even reduced) because the system is in Open Loop.

Proportional + Integral (Closed Loop)

Figure 6-3 shows the closed loop effects of integral action. The bottom curve displays the load change. The next curve up shows the setpoint and the measured variable, temperature. With the load change the temperature droops or deviates from the setpoint. The next highest curve is the Proportional action and follows the measured variable proportionately. The Integral curve adds to the Proportional curve resulting in a different valve position, thereby returning the process to the Setpoint.

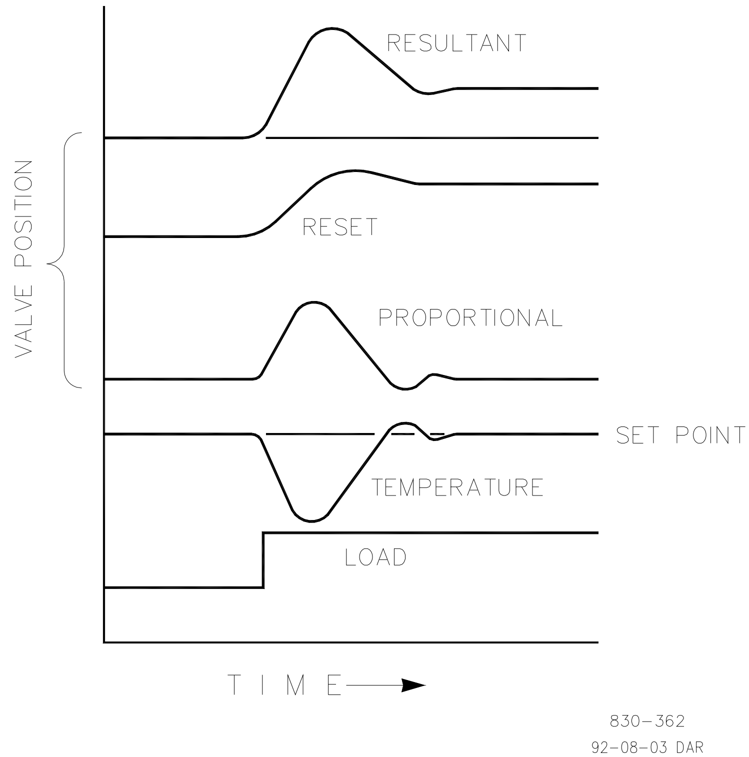


Figure 6-3. Closed Loop Proportional and Integral Response

In Closed Loop, however (as opposed to Open Loop), as the measurement decays toward the setpoint, the Proportional action is taking place proportionally to the measurement change, and the Integral action is decaying proportionately to the magnitude and duration of the deviation until the measurement reaches the setpoint at which time the Integral action is zero.

Integral (Effects of Settings)

Figure 6-4 shows the effect of fast or slow Integral action. For a given load change an offset results with Proportional response only. Since recovery time (for a given load change) is important, the Integral setting should remove the offset in minimum time without adding additional cycling. If two cycles are added, then too much Integral Gain has been added. Of course, Proportional only must first establish the 1/4 decay ratio. If increased cycling occurs, the Integral must be turned off or the controller switched to "manual" if allowed to go too far. Ideally, the process should not continue to cycle after the setpoint has been reached as in the second curve from the bottom.

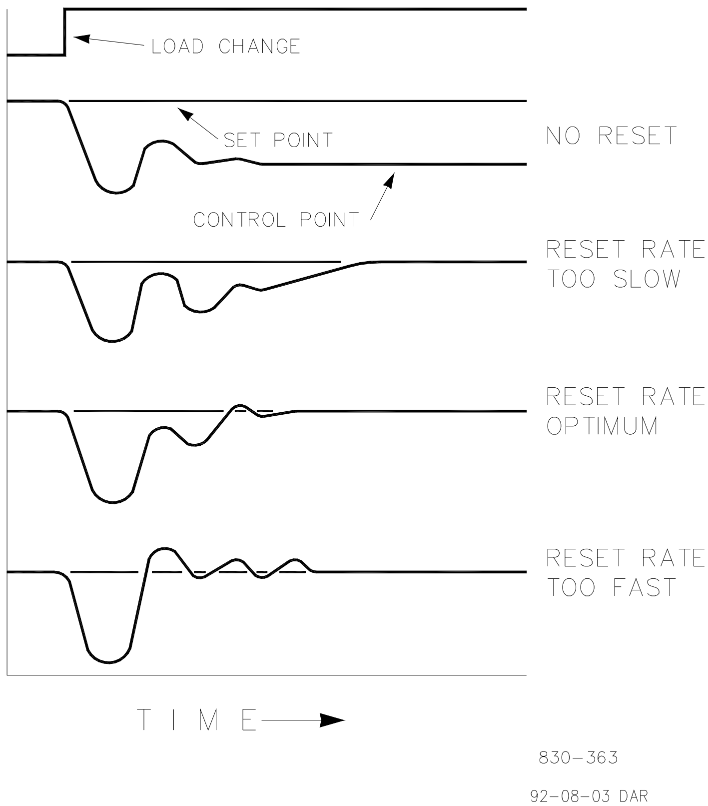


Figure 6-4. Integral Gain (Reset) Setting Responses

Derivative Response

In a process control loop the Derivative action is directly related to how fast the process changes (rate of change). If the process change is slow then the Derivative action is proportional to that rate of change. Derivative acts by advancing the Proportional action. Derivative acts at the start of the process change, when the process changes its rate and when the process stops its change.

Derivative action takes place at only three times:

- When the process starts to change.
- When the rate of change takes place in the process.
- When the process stops changing.

