WOODWARD

Product Manual 26451V2
(Revision A)
Original Instructions

505CC-2 Steam Turbine and Compressor Control

Volume 2
Steam Turbine Control Manual
Part Number 8701-1356

Manual 26451 consists of 4 volumes (26451V1, 26451V2, 26451V3, & 26451sup).

Installation and Operation 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:

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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 Out-of-date translations are marked with ⚠.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.

Contents

Illustrations and Tables

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 505CC-2 is a steam turbine and compressor control designed for use on a single- or two-valve steam turbine and/or a one- or two-loop dynamic compressor. This manual should be used along with the standard Atlas-II™ hardware manual (26415), and therefore, the scope of this document is only to describe the 505CC-2 application software functionality and assist the customer in configuration and start-up of the control. Refer to manual 26415 for information on hardware specifications, mounting information, and wiring details.

This manual, 26451, encompasses three separate volumes:
- Volume 1—Installation and Operation
- Volume 2—Steam Turbine Control
- Volume 3—Compressor Control

This volume is dedicated to the steam turbine control, describing turbine I/O, 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.

Quick Start Guide

The following links provide shortcuts to pertinent information within this manual required of a typical installation. However, they are not intended to replace comprehensive understanding of the 505CC-2 and its functionality—***be sure to read and understand this manual fully***. As described above, refer to Manual 26415 for information on the physical installation and wiring of the Atlas-II control.

Topic	Location (manual 26451)
Software / System Configuration	Volume 1, Chapter 2
Configuration File Management	Volume 1, Chapter 2
Modbus® *	Volume 1, Chapter 2
Security / Log-In Passwords	Volume 1, Appendix A
Turbine Configuration	Volume 2, Chapter 4
Turbine Operation	Volume 2, Chapter 5
Turbine Dynamics (PID) Tuning	Volume 2, Chapters 4 and 5
Compressor Configuration	Volume 3, Chapter 4
Compressor Operation	Volume 3, Chapter 5
Compressor Dynamics (PID) Tuning	Volume 3, Chapters 4 and 5

*—Modbus is a trademark of Schneider Automation Inc.

Chapter 2.
505CC-2 Turbine Control Description

Introduction

The 505CC-2 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 505CC-2 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 an internal value from the Compressor Control (e.g. discharge pressure, suction pressure, flow) or from an external source (4–20 mA input).

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

See 26451V1 for a description of the Control Configuration parameter, available on the HMI/CCT’s System Configuration Screen. With this parameter, the 505CC-2 may be configured to operate in a Turbine-Only Mode, functioning similarly to a Woodward 505E in mechanical drive applications. In this mode, compressor control is inhibited, but the remainder of the functionality detailed in this manual (26451V2), except where otherwise noted, is largely active.

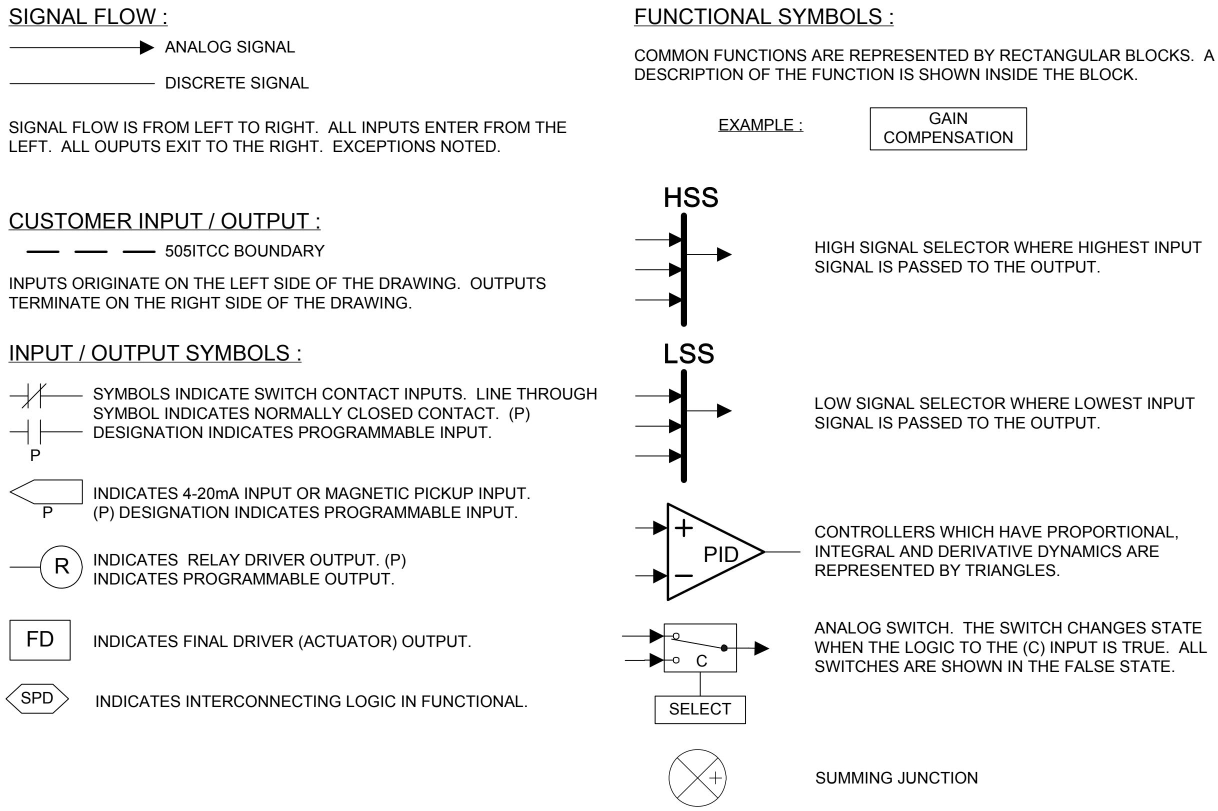


Figure 2-1. Overview of 505CC-2 Control Functionality Notes

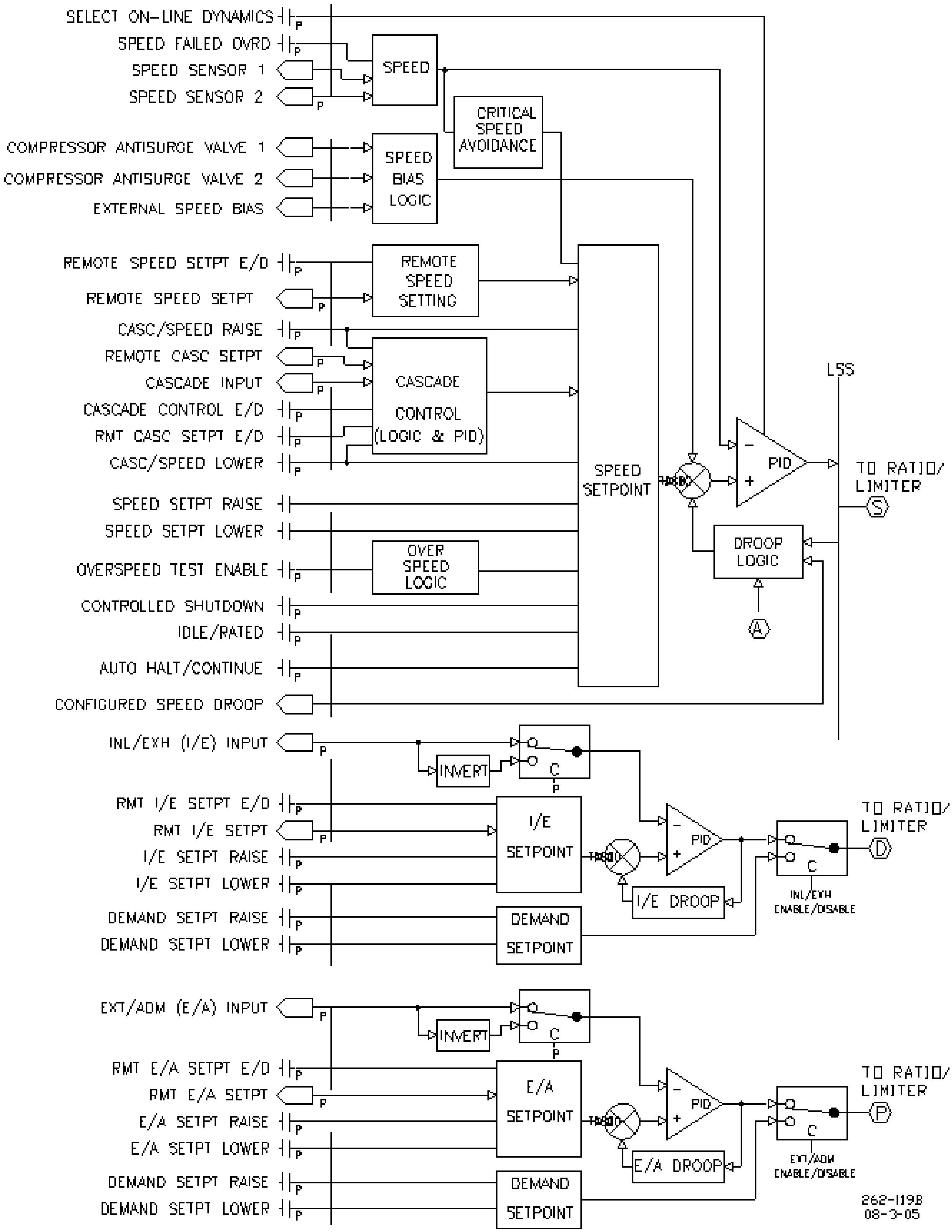


Figure 2-2. Overview of 505CC-2 Turbine Control Functionality

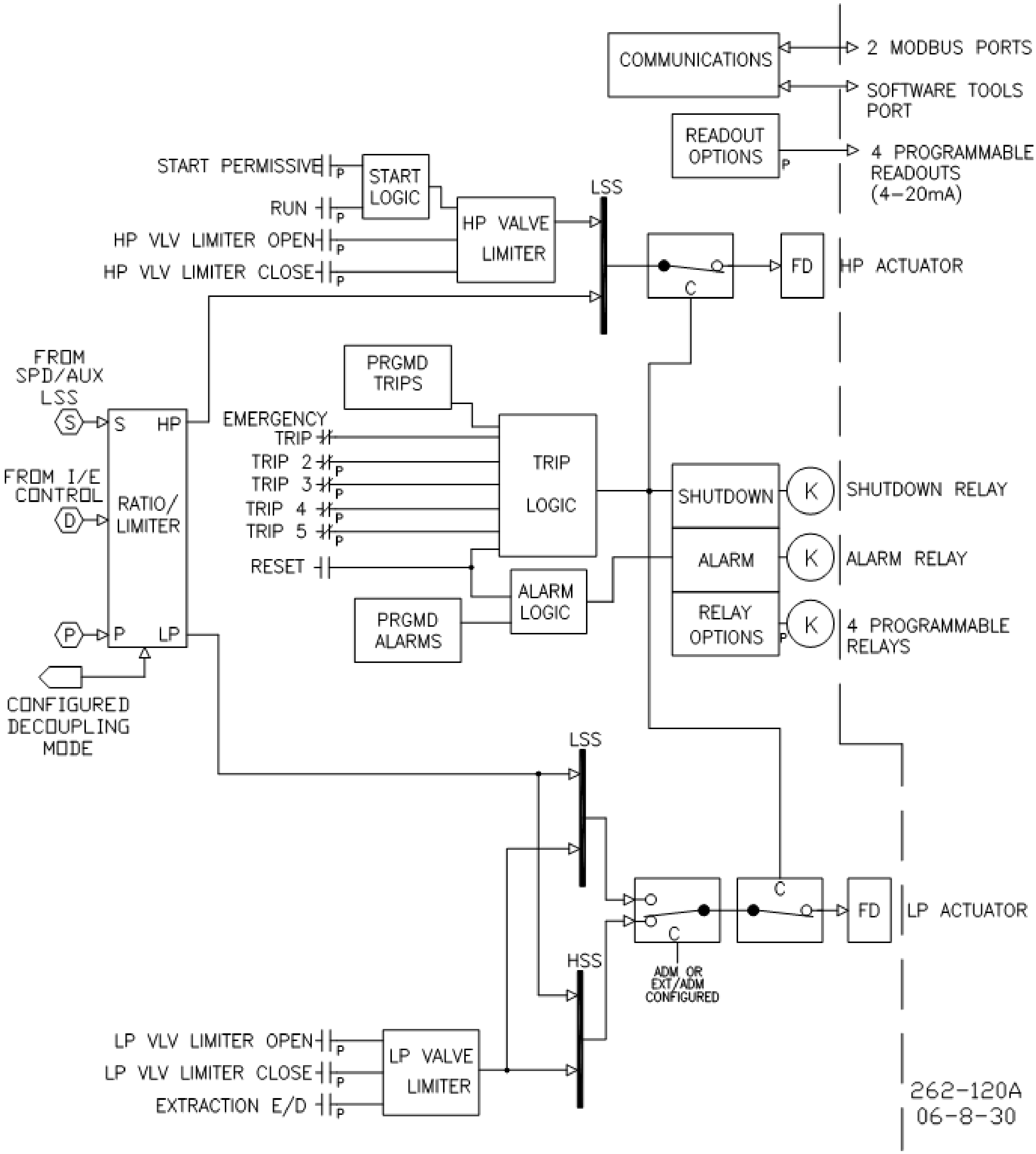


Figure 2-3. Overview of 505CC-2 Turbine Control Functionality

Extraction Turbines

The 505CC-2 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. (The 505CC-2 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 505CC-2's ratioing logic, based on the turbine performance parameters, to minimize valve/process interaction.

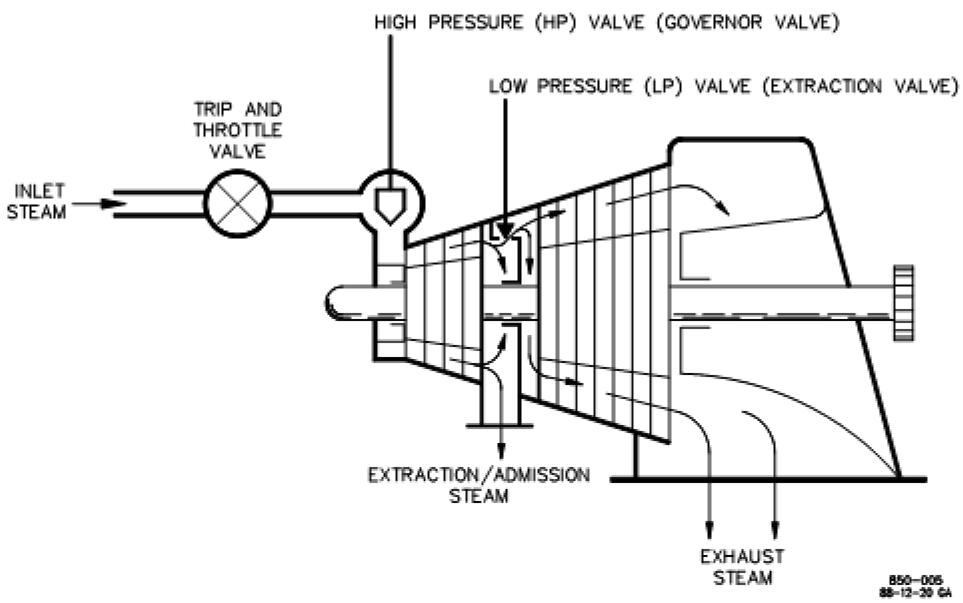


Figure 2-4. Typical Extraction or Extraction/Admission Steam Turbine

Admission Turbines

The 505CC-2 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 505CC-2's ratioing logic, based on the turbine performance parameters, to minimize valve/process interaction.

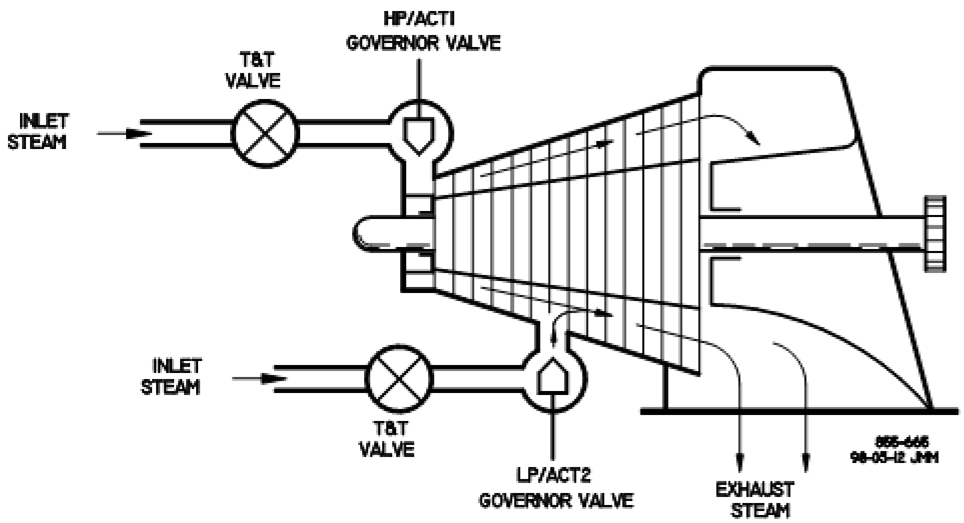


Figure 2-5. Typical Admission Steam Turbine

Extraction and Admission Turbines

The 505CC-2 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 505CC-2'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 two 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 505CC-2's speed inputs 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:

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

IMPORTANT

If both speed inputs are utilized (two separate probes), they must be mounted on the same gear--The Teeth Seen by MPU and Gear Ratio settings, used to calculate actual turbine speed, are common for both inputs.

