WOODWARD

Product Manual 26421
(Revision NEW)
Original Instructions

Integrated Steam Turbine and Compressor Control Application

Part Numbers 5418-2789, 5418-2790

Application Software Manual

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 *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, 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 *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, 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 Out-of-date translations are marked with ⚠.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—Changes in this publication since the last revision are indicated by a black line alongside the text.

Contents

Illustrations and Tables

Warnings and Notices

Important Definitions

This is the safety alert symbol. It is 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.

WARNING

Automotive Applications

On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.

NOTICE

Battery Charging Device

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

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 Integrated Steam Turbine and Compressor Control software is a GAP™ (Graphical Application Programmer) application designed for sequencing and control of a steam turbine driven dynamic compressor. Compressor sequencing and anti-surge control is handled via dedicated, external software cores—This main application handles steam turbine sequencing, closed-loop speed and process control, alarming and shutdown, external Modbus® * communications, etc., similar to the 505 family of Woodward Steam Turbine control products (505, 505E, 5009, 505DE, 505CC-2).

*—Modbus is a trademark of Schneider Automation Inc.

The software is semi-configurable and may be applied toward a variety of prime mover designs (single- or two-valve with extraction and/or admission steam). Also, startup modes, critical speeds, and similar auxiliary functions are fully configurable to allow complete customization of the control. Some functionality is not configurable and must be included in the software at the time of compilation. Therefore, while much of Woodward's standard steam turbine control philosophy has been included in this application, some features may require physical software changes, not simple configuration, to activate.

This manual describes turbine control functionality, operation, and configuration and tuning procedures.

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

Chapter 2.
Turbine Control Overview

Introduction

This software application is designed to control single-valve, as well as extraction, extraction/admission, or admission steam turbines. The difference between the single-valve turbine and the latter two-valve turbines is the capability of the turbine to allow low pressure steam, which is at a lower pressure than the inlet, to enter and/or exit the turbine. An extraction turbine allows the lower pressure (extraction) steam to exit the turbine and will have a non-return valve in the extraction header/line to prevent steam from entering the turbine. An admission turbine (also called induction) will allow excess header steam to enter the turbine through the low-pressure inlet. An extraction/admission turbine will allow low-pressure header steam to enter or exit the turbine depending on system pressures. A turbine with admission capability will have a stop valve or Trip & Throttle Valve in the low-pressure line to prevent steam from entering the turbine when the unit is tripped. The type of turbine used will depend on the system requirements and must be designed by the turbine manufacturer to perform the functions required.

The application controls turbine speed via a PID (Proportional-Integral-Derivative) controller. Likewise, a second PID controller is provided for Extraction/Admission steam pressure control for two-valve turbines. If a turbine decoupling mode is selected, more PID controllers are provided for Inlet and Exhaust steam pressure control. The outputs of these controllers are sent to a ratio limiter, where the HP and LP Valve demands are calculated according to the configured steam map and decoupling option. In addition, another controller, in a Cascade Control scheme, can manipulate the speed setpoint, providing external process control through turbine speed. The Cascade process variable may be any external process that is dependent upon turbine speed, typically compressor suction or discharge pressure, or turbine inlet steam header pressure.

All PID setpoints may alternatively be received from a remote device through a configurable 4–20 mA analog input.

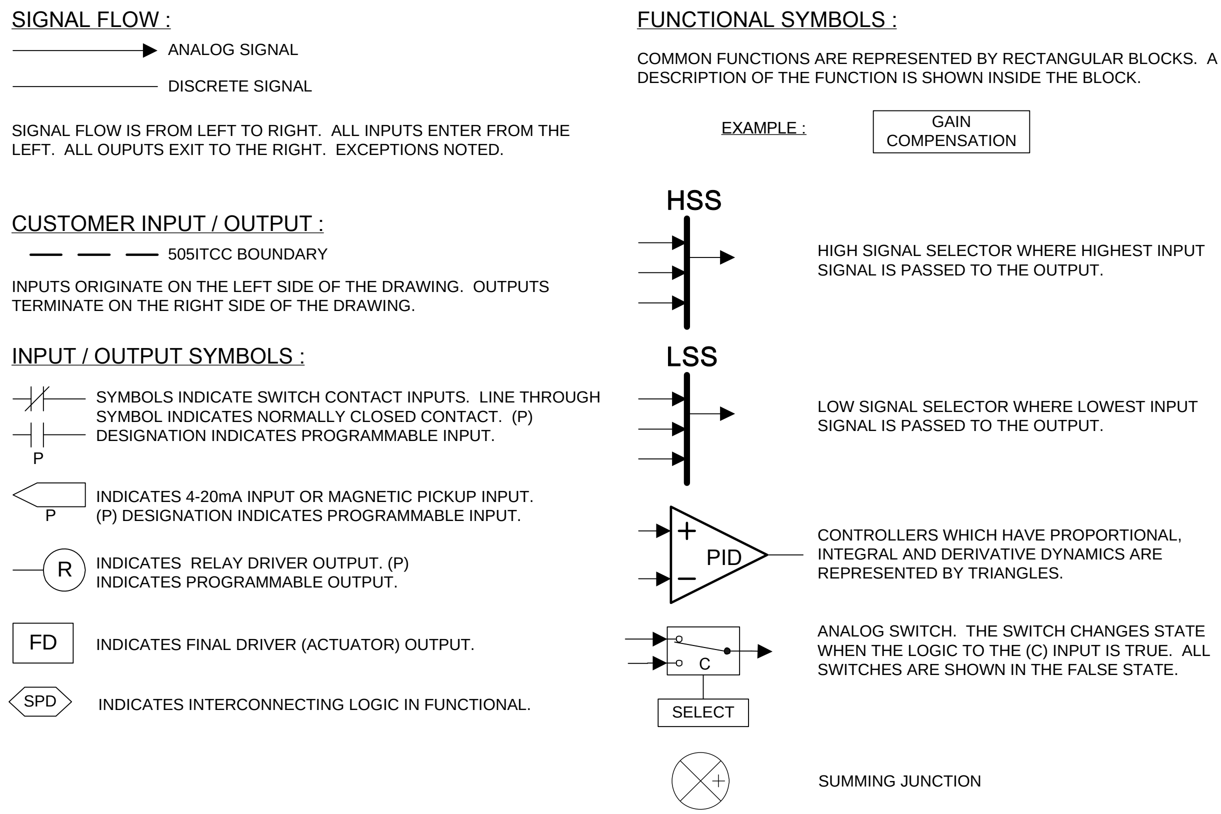


Figure 2-1. Overview of Control Functionality Notes

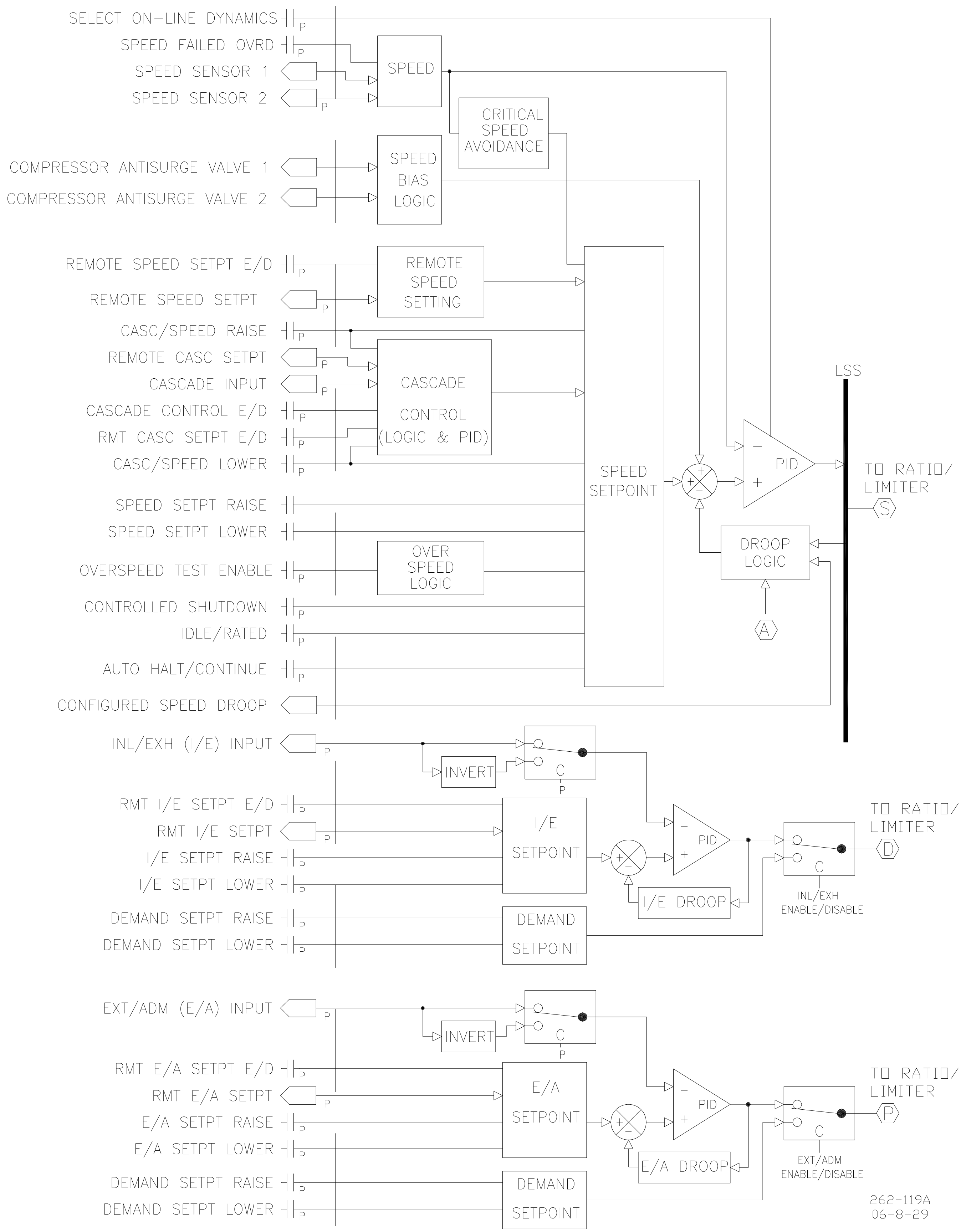


Figure 2-2. Overview of Turbine Control Functionality

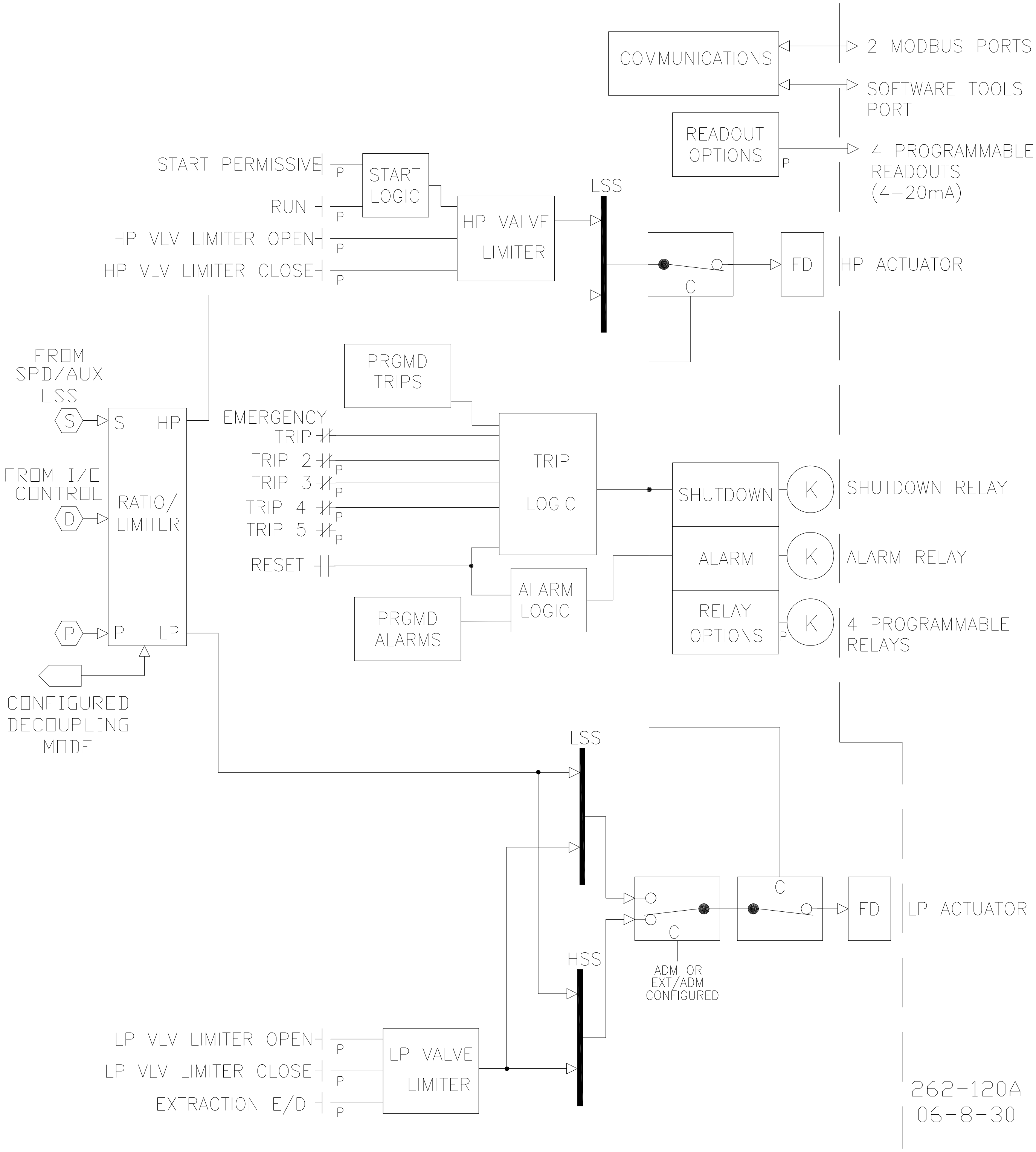


Figure 2-3. Overview of Turbine Control Functionality

Extraction Turbines

The application can be configured to operate single automatic extraction turbines by controlling the interaction of the governor (HP or high pressure) valve and the extraction (LP or low pressure) valve. (It can also operate the governor valve and the first extraction valve of multiple extraction turbines.)

Single automatic 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 2-4). 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 through the extraction line. As the LP Valve is opened, more steam enters the LP stage and less is extracted.

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

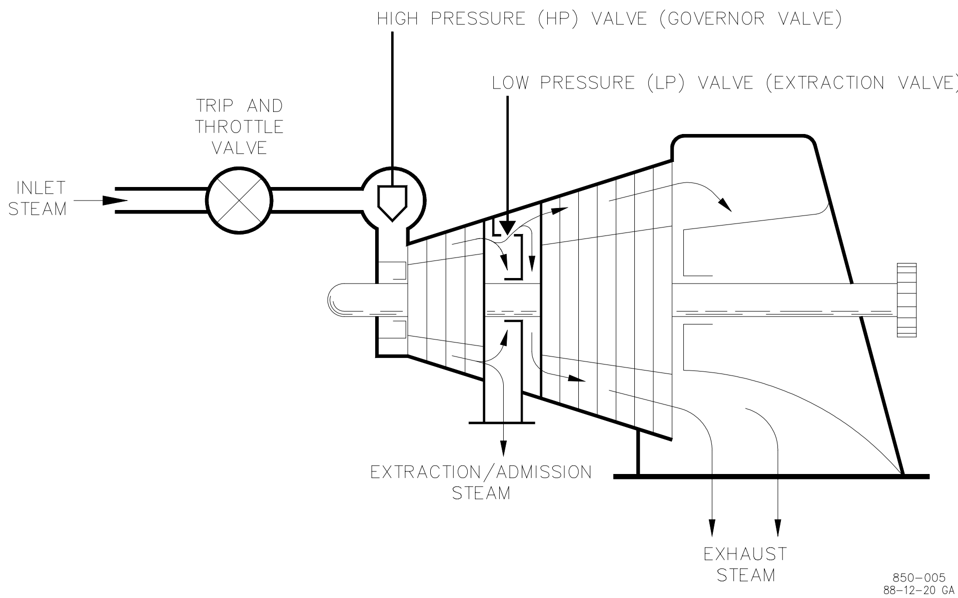


Figure 2-4. Typical Extraction or Extraction/Admission Steam Turbine

Admission Turbines

The application can be configured to operate single automatic admission turbines by controlling the interaction of the governor (HP or high pressure) valve and the admission (LP or low pressure) valve.

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 2-5) and, at the downstream end of the HP turbine stage, through 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.

In most cases, the operator of an admission turbine needs to maintain both turbine speed/load and admission pressure/flow at constant levels. Changing the position of either the HP Valve or the LP Valve affects both turbine speed/load and admission. If either the load on the turbine or the admission demand changes, both the HP Valve position and the LP Valve position must be changed to maintain speed/load and admission.

The movement of both valves is automatically calculated by the control software's ratioing logic, based on the turbine performance parameters, to minimize valve/process interaction.

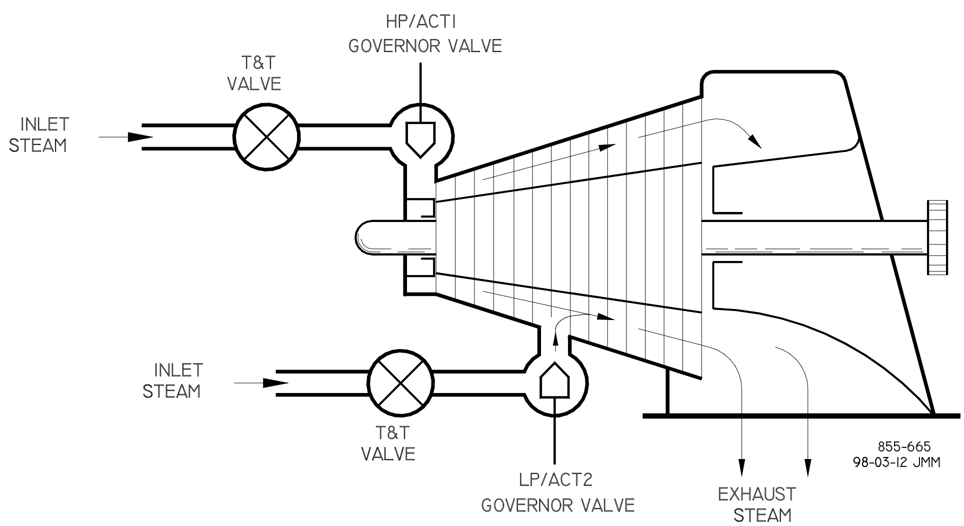


Figure 2-5. Typical Admission Steam Turbine

Extraction and Admission Turbines

The application can be configured to operate single automatic extraction and admission turbines by controlling the interaction of the governor (HP or high pressure) valve and the extraction (LP or low pressure) valve.

Single automatic Extr/Adm 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 2-4). 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.

In most cases, the operator of an Extr/Adm turbine needs to maintain both turbine speed/load and extr/adm pressure/flow at constant levels. Changing the position of either the HP Valve or the LP Valve affects both turbine speed/load and extr/adm. If either the load on the turbine or the extr/adm demand changes, both the HP Valve position and the LP Valve position must be changed to maintain speed/load and extr/adm. The movement of both valves is automatically calculated by the control software's ratioing logic, based on the turbine performance parameters, to minimize valve/process interaction.

Speed Control

The speed control receives a turbine speed signal from one or more magnetic pickups (MPUs) or proximity probes. The frequency input is converted to speed by the following equation:

$$\text{Speed (rpm)} = \frac{\text{Frequency Input (Hz)}}{\text{Number of Teeth} * \text{Gear Ratio} * 0.016667}$$

Number of Teeth and Gear Ratio are configured into the control during commissioning. The maximum frequency sensed by the control's hardware speed input channels is 25 000 Hz. And, the maximum speed, an internal limit used by the control, is calculated as 105% (configurable) of the configured Overspeed Test Limit. Therefore, the following rule applies to the Gear Ratio and Number of Teeth:

$$\frac{\text{Max Speed (rpm)} * \text{Gear Ratio} * \text{Number of Teeth}}{60} < 25000\ \text{(Hz)}$$

$$\frac{\text{Overspeed Test Limit (rpm)} * 1.05 * \text{Gear Ratio} * \text{Number of Teeth}}{60} < 25000\ \text{(Hz)}$$

$$\text{Gear Ratio} * \text{Number of Teeth} < \frac{25000\ \text{(Hz)} * 60}{\text{Overspeed Test Limit (rpm)} * 1.05}$$

If this condition is not met, the largest measured speed will be:

$$\text{Speed (rpm)} = \frac{25{,}000}{\text{Number of Teeth} * \text{Gear Ratio} * 0.016667}$$

The Speed PID then compares this signal to the speed setpoint to generate an output signal to the Ratio-Limiter. The Speed PID operates in a Speed control mode at all times, which means that the Speed PID will control the turbine at the same speed regardless of the load it is supplying (up to the unit's load capability).

Supplemental Speed PID features include a configurable droop mode, based upon Speed PID demand feedback, which may be needed to prevent process instabilities (extraction pressure) when using the Inlet/Speed Decoupling mode. In addition, bias signals from the compressor control (one for each compressor) may be configured to interact with the speed controller. These bias signals, proportional to movement in the compressor's anti-surge valves, may be used to decrease any adverse interaction between the compressor control and the steam turbine control.

Speed Setpoint (Speed Reference)

The speed control's setpoint is adjustable with raise or lower commands from internal tunables (Woodward software tools required), remote contact inputs, or Modbus®. In addition, a 4–20 mA analog input may be assigned for Remote Speed Setpoint, allowing an external device (e.g. DCS, PLC) to remotely set the speed setpoint. As discussed later in this chapter, the Cascade PID, if configured, will also directly affect the speed setpoint.

The speed setpoint's normal range is defined by the turbine's normal operating range—that is, between Rated/Minimum Governor and Maximum Governor, both of which are configurable. The speed setpoint cannot be raised above Maximum Governor unless an Overspeed Test is performed. Once the speed setpoint is above Minimum Governor, it cannot go below it again unless Idle is commanded or a Controlled Stop is initiated.

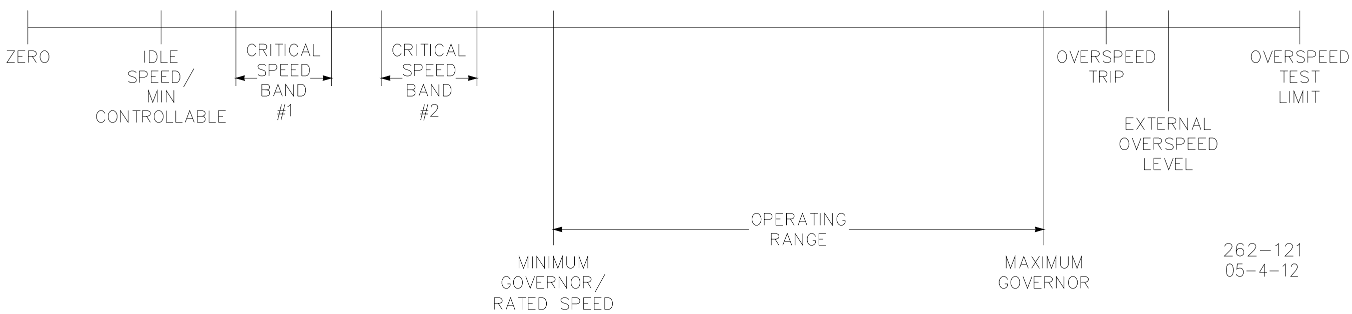


Figure 2-6. Speed Setpoint Relationships

Above Minimum Governor, the speed setpoint may be adjusted through discrete raise and lower commands. When a Raise/Lower command is issued, the setpoint moves at the configured Default Rate. If a Raise/Lower command is held for the configured Fast Rate Delay time, the setpoint will begin to ramp at the configured Fast Rate. Whether from tunables, remote contact inputs, or Modbus, the Raise/Lower commands are received as toggles. That is to say, the setpoint will ramp as long as the command is active.

⚠WARNING

The user should consider some appropriate engineering solution if there is any failure mode for the contact inputs or Modbus commands that might keep them active unintentionally.

All pertinent speed control parameters are available through Modbus. See Chapter 4 for a complete Modbus list.

Remote Speed Setpoint

One of the configurable 4–20 mA analog inputs can be assigned to remotely position the speed reference. Typically, some external process control (e.g. PLC, DCS) may interface with this input to regulate the turbine's speed or load to control a related process.

The Remote Speed Setpoint function may be enabled and disabled from tunables, remote contact input, or Modbus. The last command given from any of these three sources dictates the enabled/disabled state. If the contact input is used, Remote Speed Setpoint is disabled when the contact is open and enabled when closed. The contact can be either open or closed when a trip condition is cleared. If the contact is closed it must be opened and re-closed to enable Remote Speed Setpoint. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled. The Remote Rate dictates the rate at which the analog input will position the speed reference.

The minimum (4 mA) and maximum (20 mA) engineering unit values for this analog input should normally be configured as (or within) Minimum and Maximum Governor. The analog signal is limited accordingly, regardless of the upper and lower range values of the input. If the milliamp signal to the Remote Speed Setpoint input is out of range (defaulted to 2–22 mA) an alarm is generated and Remote Speed Setpoint is disabled and inhibited until the input signal is corrected. Remote Speed must be re-enabled after the input is re-established.

Since Cascade Control also acts on the speed setpoint, it and Remote Speed Setpoint cannot be active at the same time. If Cascade is configured and active, it will be disabled as soon as Remote Speed Setpoint is enabled. Likewise, Remote Speed will automatically be disabled if Cascade is enabled. If Remote Speed Setpoint is enabled, all other speed setpoint commands (Raise/Lower) are inhibited.

When online, the compressor software controls compressor operation on or to the right of its control line. Compressor flow is proportional to speed. Therefore, when operating on the control line, any decrease in speed could inadvertently drive the compressor into surge by reducing flow. To prevent this undesirable effect, speed reference lower commands from the remote speed setpoint are inhibited when compressor operation is on or near its control line. Boolean speed lower commands from tunables, discrete input, or Modbus are still permitted for operational flexibility.

All pertinent Remote Speed Setpoint parameters are available through Modbus. Refer to Chapter 4 for a complete Modbus list.

Speed Control Dynamics (PID Tuning)

The application offers two sets of configurable dynamics for the Speed PID, the second of which is available at one of three configurable switch points. The two sets of tuning parameters are termed *offline* and *online*, the latter available after reaching Minimum Governor, with Decoupling enabled, or at the switch of a contact input. These dynamic variables allow the Speed PID to be tuned for optimal response under varying process conditions.

If Above Minimum Governor is configured as the Dual Dynamics switch point, the Speed PID's offline dynamics, or set 1, are used when turbine speed is below Minimum Governor. Conversely, the online dynamics, or set 2, are selected when turbine speed is above Minimum Governor. Similarly, the online dynamics can be selected when decoupling is enabled.

A contact input may be assigned to perform this switching, but it would require a change to the application software to connect the assigned input. If connected, the online tuning parameters are selected when the contact is closed.

Refer to the Dynamics Adjustments section in Chapter 3.

Cascade Control

Cascade can be configured to control any system process, related to or affected by turbine speed or load. Typically, this controller is used to regulate turbine inlet or exhaust pressure or compressor suction or discharge pressure. When Total Decoupling (No Ratioing) is configured for an Extr/Adm turbine, the cascade controller is typically configured for inlet steam pressure.

The Cascade controller is a PID controller that compares a 4–20 mA process signal or internally available process variable with a setpoint. The Cascade PID adjusts the speed controller setpoint until the process variable and setpoint match. By cascading two PIDs in this fashion, a bumpless transfer between the two controlling parameters can be performed.

Cascade control may be enabled and disabled from tunables, remote contact input, or Modbus. The last command given from any of these three sources dictates the Cascade PID's control state. If the contact input is used, Cascade is disabled when the contact is open and enabled when closed. The contact can be either open or closed when a trip condition is cleared. If the contact is closed it must be opened and re-closed to enable Cascade. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled.

Since Cascade is a secondary speed setting function, the Speed PID must be in control in order for Cascade to take control. And, turbine speed must be greater than Minimum Governor, or Cascade Min Speed, if configured, before Cascade can be enabled. Cascade Control is inhibited if the compressor is in its shutdown sequence (commanded to full recycle).

Since the speed reference is also affected by Remote Speed Setpoint, it and Cascade Control cannot be active at the same time. If Remote Speed Setpoint is configured and active, it will be disabled as soon as Cascade is enabled. Likewise, Cascade will automatically be disabled if Remote Speed is enabled.

When online, the compressor software controls compressor operation on or to the right of its control line. Compressor flow is proportional to speed. Therefore, when operating on the control line, any decrease in speed could inadvertently drive the compressor into surge by reducing flow. To prevent this undesirable effect, some speed reference lower commands, including those from the Cascade controller, are inhibited when compressor operation is on or near its control line.

All pertinent Cascade Control parameters are available through Modbus. Refer to Chapter 4 for a complete Modbus list.

Cascade Setpoint (Cascade Reference)

The Cascade Control's setpoint is adjustable with raise or lower commands from tunables, remote contact inputs, or Modbus. In addition, a 4–20 mA analog input may be assigned for Remote Cascade Setpoint, allowing an external device (e.g. DCS, PLC) to remotely position the Cascade setpoint. When the control is powered-up, the setpoint is reset to the configured Setpoint Initial Value.

The Cascade setpoint range must be defined by Min Cascade Setpoint and Max Cascade Setpoint in the application's configuration sheets. While these parameters can be somewhat arbitrary, and are used primarily to normalize the PID to 0-100%, it is advisable that they correspond roughly to the turbine's normal operating speed range—that is, the Cascade process variable when the turbine is at Minimum Governor (or Cascade Min Speed) and Maximum Governor under normal operating conditions. For example, if the range is set too narrow, and Cascade is enabled when the process variable is well outside the setpoint range, the Cascade PID may drive its demand to 0% or 100%. And following, the speed reference may be driven to its limits.

When a Raise/Lower Cascade Setpoint command is issued, the reference moves at the configured Cascade Default Rate. If the command is held for the configured Fast Rate Delay time, the reference will begin to ramp at the configured Fast Rate. Whether from tunables, remote contact inputs, or Modbus, the Raise/Lower commands are received as toggles. That is to say, the setpoint will ramp as long as the command is active.

WARNING	**The user should consider some appropriate engineering solution if there is any failure mode for the contact inputs or Modbus commands that might keep them active unintentionally.**

Cascade Setpoint Tracking

To allow a bumpless transfer from turbine Speed/Load control to Cascade control, the Cascade PID can be configured to track its controlling process input when disabled.

When this tracking feature is programmed, the Cascade PID will be satisfied when enabled, providing a bumpless transfer to Cascade control. After enabling, the reference will ramp to the active commanded setpoint, if any, or respond to Raise/Lower commands as normal.

If Setpoint Tracking is not enabled, the reference will remain at its last setting (running or shutdown). With this configuration, when Cascade control is enabled, and the sensed process signal does not match setpoint, the Cascade PID will instantly take control and begin to move the Speed Reference. 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 otherwise adjusted.

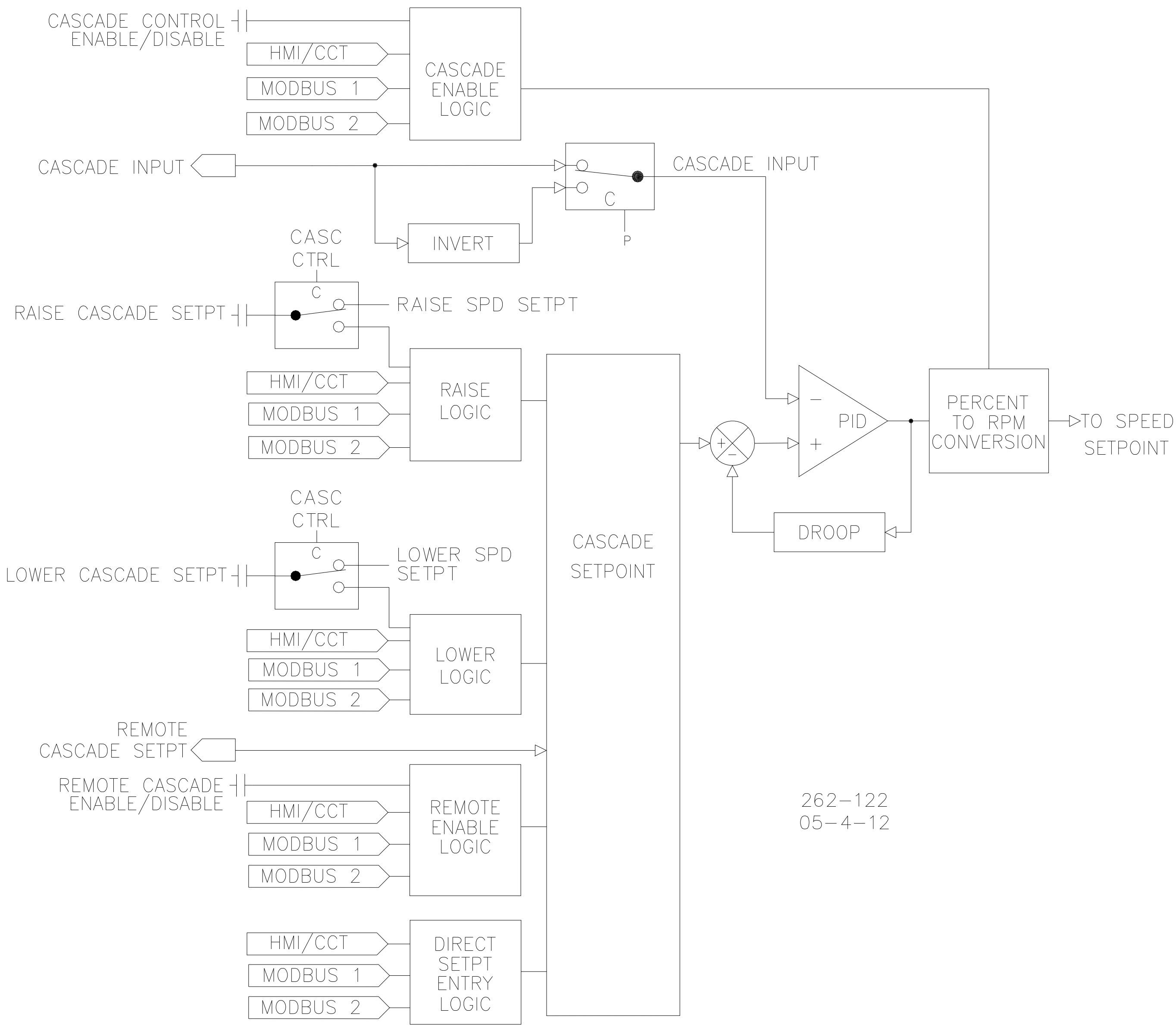


Figure 2-7. Cascade Control Functional Diagram

Cascade Droop

When sharing control of a parameter with another external controller, the Cascade PID can also be configured with a droop feedback signal for control loop stability, helping prevent multiple control loops from *fighting*. 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 configured and the output of the Cascade PID.

The droop value is subtracted from the normalized Cascade process variable input and is calculated as a percentage of the speed reference. In other words, after the Cascade input and setpoint are normalized as a percentage of Cascade setpoint range (Max Cascade Setpoint–Min Cascade Setpoint), droop is subtracted, itself a percentage of the current speed reference.

Invert Cascade Input

Depending on the control action required, the Cascade input signal can be inverted. If a decrease in speed is required to increase the Cascade process signal, such as for turbine inlet steam pressure or compressor suction pressure, Invert Cascade Input should be configured.

Remote Cascade Setpoint

One of the 4–20 mA analog inputs can be assigned to remotely position the Cascade reference. Typically, some external process control (e.g. PLC, DCS) may interface with this input to regulate the turbine's speed or load to control a related process in a Cascade Control scheme.

The Remote Cascade Setpoint function may be enabled and disabled from tunables, remote contact input, or Modbus. The last command given from any of these three sources dictates the enabled/disabled state. If the contact input is used, Remote Cascade Setpoint is disabled when the contact is open and enabled when closed. The contact can be either open or closed when a trip condition is cleared. If the contact is closed it must be opened and re-closed to enable Remote Cascade Setpoint. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled. The Remote Rate dictates the rate at which the analog input will position the Cascade reference.

The minimum (4 mA) and maximum (20 mA) engineering unit values for this analog input should normally be configured as (or within) the configured Cascade Remote Min Setting and Remote Max Setting. The analog signal is limited accordingly, regardless of the upper and lower range values of the input. If the milliamp signal to the Remote Cascade Setpoint input is out of range (defaulted to 2–22 mA) an alarm is generated and Remote Cascade Setpoint is disabled and inhibited until the input signal is corrected. Remote Cascade must be re-enabled after the input is re-established.

