GENERAL SPECIFICATIONS FOR WOODWARD'S COMPRESSOR CONTROL

COMPRESSOR CONTROL SPECIFICATION – CCS

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CONTENTS

List of Acronyms

ASV (Anti-Surge Valve)
CCS (Compressor Control System)
CDR (Critical Design Review)
CPU (Central Processing Unit)
DCS (Distributed Control System)
DMR (Dual Modular Redundant)
ETA (External Termination Assembly)
EWS (Engineering Workstation)
HART (Highway Addressable Remote Transducer)
HMI (Human Machine Interface)
IAMS (Instrument Asset Management System)
IGV (Inlet Guide Vanes)
PCB (Printed Circuit Board)
PDR (Preliminary Design Review)
PIB (Process Interface Building)
PID (Proportional, Integral, Derivative)
PSU (Power Supply Unit)
SLL (Surge Limit Line)
SNTP (Simple Network Time Protocol)
TMR (Triple Modular Redundant)

COMPRESSOR CONTROL SPECIFICATIONS

SYSTEM REQUIREMENT

- The CCS includes intergrated turbine governing (if required), start-up/shutdown sequencing, anti-surge protection, performance control, quench control, and load-sharing.
- The CCS can be used as a Simplex or Dual Modular redundant or Triple Modular redundant system. All systems are modular and can be expanded for future use. Online changes are supported with the Dual Redundant option, which is capable of logic changes and changes to hardware channel function assignment.
- CCS system firmware and software are the latest revision at the time of delivery.
- Support for all hardware, firmware, and software associated with the controller, Input/Output (I/O) sub-systems, power supplies, and any proprietary communication equipment will be provided for a minimum of 15 years from the CDR. Support includes availability of spare parts and technical support. This support is not contingent on the customer upgrading to later releases of software or hardware.
- Customers are notified of product support withdrawal 12 months in advance.

ENVIRONMENTAL AND OPERATING CONDITION

- Temperature: 0 to 55 °C (32 to 131 °F) ambient air temperature range.
- Shock: US MIL-STD-810C, method 516.2-1, procedure 1B (15 G, 11 ms half-sine pulse).
- Vibration Lloyd's ENV2 Test #1
- All PCB should have conformal coating.
- Major control hardware components are CE marked and comply with the EMC Directive, the Low Voltage Directive, and the ATEX Directive (Zone 2).

DESIGN VERIFICATION

- All drawings for each application are reviewed by the end-user and requires approval for manufacturing clearance.
- If required, the CCS vendor is able to perform anti-surge valve sizing and flow metering device calculations and provide recommendations.
- The CCS vendor produces a detailed analysis of the OEM-provided compressor performance curves, including conversion to an invariant coordinate system. The CCS vendor can demonstrate that all SLL points from all operating conditions have been converted to a single SLL in the invariant coordinate system. CCS is able to adjust the position of the SLL in the invariant coordinate system based on IGV position (if required).
- HMI screen is ISA101 compliant.

REDUNDANCY – TO AVOID ANY SINGLE POINT OF FAILURE (OPTIONAL)

- Redundant power supplies.
- One controller in primary and one controller in hot backup mode.
- All IO modules are capable of supporting the operation of redundant pairs with online replacement of one module in the pair.
- Dual Ethernet switches are available for redundant communication with the third party controller (DCS).

TIME SYNCHRONISATION

- The controller supports digital signal input and/or SNTP (server based) time synchronization.