The net result of Derivative action is to oppose any process change and combined with Proportional action to reduce stabilization time in returning the process to the setpoint after an upset. Derivative will not remove offset. Woodward Derivative is split into two working domains, Input dominant and Feedback dominant. The allowed values for DR range from 0.01 to 100. The most common derivative is Feedback dominant, it is automatically selected with an Derivative Ratio (DR) from 1 to 100. The Input dominant domain is selected with DR values between 0.01 to 1.

Feedback dominant applies the derivative action to the integrator feedback term of the PID equation and is more stable than input dominant derivative. This will not take corrective action as early and it will be less noise sensitive. When tuning the derivative, the DR will be established in the 1 to 100 range because it is easier to tune and more forgiving of excessive values. Most PIDs will employ feedback dominant derivative.

Input dominant derivative applies the DR term before the integrator term of the PID equation. When the DR is less than 1, the derivative is input dominant and reacts very quickly to process upsets. This function is very adapted for PIDs that control the load parameter, such as load shaft turbine speed. Since the input dominant derivative is so sensitive, it should be reserved only for applications without high frequency noise.

Except for input dominant and feedback dominant features, the reciprocal of one domain will appear identical in the other domain. As an example, consider an DR of 5.0, the reciprocal being 1/5. That means that an DR of 5.0 will appear the same as DR of 0.200. The difference in response between these values of 5.0 and 0.2 is in the dominance feature. If in doubt about the type of derivative to use, then set up for feedback dominant, 1 < DR < 100.

Proportional + Derivative (Closed Loop)

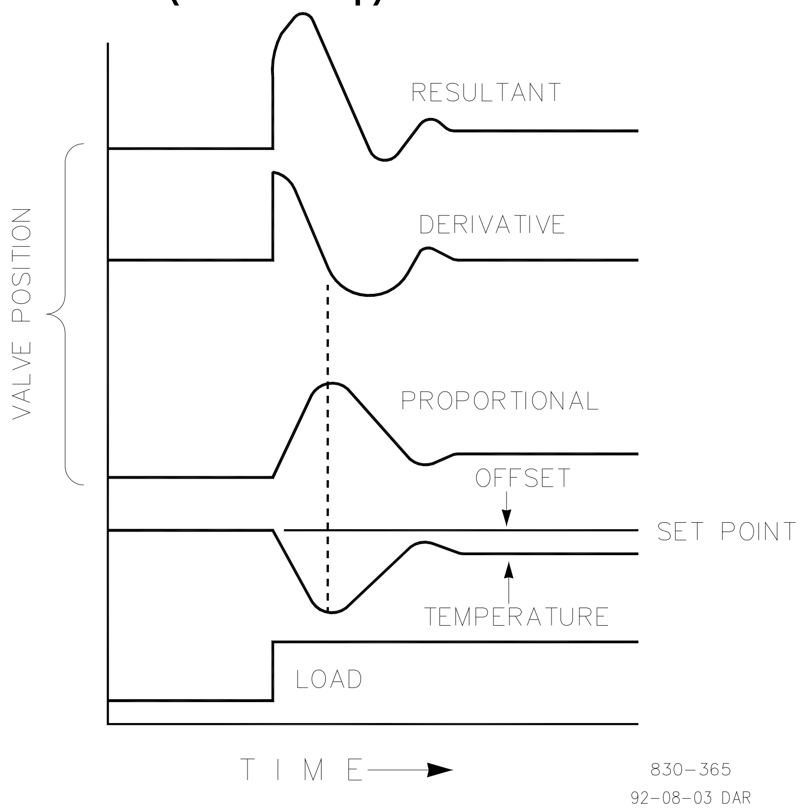


Figure 6-5. Closed Loop Proportional and Derivative Action

Figure 6-5 shows how Derivative acts to oppose a change in process in either direction. The dashed line shows the Derivative action going through zero to oppose the process deviation traveling toward zero. Notice offset still exists between the desired setpoint and the drooped control point that resulted from the load change. The top curve is the resultant controller output, Proportional plus Derivative. If an upset (momentary) had occurred rather than a load change, there would be no offset.

Derivative (Effects of Settings)