The Speed PID then compares this signal to the speed setpoint to generate an output signal to the Ratio-Limiter. The 505CC-2 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, two 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. The control can be configured an external speed bias (4–20 mA) as a turbine configurable analog input,

Speed Setpoint (Speed Reference)

The speed control's setpoint is adjustable with raise or lower commands from the HMI/CCT, remote contact inputs, or Modbus. The setpoint can also be directly entered from the HMI/CCT or through Modbus. In addition, a 4–20 mA analog input may be configured 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 on the Turbine Speed Control Configuration Screen. 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.

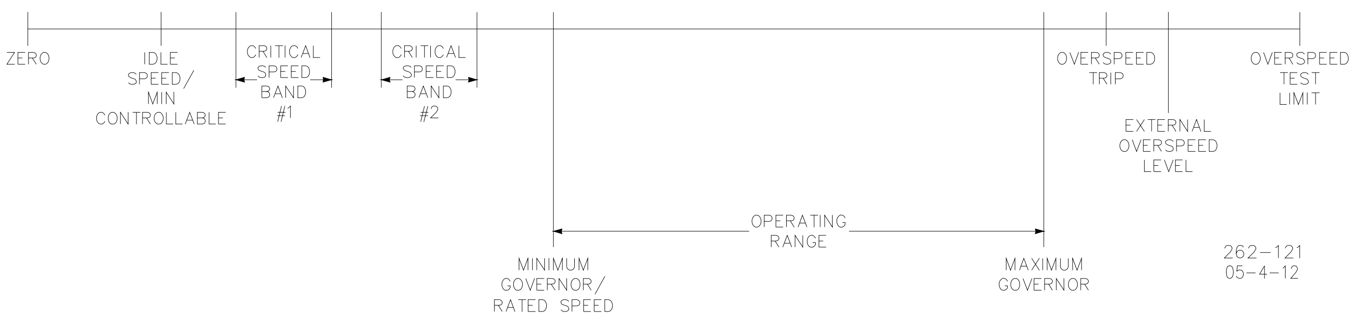


Figure 2-6. Speed Setpoint Relationships

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 the HMI/CCT, 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 speed setpoint may be specified directly by entering the desired value through the HMI/CCT. This value must be below Maximum Governor and above Idle (or Minimum Controllable) and not within a critical speed band. Once the speed reference is above Minimum Governor, the entered setpoint cannot be set below Minimum Governor. Likewise, a value can be entered directly via Modbus. However, the allowable range is between Minimum and Maximum Governor. In either case, the reference will ramp to the entered value if it is within these prescribed limits. If the entered value is outside of these limits, it will not be accepted.

If Remote Speed Setpoint is enabled, the reference will ramp at the configured Remote Rate. HMI/CCT and Modbus entered setpoints will ramp at the configured Default Rate.

These four setpoint sources are prioritized in descending order as Remote 4–20 mA, HMI/CCT, Modbus 1, and Modbus 2 (the Remote 4–20 mA signal has the highest priority). If Remote Speed Setpoint is enabled, all other speed setpoint commands (Raise/Lower, HMI/CCT or Modbus entered setpoint) are inhibited.

When online and the Compressor Control is enabled, either in ITCC or in Compressor-Only Mode, 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 direct setpoint entry and remote speed setpoint are inhibited when compressor operation is on or near its control line. Boolean speed lower commands from the HMI/CCT, discrete input, or Modbus are still permitted for operational flexibility.

IMPORTANT **The compressor functionality described above is not active if the unit is configured for Turbine-Only Mode.**

All pertinent speed control parameters are available through Modbus. See Volume 1, Chapter 2 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 process control external to the 505CC-2 (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 the HMI/CCT, remote contact input, or Modbus. The last command given from any of these three sources dictates the enable/disable 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, HMI/CCT or Modbus entered setpoint) are inhibited. And, as described above, remote speed setpoint is inhibited if it is decreasing while the compressor is operating on or near its control line.

IMPORTANT **The compressor functionality described above is not active if the unit is configured for Turbine-Only Mode.**

Remote Speed Setpoint Status Messages

The Remote Speed Setpoint function may be in one of the following states as displayed on the HMI/CCT:

- *Disabled* - The Remote Speed Setpoint function is not enabled and will have no effect on the speed reference.
- *Enabled* - Remote Speed Setpoint has been enabled.
- *Active* - The remote setpoint is in control of the speed reference, but the Speed PID is not in control of the actuator output.
- *In Control* - The remote setpoint is in control of the speed reference, and the Speed PID is in control of the actuator output.
- *Inhibited*–Remote Speed Setpoint cannot be enabled. The input signal has failed, a controlled stop is selected, a shutdown is active, or Remote Speed Setpoint is not configured.

All pertinent Remote Speed Setpoint parameters are available through Modbus. Refer to Volume 1, Chapter 2 for a complete Modbus list.

Speed Reference Bias

An external speed bias may be used to manipulate the speed controller during transient conditions where an external process disturbance may affect turbine speed/load. Without this bias, the Speed PID will respond to the transient as normal. But, under some circumstances, the biasing feature may enhance controllability and bring the system to stability sooner.

For example, if the compressor anti-surge control opens the anti-surge valve to recycle flow around the compressor, load is increased on the turbine and speed will decrease. Rather than waiting for PID action to regain control of speed, the anti-surge valve demand signal could be used to bias the speed control, instantly adding a small amount of speed reference. The result is that the Speed PID now acts on a larger error and will respond more aggressively than without the bias. The bias is a temporary action and will ramp out after a configured delay time, allowing the Speed PID to settle into control. In this example, compressor anti-surge valve demand is available internally to the control, but any similar external signal that is proportional to turbine speed/load may be used.

Speed Control Dynamics (PID Tuning)

The 505CC-2 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 configurable 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, a configurable contact input may be assigned to perform this switching—The online tuning parameters are selected when the contact is closed. Or, the online dynamics can be selected when decoupling is enabled.

A relay output can be configured to indicate when the online dynamics are selected and used by the Speed PID. Refer to the Dynamics Adjustments section in Chapter 4.

Cascade Control

IMPORTANT — **The Cascade Controller is also available if the unit is configured for Compressor-Only Mode.**

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 the HMI/CCT, 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 tripped (commanded to full recycle) via the "Stage Trip" button on the compressor operating screen.

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.

IMPORTANT

The compressor functionality described above is not active if the unit is configured for Turbine-Only Mode.

Cascade Control Status Messages

Cascade Control may be in one of the following states as displayed on the HMI/CCT:

- *Cascade Disabled* - Cascade control is not enabled and will have no effect on the speed reference.
- *Cascade Enabled* - Cascade has been enabled but is not active or in control.
- *Cascade Active / Not in Speed Control* - Cascade has been enabled but the Speed PID is not in control of the LSS bus (Valve Limiter is in control).
- *Cascade In Control* - Cascade is in control of the LSS bus (via the Speed PID).
- *Cascade Active with Remote Setpoint* - Cascade has been enabled and the Remote Cascade Setpoint is in control of the setpoint but the Speed PID is not in control of the LSS bus.
- *Cascade in Control with Remote Setpoint* - Cascade is in control of the LSS bus (via the Speed PID) and the Remote Cascade Setpoint is positioning the Cascade setpoint.
- *Cascade is Inhibited* - Cascade cannot be enabled because the Cascade input signal has failed, a controlled stop is selected, a shutdown is active, or Cascade Control is not configured.

All pertinent Cascade Control parameters are available through Modbus. Refer to Volume 1, Chapter 2 for a complete Modbus list.

Cascade Setpoint (Cascade Reference)

The Cascade Control's setpoint is adjustable with raise or lower commands from the HMI/CCT, remote contact inputs, or Modbus. The setpoint can also be directly entered from the HMI/CCT or through Modbus. In addition, a 4–20 mA analog input may be configured for Remote Cascade Setpoint, allowing an external device (e.g. DCS, PLC) to remotely position the Cascade setpoint. When the 505CC-2 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 Turbine Cascade Control Configuration screen. 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 the HMI/CCT, 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 Cascade setpoint may be specified directly by entering the desired value through the HMI/CCT or Modbus. These entered setpoints are limited by the configured Min and Max Cascade Setpoint and will ramp at the configured Default Rate. Likewise, a configurable 4–20 mA analog input may be assigned to remotely position the Cascade setpoint. This setting will be limited by the configured Remote Min and Max Settings and will ramp at the configured Remote Rate.

These four setpoint sources are prioritized in descending order as Remote 4–20 mA, HMI/CCT, Modbus 1, and Modbus 2 (the Remote 4–20 mA signal has the highest priority). If Remote Cascade Setpoint is enabled, all other Cascade setpoint commands (Raise/Lower, HMI/CCT or Modbus entered setpoint) are inhibited.

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.

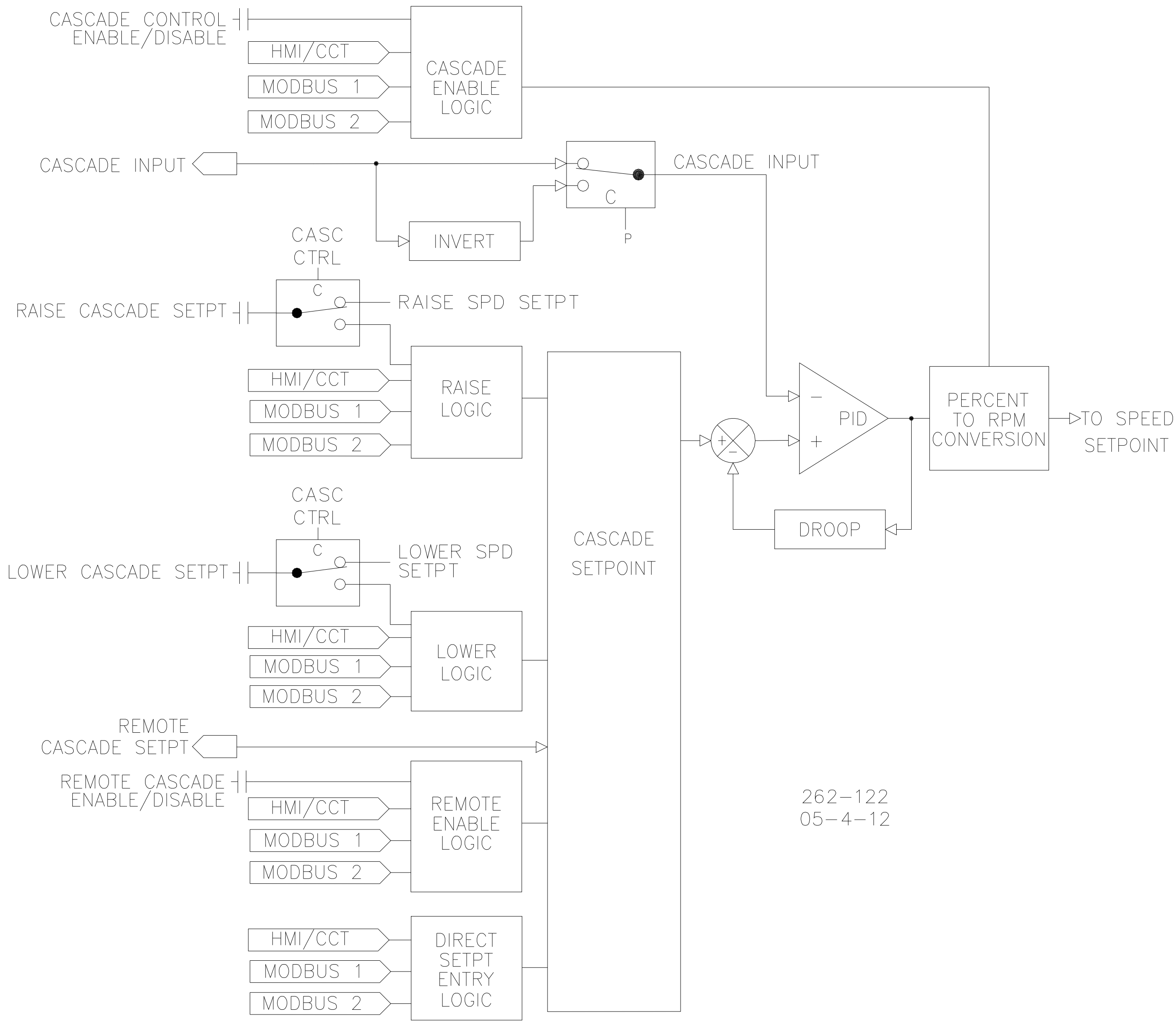


Figure 2-7. Cascade Control Functional Diagram

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.

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 configurable 4–20 mA analog inputs can be assigned to remotely position the Cascade reference. Typically, some process control external to the 505CC-2 (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 the HMI/CCT, 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, HMI/CCT or Modbus entered setpoint) are inhibited.

Remote Cascade Setpoint Status Messages

Remote Cascade Setpoint may be in one of the following states as displayed on the HMI/CCT:

- *Disabled* - The Remote Cascade Setpoint function is not enabled and will have no effect on the Cascade setpoint.
- *Enabled* - Remote Cascade Setpoint has been enabled but Cascade Control is not active. Speed is less than Minimum Governor or Cascade has not taken control.
- *Active* - The remote setpoint has been enabled but Cascade is not in control. Cascade has been enabled, and the Remote Cascade Setpoint is in control of the reference, but the Speed PID is not in control (Valve Limiter is in control).
- *In Control* - Cascade is in control (via the Speed PID) and the Remote Cascade Setpoint is positioning the Cascade reference.
- *Inhibited* - Remote Cascade Setpoint cannot be enabled because the remote setpoint input signal is failed, the Cascade process variable input signal is failed, a controlled stop is selected, a shutdown is active, or Remote Cascade Setpoint is not configured.

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 4.

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 #6. 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 the HMI/CCT, 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 Control Status Messages

- Extr/Adm Control may be in one of the following states as displayed on the HMI/CCT:
- *Disabled* - Extr/Adm control is not enabled and will have no effect.
- *Enabled* - Extr/Adm has been enabled but is not active or in control.
- *Active / Not in Control* - Extr/Adm has been enabled but the turbine is on an operating limit with speed priority or the LP Valve Limiter is limiting Extr/Adm PID output.

- *In Control* - Extr/Adm PID is in control of its process.
- *Active with Remote Setpoint* - Extr/Adm has been enabled and the Remote Extr/Adm setpoint is in control of the setpoint, but the turbine is on a operating limit with speed priority or the LP Valve Limiter is limiting Extr/Adm PID output.
- *In Control with Remote Setpoint* - Extr/Adm is in control and the Remote Extr/Adm setpoint is positioning the Extr/Adm reference.
- *Inhibited* - Extr/Adm cannot be enabled because the Extr/Adm input signal has failed, the Inlet/Exhaust pressure input has failed in Total Decoupled mode (if configured), speed is below Minimum Governor, a controlled stop is selected, or a shutdown is active.

Extr/Adm Setpoint (Extr/Adm Reference)

The Extr/Adm setpoint is adjustable with raise or lower commands from the HMI/CCT, remote contact inputs, or Modbus. The setpoint can also be directly entered from the HMI/CCT or Modbus. In addition, a 4–20 mA analog input may be configured for Remote Extr/Adm Setpoint, allowing an external device (e.g. DCS, PLC) to remotely set the Extr/Adm setpoint. When the 505CC-2 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 Turbine Extr/Adm Control Configuration screen. 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 the HMI/CCT, 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 Extr/Adm setpoint may be specified directly by entering the desired value through the HMI/CCT or Modbus. These entered setpoints are limited by the configured Min and Max Extr/Adm Setpoint and will ramp at the configured Default Rate. Likewise, a configurable 4–20 mA analog input may be assigned to remotely position the Extr/Adm setpoint. This setting will be limited by the configured Remote Min and Max Settings and will ramp at the configured Remote Rate.

These four setpoint sources are prioritized in descending order as Remote 4–20 mA, HMI/CCT, Modbus 1, and Modbus 2 (the Remote 4–20 mA signal has the highest priority). If Remote Extr/Adm Setpoint is enabled, all other Extr/Adm setpoint commands (Raise/Lower, HMI/CCT or Modbus entered setpoint) are inhibited.