DISTRIBUTED CONTROL SYSTEM INTERFACE

- If DMR or TMR hardware is chosen, each CCS is provided a redundant communication link to the DCS. Communication protocol is Modbus Transmission Control Protocol / Internet Protocol (TCP/IP). CCS supports Serial Modbus communication (RS-485, RS-422, RS-232) as an option.
- Data required to be exchanged between the CCS and DCS include the following:
    a. All process signals wired directly to the CCS are transmitted to the DCS for indication.
    b. Performance controllers PV, SP, MV, Mode and any other control that is being used in the controller (if used).
    c. Anti-surge controllers PV, SP, MV, Mode and any other control that is being used in the controller.
    d. Load Share controllers PV, SP, MV, Mode and any other control that is being used in the controller (if used).
    e. Quench controllers PV, SP, MV, Mode and any other control that is being used in the controller (if used).
    f. Compressor operating point relative to the anti-surge control line.
    g. Any process or system alarm limits configured in the CCS are transferred to DCS as indication only.
    h. All data required to display the dynamic compressor operating map at the DCS Operator Workstation (OWS).
    i. System alarm for any failure of any component of CCS.
    j. CPUs switch over with their fault alarms (if Dual Modular redundant used).
    k. Compressor controller diagnostic alarms.
- CCS alarms to be communicated to the DCS (Modbus communication) include the following:
    a. Compressor surge alarm
    b. Compressor near surge alarm
    c. Anti-surge fall-back strategy alarms
    d. Activation of any open loop function that increases ASV opening in order to prevent surge or break a surge cycle.
    e. Surge count alarm
    f. Any transmitter failure alarm
    g. System alarm for any failure of any component of CCS
- CCS is capable of switching the anti-surge controller between manual mode and automatic mode based on external commands. CCS is capable of positioning the anti-surge valve based on an external demand without overriding the anti-surge protections in the CCS.
- Auto fail-over to the redundant healthy communications channel is provided.
- CCS provides system diagnostic faults over Modbus to the DCS.

EMERGENCY SHUTDOWN SYSTEM INTERFACE

- All critical signals as required by the customer are hardwired between the CCS and Emergency Shutdown (ESD) System to ensure safe equipment operation and full equipment protection. Critical signals include the following at a minimum:
    a. Trip Signal from ESD System
    b. CCS trip to ESD
    c. Excessive surge signal to ESD from CCS
- The ESD and CCS I/O for these connections are shown in the respective I/O list developed during detailed design.

INSTRUMENT ASSET MANAGEMENT SYSTEM INTERFACE (OPTIONAL)

- CCS cabinets, if required, are supplied with HART-enabled External Termination Assembly(s) (ETAs) or embedded within the CCS system for interfacing with the IAMS. The HART ETAs that are selected are fully compatible with the IAMS.

CCS - OPERATOR AND ENGINEERING WORK STATION INTERFACE

- CCS includes all internal and external communications equipment required for load-sharing and loop decoupling within a Process Interface Building (PIB)/ rack room/ panel room.
- CCS includes all communication equipment required to communicate between CCS controllers and CCS Engineering Workstations (EWS). CCS supports communication over fiber optic cable.
- All CCS EWS Server/Workstation CPUs are locally mounted, as panel HMI or external PCs. Activation of any open loop function that increases ASV opening in order to prevent surge or break a surge cycle.
- CCS HMI can be deployed in a panel-mount computer or a desktop computer.
- The CCS EWS is supplied with software tools (separate from the HMI program) that provide the following functions:
    a. Configuration of the CCS software to meet project-specific requirements.
    b. Retrieving and loading CCS software settings.
    c. Real-time trending of any software parameter with an update rate better than 0.5 seconds. Also, Alarms and Event logging.
    d. Retrieving files from and loading files to the CPUs (diagnostic logs, high speed data, application files, etc.).
    e. Configuring CPU security settings.
    f. Displaying trends of high speed data captured by the CPU.
    g. Viewing of CCS software logic, including live values from the CPUs.
    h. Automatic retrieval of files saved on the CPU, including high-speed data log files.
- CCS supports connections to multiple HMI and EWS computers.
- CCS supports SSH for file transfer to and from EWS.
- EWS is the latest available high-end processor at the time of PDR (hardware freeze).
- CCS EWS is configured with multiple access levels with appropriate privileges for each access level. Multiple access levels include administrator, engineering, maintenance, and operator.
- The EWS edits, uploads, and downloads application programs into the controllers. Editing is optional.
- The operating system is equipped with the latest compatible version of Microsoft Windows.
- Each CCS EWS is installed and configured with latest available anti-virus software with three years of expiration.
- CCS software is in compliance with IEC 61131-3.
    a. Compressor map— Build and display a dynamic compressor map utilising controller measured process variables and calculated parameters. Compressor map can be displayed in invariant coordinates or non-invariant coordinates (polytropic head / discharge pressure / pressure ratio vs. actual flow / standard flow / mass flow).
    b. Dynamic Updating— Displaying real-time surge limit and surge control lines which are dynamically updated to reflect changing process inlet conditions and compressor operating parameters.
    c. Archiving Automatically— Archiving controller events, such as surge detection, fault detection, and mode switching and records, at least once every second. The archiving software permits replay or download of transient conditions, process disturbances, or shutdown data to digital storage media. CCS EWS can be used as a trend recorder for multiple controllers.