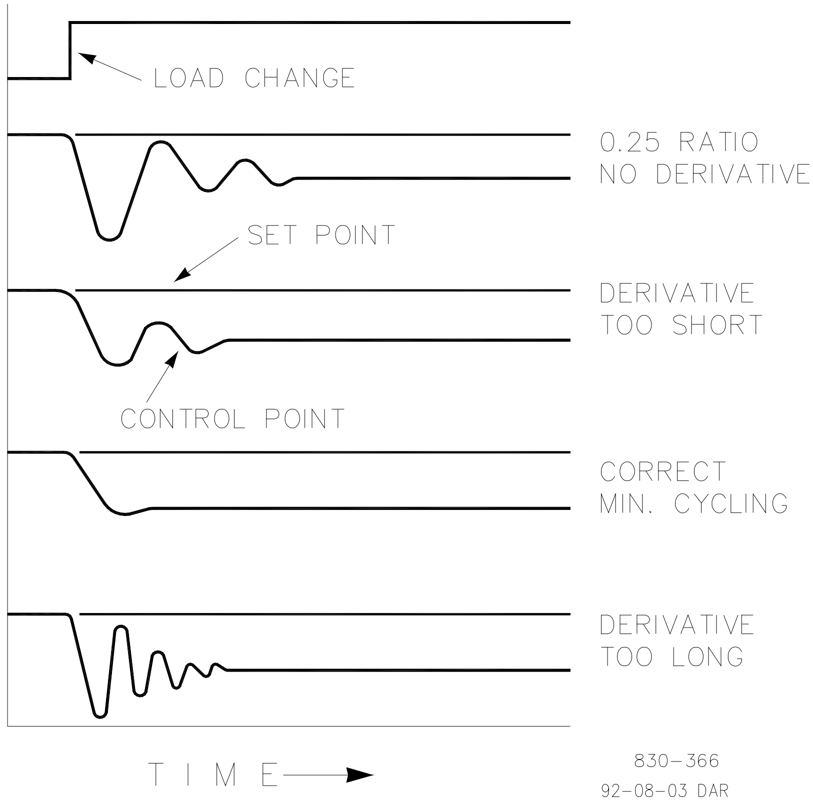


Figure 6-6. Derivative Setting Effects

Figure 6-6 shows the effect of different Derivative settings. The curves are relative since it depends on what type of control is desired in order to properly adjust Derivative time. For example, if minimum cycling is desired (as is shown here) then Derivative is added to the 1/4 decay cycle provided by Proportional until more than one cycle is removed and of course the 1/4 decay is destroyed. However, in most cases it is desirable to retain the 1/4 decay cycle, in which case Derivative is added to the point of removing only one cycle from the 1/4 decay ratio then the gain is increased until the 1/4 decay ratio is restored. In all the above curves, you will note offset exists since offset can only be eliminated by the addition of Integral (or Reset).

Proportional + Integral + Derivative (Closed Loop)

Figure 6-7 shows the relationship of valve position to the interaction of the PID modes of control whenever a load change takes place in closed loop. As the temperature drops due to the load change, the proportional action moves the control valve proportionately to the measurement (temperature) change. The integral gain/reset adds to the proportional action as a result of the magnitude and time (duration) of the deviation. And the derivative temporarily over-corrects based on the speed at which the measurement moves in any direction. The resultant curve (at the top) shows a similar over-correction (in this case), but in addition the valve will stay at the new position required to keep the measurement at the setpoint.

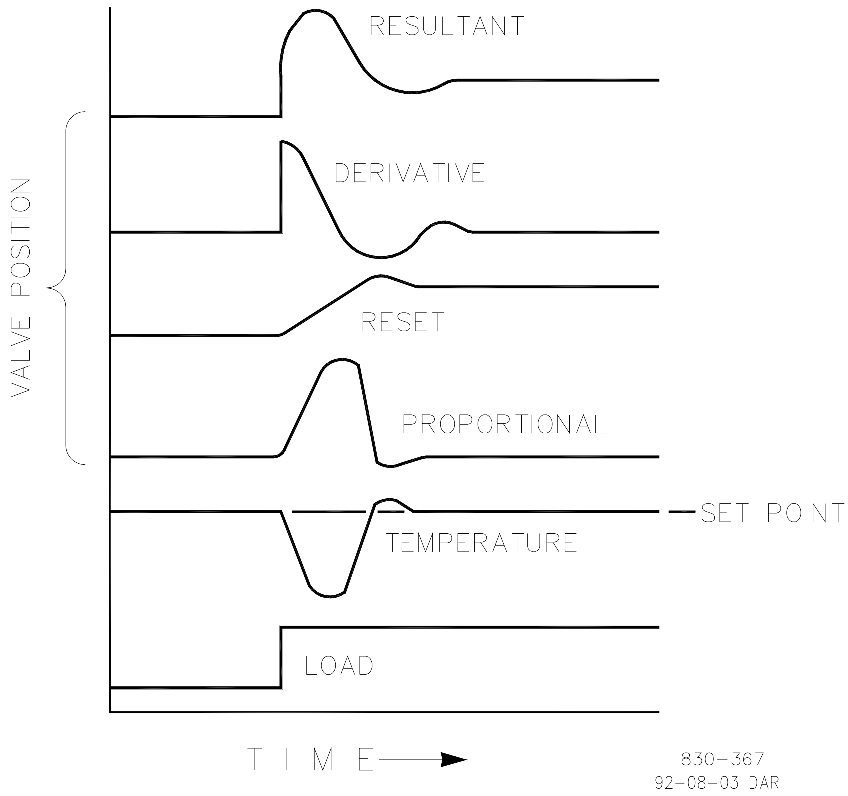


Figure 6-7. Closed Loop Proportional, Integral and Derivative Action

In summary, Derivative provides a temporary over-correction to compensate for long transfer lags and reduce stabilization time on process upsets (momentary disturbances).

> **NOTICE**
>
> **Do not use if high frequency noise is normally in the measured variable or the main lag is dead time. After Proportional is set to 1/4 decay ratio and Derivative is adjusted to remove one cycle as well as decreasing the 1/4 decay ratio, then the Proportional gain can be increased to restore the 1/4 decay ratio.**

Adding Derivative

The value of the Derivative Ratio (DR) term can range from 0.01 to 100. In order to simplify adjustment of the dynamics of the 5009 Control, adjusting the integral gain value sets both the I and D terms of the PID controller. The DR term establishes the degree of effect the integral gain value has on the “D” term, and changes the configuration of a controller from input rate sensitive (input dominant) to feedback rate sensitive (feedback dominant) and vice versa. Another possible use of the DR adjustment is to reconfigure the controller from a PID to a PI controller. This is done by adjusting the DR term to its upper or lower limits, depending on whether an input or feedback dominant controller is desired.

- A DR setting of 1 to 100 selects feedback dominant mode.
- A DR setting of .01 to 1 selects input dominant mode.
- A DR setting of .01 or 100 selects a PI only controller, input and feedback dominant respectively.