Since Cascade Control also acts on the speed setpoint, it and Remote Speed Setpoint cannot be active at the same time. If Cascade is configured and active, it will be disabled as soon as Remote Speed Setpoint is enabled. Likewise, Remote Speed will automatically be disabled if Cascade is enabled. If Remote Cascade Setpoint is enabled, all other Cascade setpoint commands (Raise/Lower) are inhibited.

Cascade Control Dynamics (PID Tuning)

The Cascade PID control uses its own set of tuning parameters. These values are configurable and may be tuned at any time. Refer to the Dynamics Adjustments section in Chapter 3.

Extraction and/or Admission Control

The Extraction/Admission (Extr/Adm) controller receives an extr/adm pressure or flow signal from a field transmitter via 4–20 mA Analog Input. The Extr/Adm PID then compares this signal to the setpoint, generating an output to the Ratio-Limiter. The ratio logic ratios this input with a similar speed demand input and, based on the turbine performance parameters, produces two output signals--one to control the HP Valve and one to control the LP Valve. The limiter logic restricts the valve demands within the boundaries of the turbine steam map.

Extr/Adm control may be enabled and disabled from tunables, remote contact input, or Modbus. The last command given from any of these three sources dictates the Extr/Adm PID's control state. If the contact input is used, Extr/Adm is disabled when the contact is open and enabled when closed. The contact can be either open or closed when a trip condition is cleared. If the contact is closed it must be opened and re-closed to enable Extr/Adm. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled.

Extr/Adm Setpoint (Extr/Adm Reference)

The Extr/Adm setpoint is adjustable with raise or lower commands from tunables, remote contact inputs, or Modbus. In addition, a 4–20 mA analog input may be assigned for Remote Extr/Adm Setpoint, allowing an external device (e.g. DCS, PLC) to remotely set the Extr/Adm setpoint. When the control is powered-up, the setpoint is reset to the configured Setpoint Initial Value.

The Extr/Adm setpoint range must be defined by Min Extr/Adm Setpoint and Max Extr/Adm Setpoint in the application's configuration sheets. While these parameters can be somewhat arbitrary, and are used primarily to normalize the PID to 0-100%, it is advisable that they correspond roughly to the turbine's normal operating speed range—that is, the Extr/Adm process variable when the turbine is at Minimum Governor and Maximum Governor under normal operating conditions.

When a Raise/Lower Extr/Adm Setpoint command is issued, the reference moves at the configured Extr/Adm Default Rate. If the command is held for the configured Fast Rate Delay time, the reference will begin to ramp at the configured Fast Rate. Whether from tunables, remote contact inputs, or Modbus, the Raise/Lower commands are received as toggles. That is to say, the setpoint will ramp as long as the command is active.

WARNING **The user should consider some appropriate engineering solution if there is any failure mode for the contact inputs or Modbus commands that might keep them active unintentionally.**

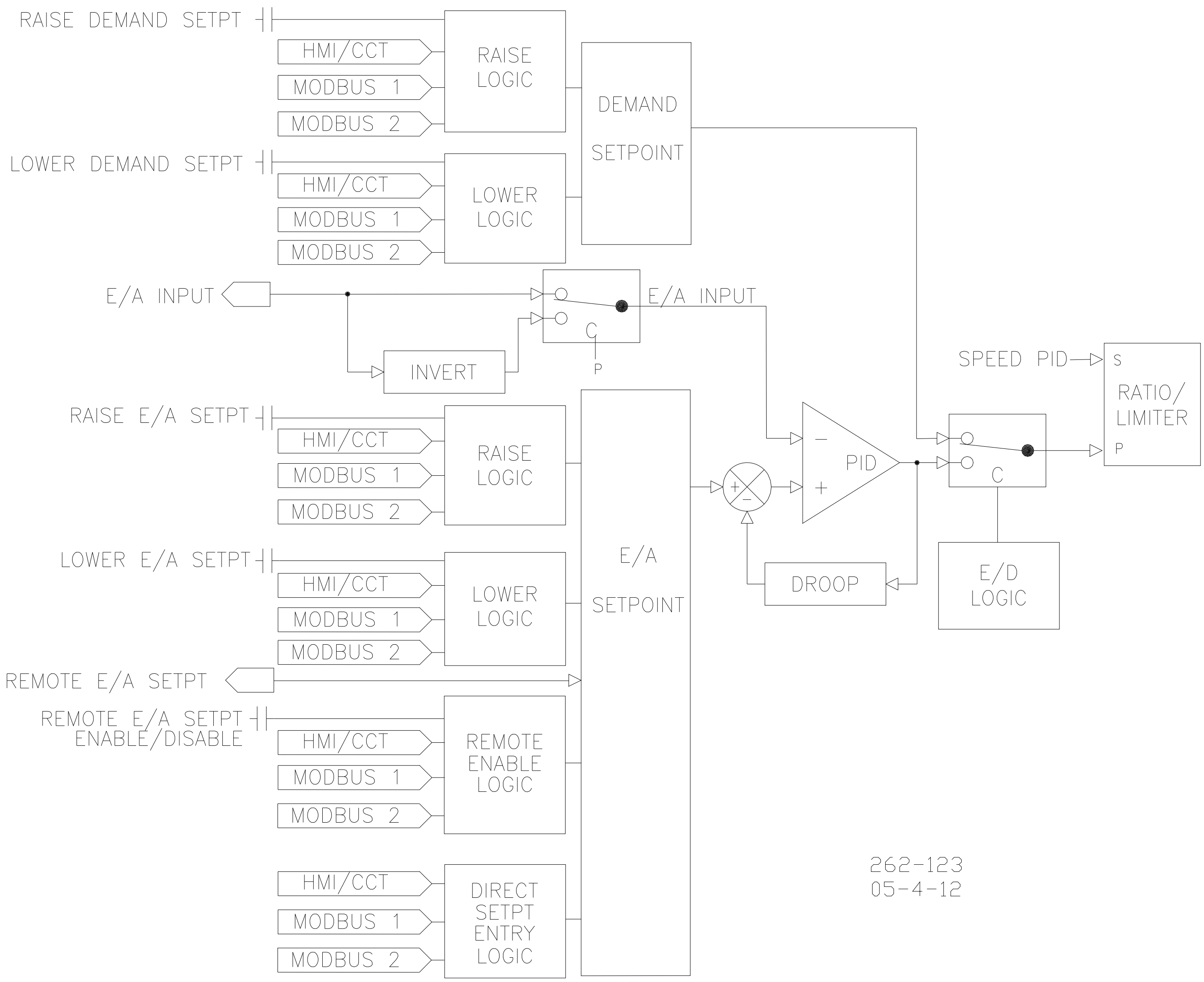


Figure 2-8. Extr/Adm Control Functional Diagram

Extr/Adm Setpoint Tracking

To reduce the number of steps required to enable Extr/Adm control bumplessly, the Extr/Adm setpoint can be programmed to track the Extr/Adm process input when disabled. With Extr/Adm Setpoint Tracking configured, the Extr/Adm PID will be satisfied when enabled, thus there is no immediate or radical process correction required. After enabling, the reference will ramp to the active commanded setpoint, if any, or respond to Raise/Lower commands as normal.

If Setpoint Tracking is not configured, the reference will remain at its last setting (running or shutdown). When Extr/Adm control is enabled, and the sensed process signal does not match setpoint, the Extr/Adm PID will instantly take control and begin to move the pressure demand signal. If one of the permissives is lost or Extr/Adm is disabled, the Extr/Adm reference will remain at the last setting until otherwise adjusted.

All pertinent Extr/Adm control parameters are available through Modbus. See Chapter 4 for a complete Modbus list.

Extr/Adm Droop

When sharing control of a parameter with another external controller, the Extr/Adm PID can also be configured with a droop feedback signal for control loop stability, helping prevent multiple control loops from *fighting*. This feedback signal is a percentage of the Extr/Adm PID's output. If Extr/Adm droop is used, the Extr/Adm input signal will not match the Extr/Adm setpoint when in control. The difference will depend on the amount (%) of droop configured and the output of the Extr/Adm PID.

The droop value is subtracted from the normalized Extr/Adm process variable input and is calculated as a percentage of the Ratio-Limiter pressure demand (P-demand). In other words, after the Extr/Adm input and setpoint are normalized as a percentage of Extr/Adm setpoint range (Max Extr/Adm Setpoint–Min Extr/Adm Setpoint), droop is subtracted, itself a percentage of the current P-demand.

Invert Extr/Adm Input

Depending on the control action required, the Extr/Adm input signal can be inverted. If a decrease in valve position is required to increase the Extr/Adm process signal, such as for typical admission turbines, Invert Extr/Adm Input should be configured.

If the Extr/Adm input signal fails (defaulted to 2–22 mA) during operation, the control can be configured to trip, continue running and ramp the LP Valve to its open limit, continue running and ramp the LP Valve to its closed limit, or switch directly to Manual Pressure (Flow) Demand control.

Remote Extr/Adm Setpoint

One of the 4–20 mA analog inputs can be assigned to remotely position the Extr/Adm reference. Typically, some external process control (e.g. PLC, DCS) may interface with this input to regulate the turbine's Extr/Adm pressure.

The Remote Extr/Adm Setpoint function may be enabled and disabled from tunables, remote contact input, or Modbus. The last command given from any of these three sources dictates the enabled/disabled state. If the contact input is used, Remote Extr/Adm Setpoint is disabled when the contact is open and enabled when closed. The contact can be either open or closed when a trip condition is cleared. If the contact is closed it must be opened and re-closed to enable Remote Extr/Adm Setpoint. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled. The Remote Rate dictates the rate at which the analog input will position the Extr/Adm reference.

The minimum (4 mA) and maximum (20 mA) engineering unit values for this analog input should normally be configured as (or within) the configured Remote Minimum Extr/Adm Setting and Maximum Extr/Adm Setting. The analog signal is limited accordingly, regardless of the upper and lower range values of the input. If the milliamp signal to the Remote Extr/Adm Setpoint input is out of range (defaulted to 2–22 mA) an alarm is generated and Remote Extr/Adm Setpoint is disabled and inhibited until the input signal is corrected. Remote Extr/Adm must be re-enabled after the input is re-established.

If Remote Extr/Adm Setpoint is enabled, all other Extr/Adm setpoint commands (Raise/Lower) are inhibited.

Extr/Adm Control Dynamics (PID Tuning)

The Extr/Adm PID uses its own set of tuning parameters. These values are configurable and may be tuned at any time. Refer to the Dynamics Adjustments section in Chapter 3.

Extr/Adm Manual Pressure (Flow) Demand

In some instances, it is not necessary the control the Extr/Adm pressure (flow) on an Extr/Adm turbine, such as when using only Inlet Pressure/Exhaust Pressure control (see Decoupling). In this case, by configuring Extraction By-Pass, the Extr/Adm pressure (flow) demand can be controlled in manual mode. This Manual Pressure (Flow) Demand control mode is also available if the Extr/Adm pressure (flow) sensor fails while online.

The Manual Pressure (Flow) demand is adjustable with raise or lower commands from tunables, remote contact inputs, or Modbus. In addition, a 4–20 mA analog input may be assigned for Remote Manual Pressure (Flow) Demand, allowing an external device (e.g. DCS, PLC) to remotely set the demand. When the control is powered-up, the setpoint is reset to the configured Setpoint Initial Value.

The Manual Pressure (Flow) Demand range must be defined by Min Flow Setpoint and Max Flow Setpoint (typically 0 and 100%) in the application's configuration sheets.

When a Raise/Lower Manual Pressure (Flow) Demand command is issued, the reference moves at the configured Default Rate. If the command is held for the configured Fast Rate Delay time, the demand will begin to ramp at the configured Fast Rate. Whether from tunables, remote contact inputs, or Modbus, the Raise/Lower commands are received as toggles. That is to say, the setpoint will ramp as long as the command is active.

WARNING **The user should consider some appropriate engineering solution if there is any failure mode for the contact inputs or Modbus commands that might keep them active unintentionally.**

The Manual Pressure (Flow) Demand is actually P-demand, or Extraction Pressure Demand, not manual valve position. Raising Manual (Pressure) Flow Demand on an Admission or Extr/Adm turbine will decrease admission flow. However, if operating in Total Decoupled Mode (see the Ratio-Limiter section later in this chapter), the Raise/Lower Manual Pressure (Flow) Demand will act directly on valve position.

Remote Extr/Adm Manual Pressure (Flow) Demand

One of the 4–20 mA analog inputs can be assigned to remotely adjust the Extr/Adm Pressure (Flow) Demand. The maximum rate at which the remote input signal can change the Extr/Adm Pressure (Flow) Demand is configurable as the Remote Rate.

The Remote Manual Demand function may be enabled and disabled from tunables, remote contact input, or Modbus. The last command given from any of these sources dictates the enabled/disabled state. The control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled. The Remote Rate dictates the rate at which the analog input will position the Extr/Adm Manual Pressure (Flow) demand.

The minimum (4 mA) and maximum (20 mA) engineering unit values for this analog input should normally be configured as (or within) the configured Remote Minimum Pressure (Flow) Setting and Maximum Pressure (Flow) Setting. The analog signal is limited accordingly, regardless of the upper and lower range values of the input. If the milliamp signal to the Remote Manual Demand input is out of range (defaulted to 2–22 mA) an alarm is generated and Remote Manual Demand is disabled and inhibited until the input signal is corrected. Remote Manual Demand must be re-enabled after the input is re-established.

If Remote Manual Demand is enabled, all other Pressure (Flow) Demand setpoint commands (Raise/Lower) are inhibited.

Extraction-Only Control

Extraction Control enabling may be automatic or manual and performed after one of the three Start Modes has been completed, and related permissives met. Typically a turbine is controlling speed/load at or above Minimum Governor and at some minimum process load before Extraction Control is enabled. After startup, the HP and LP Valve Limiters should normally both be fully open. If the HP Valve Limiter is not fully open, it will act as a speed/load limiter and will interfere with automatic governor operation.

When configured for Extraction Control the LP Valve Limiter is high signal selected with the output of the Ratio-Limiter. Because the LP Valve Limiter is automatically ramped to 100% during startup, the LP Valve cannot be controlled below its 100% open position. All related Extraction enable permissives must be met before the application will allow the Extr/Adm PID to take control of the Extraction steam process.

There are two ways of enabling/disabling Extraction Control: manually or automatically. The manual enable/disable routine uses the LP Valve Limiter's Raise/Lower commands. The automatic routine uses an Enable/Disable command from tunables, remote contact input, or Modbus. Automatic enabling/disabling can only be performed if Use Automatic Enable is configured in the application's configuration sheets. Even with automatic enabling configured, an operator can still enable and disable Extraction Control manually, if desired.

Manual Enable/Disable

To manually enable Extraction Control, slowly lower the LP Valve Limiter until the Extr/Adm PID takes control of its process. Then, continue lowering 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 before the control will allow the LP Valve Limiter to be lowered and Extr/Adm Control enabled.

To disable Extraction Control, slowly raise the LP Valve Limiter until the Extr/Adm PID relinquishes control of its respective process. Then, continue raising the LP Valve Limiter to its maximum (open) position.

Automatic Enable/Disable

After receiving an enable command, the control will automatically lower the LP Valve Limiter at the configured LP Valve Limiter Rate. After the Extr/Adm demand is inside the steam map or the PID takes control of its process, the LP Valve Limiter will continue lowering to its minimum (closed) position at five times the configured rate. The LP Valve Limiter may be stopped at any time during the automatic enabling routine by momentarily issuing an LP Limiter Raise or Lower command.

Stopping the automatic enabling routine halts the LP Valve Limiter. The Extr/Adm PID's output will still be enabled. This allows an operator to manually adjust the LP Valve Limiter as desired. By reissuing 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 reissue an enable command.

The control accepts an Extraction enable command only if all related permissives are met. An enable/disable command may be given from tunables, a remote 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 enable/disable 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 trip condition is cleared. If the contact is closed, it must be opened and re-closed to issue an enable command. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled.

Upon receiving a disable command, the control will instantly step the LP Valve Limiter to the LP Valve's present position, then raise the LP Limiter to its maximum (open) position at the configured LP Valve Limiter Rate. At some point, depending on system conditions, the Extr/Adm PID will relinquish 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. An operator can continue the disabling routine manually, as desired, or reissue a disable command. After reissuing a disable command, the disable routine will continue raising the LP Valve Limiter to its maximum (open) position.

Admission or Extraction/Admission Control

The procedure for enabling the Extr/Adm PID with Admission or Extraction/Admission applications is the same as described above for Extraction-Only turbines. In all cases, it is assumed that an external trip valve or a Trip & Throttle Valve is used to completely stop any admission steam from entering the turbine when a system shutdown exists.

⚠WARNING

An external Adm or Extr/Adm Trip & Throttle valve is required to prevent any admission steam from entering the turbine when shut down. Otherwise, there exists a possibility of turbine runaway, possibly resulting in serious equipment damage, personnel injury, or loss of life. Configure a closed limit switch on the T&T Valve as a start permissive for additional protection.

Admission (Adm) or Extraction/Admission (Extr/Adm) Control can be enabled after one of the three Starts Modes has been completed. 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.

When configured for any Admission turbine, the control's LP Valve Limiter is low signal selected with the output of the Ratio/Limiter. Because the LP Valve Limiter is automatically ramped to 100% during startup, the LP Valve will take its demand from the Ratio-Limiter. During startup, this demand will likely be at or close to 0%. If it is necessary to have the LP Valve fully open during startup of an Admission or Extr/Adm turbine, to provide cooling to the LP turbine section for example, configure Use HSS for LP in the application's configuration sheets. This will configure the control to utilize the high signal selection of Ratio-Limiter and LP Valve Limiter demands, similar to that described previously for Extraction turbines. In this case, the Limiter will be fully open on startup only—When Extraction Control is disabled, the Limiter will not ramp open.

All related Extr/Adm enable permissives must be met before the application will allow the Extr/Adm PID to take control of the Extr/Adm steam process.

To perform a bumpless transfer into Adm or Extr/Adm control, the pressures on each side of the Admission trip valve or T&T Valve should be matched. The following procedure facilitates a bumpless transfer into Adm or Extr/Adm control:
1. Verify that all Extr/Adm enable permissives are met.
2. Match the Extr/Adm setpoint to that of the pressure on the plant side of the Extr/Adm T&T Valve. Skip this step if Setpoint Tracking is used.
3. Vary the Manual Pressure (Flow) Demand to match the turbine's internal Extr/Adm pressure to that of the pressure on the plant side of the Ext/Adm T&T valve.
4. Open the Extr/Adm T&T valve.
5. Enable Adm or Extr/Adm control.

All the functions required for bumpless enable/disable of Adm or Extr/Adm control can be performed through tunables, remote contact inputs, or Modbus.

The control accepts an enable command only if all related permissives are met. An enable/disable command may be given from tunables, a remote contact input, or Modbus. The last command given from any of these three sources dictates the state of the Extr/Adm control. When a contact input is programmed to function as an enable/disable 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 trip condition is cleared. If the contact is closed, it must be opened and re-closed to issue an enable command. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled.

The following procedure allows Adm or Extr/Adm control to be disabled in a controlled manner:

Adm or Extr/Adm Disabling Procedure:
1. Disable Adm or Extr/Adm control. (At this point the Manual Pressure (Flow) Demand will step to the Extr/Adm PID's last position, take control of the process from the PID, then ramp back to the setting that was used to enable Extr/Adm Control. This setting should be at or close to zero.)
2. If necessary, manually adjust the Manual Pressure (Flow) Demand to reach zero Extr/Adm flow.
3. Close the Extr/Adm T&T Valve.

Ratio-Limiter

The Ratio-Limiter receives input signals from the Speed and Extr/Adm Control PIDs (or Inlet/Exhaust PIDs if decoupled, see below). 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 restricts the actuator outputs within the boundaries of the turbine steam map.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed/load and extraction/admission pressure/flow levels. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When speed/load or extraction/admission demands cause the turbine to reach an operating limit, the limiter logic restricts the HP or LP Valves to maintain speed/load (speed priority) in compressor drive applications. Extraction/Admission pressure priority configuration is also by reconfiguring the software.

HP & LP Coupled Mode (Speed/Extraction)

In most cases, an extr/adm turbine needs to maintain both turbine speed/load and extr/adm pressure/flow at constant levels. Changing the position of either the HP Valve or the LP Valve affects both turbine speed/load and extr/adm pressure/flow. If either the load on the turbine or the extr/adm demand changes, both the HP Valve position and the LP Valve position must be changed to maintain speed/load and extr/adm pressure/flow.

In this operating mode, the turbine's HP and LP Valves are coupled (ratioed) together to control both processes without interacting with each other—Turbine load and extr/adm pressure are controlled by moving both valves simultaneously. Responding to a change in either process, both valves are repositioned so as not to affect the other process.

HP & LP Coupled Mode is configured by selecting Speed/Extraction for the Decoupling Type in the application's configuration sheets.

Decoupling

There are cases when the ratioing described above is not desired, requiring decoupling of one or both valve outputs. There are three decoupling options available in the software application that have been designed to continuously control speed (necessary for compressor drive applications) and a third parameter, instead of extr/adm pressure (flow).

These decoupling modes are:
- Decoupled HP (or inlet) & speed
- Decoupled LP (or exhaust) & speed
- Decoupled HP and LP (speed PID acts only on HP, without ratioing)

In any of these modes, the speed setpoint can still be manipulated by the Cascade PID or Remote Speed Setpoint to maintain another process variable.

Selecting Inlet or Exhaust Decoupling permits further configuration of that control's reference, rate, and dynamics settings, as described previously for Extr/Adm control. Refer to the earlier Extraction and/or Admission Control section for details on specific settings

HP Decoupled Mode (Inlet/Speed)

This mode is typically used when the two controlled parameters during normal operation are turbine inlet pressure (or flow) and speed/load. The turbine's HP and LP Valve actions are decoupled to allow control of a turbine's inlet pressure without interaction from speed/load changes. Turbine speed/load is controlled by only moving the LP Valve. Although turbine extr/adm pressure is not controlled, it is still limited within the turbine's configured operating limits.

The HP and LP Valve actions are, however, still coupled to control turbine speed/load without interaction from turbine inlet pressure or flow changes. Turbine inlet pressure is controlled by moving both the HP and LP valves simultaneously, based on the Decoupled Ratio algorithm, to avoid any disturbance in speed control. Responding to a change in either process, both valves are repositioned so as not to affect the other process. Turbine inlet pressure is controlled through the Inlet Decoupling PID. Speed/load can be controlled through either the Speed or Cascade PIDs.

If desired, the Inlet PID can be put into manual mode at any time, such as when process instabilities are negatively affecting turbine operation or a pressure reducing station is in operation. The HP Valve demand is then frozen but can be manually adjusted open or closed by the operator via Raise/Lower commands from tunables, remote contact inputs, or Modbus.

It is not necessary to configure an extr/adm pressure input when this decoupling mode is configured, in which case Bypass Extraction should be configured in the application's configuration sheets. However, Extr/Adm Control, even if no input is used, must be enabled manually or automatically first, to make sure that the transfer between decoupled and coupled is bumpless. Inlet Decoupled mode cannot be activated if Extr/Adm is disabled. To enable Inlet Decoupled mode, the LP Valve position must be within the steam map limits, and not limited by the LP Valve Limiter.

HP Decoupled Mode is configured by selecting Inlet/Speed for the Decoupling Type in the application's configuration sheets.

LP Decoupled Mode (Exhaust/Speed)

This mode is typically used when the two controlled parameters during normal operation are turbine speed/load and exhaust pressure (or flow). The turbine's HP and LP Valve actions are decoupled to allow control of a turbine's exhaust pressure without interaction from speed/load changes. Turbine speed/load is controlled by only moving the HP Valve. Although turbine extr/adm pressure is not controlled, it is still limited within the turbine's configured operating limits.

The HP and LP Valve actions are, however, still coupled to control turbine speed/load without interaction from turbine exhaust pressure or flow changes. Turbine exhaust pressure is controlled by moving both the HP and LP Valves simultaneously, based on the Decoupled Ratio algorithm, to avoid any disturbance in speed control. Responding to a change in either process, both valves are repositioned so as not to affect the other process. Turbine exhaust pressure can be controlled through the Exhaust Decoupling PID. Speed/load can be controlled through either the Speed or Cascade PIDs.

If desired, the Exhaust PID can be put into manual mode at any time, such as when process instabilities are negatively affecting turbine operation or a pressure reducing station is in operation. The LP Valve demand is then frozen but can be manually adjusted open or closed by the operator via Raise/Lower commands from tunables, remote contact inputs, or Modbus.

It is not necessary to configure an extr/adm pressure input when this decoupling mode is configured, in which case Bypass Extraction should be configured in the application's configuration sheets. However, Extr/Adm Control, even if no input is used, must be enabled manually or automatically first, to make sure that the transfer between decoupled and coupled is bumpless. Exhaust Decoupled mode cannot be activated if Extr/Adm is disabled. To enable Exhaust Decoupled mode, the LP Valve position must be within the steam map limits, and not limited by the LP Valve Limiter.

LP Decoupled Mode is configured by selecting Exhaust/Speed for the Decoupling Type in the application's configuration sheets.

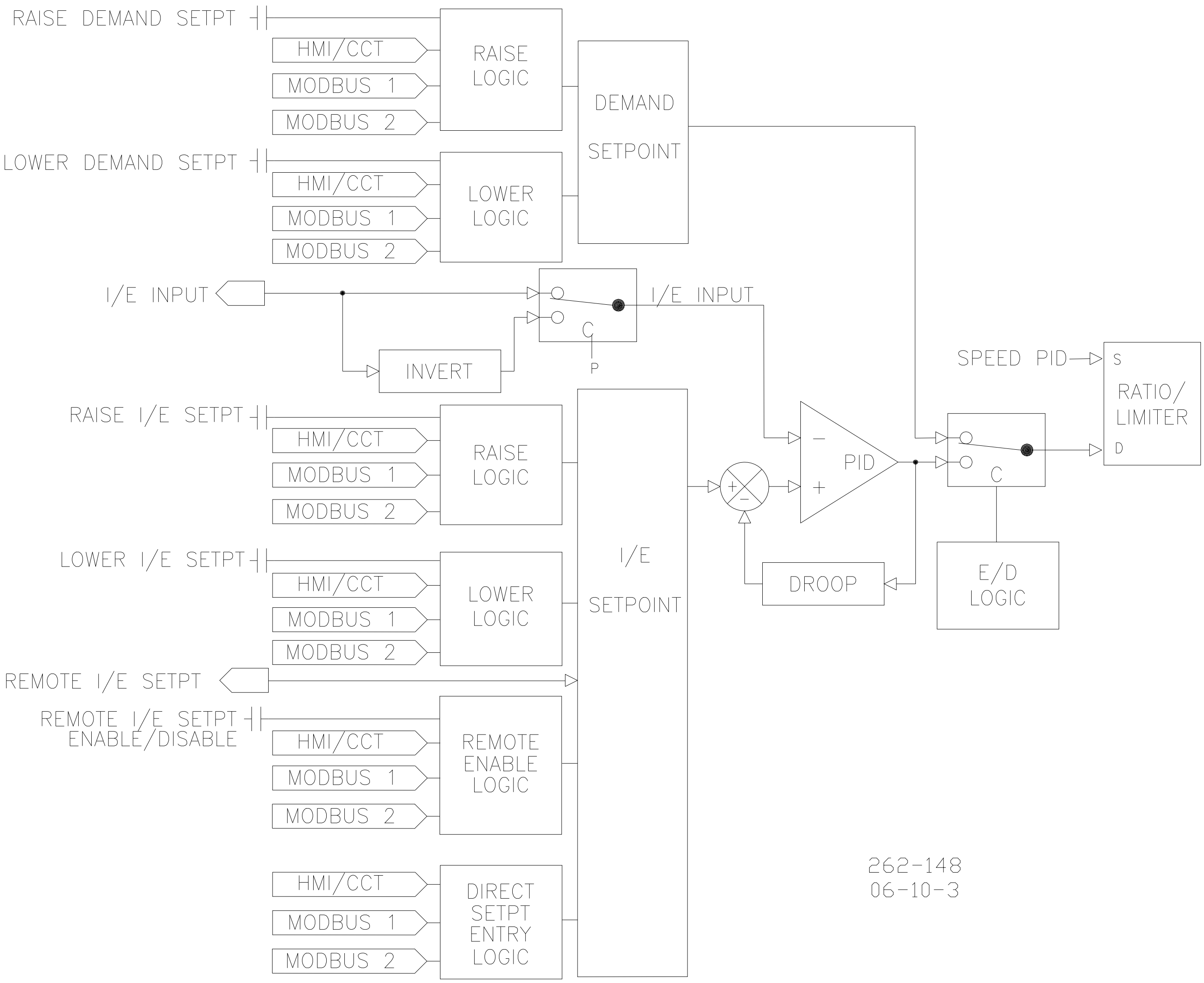


Figure 2-9. Inlet/Exhaust Decoupling Control Functional Diagram

HP & LP Total Decoupled (No Ratioing)

This mode is typically used when the two controlled parameters during normal operation are turbine inlet pressure (or flow) and exhaust pressure (or flow). The turbine's HP and LP Valve actions are fully decoupled, bypassing the Ratio-Limiter.

> **⚠WARNING**
>
> **No Steam Map limiting is available in Total Decoupled Mode. It is the turbine operator's responsibility to ensure that the HP and LP Valves are controlled in a safe operating range.**

The HP Valve can be positioned by the Speed or Cascade PIDs, and the LP Valve is positioned by the Extr/Adm PID. The decoupled configuration allows control of a turbine's inlet pressure without interaction from exhaust flow changes. Turbine inlet pressure is controlled by moving the HP Valve only, and exhaust pressure is controlled by moving the LP Valve only.

The turbine's HP and LP Valve actions are also decoupled to control turbine exhaust pressure/flow without interaction from turbine inlet pressure/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 is controlled through the Cascade PID and turbine exhaust pressure is controlled through the Ext/Adm PID. Therefore, connect the inlet steam pressure transmitter to an analog input as the Cascade controller's process variable and configure the Cascade controller in the application's configuration sheets. Similarly, connect the exhaust pressure transmitter to the Ext/Adm pressure input and configure Ext/Adm control.

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 Control and represents the Speed or Casc PID demand. The P input signal originates from the Ext/Adm PID or the Extr/Adm Manual Pressure (Flow) Demand, depending on selected modes, and represents Ext/Adm Pressure (Flow) Demand. The D input signal originates from the Inlet/Exhaust PID when either decoupling mode is selected. The DC 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.

The P signal must pass through map limiters before it used in the ratioing equations. The P signal is limited because speed priority is defaulted for compressor applications.

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 turbine operating limit is labeled and displayed graphically. All Limiters are based on the entered steam map values and actual HP and LP Valve positions (as derived from the control's actuator driver signals).

Downstream of the limiter, the signals 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 configured for decoupled operation, digital ramps are used to transfer between Ratio-Limiters. During normal enabling and disabling of the decoupled mode, these ramps take 50 seconds to completely ramp from one Ratio-Limiter to the next. The control starts by using the Coupled Ratio-Limiter, then switches to the Decoupled Ratio-Limiter when the Cascade PID is enabled. The control switches back to the Coupled Ratio-Limiter when the Cascade PID is disabled.

The HP output signal represents HP Valve demand and is connected to the control's HP LSS bus. The LP output signal represents LP Valve demand and is connected to the control's LP LSS and HSS busses (depending upon turbine type and configuration).