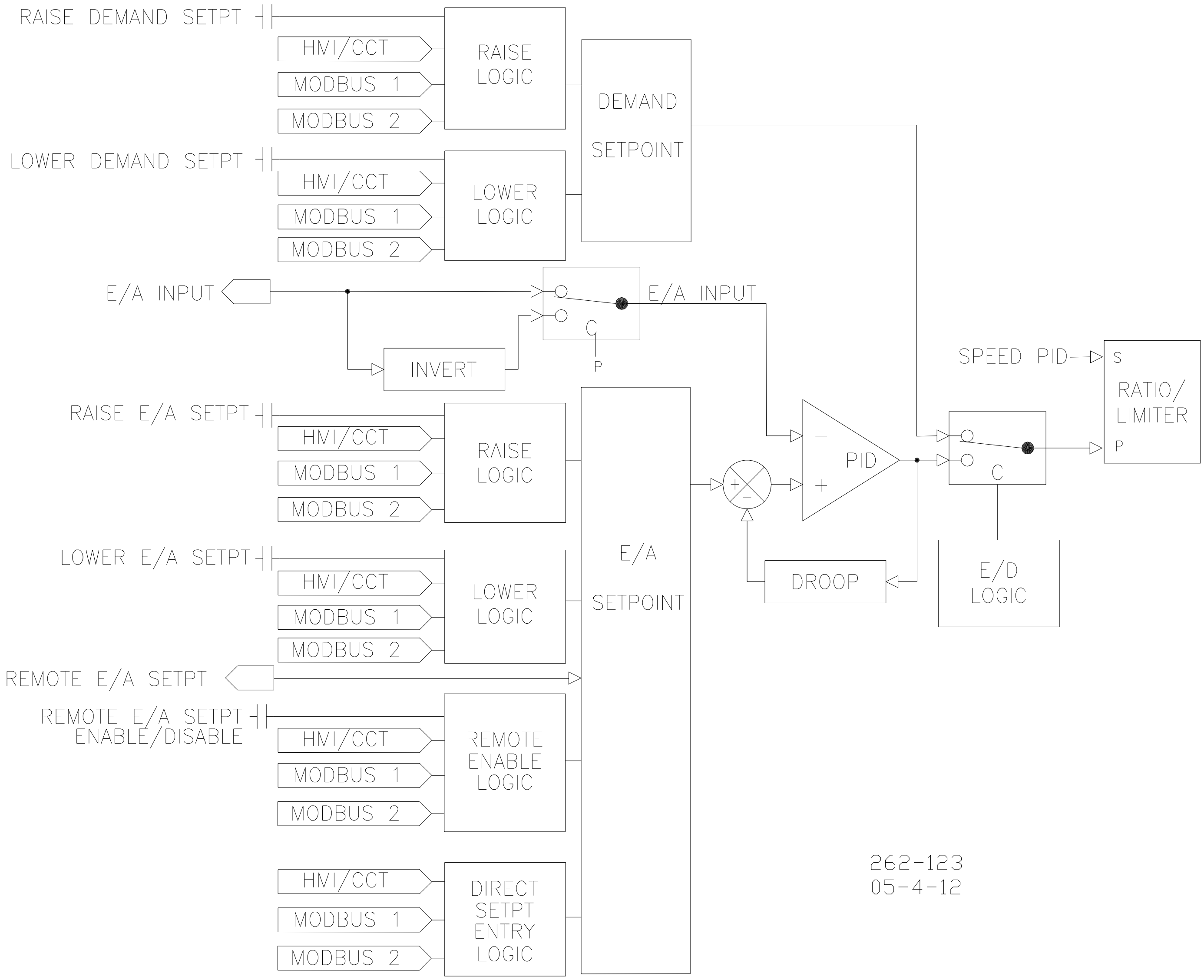


Figure 2-8. Extr/Adm Control Functional Diagram

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 Volume 1, Chapter 2 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 505CC-2 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 configurable 4–20 mA analog inputs can be assigned to remotely position the Extr/Adm reference. Typically, some process control external to the 505CC-2 (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 the HMI/CCT, 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, HMI/CCT or Modbus entered setpoint) are inhibited.

Remote Extr/Adm Setpoint Messages

Remote Extr/Adm Setpoint may be in one of the following states as displayed on the HMI/CCT:

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

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 4.

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 the HMI/CCT, remote contact inputs, or Modbus. The setpoint can also be directly entered from the HMI/CCT or Modbus. In addition, a 4–20 mA analog input may be configured for Remote Manual Pressure (Flow) Demand, allowing an external device (e.g. DCS, PLC) to remotely set the demand. When the 505CC-2 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 Turbine Manual Flow Control Configuration screen.

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 the HMI/CCT, 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 may be specified directly by entering the desired value through the HMI/CCT or Modbus. These entered setpoints are limited by the configured Min and Max Flow Setpoint and will ramp at the configured Default Rate. Likewise, a configurable 4–20 mA analog input may be assigned to remotely position the demand. This setting will be limited by the configured Remote Min and Max Flow Settings and will ramp at the configured Remote Rate.

These four setpoint sources are prioritized in descending order as Remote 4–20 mA, HMI/CCT, Modbus 1, and Modbus 2 (the Remote 4–20 mA signal has the highest priority). If Remote Manual Pressure (Flow) Demand is enabled, all other Manual Demand commands (Raise/Lower, HMI/CCT or Modbus entered setpoint) are inhibited.

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 configurable 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 the HMI/CCT 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, HMI/CCT or Modbus entered setpoint) are inhibited.

Extraction-Only Control

Extraction Control enabling may be automatic or manual and performed after one of the 505CC-2's 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 505CC-2's 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 505CC-2 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 the HMI/CCT, remote contact input, or Modbus. Automatic enabling/disabling can only be performed if Use Automatic Enable is selected on the Extr/Adm Map Configuration Screen. 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 505CC-2 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 505CC-2 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 505CC-2 accepts an Extraction enable command only if all related permissives are met. An enable/disable command may be given from the HMI/CCT, 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 505CC-2 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 505CC-2'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 on the Turbine Extr/Adm Control Configuration screen. This will configure the 505CC-2 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 505CC-2 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 the HMI/CCT, remote contact inputs, or Modbus.

The 505CC-2 accepts an enable command only if all related permissives are met. An enable/disable command may be given from the HMI/CCT, 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 in compressor drive applications.

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 on the Turbine General Configuration screen.

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 505CC-2 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 505CC-2's Inlet 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 the HMI/CCT 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 on the Extr/Adm Control Configuration screen. 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 on the Turbine General Configuration screen.

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 505CC-2's Exhaust 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 the HMI/CCT 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 on the Extr/Adm Control Configuration screen. 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 on the Turbine General Configuration screen.

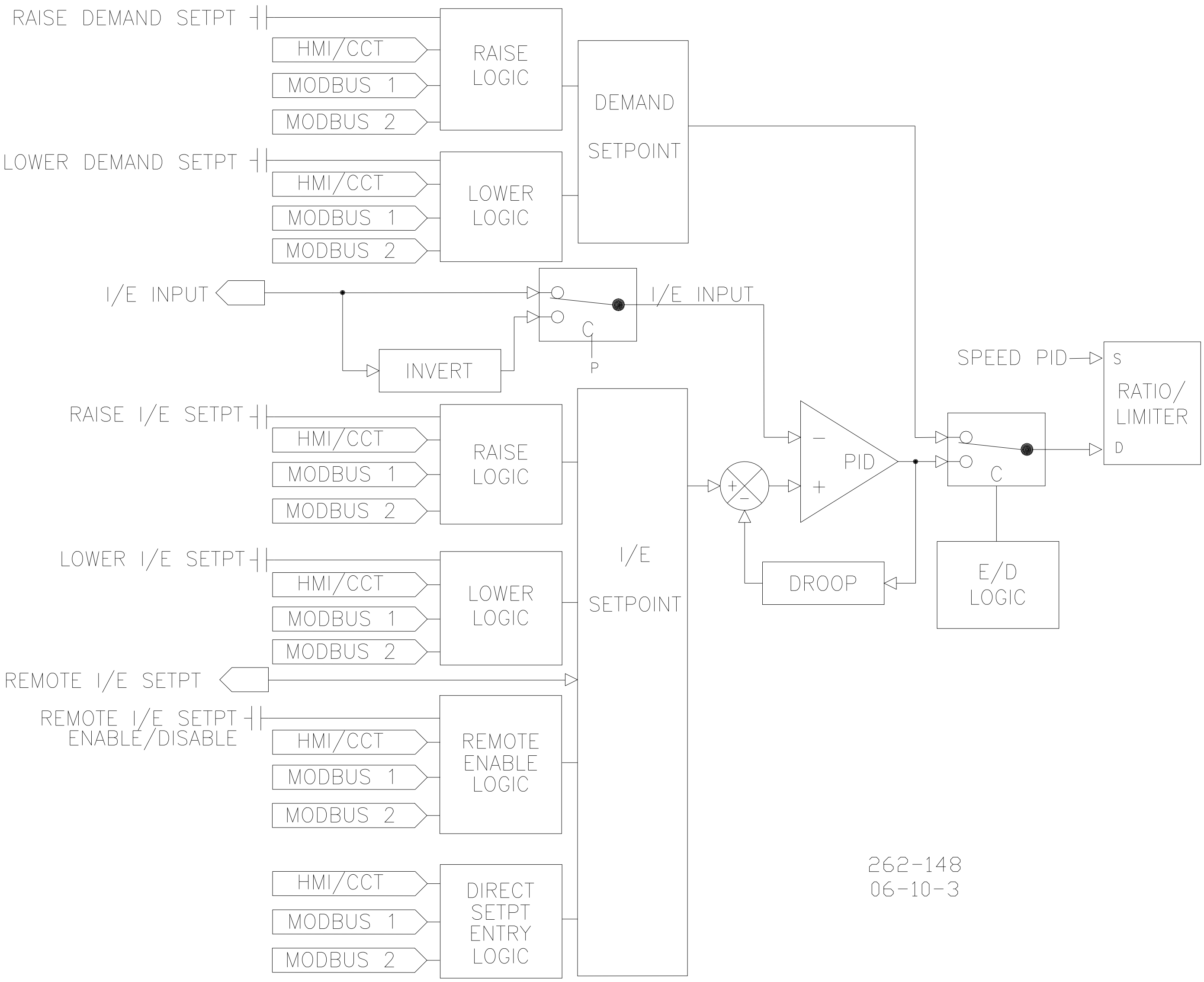


Figure 2-9. Inlet/Exhaust Decoupling Control Functional Diagram

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 a turbine configurable analog input as the Cascade controller's process variable and configure the controller on the Cascade Configuration screen. Similarly, connect the exhaust pressure transmitter to the Ext/Adm pressure input (analog input #6) 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, the control starts by using the Coupled Ratio-Limiter, then switches to the Decoupled Ratio-Limiter when decoupling is enabled by the operator. The control switches back to the Coupled Ratio-Limiter when decoupling 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).