The change from one of these configurations to the other may have no effect during normal operation, however, it can cause great differences in response when the governor is coming into control. (at start-up, during a full load change, or during transfer of control from another channel).

An input dominant controller is more sensitive to the change-of-rate of its input (Speed, Cascade in or Auxiliary in), and can therefore prevent overshoot of the setpoint better than a feedback dominant controller. Although this response is desirable during a start-up or full load rejections, it can cause excessive control motions in some systems where a smooth transition response is desired.

A controller configured as feedback dominant is more sensitive to the change-of-rate of its feedback (LSS). A feedback dominant controller has the ability to limit the rate of change of the LSS bus when a controller is near its setpoint but is not yet in control. This limiting of the LSS bus allows a feedback dominant controller to make smoother control transitions than an input dominant controller.

General Field Tuning Guidelines

The quality of regulation obtained from an automatic control system depends upon the adjustments that are made to the various controller modes. Best results are obtained when the adjustment (tuning) is done systematically. Prior training and experience in controller tuning are desirable for effective application of this procedure.

This procedure will lead to controller settings which will provide:
- Process control without sustained cycling.
- Process recovery in a minimum time

Controller settings derived for given operating conditions are valid over a narrow range of load change. The settings made for one operating set of conditions may result in excessive cycling or highly damped response at some other operating condition. This procedure should be applied under the most difficult operating conditions to ensure conservative settings over the normal operating range. It is good practice to keep the average of the setpoint changes near the normal setpoint of the process to avoid excessive departure from normal operating level. After each setpoint change, allow sufficient time to observe the effect of the last adjustment (see Figure 6-8). It is wise to wait until approximately 90% of the change has been completed.

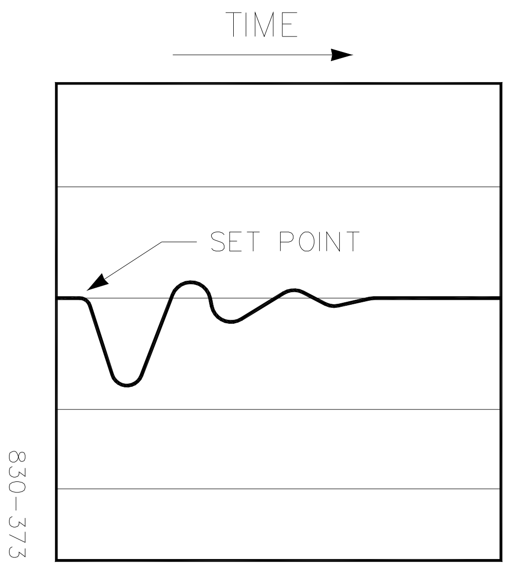


Figure 6-8. Typical Response to Load Change

Tuning Example

If the system is unstable, make sure the governor is the cause. This can be checked by closing the valve limiter until it has control of the actuator output. If the governor is causing the oscillation, time the oscillation cycle time. A rule-of- thumb is, if the system's oscillation cycle time is less than 1 second reduce the Proportional gain term. A rule-of-thumb is, if the system's oscillation cycle time is greater the 1 second reduce the Integral gain term (proportional gain may need to be increased also). On an initial start-up with the 5009 Control, all PID dynamic gain terms will require adjustment to match the respective PID's response to that of its control loop. There are multiple dynamic tuning methods available that can be used with the control's PIDs to assist in determining the gain terms that provide optimum control loop response times.

The following method can be used to achieve PID gain values that are close to optimum:

1. Increase Derivative Ratio (DR) to 100 (Service Mode adjustment)

2. Reduce integral gain to 0.01 (Start Mode adjustment)

3. Increase proportional gain until system just starts to oscillate (Start Mode).

   The optimum gain for this step is when the system just starts to oscillate and maintains a self-sustaining oscillation that does not increase or decrease in magnitude.

4. Record the control gain (Kc) and oscillation period (T) in seconds.

5. Set the dynamics as follows:
   For PI control: G=P(I/s + 1)
   Set: Proportional gain = 0.45*Kc
   Integral gain = 1.2/T
   Derivative ratio = 100

   For PID control: G=P(I/s + 1 + Ds)
   Set: Proportional gain = 0.60*Kc
   Integral gain = 2/T
   Deriv ratio = 8/(T*Integral Gain) for fdbk dominant
   = (T*Integral Gain)/8 for input dominant

This method of tuning will get the gain settings close, they can be fine-tuned from this point.

Speed, Casc, Aux, and Ext/Adm Dynamics Adjustments

Dynamic control values are programmed in the program mode and adjusted in the Run mode. They can be accessed by the CCT Interface program (refer to Volume 3) or the OpView (refer to Volume 4). The Speed, Cascade, Auxiliary, and Extr/ Adm controls are PID controllers. The response of each control loop can be adjusted by selecting the dynamics mode as described above. Proportional gain, integral gain (stability), and SDR (speed derivative ratio) are the adjustable and interacting parameters used to match the response of the control loop with the response of the system. They correspond to the P (proportional), I (integral), and D (derivative) terms, and are displayed by the 5009 Control as follows:

P = Proportional gain (%)
I = Integral gain (%)
D = Derivative (determined by SDR and I)

Tuning P & I Gains

Proportional gain must be tuned to best respond to a system transient or step change. If system response is not known, a typical starting value is 5%. If proportional gain is set too high, the control will appear to be overly sensitive, and may oscillate with a cycle time of less than 1 second.