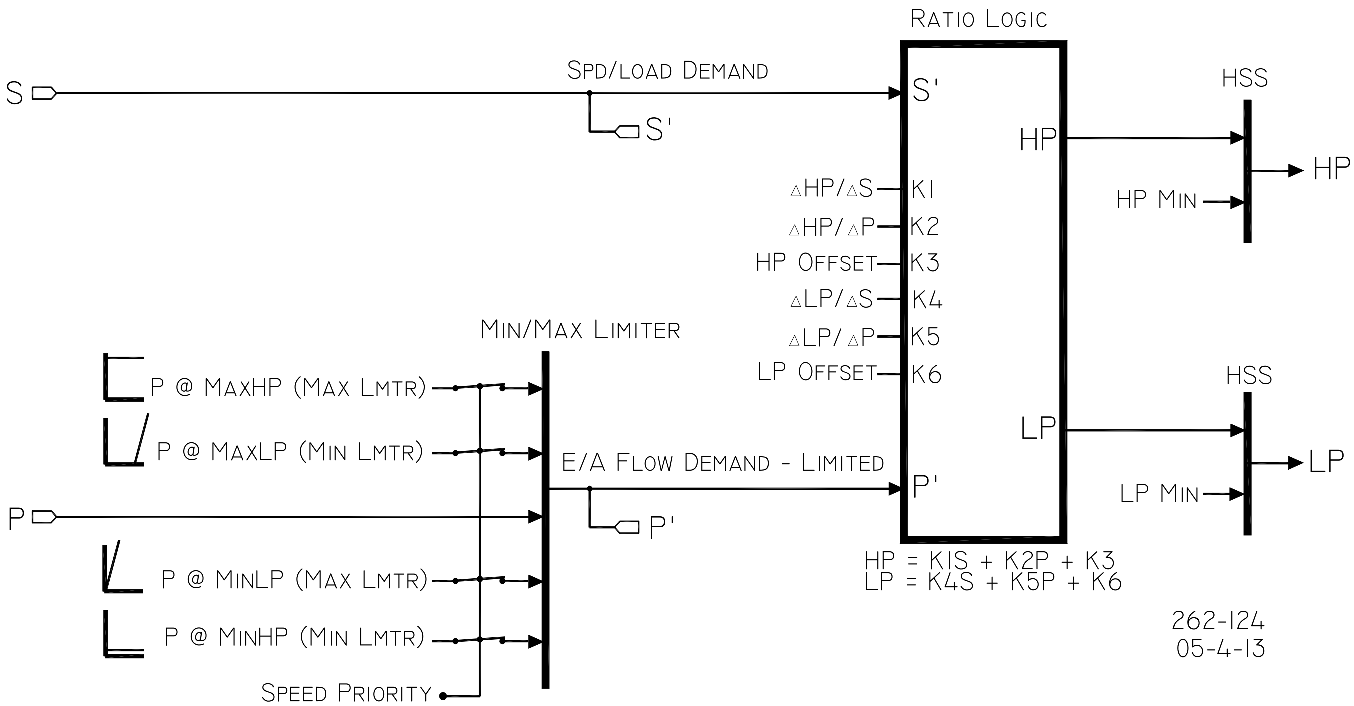


Figure 2-10. Coupled HP & LP Mode

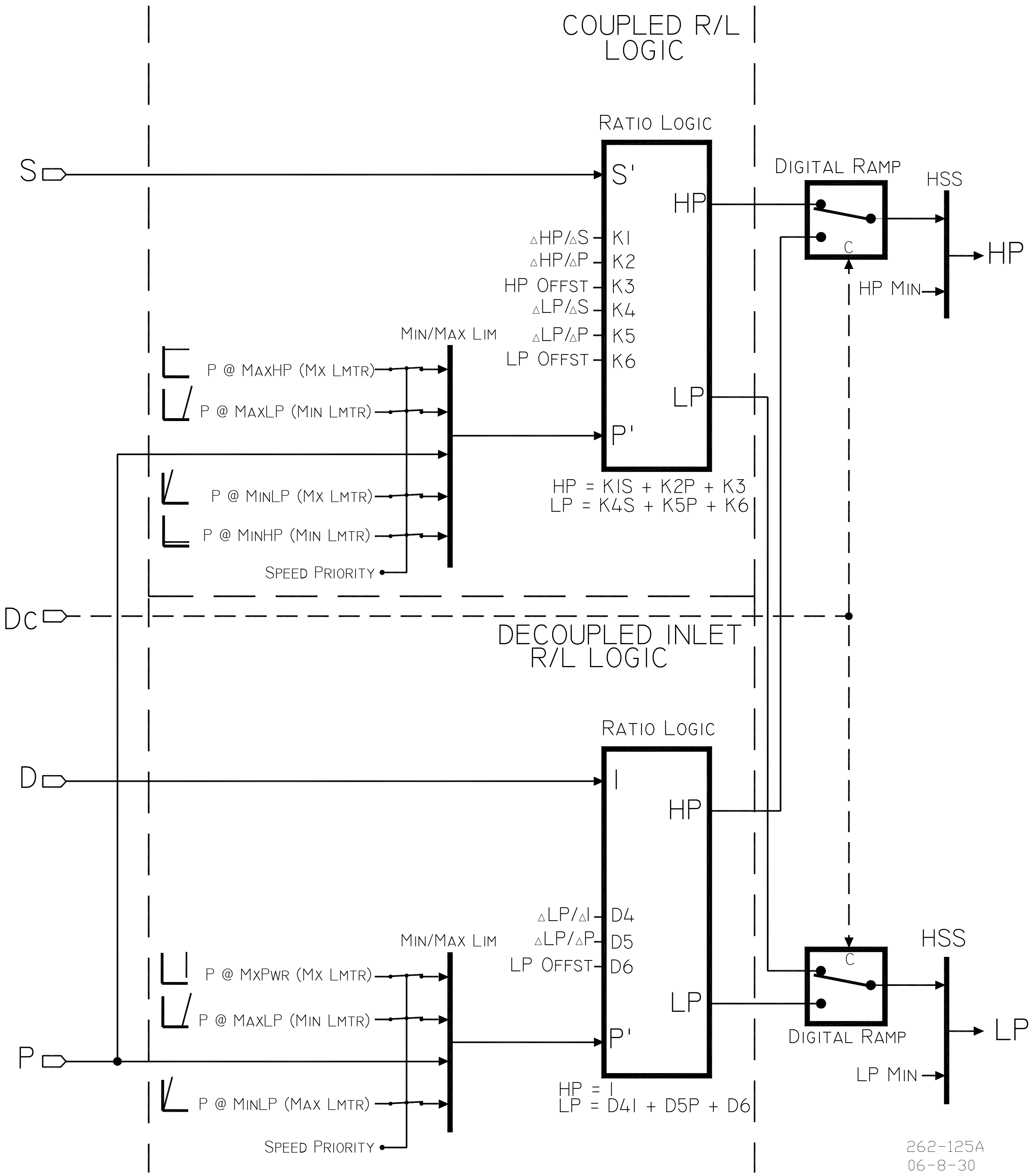


Figure 2-11. Decoupled Inlet (HP) Mode

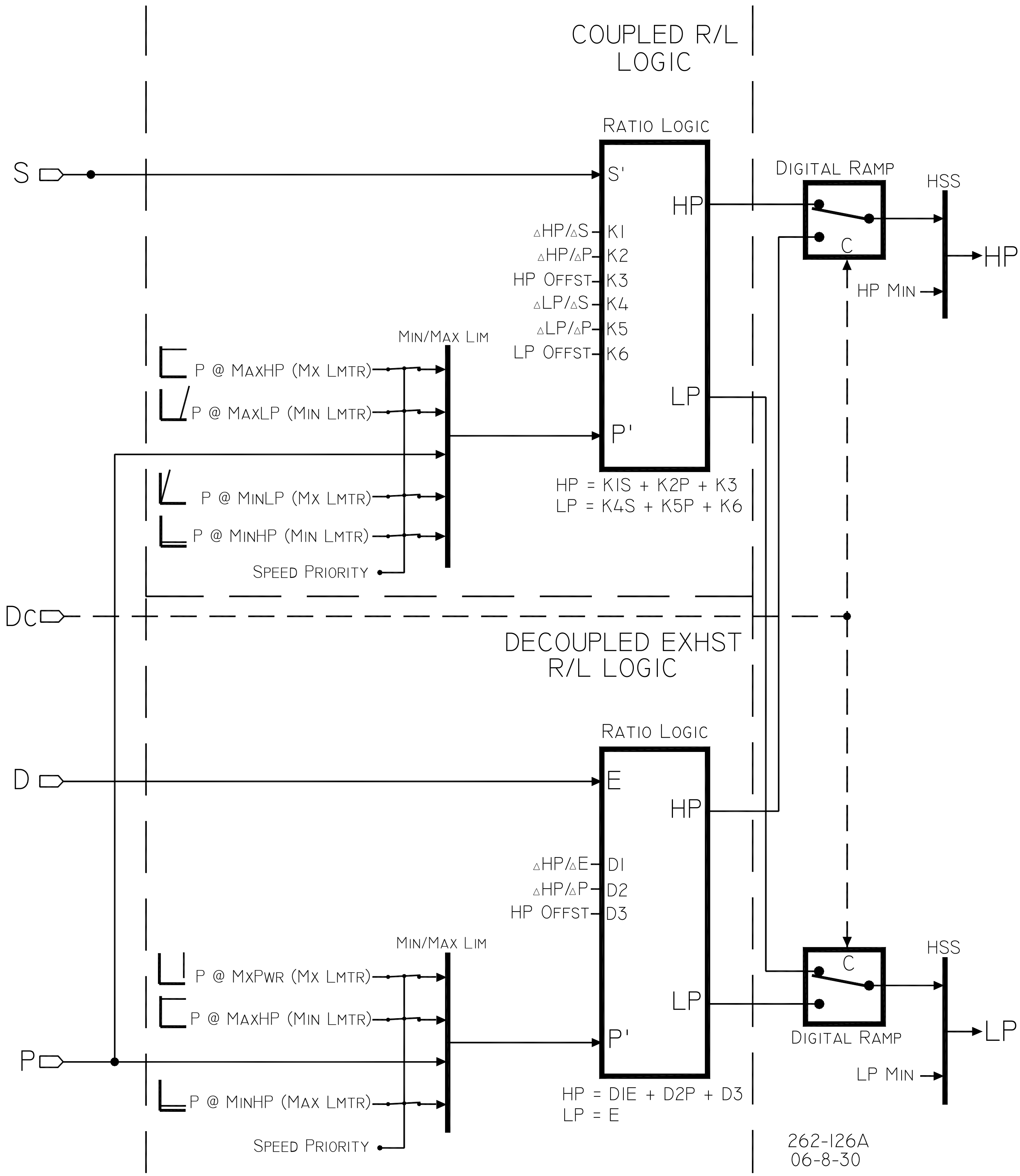


Figure 2-12. Decoupled Exhaust (LP) Mode

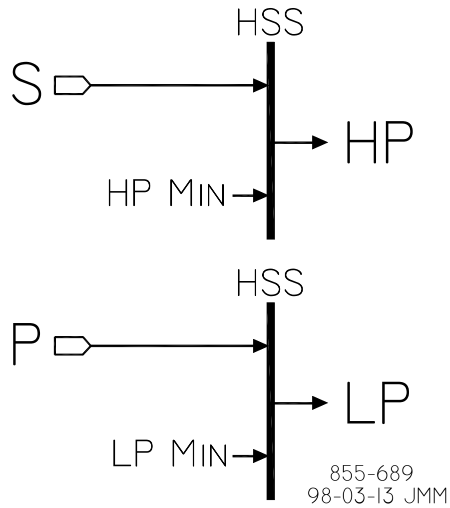


Figure 2-13. Decoupled HP & LP Mode

Valve Limiters

The HP and LP Valve Limiters limit the HP and LP Valve demands to aid in starting and shutting down the turbine. The limiters are adjustable with raise or lower commands from tunables, remote contact inputs, or Modbus. When raise or lower commands are received, the limiters move up or down, respectively, at the configured rate. In all cases, a limiter's range is defaulted to 0-100%. However, these limits are configurable in the application's configuration sheets.

The output of the HP Valve Limiter is low signal selected with the output of the Ratio-Limiter--The lower signal will control the HP Valve position. Thus, the HP Valve Limiter limits the maximum HP Valve position.

The output of the LP Valve Limiter is high signal selected with the output of the Ratio-Limiter for extraction steam turbines, and low signal selected for admission or extraction/admission steam turbines. Thus, the LP Valve Limiter limits the minimum or maximum LP Valve position, depending on the type of turbine configured.

If configured for semi-automatic starts, the valve limiter provides the turbine operator a mechanism for safely increasing speed during a start sequence. The valve limiters also can be used to troubleshoot system dynamic problems. If it is believed that the 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 to prevent the system from reaching a dangerous operating point.

Min HP and LP Lift

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

- Adm or Ext/Adm is configured
- Extr/Adm control is enabled
- HP Valve demand is above the Min HP Lift limiter

The Min LP Lift limiter is used to limit the LP Valve's minimum position. This limiter is active at all times (except shutdowns) and prevents the Ratio/Limiter from taking the LP Valve fully closed. However, during shutdown conditions the LP Valve is taken fully closed. Unless specified by the turbine manufacture, this setting should be zero.

Min Lift values can be derived from the turbine's steam map. See the Extr/Adm Steam Map Configuration section in Chapter 3 for examples. All pertinent valve limiter parameters are available through Modbus. See Chapter 4 for a complete Modbus list.

Turbine Starting Features

The software application provides three different starting modes: automatic, semi-automatic, and manual. One of these modes must be programmed to get the turbine from a shutdown state to speed control at minimum speed. Once a Start/Run command is issued, the speed setpoint and HP Valve Limiter are manipulated automatically by the control, or manually by the operator, depending on which start mode is configured. After a turbine start is initiated, speed will be controlled at a minimum controlling speed (Idle speed if Idle/Rated or Auto Start Sequence are configured--Minimum Governor otherwise).

A Start/Run command may be issued from tunables, remote contact input, or Modbus. If a contact input is configured for Start/Run, the 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/Run command. Likewise for Modbus commands, the Start is pulsed from a positive edge trigger.

If turbine speed is sensed when a Start/Run command is issued, the control will instantly match the speed setpoint to the sensed speed and continue towards the minimum controlling speed. 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 by the operator. If the turbine speed is first sensed within a critical speed avoidance band, the speed reference will match the actual speed after coasting to the bottom end of the critical band, and wait for action by the operator.

The Start Mode and Minimum Governor controlling speed configured will depend on normal plant operating procedures and turbine manufacturer's recommendations.

Start Permissive

A remote contact input may be used as a turbine Start Permissive. When configured as such, the contact input must be closed in order for a Start/Run command to be executed. Should the contact be open when a Start/Run is attempted, an alarm will be issued indicating that the start permissive was not met. The alarm does not need to be cleared, but the contact must be closed before the control will accept a Start/Run command. After a start, the Start Permissive contact will have no effect on operation. This input is typically from a Trip & Throttle (T&T) Valve's closed limit switch to verify that the T&T is in the closed position before startup.

Zero Speed Signal Override

The control issues a shutdown if no speed signal is detected (e.g. magnetic pickup voltage less than the typical detectable threshold ~1V_{rms}), or speed is less than the configured 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 manual or automatic speed override. For added protection, a timed limit on the override is available.

Manual Speed Override

If the Override MPU Fault function is assigned to a contact input, the loss-of-speed detection logic is overridden as long as this contact is closed or until the Override Timer expires (if configured). Opening the assigned contact input disables the override logic and re-arms the loss-of-speed detection circuit. Once re-armed, a system shutdown is executed if the sensed speed drops below the configured Failed Speed Level.

The Override Timer, up to ten minutes in length, is provided as an extra level of protection, in the event the contact input is unintentionally left closed. The timer begins when a Start/Run command is initiated. When it expires, loss-of-speed detection is re-armed--The control will execute a system shutdown if turbine speed is not above the configured Failed Speed Level when the timer expires.

Automatic Speed Override

If Manual Speed Override is not utilized (contact input not configured for Override MPU Fault), the Automatic Speed Override logic is used by the control to override the loss-of-speed detection logic during a startup. In this case, the loss-of-speed detection circuit is armed when the turbine trips and remains armed until the sensed turbine speed exceeds the configured Failed Speed Level (+25 rpm) on the subsequent start. Once re-armed, the control will execute a system shutdown if sensed speed drops below the Failed Speed Level setting.

The Override Timer, up to ten minutes in length, is provided as an extra level of protection, in the event the turbine is unable to accelerate or if the speed inputs are indeed failed. The timer begins when a Start/Run command is initiated. When it expires, loss-of-speed detection is re-armed--The control will execute a system shutdown if turbine speed is not above the configured Failed Speed Level when the timer expires.

Critical Speed Avoidance

In many applications, it is desirable to avoid certain speeds or speed ranges (or pass through them as quickly as possible) due to excessive turbine vibration or other factors. During configuration, two critical speed avoidance bands may be selected. These bands may be any speed ranges that are between idle speed and minimum governor speed. Within a critical speed range, the control moves the speed setpoint at the configured critical speed rate and does not allow the speed setpoint to stop within the critical speed avoidance band.

Any operator command on the speed reference is inhibited while the turbine crosses a critical band. But, that command, whether a Raise/Lower, Idle/Rated, Auto Sequence Halt, etc., will be executed once the turbine leaves the critical.

A speed setpoint value cannot be directly entered within the configured critical speed bands. If this is attempted, an alarm is generated and the setpoint value is rejected.

During startup, if the Speed PID cannot accelerate the unit through a critical band within a calculated length of time, a Stuck in Critical alarm will be issued and the unit tripped or returned to idle. This *calculated length of time* is double the length of time it should normally take to accelerate through the band (based on the Critical Speed Rate) and must be at least 15 seconds. If configured for Idle/Rated or Auto Start Sequence, the reference is instantly stepped to idle. If after the idle step the turbine speed remains in the critical band for another similar time period, the unit is tripped. For Minimum Governor starts, or during a controlled stop sequence, the control will simply shutdown if the Stuck in Critical alarm is received.

All critical speed band settings must be between the Idle Speed (or Minimum Controllable Speed) and Minimum Governor settings. A configuration error will occur if an Idle setpoint is programmed within a critical speed band. The rate at which the speed setpoint moves through a critical speed band is configured as the Critical Speed Rate. It should normally be set at, but no higher than, the turbine’s rated maximum acceleration rate.

Turbine Start Modes

Manual Start Mode

The following startup procedure is employed when the Manual Start mode is configured:

1. Issue a Reset command (to reset all alarms and shutdowns).
2. Verify that the Trip & Throttle Valve is closed and issue a Start/Run command.
    - The control will ramp open the LP Valve Limiter to its maximum position at the configured LP Valve Limiter Rate. (For Extraction-only Turbines, the LP Valve position will ramp to the maximum limit until extraction is enabled. For any Admission Turbine, the LP Valve position will vary to maintain zero extr/adm flow or open fully, depending upon the configuration.)
    - The control will ramp open the HP Valve Limiter to its maximum position at the configured HP Valve Limiter Rate.
    - The speed setpoint will ramp from zero to the minimum controlling speed setting at the configured Rate to Min.

3. Open the HP Trip & Throttle Valve at a controlled rate.
   - When turbine speed increases to the minimum controlling speed, the Speed PID will take control of turbine speed by throttling the HP Valve.
4. Open the HP Trip & Throttle Valve to 100%.
   - Speed remains at the minimum controlling setpoint until action is taken by the operator, or until the Auto Start Sequence, if configured, begins controlling.
   - Extr/Adm Control may be enabled using the procedures described earlier in this chapter.

WARNING **The HP Trip & Throttle Valve must be closed before initiating a Start/Run command in Manual Start mode. If a Start/Run command is given while the Trip & Throttle Valve is open, there exists a possibility of turbine runaway, possibly resulting in serious equipment damage, personnel injury, or loss of life.**

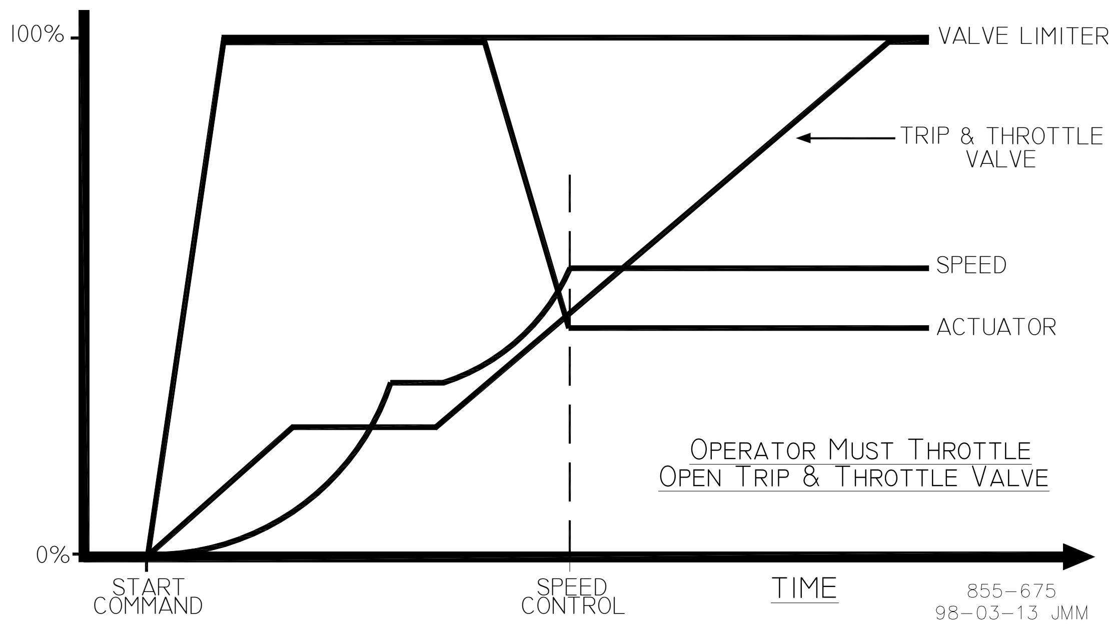


Figure 2-14. Manual Start Mode Example

Semiautomatic Start Mode

The following startup procedure is employed when the Semiautomatic Start mode is configured:

1. Issue a Reset command (to reset all alarms and shutdowns).
2. Open the HP Trip & Throttle Valve and verify that the turbine does not accelerate.
3. Issue a Start/Run command.
   - The control will ramp open the LP Valve Limiter to its maximum position at the configured LP Valve Limiter Rate. (For Extraction-only Turbines, the LP Valve position will ramp to the maximum limit until extraction is enabled. For any Admission Turbine, the LP Valve position will vary to maintain zero extr/adm flow or open fully, depending upon the configuration.)
   - The speed setpoint will ramp to the minimum controlling speed setting at the configured Rate to Min.

4. Raise the HP Valve Limiter at a controlled rate.
   - When turbine speed increases to the minimum controlling speed, the Speed PID will take control of turbine speed by throttling the HP Valve.
5. Raise the HP Valve Limiter to 100%.
   - Speed remains at the minimum controlling setpoint until action is taken by the operator, or until the Auto Start Sequence, if configured, begins controlling.
   - Extr/Adm Control may be enabled using the procedures described earlier in this chapter.

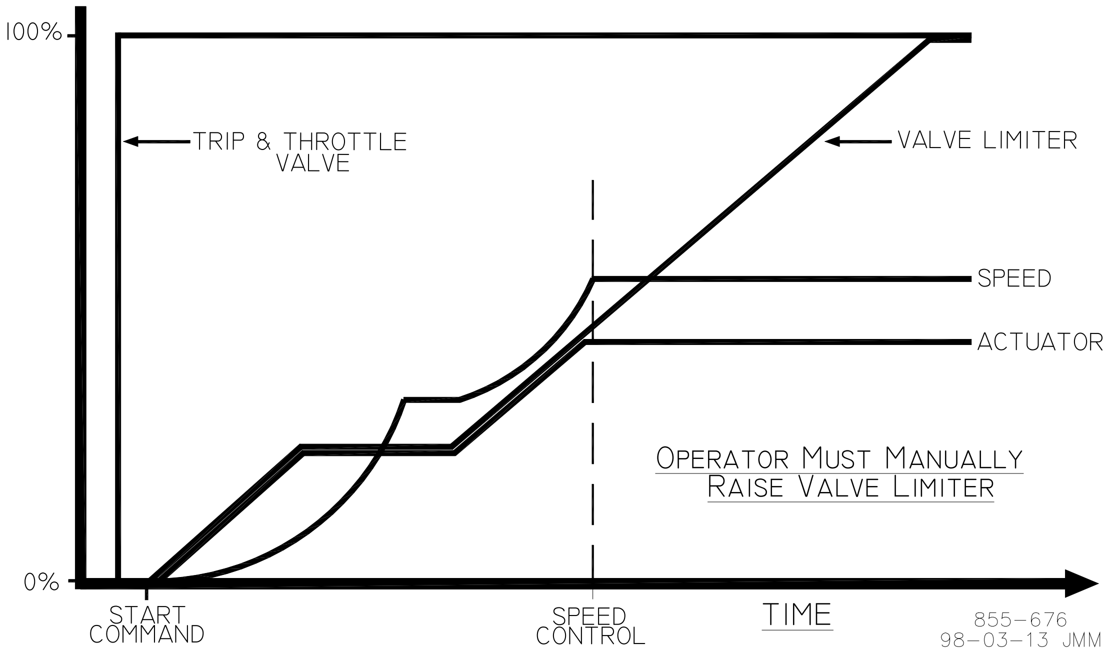


Figure 2-15. Semiautomatic Start Mode Example

Automatic Start Mode

The following startup procedure is employed when the Automatic Start mode is configured:

1. Issue a Reset command (to reset all alarms and shutdowns).
2. Open the HP Trip & Throttle Valve and verify that the turbine does not accelerate.
3. Issue a Start/Run command.
   - The control will ramp open the LP Valve Limiter to its maximum position at the configured LP Valve Limiter Rate. (For Extraction-only Turbines, the LP Valve position will ramp to the maximum limit until extraction is enabled. For any Admission Turbine, the LP Valve position will vary to maintain zero extr/adm flow or open fully, depending upon the configuration.)
   - The HP Valve Limiter will ramp to its maximum position at the configured HP Valve Limiter Rate.
   - The speed setpoint will ramp to the minimum controlling speed setting at the configured Rate to Min.
   - When turbine speed increases to match the ramping setpoint, the Speed PID will take control by throttling the HP Valve.

- Speed remains at the minimum controlling setpoint until action is taken by the operator, or until the Auto Start Sequence, if configured, begins controlling.
- Extr/Adm Control may be enabled using the procedures described earlier in this chapter.

The Automatic Start routine may be aborted at any time by issuing HP Valve Limiter Raise or Lower commands or an Emergency Shutdown.

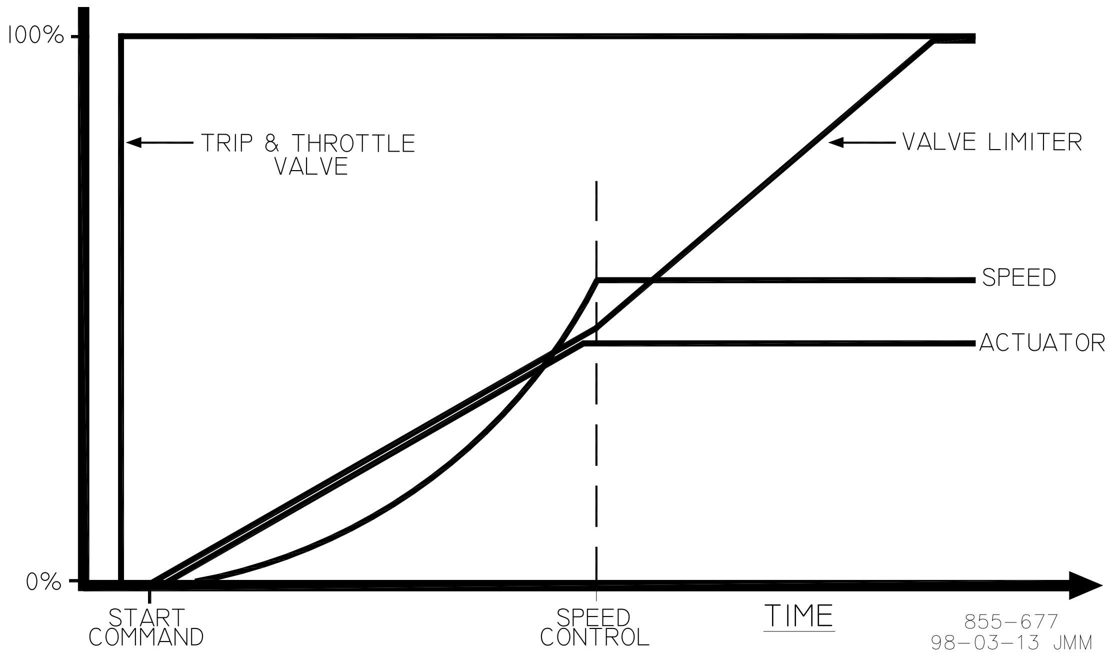


Figure 2-16. Automatic Start Mode Example

Turbine Start Speeds

Minimum Governor

Selecting a Minimum Governor start will ramp the speed setpoint from zero to the Minimum Governor setpoint at the configured Rate to Min.

Idle/Rated (Single Idle)

The Idle/Rated function gives the operator the ability to move between a configured Idle speed and Rated speed (Minimum Governor) at a configured rate. The selection of Idle or Rated speed setpoint positions can be made through tunables, remote contact inputs, or Modbus. When deselected, the turbine speed ramps down to Idle.

The Idle/Rated function can be used with any configured start mode (Manual, Semiautomatic, Automatic). When a Start/Run is initiated, the speed setpoint will ramp from zero up to, and hold at, the configured Idle Speed. When the Rated command is issued, the speed setpoint ramps to Minimum Governor at the configured Rate to Min. While ramping to Minimum Governor, the setpoint can be stopped by a Raise or Lower speed command or a valid, entered speed setpoint, if analog setpoints have been programmed.

The speed setpoint cannot be stopped within a critical speed avoidance band, and any such command will be inhibited until the critical is exited. If Idle is selected while in a critical speed band, the speed setpoint will return to Idle through the critical band after exiting the top of the band.

Ramp to Rated Feature
The Idle/Rated function can be configured as a Ramp to Rated. In this configuration, the speed setpoint holds at the Idle speed setting until the Rated command is given. Upon command the speed setpoint will accelerate to Minimum Governor. However, it will not ramp back to Idle. When Rated is de-selected, the speed setpoint stops, as opposed to returning to Idle.

If Rated is de-selected while in a critical speed band, the speed setpoint will stop at the top end of the avoidance band. If the Ramp to Rated function is stopped/halted using a Raise or Lower speed setpoint command, the setpoint will continue to the upper limit of the band but then stop and await further commands..

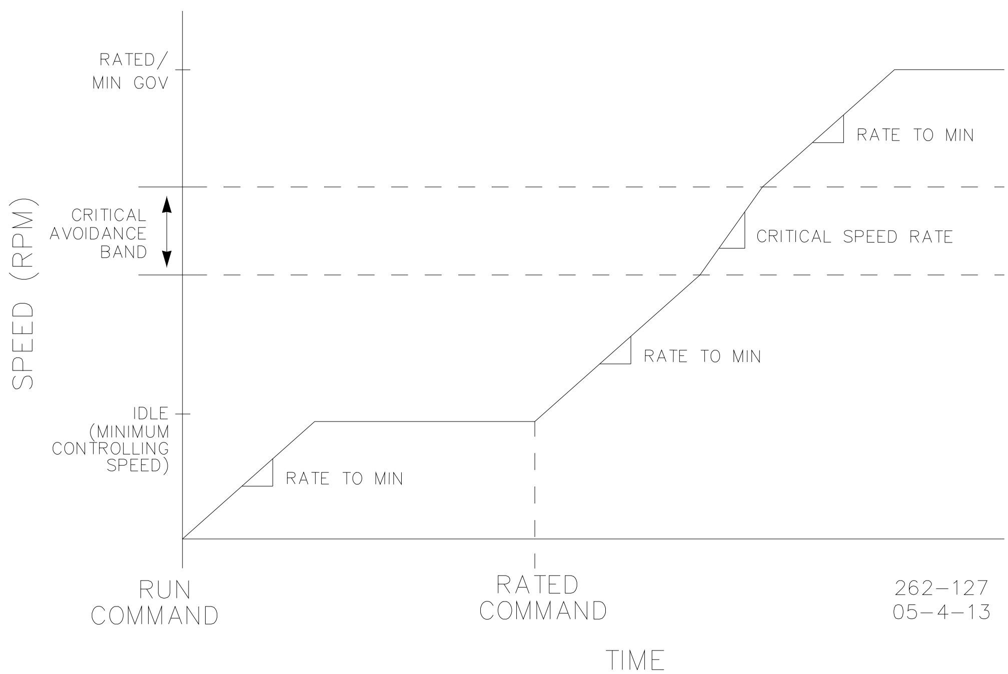


Figure 2-17. Idle/Rated Start

A Ramp to Idle or Ramp to Rated command may be selected from tunables, remote contact input, or Modbus. The last command given from any of these three sources dictates the function performed.

If a contact input is configured for Idle/Rated, Idle is selected when the contact is open, and Rated is selected when it is closed. The Idle/Rated contact may be either open or closed when a trip condition is cleared. If the contact is closed at that time, it must be opened and re-closed to initiate a Ramp to Rated. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled.

All pertinent Idle/Rated parameters are available through Modbus. Refer to Chapter 4 for a complete Modbus list.

Auto Start Sequence

IMPORTANT **Auto Start Sequence is not the same as Automatic Start Mode. Auto Start Sequence can be used with any of the three start modes.**

The Auto Start Sequence logic allows the control to perform a completely automatic, controlled system startup from zero speed to Minimum Governor, and may be used with any Start Mode (Manual, Semiautomatic, Automatic). The unit first ramps to a configured Low Idle speed, holding there until the configured Low Idle Delay (warm-up) time has expired. Then, the control ramps, at a configurable rate, to a configured High Idle speed, again holding until the configured High Idle Delay (warm-up) time has expired. Finally, the control will ramp to Minimum Governor.

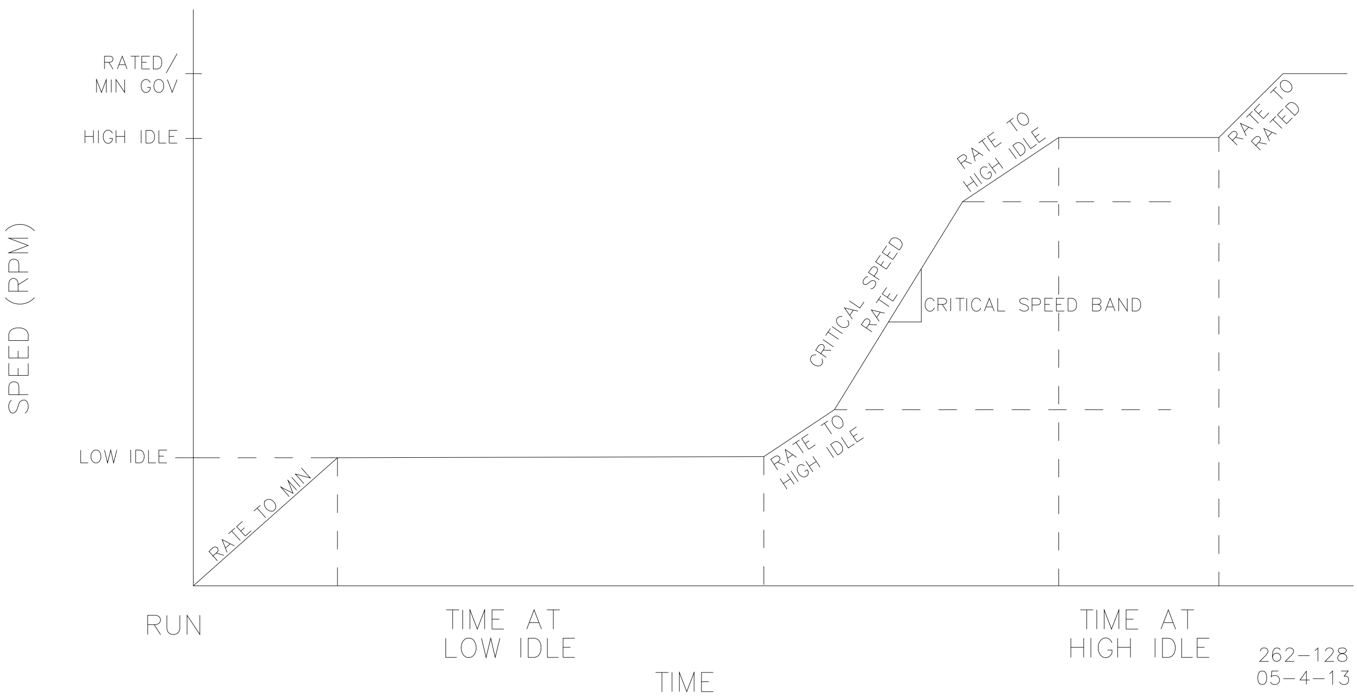


Figure 2-18. Automatic Start Sequence

The hold times and ramp rates will vary with configured *hot* and *cold* parameters according to how long the turbine has been shut down. A timer starts when a shutdown occurs and the turbine rolls below Idle (or Minimum Controllable) speed. If the shutdown is reset while the unit coasts down, the timer stops but will not reset (unless speed is above Minimum Governor). If the unit is not restarted, the timer will continue until a subsequent start and run above Minimum Governor. When a Start/Run is initiated, this timer value is compared to the configured hot and cold time values to generate the appropriate idle times and ramp rates. If the timer value exceeds the configured Cold Start Hours, the cold parameters are used. Conversely, the hot parameters are used if the timer value is less than the configured Hot Start Hours. If the timer is between hot and cold values, the control interpolates between the hot and cold data points to determine the appropriate ramp rates and hold times.

IMPORTANT **The hot hours value should be configured less than the cold hours value. Otherwise, the control cannot interpolate between settings. In this case, the higher hot hours value is ignored, and the control will use either the hot or cold idle delays and ramp rates, depending upon the current timer value relative to the configured cold hours value.**

For example, consider 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 MIN
LOW IDLE DELAY (HOT) = 10 MIN
HI IDLE SETPT = 2000 RPM
RATE TO HI IDLE (COLD) = 5 RPM/SEC
RATE TO HI IDLE (HOT) = 15 RPM/SEC
HI IDLE DELAY TIME (COLD) = 15 MIN
HI IDLE DELAY TIME (HOT) = 5 MIN
RATE TO RATED (COLD) = 10 RPM/SEC
RATE TO RATED (HOT) = 20 RPM/SEC
MINIMUM GOVERNOR SETPOINT = 3400 RPM

If, at the next start, the unit's Hours Since Trip timer was at 12 hours, the control would interpolate between the Hot and Cold parameters and use the following rates and delays:
LOW IDLE DELAY = 20 MIN
RATE TO HI IDLE = 10 RPM/SEC
HI IDLE DELAY = 10 MIN
RATE TO RATED = 15 RPM/SEC

Based on this example, the speed setpoint would ramp to 1000 rpm at the configured Rate to Min and hold for 20 minutes; then move to 2000 rpm at 10 rpm/sec and hold there for 10 minutes; and lastly, move to 3400 rpm at 15 rpm/sec. At 3400 rpm, the sequence would be completed.

IMPORTANT **The control will automatically set the Hours Since Trip timer to 1000 hours to insure that a cold start is selected after a control system power-up. This timer will reset only after a Start is initiated and speed increases past idle (or minimum controllable).**

The Auto Start Sequence can be stopped and restarted, if desired, by issuing Halt/Continue commands, which can be made through tunables, remote contact inputs, or Modbus. Any Speed Raise/Lower or Speed Setpoint entry will also halt the sequence. Alternatively, the Auto Start Sequence can be configured to automatically halt at each idle setpoint.

When the sequence is halted, the delay timers do not stop if they have already started counting. 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 Idle Delay Time, which in this example would be 5 minutes. And, if a Speed Raise/Lower or Speed Setpoint entry cause the speed to exceed the idle setpoint while the sequence is halted, that idle delay is considered complete regardless of the timer—The sequence will continue on the next ramp.

If a contact input is programmed to function as a Halt/Continue command, the sequence is halted when the contact is closed, and continued when the contact is opened. If the contact is closed when a Reset and Start are initiated, it must be opened and re-closed to halt. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled. And, a relay output can be assigned to indicate when the Auto Start Sequence is halted.

An option is available to automatically halt the Auto Start Sequence at the Low and High Idle setpoints. If the unit is started and the speed is above the Low Idle setpoint, the sequence will initialize as halted. The Halt/Continue contact input, if configured, must transition open to continue the sequence, as described previously. The hold timers are still active with this option. If Continue is commanded, and the hold timer has not expired, the sequence will remain in a timed wait until the hold timer has expired and then continue.

Emergency Shutdown

When an Emergency Shutdown occurs, both valve output signals are stepped to their minimum current levels, the Shutdown relay output de-energizes, and the shutdown cause (first-out indication) is captured and passed to Modbus.

Up to ten Emergency Shutdown inputs (remote contact inputs, de-energize to trip) can be assigned to initiate an Emergency Shutdown. The first of these ten is required. By wiring trip initiators directly into the control instead of a hard-wired trip string, the application can pass a trip signal directly to its output relay (to trip the T&T valve) and indicate the first trip condition sensed. All trip conditions are indicated through Modbus.

The last trip indication is latched and can be viewed until the shutdown conditions are reset. Once, the shutdowns are cleared, the first-out indication is also cleared, awaiting another start.

The Shutdown or Trip Relay will include the ten external trip inputs in its action by configuring Ext Trips in Trip Relay in the application’s configuration sheets. If not selected, these external trip initiators will trip the unit but will not be indicated on the Shutdown or Trip Relay output. And, by selecting Reset Clears Trip Output, these relay outputs are re-energized on a Reset command, regardless of the status of any trip initiators. This allows the external trip circuits to be reset when Shutdown or Trip Relay output is interconnected with the external logic feeding any of the ten external trip inputs.