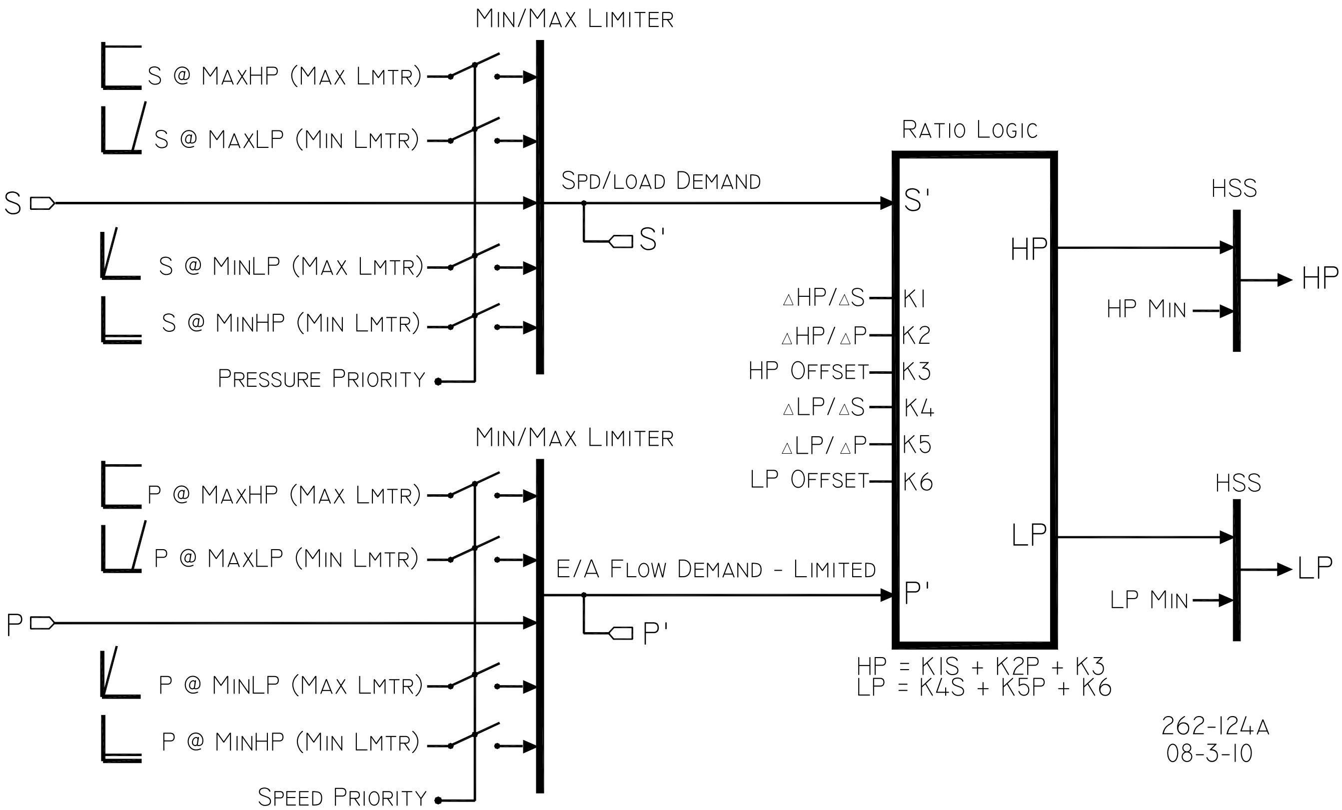


Figure 2-10. Coupled HP & LP Mode

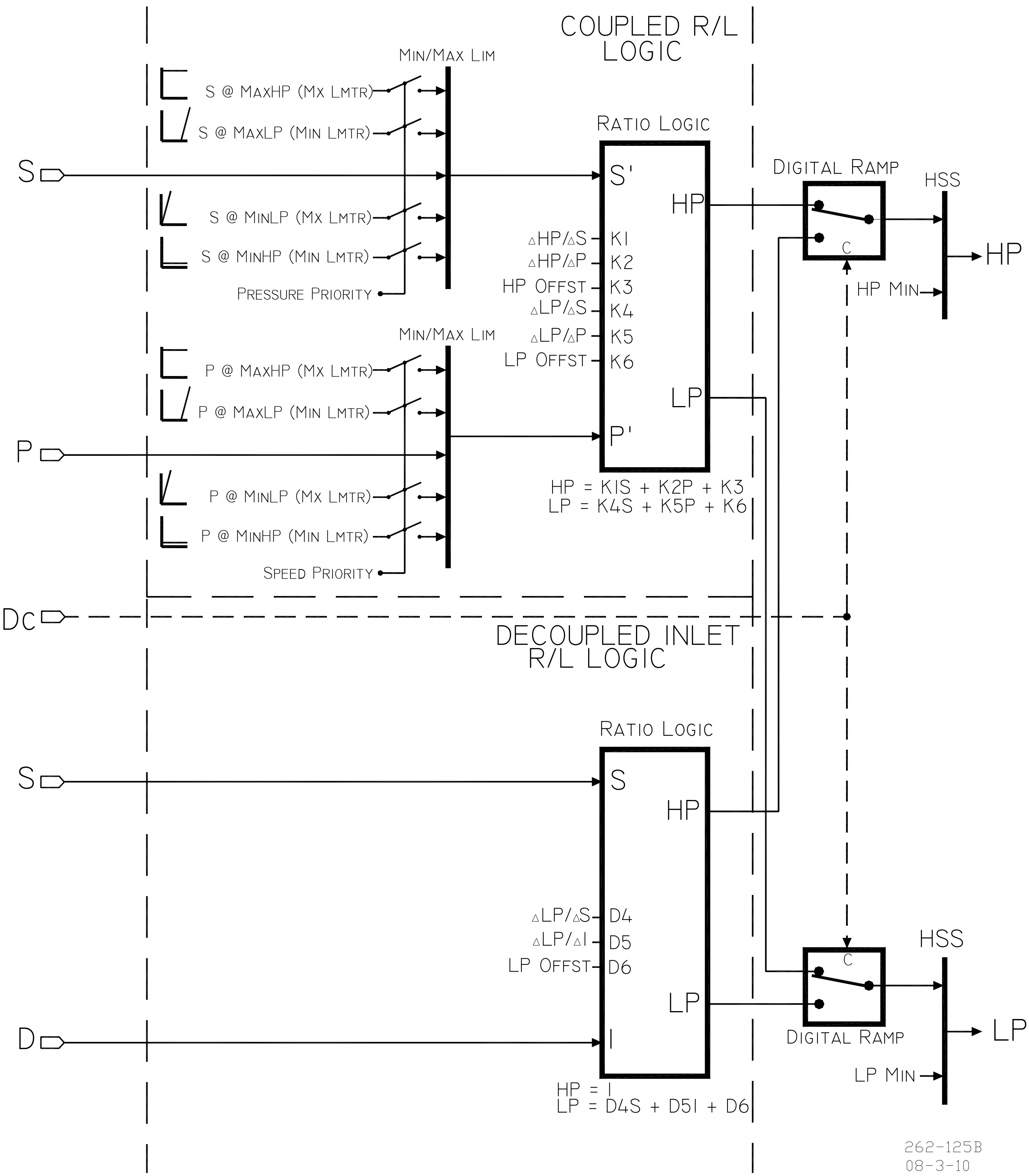


Figure 2-11. Decoupled Inlet (HP) Mode

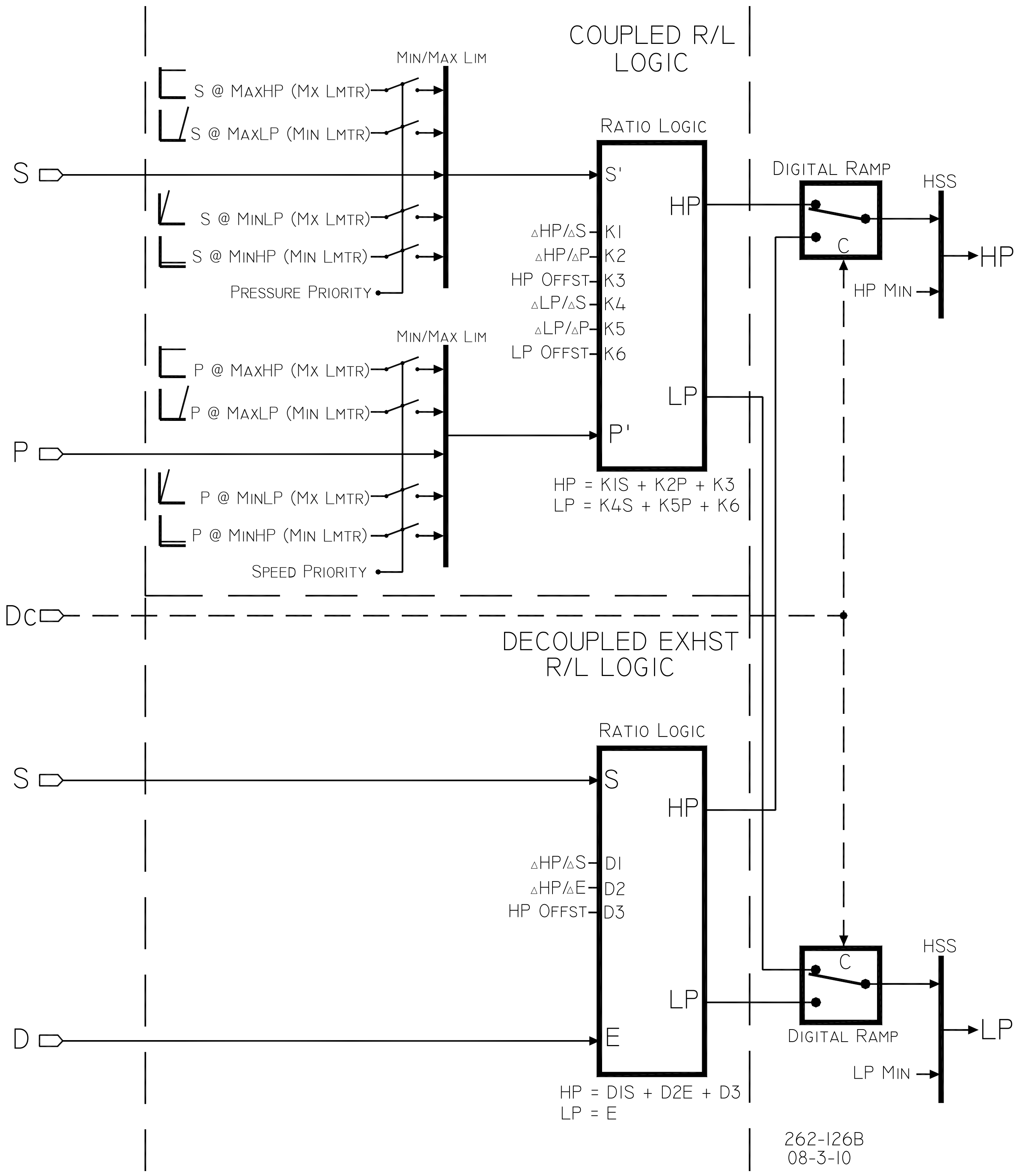


Figure 2-12. Decoupled Exhaust (LP) Mode

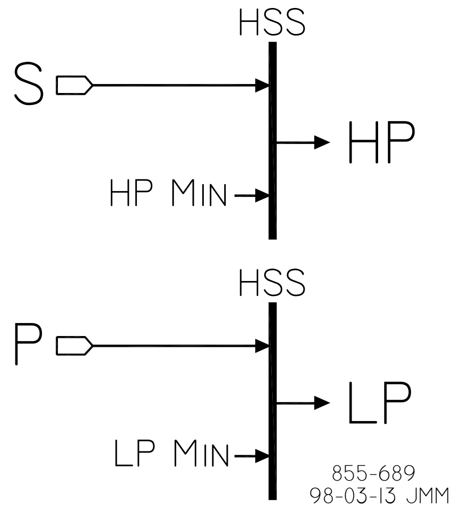


Figure 2-13. Decoupled HP & LP Mode

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 the HMI/CCT, 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 on the Valve Limiter Settings Configuration screen.

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.

See the Starting Procedures section in Chapter 5 for information on using the valve limiters during start-up. The valve limiters also can be used to troubleshoot system dynamic problems. If it is believed that the 505CC-2 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 4 for examples. All pertinent valve limiter parameters are available through Modbus. See Volume 1, Chapter 2 for a complete Modbus list.

Turbine Starting Features

The 505CC-2 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 completed, 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 the HMI/CCT, 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 (unless Auto Start Sequence is configured). If the turbine speed is first sensed within a critical speed avoidance band, the speed reference will match the actual speed, increase to the upper-end of the critical avoidance 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 505CC-2 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 505CC-2 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 505CC-2 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 505CC-2 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 505CC-2 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 505CC-2 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.

If a Raise/Lower Speed Setpoint command is issued while in a critical band, the speed setpoint will ramp up or down (depending on the command received) to the extent of the critical range. Since the Lower command has priority over a Raise command, issuing a Lower command while increasing through the band will reverse the setpoint direction and return it to the lower limit of the band. This might be the necessary action if excessive vibration is observed while accelerating through the critical band. If a Lower command is given while in a critical band, turbine speed must reach the bottom of the band before another command can be executed.

A speed setpoint value cannot be directly entered within the 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. 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.

Critical speed bands are defined in the Turbine Speed Control Configuration Screen. 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 505CC-2 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 505CC-2 will ramp open the HP Valve 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.

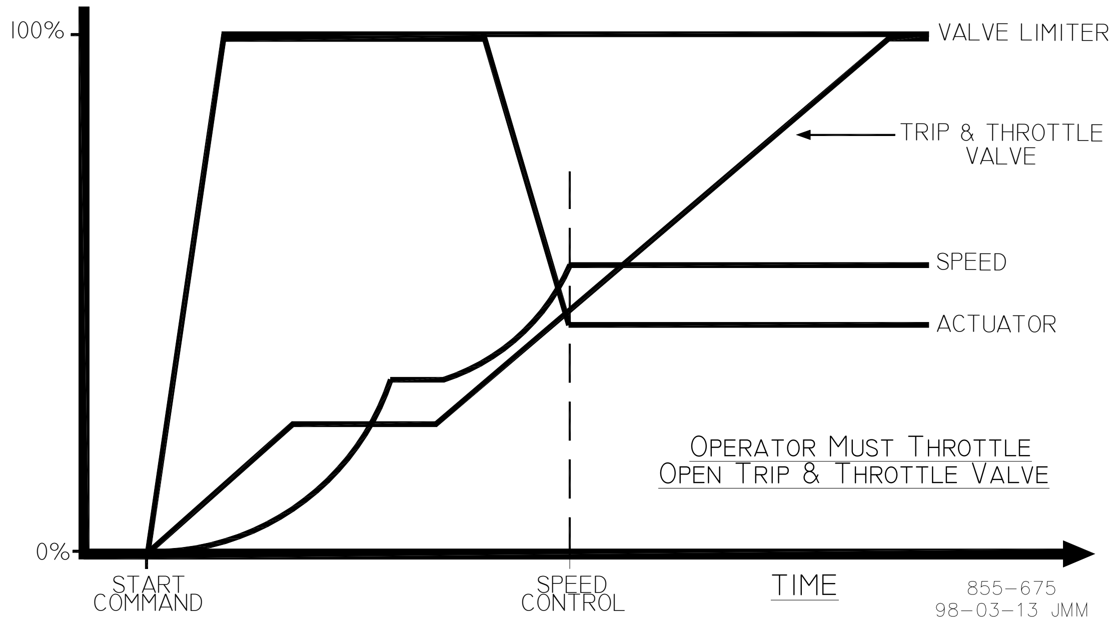


Figure 2-14. Manual Start Mode Example

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 505CC-2 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.

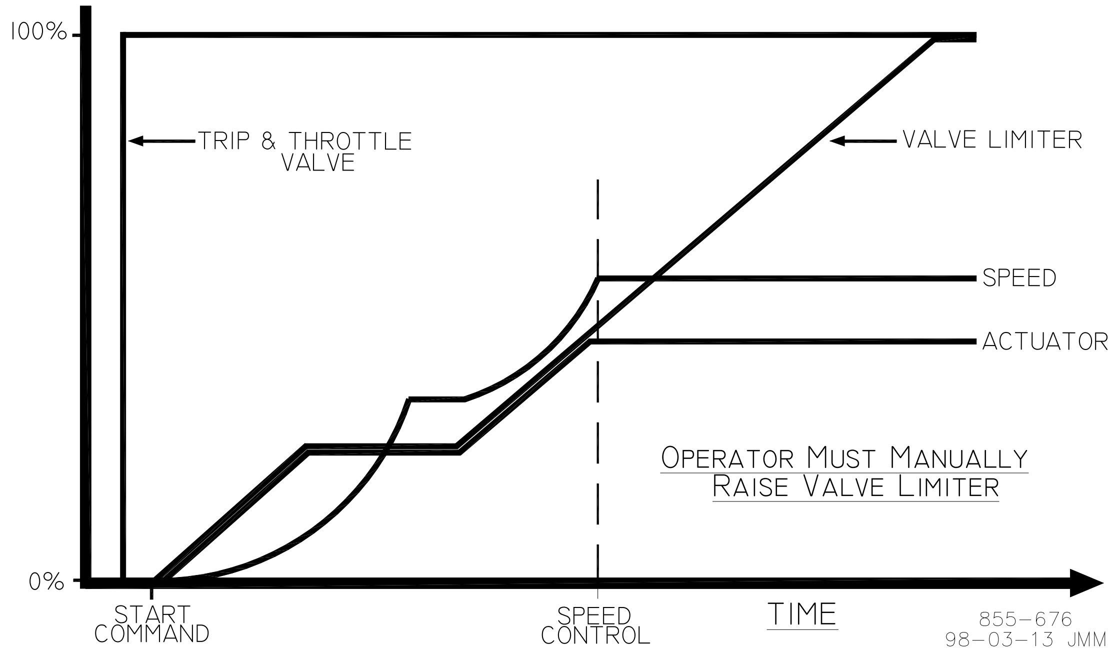


Figure 2-15. Semiautomatic Start Mode Example

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 505CC-2 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.

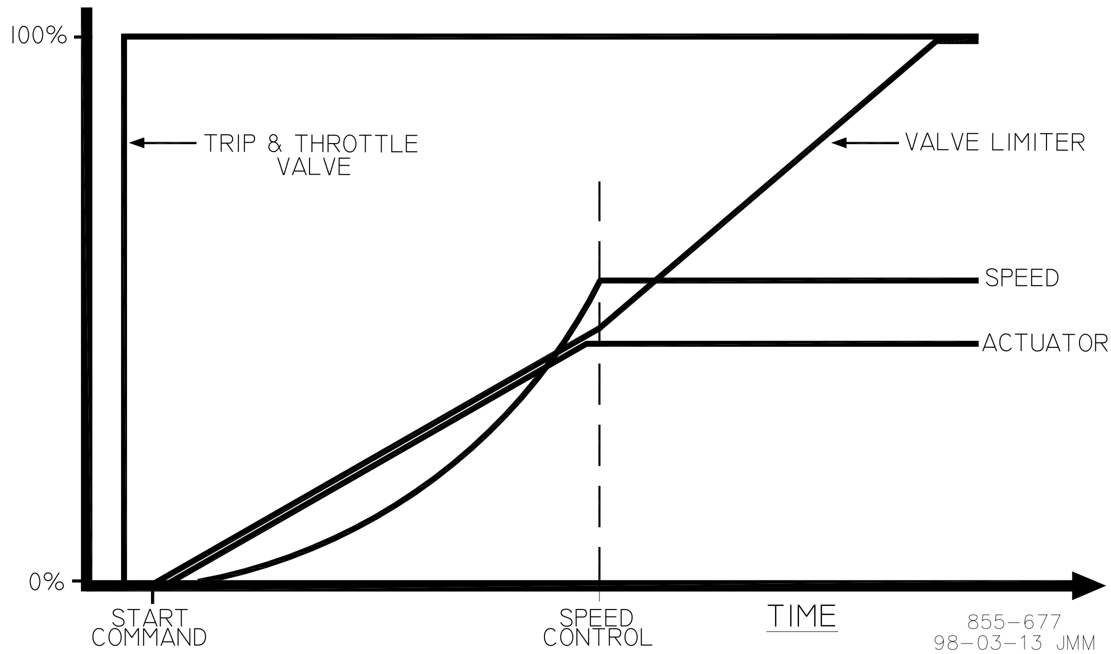


Figure 2-16. Automatic Start Mode Example

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 the HMI/CCT, remote contact inputs, or Modbus. When deselected, the turbine speed ramps down to Idle.

The Idle/Rated function can be used with any 505CC-2 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 Idle is selected while in a critical speed band, the speed setpoint will return to Idle, continuing to move at the critical avoidance rate while within the band. The speed setpoint cannot be stopped within a critical speed avoidance band. Attempting to stop the ramp to Minimum Governor while in a critical band will continue the speed setpoint to the upper or lower limit of the band, depending upon the command issued (Raise or Lower).

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 or lower limit of the band, depending upon the command issued.

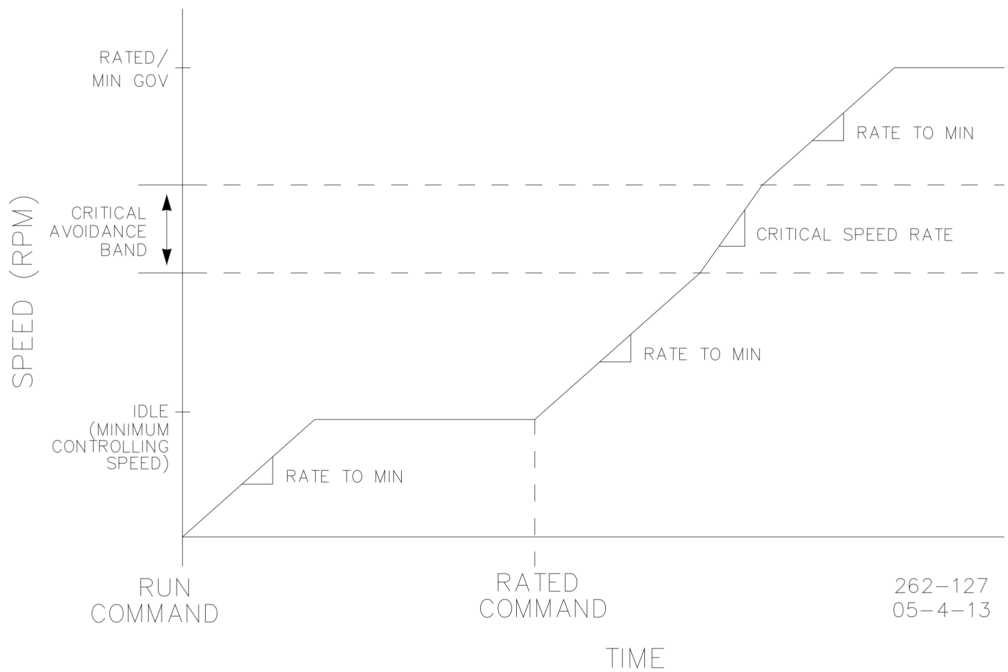


Figure 2-17. Idle/Rated Start

A Ramp to Idle or Ramp to Rated command may be selected from the HMI/CCT, 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 Volume 1, Chapter 2 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 505CC-2 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.

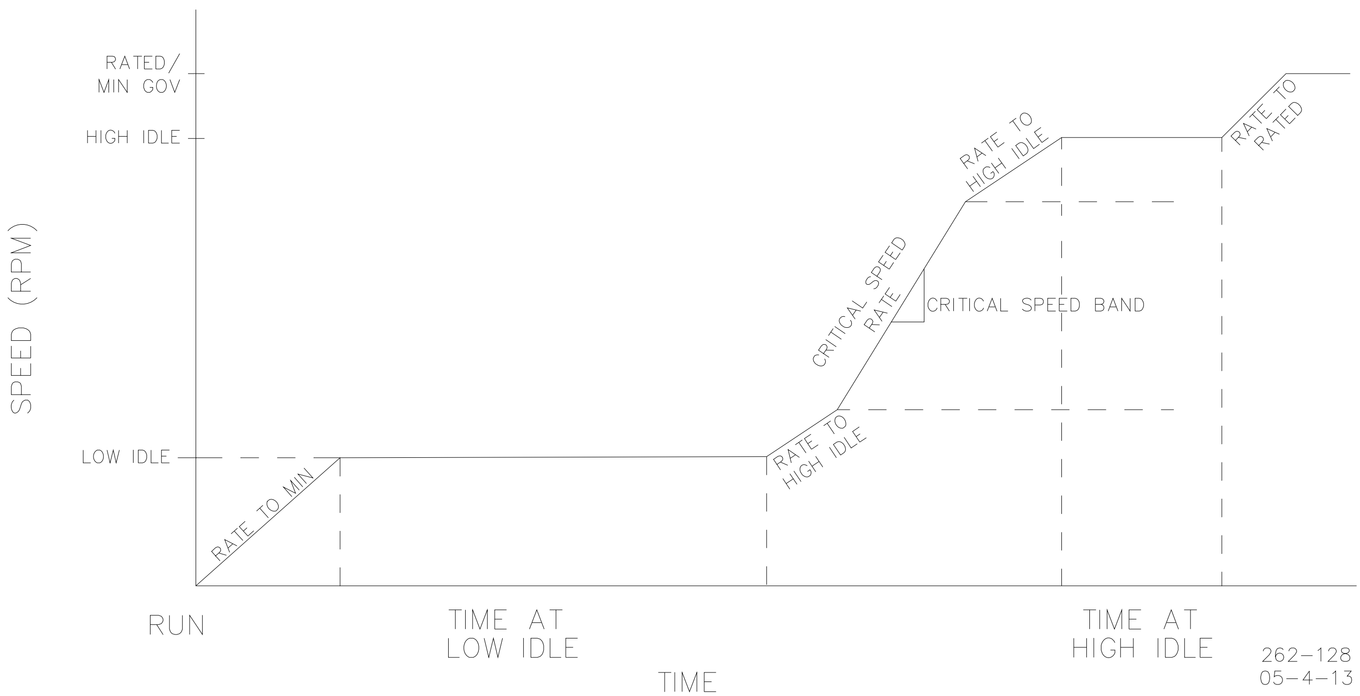


Figure 2-18. Automatic Start Sequence

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 505CC-2 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 505CC-2 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 the HMI/CCT, remote contact inputs, or Modbus. Any Speed Raise/Lower or Speed Setpoint entry via the HMI/CCT or Modbus 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 displayed on the HMI/CCT.