Integral gain must be tuned for best control at steady state. If system response is not known a typical starting value is 0.5%. If the integral gain is set too high the control may hunt or oscillate at cycle times of over 1 second.

For best response the proportional gain and integral gain should be as high as possible. To obtain a faster transient response, slowly increase the proportional gain setting until the actuator or final driver output begins to oscillate or waver. Then adjust the integral gain as necessary to stabilize the output. If stability cannot be obtained with the integral gain adjustment, reduce the proportional gain setting.

A well tuned system, when given a step change, should slightly overshoot the control point then come into control.

A PID control loop's gain is a combination of all the gains in the loop. The loop's total gain includes actuator gain, valve gain, valve linkage gain, transducer gain, internal turbine gains, and the control's adjustable gains. If the accumulated mechanical gain (actuators, valves, valve linkage, etc.) is very high, the control's gain must be very low to be added to the system gain required for system stability.

In cases where a small change in the control's output results in a large speed or load change (high mechanical gain) it may not be possible to take the control's gains low enough to reach stable operation. In those cases the mechanical interface (actuator, linkage, servo, valve rack) design and/or calibration should be reviewed and changed to achieve a gain of one where 0-100% 5009 output corresponds to 0-100% valve travel.

Dual Dynamics (Speed/Load)

The Speed PID has two sets of dynamics, On-Line and Off-Line; each include Proportional Gain, Integral Gain, and Derivative Ratio (SDR) variables. There are three cases that determine when the dynamics switch between **On-Line and Off-Line**:

- A "Select On-Line Dynamics" contact input is programmed
- Unit is driving a generator
- Unit is driving a mechanical drive (not a generator)

If a contact input is programmed to "Select On-Line Dynamics", it has priority regardless of the driven device. When the contact is closed, On-Line dynamics are selected; when open, Off-Line dynamics are selected.

If the unit is driving a generator and no "Select On-Line Dynamics" contact input is programmed, the Speed Off-Line dynamics are used by the Speed PID when the generator or utility tie breaker contacts are open. The speed On-Line dynamics are used by the speed PID when the generator and utility tie breaker contacts are closed. If the Speed Dynamics Select contact is programmed, the generator and utility tie contacts do not affect the dynamics selection.

If the unit is not driving a generator and no "Select On-Line Dynamics" contact input is programmed, the Speed Off-Line dynamic settings are used when the turbine speed is below minimum governor speed. On-Line dynamics are used if the turbine speed is above minimum governor speed. If the Speed Dynamics Select contact is programmed, the turbine speed does not affect the dynamics selection. A relay can be programmed to indicate that the On-Line Dynamics mode is selected.

Cascade, Auxiliary, or Extr/Adm Droop

The Cascade, Auxiliary, and Extr/Adm controllers can be programmed to use droop for control loop stability. If the parameter being controlled (Casc, Aux, Extr/Adm) is also being controlled by another device (letdown station, boiler, or other turbine), droop is typically required for control loop stability. If required, no less than 5% droop is recommended for stable operation.

Tuning Derivative

The value of the Derivative Ratio (DR) term can range from 0.01 to 100. If unsure of the correct value, set the Speed control's DR term to 5% and the Aux, Cascade, & Extr/Adm controllers' DR terms to 100%. In order to simplify adjustment of the dynamics, adjusting the integral gain value sets both the I and D terms of the PID controller. The DR term establishes the degree of effect the integral gain value has on the "D" term, and changes the configuration of a controller from input rate sensitive (input dominant) to feedback rate sensitive (feedback dominant) and vice versa.

Another possible use of the DR adjustment is to reconfigure the controller from a PID to a PI controller. This is done by adjusting the DR term to its upper or lower limits, depending on whether an input or feedback dominant controller is desired.

- A DR setting of 1 to 100 selects feedback dominant mode.
- A DR setting of .01 to 1 selects input dominant mode.
- A DR setting of .0101 or 100 selects a PI only controller, input and feedback dominant respectively.

The change from one of these configurations to the other may have no effect during normal operation, however, it can cause great differences in response when the governor is coming into control. (at start-up, during a full load change, or during transfer of control from another channel).

An input dominant controller is more sensitive to the change-of-rate of its input (Speed, Cascade in, Auxiliary in, or Extr/Adm in), and can therefore prevent overshoot of the setpoint better than a feedback dominant controller. Although this response is desirable during a start-up or full load rejections, it can cause excessive control motions in some systems where a smooth transition response is desired.

A controller configured as feedback dominant is more sensitive to the change-of- rate of its feedback (LSS in the case of Speed and Aux). A feedback dominant controller has the ability to limit the rate of change of the LSS bus when a controller is near its setpoint but is not yet in control. This limiting of the LSS bus allows a feedback dominant controller to make smoother control transitions than an input dominant controller.

Overspeed Test Function

The Overspeed Test function allows an operator to increase turbine speed above its rated operating range to periodically test the turbine's electrical and/or mechanical overspeed protection logic and circuitry. This includes the control's internal overspeed trip logic and any external overspeed trip device's settings and logic.

There are two types of overspeed tests available depending on whether you are testing the control's trip logic or and external device. The Electrical (5009 Control) Overspeed Test tests the overspeed functionality of the 5009 control. The External Overspeed Test tests the functionality of any external overspeed device and overrides the 5009 Control's overspeed trip. An overspeed test is only allowed under the following conditions:

- The Speed PID must be in control.
- Auxiliary, Cascade, Ext/Adm, and Remote Speed Setpoint functions must be disabled.
- Generator breaker must be open, if configured for a generator application.
- Speed setpoint must be at the maximum governor speed setting.