Table 2-1 lists the control’s shutdown initiators. The numerical reference can be used as an index to determine the cause of a trip via the first-out number in the Datalog or passed to Modbus.

Shutdown Number	Shutdown Initiator
0	Trips Cleared
1	Trip - Power Up Trip
2	Trip - External Trip Input
3	Trip - External Trip #2 (if programmed)
4	Trip - External Trip #3 (if programmed)
5	Trip - External Trip #4 (if programmed)
6	Trip - External Trip #5 (if programmed)
7	Trip - External Trip #6 (if programmed)
8	Trip - External Trip #7 (if programmed)
9	Trip - External Trip #8 (if programmed)
10	Trip - External Trip #9 (if programmed)
11	Trip - External Trip #10 (if programmed)
12	Not Used
13	Trip - Modbus Link #1 Trip
14	Trip - Modbus Link #2 Trip
15	Trip - Overspeed Trip
16	Trip - Loss of All Speed Inputs
17	Trip - All Anlg I/O Mods Failed
18	Trip - All Combo Mods Failed
19	Trip - All Discrete I/O Mods Failed
20	Trip - Act #1 (HP) Fault
21	Trip - Act #2 (LP) Fault
22	Not Used
23	Not Used
24	Not Used
25	Not Used
26	Trip - Controlled Shutdown Complete
27	Trip - Configuration Error
28	Trip - Stuck in Critical Band

Table 2-1. Shutdown Initiators

Controlled Shutdown

The Controlled Shutdown function is used to stop the turbine in a controlled manner, as opposed to an Emergency Trip. When a Stop command (controlled shutdown) is issued the following sequence is performed:

1. All control functions and PIDs, except Speed and Extr/Adm, are disabled.
2. Extr/Adm control is disabled (the LP limiter is raised for Extraction applications).
3. The Speed Setpoint is ramped toward Minimum Governor at the configured Controlled Shutdown Rate to Min Gov.
4. The Speed Setpoint continues ramping toward Idle at the configured Controlled Shutdown Rate to Idle.
5. At Idle, the turbine will wait for a configured Controlled Shutdown Delay at Idle time (not applicable if Start Speed is Minimum Governor).
6. After the idle delay, the Controlled Stop is complete and a Shutdown is initiated.

As noted in step 5 above, the shutdown delay at idle feature applies only if the Start Speed is configured as Single Idle (Idle/Rated) or Auto Sequence. The Minimum Governor start has no configured Idle speed, therefore no idle delay at shutdown.

A Controlled Shutdown can be initiated or aborted from tunables, remote contact input, or Modbus. If the contact input is used, the Stop is initiated when the contact is closed and aborted when opened. The contact can be either open or closed when a trip condition is cleared. If the contact is closed it must be opened and re-closed to initiate a Stop. Similarly, the control responds to Modbus commands on the positive edge transition, regardless of whether they are pulsed or toggled.

The Controlled Shutdown sequence can be aborted at any time. By issuing a Controlled Shutdown Abort command, the control will interrupt the turbine's stop ramp. If above Minimum Governor, the control will be in the *online* state and await further action by the operator. If below Minimum Governor and above Idle, the unit will be in the *Start Sequence Hold* state and await further action. At this point the shutdown sequence can be re-initiated when desired, or the unit can be brought back to a fully operational state.

Overspeed Test Function

The Overspeed Test function allows an operator to increase turbine speed above its rated operating range to periodically test the electrical overspeed protection logic and/or the turbine's mechanical overspeed device. This includes the control's internal overspeed trip logic and any external overspeed trip device's settings and logic. An Overspeed Test will allow the speed setpoint to be increased above the normal Maximum Governor limit. This test can be performed from tunables or with remote contact inputs. This test is not permissible through Modbus.

An overspeed test is allowed only under the following conditions:

- The Speed PID must be in control.
- The Cascade, Extr/Adm, and Remote Speed Setpoint functions must be disabled.
- The Speed Setpoint must be at Maximum Governor.

1. Disable all other controllers and raise speed to maximum governor. At any time, use the tunables provided in the software application to reset the peak speed indicator.
2. Enable the Overspeed Test by toggling the appropriate contact input or tunable. After enabling the test, a 60-second overspeed test timer begins. The timer is active when no speed raise/lower commands are being given. If the timer is allowed to expire, the overspeed test is automatically disabled, and speed is ramped back to maximum governor. This is the same result as disabling the test with the contact input or tunable.
3. With the test enabled, raise speed to the overspeed trip level. The unit will trip at the configured Overspeed Trip Setpoint, and the peak speed indicator will display the highest measured speed. If desired, the control's internal trip may be bypassed to allow testing of an external device with a higher setting. See the applicable logic in the GAP™ application.
4. After the test is completed, release the contact input or tunable that enabled the test. The shutdown may be reset and the control restarted immediately, if desired.

IMPORTANT	**Enabling an overspeed test does not override the compressor anti-surge controls. On overspeed, the Anti-Surge Valves will trip to their shutdown positions whether the turbine and compressor are uncoupled or coupled and online.**

All pertinent overspeed test parameters are available through Modbus. See Chapter 4 for a complete Modbus list.

Local/Remote

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

The Local/Remote function must be configured before an operator can select the Local or Local/Remote Modes. If it is not configured, all contact inputs and Modbus commands (if Modbus is configured) are active at all times. If the Local/Remote function is configured, Local and Local/Remote Modes can be selected through tunables, a remote contact input, or Modbus.

When Local Mode is selected, the unit is controlled only through tunables on a local computer running Woodward software tools. This mode disables all contact inputs and Modbus commands, with the exceptions noted below:

- External Trip Contact In (active at all times)
- External Trip 2 - 10 Contact Ins (active at all times, if configured)
-
- Override MPU Fault Contact In (active at all times, if configured)
- Start Permissive Contact In (active at all times, if configured)
- Select On-line Dynamics Contact In (active at all times, if configured)
- Local/Remote Contact In (active at all times, if configured)
- Local/Remote Modbus Command (active at all times, if Modbus configured)
- Trip Command Modbus Command (active at all times, if Modbus configured)

When Local/Remote Mode is selected, the unit can be controlled through the same tunables, remote contact inputs, and/or all Modbus commands.

When using a contact input to select Local or Local/Remote Modes, a closed contact input selects the Local/Remote Mode, and an open contact input selects the Local Mode. The current, active mode is indicated through Modbus.

The application is defaulted to only allow control operation though tunables when the Local Mode is selected. If desired, this can be modified to enable all contacts inputs and Modbus commands when in Local Mode.

All pertinent Local/Remote control parameters are available through Modbus. See Chapter 4 for a complete Modbus list.

Alarms

Alarms are divided into multiple stacks: a unit alarm stack for hardware faults and general operating alarms, and a compressor alarm stack for each compressor. The unit stack is composed of several hundred alarms, most relating to faults from the Triple Modular Redundant (TMR) hardware layout. Routine control alarms are early in the list with hardware alarms following.

See the Appendix for the complete list. The alarm number can be used as an index to determine the first alarm received via the first-alarm numbers in the Datalog or Modbus.

High-Speed Datalog

The application includes a high-speed datalogging facility that can assist in troubleshooting a unit shutdown or other event. It records all typical data for the turbine and compressor(s) at a 10-millisecond sample rate. The data that are recorded are fixed. The sample rate can be changed but only with special software tools. Also, because the datalog adds to the CPUs' workload, it is disabled by default—It must first be enabled manually with Woodward software tools.

WARNING

The datalog places additional burden on the processing capability of the CPUs. Care should be exercised when utilizing the datalog so as not to create undue loading on the CPUs—CPU total load, as indicated on the application's SYS_INFO block, should be kept below 80% at all times.

The datalog is a circular buffer that is stored in CPU memory. As shown in Table 2-2, it records 10 discrete values (TRUE/FALSE) and 86 analog values for the turbine and compressor(s). This amount of data sampled every 10 ms results in a 14-second datalog--Doubling the LOG_RATE will double the datalog length (MAX_SEC). After the buffer is full, the datalog begins overwriting the oldest data. After the datalog has been enabled, recording automatically begins when the turbine is started and automatically stops shortly after a compressor surge or unit shutdown. This time that the datalog continues after the surge or shutdown is adjustable with tunables. Starting and stopping the datalog can also be done manually to record specific transient events, process swings, etc. during commissioning or routine troubleshooting.

After the datalog is stopped, it must be downloaded from the CPU for viewing. This process, called "printing," requires Woodward's Control Assistant software (available from **www.woodward.com**). See Control Assistant's online help menu for details on printing and viewing the *.log* datalog file. The file is a comma delimited text file, so it can also be imported into most trending or spreadsheet software for viewing and data manipulation. After printing, the datalog may be restarted to continue data collection—If the datalog is restarted before a successful print of the current file to Control Assistant, the current datalog will be overwritten by the new log.

Discrete Values (TRUE/FALSE = 1/0)	**Analog Values**
Compressor 1 Surge Detected	Compressor 1 Mode / Control Status
Compressor 1 SMP Active	Compressor 1 Filtered Flow Signal
Compressor 1 AS Valve Freeze Active	Compressor 1 Suction Pressure
Compressor 2 Surge Detected	Compressor 1 Discharge Pressure
Compressor 2 SMP Active	Compressor 1 Flow Pressure
Compressor 2 AS Valve Freeze Active	Compressor 1 Suction Temp.
Compressor 3 Surge Detected	Compressor 1 Discharge Temp.
Compressor 3 SMP Active	Compressor 1 Flow Temp.
Compressor 3 AS Valve Freeze Active	Compressor 1 Flow at Sensor (Qsns)
Shutdown	Compressor 1 Flow thru Stage (Qs)
	Compressor 1 Actual Inlet Flow (Qa)
	Compressor 1 Polytropic Head (Hp)
	Compressor 1 S_PV
	Compressor 1 Control Margin
	Compressor 1 Rate PID PV
	Compressor 1 Rate PID SP

	Compressor 1 Flow Surge Capture
	Compressor 1 Speed Surge Capture
	Compressor 1 P1 Surge Capture
	Compressor 1 P2 Surge Capture
	Compressor 1 Op. Pnt. Surge Capture
	Compressor 1 Surge Counter
	Compressor 1 Decoupling Output
	Compressor 1 AS Valve HSS Output
	Compressor 1 AS Valve Demand
	Compressor 1 AS Valve Feedback
	Compressor 1 First Alarm Initiator
	Compressor 2 Mode / Control Status
	Compressor 2 Filtered Flow Signal
	Compressor 2 Suction Pressure
	Compressor 2 Discharge Pressure
	Compressor 2 Flow Pressure
	Compressor 2 Suction Temp.
	Compressor 2 Discharge Temp.
	Compressor 2 Flow Temp.
	Compressor 2 Flow at Sensor (Qsns)
	Compressor 2 Flow thru Stage (Qs)
	Compressor 2 Actual Inlet Flow (Qa)
	Compressor 2 Polytropic Head (Hp)
	Compressor 2 S_PV
	Compressor 2 Control Margin
	Compressor 2 Rate PID PV
	Compressor 2 Rate PID SP
	Compressor 2 Flow Surge Capture
	Compressor 2 Speed Surge Capture
	Compressor 2 P1 Surge Capture
	Compressor 2 P2 Surge Capture
	Compressor 2 Op. Pnt. Surge Capture
	Compressor 2 Surge Counter
	Compressor 2 Decoupling Output
	Compressor 2 AS Valve HSS Output
	Compressor 2 AS Valve Demand
	Compressor 2 AS Valve Feedback
	Compressor 2 First Alarm Initiator
	Compressor 3 Mode / Control Status
	Compressor 3 Filtered Flow Signal
	Compressor 3 Suction Pressure
	Compressor 3 Discharge Pressure
	Compressor 3 Flow Pressure
	Compressor 3 Suction Temp.
	Compressor 3 Discharge Temp.
	Compressor 3 Flow Temp.
	Compressor 3 Flow at Sensor (Qsns)
	Compressor 3 Flow thru Stage (Qs)
	Compressor 3 Actual Inlet Flow (Qa)

	Compressor 3 Polytropic Head (Hp)
	Compressor 3 S_PV
	Compressor 3 Control Margin
	Compressor 3 Rate PID PV
	Compressor 3 Rate PID SP
	Compressor 3 Flow Surge Capture
	Compressor 3 Speed Surge Capture
	Compressor 3 P1 Surge Capture
	Compressor 3 P2 Surge Capture
	Compressor 3 Op. Pnt. Surge Capture
	Compressor 3 Surge Counter
	Compressor 3 Decoupling Output
	Compressor 3 AS Valve HSS Output
	Compressor 3 AS Valve Demand
	Compressor 3 First Alarm Initiator
	Speed
	Speed Reference
	Remote Speed Setpoint
	HP Valve Demand
	Unit First Alarm Initiator
	Shutdown First Out

Table 2-2. Datalog Parameters

Chapter 3.
Interface / Configuration Overview

Introduction

The Integrated Turbine and Compressor Control application software includes several sheets of _NAME blocks to configure the turbine control. The sections below detail each of these interface sheets with recommended connections or settings for each block.

IMPORTANT

This chapter highlights basic configuration of the turbine control application only. It may be necessary to adjust other settings within the application that are not detailed in this chapter—Familiarity with the GAP™ application environment and its Help documentation are also important to understanding, commissioning, and operating this control system.

Woodward GAP blocks are grouped within categories. The category name applicable to the configuration sections detailed below is TURB_CFG. Similarly, a category named TURB_RUN includes blocks for passing operating commands from Modbus® or discrete inputs (speed raise/lower commands, for example) into the main application.

Every block within the application may be referenced with its category name and block name, such as CATEGORY.BLOCK. This name may be suffixed with an input or output connection on the block to reference the specific point (CATEGORY.BLOCK.POINT). Descriptions in the sections below utilize this naming convention. Additionally, some block inputs may be marked with a letter O or M. The former indicates an OPC tunable input (as indicated by the *) that is meant for configuration only and is generally not connected from any other GAP block.

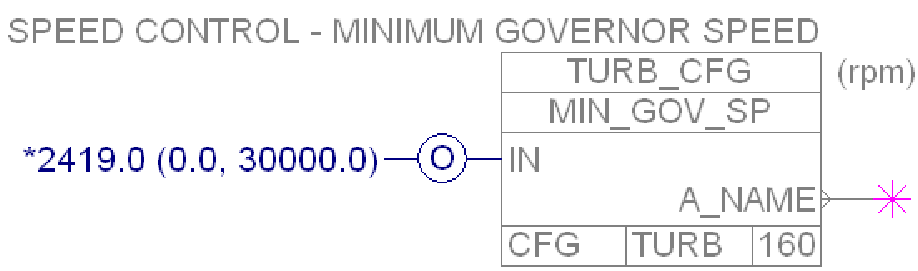


Figure 3-1. GAP Configuration Block with OPC Tunable Input

The latter indicates a typical operating command connection that may, for example, come from a Modbus block. The speed lower command, as shown in Figure 3-2, is typical of a Boolean operating input from multiple sources (Modbus, discrete input, OPC tunable.

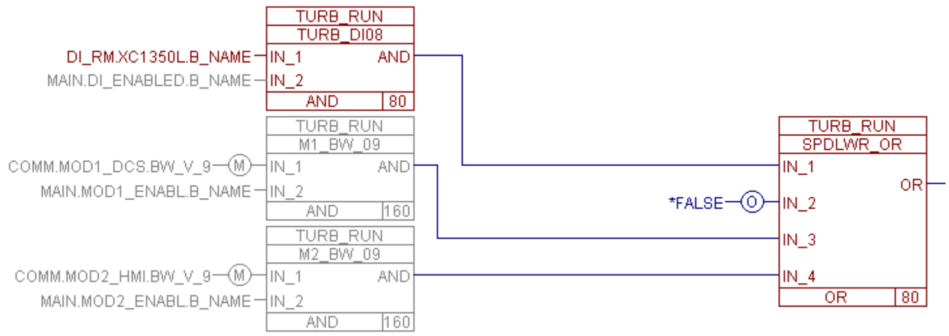


Figure 3-2. GAP Operating Command Blocks including Modbus Inputs

Any block inputs that are configured as static values are usually intended to be connected from other GAP blocks within the master application. In Figure 3-3, the Cascade process variable analog input failure indication would be connected to TURB_RUN.CAS_IN_FLD.IN. If the function is not used in the application, the input may be left at its default value, as shown in Figure 3-3, to permit software compilation.

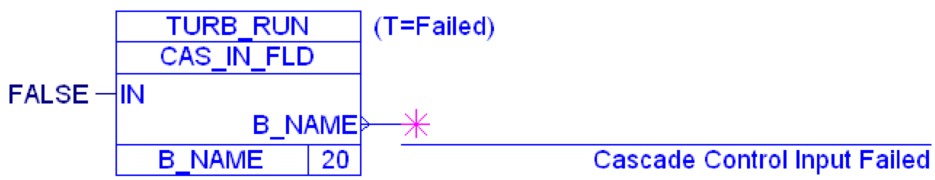


Figure 3-3. GAP Input Block

The default configuration values, except for those that require testing and tuning, such as PID gains, are representative of a typical turbine control application. But, virtually every feature can be enabled or disabled and tuned to allow full customization of the control. The turbine steam map (if applicable), startup speed diagram, manufacturer's ratings, or recommended practices will be required to properly configure the control. Most configuration can be completed prior to startup. The exceptions, which require running the turbine for testing, are as follows:

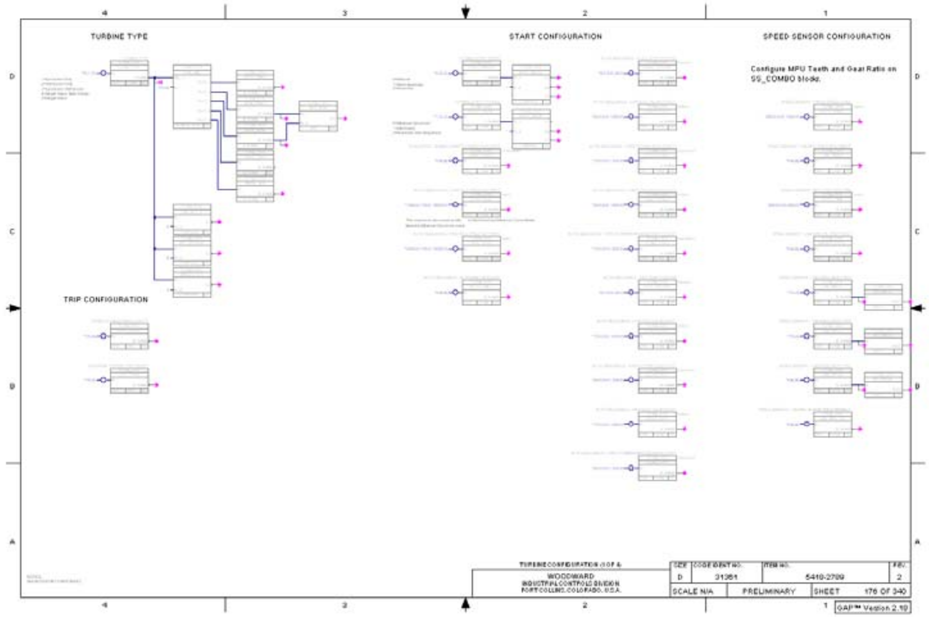
- Speed PID Tuning (Dual Dynamics, if selected)
- Extr/Adm PID Tuning (if applicable)
- Cascade PID Tuning (if applicable)
- Inlet/Exhaust PID Tuning (if applicable)
- HP/LP Valve Linearization

After initial configuration, bring the turbine on-line to complete the tuning of these controls.

Turbine Configuration Sheets

Turbine General Configuration

The selections on this sheet configure the application for turbine type, start and trip configuration, and speed sensor handling..



Turbine Settings

- **Turbine Type**
  Configure the appropriate turbine type: Single Valve, Extraction Only, Admission Only, or Extraction/Admission. Split Range actuators for a single valve turbine may also be accommodated with the two available actuator outputs, but additional software changes would be required.
- **Reset Clears Trip Output?**
  Select Reset Clears Trip Output to allow a Reset command to re-energize the Shutdown and Trip Relay outputs, even if a shutdown is still active.
- **External Trips In Trip Relay?**
  Select Ext Trips in Trip Relay to include the External Trip initiators in the Shutdown and Trip Relay outputs. If not selected, and one of the External Trips causes a shutdown, the unit will trip, but the Shutdown and Trip Relay outputs will remain energized.

Start Settings

- **Start Mode**
  Select the desired Start Mode as Manual, Semiautomatic, or Automatic. See the Turbine Start Modes section in Chapter 2.
- **Start Profile**
  Select the desired start speed as Min Governor, Idle/Rated, or Auto Start Sequence. See the Turbine Start Speeds section in Chapter 2.
- **Ramp To Rated?**
  For Idle/Rated starts, the Ramp To Rated feature configures how the control responds to an Idle command. By default, an Idle command will ramp the speed reference to idle. But, if Ramp To Rated is configured, an idle command will simply pause the ramp to rated speed, not return to idle.

- **Low Idle Speed Setpoint**
  Configure the appropriate low idle setpoint, which is used in both Idle/Rated and Auto Sequence starts.
- **High Idle Speed Setpoint**
  Configure the appropriate high idle setpoint, which is used in the Auto Start Sequence.
- **Auto Halt At Idles**
  If Auto Start Sequence was configured, select Auto Halt to force the control to automatically halt the start at the configured idles. In this configuration, the control will await a Continue command from the operator before ramping to the next speed control level.
- **Auto Start Sequence Settings (Hot/Cold Delays and Ramps)**
  If Auto Start Sequence was configured, configure the desired Hot and Cold parameters for ramps and delay times. See the Turbine Start Speeds—Auto Start Sequence section in Chapter 2.

IMPORTANT	**The hot hours value should be configured less than the cold hours value. Otherwise, the control cannot interpolate between settings. In this case, the higher hot hours value is ignored, and the control will use either the hot or cold idle delays and ramp rates, depending upon the current timer value relative to the configured cold hours value.**

Speed Sensor Settings
Primary speed sensor information (number of gear teeth and gear ratio) is configured directly on the hardware channel input blocks. Configure the number of gear teeth and gear ratio as appropriate for the installed speed sensor(s) (MPU or Proximity Probe). The control calculates speed from the MPU or Proximity Probe frequency signal as follows:

$$\text{Speed (rpm)} = \frac{\text{Frequency Input (Hz)}}{\text{Number of Teeth} * \text{Gear Ratio} * 0.016667}$$

⚠WARNING	**The speed sensor's number of teeth and gear ratio configurables may be adjusted at any time, but they are read by the control software only at system initialization. Therefore, for these settings to take effect, the control must be reset after they are configured.**

The maximum frequency sensed by the hardware channels is 25 000 Hz. And, the maximum speed, an internal limit used by the control, is calculated as 105% of the configured Overspeed Test Limit. Therefore, the following rule applies to the Gear Ratio and Number of Teeth:

$$\frac{\text{Max Speed (rpm)} * \text{Gear Ratio} * \text{Number of Teeth}}{60} < 25000\ \text{(Hz)}$$

$$\frac{\text{Overspeed Test Limit (rpm)} * 1.05 * \text{Gear Ratio} * \text{Number of Teeth}}{60} < 25000\ \text{(Hz)}$$

$$\text{Gear Ratio} * \text{Number of Teeth} < \frac{25000\ \text{(Hz)} * 60}{\text{Overspeed Test Limit (rpm)} * 1.05}$$

If this condition is not met, the largest measured speed will be:

$$\text{Speed (rpm)} = \frac{25\,000}{\text{Number of Teeth} * \text{Gear Ratio} * 0.016667}$$

- **Failed Speed Level**
  Configure the Failed Speed Level, below which speed is overridden on startup. Also, a trip is initiated if speed falls below this value while running.
- **Use MPU Override Timer?**
  Select the MPU Override Timer to configure a timed backup of the startup override function. This function will limit the time allowed for speed to be sensed after a start is issued. If speed does not increase beyond the Failed Speed level within the configured time, a trip is initiated. See the Turbine Starting Features—Zero Speed Signal Override section in Chapter 2.
- **MPU Override Time**
  Configure the MPU Override Time, in seconds.
- **Use Manual Override?**
  A discrete input may be used for the MPU Override function instead of the automatic routine. If configured, the discrete input must be closed to override the MPU on startup. The override timer is still available with this manual override.
- **Use Speed Input #2 (#3, #4)?**
  Select the appropriate number of speed inputs to be utilized. These numbers correspond to the hardware channel numbering on the Analog Combo Modules' speed inputs.
- **Use MPU Alarm Timestamping?**
  If desired, timestamping may be enabled for the various speed input alarms. If configured, the alarm timestamp will be generated from the hardware channel input (more precise time), not the alarm event latch.

Turbine Speed Control & Valve Configuration

The selections on this sheet configure the application's basic speed control and miscellaneous valve settings.

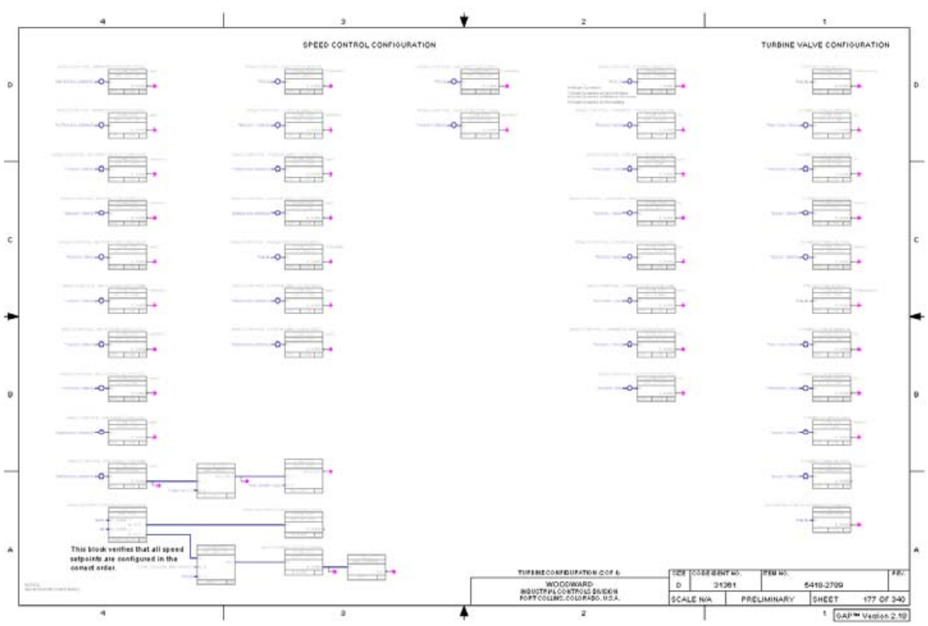


Figure 3-4. Turbine Speed Control & Valve Configuration

Speed Control Settings

- **Minimum Governor Speed**
  Configure the appropriate minimum governor speed according to the turbine manufacturer's recommendations and/or site application. This value is also used for rated speed in Idle/Rated starts.

IMPORTANT	**Exercise care when configuring Minimum Governor if speed will be used to trigger the compressor control into its online condition. In this case, it is recommended that the Minimum Governor speed be at least 3% greater than the compressor's online detection setpoint and sufficiently within the compressor's stable operating flow range.**

- **Maximum Governor Speed**
  Configure the appropriate maximum governor speed according to the turbine manufacturer's recommendations and/or site application. During normal operation (except for overspeed testing), the control will not permit the speed reference to increase beyond this setting. This value must be higher than the configured Minimum Governor Speed.
- **Setpoint Default Ramp Rate**
  Configure the appropriate ramp rate, in rpm per second, that should be applied to the speed reference. This rate is used unless another rate is specified by a particular control action, critical speed avoidance, for example.
- **Setpoint Fast Ramp Rate**
  Configure the appropriate fast ramp rate, in rpm per second, that should be applied to the speed reference when a speed raise/lower command is active for the fast rate delay time.
- **Setpoint Fast Rate Delay**
  Configure the appropriate delay time, in seconds, for triggering the setpoint fast rate.
- **Shutdown Rate To Min**
  Configure the appropriate ramp rate, in rpm per second, that should be applied to the speed reference when ramping down to minimum governor during a controlled shutdown.
- **Shutdown Rate To Idle**
  Configure the appropriate ramp rate, in rpm per second, that should be applied to the speed reference when ramping down to idle during a controlled shutdown.
- **Shutdown Delay At Idle**
  Configure the appropriate delay time, in minutes, for an idle period at the end of a controlled shutdown. If no idle is desired, configure 0.
- **Overspeed Trip Level**
  Configure the appropriate overspeed trip level as specified by the turbine manufacturer. This value must be higher than the configured Maximum Governor Speed.
- **Overspeed Test Limit**
  Configure an appropriate test limit speed, slightly higher than the overspeed trip, to permit testing of the overspeed setting. During an overspeed test, the control will not allow the speed reference beyond this setting. This value must be higher than the configured Overspeed Trip Level.

⚠WARNING	**The speed sensor's maximum input value is partially determined by the Overspeed Test Limit configurable. It may be adjusted at any time, but it is read by the control software only at system initialization. Therefore, for this setting to take effect, the control must be reset after they are configured.**

- **Critical Band Settings**
  Select and configure the desired critical band settings per the turbine/compressor manufacturers' recommendations. If criticals are configured, the speed reference will ramp through the band at the configured rate. The band's high speed should be higher than the low speed, and critical #2 should be higher than critical #1.
- **Use Remote Setpoint?**
  Select Remote Setpoint if an external 4-20mA input will be used to position the speed reference during normal operation.
- **Remote Setpoint Rate**
  Configure the appropriate ramp rate, in rpm per second, to be applied to the Remote Speed Setpoint 4-20mA input.
- **Speed Control Dynamics Settings**
  Select the desired Dynamics configuration: Single or Dual. For the latter, there are three available switch points. Configure the initial PID settings for Single or Dual Dynamics as appropriate. Fine-tuning can be performed while the turbine is running. See the Dynamics Adjustments section later in this chapter for details on P-I-D settings and general tuning procedures.

Turbine Valve Settings

- **Trip On HP Valve Fault?**
  Select to force a shutdown on an HP/V1 actuator fault. If not selected, the control will maintain normal operation and simply alarm the fault condition.
- **Turbine HP Valve Minimum**
  Configure the minimum opening percentage to be applied to the HP/V1 actuator during normal operation. For limiting and shutdown conditions, and for any single valve turbine, the control defaults to 0%. But, for Extraction/Admission turbines, this value will be used to limit closure and ensure some amount of HP cooling steam when the Extraction/Admission controller is dominating turbine operation.
- **Turbine HP Valve Maximum**
  Configure the maximum opening percentage to be applied to the HP/V1 actuator during normal operation. This is typically defaulted to 100%.
- **Turbine HP Limiter Rate**
  Configure the ramp rate, in percent per second, to be applied to HP/V1 valve limiter movements.
- **Turbine HP Manual Rate**
  Configure the ramp rate, in percent per second, to be applied to the HP/V1 valve when in manual decoupling mode.
- **Trip On LP Valve Fault?**
  Select to force a shutdown on an LP/V2 actuator fault. If not selected, the control will maintain normal operation and simply alarm the fault condition.
- **Turbine LP Valve Minimum**
  Configure the minimum opening percentage to be applied to the LP/V2 actuator during normal operation. This value will be used to limit closure and ensure some amount of LP cooling steam.
- **Turbine LP Valve Maximum**
  Configure the maximum opening percentage to be applied to the LP/V2 actuator during normal operation. This is typically defaulted to 100%.
- **Turbine LP Limiter Rate**
  Configure the ramp rate, in percent per second, to be applied to LP/V2 valve limiter movements.
- **Turbine LP Manual Rate**
  Configure the ramp rate, in percent per second, to be applied to the LP/V2 valve when in manual mode.

Turbine Extr/Adm Control Configuration

The selections on this sheet configure the application's Extraction/Admission controller, including Manual Pressure (Flow) Demand, if a two-valve turbine was configured previously.

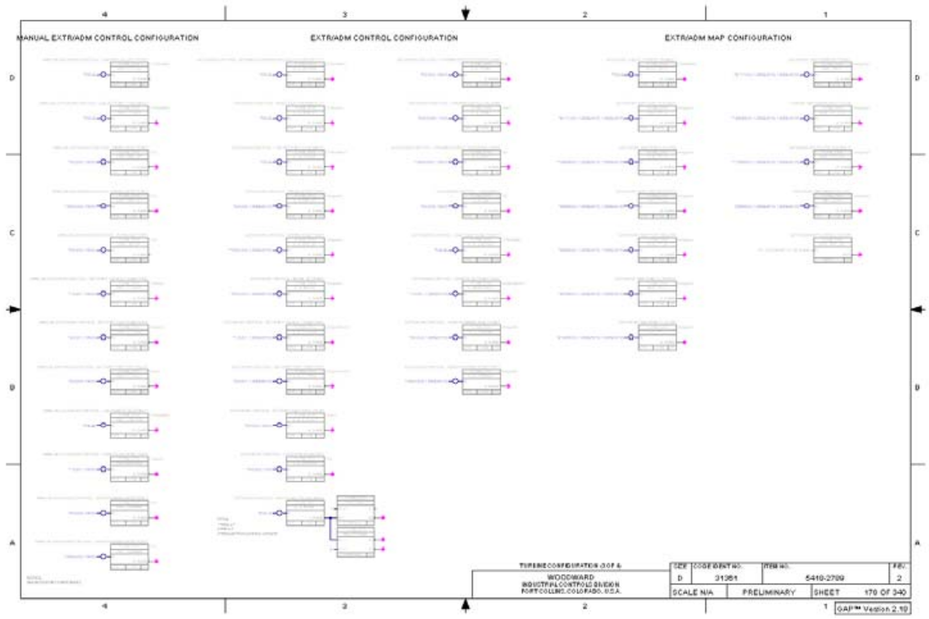


Figure 3-5. Turbine Extr/Adm Configuration

Extr/Adm Manual Pressure / Flow Control Settings

There are several scenarios in which Manual Pressure (Flow) Demand acts as a backup to automatic Extr/Adm Control, even if the operator has not commanded the control to manual (e.g. Extr/Adm sensor failed, Extr/Adm disabled, Decoupling Mode without an Extr/Adm sensor). For this reason it is recommended to examine and configure these settings for any two-valve turbine, even if normal operating procedures do not include Manual Extr/Adm Control. See the Extraction and/or Admission Control—Manual Pressure (Flow) Demand section in Chapter 2.

- **Use Manual Extr/Adm?**
  Select Use Manual Extr/Adm to configure Manual Pressure (Flow) Demand. This selection allows commands from tunables or Modbus to put the Extr/Adm controller into manual mode. If deselected, the control will still use Manual Pressure (Flow) Control as a default mode, as noted previously, but the go-to-manual commands from tunables and Modbus will be ignored.
- **Use Setpoint Tracking?**
  Select Use Setpoint Tracking to force the reference to track the Extr/Adm PID output when enabled and online. This will ensure a bumpless transfer when Manual is enabled.
- **Minimum Setpoint**
  Configure the Minimum Pressure (Flow) Setpoint to define the operating range minimum for Manual Pressure (Flow) Demand, typically 0%.
- **Maximum Setpoint**
  Configure the Maximum Pressure (Flow) Setpoint to define the operating range maximum for Manual Pressure (Flow) Demand, typically 100%.
- **Initial Setpoint**
  Configure the desired setpoint to be applied at initialization.

- **Setpoint Default Ramp Rate**
  Configure the appropriate ramp rate, in percent per second, that should be applied to the manual demand. This rate is used unless another rate is specified by a particular control action.
- **Setpoint Fast Ramp Rate**
  Configure the appropriate fast ramp rate, in percent per second, that should be applied to the manual demand when a demand raise/lower command is active for the fast rate delay time.
- **Setpoint Fast Rate Delay**
  Configure the appropriate delay time, in seconds, for triggering the setpoint fast rate.
- **Use Remote Setpoint?**
  Select Remote Setpoint if an external 4-20mA input will be used to position the manual demand during normal operation.
- **Remote Setpoint Rate**
  Configure the appropriate ramp rate, in percent per second, to be applied to the Remote Demand 4-20mA input.
- **Remote Minimum Setpoint**
  Configure the appropriate minimum value, typically 0%, used to limit the 4-20mA analog remote demand.
- **Remote Maximum Setpoint**
  Configure the appropriate maximum value, typically 100%, used to limit the 4-20mA analog remote demand.