Up to five Emergency Shutdown inputs (remote contact inputs, de-energize to trip) can be configured to initiate a 505CC-2 Emergency Shutdown. The first of these five is required. By wiring trip initiators directly into the control instead of a hard-wired trip string, the 505CC-2 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 the HMI/CCT and 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.

In addition to the dedicated Shutdown relay at Relay Output #1, any turbine configurable relay output may be assigned to indicate a Shutdown condition or as a Trip Relay. The main Shutdown Relay Output #1 and configurable Trip Relay outputs are de-energized on shutdown. However, the configurable Shutdown Condition output is normally de-energized, energizing on a trip condition to indicate the shutdown on a remote panel or to a plant DCS.

The Shutdown Relay and configurable Trip Relays will include the five external trip inputs in their action by configuring Ext Trips in Trip Relay on the Turbine General Configuration screen. If not selected, these external trip initiators will trip the unit but will not be indicated on the Shutdown and Trip Relay outputs. 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 the 505CC-2 Shutdown or Trip Relay outputs are interconnected with the external logic feeding any of the five external trip inputs.

Table 2-1 lists the 505CC-2’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	Control Power-Up
2	HMI/CCT ESD Button
3	Overspeed Trip
4	Both MPUs Failed
5	Actuator 1 Failed (if configured)
6	Actuator 2 Failed (if configured)
7	Speed Stuck in Critical
8	External Trip Input 2 (if configured)
9	External Trip Input 3 (if configured)
10	Modbus 1 ESD Command
11	Modbus 2 ESD Command
12	Not Used
13	Not Used
14	External Trip Input 1
15	Controlled Shutdown Complete
16	External Trip Input 4 (if configured)
17	External Trip Input 5 (if configured)
18	Extr/Adm Input Signal Failed (if configured)

Table 2-1. 505CC-2 Shutdown Initiators

Controlled Shutdown

The 505CC-2's 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 “Cooldown Time” (not applicable if Start Speed is Minimum Governor).
6. After the cooldown, the Controlled Stop is complete and a Shutdown is initiated.

As noted in step 5 above, the cooldown 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 cooldown.

A Controlled Shutdown can be initiated or aborted from the HMI/CCT, 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 505CC-2 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 505CC-2's 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 505CC-2's internal overspeed trip logic and any external overspeed trip device's settings and logic. An Overspeed Test will allow the control's speed setpoint to be increased above the normal Maximum Governor limit. This test can be performed from the HMI/CCT 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.

If the Overspeed Test Enable command is issued (HMI/CCT or contact input) and the above conditions are not met, the HMI/CCT will display an "Overspeed Test / Not Permissible" message. Once the test is enabled, the speed reference can be raised above Maximum Governor up to the configured Overspeed Test Limit.

There are two configurable relay output options available to indicate overspeed status. One indicates an Overspeed Trip condition. The second provides indication that an Overspeed Test is enabled and/or being performed.

See Chapter 5 of this manual for a complete Overspeed Test Procedure. All pertinent overspeed test parameters are available through Modbus. See Volume 1, Chapter 2 for a complete Modbus list.

Local/Remote

The Local/Remote functionality allows an operator at the turbine skid or through the HMI/CCT 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 505CC-2 control modes and settings.

The Local/Remote function must be configured on the System Configuration screen 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 the HMI/CCT, a remote contact input, or Modbus.

When Local Mode is selected, the 505CC-2 is controlled only through its HMI/CCT. 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 Contact In (active at all times, if configured)
- External Trip 3 Contact In (active at all times, if configured)
- External Trip 4 Contact In (active at all times, if configured)
- External Trip 5 Contact In (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)

IMPORTANT

The optional touchscreen HMI, or a similar HMI/CCT computer provided by the user, may be installed anywhere, even some distance from the 505CC-2 and/or the turbine/compressor unit. With regard to the Local/Remote functionality, the HMI/CCT is always considered Local, no matter where it is installed.

When Local/Remote Mode is selected, the 505CC-2 can be controlled through its HMI/CCT, 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.

Optionally, a configurable relay output can be assigned to indicate when Local Mode is selected. There is also indication of the Local/Remote Mode selection through Modbus.

The 505CC-2 is defaulted to only allow control operation though its HMI/CCT 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 Volume 1, Chapter 2 for a complete Modbus list.

Alarms

The 505CC-2 alarm list is based upon that from the Woodward 505/505E control. Thus, if replacing a 505/505E with the 505CC-2, any alarm interface will require minimal modifications. Specifically, a few new alarms were added to the end of the alarm stack to accommodate new turbine control functions and the compressor control’s alarms. See Table 2-2 for the complete list.

Alarm Number	Alarm Description
0	Alarms Cleared
1	Speed Sensor #1 Failed
2	Speed Sensor #2 Failed
3	4–20 mA Cascade Input Signal Failed
4	Not Used
5	Not Used
6	Not Used
7	4–20 mA Inlet/Exhaust Decoupling Pressure Signal Failed
8	4–20 mA Remote Speed Setpoint Signal Failed
9	4–20 mA Remote Cascade Setpoint Signal Failed
10	Not Used
11	Not Used
12	Turbine HP Actuator/Driver Output Failed
13	Turbine LP Actuator/Driver Output Failed
14	Start Initiated without Start Permissives Met
15	Modbus Port #1 Communications Error
16	Modbus Port #2 Communications Error
17	Not Used
18	Shutdown (Not Used unless activated)
19	Not Used
20	Overspeed Trip
21	Not Used
22	Not Used
23	Not Used
24	Not Used
25	Not Used
26	Not Used
27	Speed Stuck in Critical Band
28	4–20 mA Extr/Adm Pressure Input Signal Failed
29	4–20 mA Remote Extr/Adm Setpoint Signal Failed
30	4–20 mA HP Pressure Compensation Signal Failed
31	4–20 mA LP Pressure Compensation Signal Failed
32	Speed Setpoint Configuration Error
33	Steam Map Configuration Error
34	Speed Setpoint Entered in Critical Band
35	4–20 mA Remote Inlet/Exhaust Decoupling Setpoint Signal Failed
36	4–20 mA External Speed Bias Signal Failed
37	4–20 mA Remote Pressure Demand Signal Failed

Table 2-2. 505CC-2 Alarm List

The numerical reference can be used as an index to determine the first alarm received via the first-alarm number in the Datalog or Modbus.

Alarm 32, Speed Setpoint Configuration Error, applies to the relative ordering of Idle speeds, critical bands, Minimum and Maximum Governor, etc.

Alarm 33, Steam Map Configuration Error, applies to the relative arrangement of the Points A, B, and C from the Extraction and/or Admission steam map.

High-Speed Datalog

The 505CC-2 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 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.

The datalog is a circular buffer that is stored in CPU memory. As shown in Table 3-3, it records 44 discrete values (TRUE/FALSE) and 32 analog values for the turbine. This amount of data sampled every 10 ms results in a 68-second datalog. After the buffer is full, the datalog begins overwriting the oldest data. Recording automatically begins when the compressor train is started and automatically stops 10 seconds after a compressor surge or unit shutdown. Using special software tools, starting and stopping the datalog can also be done manually to record specific transient events, process swings, etc. Two turbine datalogs can be stored on the CPU at any given time—If two completed datalog files already exist, the older of the two will be overwritten by the next datalog file.

AppManager and Control Assistant software, included on the installation CD, can be used to retrieve and view the datalogs. (AppManager may also be downloaded from the software page at *www.woodward.com*.) See AppManager's online help menu for details on retrieving files, including datalogs, from the control. The AppManager Datalog Retrieval Tool, available with an extra, purchased license, can also be configured to automatically archive datalogs from the control to a connected network computer. The File Upload/Download screen on the HMI/CCT also provides a datalog retrieval function—See Volume 1 Chapter 2 for more details. See Control Assistant's online help menu for details on viewing the *.log* datalog files. 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.

Discrete Values (TRUE/FALSE = 1/0)	Analog Values
Shutdown Condition Active	Turbine Speed (HSS Output)
Shutdown on CPU Reset	Turbine Speed (MPU #1)
Shutdown Initiated from HMI	Turbine Speed (MPU #2)
Shutdown on Overspeed	HP/V1 Demand Output
Shutdown on MPU Failure	HP/V1 Limiter Output
Shutdown on HP/V1 Actuator Fault	LP/V2 Demand Output
Shutdown on LP/V2 Actuator Fault	LP/V2 Limiter Output
Shutdown on Speed Stuck in Critical	Steam Map K1 Value
Shutdown on External Trip Input #2	Steam Map K2 Value
Shutdown on External Trip Input #3	Steam Map K3 Value
Shutdown Initiated from Modbus Port #1	Steam Map K4 Value
Shutdown Initiated from Modbus Port #2	Steam Map K5 Value
Not Used	Steam Map K6 Value
Not Used	Steam Map Point A Power (Compensated)
Shutdown on Primary Run Input BI01	Steam Map Point A Flow (Compensated)
Shutdown on Normal Stop Completion	Steam Map Point B Power (Compensated)
Shutdown on External Trip Input #4	Steam Map Point B Flow (Compensated)
Shutdown on External Trip Input #5	Steam Map Point C Power (Compensated)
Shutdown on Extr/Adm Input Fault	Steam Map Point C Flow (Compensated)
Alarm Condition Active	Speed Reference (SP)
Turbine in Decoupled Mode	Speed PID Output (Demand)
Speed Above Overspeed Setpoint	Extraction/Admission Input (PV)
Speed in Control	Extraction/Admission Reference (SP)
HP/V1 Map in Control	Extraction/Admission PID Output (Demand)
HP/V1 Limiter in Control	Cascade Input (PV)
LP/V2 Map in Control	Cascade Reference (SP)
LP/V2 Limiter in Control	Cascade PID Decoupling Output (Demand)
Cascade Control Enabled	Inlet/Exhaust Pressure Input (PV)
Inlet/Exhaust Decoupling Enabled	Inlet/Exhaust Pressure Reference (SP)
Extraction/Admission Control Enabled	Inlet/Exhaust Pressure PID Output (Demand)
Overspeed Test Enabled	First Out Trip Initiator
Turbine Speed in Critical Band	First Alarm Initiator
Online Speed Dynamics Selected	
Steam Map SminHP Limit Reached	
Steam Map SminLP Limit Reached	
Steam Map SmaxHP Limit Reached	
Steam Map SmaxLP Limit Reached	
Steam Map PminHP Limit Reached	
Steam Map PminLP Limit Reached	
Steam Map PmaxHP Limit Reached	
Steam Map PmaxLP Limit Reached	
Steam Map Minimum Load	
Steam Map Minimum HP Flow	
Steam Map Any Limit Reached	

Table 2-3. 505CC-2 Turbine Datalog

Chapter 3.
Turbine General Description

Introduction

The 505CC-2 is designed to control single valve steam turbines or two-valve turbines in extraction only, extraction/admission, or admission only configurations. The control is field programmable, which allows a single design to be used in many different control applications and reduces both cost and delivery time. It uses menu driven software to instruct site engineers on programming the control to a specific compressor drive application. The 505CC-2 can be configured to operate as a stand-alone unit or in conjunction with a plant's Distributed Control System.

Configuration and operation are available through the provided Configuration Tool (CCT) software running on any connected computer, or on an optional fifteen-inch (15" or 381mm) touch-screen HMI (Human Machine Interface). Additional operational and monitoring capabilities are available over Modbus.

The 505CC-2 interfaces with two turbine control valves (HP & LP) to control two parameters and limit an additional parameter, if desired. These two controlled parameters are typically speed (or load) and extraction/admission pressure (or flow). However, it could be utilized to control or limit: turbine inlet pressure or flow, exhaust pressure (back-pressure) or flow, compressor inlet or discharge pressure or flow, or any other turbine related process parameter.

Additional Features

The 505CC-2 also provides the following turbine control features:
- First-Out Trip Indication (5 total trip inputs from external devices)
- Critical Speed Avoidance (2 configurable speed bands and ramp rate)
- Configurable Start Routines (Rated, Idle/Rated, Auto Start Sequence)
- Dual Speed/Load Dynamics
- Zero Speed Override
- Peak Speed Indication for Overspeed Trip

505CC-2 Inputs and Outputs

Turbine Control Inputs

Two (2) speed inputs (MPU or Proximity Probe) are available.

- Six (6) 4–20 mA analog inputs are available. Input #6 is defaulted as the steam pressure input—If the unit is configured as Extraction Only, Admission Only, or Extraction/Admission, this input will be the corresponding steam pressure input. However, if the unit is a Single Valve configuration, Input #6 may be assigned as an Inlet or Exhaust Steam Pressure. Inputs One (1) through five (5) are configurable for the following options. The numbers may be used as an index to the configuration value available in the Modbus list.

0. Not Configured
1. Remote Speed Setpoint–If configured, this input may be used to provide a speed setpoint from an external device.
2. Not Used
3. Not Used
4. Not Used
5. Cascade Input–If configured, this input may provide a process variable for Cascade control on turbine speed.
6. Remote Cascade Setpoint–If configured, this input may be used to provide a Cascade setpoint from an external device.
7. Not Used
8. Not Used
9. Inlet/Exhaust Pressure Input–If configured for Inlet or Exhaust Decoupling with a two-valve turbine, this input provides the Inlet or Exhaust Pressure measurement.
10. Remote Extraction/Admission Setpoint–If configured for a two-valve turbine, this input may be used to provide an Extraction/Admission setpoint from an external device.
11. Remote Inlet/Exhaust Setpoint–If configured for Inlet or Exhaust Decoupling with a two-valve turbine, this input may be used to provide an Inlet/Exhaust setpoint from an external device.
12. Inlet Pressure for HP/V1 compensation—Use this input for inlet steam pressure compensation of the HP/V1 valve demand. Under conditions of abnormally high or low steam pressure, the valve demand may be adjusted accordingly.
13. Remote Flow Setpoint–If configured for a two-valve turbine, this input may be used to provide a Flow Demand from an external device.
14. Ext/Adm Pressure for LP/V2 compensation—Use this input for extraction/admission steam pressure compensation of the LP/V2 valve demand. Under conditions of abnormally high or low steam pressure, the valve demand may be adjusted accordingly.
15. External Speed Bias—Use this input for temporary speed control biasing from changes in a related process.

- Twelve (12) contact inputs are available, four (4) of which are fixed for Emergency Shutdown, Reset, Speed Raise, and Speed Lower commands. The eight (8) remaining contact inputs are configurable for the following options. The numbers may be used as an index to the configuration value available in the Modbus list.

0. Not Configured
1. Not Used
2. Not Used
3. Enable Overspeed Test–(sustained)
4. External Start/Run–(momentary)
5. Start Permissive–(sustained)
6. Idle/Rated–(sustained)
7. Halt/Continue Auto Start Sequence–(sustained)
8. Override MPU Fault–(sustained)
9. Select Online Dynamics–(sustained)
10. Select Local/Remote–(sustained)
11. Enable Remote Speed Setpoint–(sustained)
12. Not Used
13. Not Used
14. Extr/Adm Setpoint Raise–(momentary or sustained)
15. Extr/Adm Setpoint Lower–(momentary or sustained)
16. Enable Extr/Adm Control–(sustained)
17. Enable Remote Extr/Adm Setpoint–(sustained)
18. Extr/Adm Pressure Priority Selection–(sustained)
19. Cascade Setpoint Raise–(momentary or sustained)
20. Cascade Setpoint Lower–(momentary or sustained)
21. Enable Cascade Control–(sustained)
22. Enable Remote Cascade Setpoint–(sustained)
23. Not Used
24. Not Used
25. Not Used
26. Not Used

27. HP Valve Limiter Raise–(momentary or sustained)
28. HP Valve Limiter Lower–(momentary or sustained)
29. LP Valve Limiter Raise–(momentary or sustained)
30. LP Valve Limiter Lower–(momentary or sustained)
31. Manual Extr/Adm Pressure Demand Raise–(momentary or sustained)
32. Manual Extr/Adm Pressure Demand Lower–(momentary or sustained)
33. External Trip Input 2–(sustained, normally open)
34. External Trip Input 3–(sustained, normally open)
35. External Trip Input 4–(sustained, normally open)
36. External Trip Input 5–(sustained, normally open)
37. Initiate Controlled Shutdown–(sustained)
38. Inlet/Exhaust Decoupling Setpoint Raise–(momentary or sustained)
39. Inlet/Exhaust Decoupling Setpoint Lower–(momentary or sustained)
40. Enable Remote Inlet/Exhaust Decoupling Setpoint–(sustained)
41. Inlet/Exhaust Manual Demand Raise–(momentary or sustained)
42. Inlet/Exhaust Manual Demand Lower–(momentary or sustained)
43. Enable Decoupled Mode–(sustained)
44. Enable Remote Extr/Adm Pressure Demand–(sustained)
45. Synchronize Control Clock–(momentary)
46. Enable Manual Decoupled Mode–(sustained)
47. Enable Manual Coupled Mode–(sustained)

Turbine Control Outputs

Two (2) actuator outputs are provided for the HP and LP valves, configurable for either 4–20 mA or 20-160 mA, nominal. If desired, a failed actuator output (actuator current does not match demand) may be configured to trip the unit.

Two (2) additional configurable analog outputs are provided for readouts of any of the following parameters. The numbers may be used as an index to the configuration value available in the Modbus list.