Peak Speed Register—The control uses a Peak Speed register to save the highest speed sensed by the control. This register can only be reset through the control's CCT program or a "Clear Highest/Max Speed Hold Value" Modbus command. It is recommended that this register be reset before every overspeed test.

Testing Notes

- During an Overspeed Test, the speed setpoint can only be raised up to the "Overspeed Test Limit" setting. The control is defaulted to automatically trip if turbine speed reaches the Overspeed Test Limit setting (changeable via the CCT program's Service mode).
- If the speed remains above the maximum governing speed for more than 60 seconds (as defaulted in Service mode) without any adjustment to the speed set point, the speed set point will automatically ramp back down to the maximum governing speed. If the speed remains above the Overspeed trip (External Test) setting for more than 60 seconds (as defaulted in Service mode) without any adjustment to the speed set point, an emergency shutdown will be issued.
- The programmable "Overspeed Trip" indication relay only energizes when an Emergency shutdown is performed due to an Overspeed Trip condition.
- The programmable "Overspeed Test Enabled" indication relay will energize when an Overspeed Test is performed. This relay toggles on and off when turbine speed is above the turbine Overspeed trip setting.

Electrical (5009 Control) Overspeed Test Procedure—The Electrical (5009 Control) Overspeed Test tests the overspeed functionality of the 5009 Control. This test is performed via the CCT on the RUN mode – Turbine Start/Run page.

1. Reset the control's Peak-Speed register (found on the Service Mode turbine speed tuning page or found on the test page once the Test Mode is active).

2. Verify that the turbine is in speed control then raise the speed setpoint to the “maximum control speed” setting.

3. Initiate the Overspeed Test through the CCT program.

4. Raise the speed setpoint to the Electrical Overspeed Trip point. NOTE: If no raise or lower speed setpoint commands are received for any 60 second interval, the control will exit the overspeed test mode.

5. When the turbine reaches the overspeed trip point, the control will issue a shutdown and trip the turbine.

   Contact Input based test—If performing this test with the Overspeed Test contact input, the contact should remain closed during the test. Once this contact is opened, the test is disabled.

External (5009 Control) Overspeed Test Procedure—The External Overspeed Test tests the functionality of any external overspeed device and overrides the 5009 Control’s overspeed trip. The following procedure will test the turbine’s external overspeed trip(s).

1. Reset the control’s Peak-Speed register.

2. Verify that the turbine is in speed control then raise the speed setpoint to the “maximum control speed” setting.

3. Raise the speed to max governor speed (if GEN unit the breaker must be open).

4. Initiate the Overspeed Test through the CCT program or a contact input.

5. Raise the speed setpoint to the Electrical Overspeed Trip point.

6. When the turbine reaches the overspeed trip point, the control will issue an alarm, but WILL NOT shut down the turbine.

7. When the turbine reaches the external overspeed trip point, the external overspeed device (mechanical or electrical device) will trip the turbine.

8. If the turbine speed reaches the Maximum Overspeed Test setpoint without the External trip occurring, then the control will Trip the turbine.

There are two programmable relay options available to indicate overspeed status. One programmable relay option indicates an Overspeed Trip condition. The second relay option provides indication that a Overspeed Test is being performed. All pertinent overspeed test parameters are available through Modbus.

Operation Information

Once the control has been configured, calibrated, and dynamically adjusted, it is considered to be in the operational or Run mode. All of the operating parameters necessary to run the turbine are available from either the configurable contact and analog inputs or from a Modbus port. Input changes or Modbus communications are referred to as Start mode “commands”. The Modbus ports in the 5009FT Control can talk to the OpView touch screen workstation, and/or any external control system (DCS) capable of communicating via Modbus. For detailed information on how the CCT and OpView access the Run mode parameters, Refer to Volume 3 (CCT) and Volume 4 (OpView). For detailed information on how CCT configures the contact and analog input “commands” and tunes the analog inputs (Service Mode), refer to Volume 3.

IMPORTANT **In the event that more than one command is received (conflicting contact input and Modbus command) the last command received will be the command acted upon.**

Speed Control

The Speed controller cannot be disabled. When auxiliary and cascade control have been disabled, the speed PID will try to control the turbine at the speed setpoint, offset by the amount of droop configured into the speed loop. The Auxiliary controller and the Cascade controller will track the speed PID through the LSS bus in order to achieve a bumpless transfer if they are enabled. Control of the speed of the turbine is obtained by manipulating the speed setpoint, when the Speed controller is the controlling parameter.

During the initial start sequence, the 5009 Control ramps the speed setpoint up to the configured idle or minimum control settings. The rate at which the setpoint changes is configured in the CCT Interface program. Once the turbine is up to minimum control speed, the speed setpoint is adjusted through the RAISE SPEED and LOWER SPEED commands. Again, the rate of change is configurable through the CCT Interface program. If the RAISE or LOWER command is continually given for more than three seconds, the rate of change goes to the fast rate (configurable). The speed setpoint adjustment commands are available whenever the Auxiliary controller and the Cascade controller are both disabled.

If the Cascade controller is enabled, the cascade setpoint will have tracked the speed setpoint and will provide a bumpless transfer to cascade control. The speed setpoint will be adjusted by the cascade PID and at the point of transfer they will be the same. The Speed controller will still control the turbine, but the Cascade controller will now control the speed setpoint. Since the Cascade controller is based on some other parameter (not speed), the raise and lower speed commands are disabled. Because the Cascade controller changes the speed setpoint and not the actual LSS bus, whenever the Cascade is disabled, a bumpless transfer back to speed control occurs. The raise and lower speed commands are then enabled.