Extraction/Admission Control Settings

- **Bypass Extr/Adm If No Decoupling Input?**
  Select Bypass Extr/Adm to bypass automatic control in Decoupled Mode, for example when an inlet or exhaust sensor is not available. Whereas the Extr/Adm controller would normally be used for automatic control of inlet or exhaust pressure, this Bypass mode will force the Extr/Adm controller into manual at all times.
- **Invert Extr/Adm Input?**
  Select Invert Extr/Adm Input if the control loop requires reverse action (e.g. Admission-only turbine).
- **Use Setpoint Tracking?**
  Select Use Setpoint Tracking to force the reference to track the process variable when not controlling. This will ensure a bumpless transfer when Extr/Adm is enabled.
- **Minimum Setpoint**
  Configure the Minimum Setpoint, in engineering units, to define the operating range minimum for Extr/Adm control. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Minimum Governor speed under normal operating conditions.
- **Maximum Setpoint**
  Configure the Maximum Setpoint, in engineering units, to define the operating range maximum for Extr/Adm control. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Maximum Governor speed under normal operating conditions.
- **Initial Setpoint**
  Configure the desired setpoint to be applied at initialization.
- **Setpoint Default Ramp Rate**
  Configure the appropriate ramp rate, in engineering units per second, that should be applied to the Extr/Adm reference. This rate is used unless another rate is specified by a particular control action.

- **Setpoint Fast Ramp Rate**
  Configure the appropriate fast ramp rate, in engineering units per second, that should be applied to the Extr/Adm reference when a setpoint raise/lower command is active for the fast rate delay time.
- **Setpoint Fast Rate Delay**
  Configure the appropriate delay time, in seconds, for triggering the setpoint fast rate.
- **Droop Percentage**
  If desired for control stability, configure an Extr/Adm Droop percentage. This droop percentage is subtracted from the reference, usually to keep multiple controls from “fighting” over a single parameter. If droop is configured, the extr/adm process variable input will not match the reference when in control—The difference will be the amount of droop.
- **Input Failure Fallback**
  Select the desired response to an Extr/Adm Pressure Input failure. If the signal from the field transmitter fails, the control can be configured to trip the turbine, move the LP/V2 valve to its minimum or maximum position, or switch to manual pressure/flow demand.
- **Extraction/Admission PID Settings**
  Configure the initial PID settings as appropriate. Fine-tuning can be performed while the turbine is running. See the Dynamics Adjustments section later in this chapter for details on P-I-D settings and general tuning procedures.
- **Deadband**
  If desired for control stability, configure a deadband percentage within which process variable movements will be ignored by the PID controller. If configured at all, the deadband value should be as small as possible.
- **Use Remote Setpoint?**
  Select Remote Setpoint if an external 4-20mA input will be used to position the Extr/Adm reference during normal operation.
- **Remote Setpoint Rate**
  Configure the appropriate ramp rate, in engineering units per second, to be applied to the remote setpoint 4-20mA input.
- **Remote Minimum Setpoint**
  Configure the Minimum Setpoint, in engineering units, to define the operating range minimum for the 4-20mA remote reference input. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Minimum Governor speed under normal operating conditions.
- **Remote Maximum Setpoint**
  Configure the Maximum Setpoint, in engineering units, to define the operating range maximum for the 4-20mA remote reference input. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Maximum Governor speed under normal operating conditions.

Extraction/Admission Map Settings
Before configuring the map, read the discussion below on steam maps and how to convert map information into a format usable by the application.

The steam map is a graphical representation of the operating range and limitations of an Extraction and/or Admission steam turbine. This map is often called a steam envelope, since normal turbine operation must be contained within the envelope lines.

The control uses the configured values to calculate the turbine's internal pressure ratios and limits. In order to get these values from the steam map, the following conditions must be met:

- The map must be linear (all lines straight).
- Lines for Extr/Adm flow = 0% and Extr/Adm flow =100% must be parallel.
- Lines for LP Valve = 0% and LP Valve = 100% must be parallel.

If these conditions do not apply, the map must be modified accordingly. If the envelope lines are not straight and parallel, use graph paper or a computer to redraw the envelope so that they are. The redrawn envelope should approximate the old envelope as closely as possible.

The lines on the envelope define the operating characteristics of the turbine. Refer to the example steam maps later in this section. The different lines or limits of a Steam map are as follows:

- The horizontal axis is turbine power (S).
- The vertical axis is HP Valve position (HP).
- The vertical line at S=100 is the maximum power limiter. This limiter prevents turbine operation beyond its maximum power limit.
- The horizontal line at HP=100 is the maximum HP flow limiter. The HP flow limiter prevents turbine operation beyond its maximum HP flow limit.
- The parallel lines labeled P=0 and P=100 define the Extr/Adm flow range from 0 flow (or maximum admission flow) to maximum Extraction flow. The P-term represents pressure demand.
- The parallel lines labeled LP=0 and LP=100 define the LP Valve position range from closed to 100% open.

The turbine's operating characteristics are configured into the application as Extr/Adm data taken from this steam map or envelope. When entering this data, it does not matter which units are used, as long as the same units are used throughout for power, and the same units throughout for HP and Extr/Adm flow.

The control calculates an Extraction and/or Admission turbine's ratios and limits from the steam map's Max Power, Max HP Flow, Point A, Point B, and Point C values (as shown in the following examples). The Points A, B, and C are identified by their respective horizontal and vertical axis values, as explained below.

As illustrated in the following examples, steam maps often show a series of parallel lines representing Extraction flow. The bottom flow line must be P=0, and the top flow line must be P=100. The P-term is used to represent pressure demand--The higher the pressure at this point in a turbine, the higher the Extraction steam flow, or the lower the Admission flow. Notice, that all the P-lines in these examples are parallel.

The remaining pair of lines on opposite sides of the envelope must correspond to LP=0 (Extraction Valve closed) and LP=100 (Extraction Valve fully open). Note that the LP=0 line is parallel to the LP=100 line, as required.

The control can be configured for three different types of steam turbines, Extraction-Only, Admission-Only, or Extraction/Admission. Following are examples for each of these configurations.

Extraction-Only Steam Map

Before an Extraction steam map can be configured into the control, Points A, B, and C must be identified (See Figure 3-6).

Typically, Point C, the intersection of the LP=0 line and the P=0 line does not exist. If this is the case, extend the LP=0 line and the P=0 line until they intersect. This will define Point C, which is required by the control to calculate the turbine's internal pressure ratios and limits.

The eight required values can be taken from the converted steam map. As an example, the following data was derived using the steam map in Figure 3-6.

1. Max Power is the load corresponding to the S=100 line, about 20 000 kW in this example.
2. Max HP Flow is the flow corresponding to the HP=100 line, about 108 000 lb/h in this example.
3. Point A is where the P=0 and LP=100 lines intersect. Max Power at Min Extraction is about 15 062 kW, and Max HP Flow at Min Extraction is about 36 000 lb/h in this example.
4. Point B is where the LP=0 and P=100 lines intersect. Min Power at Max Extraction is about 3623 kW, and Min HP Flow at Max Extraction is about 86 000 lb/h in this example.
5. Point C is where the LP=0 and P=0 lines intersect. Min Power at Min Extraction is about –3 000 kW, and Min HP Flow at Min Extraction is about 6 000 lb/h in this example.

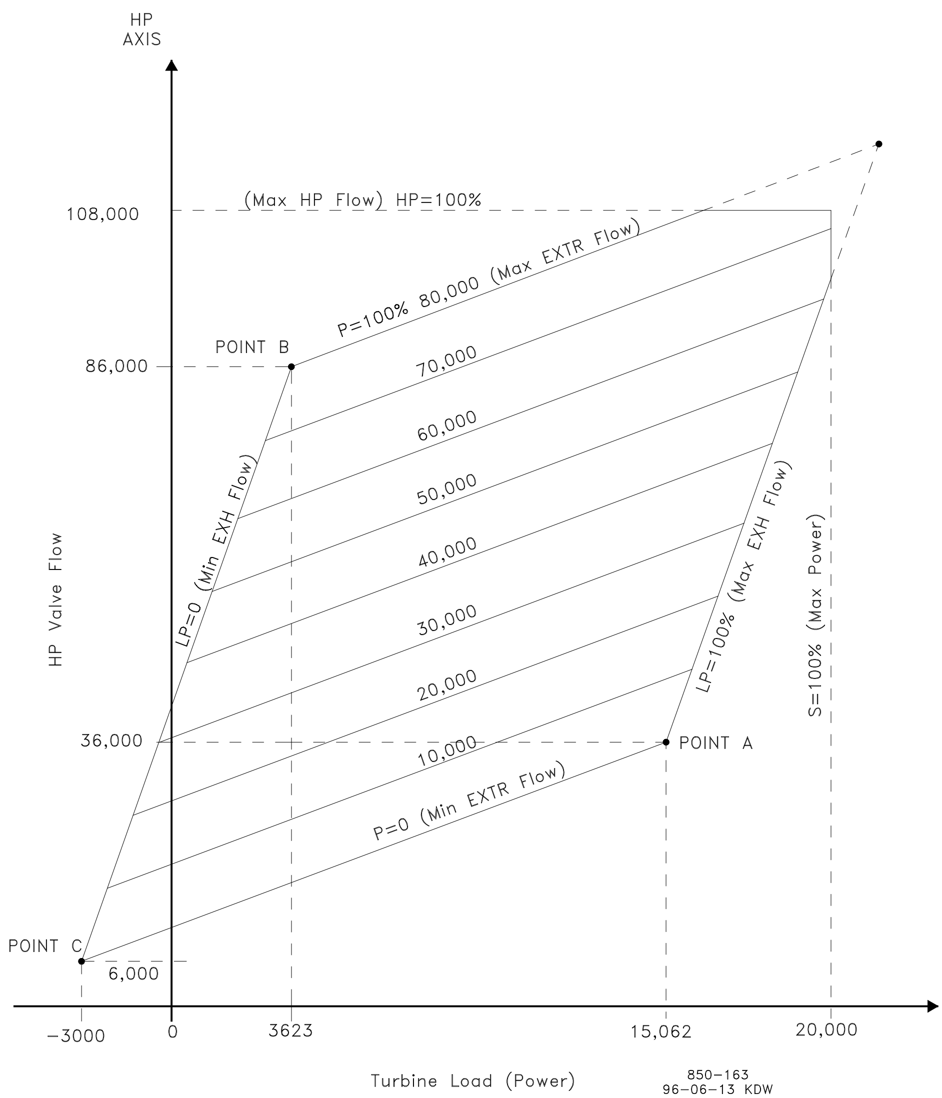


Figure 3-6. Typical Extraction Steam Map

Admission Only Steam Map

Before an Admission steam map can be configured into the control, Points A, B, and C must be identified (See Figure 3-7).

If Points A and B already exist, the only conversion necessary is the extension of the LP=100 line and the P=100 line until they intersect, which defines Point C.

If only Point A exists, the map must be modified to include Points B and C. The LP=0 line must be created. To do so, the minimum required steam flow through the back-end of the turbine must be defined. In this example, the minimum required flow is 10 000 lb/h.

1. Extend the zero Admission line (P=100%) down. Find the turbine's minimum back-end steam flow, which corresponds to Point B's HP flow. Mark the intersection of these two as Point B.
2. Draw a line through Point B created in step 1 but parallel to the LP=100 line. This is the LP=0 line (LP Valve closed).
3. Mark the intersection of the P=100 and LP=100 lines. This is Point C. Typically, Point C does not exist on the given map.

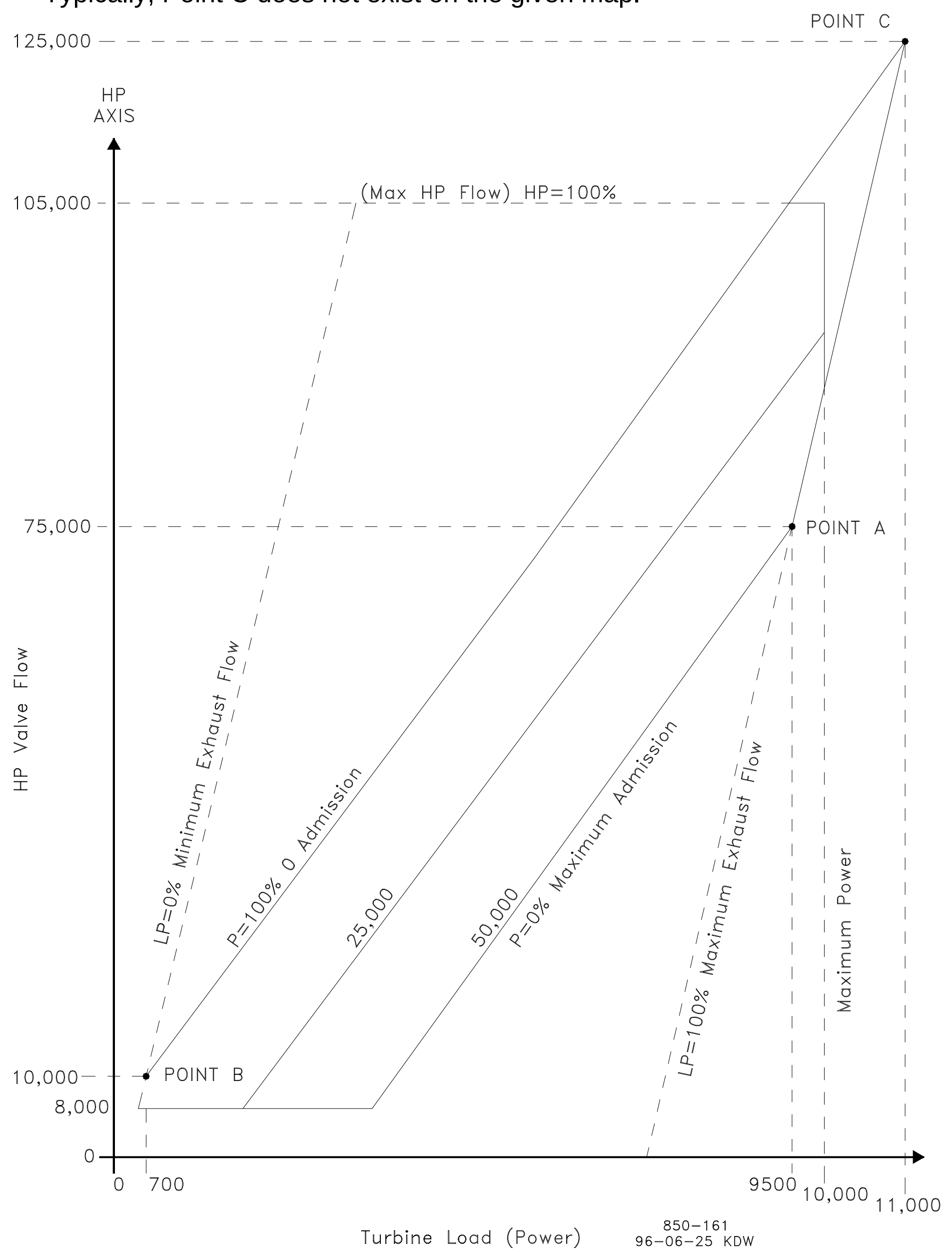


Figure 3-7. Typical Admission Steam Map

The nine required values can be taken from the converted steam map. As an example, the following data was derived using the steam map in Figure 3-7.

1. Max Power is the load corresponding to the S=100 line, about 10 000 kW in this example.
2. Max HP Flow is the flow corresponding to the HP=100 line, about 105 000 lb/h in this example.
3. Point A is where the P=0 and LP=100 lines intersect. Max Power at Max Admission is about 9500 kW, and Max HP Flow at Max Admission is about 75 000 lb/h in this example. In addition, the Max Admission Flow is about 50 000 lb/h.
4. Point B is where the LP=0 and P=100 lines intersect. Min Power at Min Admission is about 700 kW, and Min HP Flow at Min Admission is about 10 000 lb/h in this example. Again, this point was used because 10 000 lb/h is the minimum back-end cooling steam flow required by the turbine.
5. Point C is where the LP=100 and P=100 lines intersect. Max Power at Min Admission is about 11 000 kW, and Max HP Flow at Min Admission is about 125 000 lb/h in this example.
6. An additional parameter, HP Min Lift should be configured to 7.6% (8000/ 105 000).

Extraction/Admission Steam Map

Before an Extraction/Admission steam map can be configured into the control, Points A, B, and C must be identified (See Figure 3-8).

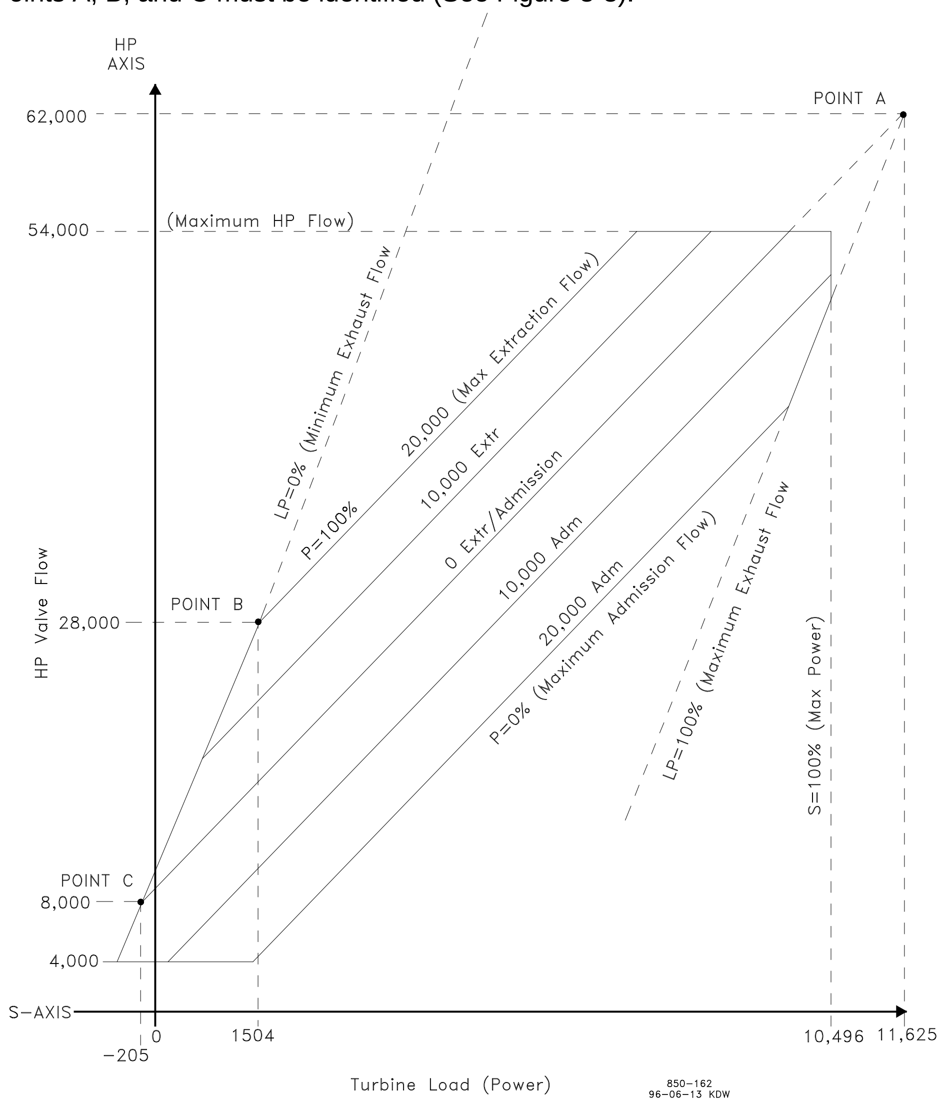


Figure 3-8. Typical Extraction/Admission Steam Map

If Points A and B already exist, the only conversion necessary is the extension of the LP=0 line and the zero Extraction/Admission flow line until they intersect, which defines Point C. If Point A does not exist, extend the LP=100 line and the zero Extraction/Admission flow line until they intersect, which defines Point A.

If only Point A exists, the map must be modified to include Points B and C. The LP=0 line must be created. To do so, the minimum required steam flow through the back-end of the turbine must be defined. In this example, the minimum required flow is 8 000 lb/h.

1. Extend the zero Extraction/Admission line down. Find the turbine's minimum back-end steam flow, which corresponds to Point C's HP flow. Mark the intersection of these two as Point C.
2. Draw a line through Point C created in step1 but parallel to the LP=100 line. This is the LP=0 line (LP valve closed).
3. Mark the intersection of the P=100 and LP=0 lines. This is Point B.

The ten required values can be taken from the converted steam map. As an example, the following data was derived using the steam map in Figure 3-8.

1. Max Power is the load corresponding to the S=100 line, about 10 496 kW in this example.
2. Max HP Flow is the flow corresponding to the HP=100 line, about 54 000 lb/h in this example.
3. Point A is where the zero Extr/Adm flow and LP=100 lines intersect. Max Power at 0 Extr/Adm is about 11 625 kW, and Max HP Flow at 0 Extr/Adm is about 62 000 lb/h in this example. In addition, Max Admission Flow is about 20 000 lb/h.
4. Point B is where the LP=0 and P=100 lines intersect. Min Power at Max Extraction is about 1504 kW, and Min HP Flow at Max Extraction is about 28 000 lb/h in this example.
5. Point C is where the LP=0 and zero Extr/Adm flow lines intersect. Min Power at 0 Extr/Adm is about -205 kW, and Min HP Flow at 0 Extr/Adm is about 8 000 lb/h in this example.
6. An additional parameter, HP Min Lift should be configured to 7.4% (4000/54 000).

Given these steam map interpretations, proceed with the configuration as follows.

- **Use Automatic Enable?**

Select Use Automatic Enable to configure the control to automatically enable Extr/Adm Control upon an enable command from tunables, remote contact input, or Modbus. See the Extraction-Only Control—Automatic Enable/Disable section in Chapter 2. If Use Automatic Enable is not selected, manual enabling via the valve limiter is required.

- **Steam Map Limits**

Configure the points and limits per the manufacturer's steam map as described above.

Turbine Decoupling and Cascade Control Configuration

In addition to the Cascade Controller, the selections on this sheet will configure the Inlet/Exhaust Decoupling Controller, if a two-valve turbine was configured previously. See the Ratio-Limiter--Decoupling section in Chapter 2.

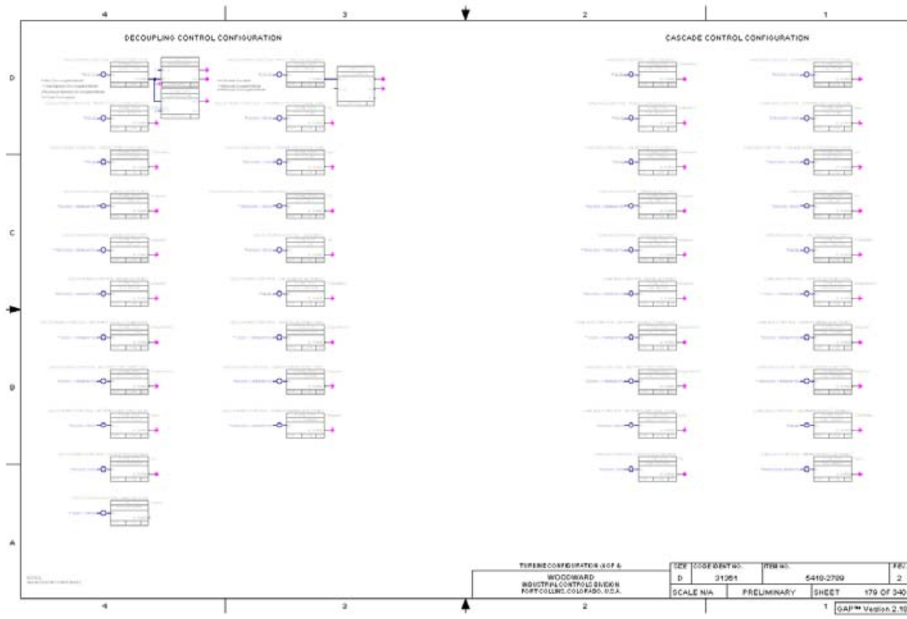


Figure 3-9. Turbine Decoupling Control Configuration

Decoupling Control Settings

- **Decoupling Type**

Configure the desired decoupling type: None (Ratioed), Inlet/Speed (Decoupled HP), Exhaust/Speed (Decoupled LP), or Total Decoupling. See the Ratio-Limiter--Decoupling section in Chapter 2.

- **Invert Decoupling Input?**

Select Invert Input if the control loop requires reverse action (e.g. if Inlet is configured).

- **Use Setpoint Tracking?**

Select Use Setpoint Tracking to force the reference to track the process variable when not controlling. This will ensure a bumpless transfer when Decoupling is enabled.

- **Minimum Setpoint**

Configure the Minimum Setpoint, in engineering units, to define the operating range minimum for Decoupling control. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Minimum Governor speed under normal operating conditions.

- **Maximum Setpoint**

Configure the Maximum Setpoint, in engineering units, to define the operating range maximum for Decoupling control. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Maximum Governor speed under normal operating conditions.

- **Initial Setpoint**

Configure the desired setpoint to be applied at initialization.

- **Setpoint Default Ramp Rate**

Configure the appropriate ramp rate, in engineering units per second, that should be applied to the Decoupling reference. This rate is used unless another rate is specified by a particular control action.

- **Setpoint Fast Ramp Rate**

Configure the appropriate fast ramp rate, in engineering units per second, that should be applied to the Decoupling reference when a setpoint raise/lower command is active for the fast rate delay time.

- **Setpoint Fast Rate Delay**

Configure the appropriate delay time, in seconds, for triggering the setpoint fast rate.

- **Droop Percentage**

If desired for control stability, configure a Decoupling droop percentage. This droop percentage is subtracted from the reference, usually to keep multiple controls from “fighting” over a single parameter. If droop is configured, the inlet/exhaust process variable input will not match the reference when in control—The difference will be the amount of droop.

- **Manual Rate**

Configure the ramp rate, in percent per second, to be applied to the Decoupling demand when in manual mode.

- **Input Failure Fallback**

Select the desired response to a failure of the Inlet/Exhaust pressure input as Disable Extr/Adm Control, Revert to Manual Coupled Mode, or Revert to Manual Decoupled Mode.

- **Decoupling PID Settings**

Configure the initial PID settings as appropriate. Fine-tuning can be performed while the turbine is running. See the Dynamics Adjustments section later in this chapter for details on P-I-D settings and general tuning procedures.

- **Deadband**

If desired for control stability, configure a deadband percentage within which process variable movements will be ignored by the PID controller. If configured at all, the deadband value should be as small as possible.

- **Use Remote Setpoint?**

Select Remote Setpoint if an external 4-20mA input will be used to position the Decoupling reference during normal operation.

- **Remote Setpoint Rate**

Configure the appropriate ramp rate, in engineering units per second, to be applied to the remote setpoint 4-20mA input.

- **Remote Minimum Setpoint**

Configure the Minimum Setpoint, in engineering units, to define the operating range minimum for the 4-20mA remote reference input. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Minimum Governor speed under normal operating conditions.

- **Remote Maximum Setpoint**

Configure the Maximum Setpoint, in engineering units, to define the operating range maximum for the 4-20mA remote reference input. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Maximum Governor speed under normal operating conditions.

Cascade Control Settings

- **Use Cascade Control?**

Select Use Cascade Control to configure the Cascade controller.

- **Invert Cascade Input?**

Select Invert Cascade Input if the control loop requires reverse action (e.g. Turbine Inlet Pressure or Compressor Suction Pressure).

- **Use Setpoint Tracking?**

Select Use Setpoint Tracking to force the reference to track the process variable when not controlling. This will ensure a bumpless transfer when Cascade is enabled.

- **Minimum Setpoint**

Configure the Minimum Setpoint, in engineering units, to define the operating range minimum for Cascade control. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Minimum Governor speed under normal operating conditions.

- **Maximum Setpoint**

Configure the Maximum Setpoint, in engineering units, to define the operating range maximum for Cascade control. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Maximum Governor speed under normal operating conditions.

- **Initial Setpoint**

Configure the desired setpoint to be applied at initialization.

- **Setpoint Default Ramp Rate**

Configure the appropriate ramp rate, in engineering units per second, that should be applied to the Cascade reference. This rate is used unless another rate is specified by a particular control action.

- **Setpoint Fast Ramp Rate**

Configure the appropriate fast ramp rate, in engineering units per second, that should be applied to the Cascade reference when a setpoint raise/lower command is active for the fast rate delay time.

- **Setpoint Fast Rate Delay**

Configure the appropriate delay time, in seconds, for triggering the setpoint fast rate.

- **Droop Percentage**

If desired for control stability, configure a Cascade Droop percentage. This droop percentage is subtracted from the reference, usually to keep multiple controls from “fighting” over a single parameter. If droop is configured, the cascade process variable input will not match the reference when in control—The difference will be the amount of droop.

- **Cascade PID Settings**

Configure the initial PID settings as appropriate. Fine-tuning can be performed while the turbine is running. See the Dynamics Adjustments section later in this chapter for details on P-I-D settings and general tuning procedures.

- **Deadband**

If desired for control stability, configure a deadband percentage within which process variable movements will be ignored by the PID controller. If configured at all, the deadband value should be as small as possible.

- **Use Remote Setpoint?**

Select Remote Setpoint if an external 4-20mA input will be used to position the Cascade reference during normal operation.

- **Remote Setpoint Rate**

Configure the appropriate ramp rate, in engineering units per second, to be applied to the remote setpoint 4-20mA input.

- **Remote Minimum Setpoint**

Configure the Minimum Setpoint, in engineering units, to define the operating range minimum for the 4-20mA remote reference input. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Minimum Governor speed under normal operating conditions.

- **Remote Maximum Setpoint**

Configure the Maximum Setpoint, in engineering units, to define the operating range maximum for the 4-20mA remote reference input. Though this value can be configured as desired, it is recommended that it correspond, roughly, to the process value at Maximum Governor speed under normal operating conditions.

- **Use Minimum Speed Enable?**

Select Minimum Speed if some value other (greater) than Minimum Governor is desired for the Cascade Control minimum.

- **Minimum Speed Setpoint**

Configure the desired minimum enable speed (greater than minimum governor) for Cascade control.

Dynamics Adjustments

The Speed, Cascade, Extr/Adm, and Inlet/Exhaust Decoupling controls are PID controllers. The response of each control loop can be adjusted by configuring its proportional gain, integral gain (stability), and SDR (speed derivative ratio). These 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:

- P = Prop Gain (% output per unit error)
- I = Int Gain (repeats per second)
- D = Deriv Ratio

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 cycles 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 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, and 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, and the control system's adjustable gains. If the accumulated mechanical gain (actuators, valves, valve linkage, etc.) is very high, the control's adjustable gains must be very low to result in a system gain that affords stability.

In cases where a small change in the control's output results in a large 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 such that 0-100% control output corresponds to 0-100% valve travel.

Tuning Derivative

The value of the Derivative Ratio (DR) term can range from 0.01 to 100. 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 .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 coming into control. (e.g. at startup, during a 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, and can therefore prevent overshoot of the setpoint better than a feedback dominant controller. Although this response is desirable during a startup or load rejections, it can cause excessive control motions in some systems where a smooth transition response is desired and where noise is present.

A controller configured as feedback dominant is more sensitive to the change-of-rate of its feedback (the HSS bus). A feedback dominant controller has the ability to limit the rate of change of the HSS bus when a controller is near its set-point but is not yet in control. This limiting of the HSS bus allows a feedback dominant controller to make smoother control transitions than an input dominant controller. However, the feedback dominant controller is slightly slower to respond to the initial input disturbance. Because it is more forgiving (easier to tune) and less sensitive to signal noise, most PIDs will be configured as feedback dominant (1<DR<100).

Tuning Example

If the system is unstable, first verify whether or not the control is the cause. Place the control in Manual if available, or use the respective Valve Limiter to gain control of the valve. If the system continues to oscillate when the control output is clamped, the system instability is caused by an external device/function. If the controller is causing the oscillation, time the oscillation cycle. Generally, if the system's oscillation cycle time is less than 1 second, reduce the proportional gain term. Conversely, if the system's oscillation cycle time is greater than 1 second, reduce the integral gain term (proportional gain may need to be increased as well).

On an initial startup, 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 (Ziegler Nichols, etc.). The following method is a simplified version of other tuning methods, and can be used to achieve PID gain values that are close to optimum:

1. Place the control in Automatic.
2. Increase the Derivative Ratio (DR) to 100.00 (This is the default setting).
3. Reduce integral gain to minimum.
4. Increase the proportional gain until the system just starts to oscillate.
5. Record the system gain (G) as the current proportional gain value and time the oscillation period (T) in seconds.
6. Set the dynamics as follows:
    - For PID control set the proportional gain=0.60*G; integral gain=20/T; SDR=5
    - For PI control set the proportional gain=0.45*G; integral gain=12/T; SDR=100

This method of tuning will result in acceptable gain settings. They can be fine-tuned from this point. Figure 3–10 shows the typical response to a load change when the dynamics are optimally adjusted.

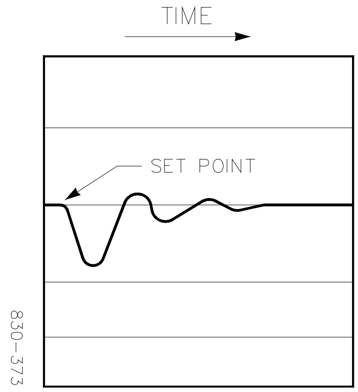


Figure 3-10. Typical Response to Load Change

Chapter 4.
Modbus

General

The control has available a fixed and complete set of process data for transfer to an external device "master" through serial data ports using the Modbus® * communication protocol (See the hardware manual (B26167) for port locations and wiring pinout). The Modbus protocol determines how the master and slaves establish and break off contact, how the sender and receiver are identified, how messages are exchanged in an orderly manner, and how errors are detected. The control acts as a slave to give the external device more flexibility in requesting data. The data made available by the control is constantly updated and, thus, always current. The master initiates all data transactions (requests from the master to the slave and responses from the slave).

*—Modbus is a trademark of Modicon, Inc.

For data transactions to take place, address lists, or Modbus lists, are created in the Modbus master and slave. The control contains one list consisting of analog and Boolean inputs and outputs ("reads" and "writes"). The slave must have a dedicated list in the master. The slave list must match the corresponding master list(s) in order for all data to be transferred.

As a slave, the control system is set up to use input coils and holding registers as memory locations for outputs received from the master, meaning any value written here by the master is intended to be used as a command function in the control (remote setpoint, raise/lower, etc.). Therefore, input coils and holding registers are "write only" memory and cannot be used as read memory by the slave. Input coils and holding registers are read by the control only to see what data was last written. All reads input from the control must be an input status or an input register and are therefore "read only" memory.

Address 0:XXXX … Input Coils …	Boolean Writes to the control
Address 1:XXXX … Input Status …	Boolean Reads from the control
Address 3:XXXX … Input Register …	Analog Reads from the control
Address 4:XXXX … Holding Register …	Analog Writes to the control

The analog values stored in the control are floating point numbers representing engineering units (e.g. kPa, rpm, m^3/hr). However, values sent to and received from the master are signed integers ranging from -32767 to +32767. Decimals are truncated before being passed. Thus, any value sent to or received from the master, whose decimal bits are significant, will require an appropriate scalar. In addition to providing this decimal point resolution, the scalar also facilitates large numbers (greater than 32767) to be transferred.

For many analog values that have defined ranges, the scalar can be fixed. For example, valve position is always between 0 and 100 percent. Therefore, a fixed multiplier of 100 can provide two decimal points of resolution. The fixed analog scalars shown in the Modbus list are multipliers with respect to the control. That is, analog reads from the control are multiplied by this scalar before being passed to the master device—The value received by the master device must be divided by the same scalar. Conversely, the control will multiply analog writes from the master by this scalar before being used. So, the master device should divide its analog write value by the same scalar before sending.

Some data, however, such as pressures, flows, etc. will vary according to the size of the turbine/compressor and the nature of the process in which it operates. In these cases, the scalar must be selected according to the specific application. For example, assume that the Cascade Control is configured for compressor discharge pressure, which normally runs 40 000 to 50 000 kPa. These values are too large to pass across Modbus, which is limited to an integer value of 32 767. So, an appropriate scalar might be selected as 0.1. In this case, if the Cascade process variable (compressor discharge pressure) is running at 45 000 kPa, it will be scaled down to 4500 before sending to the Modbus master. The master must then scale up by 10 to achieve the actual value of 45 000 kPa. Similarly, a Modbus entered setpoint of 48 000 kPa must be scaled down by the value of 10 before being written to the control. The control will scale up the 4800 value that is received to achieve the desired setpoint of 48 000 kPa.

Scalars for values such as compressor flows and head, for example, have been selected per the predicted compressor performance maps and are indicated in the list below. An '*' in the 'multiplier' column indicates a tunable scalar, not fixed in the Modbus block.