d. Alarm Information— The software provides an alarm annunciation facility to dynamically display the status of all alarms. The facility provides a means of displaying all current points, which are in alarm, and distinguishes between acknowledged and unacknowledged status.
e. Controller Configuration— Configuring all performance controllers, anti-surge controllers, and load- sharing controllers.
f. Anti-surge PID, Rate PID, Performance Control PID, Quench Control PID, P1 override PID, and P2 override PID can be tuned through Toolkit.

- Adheres to ISA 101 standards, which incorporates Human Factors Engineering through use of situational awareness and a streamlined alarm philosophy.
- "Go 2 GAP" — the ability to quickly trace HMI alarms/readings back into the GAP source code (reducing troubleshooting time).
- Historian playback features that allow operators to review recorded scenarios by stepping forward through time.
- Optional Woodward Alarm Summary & Export Utility that handles all alarm history functions and can be installed as a separate desktop program to handle troubleshooting on engineering/maintenance laptops.

DISPLAY

- The following display types are included:
  a. Dynamic process graphic showing the overall compressor train process schematic, which contains dynamically updated data for all process variables and controllers being operated by the CCS.
  b. Dynamic compressor operating map, which displays the compressor operating point in relation to the configured surge control line and surge limit line for individual compressors and the load-sharing operation for compressors running in parallel.
  c. Operator interfaces for controller enabling / disabling as well as setpoint adjustment.
  d. System monitoring display, which shows the status of all CCS modules.
  e. Alarm summary display.
  f. Trend displays as indicated below.
- Trend displays are provided with the following functionality:
  a. Displaying trends, either real-time or from event history files for multiple controllers.
  b. Display of up to 8 process variables, in real-time.
  c. Custom trend configuration.
- The CCS provides a comprehensive system to restrict system access, administration of system policies, administration of user accounts and passwords and system security.
- CCS controller has cyber security ceritficate.
- CCS EWS functions correctly when added to a plant domain.
- CCS EWS can be configured to automatically boot-up in view only access environment.

DIAGNOSTICS

- CCS diagnostic errors and status information is communicated to the DCS for alarming and historization.
- Each CCS employs self-diagnostics, which continuously monitors its own status and indicates any fault. Fault indicators on the controller's operator interface are provided. Faults are communicated to the DCS and configured as a common system fault alarm. These diagnostics include the following failures:
  a. CPU failures
  b. Loss of external data communications
  c. Loss of an I/O channel (identified to the associated card and chassis)

d. Loss or fault of an I/O module
e. Power Supply Unit (PSU) failures
f. Cabinet fan failure or cabinet over temperature alarms
g. CCS fan failure

RECYCLE VALVE

- If required, the recycle/anti-surge valve data sheets can be reviewed by the vendor as part of the CCS design to validate the following valve requirements as a minimum:
    a. The response time from fully closed to fully open is a nominal two seconds or less (accomplished by using volume boosters, close tubing connections, and the correct orifice CV, in accordance with the compressor manufacturer's recommendations).
    b. The valve Cv shall be 1.8 to 2.2 times the highest Cv required for surge limit line flow across all operating conditions. If insufficient information is available to calculate the Cv from surge limit line flow, the Cv shall be 1.5 times the Cv required for the rated flow condition.
    c. The anti-surge (recycle control) valve is air fail open.