If the Auxiliary controller is enabled, the auxiliary setpoint will have tracked the speed setpoint and will provide a bumpless transfer to auxiliary control. The speed setpoint will then be automatically adjusted by the 5009 Control to track the LSS bus. The raise and lower speed commands are disabled whenever the Auxiliary controller is enabled. The PID feedback loop of the Speed controller will manipulate the speed setpoint to allow a bumpless transfer back to speed control in the event the Auxiliary controller is disabled. In both the auxiliary control and the cascade control, if the controlling parameter changes, the speed setpoint will keep the turbine at the same controlling point.

If the application is a generator driving a utility, the Speed controller can be used to control load or power. If the Auxiliary controller is not configured to control on Load/Power, the speed setpoint can be used (with droop) to increase load on the turbine. The raise and lower speed commands would be used to bring the turbine on line and then used again to increase and decrease the load on the turbine.

Remote Speed Setpoint—An additional feature of the Speed controller is the remote speed setpoint. The Remote Speed Setpoint mode can be enabled and disabled through ENABLE and DISABLE commands. It can only be enabled if the Auxiliary controller and the Cascade controller are both disabled. If the Remote Speed Setpoint is enabled, the speed setpoint will ramp towards the Remote Speed Setpoint at a configured rate (initial CCT configuration). The Remote Speed Setpoint is determined by a 4–20 mA analog input. This input signal is controlled from an external device. This allows some other parameter not monitored by the 5009 to control the speed of the turbine. The actual speed setpoint will ramp to the Remote Speed Setpoint at an initial configured rate whenever the Remote Speed Setpoint Mode is enabled. Once in control, as the Remote Speed Setpoint input changes, the speed setpoint will ramp towards it at the max speed setpoint rate (as configured in the CCT). If the Remote Speed Setpoint mode is disabled, the speed setpoint will remain where it is at until a new command is received.

In the event that the Remote Speed Setpoint input(4–20 mA) is not within tolerance (failed input), an alarm will be given and the Remote Speed Setpoint mode will be automatically disabled.

Synchronous Load sharing Control—An additional feature of the Speed controller is the Synchronous/Load Sharing controller. The Synchronous Load Sharing Control can be enabled and disabled through ENABLE and DISABLE commands. When load sharing is enabled, the Auxiliary and cascade controller are both disabled. This function is only used in a generator application. After the turbine is at rated speed, the Synchronous Load Sharing Control can be enabled to synchronize the generator to the utility.

Synchronization is done automatically by a Woodward DSLC™ control or EGCP-3 control and the 5009FT Control. The DSLC/EGCP-3 communicates commands to the 5009FT Control in order to match speed and phase to the utility. After synchronization and the breakers are closed, the speed setpoint is adjusted up 3% (tunable in the service mode of the CCT) in order to prevent reverse power. The 5009FT Control then uses the breaker logic to initiate load sharing. If the control has not been configured for load sharing, this function is ignored.

In the event that the Remote Auxiliary Setpoint input (4–20 mA) is not within tolerance (failed input), an alarm will be given and the Remote Auxiliary Setpoint mode will be automatically disabled.

Events—Alarms & Trips

A listing of all Alarm and Trip messages is available through the Modbus ports and on the OpView, and CCT programs. Relay outputs can be configured in the CCT program for some individual alarm/trip indications (refer to Volume 3) and also for any alarm/trip present indication. A running history of all events (in a text file format) is kept on the CCT in the Woodward/Event_History folder. It contains a sequential description and time stamping of each alarm and trip event.

Chapter 7.
Product Support and Service Options

Product Support Options

If you are experiencing problems with the installation, or unsatisfactory performance of a Woodward product, the following options are available:

- Consult the troubleshooting guide in the manual.
- Contact the manufacturer or packager of your system.
- Contact the Woodward Full Service Distributor serving your area.
- Contact Woodward technical assistance (see “How to Contact Woodward” later in this chapter) and discuss your problem. In many cases, your problem can be resolved over the phone. If not, you can select which course of action to pursue based on the available services listed in this chapter.

OEM or Packager Support: Many Woodward controls and control devices are installed into the equipment system and programmed by an Original Equipment Manufacturer (OEM) or Equipment Packager at their factory. In some cases, the programming is password-protected by the OEM or packager, and they are the best source for product service and support. Warranty service for Woodward products shipped with an equipment system should also be handled through the OEM or Packager. Please review your equipment system documentation for details.

Woodward Business Partner Support: Woodward works with and supports a global network of independent business partners whose mission is to serve the users of Woodward controls, as described here:

- A **Full Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.
- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.
- A **Recognized Turbine Retrofitter (RTR)** is an independent company that does both steam and gas turbine control retrofits and upgrades globally, and can provide the full line of Woodward systems and components for the retrofits and overhauls, long term service contracts, emergency repairs, etc.

A current list of Woodward Business Partners is available at **www.woodward.com/directory**.

Product Service Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

- Replacement/Exchange (24-hour service)
- Flat Rate Repair
- Flat Rate Remanufacture

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is a flat-rate program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

This option allows you to call your Full-Service Distributor in the event of an unexpected outage, or in advance of a scheduled outage, to request a replacement control unit. If the unit is available at the time of the call, it can usually be shipped out within 24 hours. You replace your field control unit with the like-new replacement and return the field unit to the Full-Service Distributor.

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned within 60 days, a credit for the core charge will be issued.