Modbus Configuration

The two available Modbus ports are configured in the GAP™ application, as shown in Figure 4-1. Select Use Modbus #1 (or 2) to enable the port and continue its configuration. Without this selection, the Modbus port will function as read-only.

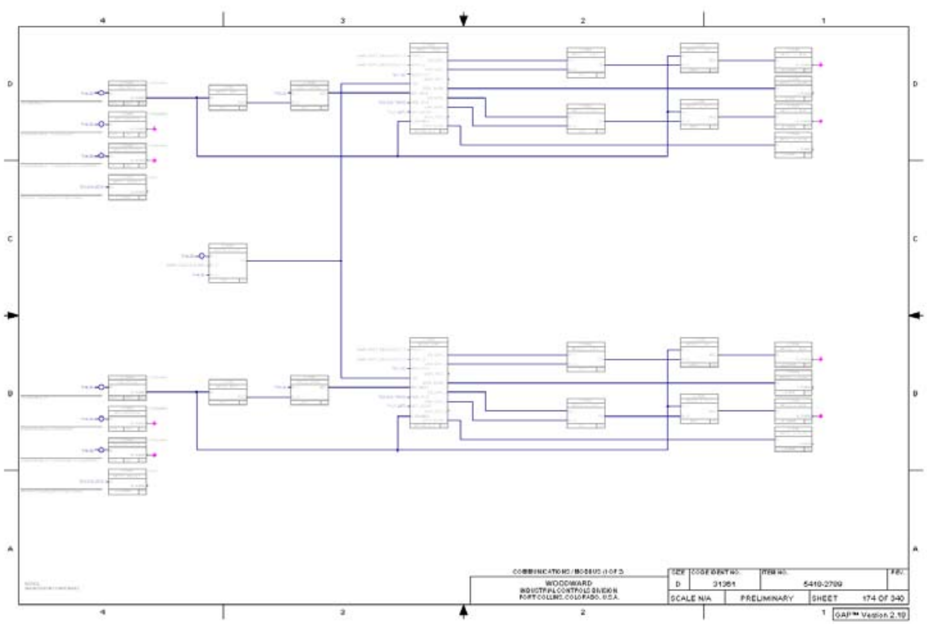


Figure 4-1. Modbus Configuration

Also, enable Modbus write commands for the individual ports, if desired. Writes are enabled as a whole with blocks MOD1WRITES and MOD2WRITES, and if Local/Remote is configured, use MOD1WRTLOC and MOD2WRTLOC to enable writes even when in Local control mode. If de-selected, and with Local/Remote configured, Boolean write commands will only function in Local/Remote Mode, not in Local. This selection has no effect if Local/Remote is not configured, in which case the commands are active if Use Modbus #1 (or 2) was selected previously.

Additional parameters are available for tuning directly on the Modbus blocks MOD1_DCS and MOD2_HMI. Select the Transmission Mode (ASCII_RTU) as ASCII or RTU. The latter is defaulted and generally preferred for Modbus speed and efficiency. The Network Address (NET_ADDR) is defaulted to 1 but can be tuned if the control is on a serial multi-drop network. Adjust the Timeout Delay (TIME_OUT), which defines the Modbus link dead time, in seconds, allowed before a link error is assumed and an alarm generated.

Port Configuration

Refer to the application's serial ports for port-specific configuration, such as protocol, baud rate, etc.

Trip Configuration

Whether or not the control will respond to shutdown commands from the Modbus ports depends upon the Modbus Trip Configuration (See Figure 4-2)

Enable ESD from Modbus #1 (or 2) to allow the Modbus port to initiate system shutdowns. If de-selected, Modbus ESD commands are ignored.

This can also be configured to include the Local control mode as described previously for generic Boolean write commands. If de-selected, and with Local/Remote configured, the Modbus ESD will only function in Local/Remote Mode, not in Local. This selection has no effect if Local/Remote is not configured, in which case the Modbus ESD is active if Use Modbus #1 (or 2) Trip was selected previously.

Select the Two Step Trip feature to configure the ESD Acknowledge function, which requires that the ESD command (0:0001) be followed by the ESD Acknowledge command (0:0002) within 5 seconds to initiate a shutdown.

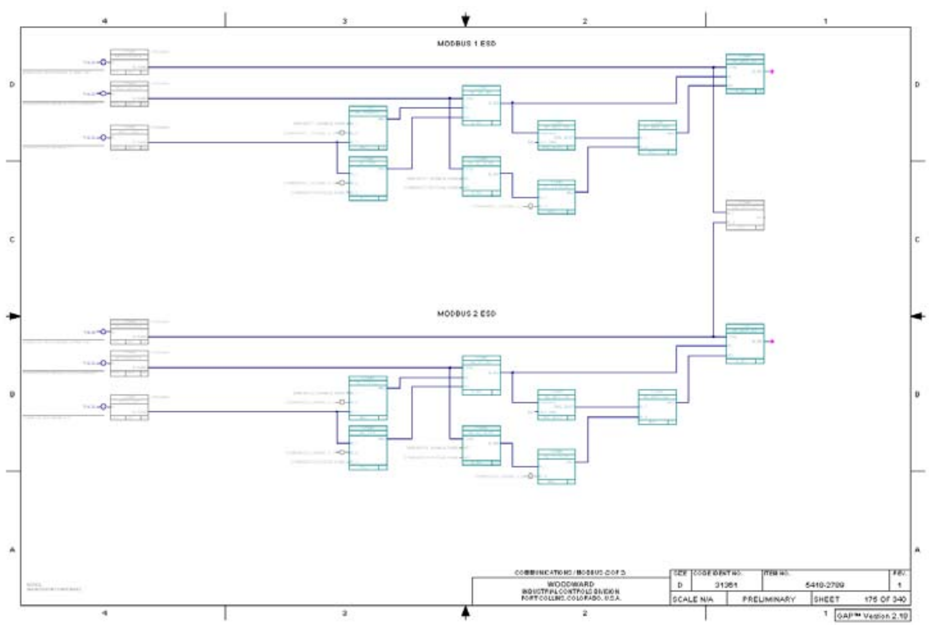


Figure 4-2. Modbus ESD Configuration

Reset Modbus

The Reset Modbus command will reset both Modbus ports to clear exception errors caused by illegal function calls, data addresses, or values; checksum errors; or garbled messages. If the block has an error, the error code ERR_NUM_1 or ERR_NUM_2 may indicate the cause—Use GAP's help pages for additional troubleshooting.

Modbus List

Boolean Writes (writes from the master device to the control)

Addr	Description
0:0001	Emergency Shutdown
0:0002	Emergency Shutdown Acknowledge
0:0003	Controlled Shutdown
0:0004	Abort Controlled Shutdown
0:0005	System Reset
0:0006	Start / Run
0:0007	Open HP Valve Limiter
0:0008	Close HP Valve Limiter
0:0009	Lower Speed Setpoint
0:0010	Raise Speed Setpoint
0:0011	Go To Rated (Idle / Rated)
0:0012	Go To Idle (Idle / Rated)
0:0013	Halt Auto Start Seq
0:0014	Continue Auto Start Seq
0:0015	Enable Remote Speed Setpoint Control
0:0016	Disable Remote Speed Setpoint Control
0:0017	Go To Modbus Entered Speed Setpt
0:0018	Synchronize CPU Clock
0:0019 – 0:0022	Spare (Function Not Used)
0:0023	Enable Cascade Control
0:0024	Disable Cascade Control
0:0025	Lower Cascade Setpoint
0:0026	Raise Cascade Setpoint
0:0027	Enable Remote Cascade Setpoint Control
0:0028	Disable Remote Cascade Setpoint Control
0:0029	Go to Modbus Entered Cascade Setpoint
0:0030	Spare
0:0031 – 0:0037	Spare (Function Not Used)
0:0038	Spare
0:0039	Select Remote Ctrl (Remote/Local)
0:0040	Select Local Ctrl (Remote/Local)
0:0041	Spare
0:0042	Modbus Alarm Acknowledge
0:0043 – 0:0054	Spare (Function Not Used)
0:0055 – 0:0056	Spare
0:0057	Enable Extraction Control
0:0058	Disable Extraction Control
0:0059	Lower Extraction Setpoint
0:0060	Raise Extraction Setpoint
0:0061	Enable Remote Extr Setpoint Control
0:0062	Disable Remote Extr Setpoint Control
0:0063	Go To Modbus Entered Extraction Setpt
0:0064	Open LP Valve Limiter
0:0065	Close LP Valve Limiter
0:0066 – 0:0067	Spare (Function Not Used)
0:0068	Enable Extr/Adm Priority
0:0069	Disable Extr/Adm Priority
0:0070	Spare
0:0071 – 0:0080	Spare (Function Not Used)
0:0081	Spare
0:0082	Enable Inlet/Exhaust Dcpl
0:0083	Disable Inlet/Exhaust Dcpl

0:0084	Lower Inlet/Exhaust Dcpl Setpoint
0:0085	Raise Inlet/Exhaust Dcpl Setpoint
0:0086	Enable Remote Inlet/Exhaust Setpoint
0:0087	Disable Remote Inlet/Exhaust Setpoint
0:0088	Go To Modbus Entered Inl/Exh Setpoint
0:0089	Spare
0:0090	Enable Manual E/A Pressure Control
0:0091	Disable Manual E/A Pressure Control
0:0092	Lower Manual E/A Press Dmnd
0:0093	Raise Manual E/A Press Dmnd
0:0094	Enable Remote E/A Pressure Demand
0:0095	Disable Remote E/A Pressure Demand
0:0096	Go To Modbus Entered E/A Pressure Dmnd
0:0097	Spare
0:0098	HP/V1 Valve Go To Manual
0:0099	HP/V1 Valve Revert to Automatic
0:0100	Close HP/V1 Valve in Manual
0:0101	Open HP/V1 Valve in Manual
0:0102 – 0:0104	Spare (Function Not Used)
0:0105	Spare
0:0106 – 0:0112	Spare (Function Not Used)
0:0113 – 0:0114	Spare
0:0115	Comp. 1 - Lower Surge Control Margin
0:0116	Comp. 1 - Raise Surge Control Margin
0:0117	Comp. 1 - Auxiliary OnLine Input
0:0118	Comp. 1 - Initiate Purge Sequence
0:0119	Comp. 1 - Reset Surge Minimum Position
0:0120	Comp. 1 - Reset Surge Information
0:0121	Comp. 1 - Emergency Compressor Trip
0:0122	Comp. 1 - Controlled Compressor Trip
0:0123	Comp. 1 - Select AUTO Mode
0:0124	Comp. 1 - Select MANUAL W/ BACKUP Mode
0:0125	Comp. 1 - Select FULL MANUAL Mode
0:0126	Comp. 1 - Close AntiSurge Valve
0:0127	Comp. 1 - Open AntiSurge Valve
0:0128	Comp. 1 - Go To MB Entered Valve Pos.
0:0129	Comp. 1 - Initiate Start Sequence
0:0130	Comp. 1 - Enable Suction Press. Ovrd.
0:0131	Comp. 1 - Goto MB P1 Ovrd. Setpoint
0:0132	Comp. 1 - Enable Disch. Press. Ovrd.
0:0133	Comp. 1 - Goto MB P2 Ovrd. Setpoint
0:0134 – 0:0139	Spare
0:0140	Comp. 2 - Lower Surge Control Margin
0:0141	Comp. 2 - Raise Surge Control Margin
0:0142	Comp. 2 - Auxiliary OnLine Input
0:0143	Comp. 2 - Initiate Purge Sequence
0:0144	Comp. 2 - Reset Surge Minimum Position
0:0145	Comp. 2 - Reset Surge Information
0:0146	Comp. 2 - Emergency Compressor Trip
0:0147	Comp. 2 - Controlled Compressor Trip
0:0148	Comp. 2 - Select AUTO Mode
0:0149	Comp. 2 - Select MANUAL W/ BACKUP Mode
0:0150	Comp. 2 - Select FULL MANUAL Mode
0:0151	Comp. 2 - Close AntiSurge Valve
0:0152	Comp. 2 - Open AntiSurge Valve
0:0153	Comp. 2 - Go To MB Entered Valve Pos.
0:0154	Comp. 2 - Initiate Start Sequence
0:0155	Comp. 2 - Enable Suction Press. Ovrd.
0:0156	Comp. 2 - Goto MB P1 Ovrd. Setpoint
0:0157	Comp. 2 - Enable Disch. Press. Ovrd.
0:0158	Comp. 2 - Goto MB P2 Ovrd. Setpoint
0:0159 – 0:0164	Spare
0:0165	Comp. 3 - Lower Surge Control Margin
0:0166	Comp. 3 - Raise Surge Control Margin
0:0167	Comp. 3 - Auxiliary OnLine Input
0:0168	Comp. 3 - Initiate Purge Sequence
0:0169	Comp. 3 - Reset Surge Minimum Position
0:0170	Comp. 3 - Reset Surge Information
0:0171	Comp. 3 - Emergency Compressor Trip

0:0172	Comp. 3 - Controlled Compressor Trip
0:0173	Comp. 3 - Select AUTO Mode
0:0174	Comp. 3 - Select MANUAL W/ BACKUP Mode
0:0175	Comp. 3 - Select FULL MANUAL Mode
0:0176	Comp. 3 - Close AntiSurge Valve
0:0177	Comp. 3 - Open AntiSurge Valve
0:0178	Comp. 3 - Go To MB Entered Valve Pos.
0:0179	Comp. 3 - Initiate Start Sequence
0:0180	Comp. 3 - Enable Suction Press. Ovrd.
0:0181	Comp. 3 - Goto MB P1 Ovrd. Setpoint
0:0182	Comp. 3 - Enable Disch. Press. Ovrd.
0:0183	Comp. 3 - Goto MB P2 Ovrd. Setpoint

Table 4-1. Modbus Boolean Writes

Boolean Reads (reads from the control by the master device)

Addr	Description
1:0001	Idle/Rated
1:0002	Normal Stop
1:0003	Remote Speed Setpoint Enable/Disable
1:0004	Main Turbine Start
1:0005	System Reset
1:0006	Purge String
1:0007	MNC Common Alarm
1:0008	MNC Start Permissive
1:0009	Spare
1:0010	Raise Speed
1:0011	Lower Speed
1:0012	DCS Start Permissive
1:0013 – 1:0015	Spare
1:0016	Minimum Governor Speed
1:0017	Remote Speed Setpoint Enabled
1:0018	Spare
1:0019	Overspeed Test
1:0020	Lamp Test
1:0021	24VDC Power Supply A Fault
1:0022	24VDC Power Supply B Fault
1:0023 – 1:0024	Spare
1:0025	Overspeed Test In Progress
1:0026 – 1:0027	Spare
1:0028	SIS Emergency Shutdown
1:0029 – 1:0033	Spare
1:0034	MNC Common Trip
1:0035 – 1:0199	Spare
1:0200	Alarm - MPU #1 Failed
1:0201	Alarm - MPU #2 Failed
1:0202	Alarm - Aux Input Failed
1:0203	Alarm - First Stage Press Input Failed
1:0204	Alarm - Remote Speed Input Failed
1:0205	Alarm - Remote Aux Input Failed
1:0206	Alarm - Actuator #1 Failed
1:0207	Alarm - Actuator #2 Failed
1:0208	Alarm - Start Permissive Not Met
1:0209	Alarm - Communication Link #1 Failed
1:0210	Alarm - Communication Link #2 Failed
1:0211	Alarm - Turbine Trip
1:0212	Alarm - Overspeed Alarm
1:0213	Alarm - Stuck in Critical Alarm
1:0214	Alarm - Extr Input Failed
1:0215	Alarm - Remote Extr Input Failed
1:0216	Alarm - Speed Stpnt. in Critical Band
1:0217	Alarm Not Acknowledged
1:0218	Alarm Acknowledge
1:0219	Alarm Exists (Common Alarm Indication)
1:0220	Trip - Power up
1:0221	Trip - HMI ESD Button

1:0222	Trip - Overspeed Trip
1:0223	Trip - Loss of Speed Signals
1:0224	Trip - Actuator # 1 Fault
1:0225	Trip - Actuator # 2 Fault
1:0226	Trip - Speed in Critical Band Too Long
1:0227	Trip - External Trip 2
1:0228	Trip - External Trip 3
1:0229	Trip - Modbus Link #1 Trip
1:0230	Trip - Modbus Link #2 Trip
1:0231	Trip - Tie Breaker Open
1:0232	Trip - Gen Breaker Open
1:0233	Trip - External Trip (BI_01)
1:0234	Trip - Controlled Shutdown Complete
1:0235	Trip - External Trip 4
1:0236	Trip - External Trip 5
1:0237	Trip - Extraction Input Failed
1:0238	Shutdown Exists (Trip Indication)
1:0239	Remote/Local Remote Selected
1:0240	MODBUS 1 Active
1:0241	Start Permissive
1:0242	Shutdown Relay Energized
1:0243	Alarm Relay Energized
1:0244	Alarm - Invalid Compressor Config.
1:0245	Alarm - Comp. 1 Flow Input Fld.
1:0246	Alarm - Comp. 1 Suct. Prs. Input Fld.
1:0247	Alarm - Comp. 1 Dsch. Prs. Input Fld.
1:0248	Alarm - Comp. 1 Suct. Temp. Input Fld.
1:0249	Alarm - Comp. 1 Dsch. Temp. Input Fld.
1:0250	Alarm - Comp. 1 Flow Prs. Input Fld.
1:0251	Alarm - Comp. 1 Flow Temp. Input Fld.
1:0252	Alarm - Comp. 1 Dcpl. Input #1 Fld.
1:0253	Alarm - Comp. 1 Dcpl. Input #2 Fld.
1:0254	Alarm - Comp. 1 HSS Aux. Input #1 Fld.
1:0255	Alarm - Comp. 1 HSS Aux. Input #2 Fld.
1:0256	Alarm - Comp. 1 Rmt. Man. Input Fld.
1:0257	Alarm - Comp. 1 Red. Flow Input Fld.
1:0258	Alarm - Comp. 1 Red. P1 Input Fld.
1:0259	Alarm - Comp. 1 Red. P2 Input Fld.
1:0260	Alarm - Comp. 1 Started-Not in Auto
1:0261	Alarm - Comp. 1 In Man.-No Surge Rcvry
1:0262	Alarm - Comp. 1 Steady State Failed
1:0263	Alarm - Comp. 1 Surge Detected
1:0264	Alarm - Comp. 1 SMP Active
1:0265	Alarm - Comp. 1 AS Valve Output Fld.
1:0266	Comp. 1 - Auto Mode
1:0267	Comp. 1 - Manual with Backup Mode
1:0268	Comp. 1 - Full Manual Mode
1:0269	Comp. 1 - P1 Default Value in Use
1:0270	Comp. 1 - P1 Last Good Value in Use
1:0271	Comp. 1 - P2 Default Value in Use
1:0272	Comp. 1 - P2 Last Good Value in Use
1:0273	Comp. 1 - PF Default Value in Use
1:0274	Comp. 1 - PF Last Good Value in Use
1:0275	Comp. 1 - Surge Detected
1:0276	Comp. 1 - Surged by Flow Derivative
1:0277	Comp. 1 - Surged by Minimum Flow
1:0278	Comp. 1 - Surged by P1 Derivative
1:0279	Comp. 1 - Surged by P2 Derivative
1:0280	Comp. 1 - Surged by Speed Derivative
1:0281	Comp. 1 - Surge Limit Line Crossed
1:0282	Comp. 1 - T1 Default Value in Use
1:0283	Comp. 1 - T1 Last Good Value in Use
1:0284	Comp. 1 - T2 Default Value in Use
1:0285	Comp. 1 - T2 Last Good Value in Use
1:0286	Comp. 1 - TF Default Value in Use
1:0287	Comp. 1 - TF Last Good Value in Use
1:0288	Alarm - Comp. 2 Flow Input Fld.
1:0289	Alarm - Comp. 2 Suct. Prs. Input Fld.
1:0290	Alarm - Comp. 2 Dsch. Prs. Input Fld.

1:0291	Alarm - Comp. 2 Suct. Temp. Input Fld.
1:0292	Alarm - Comp. 2 Dsch. Temp. Input Fld.
1:0293	Alarm - Comp. 2 Flow Prs. Input Fld.
1:0294	Alarm - Comp. 2 Flow Temp. Input Fld.
1:0295	Alarm - Comp. 2 Dcpl. Input #1 Fld.
1:0296	Alarm - Comp. 2 Dcpl. Input #2 Fld.
1:0297	Alarm - Comp. 2 HSS Aux. Input #1 Fld.
1:0298	Alarm - Comp. 2 HSS Aux. Input #2 Fld.
1:0299	Alarm - Comp. 2 Rmt. Man. Input Fld.
1:0300	Alarm - Comp. 2 Red. Flow Input Fld.
1:0301	Alarm - Comp. 2 Red. P1 Input Fld.
1:0302	Alarm - Comp. 2 Red. P2 Input Fld.
1:0303	Alarm - Comp. 2 Started-Not in Auto
1:0304	Alarm - Comp. 2 In Man.-No Surge Rcvry
1:0305	Alarm - Comp. 2 Steady State Failed
1:0306	Alarm - Comp. 2 Surge Detected
1:0307	Alarm - Comp. 2 SMP Active
1:0308	Alarm - Comp. 2 AS Valve Output Fld.
1:0309	Comp. 2 - Auto Mode
1:0310	Comp. 2 - Manual with Backup Mode
1:0311	Comp. 2 - Full Manual Mode
1:0312	Comp. 2 - P1 Default Value in Use
1:0313	Comp. 2 - P1 Last Good Value in Use
1:0314	Comp. 2 - P2 Default Value in Use
1:0315	Comp. 2 - P2 Last Good Value in Use
1:0316	Comp. 2 - PF Default Value in Use
1:0317	Comp. 2 - PF Last Good Value in Use
1:0318	Comp. 2 - Surge Detected
1:0319	Comp. 2 - Surged by Flow Derivative
1:0320	Comp. 2 - Surged by Minimum Flow
1:0321	Comp. 2 - Surged by P1 Derivative
1:0322	Comp. 2 - Surged by P2 Derivative
1:0323	Comp. 2 - Surged by Speed Derivative
1:0324	Comp. 2 - Surge Limit Line Crossed
1:0325	Comp. 2 - T1 Default Value in Use
1:0326	Comp. 2 - T1 Last Good Value in Use
1:0327	Comp. 2 - T2 Default Value in Use
1:0328	Comp. 2 - T2 Last Good Value in Use
1:0329	Comp. 2 - TF Default Value in Use
1:0330	Comp. 2 - TF Last Good Value in Use
1:0331	Alarm - Comp. 3 Flow Input Fld.
1:0332	Alarm - Comp. 3 Suct. Prs. Input Fld.
1:0333	Alarm - Comp. 3 Dsch. Prs. Input Fld.
1:0334	Alarm - Comp. 3 Suct. Temp. Input Fld.
1:0335	Alarm - Comp. 3 Dsch. Temp. Input Fld.
1:0336	Alarm - Comp. 3 Flow Prs. Input Fld.
1:0337	Alarm - Comp. 3 Flow Temp. Input Fld.
1:0338	Alarm - Comp. 3 Dcpl. Input #1 Fld.
1:0339	Alarm - Comp. 3 Dcpl. Input #2 Fld.
1:0340	Alarm - Comp. 3 HSS Aux. Input #1 Fld.
1:0341	Alarm - Comp. 3 HSS Aux. Input #2 Fld.
1:0342	Alarm - Comp. 3 Rmt. Man. Input Fld.
1:0343	Alarm - Comp. 3 Red. Flow Input Fld.
1:0344	Alarm - Comp. 3 Red. P1 Input Fld.
1:0345	Alarm - Comp. 3 Red. P2 Input Fld.
1:0346	Alarm - Comp. 3 Started-Not in Auto
1:0347	Alarm - Comp. 3 In Man.-No Surge Rcvry
1:0348	Alarm - Comp. 3 Steady State Failed
1:0349	Alarm - Comp. 3 Surge Detected
1:0350	Alarm - Comp. 3 SMP Active
1:0351	Alarm - Comp. 3 AS Valve Output Fld.
1:0352	Comp. 3 - Auto Mode
1:0353	Comp. 3 - Manual with Backup Mode
1:0354	Comp. 3 - Full Manual Mode
1:0355	Comp. 3 - P1 Default Value in Use
1:0356	Comp. 3 - P1 Last Good Value in Use
1:0357	Comp. 3 - P2 Default Value in Use
1:0358	Comp. 3 - P2 Last Good Value in Use
1:0359	Comp. 3 - PF Default Value in Use

1:0360	Comp. 3 - PF Last Good Value in Use
1:0361	Comp. 3 - Surge Detected
1:0362	Comp. 3 - Surged by Flow Derivative
1:0363	Comp. 3 - Surged by Minimum Flow
1:0364	Comp. 3 - Surged by P1 Derivative
1:0365	Comp. 3 - Surged by P2 Derivative
1:0366	Comp. 3 - Surged by Speed Derivative
1:0367	Comp. 3 - Surge Limit Line Crossed
1:0368	Comp. 3 - T1 Default Value in Use
1:0369	Comp. 3 - T1 Last Good Value in Use
1:0370	Comp. 3 - T2 Default Value in Use
1:0371	Comp. 3 - T2 Last Good Value in Use
1:0372	Comp. 3 - TF Default Value in Use
1:0373	Comp. 3 - TF Last Good Value in Use
1:0374 – 1:0498	Spare
1:0499	Alarm - Kernel A Anlg I/O Module Flt
1:0500	Alarm - Kernel B Anlg I/O Module Flt
1:0501	Alarm - Kernel C Anlg I/O Module Flt
1:0502	Alarm - Kernel A Discrete I/O Mod Flt
1:0503	Alarm - Kernel B Discrete I/O Mod Flt
1:0504	Alarm - Kernel C Discrete I/O Mod Flt
1:0505	Alarm - Kernel A Cmbo I/O Module Flt
1:0506	Alarm - Kernel B Cmbo I/O Module Flt
1:0507	Alarm - Kernel C Cmbo I/O Module Flt
1:0508	Alarm - 24VDC Power Supply A Fault
1:0509	Alarm - 24VDC Power Supply B Fault
1:0510	Alarm - Spare
1:0511	Alarm - Kernel A Fault
1:0512	Alarm - Kernel B Fault
1:0513	Alarm - Kernel C Fault
1:0514	Alarm - Fan Fault
1:0515	Alarm - MicroNet Power Supply #1 Fault
1:0516	Alarm - MicroNet Power Supply #2 Fault
1:0517	Alarm - Operating System Alarm
1:0518	Alarm - Start Perm Not Closed
1:0519	Alarm - MOD1 P1 Comm Link Failed
1:0520	Alarm - MOD2 P1 Comm Link Failed
1:0521	Alarm - Spare
1:0522	Alarm - Turbine Trip
1:0523	Alarm - Overspeed
1:0524	Alarm - Stuck in Critical Band
1:0525 – 1:0545	Alarm - Spare
1:0546	Alarm - Configuration Error
1:0547	Alarm - MOD2 P2 Comm Link Failed
1:0548	Alarm - MOD1 P2 Comm Link Failed
1:0549	Alarm - Kernel A Overtemp
1:0550	Alarm - Kernel B Overtemp
1:0551	Alarm - Kernel C Overtemp
1:0552	Alarm - CPU A Time Fault
1:0553	Alarm - CPU B Time Fault
1:0554	Alarm - CPU C Time Fault
1:0555	Alarm - Spd Probe #1 Input Fld
1:0556	Alarm - Spd Probe #1 Deviation Alm
1:0557	Alarm - Spd Probe #1 Ospd Alm
1:0558	Alarm - Spd Probe #1 Kernel A Fault
1:0559	Alarm - Spd Probe #1 Kernel B Fault
1:0560	Alarm - Spd Probe #1 Kernel C Fault
1:0561	Alarm - Spd Probe #2 Input Failed
1:0562	Alarm - Spd Probe #2 Deviation Alm
1:0563	Alarm - Spd Probe #2 Ospd Alm
1:0564	Alarm - Spd Probe #2 Kernel A Fault
1:0565	Alarm - Spd Probe #2 Kernel B Fault
1:0566	Alarm - Spd Probe #2 Kernel C Fault
1:0567	Alarm - Spd Probe #3 Input Failed
1:0568	Alarm - Spd Probe #3 Deviation Alm
1:0569	Alarm - Spd Probe #3 Ospd Alm
1:0570	Alarm - Spd Probe #3 Kernel A Fault
1:0571	Alarm - Spd Probe #3 Kernel B Fault
1:0572	Alarm - Spd Probe #3 Kernel C Fault

1:0573	Alarm - Spd Probe #4 Input Failed
1:0574	Alarm - Spd Probe #4 Deviation Alm
1:0575	Alarm - Spd Probe #4 Ospd Alm
1:0576	Alarm - Spd Probe #4 Kernel A Fault
1:0577	Alarm - Spd Probe #4 Kernel B Fault
1:0578	Alarm - Spd Probe #4 Kernel C Fault
1:0579	Alarm - AI #1 ZT-1059 Kernel A Fault
1:0580	Alarm - AI #1 ZT-1059 Kernel B Fault
1:0581	Alarm - AI #1 ZT-1059 Kernel C Fault
1:0582	Alarm - AI #1 ZT-1059 Input Failed
1:0583	Alarm - AI #1 ZT-1059 Input High Alarm
1:0584	Alarm - AI #1 ZT-1059 Input Low Alarm
1:0585	Alarm - AI #2 Kernel A Fault
1:0586	Alarm - AI #2 Kernel B Fault
1:0587	Alarm - AI #2 Kernel C Fault
1:0588	Alarm - AI #2 Input Failed
1:0589	Alarm - AI #2 Input High Alarm
1:0590	Alarm - AI #2 Input Low Alarm
1:0591	Alarm - AI #3 Kernel A Fault
1:0592	Alarm - AI #3 Kernel B Fault
1:0593	Alarm - AI #3 Kernel C Fault
1:0594	Alarm - AI #3 Input Failed
1:0595	Alarm - AI #3 Input High Alarm
1:0596	Alarm - AI #3 Input Low Alarm
1:0597	Alarm - AI #4 Kernel A Fault
1:0598	Alarm - AI #4 Kernel B Fault
1:0599	Alarm - AI #4 Kernel C Fault
1:0600	Alarm - AI #4 Input Failed
1:0601	Alarm - AI #4 Input High Alarm
1:0602	Alarm - AI #4 Input Low Alarm
1:0603	Alarm - AI #5 Kernel A Fault
1:0604	Alarm - AI #5 Kernel B Fault
1:0605	Alarm - AI #5 Kernel C Fault
1:0606	Alarm - AI #5 Input Failed
1:0607	Alarm - AI #5 Input High Alarm
1:0608	Alarm - AI #5 Input Low Alarm
1:0609	Alarm - AI #6 Kernel A Fault
1:0610	Alarm - AI #6 Kernel B Fault
1:0611	Alarm - AI #6 Kernel C Fault
1:0612	Alarm - AI #6 Input Failed
1:0613	Alarm - AI #6 Input High Alarm
1:0614	Alarm - AI #6 Input Low Alarm
1:0615	Alarm - AI #7 Kernel A Fault
1:0616	Alarm - AI #7 Kernel B Fault
1:0617	Alarm - AI #7 Kernel C Fault
1:0618	Alarm - AI #7 Input Failed
1:0619	Alarm - AI #7 Input High Alarm
1:0620	Alarm - AI #7 Input Low Alarm
1:0621	Alarm - AI #8 Kernel A Fault
1:0622	Alarm - AI #8 Kernel B Fault
1:0623	Alarm - AI #8 Kernel C Fault
1:0624	Alarm - AI #8 Input Failed
1:0625	Alarm - AI #8 Input High Alarm
1:0626	Alarm - AI #8 Input Low Alarm
1:0627	Alarm - AI #9 PT-1250 Kernel A Fault
1:0628	Alarm - AI #9 PT-1250 Kernel B Fault
1:0629	Alarm - AI #9 PT-1250 Kernel C Fault
1:0630	Alarm - AI #9 PT-1250 Input Failed
1:0631	Alarm - AI #9 PT-1250 Input High Alarm
1:0632	Alarm - AI #9 PT-1250 Input Low Alarm
1:0633	Alarm - AI #10 TT-1251 Kernel A Fault
1:0634	Alarm - AI #10 TT-1251 Kernel B Fault
1:0635	Alarm - AI #10 TT-1251 Kernel C Fault
1:0636	Alarm - AI #10 TT-1251 Input Failed
1:0637	Alarm - AI #10 TT-1251 Input High Alarm
1:0638	Alarm - AI #10 TT-1251 Input Low Alarm
1:0639	Alarm - AI #11 ZT-1254 Kernel A Fault
1:0640	Alarm - AI #11 ZT-1254 Kernel B Fault
1:0641	Alarm - AI #11 ZT-1254 Kernel C Fault

1:0642	Alarm - AI #11 ZT-1254 Input Failed
1:0643	Alarm - AI #11 ZT-1254 Input High Alarm
1:0644	Alarm - AI #11 ZT-1254 Input Low Alarm
1:0645	Alarm - AI #12 FT-1257 Kernel A Fault
1:0646	Alarm - AI #12 FT-1257 Kernel B Fault
1:0647	Alarm - AI #12 FT-1257 Kernel C Fault
1:0648	Alarm - AI #12 FT-1257 Input Failed
1:0649	Alarm - AI #12 FT-1257 Input High Alarm
1:0650	Alarm - AI #12 FT-1257 Input Low Alarm
1:0651	Alarm - AI #13 PT-1258 Kernel A Fault
1:0652	Alarm - AI #13 PT-1258 Kernel B Fault
1:0653	Alarm - AI #13 PT-1258 Kernel C Fault
1:0654	Alarm - AI #13 PT-1258 Input Failed
1:0655	Alarm - AI #13 PT-1258 Input High Alarm
1:0656	Alarm - AI #13 PT-1258 Input Low Alarm
1:0657	Alarm - AI #14 TT-1259 Kernel A Fault
1:0658	Alarm - AI #14 TT-1259 Kernel B Fault
1:0659	Alarm - AI #14 TT-1259 Kernel C Fault
1:0660	Alarm - AI #14 TT-1259 Input Failed
1:0661	Alarm - AI #14 TT-1259 Input High Alarm
1:0662	Alarm - AI #14 TT-1259 Input Low Alarm
1:0663	Alarm - AI #15 ZT-1257 Kernel A Fault
1:0664	Alarm - AI #15 ZT-1257 Kernel B Fault
1:0665	Alarm - AI #15 ZT-1257 Kernel C Fault
1:0666	Alarm - AI #15 ZT-1257 Input Failed
1:0667	Alarm - AI #15 ZT-1257 Input High Alarm
1:0668	Alarm - AI #15 ZT-1257 Input Low Alarm
1:0669	Alarm - AI #16 TT-1260 Kernel A Fault
1:0670	Alarm - AI #16 TT-1260 Kernel B Fault
1:0671	Alarm - AI #16 TT-1260 Kernel C Fault
1:0672	Alarm - AI #16 TT-1260 Input Failed
1:0673	Alarm - AI #16 TT-1260 Input High Alarm
1:0674	Alarm - AI #16 TT-1260 Input Low Alarm
1:0675	Alarm - AI #17 PT-1261 Kernel A Fault
1:0676	Alarm - AI #17 PT-1261 Kernel B Fault
1:0677	Alarm - AI #17 PT-1261 Kernel C Fault
1:0678	Alarm - AI #17 PT-1261 Input Failed
1:0679	Alarm - AI #17 PT-1261 Input High Alarm
1:0680	Alarm - AI #17 PT-1261 Input Low Alarm
1:0681	Alarm - AI #18 FT-1262 Kernel A Fault
1:0682	Alarm - AI #18 FT-1262 Kernel B Fault
1:0683	Alarm - AI #18 FT-1262 Kernel C Fault
1:0684	Alarm - AI #18 FT-1262 Input Failed
1:0685	Alarm - AI #18 FT-1262 Input High Alarm
1:0686	Alarm - AI #18 FT-1262 Input Low Alarm
1:0687	Alarm - AI #19 Kernel A Fault
1:0688	Alarm - AI #19 Kernel B Fault
1:0689	Alarm - AI #19 Kernel C Fault
1:0690	Alarm - AI #19 Input Failed
1:0691	Alarm - AI #19 Input High Alarm
1:0692	Alarm - AI #19 Input Low Alarm
1:0693	Alarm - AI #20 Kernel A Fault
1:0694	Alarm - AI #20 Kernel B Fault
1:0695	Alarm - AI #20 Kernel C Fault
1:0696	Alarm - AI #20 Input Failed
1:0697	Alarm - AI #20 Input High Alarm
1:0698	Alarm - AI #20 Input Low Alarm
1:0699	Alarm - AI #21 TT-1252 Kernel A Fault
1:0700	Alarm - AI #21 TT-1252 Kernel B Fault
1:0701	Alarm - AI #21 TT-1252 Kernel C Fault
1:0702	Alarm - AI #21 TT-1252 Input Failed
1:0703	Alarm - AI #21 TT-1252 Input High Alarm
1:0704	Alarm - AI #21 TT-1252 Input Low Alarm
1:0705	Alarm - AI #22 PT-1253 Kernel A Fault
1:0706	Alarm - AI #22 PT-1253 Kernel B Fault
1:0707	Alarm - AI #22 PT-1253 Kernel C Fault
1:0708	Alarm - AI #22 PT-1253 Input Failed
1:0709	Alarm - AI #22 PT-1253 Input High Alarm
1:0710	Alarm - AI #22 PT-1253 Input Low Alarm