1. Not Configured
2. Actual Speed (rpm)
3. Speed Setpoint (rpm)
4. Remote Speed Setpoint (rpm)
5. Not Used
6. Not Used
7. Not Used
8. Extr/Adm Pressure Input (eng. units)
9. Extr/Adm Setpoint (eng. units)
10. Remote Extr/Adm Setpoint (eng. units)
11. Cascade Input (eng. units)
12. Cascade Setpoint (eng. units)
13. Remote Cascade Setpoint (eng. units)
14. Not Used
15. Not Used
16. Not Used
17. Not Used
18. Extr/Adm Demand (%)
19. HP Valve Limiter Value (%)
20. LP Valve Limiter Value (%)
21. HP Valve Demand (%)
22. LP Valve Demand (%)
23. Not Used

Six (6) relay outputs are available. These outputs are low-side relay drivers providing up to 200 mA and powered by an external +12 Vdc or +24 Vdc (9–32 Vdc). The outputs are not isolated from each other but are isolated from the control's internal power supplies. Two (2) of the outputs are fixed for Shutdown and Alarm indications. The four (4) remaining outputs are configurable for the following discrete statuses or level switches. The numbers may be used as an index to the configuration value available in the Modbus list.

1. Relay Not Configured
2. Shutdown Active
3. Trip Relay (Normally Open)
4. Alarm Active
5. Atlas-II Control Status (OK)
6. Overspeed Trip
7. Overspeed Test Enabled
8. Speed PID In Control
9. Remote Speed Setpoint Enabled
10. Remote Speed Setpoint Active
11. Not Used
12. Auto-Start Sequence Halted
13. Online Dynamics Active
14. Local Control Mode
15. Not Used
16. Not Used
17. Not Used
18. Not Used
19. Not Used
20. Extr/Adm Control Enabled
21. Extr/Adm Control Active
22. Extr/Adm PID In Control
23. Remote Extr/Adm Setpoint Enabled
24. Remote Extr/Adm Setpoint Active
25. Cascade Control Enabled
26. Cascade Control Active
27. Not Used
28. Not Used
29. Not Used
30. Not Used
31. Not Used
32. HP Valve Limiter In Control
33. LP Valve Limiter In Control
34. Not Used
35. Not Used
36. Steam Map Limiter In Control
37. Modbus Commands Selected
38. Level Switch Selected but not Configured
39. Actual Speed Level Switch
40. Speed Setpoint Level Switch
41. Not Used
42. Not Used
43. Extr/Adm Input Level Switch
44. Extr/Adm Setpoint Level Switch
45. Cascade Input Level Switch
46. Cascade Setpoint Level Switch
47. Not Used
48. Not Used
49. Not Used
50. Extr/Adm Demand Level Switch
51. HP Valve Limiter Level Switch
52. LP Valve Limiter Level Switch
53. HP Valve Demand Level Switch
54. LP Valve Demand Level Switch
55. Not Used

Chapter 4.
Turbine Configuration Overview

Introduction

The 505CC-2 may be configured using the Configuration & Commissioning Tool (CCT) software running on a connected computer or via the optional 15" display. See Manual 26451V1 for a description of system level configuration and Volume 3 for compressor configuration. This chapter will provide detailed information concerning the turbine configuration only.

Screens are shown below as configured for ITCC Mode (See 26451V1 for Control Mode Configuration options)—In Turbine-Only or Compressor-Only Modes, there will be some variation in screen appearance from those shown below.

Turbine configuration is limited to the Service and Online Configuration log-in levels. The former is restricted to those parameters that can safely be tuned while the unit is running. However, some configurables, such as the turbine type, MPUs' number of teeth, etc., can only be tuned while the unit is shutdown in the Online Configuration log-in. And, as always, the Offline Configuration log-in is available to generate a configuration file while disconnected from a control.

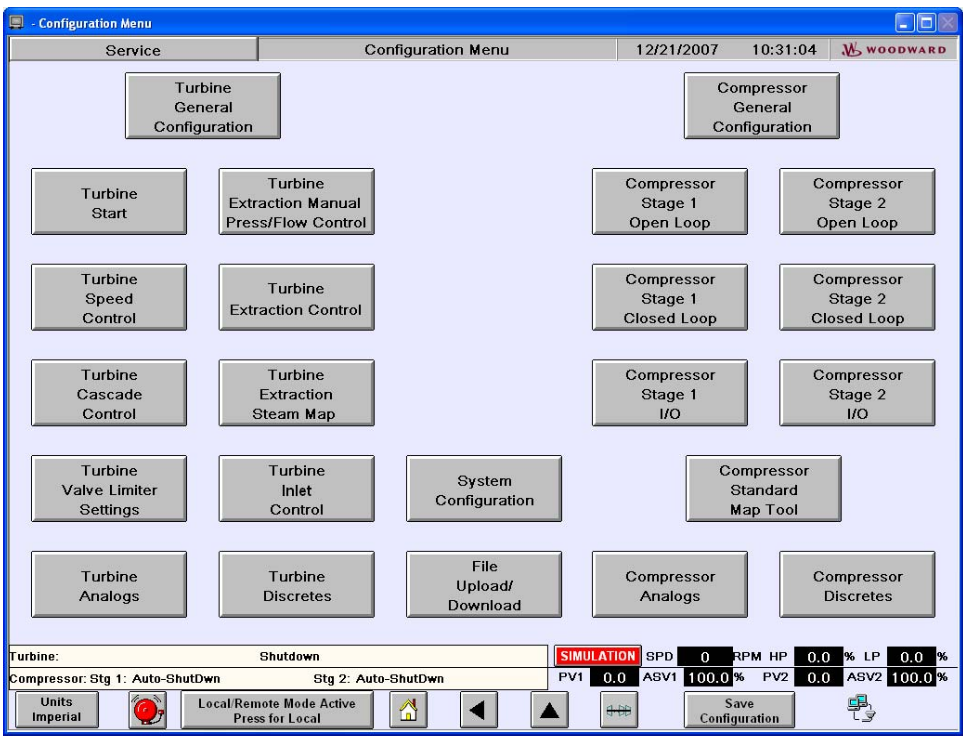


Figure 4-1. Configuration Menu Screen

Depending on the turbine type and desired control functionality, there are up to eleven configuration screens for the turbine. Screens and individual items are hidden or inhibited based upon the selections made and functions enabled or disabled—Any item that is not selectable is not used in the current configuration. Conversely, any item that is visible and appears selectable should be reviewed to determine its appropriate setting. The configuration items and screens are arranged to facilitate an orderly, sequential configuration, screen by screen, as outlined in the following sections.

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.

505CC-2 Turbine Configuration Screens

Turbine General Configuration Screen

The selections on this screen configure the 505CC-2 for the turbine type and very basic functionality, as well as HMI appearance.

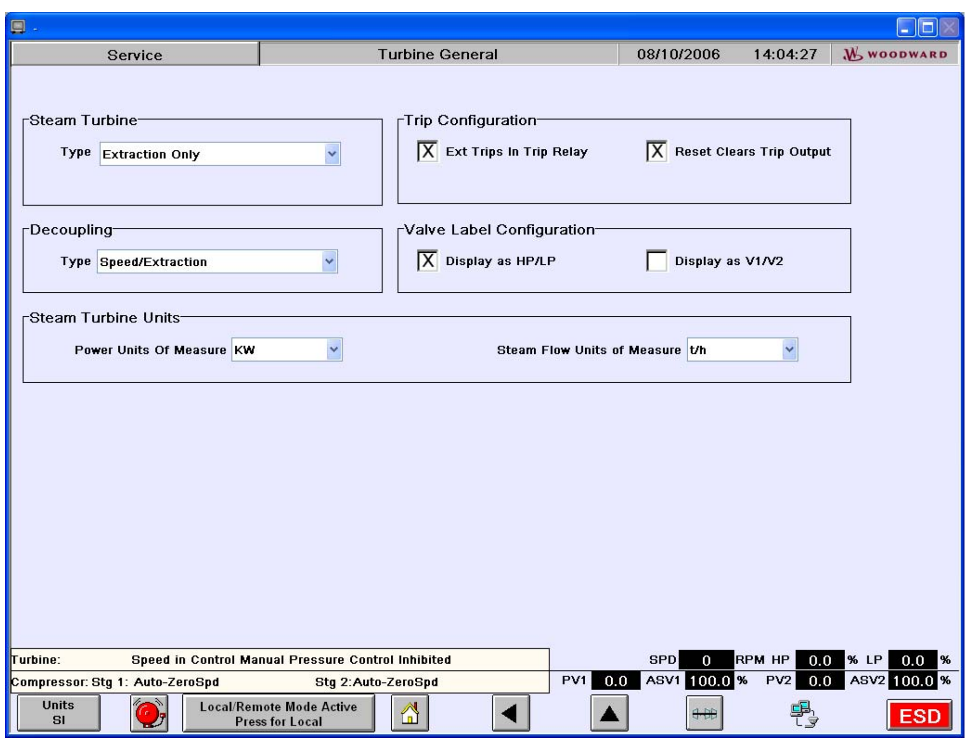


Figure 4-2. Turbine General Configuration Screen

Steam Turbine Type
Select the appropriate turbine type from the list: Single Valve, Extraction Only, Admission Only, or Extraction/Admission.

Decoupling Type
If a two-valve turbine was configured above, select the desired Decoupling type from the list:
- Speed/Extraction for HP & LP Coupled Mode
- Inlet/Speed for HP Decoupled Mode
- Exhaust/Speed for LP Decoupled Mode
- No Ratioing for HP & LP Total Decoupled Mode

See the Ratio-Limiter Section in Chapter 3.

Trip Configuration
Select Ext Trips in Trip Relay to include the 5 External Trip initiators in the Shutdown and Trip Relay outputs. If not selected, and one of the 5 External Trips causes a shutdown, the unit will trip, but the Shutdown and Trip Relay outputs will remain energized.

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.

Valve Label Configuration
Select the desired valve labels as HP/LP or V1/V2. This merely customizes the appearance of the HMI/CCT.

Steam Turbine Units
Select the desired Power and Steam Flow Units. The available units will depend upon the System Units configuration as SI or Imperial. These selections merely customize the appearance of the HMI/CCT.

Turbine Start Configuration Screen

The selections on this screen determine the turbine Start Mode and Speed Setpoints.

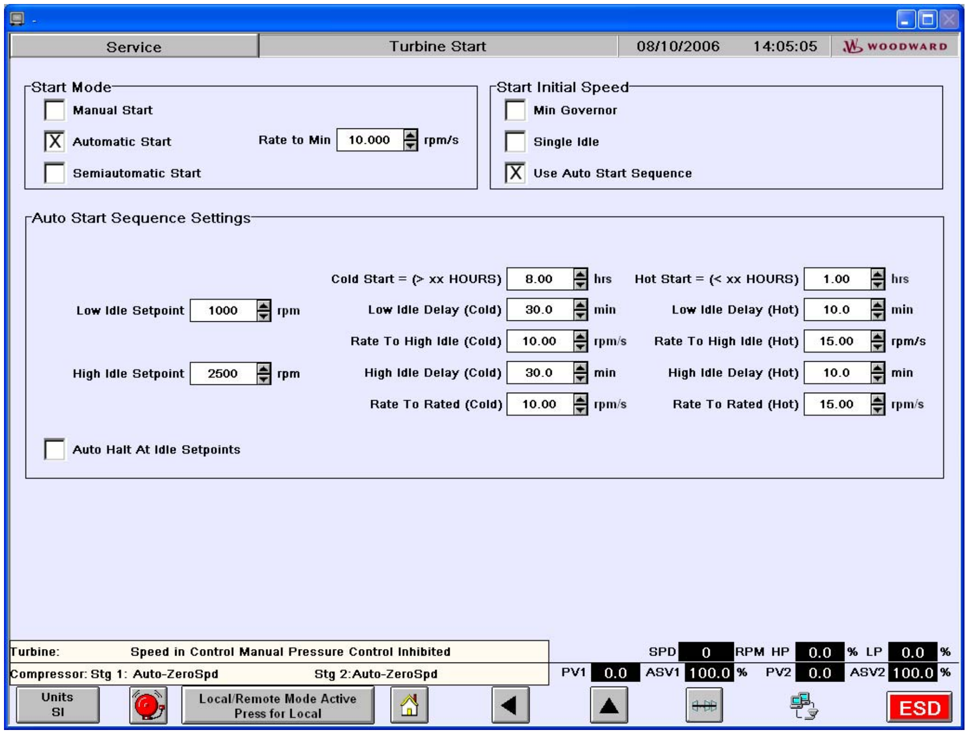


Figure 4-3. Turbine Start Configuration Screen

Start Mode

Select the desired Start Mode as Manual, Semiautomatic, or Automatic. See the Turbine Start Modes section in Chapter 3.

Also, configure the desired Rate to Min for the speed reference. This rate is used for any ramp to Minimum Governor, unless otherwise configured (e.g. Auto Start Sequence) or a higher priority ramp is activated (e.g. critical speed avoidance).

Start Initial Speed

Select the desired start speed as Min Governor, Single Idle, or Auto Start Sequence. See the Turbine Start Speeds section in Chapter 3.

For Min Governor and Single Idle (Idle/Rated), also configure the Min Controllable and Idle Speeds, respectively. The 505CC-2 uses the Min Controllable speed in a Minimum Governor start to enable/disable some functions and timers. It is analogous to the Idle speed, although it does not control there in an idle sequence.

Auto Start Sequence Settings

If Auto Start Sequence was selected above, configure the desired Low and High Idle speeds, as well as the Hot and Cold parameters for ramps and delay times. See the Turbine Start Speeds—Auto Start Sequence section in Chapter 3.

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.

Select Auto Halt at Idle Setpoints to automatically halt the Auto Start Sequence at Low and High Idles. In this configuration, the control will await a Continue command from the operator before ramping to the next speed control level.

Turbine Speed Control Configuration Screen

The selections on this screen configure all Speed Control parameters.

Speed Sensor Settings
Configure the Teeth Seen by MPU and Gear Ratio as appropriate for the installed speed sensor(s) (MPU or Proximity Probe). The 505CC-2 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 (upon leaving the Online Configuration mode). Therefore, for these settings to take effect, they should be tuned in Online Configuration.

The maximum frequency sensed by the 505CC-2's speed inputs 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:

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

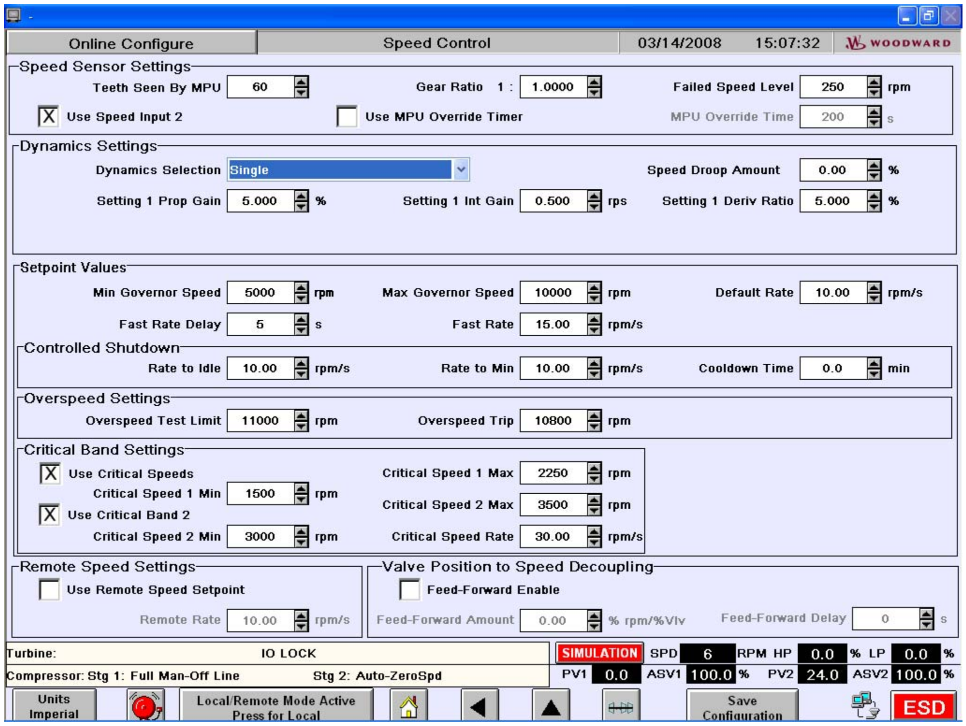


Figure 4-4. Turbine Speed Control Configuration Screen

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

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

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

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

IMPORTANT

If both speed inputs are utilized (two separate probes), they must be mounted on the same gear--The Teeth Seen by MPU and Gear Ratio settings, used to calculate actual turbine speed, are common for both inputs.

Also configure the Failed Speed Level. Speed is overridden below this value on startup, and a trip initiated if speed falls below this value while running.

Select Use Speed Input 2 if both speed sensor inputs will be utilized for control.

If desired, select Use MPU Override Timer and configure the timer value to provide a time-based override limit on startup. See the Turbine Starting Features—Zero Speed Signal Override section in Chapter 3.

Dynamics Settings

Select the desired Dynamics configuration from the list: 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.

Setpoint Values

Configure the appropriate Governor and Overspeed settings according to the turbine manufacturer's recommendations and/or site application. Minimum Governor, Maximum Governor, Overspeed Trip, and Overspeed Test Limit must be in ascending order.

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.**

⚠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 (upon leaving the Online Configuration mode). Therefore, for this setting to take effect, it should be tuned in Online Configuration.**

Configure the Default Rate as appropriate. This ramp rate is used for the speed reference unless some other priority rate is activated. Configure the Fast Rate Delay and Fast Rate to accommodate a faster ramp when Raise/Lower commands are held continuously.