CONTROL REQUIREMENT

COMPRESSOR PERFORMANCE CONTROL

- Fall-back strategies should include holding last good value and default value on field signal failure.
- Maintainance override switch is provided for the maintainance of a faulty transmitter.
- CCS meets or exceeds the following control objectives:
    a. Capacity Control— The performance control algorithm is designed to provide precise capacity control for its associated compressor or compressor train.
    b. Temperature Control— Performance control for refrigeration compressors includes vapour surge drum. The CCS vendor implements drum temperature control and quench control based on dew point within the CCS.
    c. Process Limiting Variables— Maintain selected process limiting variables, such as compressor suction and/or discharge pressure, turbine power, and electric motor driver current or power, within safe and acceptable operating ranges.
    d. Control Mode Changes— Control mode changes, such as from Manual to Automatic, or vice-versa, are bumpless.
    e. Start-up— An input signal to the CCS indicates start-up. The CCS automatically adjusts the performance control variable while maintaining overrides within a safe operating range during the start-up process. Prior to compressor start-up, start sequence will kick in and keep the Anti Surge Valve full open, maintaining its minimum flow requirement.
    f. Normal Shutdown—CCS is configured to automatically unload the compressor by ramping the recycle valve to fully open prior to the shutdown of the machine.
    g. Controller-manipulated Value Display— The performance controller calculates and displays process input variables such as temperature, pressure, actual volumetric flow rates, and compensated mass and volumetric flow rates in conjunction with compressor curves.
    h. Controller Interaction Minimization Control Loop— Decoupling is applied to minimize any potential destabilizing interactions between performance and anti-surge controllers, or other associated process controllers.

ANTI-SURGE CONTROL

- Surge monitoring
- Surge detection and protection algorithms monitor one or more coincident variables such as compressor inlet flow, minimum flow, speed, suction and discharge pressure, motor/driver power, or

other suitable process or machinery measurements that serve as a dynamic precursor of an impending compressor surge.

- CCS filters the transmitter field value so the fastest and the most stable response can be selected.
- A fast action derivative-based PID (other than Anti-Surge PID) is available as an additional protection in the CCS. This PID should regulate CCS operating point movement toward the surge limit line.
- CCS calculates compressor stage flow based on measured side-stream flow and either an upstream or downstream compressor stage flow.
- Calculation of the operating point is achieved using a multi-variable algorithm that compensates for changes in process stream variables such as pressure, temperature, and molecular weight of the process gas.
- Manual override or anti-surge bypass features are provided for all CCS related transmitters for maintenance only. Whenever a transmitter is put in maintenance mode, the seperate maintenance value is used for calculations. Bypass indication is provided on the DCS OWS.
- CCS provides recycle valve with a manual mode, which allows the CCS to take control by overriding the manual demand in case of a surge event.
- CCS includes:
    a. Closed-loop PID control based on the location of the operating point
    b. Closed-loop PID control based on the rate of change of the operating point
    c. Open-loop responses take action when the closed-loop controls are not adequate
- The anti-surge control strategy has multiple levels of handling a compressor surge:
    a. The first level monitors the compressor's rate of advance towards its surge control line and arrests the advance by opening its recycle valve.
    b. The second level rapidly advances manipulation of the recycle valve, whenever a compressor enters the operating region between its surge control line and its surge limit line.
    c. The third level is detected when the compressor has entered surge, generates an alarm, increments a counter, and immediately drives the compressor to a safe operating region.
    d. CCS is able to provide a step response if the operating point is under the surge area to avoid valve stickiness in Anti-Surge Opening.
    e. CCS is capable of generating a trip command if the operating point duration in surge area exceeds a pre-configured time limit.
    f. CCS must be capable of holding the recycle valve to a minimum safe level of opening when a surge event occurs. This safety threshold can be removed after an operator's intervention.
- The surge control is based on a calculated invariant parameter to ensure compressor protection irrespective of changes to inlet condition changes, such as gas MW variation, without compromising compressor operating envelope.
- The CCS is configured to automatically increase the safety margin (i.e. the margin between the surge limit line and the surge control line) whenever the compressor operating point moves past the surge limit line. It is possible to adjust the percentage increase to the safety margin applied and to enable or disable this feature within the CCS.
- It is possible to reset the surge counter from the CCS HMI or from the DCS.
- The controller employs dedicated microprocessor-based technology that executes its algorithms at 40 ms and fastest tripping loop at 10 ms.
- An optional remote limiter set point (typically from DCS) is provided for the ASV closing.
- A graphical display of the compressor's control map that dynamically indicates the compressor's operating point relative to the surge control line is provided. This information is available from the CCS EWS and DCS is provided with all map points so that it can be developed in the customer's system, for the purpose of monitoring only.
- Fall-back strategies are implemented to maintain operation of the compressor within safe operating range in the event of a failure of any process input to the anti-surge controller. The following fall-back strategies are available as a minimum:

a. Failure of suction flow transmitter. Upon failure, the transmitter holds last good value or pre-configured default value if multiple transmitters are failed.
b. Failure of suction pressure transmitter. Upon failure, the transmitter holds last good value or pre-configured default value if multiple transmitters are failed.
c. Failure of discharge pressure transmitter. Upon failure, the transmitter holds last good value or pre-configured default value if mutliple transmitters are failed. Optionally, default discharge pressure value can be calculated from the suction pressure and a default pressure ratio.
d. Failure of compressor speed signal. Upon failure or invalidation of the compressor rotational speed input, the controller reverts to a fixed speed.
e. Optional flow transmittter failure response. The control will shift to Full Manual and add the pre-configured amount to the existing opening.
f. Maintenance Override Feature is provided for safe maintenance of the faulty transmitter.

LOAD SHARING CONTROL

- Load-sharing applies where compressors are operated in parallel or series, and any controller can be set as Master.
- The load share controller (Master) is configurable to enable distribution of load by suction header pressure, discharge header pressure, mass flow rate, or other suitable control variable of the composite compressor train.
- The load share controller (Master) adjusts the performance controller of each compressor such that all compressors are operating at the same distance from the surge control line.
- Load redistribution occurs automatically, even when compressors are being brought off- or on-line, if gas inlet process conditions change, or in the event of a change in compression efficiency.
- It is possible to switch any of the compressors within a train between load-sharing and stand-alone operation via a command issued through the DCS.
- It is possible to make any participating load-sharing controller the Master load-sharing controller.

HIGH SPEED DATA AND TRIP EVENT CAPTURING SYSTEM

- CCS is capable of high-speed data and trip event capturing for performing high-speed sequence of events and data recording. Typical trip datalog capture is as fast as 5 msec resolution.
- The system captures all compressor operating parameters at a maximum scan (sampling rate) rate of 40 ms from the moment of start-up to all shutdowns.
- High speed data capture is stored to the hard drive of the CPU during critical event periods. Critical events are defined as start-up, shutdown, compressor surge, emergency trip events.
- High speed recording and archiving of all the recent critical events is logged in controller memory.

TESTING OF CONFIGURATION ON IN-HOUSE SIMULATION STEAM OR COMPRESSOR MODEL

Control solution can easily run/execute the control software and connect to models of steam turbine/ compressors to test/validate the configured control philosophy.

Simulation tool is capable of accurately driving communications to HMI’s, allowing to test and demonstrate this aspect of “control” deliverable as well.

REVISION HISTORY

Date	Version	Prepared by	Reviewed by	Approved by
Jan 15, 2025	Preliminary version	P. Kumar	V.Misra	V.Misra
Feb 17, 2025	Rev -	P. Kumar	V.Misra	V.Misra