1:0711	Alarm - AI #23 FT-1254 Kernel A Fault
1:0712	Alarm - AI #23 FT-1254 Kernel B Fault
1:0713	Alarm - AI #23 FT-1254 Kernel C Fault
1:0714	Alarm - AI #23 FT-1254 Input Failed
1:0715	Alarm - AI #23 FT-1254 Input High Alarm
1:0716	Alarm - AI #23 FT-1254 Input Low Alarm
1:0717	Alarm - AI #24 Kernel A Fault
1:0718	Alarm - AI #24 Kernel B Fault
1:0719	Alarm - AI #24 Kernel C Fault
1:0720	Alarm - AI #24 Input Failed
1:0721	Alarm - AI #24 Input High Alarm
1:0722	Alarm - AI #24 Input Low Alarm
1:0723	Alarm - AI #25 TT-1390 Kernel A Fault
1:0724	Alarm - AI #25 TT-1390 Kernel B Fault
1:0725	Alarm - AI #25 TT-1390 Kernel C Fault
1:0726	Alarm - AI #25 TT-1390 Input Failed
1:0727	Alarm - AI #25 TT-1390 Input High Alarm
1:0728	Alarm - AI #25 TT-1390 Input Low Alarm
1:0729	Alarm - AI #26 Kernel A Fault
1:0730	Alarm - AI #26 Kernel B Fault
1:0731	Alarm - AI #26 Kernel C Fault
1:0732	Alarm - AI #26 Input Failed
1:0733	Alarm - AI #26 Input High Alarm
1:0734	Alarm - AI #26 Input Low Alarm
1:0735	Alarm - AI #27 Kernel A Fault
1:0736	Alarm - AI #27 Kernel B Fault
1:0737	Alarm - AI #27 Kernel C Fault
1:0738	Alarm - AI #27 Input Failed
1:0739	Alarm - AI #27 Input High Alarm
1:0740	Alarm - AI #27 Input Low Alarm
1:0741	Alarm - AI #28 PY-0005 Kernel A Fault
1:0742	Alarm - AI #28 PY-0005 Kernel B Fault
1:0743	Alarm - AI #28 PY-0005 Kernel C Fault
1:0744	Alarm - AI #28 PY-0005 Input Failed
1:0745	Alarm - AI #28 PY-0005 Input High Alarm
1:0746	Alarm - AI #28 PY-0005 Input Low Alarm
1:0747	Alarm - AI #29 HC-1254 Kernel A Fault
1:0748	Alarm - AI #29 HC-1254 Kernel B Fault
1:0749	Alarm - AI #29 HC-1254 Kernel C Fault
1:0750	Alarm - AI #29 HC-1254 Input Failed
1:0751	Alarm - AI #29 HC-1254 Input High Alarm
1:0752	Alarm - AI #29 HC-1254 Input Low Alarm
1:0753	Alarm - AI #30 HC-1257 Kernel A Fault
1:0754	Alarm - AI #30 HC-1257 Kernel B Fault
1:0755	Alarm - AI #30 HC-1257 Kernel C Fault
1:0756	Alarm - AI #30 HC-1257 Input Failed
1:0757	Alarm - AI #30 HC-1257 Input High Alarm
1:0758	Alarm - AI #30 HC-1257 Input Low Alarm
1:0759	Alarm - AI #31 Kernel A Fault
1:0760	Alarm - AI #31 Kernel B Fault
1:0761	Alarm - AI #31 Kernel C Fault
1:0762	Alarm - AI #31 Input Failed
1:0763	Alarm - AI #31 Input High Alarm
1:0764	Alarm - AI #31 Input Low Alarm
1:0765	Alarm - AI #32 Kernel A Fault
1:0766	Alarm - AI #32 Kernel B Fault
1:0767	Alarm - AI #32 Kernel C Fault
1:0768	Alarm - AI #32 Input Failed
1:0769	Alarm - AI #32 Input High Alarm
1:0770	Alarm - AI #32 Input Low Alarm
1:0771	Alarm - DI #1 XC-1350D Kernel A Fault
1:0772	Alarm - DI #1 XC-1350D Kernel B Fault
1:0773	Alarm - DI #1 XC-1350D Kernel C Fault
1:0774	Alarm - DI #2 XC-1350B Kernel A Fault
1:0775	Alarm - DI #2 XC-1350B Kernel B Fault
1:0776	Alarm - DI #2 XC-1350B Kernel C Fault
1:0777	Alarm - DI #3 XC-1350H Kernel A Fault
1:0778	Alarm - DI #3 XC-1350H Kernel B Fault
1:0779	Alarm - DI #3 XC-1350H Kernel C Fault

1:0780	Alarm - DI #4 XC-1350A Kernel A Fault
1:0781	Alarm - DI #4 XC-1350A Kernel B Fault
1:0782	Alarm - DI #4 XC-1350A Kernel C Fault
1:0783	Alarm - DI #5 XC-1362 Kernel A Fault
1:0784	Alarm - DI #5 XC-1362 Kernel B Fault
1:0785	Alarm - DI #5 XC-1362 Kernel C Fault
1:0786	Alarm - DI #6 HC-1395 Kernel A Fault
1:0787	Alarm - DI #6 HC-1395 Kernel B Fault
1:0788	Alarm - DI #6 HC-1395 Kernel C Fault
1:0789	Alarm - DI #7 XC-1350K Kernel A Fault
1:0790	Alarm - DI #7 XC-1350K Kernel B Fault
1:0791	Alarm - DI #7 XC-1350K Kernel C Fault
1:0792	Alarm - DI #8 XC-1350L Kernel A Fault
1:0793	Alarm - DI #8 XC-1350L Kernel B Fault
1:0794	Alarm - DI #8 XC-1350L Kernel C Fault
1:0795	Alarm - DI #9 XC-1350C Kernel A Fault
1:0796	Alarm - DI #9 XC-1350C Kernel B Fault
1:0797	Alarm - DI #9 XC-1350C Kernel C Fault
1:0798	Alarm - DI #10 Kernel A Fault
1:0799	Alarm - DI #10 Kernel B Fault
1:0800	Alarm - DI #10 Kernel C Fault
1:0801	Alarm - DI #11 Kernel A Fault
1:0802	Alarm - DI #11 Kernel B Fault
1:0803	Alarm - DI #11 Kernel C Fault
1:0804	Alarm - DI #12 Kernel A Fault
1:0805	Alarm - DI #12 Kernel B Fault
1:0806	Alarm - DI #12 Kernel C Fault
1:0807	Alarm - DI #13 HS-1397 Kernel A Fault
1:0808	Alarm - DI #13 HS-1397 Kernel B Fault
1:0809	Alarm - DI #13 HS-1397 Kernel C Fault
1:0810	Alarm - DI #14 HS-1360B Kernel A Fault
1:0811	Alarm - DI #14 HS-1360B Kernel B Fault
1:0812	Alarm - DI #14 HS-1360B Kernel C Fault
1:0813	Alarm - DI #15 24VDC PS_A Kernel A Fau
1:0814	Alarm - DI #15 24VDC PS_A Kernel B Fau
1:0815	Alarm - DI #15 24VDC PS_A Kernel C Fau
1:0816	Alarm - DI #16 24VDC PS_B Kernel A Fau
1:0817	Alarm - DI #16 24VDC PS_B Kernel B Fau
1:0818	Alarm - DI #16 24VDC PS_B Kernel C Fau
1:0819	Alarm - DI #17 Kernel A Fault
1:0820	Alarm - DI #17 Kernel B Fault
1:0821	Alarm - DI #17 Kernel C Fault
1:0822	Alarm - DI #18 Kernel A Fault
1:0823	Alarm - DI #18 Kernel B Fault
1:0824	Alarm - DI #18 Kernel C Fault
1:0825	Alarm - DI #19 ESD-1352B Kernel A Faul
1:0826	Alarm - DI #19 ESD-1352B Kernel B Faul
1:0827	Alarm - DI #19 ESD-1352B Kernel C Faul
1:0828	Alarm - DI #20 Kernel A Fault
1:0829	Alarm - DI #20 Kernel B Fault
1:0830	Alarm - DI #20 Kernel C Fault
1:0831	Alarm - DI #21 Kernel A Fault
1:0832	Alarm - DI #21 Kernel B Fault
1:0833	Alarm - DI #21 Kernel C Fault
1:0834	Alarm - DI #22 Kernel A Fault
1:0835	Alarm - DI #22 Kernel B Fault
1:0836	Alarm - DI #22 Kernel C Fault
1:0837	Alarm - DI #23 Kernel A Fault
1:0838	Alarm - DI #23 Kernel B Fault
1:0839	Alarm - DI #23 Kernel C Fault
1:0840	Alarm - DI #24 Kernel A Fault
1:0841	Alarm - DI #24 Kernel B Fault
1:0842	Alarm - DI #24 Kernel C Fault
1:0843 – 1:0933	Alarm - Spare
1:0934	Alarm - Act #1 (HP) Failed
1:0935	Alarm - Act #1 Driver A Fault
1:0936	Alarm - Act #1 Driver B Fault
1:0937	Alarm - Act #1 Driver C Fault
1:0938	Alarm - Act #1 (HP) Load Fault

1:0939	Alarm - Act #1 (HP) Load 'A/B' Fault
1:0940	Alarm - Act #1 (HP) Load 'C' Fault
1:0941	Alarm - Act #2 (LP) Failed
1:0942	Alarm - Act #2 Driver A Fault
1:0943	Alarm - Act #2 Driver B Fault
1:0944	Alarm - Act #2 Driver C Fault
1:0945	Alarm - Act #2 (LP) Load Fault
1:0946	Alarm - Act #2 (LP) Load 'A/B' Fault
1:0947	Alarm - Act #2 (LP) Load 'C' Fault
1:0948	Alarm - DO #1 XA-1350 A1 Driver Fault
1:0949	Alarm - DO #1 XA-1350 A2 Driver Fault
1:0950	Alarm - DO #1 XA-1350 A1 Fault
1:0951	Alarm - DO #1 XA-1350 A2 Fault
1:0952	Alarm - DO #1 XA-1350 B1 Driver Fault
1:0953	Alarm - DO #1 XA-1350 B2 Driver Fault
1:0954	Alarm - DO #1 XA-1350 B1 Fault
1:0955	Alarm - DO #1 XA-1350 B2 Fault
1:0956	Alarm - DO #1 XA-1350 C1 Driver Fault
1:0957	Alarm - DO #1 XA-1350 C2 Driver Fault
1:0958	Alarm - DO #1 XA-1350 C1 Fault
1:0959	Alarm - DO #1 XA-1350 C2 Fault
1:0960	Alarm - DO #1 XA-1350 A1 or B1 Fault
1:0961	Alarm - DO #1 XA-1350 C2 or A2 Fault
1:0962	Alarm - DO #1 XA-1350 B2 or C1 Fault
1:0963	Alarm - DO #2 XL-1350C A1 Driver Fault
1:0964	Alarm - DO #2 XL-1350C A2 Driver Fault
1:0965	Alarm - DO #2 XL-1350C A1 Fault
1:0966	Alarm - DO #2 XL-1350C A2 Fault
1:0967	Alarm - DO #2 XL-1350C B1 Driver Fault
1:0968	Alarm - DO #2 XL-1350C B2 Driver Fault
1:0969	Alarm - DO #2 XL-1350C B1 Fault
1:0970	Alarm - DO #2 XL-1350C B2 Fault
1:0971	Alarm - DO #2 XL-1350C C1 Driver Fault
1:0972	Alarm - DO #2 XL-1350C C2 Driver Fault
1:0973	Alarm - DO #2 XL-1350C C1 Fault
1:0974	Alarm - DO #2 XL-1350C C2 Fault
1:0975	Alarm - DO #2 XL-1350C A1 or B1 Fault
1:0976	Alarm - DO #2 XL-1350C C2 or A2 Fault
1:0977	Alarm - DO #2 XL-1350C B2 or C1 Fault
1:0978	Alarm - DO #3 A1 Driver Fault
1:0979	Alarm - DO #3 A2 Driver Fault
1:0980	Alarm - DO #3 A1 Fault
1:0981	Alarm - DO #3 A2 Fault
1:0982	Alarm - DO #3 B1 Driver Fault
1:0983	Alarm - DO #3 B2 Driver Fault
1:0984	Alarm - DO #3 B1 Fault
1:0985	Alarm - DO #3 B2 Fault
1:0986	Alarm - DO #3 C1 Driver Fault
1:0987	Alarm - DO #3 C2 Driver Fault
1:0988	Alarm - DO #3 C1 Fault
1:0989	Alarm - DO #3 C2 Fault
1:0990	Alarm - DO #3 A1 or B1 Fault
1:0991	Alarm - DO #3 C2 or A2 Fault
1:0992	Alarm - DO #3 B2 or C1 Fault
1:0993	Alarm - DO #4 XL-1350B A1 Driver Fault
1:0994	Alarm - DO #4 XL-1350B A2 Driver Fault
1:0995	Alarm - DO #4 XL-1350B A1 Fault
1:0996	Alarm - DO #4 XL-1350B A2 Fault
1:0997	Alarm - DO #4 XL-1350B B1 Driver Fault
1:0998	Alarm - DO #4 XL-1350B B2 Driver Fault
1:0999	Alarm - DO #4 XL-1350B B1 Fault
1:1000	Alarm - DO #4 XL-1350B B2 Fault
1:1001	Alarm - DO #4 XL-1350B C1 Driver Fault
1:1002	Alarm - DO #4 XL-1350B C2 Driver Fault
1:1003	Alarm - DO #4 XL-1350B C1 Fault
1:1004	Alarm - DO #4 XL-1350B C2 Fault
1:1005	Alarm - DO #4 XL-1350B A1 or B1 Fault
1:1006	Alarm - DO #4 XL-1350B C2 or A2 Fault
1:1007	Alarm - DO #4 XL-1350B B2 or C1 Fault

1:1008	Alarm - DO #5 HL-1350 A1 Driver Fault
1:1009	Alarm - DO #5 HL-1350 A2 Driver Fault
1:1010	Alarm - DO #5 HL-1350 A1 Fault
1:1011	Alarm - DO #5 HL-1350 A2 Fault
1:1012	Alarm - DO #5 HL-1350 B1 Driver Fault
1:1013	Alarm - DO #5 HL-1350 B2 Driver Fault
1:1014	Alarm - DO #5 HL-1350 B1 Fault
1:1015	Alarm - DO #5 HL-1350 B2 Fault
1:1016	Alarm - DO #5 HL-1350 C1 Driver Fault
1:1017	Alarm - DO #5 HL-1350 C2 Driver Fault
1:1018	Alarm - DO #5 HL-1350 C1 Fault
1:1019	Alarm - DO #5 HL-1350 C2 Fault
1:1020	Alarm - DO #5 HL-1350 A1 or B1 Fault
1:1021	Alarm - DO #5 HL-1350 C2 or A2 Fault
1:1022	Alarm - DO #5 HL-1350 B2 or C1 Fault
1:1023	Alarm - DO #6 A1 Driver Fault
1:1024	Alarm - DO #6 A2 Driver Fault
1:1025	Alarm - DO #6 A1 Fault
1:1026	Alarm - DO #6 A2 Fault
1:1027	Alarm - DO #6 B1 Driver Fault
1:1028	Alarm - DO #6 B2 Driver Fault
1:1029	Alarm - DO #6 B1 Fault
1:1030	Alarm - DO #6 B2 Fault
1:1031	Alarm - DO #6 C1 Driver Fault
1:1032	Alarm - DO #6 C2 Driver Fault
1:1033	Alarm - DO #6 C1 Fault
1:1034	Alarm - DO #6 C2 Fault
1:1035	Alarm - DO #6 A1 or B1 Fault
1:1036	Alarm - DO #6 C2 or A2 Fault
1:1037	Alarm - DO #6 B2 or C1 Fault
1:1038	Alarm - DO #7 XL-1397 A1 Driver Fault
1:1039	Alarm - DO #7 XL-1397 A2 Driver Fault
1:1040	Alarm - DO #7 XL-1397 A1 Fault
1:1041	Alarm - DO #7 XL-1397 A2 Fault
1:1042	Alarm - DO #7 XL-1397 B1 Driver Fault
1:1043	Alarm - DO #7 XL-1397 B2 Driver Fault
1:1044	Alarm - DO #7 XL-1397 B1 Fault
1:1045	Alarm - DO #7 XL-1397 B2 Fault
1:1046	Alarm - DO #7 XL-1397 C1 Driver Fault
1:1047	Alarm - DO #7 XL-1397 C2 Driver Fault
1:1048	Alarm - DO #7 XL-1397 C1 Fault
1:1049	Alarm - DO #7 XL-1397 C2 Fault
1:1050	Alarm - DO #7 XL-1397 A1 or B1 Fault
1:1051	Alarm - DO #7 XL-1397 C2 or A2 Fault
1:1052	Alarm - DO #7 XL-1397 B2 or C1 Fault
1:1053	Alarm - DO #8 A1 Driver Fault
1:1054	Alarm - DO #8 A2 Driver Fault
1:1055	Alarm - DO #8 A1 Fault
1:1056	Alarm - DO #8 A2 Fault
1:1057	Alarm - DO #8 B1 Driver Fault
1:1058	Alarm - DO #8 B2 Driver Fault
1:1059	Alarm - DO #8 B1 Fault
1:1060	Alarm - DO #8 B2 Fault
1:1061	Alarm - DO #8 C1 Driver Fault
1:1062	Alarm - DO #8 C2 Driver Fault
1:1063	Alarm - DO #8 C1 Fault
1:1064	Alarm - DO #8 C2 Fault
1:1065	Alarm - DO #8 A1 or B1 Fault
1:1066	Alarm - DO #8 C2 or A2 Fault
1:1067	Alarm - DO #8 B2 or C1 Fault
1:1068	Alarm - DO #9 A1 Driver Fault
1:1069	Alarm - DO #9 A2 Driver Fault
1:1070	Alarm - DO #9 A1 Fault
1:1071	Alarm - DO #9 A2 Fault
1:1072	Alarm - DO #9 B1 Driver Fault
1:1073	Alarm - DO #9 B2 Driver Fault
1:1074	Alarm - DO #9 B1 Fault
1:1075	Alarm - DO #9 B2 Fault
1:1076	Alarm - DO #9 C1 Driver Fault

1:1077	Alarm - DO #9 C2 Driver Fault
1:1078	Alarm - DO #9 C1 Fault
1:1079	Alarm - DO #9 C2 Fault
1:1080	Alarm - DO #9 A1 or B1 Fault
1:1081	Alarm - DO #9 C2 or A2 Fault
1:1082	Alarm - DO #9 B2 or C1 Fault
1:1083	Alarm - DO #10 XC-1353 A1 Driver Fault
1:1084	Alarm - DO #10 XC-1353 A2 Driver Fault
1:1085	Alarm - DO #10 XC-1353 A1 Fault
1:1086	Alarm - DO #10 XC-1353 A2 Fault
1:1087	Alarm - DO #10 XC-1353 B1 Driver Fault
1:1088	Alarm - DO #10 XC-1353 B2 Driver Fault
1:1089	Alarm - DO #10 XC-1353 B1 Fault
1:1090	Alarm - DO #10 XC-1353 B2 Fault
1:1091	Alarm - DO #10 XC-1353 C1 Driver Fault
1:1092	Alarm - DO #10 XC-1353 C2 Driver Fault
1:1093	Alarm - DO #10 XC-1353 C1 Fault
1:1094	Alarm - DO #10 XC-1353 C2 Fault
1:1095	Alarm - DO #10 XC-1353 A1 or B1 Fault
1:1096	Alarm - DO #10 XC-1353 C2 or A2 Fault
1:1097	Alarm - DO #10 XC-1353 B2 or C1 Fault
1:1098	Alarm - DO #11 A1 Driver Fault
1:1099	Alarm - DO #11 A2 Driver Fault
1:1100	Alarm - DO #11 A1 Fault
1:1101	Alarm - DO #11 A2 Fault
1:1102	Alarm - DO #11 B1 Driver Fault
1:1103	Alarm - DO #11 B2 Driver Fault
1:1104	Alarm - DO #11 B1 Fault
1:1105	Alarm - DO #11 B2 Fault
1:1106	Alarm - DO #11 C1 Driver Fault
1:1107	Alarm - DO #11 C2 Driver Fault
1:1108	Alarm - DO #11 C1 Fault
1:1109	Alarm - DO #11 C2 Fault
1:1110	Alarm - DO #11 A1 or B1 Fault
1:1111	Alarm - DO #11 C2 or A2 Fault
1:1112	Alarm - DO #11 B2 or C1 Fault
1:1113	Alarm - DO #12 A1 Driver Fault
1:1114	Alarm - DO #12 A2 Driver Fault
1:1115	Alarm - DO #12 A1 Fault
1:1116	Alarm - DO #12 A2 Fault
1:1117	Alarm - DO #12 B1 Driver Fault
1:1118	Alarm - DO #12 B2 Driver Fault
1:1119	Alarm - DO #12 B1 Fault
1:1120	Alarm - DO #12 B2 Fault
1:1121	Alarm - DO #12 C1 Driver Fault
1:1122	Alarm - DO #12 C2 Driver Fault
1:1123	Alarm - DO #12 C1 Fault
1:1124	Alarm - DO #12 C2 Fault
1:1125	Alarm - DO #12 A1 or B1 Fault
1:1126	Alarm - DO #12 C2 or A2 Fault
1:1127	Alarm - DO #12 B2 or C1 Fault
1:1128	Alarm - DO #1 XA-1350 Power Fault
1:1129	Alarm - DO #2 XL-1350C Power Fault
1:1130	Alarm - DO #3 Power Fault
1:1131	Alarm - DO #4 XL-1350B Power Fault
1:1132	Alarm - DO #5 HL-1350 Power Fault
1:1133	Alarm - DO #6 Power Fault
1:1134	Alarm - DO #7 XL-1397 Power Fault
1:1135	Alarm - DO #8 Power Fault
1:1136	Alarm - DO #9 Power Fault
1:1137	Alarm - DO #10 XC-1353 Power Fault
1:1138	Alarm - DO #11 Power Fault
1:1139	Alarm - DO #12 Power Fault
1:1140	Alarm - AO #1 Failed
1:1141	Alarm - AO #1 Drvr A Fault
1:1142	Alarm - AO #1 Drvr B Fault
1:1143	Alarm - AO #1 Drvr C Fault
1:1144	Alarm - AO #1 Load Fault
1:1145	Alarm - AO #2 Failed

1:1146	Alarm - AO #2 Drvr A Fault
1:1147	Alarm - AO #2 Drvr B Fault
1:1148	Alarm - AO #2 Drvr C Fault
1:1149	Alarm - AO #2 Load Fault
1:1150	Alarm - AO #3 Failed
1:1151	Alarm - AO #3 Drvr A Fault
1:1152	Alarm - AO #3 Drvr B Fault
1:1153	Alarm - AO #3 Drvr C Fault
1:1154	Alarm - AO #3 Load Fault
1:1155	Alarm - AO #4 Failed
1:1156	Alarm - AO #4 Drvr A Fault
1:1157	Alarm - AO #4 Drvr B Fault
1:1158	Alarm - AO #4 Drvr C Fault
1:1159	Alarm - AO #4 Load Fault
1:1160	Alarm - AO #5 PY-0092 Failed
1:1161	Alarm - AO #5 PY-0092 Drvr A Fault
1:1162	Alarm - AO #5 PY-0092 Drvr B Fault
1:1163	Alarm - AO #5 PY-0092 Drvr C Fault
1:1164	Alarm - AO #5 PY-0092 Load Fault
1:1165	Alarm - AO #6 SI-1059A Failed
1:1166	Alarm - AO #6 SI-1059A Drvr A Fault
1:1167	Alarm - AO #6 SI-1059A Drvr B Fault
1:1168	Alarm - AO #6 SI-1059A Drvr C Fault
1:1169	Alarm - AO #6 SI-1059A Load Fault
1:1170	Alarm - AO #7 Failed
1:1171	Alarm - AO #7 Drvr A Fault
1:1172	Alarm - AO #7 Drvr B Fault
1:1173	Alarm - AO #7 Drvr C Fault
1:1174	Alarm - AO #7 Load Fault
1:1175	Alarm - AO #8 Failed
1:1176	Alarm - AO #8 Drvr A Fault
1:1177	Alarm - AO #8 Drvr B Fault
1:1178	Alarm - AO #8 Drvr C Fault
1:1179	Alarm - AO #8 Load Fault
1:1180	Alarm - AO #9 FY-1254 Failed
1:1181	Alarm - AO #9 FY-1254 Drvr A Fault
1:1182	Alarm - AO #9 FY-1254 Drvr B Fault
1:1183	Alarm - AO #9 FY-1254 Drvr C Fault
1:1184	Alarm - AO #9 FY-1254 Load Fault
1:1185	Alarm - AO #10 FY-1257 Failed
1:1186	Alarm - AO #10 FY-1257 Drvr A Fault
1:1187	Alarm - AO #10 FY-1257 Drvr B Fault
1:1188	Alarm - AO #10 FY-1257 Drvr C Fault
1:1189	Alarm - AO #10 FY-1257 Load Fault
1:1190	Alarm - AO #11 SI-1059B Failed
1:1191	Alarm - AO #11 SI-1059B Drvr A Fault
1:1192	Alarm - AO #11 SI-1059B Drvr B Fault
1:1193	Alarm - AO #11 SI-1059B Drvr C Fault
1:1194	Alarm - AO #11 SI-1059B Load Fault
1:1195	Alarm - AO #12 Failed
1:1196	Alarm - AO #12 Drvr A Fault
1:1197	Alarm - AO #12 Drvr B Fault
1:1198	Alarm - AO #12 Drvr C Fault
1:1199	Alarm - AO #12 Load Fault
1:1200	Alarm - AO #1 in Calib or Out Removed
1:1201	Alarm - AO #2 in Calib or Out Removed
1:1202	Alarm - AO #3 in Calib or Out Removed
1:1203	Alarm - AO #4 in Calib or Out Removed
1:1204	Alarm - AO #5 PY-0092 in Calib or Out
1:1205	Alarm - AO #6 SI-1059A in Calib or Out
1:1206	Alarm - AO #7 in Calib or Out Removed
1:1207	Alarm - AO #8 in Calib or Out Removed
1:1208	Alarm - AO #9 FY-1254 in Calib or Out
1:1209	Alarm - AO #10 FY-1257 in Calib or Out
1:1210	Alarm - AO #11 SI-1059B in Calib or Ou
1:1211	Alarm - AO #12 in Calib or Out Removed
1:1212	Alarm - Act #1 (HP) in Cal or Removed
1:1213	Alarm - Act #2 (LP) in Cal or Removed
1:1214 – 1:1248	Spare

1:1249	Trip - Power Up Trip
1:1250	Trip - External Trip Input
1:1251	Trip - External Trip #2
1:1252	Trip - External Trip #3
1:1253	Trip - External Trip #4
1:1254	Trip - External Trip #5
1:1255	Trip - External Trip #6
1:1256	Trip - External Trip #7
1:1257	Trip - External Trip #8
1:1258	Trip - External Trip #9
1:1259	Trip - External Trip #10
1:1260	Trip - PC Programmer Trip
1:1261	Trip - Modbus Link #1 Trip
1:1262	Trip - Modbus Link #2 Trip
1:1263	Trip - Overspeed Trip
1:1264	Trip - Loss of All Speed Inputs
1:1265	Trip - All Anlg I/O Mods Failed
1:1266	Trip - All Combo Mods Failed
1:1267	Trip - All Discrete I/O Mods Failed
1:1268	Trip - Act #1 (HP) Fault
1:1269	Trip - Act #2 (LP) Fault
1:1270	Trip - Aux Input Failed
1:1271	Trip - Extr/Adm Input Failed
1:1272	Trip - Tie Breaker Opened
1:1273	Trip - Gen Breaker Opened
1:1274	Trip - Controlled Shutdown
1:1275	Trip - Configuration Error
1:1276	Trip - Stuck in Critical Band

Table 4-2. Modbus Boolean Reads

Analog Reads (reads from the control by the master device)

Addr	Description	Multiplier	Units
3:0001	Turbine Speed	10	rpm
3:0002	Turbine Speed	10	rpm
3:0003 – 3:0004	Spare		
3:0005	Turbine Inlet Vane Actuator Pos. Req.	10	%
3:0006	Turbine Inlet Vane Actuator Pos. Fdbk.	10	%
3:0007 – 3:0009	Spare		
3:0010	Turbine Speed	10	rpm
3:0011 – 3:0018	Spare		
3:0019	First Stage Suction Pressure	100	engunit
3:0020	First Stage Suction Temperature	10	engunit
3:0021	First Stage Anti-surge Valve Position	10	%
3:0022	Side Load Inlet Flow	10	engunit
3:0023	Side Load Inlet Pressure	100	engunit
3:0024	Side Load Inlet Temperature	10	engunit
3:0025	Side Load Anti-surge Valve Pos. Fdbk.	10	%
3:0026	Extraction Discharge Temperature	10	engunit
3:0027	Extraction Discharge Pressure	100	engunit
3:0028	Extraction Discharge Flow	10	engunit
3:0029	Spare		
3:0030	Spare		
3:0031	Flow Control Valve Position (DCS HSS)		%
3:0032	Actual Speed to DCS		rpm
3:0033 – 3:0034	Spare		
3:0035	Discharge Temperature	10	engunit
3:0036	Discharge Pressure	100	engunit
3:0037	Discharge Flow	10	engunit
3:0038	Spare		
3:0039	Control Panel Temperature	10	engunit
3:0040 – 3:0041	Spare		
3:0042	Remote Speed Setpoint	10	rpm
3:0043	First Stage Recycle Vlv. Man. Pos. Req	10	%
3:0044	Side Load Recycle Vlv. Man. Pos. Req.	10	%
3:0045 – 3:0046	Spare		

3:0047	First Stage Anti-surge Vlv. Pos. Req.	10	%
3:0048	Side Load Anti-surge Vlv. Pos. Req.	10	%
3:0049	Actual Speed to Local Panel	10	rpm
3:0050 – 3:0200	Spare		
3:0201	Cause of last turbine trip		
3:0202	Comp. 1 - AntiSurge PID Output	*10	%
3:0203	Comp. 1 - Flow Filtered Input Signal	*10	engunit
3:0204	Comp. 1 - Calculated Polytropic Head	*0.1	engunit
3:0205	Comp. 1 - Calculated Reduced Head	*1000	
3:0206	Comp. 1 - Calculated Spec. Heat Ratio	*1000	
3:0207	Comp. 1 - Manual Valve Position	*10	%
3:0208	Comp. 1 - Manual Position Ramp	*10	%
3:0209	Comp. 1 - Surge Control Line Margin	*10	%
3:0210	Comp. 1 - Calculated Pressure Ratio	*100	
3:0211	Comp. 1 - "Corrected" Suction Flow		
3:0212	Comp. 1 - Surge Control Line Flow	*0.1	engunit
3:0213	Comp. 1 - Actual Suction Flow	*0.1	engunit
3:0214	Comp. 1 - Stage Flow	*0.01	engunit
3:0215	Comp. 1 - Rate PID Output	*10	%
3:0216	Comp. 1 - Surge Event Counter		
3:0217	Comp. 1 - Total Number of Surges		
3:0218	Comp. 1 - S_PV Surge Process Variable	*10	%
3:0219	Comp. 1 - Surge Minimum Position	*10	%
3:0220	Comp. 1 - Valve Final Output	*10	%
3:0221	Comp. 1 - Surge Capture Operating Pnt.	*10	engunit
3:0222	Comp. 1 - Opr. Pnt. (Map X-axis Value)	*0.1	engunit
3:0223	Comp. 1 - Opr. Pnt. (Map Y-axis Value)	*0.1	engunit
3:0224	Comp. 1 - Mode Selected		
3:0225	Comp. 1 - Status		
3:0226	Comp. 1 - Active Control Routine		
3:0227	Comp. 1 - Mode and Routine Active		
3:0228	Comp. 1 - Alarm First-out		
3:0229	Comp. 2 - AntiSurge PID Output	*10	%
3:0230	Comp. 2 - Flow Filtered Input Signal	*10	engunit
3:0231	Comp. 2 - Calculated Polytropic Head	*0.1	engunit
3:0232	Comp. 2 - Calculated Reduced Head	*1000	
3:0233	Comp. 2 - Calculated Spec. Heat Ratio	*1000	
3:0234	Comp. 2 - Manual Valve Position	*10	%
3:0235	Comp. 2 - Manual Position Ramp	*10	%
3:0236	Comp. 2 - Surge Control Line Margin	*10	%
3:0237	Comp. 2 - Calculated Pressure Ratio	*100	
3:0238	Comp. 2 - "Corrected" Suction Flow		
3:0239	Comp. 2 - Surge Control Line Flow	*0.1	engunit
3:0240	Comp. 2 - Actual Suction Flow	*0.1	engunit
3:0241	Comp. 2 - Stage Flow	*0.01	engunit
3:0242	Comp. 2 - Rate PID Output	*10	%
3:0243	Comp. 2 - Surge Event Counter		
3:0244	Comp. 2 - Total Number of Surges		
3:0245	Comp. 2 - S_PV Surge Process Variable	*10	%
3:0246	Comp. 2 - Surge Minimum Position	*10	%
3:0247	Comp. 2 - Valve Final Output	*10	%
3:0248	Comp. 2 - Surge Capture Operating Pnt.	*10	engunit
3:0249	Comp. 2 - Opr. Pnt. (Map X-axis Value)	*0.1	engunit
3:0250	Comp. 2 - Opr. Pnt. (Map Y-axis Value)	*0.1	engunit
3:0251	Comp. 2 - Mode Selected		
3:0252	Comp. 2 - Status		
3:0253	Comp. 2 - Active Control Routine		
3:0254	Comp. 2 - Mode and Routine Active		
3:0255	Comp. 2 - Alarm First-out		
3:0256	Comp. 3 - AntiSurge PID Output	*10	%
3:0257	Comp. 3 - Flow Filtered Input Signal	*10	engunit
3:0258	Comp. 3 - Calculated Polytropic Head	*0.1	engunit
3:0259	Comp. 3 - Calculated Reduced Head	*1000	
3:0260	Comp. 3 - Calculated Spec. Heat Ratio	*1000	
3:0261	Comp. 3 - Manual Valve Position	*10	%
3:0262	Comp. 3 - Manual Position Ramp	*10	%
3:0263	Comp. 3 - Surge Control Line Margin	*10	%
3:0264	Comp. 3 - Calculated Pressure Ratio	*100	
3:0265	Comp. 3 - "Corrected" Suction Flow		

3:0266	Comp. 3 - Surge Control Line Flow	*0.1	engunit
3:0267	Comp. 3 - Actual Suction Flow	*0.1	engunit
3:0268	Comp. 3 - Stage Flow	*0.01	engunit
3:0269	Comp. 3 - Rate PID Output	*10	%
3:0270	Comp. 3 - Surge Event Counter		
3:0271	Comp. 3 - Total Number of Surges		
3:0272	Comp. 3 - S_PV Surge Process Variable	*10	%
3:0273	Comp. 3 - Surge Minimum Position	*10	%
3:0274	Comp. 3 - Valve Final Output	*10	%
3:0275	Comp. 3 - Surge Capture Operating Pnt.	*10	engunit
3:0276	Comp. 3 - Opr. Pnt. (Map X-axis Value)	*0.1	engunit
3:0277	Comp. 3 - Opr. Pnt. (Map Y-axis Value)	*0.1	engunit
3:0278	Comp. 3 - Mode Selected		
3:0279	Comp. 3 - Status		
3:0280	Comp. 3 - Active Control Routine		
3:0281	Comp. 3 - Mode and Routine Active		
3:0282	Comp. 3 - Alarm First-out		
3:0283 – 3:0300	Spare		

Table 4-3. Modbus Analog Reads

Analog Writes (writes from the master device to the control)

Addr	Description	Multiplier	Units
4:0001	Modbus Entered Speed Setpoint		rpm
4:0002	Modbus Entered Casc Setpoint		engunit
4:0003	Modbus Entered Aux Setpoint (Not Used)		
4:0004	Modbus Entered Extr Setpoint		engunit
4:0005	Modbus Entered Inlet/Exhaust Setpoint		engunit
4:0006	Modbus Entered Manual E/A Press Demand	0.01	%
4:0007	Modbus Entered Manual HP/V1 Setpoint	0.01	%
4:0008	Modbus Entered Manual LP/V2 Setpoint	0.01	%
4:0009	Spare		
4:0010	Comp. 1 - MB Entered P1 Override Stpt.		engunit
4:0011	Comp. 1 - MB Entered P2 Override Stpt.		engunit
4:0012	Comp. 1 - MB Entered Manual Valve Pos.	0.01	%
4:0013	Spare		
4:0014	Comp. 2 - MB Entered P1 Override Stpt.		engunit
4:0015	Comp. 2 - MB Entered P2 Override Stpt.		engunit
4:0016	Comp. 2 - MB Entered Manual Valve Pos.	0.01	%
4:0017	Spare		
4:0018	Comp. 3 - MB Entered P1 Override Stpt.		engunit
4:0019	Comp. 3 - MB Entered P2 Override Stpt.		engunit
4:0020	Comp. 3 - MB Entered Manual Valve Pos.	0.01	%
4:0021	Spare		
4:0022	Spare		

Table 4-4. Modbus Analog Writes

Chapter 5.
Service Options

Product Service 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 and 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 Engine Retrofitter (RER)** is an independent company that does retrofits and upgrades on reciprocating gas engines and dual-fuel conversions, and can provide the full line of Woodward systems and components for the retrofits and overhauls, emission compliance upgrades, long term service contracts, emergency repairs, etc.
- 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.