If recommended or required by the turbine manufacturer, or as dictated by site practice, select Use Critical Speeds to configure one or both critical speed avoidance bands on startup. Configure the Min and Max values for each band and the Critical Speed Rate as appropriate. The critical band settings must be in ascending order (Min 1 → Max 1 → Min 2 → Max 2).

Remote Speed Settings

If a configurable 4–20 mA analog input will be assigned to remotely position the Speed Reference, select Use Remote Speed Setpoint and configure the desired Remote Rate that will be applied.

Valve Position to Speed Decoupling

When the compressor's Anti-Surge Valve(s) opens, load is increased on the turbine and speed decreases. Consider, as an example, the case of simple speed control. After the speed decrease caused by recycling of the compressor, the turbine's speed PID controller must increase valve demand to restore the unit speed to its setpoint value. The rate at which this occurs is dependent upon the PID's tuning parameters. If the speed reference value were artificially increased as a result of the Anti-Surge Valve movement, the PID would temporarily act on a larger error between setpoint and reference. This may decrease the time required for the PID to return the unit to its setpoint speed, thereby increasing system stability. This situation may be even more important in other, more elaborate control schemes (cascade control, turbine decoupling modes).

If desired, select Feed-Forward Enable to manipulate the base speed reference in response to compressor recycling. Configure the Feed-Forward Amount as a scalar in percent speed per percent Anti-Surge Valve movement. This scalar is applied to both Anti-Surge Valve demands in a 2-valve system. The resulting speed biases are added to the turbine's speed reference but are limited internally to no more than five percent (5%) each. Configure the Feed-Forward Delay Time in seconds that the speed bias will be applied. After this time delay, the bias will have been removed from the reference.

IMPORTANT	**The compressor functionality described above is not active if the unit is configured for Turbine-Only Mode.**

Turbine Cascade Control Configuration Screen

The selections on this screen will configure the Cascade Controller, if applicable. See the Cascade Control section in Chapter 3.

IMPORTANT	**The Cascade Controller is also available if the unit is configured for Compressor-Only Mode.**

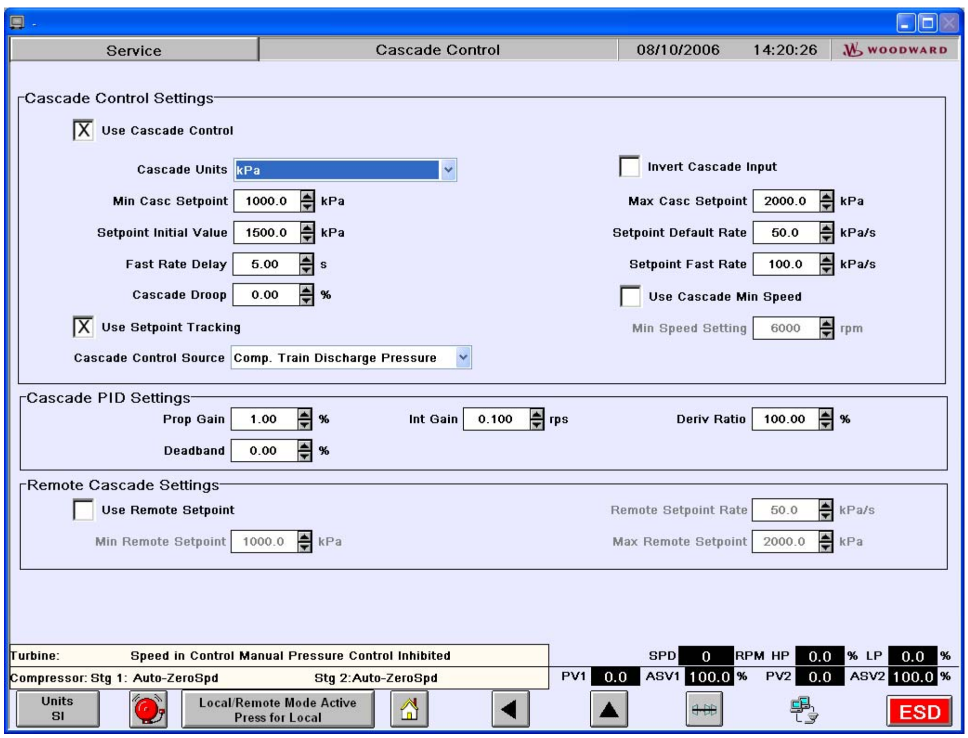


Figure 4-5. Turbine Cascade Control Configuration Screen

Cascade Control Settings
Select Use Cascade Control to configure the 505CC-2's Cascade controller.

Select the Cascade Units of measure from the list. Unlike most other controllers, where units selection has no impact on control (screen appearance only), the Cascade controller will be affected by engineering units if the source is configured below as one of the internal compressor variables (pressure or flow). These process variables are passed from the compressor control to the cascade controller in specific SI engineering units (kPa, kg/hr, Nm³/hr, Am³/hr). Therefore, the Cascade Units selection must match (pressure unit for pressure, flow unit for flow). For example, if the Cascade Control Source is configured as Compressor Discharge Pressure, a pressure unit (kPa, kg/cm², atm, BAR, mBAR, PSI, ftH_2O, ton/ft, inHg) must be selected from the unit list—Inadvertently selecting a flow unit, for example, will cause control errors. The HMI/CCT will still convert among different units of the common pressure or flow variable.

In addition, for volumetric flow, actual or normal/standard units must be maintained. For example, if the Cascade Source is Compressor Suction Volume Flow (actual inlet conditions), the configured parameters will also be interpreted in actual inlet conditions—The control cannot automatically convert between actual and normal/standard flow units because the normal/standard conditions are unknown.

If the Cascade Control Source is a configurable 4–20 mA analog input, any unit selection is permissible and, as with the other controllers, has no effect on control. Simply configure the 4–20 mA input range and the settings on this screen in the same engineering unit, and select that unit from the Units list. If the desired engineering unit is not available, simply select EU.

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

Configure the Min and Max Casc Setpoints to define the operating range for Cascade control. Though these values can be configured as desired, it is recommended that they correspond, roughly, to the process values at Minimum and Maximum Governor speeds under normal operating conditions.

Configure the Casc Default Rate, Fast Rate, and Fast Rate Delay as appropriate for the Cascade Reference ramp.

Configure the Setpoint Initial Value to that which should be applied on power-up of the control.

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.

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

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.

Select the desired Cascade Control Source process variable from the list. If one of the internal compressor process variables is selected (flow or pressure), verify that the Cascade Units selection (above) is appropriate for the selected PV.

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.

Remote Cascade Settings
If a configurable 4–20 mA analog input will be assigned to remotely position the Cascade Reference, select Use Remote Setpoint and configure the desired Remote Rate that will be applied. Also configure the Min and Max Cascade Settings that will be used to limit the remote demand.

Turbine Valve Limiter Settings Screen

The selections on this screen will configure the HP and LP Valve Limiters. See the Valve Limiters section in Chapter 3.

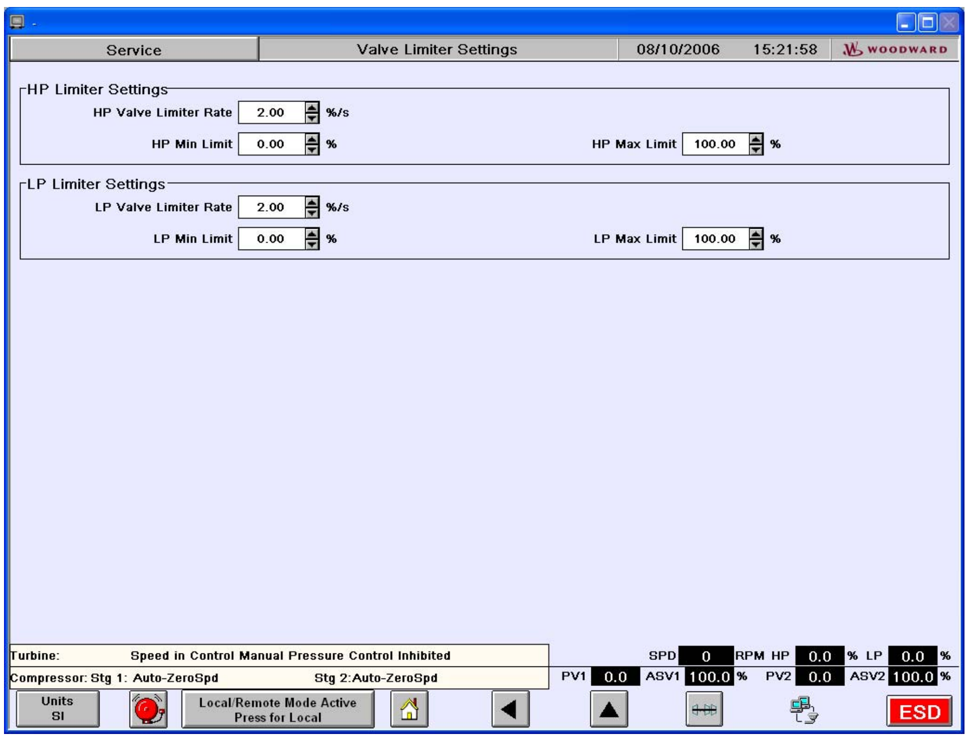


Figure 4-6. Turbine Valve Limiter Configuration Screen

HP Limiter Settings
Configure the appropriate HP Valve Limiter Rate. This rate is applied to the Limiter unless some other priority rate is activated. Also configure the HP Min and Max Limits, which define the valve's operating range, typically 0-100%.

LP Limiter Settings
For two-valve turbines, configure the appropriate LP Valve Limiter Rate. This rate is applied to the Limiter unless some other priority rate is activated. Also configure the LP Min and Max Limits, which define the valve's operating range, typically 0-100%.

Turbine Extr/Adm Manual Pressure (Flow) Control Configuration Screen

The selections on this screen will configure Manual Pressure (Flow) Demand, if a two-valve turbine was configured previously. 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 3.

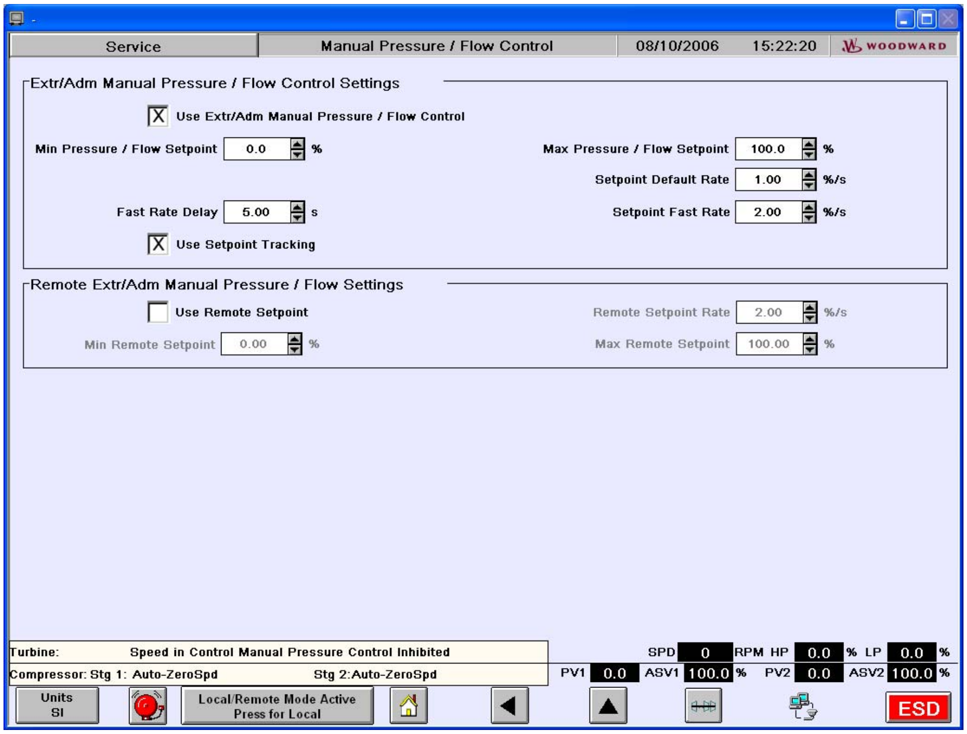


Figure 4-7. Turbine Extr/Adm Manual Pressure (Flow) Configuration Screen

Extr/Adm Manual Pressure / Flow Control Settings

Select Use Extr/Adm Manual Pressure (Flow) Control to configure Manual Pressure (Flow) Demand. This selection allows commands from the HMI/CCT and Modbus to put the Extr/Adm controller into manual mode. If deselected, the 505CC-2 will still use Manual Pressure (Flow) Control as a default mode, as noted previously, but the go-to-manual commands from the HMI/CCT and Modbus will be ignored.

Configure the Min and Max Pressure (Flow) Setpoints to define the operating range for Manual Pressure (Flow) Demand, typically 0-100%.

Configure the Default Rate, Fast Rate, and Fast Rate Delay as appropriate for the manual demand.

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.

Remote Extr/Adm Manual Pressure / Flow Settings

If a configurable 4–20 mA analog input will be assigned to remotely position the Pressure (Flow) Demand, select Use Remote Setpoint and configure the desired Remote Rate that will be applied. Also configure the Min and Max Pressure (Flow) Settings that will be used to limit the remote demand.

Turbine Extr/Adm Control Configuration Screen

The selections on this screen will configure the Extr/Adm Controller, if a two-valve turbine was configured previously. See the Extraction and/or Admission Control section in Chapter 3.

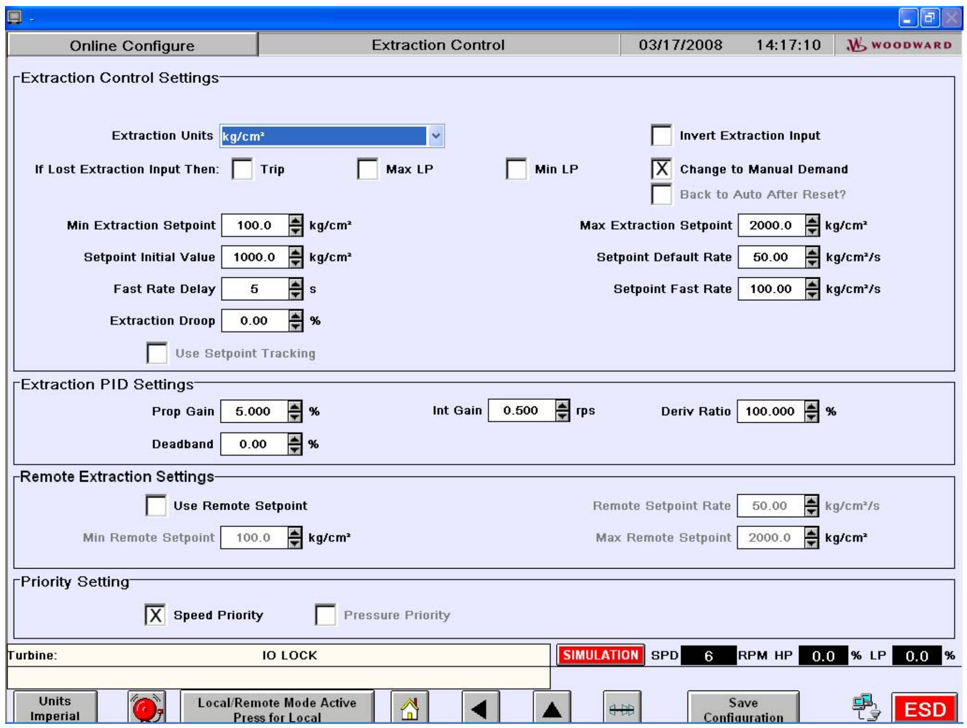


Figure 4-8. Turbine Extr/Adm Control Configuration Screen

Extraction/Admission Control Settings

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.

Select the Extr/Adm Units of measure from the list. These selections merely customize the appearance of the HMI/CCT. If the desired engineering unit is not available, simply select EU.

Select Invert Extr/Adm Input if the control loop requires reverse action (e.g. Admission-only turbine).

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 control. If the latter is selected, an additional parameter is available to force the control back to auto after reset. This feature will re-enable Extr/Adm in automatic mode after the signal failure is corrected. If deselected, Extr/Adm control will remain in manual after the signal failure is corrected and reset.

Configure the Min and Max Extr/Adm Setpoints to define the operating range for Extr/Adm control. Though these values can be configured as desired, it is recommended that they correspond, roughly, to the process values at Minimum and Maximum Governor speeds under normal operating conditions.

Configure the Default Rate, Fast Rate, and Fast Rate Delay as appropriate for the Extr/Adm Reference ramp.

Configure the Default Initial Value to that which should be applied on power-up of the control.

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.

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.

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.

Remote Extraction/Admission Settings
If a configurable 4–20 mA analog input will be assigned to remotely position the Extr/Adm Reference, select Use Remote Setpoint and configure the desired Remote Rate that will be applied. Also configure the Min and Max Extr/Adm Settings that will be used to limit the remote demand.

Priority Settings
This item only appears when Turbine-Only Mode is configured. When the ITCC Mode is configured, the software itself changes the Priority Settings to Speed Priority. When configured to Speed Priority, the software will sacrifice Ext/Adm control when the steam map reaches its limits. When configured to Pressure Priority, the software will sacrifice Speed control when the steam map reaches its limits.

Turbine Extr/Adm Steam Map Configuration Screen

The selections on this screen will configure the Extr/Adm Steam Map, if a two-valve turbine was configured previously. Before configuring the map, read the discussion below on steam maps and how to convert map information into a format usable by the 505CC-2.

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 505CC-2 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 505CC-2 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 505CC-2 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 505CC-2 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 4-9).

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 4-9.