Flat Rate Repair: Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

Flat Rate Remanufacture: Flat Rate Remanufacture is very similar to the Flat Rate Repair option with the exception that the unit will be returned to you in “like-new” condition and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). This option is applicable to mechanical products only.

Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned for repair, please contact your Full-Service Distributor in advance to obtain Return Authorization and shipping instructions.

When shipping the item(s), attach a tag with the following information:

- Return authorization number
- Name and location where the control is installed
- Name and phone number of contact person
- Complete Woodward part number(s) and serial number(s)
- Description of the problem
- Instructions describing the desired type of repair

Packing a Control

Use the following materials when returning a complete control:

- Protective caps on any connectors
- Antistatic protective bags on all electronic modules
- Packing materials that will not damage the surface of the unit
- At least 100 mm (4 inches) of tightly packed, industry-approved packing material
- A packing carton with double walls
- A strong tape around the outside of the carton for increased strength

NOTICE	**To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.**

Replacement Parts

When ordering replacement parts for controls, include the following information:
- The part number(s) (XXXX-XXXX) that is on the enclosure nameplate
- The unit serial number, which is also on the nameplate

Engineering Services

Woodward offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.
- Technical Support
- Product Training
- Field Service

Technical Support is available from your equipment system supplier, your local Full-Service Distributor, or from many of Woodward's worldwide locations, depending upon the product and application. This service can assist you with technical questions or problem solving during the normal business hours of the Woodward location you contact. Emergency assistance is also available during non-business hours by phoning Woodward and stating the urgency of your problem.

Product Training is available as standard classes at many of our worldwide locations. We also offer customized classes, which can be tailored to your needs and can be held at one of our locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability.

Field Service engineering on-site support is available, depending on the product and location, from many of our worldwide locations or from one of our Full-Service Distributors. The field engineers are experienced both on Woodward products as well as on much of the non-Woodward equipment with which our products interface.

For information on these services, please contact us via telephone, email us, or use our website: **www.woodward.com**.

Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory at **www.woodward.com/directory**, which also contains the most current product support and contact information.

You can also contact the Woodward Customer Service Department at one of the following Woodward facilities to obtain the address and phone number of the nearest facility at which you can obtain information and service.

Products Used in Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany:	
Kempen	+49 (0) 21 52 14 51
Stuttgart	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Products Used in Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Products Used in Industrial Turbomachinery Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Technical Assistance

If you need to contact technical assistance, you will need to provide the following information. Please write it down here before contacting the Engine OEM, the Packager, a Woodward Business Partner, or the Woodward factory:

General

Your Name ____________________

Site Location ____________________

Phone Number ____________________

Fax Number ____________________

Prime Mover Information

Manufacturer ____________________

Turbine Model Number ____________________

Type of Fuel (gas, steam, etc.) ____________________

Power Output Rating ____________________

Application (power generation, marine, etc.) ____________________

Control/Governor Information

Control/Governor #1

Woodward Part Number & Rev. Letter ____________________

Control Description or Governor Type ____________________

Serial Number ____________________

Control/Governor #2

Woodward Part Number & Rev. Letter ____________________

Control Description or Governor Type ____________________

Serial Number ____________________

Control/Governor #3

Woodward Part Number & Rev. Letter ____________________

Control Description or Governor Type ____________________

Serial Number ____________________

Symptoms

Description ____________________

____

If you have an electronic or programmable control, please have the adjustment setting positions or the menu settings written down and with you at the time of the call.

Appendix A.
Recommended Spares

For the 5009FT the following is a general list of recommended spares to ensure maximum availability of the control for critical applications.

Part Number	Description	Quantity
5466-1049	MicroNet Kernel Power Supply – 24 Vdc Input	1
5466-1047	CPU - PowerPC5200 400 MHz w/ Application	1
5466-1115	TMR High Density Analog Combo I/O	1
5466-1051	TMR HD Discrete I/O (24 in / 12 out)	1
5466-257	TMR High Density Analog I/O (24/8) (IF USED)	1
5501-432	Actuator Controller Module (2 Chan) (IF USED)	1
5501-380 or 5501-381	Power Supply to Main Chassis – 120 Vac/dc or 220 Vac Input	1
1752-423	Network Ethernet Switch (Hirschmann RS2-TX)	1
1784-3039	Phoenix Quint Power Supply 100–240 Vac/24 Vdc/5 A	1
5501-502	FTM – TMR Speed Input	1
5453-276	FTM – for Discrete I/O FT Relay Box	1
5501-372	FTM – for High Density Analog I/O (IF USED)	1
5437-672	FTM – for Actuator Controller	1
5417-027	Cable – 8’ (2.4 m) for analog combo	1
5417-172	Cable – 8’ (2.4 m) for discrete I/O or high density analog	1
5417-039	Cable – 8’ (2.4 m) for actuator controller (IF USED)	1

Revision History

Changes in Revision E—
- Updated part numbers in Table 1-1, Table 1-2 and Table 2-1.

Changes in Revision D—
- Updated CCT description (pages 25 & 147)

Changes in Revision C—
- Added new part numbers to Table 1-2

Changes in Revision B—
- Added new part number to Table 1-2

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 26518V1.

B26518V1 : E

WOODWARD

PO Box 1519, Fort Collins CO 80522-1519, USA
1041 Woodward Way, Fort Collins CO 80524, USA
Phone +1 (970) 482-5811

Email and Website—www.woodward.com

Woodward has company-owned plants, subsidiaries, and branches, as well as authorized distributors and other authorized service and sales facilities throughout the world.

Complete address / phone / fax / email information for all locations is available on our website.