You can locate your nearest Woodward distributor, AISF, RER, or RTR on our website at:

www.woodward.com/directory

Woodward Factory Servicing 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**.

How to Contact Woodward

For assistance, call one of the following Woodward facilities to obtain the address and phone number of the facility nearest your location where you will be able to get information and service.

Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (0) 21 52 14 51
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (711) 78954-510
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Turbine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
India	+91 (129) 4097100
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

You can also locate your nearest Woodward distributor or service facility on our website at:

www.woodward.com/directory

Technical Assistance

If you need to telephone for technical assistance, you will need to provide the following information. Please write it down here before phoning:

Your Name ______________________

Site Location ______________________

Phone Number ______________________

Fax Number ______________________

Engine/Turbine Model Number ______________________

Manufacturer ______________________

Number of Cylinders (if applicable) ______________________

Type of Fuel (gas, gaseous, steam, etc) ______________________

Rating ______________________

Application ______________________

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 ______________________

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.
Alarm List

1	Alarm - Kernel A Anlg I/O Module Flt	82	Alarm - AI #1 ZT-1059 Kernel B Fault
2	Alarm - Kernel B Anlg I/O Module Flt	83	Alarm - AI #1 ZT-1059 Kernel C Fault
3	Alarm - Kernel C Anlg I/O Module Flt	84	Alarm - AI #1 ZT-1059 Input Failed
4	Alarm - Kernel A Discrete I/O Mod Flt	85	Alarm - AI #1 ZT-1059 Input High Alarm
5	Alarm - Kernel B Discrete I/O Mod Flt	86	Alarm - AI #1 ZT-1059 Input Low Alarm
6	Alarm - Kernel C Discrete I/O Mod Flt	87	Alarm - AI #2 Kernel A Fault
7	Alarm - Kernel A Cmbo I/O Module Flt	88	Alarm - AI #2 Kernel B Fault
8	Alarm - Kernel B Cmbo I/O Module Flt	89	Alarm - AI #2 Kernel C Fault
9	Alarm - Kernel C Cmbo I/O Module Flt	90	Alarm - AI #2 Input Failed
10	Alarm - 24VDC Power Supply A Fault	91	Alarm - AI #2 Input High Alarm
11	Alarm - 24VDC Power Supply B Fault	92	Alarm - AI #2 Input Low Alarm
12	Alarm - Spare	93	Alarm - AI #3 Kernel A Fault
13	Alarm - Kernel A Fault	94	Alarm - AI #3 Kernel B Fault
14	Alarm - Kernel B Fault	95	Alarm - AI #3 Kernel C Fault
15	Alarm - Kernel C Fault	96	Alarm - AI #3 Input Failed
16	Alarm - Fan Fault	97	Alarm - AI #3 Input High Alarm
17	Alarm - MicroNet Power Supply #1 Fault	98	Alarm - AI #3 Input Low Alarm
18	Alarm - MicroNet Power Supply #2 Fault	99	Alarm - AI #4 Kernel A Fault
19	Alarm - Operating System Alarm	100	Alarm - AI #4 Kernel B Fault
20	Alarm - Start Perm Not Closed	101	Alarm - AI #4 Kernel C Fault
21	Alarm - MOD1 P1 Comm Link Failed	102	Alarm - AI #4 Input Failed
22	Alarm - MOD2 P1 Comm Link Failed	103	Alarm - AI #4 Input High Alarm
23	Alarm - Spare	104	Alarm - AI #4 Input Low Alarm
24	Alarm - Turbine Trip	105	Alarm - AI #5 Kernel A Fault
25	Alarm - Overspeed	106	Alarm - AI #5 Kernel B Fault
26	Alarm - Stuck in Critical Band	107	Alarm - AI #5 Kernel C Fault
27 - 47	Alarm - Spare	108	Alarm - AI #5 Input Failed
48	Alarm - Configuration Error	109	Alarm - AI #5 Input High Alarm
49	Alarm - MOD2 P2 Comm Link Failed	110	Alarm - AI #5 Input Low Alarm
50	Alarm - MOD1 P2 Comm Link Failed	111	Alarm - AI #6 Kernel A Fault
51	Alarm - Kernel A Overtemp	112	Alarm - AI #6 Kernel B Fault
52	Alarm - Kernel B Overtemp	113	Alarm - AI #6 Kernel C Fault
53	Alarm - Kernel C Overtemp	114	Alarm - AI #6 Input Failed
54	Alarm - CPU A Time Fault	115	Alarm - AI #6 Input High Alarm
55	Alarm - CPU B Time Fault	116	Alarm - AI #6 Input Low Alarm
56	Alarm - CPU C Time Fault	117	Alarm - AI #7 Kernel A Fault
57	Alarm - Spd Probe #1 Input Fld	118	Alarm - AI #7 Kernel B Fault
58	Alarm - Spd Probe #1 Deviation Alm	119	Alarm - AI #7 Kernel C Fault
59	Alarm - Spd Probe #1 Ospd Alm	120	Alarm - AI #7 Input Failed
60	Alarm - Spd Probe #1 Kernel A Fault	121	Alarm - AI #7 Input High Alarm
61	Alarm - Spd Probe #1 Kernel B Fault	122	Alarm - AI #7 Input Low Alarm
62	Alarm - Spd Probe #1 Kernel C Fault	123	Alarm - AI #8 Kernel A Fault
63	Alarm - Spd Probe #2 Input Failed	124	Alarm - AI #8 Kernel B Fault
64	Alarm - Spd Probe #2 Deviation Alm	125	Alarm - AI #8 Kernel C Fault
65	Alarm - Spd Probe #2 Ospd Alm	126	Alarm - AI #8 Input Failed
66	Alarm - Spd Probe #2 Kernel A Fault	127	Alarm - AI #8 Input High Alarm
67	Alarm - Spd Probe #2 Kernel B Fault	128	Alarm - AI #8 Input Low Alarm
68	Alarm - Spd Probe #2 Kernel C Fault	129	Alarm - AI #9 PT-1250 Kernel A Fault
69	Alarm - Spd Probe #3 Input Failed	130	Alarm - AI #9 PT-1250 Kernel B Fault
70	Alarm - Spd Probe #3 Deviation Alm	131	Alarm - AI #9 PT-1250 Kernel C Fault
71	Alarm - Spd Probe #3 Ospd Alm	132	Alarm - AI #9 PT-1250 Input Failed
72	Alarm - Spd Probe #3 Kernel A Fault	133	Alarm - AI #9 PT-1250 Input High Alarm
73	Alarm - Spd Probe #3 Kernel B Fault	134	Alarm - AI #9 PT-1250 Input Low Alarm
74	Alarm - Spd Probe #3 Kernel C Fault	135	Alarm - AI #10 TT-1251 Kernel A Fault
75	Alarm - Spd Probe #4 Input Failed	136	Alarm - AI #10 TT-1251 Kernel B Fault
76	Alarm - Spd Probe #4 Deviation Alm	137	Alarm - AI #10 TT-1251 Kernel C Fault
77	Alarm - Spd Probe #4 Ospd Alm	138	Alarm - AI #10 TT-1251 Input Failed
78	Alarm - Spd Probe #4 Kernel A Fault	139	Alarm - AI #10 TT-1251 Input High Alarm
79	Alarm - Spd Probe #4 Kernel B Fault	140	Alarm - AI #10 TT-1251 Input Low Alarm
80	Alarm - Spd Probe #4 Kernel C Fault	141	Alarm - AI #11 ZT-1254 Kernel A Fault
81	Alarm - AI #1 ZT-1059 Kernel A Fault	142	Alarm - AI #11 ZT-1254 Kernel B Fault

143	Alarm - AI #11 ZT-1254 Kernel C Fault
144	Alarm - AI #11 ZT-1254 Input Failed
145	Alarm - AI #11 ZT-1254 Input High Alarm
146	Alarm - AI #11 ZT-1254 Input Low Alarm
147	Alarm - AI #12 FT-1257 Kernel A Fault
148	Alarm - AI #12 FT-1257 Kernel B Fault
149	Alarm - AI #12 FT-1257 Kernel C Fault
150	Alarm - AI #12 FT-1257 Input Failed
151	Alarm - AI #12 FT-1257 Input High Alarm
152	Alarm - AI #12 FT-1257 Input Low Alarm
153	Alarm - AI #13 PT-1258 Kernel A Fault
154	Alarm - AI #13 PT-1258 Kernel B Fault
155	Alarm - AI #13 PT-1258 Kernel C Fault
156	Alarm - AI #13 PT-1258 Input Failed
157	Alarm - AI #13 PT-1258 Input High Alarm
158	Alarm - AI #13 PT-1258 Input Low Alarm
159	Alarm - AI #14 TT-1259 Kernel A Fault
160	Alarm - AI #14 TT-1259 Kernel B Fault
161	Alarm - AI #14 TT-1259 Kernel C Fault
162	Alarm - AI #14 TT-1259 Input Failed
163	Alarm - AI #14 TT-1259 Input High Alarm
164	Alarm - AI #14 TT-1259 Input Low Alarm
165	Alarm - AI #15 ZT-1257 Kernel A Fault
166	Alarm - AI #15 ZT-1257 Kernel B Fault
167	Alarm - AI #15 ZT-1257 Kernel C Fault
168	Alarm - AI #15 ZT-1257 Input Failed
169	Alarm - AI #15 ZT-1257 Input High Alarm
170	Alarm - AI #15 ZT-1257 Input Low Alarm
171	Alarm - AI #16 TT-1260 Kernel A Fault
172	Alarm - AI #16 TT-1260 Kernel B Fault
173	Alarm - AI #16 TT-1260 Kernel C Fault
174	Alarm - AI #16 TT-1260 Input Failed
175	Alarm - AI #16 TT-1260 Input High Alarm
176	Alarm - AI #16 TT-1260 Input Low Alarm
177	Alarm - AI #17 PT-1261 Kernel A Fault
178	Alarm - AI #17 PT-1261 Kernel B Fault
179	Alarm - AI #17 PT-1261 Kernel C Fault
180	Alarm - AI #17 PT-1261 Input Failed
181	Alarm - AI #17 PT-1261 Input High Alarm
182	Alarm - AI #17 PT-1261 Input Low Alarm
183	Alarm - AI #18 FT-1262 Kernel A Fault
184	Alarm - AI #18 FT-1262 Kernel B Fault
185	Alarm - AI #18 FT-1262 Kernel C Fault
186	Alarm - AI #18 FT-1262 Input Failed
187	Alarm - AI #18 FT-1262 Input High Alarm
188	Alarm - AI #18 FT-1262 Input Low Alarm
189	Alarm - AI #19 Kernel A Fault
190	Alarm - AI #19 Kernel B Fault
191	Alarm - AI #19 Kernel C Fault
192	Alarm - AI #19 Input Failed
193	Alarm - AI #19 Input High Alarm
194	Alarm - AI #19 Input Low Alarm
195	Alarm - AI #20 Kernel A Fault
196	Alarm - AI #20 Kernel B Fault
197	Alarm - AI #20 Kernel C Fault
198	Alarm - AI #20 Input Failed
199	Alarm - AI #20 Input High Alarm
200	Alarm - AI #20 Input Low Alarm
201	Alarm - AI #21 TT-1252 Kernel A Fault
202	Alarm - AI #21 TT-1252 Kernel B Fault
203	Alarm - AI #21 TT-1252 Kernel C Fault
204	Alarm - AI #21 TT-1252 Input Failed
205	Alarm - AI #21 TT-1252 Input High Alarm
206	Alarm - AI #21 TT-1252 Input Low Alarm
207	Alarm - AI #22 PT-1253 Kernel A Fault
208	Alarm - AI #22 PT-1253 Kernel B Fault
209	Alarm - AI #22 PT-1253 Kernel C Fault
210	Alarm - AI #22 PT-1253 Input Failed
279	Alarm - DI #3 XC-1350H Kernel A Fault
211	Alarm - AI #22 PT-1253 Input High Alarm
212	Alarm - AI #22 PT-1253 Input Low Alarm
213	Alarm - AI #23 FT-1254 Kernel A Fault
214	Alarm - AI #23 FT-1254 Kernel B Fault
215	Alarm - AI #23 FT-1254 Kernel C Fault
216	Alarm - AI #23 FT-1254 Input Failed
217	Alarm - AI #23 FT-1254 Input High Alarm
218	Alarm - AI #23 FT-1254 Input Low Alarm
219	Alarm - AI #24 Kernel A Fault
220	Alarm - AI #24 Kernel B Fault
221	Alarm - AI #24 Kernel C Fault
222	Alarm - AI #24 Input Failed
223	Alarm - AI #24 Input High Alarm
224	Alarm - AI #24 Input Low Alarm
225	Alarm - AI #25 TT-1390 Kernel A Fault
226	Alarm - AI #25 TT-1390 Kernel B Fault
227	Alarm - AI #25 TT-1390 Kernel C Fault
228	Alarm - AI #25 TT-1390 Input Failed
229	Alarm - AI #25 TT-1390 Input High Alarm
230	Alarm - AI #25 TT-1390 Input Low Alarm
231	Alarm - AI #26 Kernel A Fault
232	Alarm - AI #26 Kernel B Fault
233	Alarm - AI #26 Kernel C Fault
234	Alarm - AI #26 Input Failed
235	Alarm - AI #26 Input High Alarm
236	Alarm - AI #26 Input Low Alarm
237	Alarm - AI #27 Kernel A Fault
238	Alarm - AI #27 Kernel B Fault
239	Alarm - AI #27 Kernel C Fault
240	Alarm - AI #27 Input Failed
241	Alarm - AI #27 Input High Alarm
242	Alarm - AI #27 Input Low Alarm
243	Alarm - AI #28 PY-0005 Kernel A Fault
244	Alarm - AI #28 PY-0005 Kernel B Fault
245	Alarm - AI #28 PY-0005 Kernel C Fault
246	Alarm - AI #28 PY-0005 Input Failed
247	Alarm - AI #28 PY-0005 Input High Alarm
248	Alarm - AI #28 PY-0005 Input Low Alarm
249	Alarm - AI #29 HC-1254 Kernel A Fault
250	Alarm - AI #29 HC-1254 Kernel B Fault
251	Alarm - AI #29 HC-1254 Kernel C Fault
252	Alarm - AI #29 HC-1254 Input Failed
253	Alarm - AI #29 HC-1254 Input High Alarm
254	Alarm - AI #29 HC-1254 Input Low Alarm
255	Alarm - AI #30 HC-1257 Kernel A Fault
256	Alarm - AI #30 HC-1257 Kernel B Fault
257	Alarm - AI #30 HC-1257 Kernel C Fault
258	Alarm - AI #30 HC-1257 Input Failed
259	Alarm - AI #30 HC-1257 Input High Alarm
260	Alarm - AI #30 HC-1257 Input Low Alarm
261	Alarm - AI #31 Kernel A Fault
262	Alarm - AI #31 Kernel B Fault
263	Alarm - AI #31 Kernel C Fault
264	Alarm - AI #31 Input Failed
265	Alarm - AI #31 Input High Alarm
266	Alarm - AI #31 Input Low Alarm
267	Alarm - AI #32 Kernel A Fault
268	Alarm - AI #32 Kernel B Fault
269	Alarm - AI #32 Kernel C Fault
270	Alarm - AI #32 Input Failed
271	Alarm - AI #32 Input High Alarm
272	Alarm - AI #32 Input Low Alarm
273	Alarm - DI #1 XC-1350D Kernel A Fault
274	Alarm - DI #1 XC-1350D Kernel B Fault
275	Alarm - DI #1 XC-1350D Kernel C Fault
276	Alarm - DI #2 XC-1350B Kernel A Fault
277	Alarm - DI #2 XC-1350B Kernel B Fault
278	Alarm - DI #2 XC-1350B Kernel C Fault
437	Alarm - Act #1 Driver A Fault

280	Alarm - DI #3 XC-1350H Kernel B Fault
281	Alarm - DI #3 XC-1350H Kernel C Fault
282	Alarm - DI #4 XC-1350A Kernel A Fault
283	Alarm - DI #4 XC-1350A Kernel B Fault
284	Alarm - DI #4 XC-1350A Kernel C Fault
285	Alarm - DI #5 XC-1362 Kernel A Fault
286	Alarm - DI #5 XC-1362 Kernel B Fault
287	Alarm - DI #5 XC-1362 Kernel C Fault
288	Alarm - DI #6 HC-1395 Kernel A Fault
289	Alarm - DI #6 HC-1395 Kernel B Fault
290	Alarm - DI #6 HC-1395 Kernel C Fault
291	Alarm - DI #7 XC-1350K Kernel A Fault
292	Alarm - DI #7 XC-1350K Kernel B Fault
293	Alarm - DI #7 XC-1350K Kernel C Fault
294	Alarm - DI #8 XC-1350L Kernel A Fault
295	Alarm - DI #8 XC-1350L Kernel B Fault
296	Alarm - DI #8 XC-1350L Kernel C Fault
297	Alarm - DI #9 XC-1350C Kernel A Fault
298	Alarm - DI #9 XC-1350C Kernel B Fault
299	Alarm - DI #9 XC-1350C Kernel C Fault
300	Alarm - DI #10 Kernel A Fault
301	Alarm - DI #10 Kernel B Fault
302	Alarm - DI #10 Kernel C Fault
303	Alarm - DI #11 Kernel A Fault
304	Alarm - DI #11 Kernel B Fault
305	Alarm - DI #11 Kernel C Fault
306	Alarm - DI #12 Kernel A Fault
307	Alarm - DI #12 Kernel B Fault
308	Alarm - DI #12 Kernel C Fault
309	Alarm - DI #13 HS-1397 Kernel A Fault
310	Alarm - DI #13 HS-1397 Kernel B Fault
311	Alarm - DI #13 HS-1397 Kernel C Fault
312	Alarm - DI #14 HS-1360B Kernel A Fault
313	Alarm - DI #14 HS-1360B Kernel B Fault
314	Alarm - DI #14 HS-1360B Kernel C Fault
315	Alarm - DI #15 24VDC PS_A Kernel A Fau
316	Alarm - DI #15 24VDC PS_A Kernel B Fau
317	Alarm - DI #15 24VDC PS_A Kernel C Fau
318	Alarm - DI #16 24VDC PS_B Kernel A Fau
319	Alarm - DI #16 24VDC PS_B Kernel B Fau
320	Alarm - DI #16 24VDC PS_B Kernel C Fau
321	Alarm - DI #17 Kernel A Fault
322	Alarm - DI #17 Kernel B Fault
323	Alarm - DI #17 Kernel C Fault
324	Alarm - DI #18 Kernel A Fault
325	Alarm - DI #18 Kernel B Fault
326	Alarm - DI #18 Kernel C Fault
327	Alarm - DI #19 ESD-1352B Kernel A Faul
328	Alarm - DI #19 ESD-1352B Kernel B Faul
329	Alarm - DI #19 ESD-1352B Kernel C Faul
330	Alarm - DI #20 Kernel A Fault
331	Alarm - DI #20 Kernel B Fault
332	Alarm - DI #20 Kernel C Fault
333	Alarm - DI #21 Kernel A Fault
334	Alarm - DI #21 Kernel B Fault
335	Alarm - DI #21 Kernel C Fault
336	Alarm - DI #22 Kernel A Fault
337	Alarm - DI #22 Kernel B Fault
338	Alarm - DI #22 Kernel C Fault
339	Alarm - DI #23 Kernel A Fault
340	Alarm - DI #23 Kernel B Fault
341	Alarm - DI #23 Kernel C Fault
342	Alarm - DI #24 Kernel A Fault
343	Alarm - DI #24 Kernel B Fault
344	Alarm - DI #24 Kernel C Fault
345 - 435	Alarm - Spare
436	Alarm - Act #1 (HP) Failed
438	Alarm - Act #1 Driver B Fault
439	Alarm - Act #1 Driver C Fault
440	Alarm - Act #1 (HP) Load Fault
441	Alarm - Act #1 (HP) Load 'A/B' Fault
442	Alarm - Act #1 (HP) Load 'C' Fault
443	Alarm - Act #2 (LP) Failed
444	Alarm - Act #2 Driver A Fault
445	Alarm - Act #2 Driver B Fault
446	Alarm - Act #2 Driver C Fault
447	Alarm - Act #2 (LP) Load Fault
448	Alarm - Act #2 (LP) Load 'A/B' Fault
449	Alarm - Act #2 (LP) Load 'C' Fault
450	Alarm - DO #1 XA-1350 A1 Driver Fault
451	Alarm - DO #1 XA-1350 A2 Driver Fault
452	Alarm - DO #1 XA-1350 A1 Fault
453	Alarm - DO #1 XA-1350 A2 Fault
454	Alarm - DO #1 XA-1350 B1 Driver Fault
455	Alarm - DO #1 XA-1350 B2 Driver Fault
456	Alarm - DO #1 XA-1350 B1 Fault
457	Alarm - DO #1 XA-1350 B2 Fault
458	Alarm - DO #1 XA-1350 C1 Driver Fault
459	Alarm - DO #1 XA-1350 C2 Driver Fault
460	Alarm - DO #1 XA-1350 C1 Fault
461	Alarm - DO #1 XA-1350 C2 Fault
462	Alarm - DO #1 XA-1350 A1 or B1 Fault
463	Alarm - DO #1 XA-1350 C2 or A2 Fault
464	Alarm - DO #1 XA-1350 B2 or C1 Fault
465	Alarm - DO #2 XL-1350C A1 Driver Fault
466	Alarm - DO #2 XL-1350C A2 Driver Fault
467	Alarm - DO #2 XL-1350C A1 Fault
468	Alarm - DO #2 XL-1350C A2 Fault
469	Alarm - DO #2 XL-1350C B1 Driver Fault
470	Alarm - DO #2 XL-1350C B2 Driver Fault
471	Alarm - DO #2 XL-1350C B1 Fault
472	Alarm - DO #2 XL-1350C B2 Fault
473	Alarm - DO #2 XL-1350C C1 Driver Fault
474	Alarm - DO #2 XL-1350C C2 Driver Fault
475	Alarm - DO #2 XL-1350C C1 Fault
476	Alarm - DO #2 XL-1350C C2 Fault
477	Alarm - DO #2 XL-1350C A1 or B1 Fault
478	Alarm - DO #2 XL-1350C C2 or A2 Fault
479	Alarm - DO #2 XL-1350C B2 or C1 Fault
480	Alarm - DO #3 A1 Driver Fault
481	Alarm - DO #3 A2 Driver Fault
482	Alarm - DO #3 A1 Fault
483	Alarm - DO #3 A2 Fault
484	Alarm - DO #3 B1 Driver Fault
485	Alarm - DO #3 B2 Driver Fault
486	Alarm - DO #3 B1 Fault
487	Alarm - DO #3 B2 Fault
488	Alarm - DO #3 C1 Driver Fault
489	Alarm - DO #3 C2 Driver Fault
490	Alarm - DO #3 C1 Fault
491	Alarm - DO #3 C2 Fault
492	Alarm - DO #3 A1 or B1 Fault
493	Alarm - DO #3 C2 or A2 Fault
494	Alarm - DO #3 B2 or C1 Fault
495	Alarm - DO #4 XL-1350B A1 Driver Fault
496	Alarm - DO #4 XL-1350B A2 Driver Fault
497	Alarm - DO #4 XL-1350B A1 Fault
498	Alarm - DO #4 XL-1350B A2 Fault
499	Alarm - DO #4 XL-1350B B1 Driver Fault
500	Alarm - DO #4 XL-1350B B2 Driver Fault
501	Alarm - DO #4 XL-1350B B1 Fault
502	Alarm - DO #4 XL-1350B B2 Fault
503	Alarm - DO #4 XL-1350B C1 Driver Fault
504	Alarm - DO #4 XL-1350B C2 Driver Fault

505	Alarm - DO #4 XL-1350B C1 Fault	573	Alarm - DO #9 A2 Fault
506	Alarm - DO #4 XL-1350B C2 Fault	574	Alarm - DO #9 B1 Driver Fault
507	Alarm - DO #4 XL-1350B A1 or B1 Fault	575	Alarm - DO #9 B2 Driver Fault
508	Alarm - DO #4 XL-1350B C2 or A2 Fault	576	Alarm - DO #9 B1 Fault
509	Alarm - DO #4 XL-1350B B2 or C1 Fault	577	Alarm - DO #9 B2 Fault
510	Alarm - DO #5 HL-1350 A1 Driver Fault	578	Alarm - DO #9 C1 Driver Fault
511	Alarm - DO #5 HL-1350 A2 Driver Fault	579	Alarm - DO #9 C2 Driver Fault
512	Alarm - DO #5 HL-1350 A1 Fault	580	Alarm - DO #9 C1 Fault
513	Alarm - DO #5 HL-1350 A2 Fault	581	Alarm - DO #9 C2 Fault
514	Alarm - DO #5 HL-1350 B1 Driver Fault	582	Alarm - DO #9 A1 or B1 Fault
515	Alarm - DO #5 HL-1350 B2 Driver Fault	583	Alarm - DO #9 C2 or A2 Fault
516	Alarm - DO #5 HL-1350 B1 Fault	584	Alarm - DO #9 B2 or C1 Fault
517	Alarm - DO #5 HL-1350 B2 Fault	585	Alarm - DO #10 XC-1353 A1 Driver Fault
518	Alarm - DO #5 HL-1350 C1 Driver Fault	586	Alarm - DO #10 XC-1353 A2 Driver Fault
519	Alarm - DO #5 HL-1350 C2 Driver Fault	587	Alarm - DO #10 XC-1353 A1 Fault
520	Alarm - DO #5 HL-1350 C1 Fault	588	Alarm - DO #10 XC-1353 A2 Fault
521	Alarm - DO #5 HL-1350 C2 Fault	589	Alarm - DO #10 XC-1353 B1 Driver Fault
522	Alarm - DO #5 HL-1350 A1 or B1 Fault	590	Alarm - DO #10 XC-1353 B2 Driver Fault
523	Alarm - DO #5 HL-1350 C2 or A2 Fault	591	Alarm - DO #10 XC-1353 B1 Fault
524	Alarm - DO #5 HL-1350 B2 or C1 Fault	592	Alarm - DO #10 XC-1353 B2 Fault
525	Alarm - DO #6 A1 Driver Fault	593	Alarm - DO #10 XC-1353 C1 Driver Fault
526	Alarm - DO #6 A2 Driver Fault	594	Alarm - DO #10 XC-1353 C2 Driver Fault
527	Alarm - DO #6 A1 Fault	595	Alarm - DO #10 XC-1353 C1 Fault
528	Alarm - DO #6 A2 Fault	596	Alarm - DO #10 XC-1353 C2 Fault
529	Alarm - DO #6 B1 Driver Fault	597	Alarm - DO #10 XC-1353 A1 or B1 Fault
530	Alarm - DO #6 B2 Driver Fault	598	Alarm - DO #10 XC-1353 C2 or A2 Fault
531	Alarm - DO #6 B1 Fault	599	Alarm - DO #10 XC-1353 B2 or C1 Fault
532	Alarm - DO #6 B2 Fault	600	Alarm - DO #11 A1 Driver Fault
533	Alarm - DO #6 C1 Driver Fault	601	Alarm - DO #11 A2 Driver Fault
534	Alarm - DO #6 C2 Driver Fault	602	Alarm - DO #11 A1 Fault
535	Alarm - DO #6 C1 Fault	603	Alarm - DO #11 A2 Fault
536	Alarm - DO #6 C2 Fault	604	Alarm - DO #11 B1 Driver Fault
537	Alarm - DO #6 A1 or B1 Fault	605	Alarm - DO #11 B2 Driver Fault
538	Alarm - DO #6 C2 or A2 Fault	606	Alarm - DO #11 B1 Fault
539	Alarm - DO #6 B2 or C1 Fault	607	Alarm - DO #11 B2 Fault
540	Alarm - DO #7 XL-1397 A1 Driver Fault	608	Alarm - DO #11 C1 Driver Fault
541	Alarm - DO #7 XL-1397 A2 Driver Fault	609	Alarm - DO #11 C2 Driver Fault
542	Alarm - DO #7 XL-1397 A1 Fault	610	Alarm - DO #11 C1 Fault
543	Alarm - DO #7 XL-1397 A2 Fault	611	Alarm - DO #11 C2 Fault
544	Alarm - DO #7 XL-1397 B1 Driver Fault	612	Alarm - DO #11 A1 or B1 Fault
545	Alarm - DO #7 XL-1397 B2 Driver Fault	613	Alarm - DO #11 C2 or A2 Fault
546	Alarm - DO #7 XL-1397 B1 Fault	614	Alarm - DO #11 B2 or C1 Fault
547	Alarm - DO #7 XL-1397 B2 Fault	615	Alarm - DO #12 A1 Driver Fault
548	Alarm - DO #7 XL-1397 C1 Driver Fault	616	Alarm - DO #12 A2 Driver Fault
549	Alarm - DO #7 XL-1397 C2 Driver Fault	617	Alarm - DO #12 A1 Fault
550	Alarm - DO #7 XL-1397 C1 Fault	618	Alarm - DO #12 A2 Fault
551	Alarm - DO #7 XL-1397 C2 Fault	619	Alarm - DO #12 B1 Driver Fault
552	Alarm - DO #7 XL-1397 A1 or B1 Fault	620	Alarm - DO #12 B2 Driver Fault
553	Alarm - DO #7 XL-1397 C2 or A2 Fault	621	Alarm - DO #12 B1 Fault
554	Alarm - DO #7 XL-1397 B2 or C1 Fault	622	Alarm - DO #12 B2 Fault
555	Alarm - DO #8 A1 Driver Fault	623	Alarm - DO #12 C1 Driver Fault
556	Alarm - DO #8 A2 Driver Fault	624	Alarm - DO #12 C2 Driver Fault
557	Alarm - DO #8 A1 Fault	625	Alarm - DO #12 C1 Fault
558	Alarm - DO #8 A2 Fault	626	Alarm - DO #12 C2 Fault
559	Alarm - DO #8 B1 Driver Fault	627	Alarm - DO #12 A1 or B1 Fault
560	Alarm - DO #8 B2 Driver Fault	628	Alarm - DO #12 C2 or A2 Fault
561	Alarm - DO #8 B1 Fault	629	Alarm - DO #12 B2 or C1 Fault
562	Alarm - DO #8 B2 Fault	630	Alarm - DO #1 XA-1350 Power Fault
563	Alarm - DO #8 C1 Driver Fault	631	Alarm - DO #2 XL-1350C Power Fault
564	Alarm - DO #8 C2 Driver Fault	632	Alarm - DO #3 Power Fault
565	Alarm - DO #8 C1 Fault	633	Alarm - DO #4 XL-1350B Power Fault
566	Alarm - DO #8 C2 Fault	634	Alarm - DO #5 HL-1350 Power Fault
567	Alarm - DO #8 A1 or B1 Fault	635	Alarm - DO #6 Power Fault
568	Alarm - DO #8 C2 or A2 Fault	636	Alarm - DO #7 XL-1397 Power Fault
569	Alarm - DO #8 B2 or C1 Fault	637	Alarm - DO #8 Power Fault
570	Alarm - DO #9 A1 Driver Fault	638	Alarm - DO #9 Power Fault
571	Alarm - DO #9 A2 Driver Fault	639	Alarm - DO #10 XC-1353 Power Fault
572	Alarm - DO #9 A1 Fault	640	Alarm - DO #11 Power Fault
641	Alarm - DO #12 Power Fault	709	Alarm - AO #8 in Calib or Out Removed

642	Alarm - AO #1 Failed
643	Alarm - AO #1 Drvr A Fault
644	Alarm - AO #1 Drvr B Fault
645	Alarm - AO #1 Drvr C Fault
646	Alarm - AO #1 Load Fault
647	Alarm - AO #2 Failed
648	Alarm - AO #2 Drvr A Fault
649	Alarm - AO #2 Drvr B Fault
650	Alarm - AO #2 Drvr C Fault
651	Alarm - AO #2 Load Fault
652	Alarm - AO #3 Failed
653	Alarm - AO #3 Drvr A Fault
654	Alarm - AO #3 Drvr B Fault
655	Alarm - AO #3 Drvr C Fault
656	Alarm - AO #3 Load Fault
657	Alarm - AO #4 Failed
658	Alarm - AO #4 Drvr A Fault
659	Alarm - AO #4 Drvr B Fault
660	Alarm - AO #4 Drvr C Fault
661	Alarm - AO #4 Load Fault
662	Alarm - AO #5 PY-0092 Failed
663	Alarm - AO #5 PY-0092 Drvr A Fault
664	Alarm - AO #5 PY-0092 Drvr B Fault
665	Alarm - AO #5 PY-0092 Drvr C Fault
666	Alarm - AO #5 PY-0092 Load Fault
667	Alarm - AO #6 SI-1059A Failed
668	Alarm - AO #6 SI-1059A Drvr A Fault
669	Alarm - AO #6 SI-1059A Drvr B Fault
670	Alarm - AO #6 SI-1059A Drvr C Fault
671	Alarm - AO #6 SI-1059A Load Fault
672	Alarm - AO #7 Failed
673	Alarm - AO #7 Drvr A Fault
674	Alarm - AO #7 Drvr B Fault
675	Alarm - AO #7 Drvr C Fault
676	Alarm - AO #7 Load Fault
677	Alarm - AO #8 Failed
678	Alarm - AO #8 Drvr A Fault
679	Alarm - AO #8 Drvr B Fault
680	Alarm - AO #8 Drvr C Fault
681	Alarm - AO #8 Load Fault
682	Alarm - AO #9 FY-1254 Failed
683	Alarm - AO #9 FY-1254 Drvr A Fault
684	Alarm - AO #9 FY-1254 Drvr B Fault
685	Alarm - AO #9 FY-1254 Drvr C Fault
686	Alarm - AO #9 FY-1254 Load Fault
687	Alarm - AO #10 FY-1257 Failed
688	Alarm - AO #10 FY-1257 Drvr A Fault
689	Alarm - AO #10 FY-1257 Drvr B Fault
690	Alarm - AO #10 FY-1257 Drvr C Fault
691	Alarm - AO #10 FY-1257 Load Fault
692	Alarm - AO #11 SI-1059B Failed
693	Alarm - AO #11 SI-1059B Drvr A Fault
694	Alarm - AO #11 SI-1059B Drvr B Fault
695	Alarm - AO #11 SI-1059B Drvr C Fault
696	Alarm - AO #11 SI-1059B Load Fault
697	Alarm - AO #12 Failed
698	Alarm - AO #12 Drvr A Fault
699	Alarm - AO #12 Drvr B Fault
700	Alarm - AO #12 Drvr C Fault
701	Alarm - AO #12 Load Fault
702	Alarm - AO #1 in Calib or Out Removed
703	Alarm - AO #2 in Calib or Out Removed
704	Alarm - AO #3 in Calib or Out Removed
705	Alarm - AO #4 in Calib or Out Removed
706	Alarm - AO #5 PY-0092 in Calib or Out
707	Alarm - AO #6 SI-1059A in Calib or Out
708	Alarm - AO #7 in Calib or Out Removed
710	Alarm - AO #9 FY-1254 in Calib or Out
711	Alarm - AO #10 FY-1257 in Calib or Out
712	Alarm - AO #11 SI-1059B in Calib or Ou
713	Alarm - AO #12 in Calib or Out Removed
714	Alarm - Act #1 (HP) in Cal or Removed
715	Alarm - Act #2 (LP) in Cal or Removed

We appreciate your comments about the content of our publications.

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