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/hr 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/hr in this example.
4. Point B is where the LP=0 and P=100 lines intersect. Min Power at Max Extraction is about 3,623 kW, and Min HP Flow at Max Extraction is about 86,000 lb/hr 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/hr in this example.

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 4-10).

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.

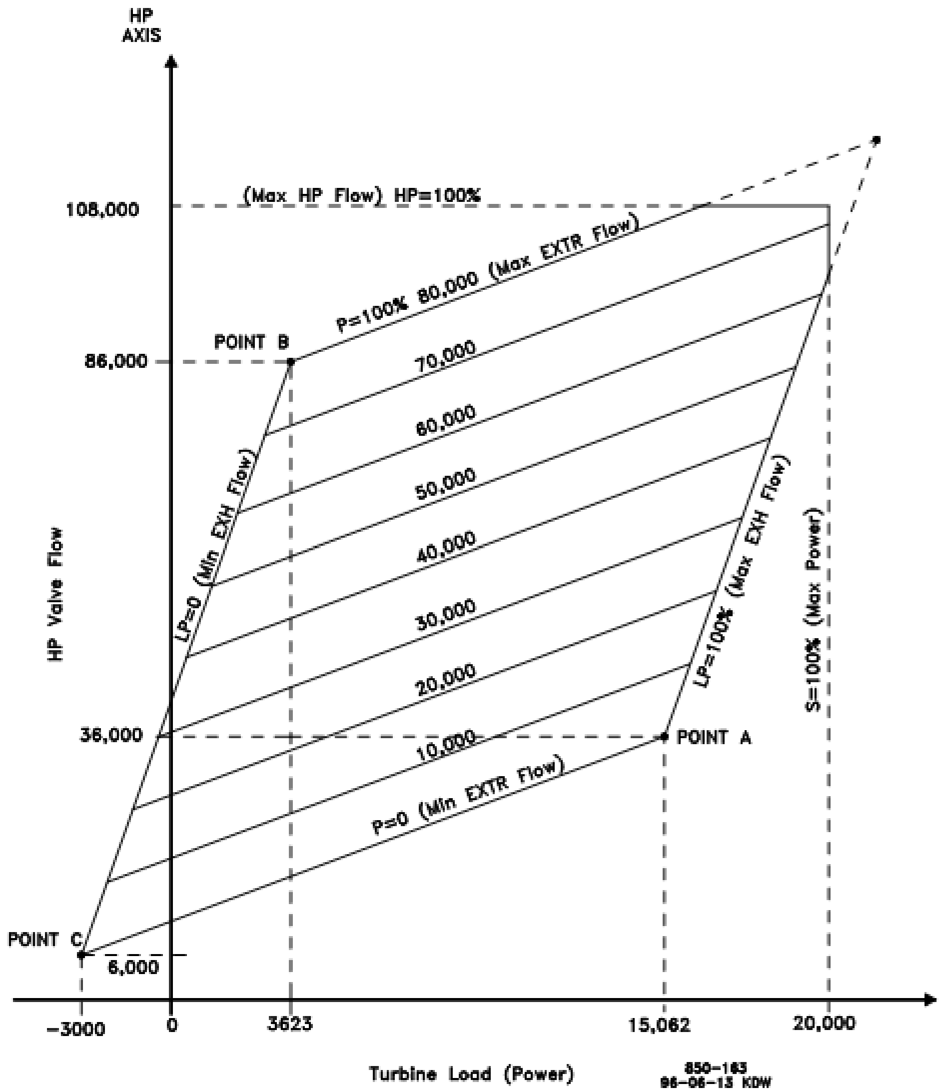


Figure 4-9. Typical Extraction Steam Map

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/hr.

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.

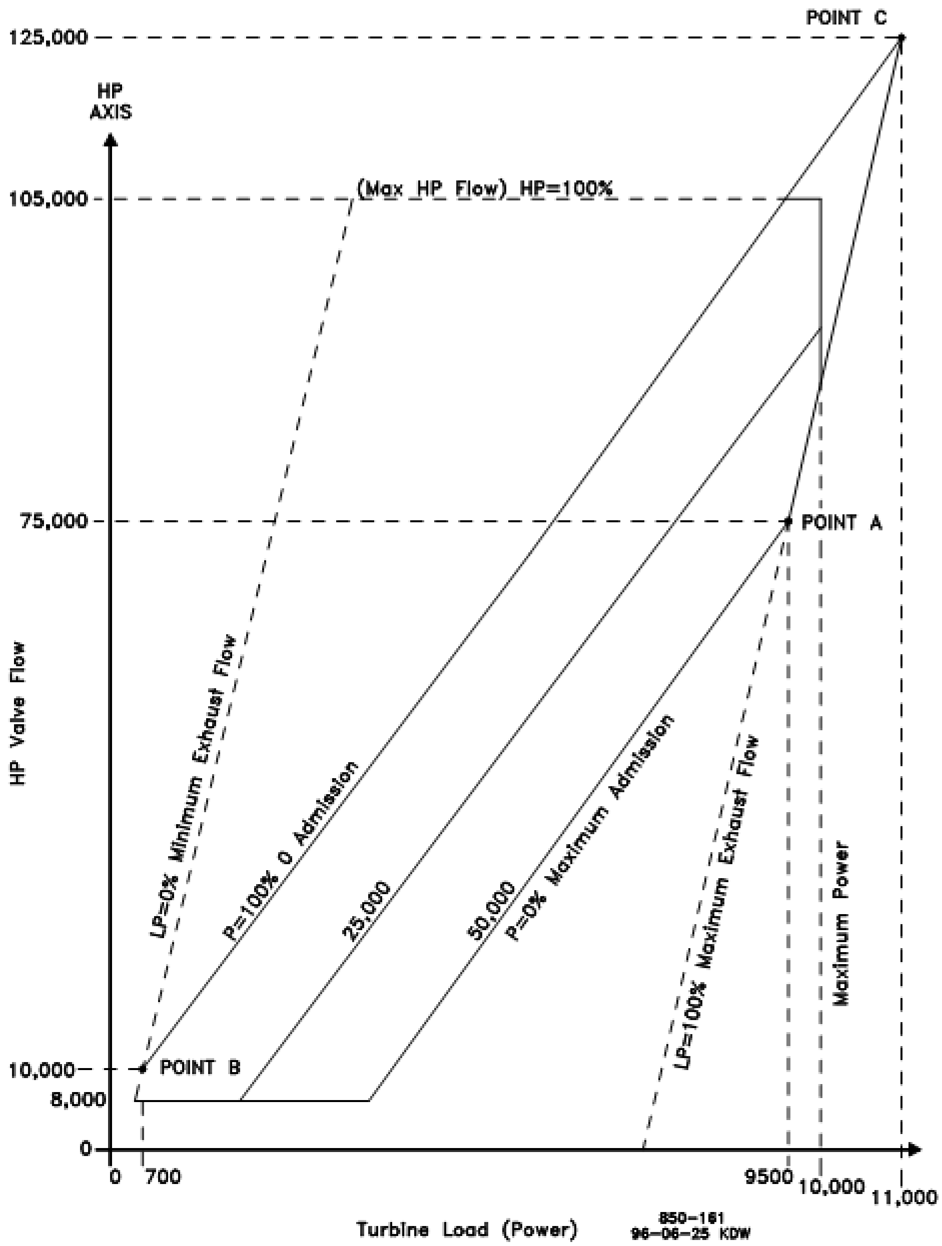


Figure 4-10. Typical Admission Steam Map

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 4-10.

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/hr in this example.
3. Point A is where the P=0 and LP=100 lines intersect. Max Power at Max Admission is about 9,500 kW, and Max HP Flow at Max Admission is about 75,000 lb/hr in this example. In addition, the Max Admission Flow is about 50,000 lb/hr.
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/hr in this example. Again, this point was used because 10,000 lb/hr 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/hr 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 4-11).

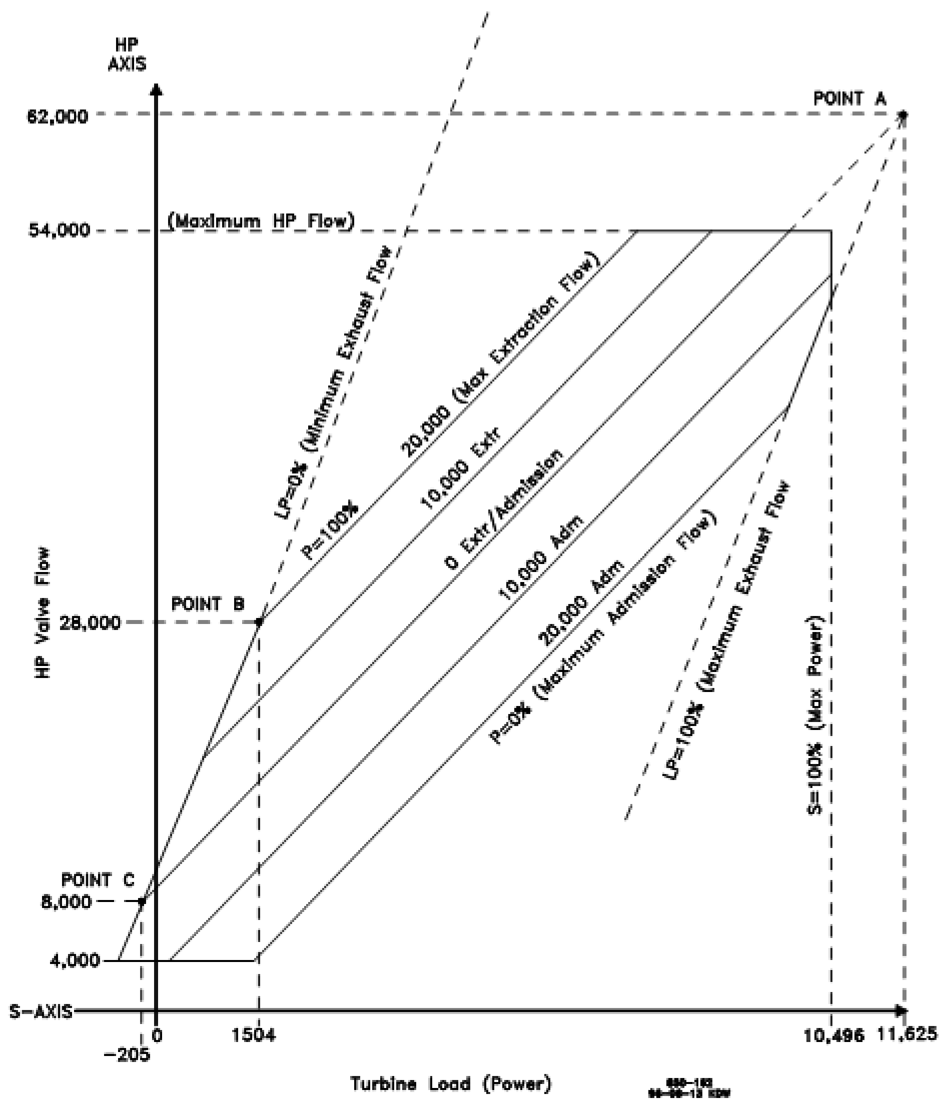


Figure 4-11. Typical Extraction/Admission Steam Map

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/hr.

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 4-11.

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/hr 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/hr in this example. In addition, Max Admission Flow is about 20,000 lb/hr.
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/hr 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/hr in this example.
6. An additional parameter, HP Min Lift should be configured to 7.4% (4000/54000).

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

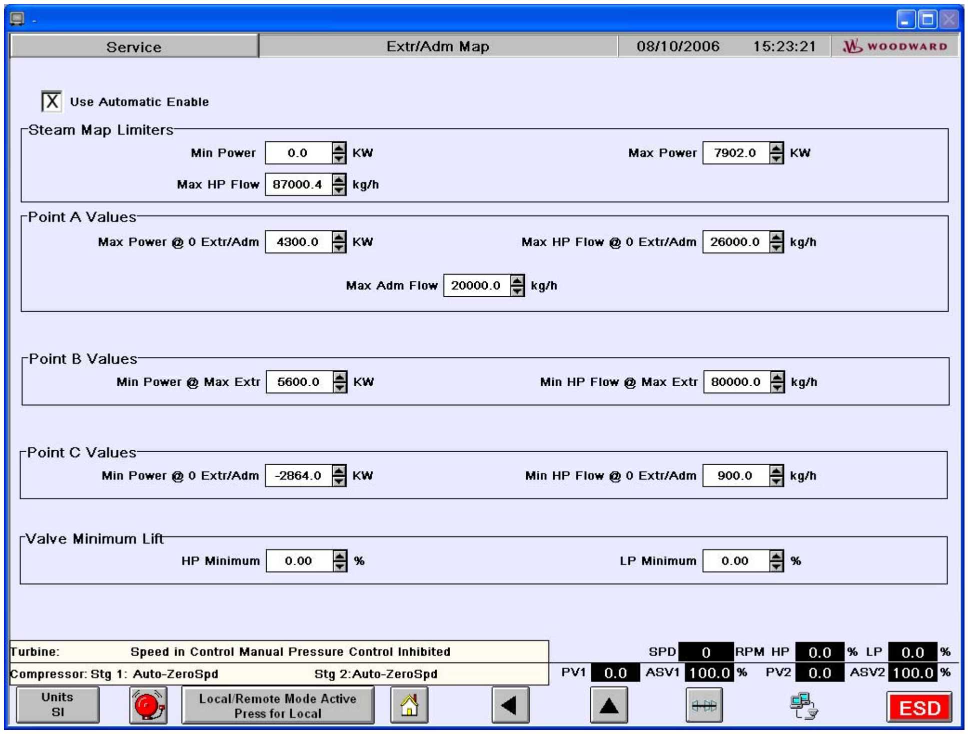


Figure 4-12. Turbine Extr/Adm Steam Map Configuration Screen

Select Use Automatic Enable to configure the 505CC-2 to automatically enable Extr/Adm Control upon an enable command from the HMI/CCT, remote contact input, or Modbus. See the Extraction-Only Control—Automatic Enable/Disable section in Chapter 3. If Use Automatic Enable is not selected, manual enabling via the valve limiter is required.

Steam Map Limiters
Configure the turbine's Max Power and Max HP Flow per the manufacturer's steam map as described above.

Point A Values
Configure the appropriate parameters from the manufacturer's steam map as described above.

Point B Values
Configure the appropriate parameters from the manufacturer's steam map as described above.

Point C Values
Configure the appropriate parameters from the manufacturer's steam map as described above.

Valve Minimum Lift
Configure the appropriate parameters as recommended by the turbine manufacturer.

Turbine Inlet/Exhaust Control Configuration Screen

The selections on this screen will configure the Inlet/Exhaust Controller, if a two-valve turbine with HP (Inlet/Speed) or LP (Exhaust/Speed) Decoupling was configured previously. See the Ratio-Limiter--Decoupling section in Chapter 3.

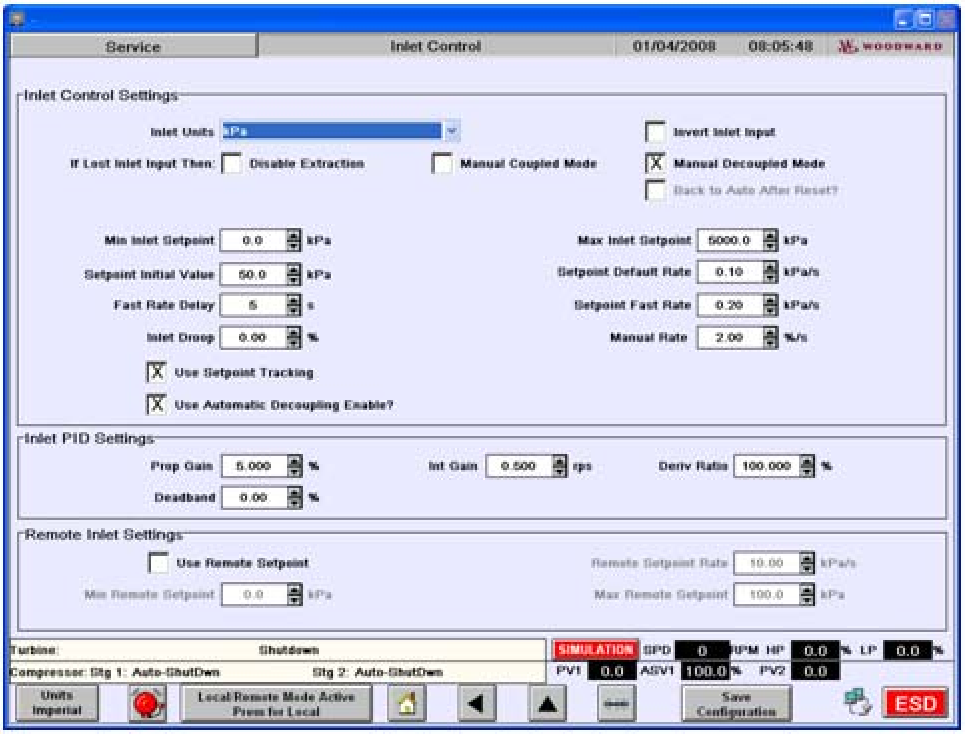


Figure 4-13. Turbine Inlet/Exhaust Control Configuration Screen

Inlet/Exhaust Control Settings

Select the Inlet/Exhaust Units of measure from the list. These selections merely customize the appearance of the HMI/CCT. If the desired engineering unit is not available, simply select EU.

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

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. If the latter is selected, an additional parameter is available to force the control back to auto after reset. This feature will re-enable Extr/Adm in automatic mode after the signal failure is corrected. If deselected, Extr/Adm control will remain in manual after the signal failure is corrected and reset.

Configure the Min and Max Inlet/Exhaust Setpoints to define the operating range for Inlet/Exhaust control. Though these values can be configured as desired, it is recommended that they correspond, roughly, to the process values at Minimum and Maximum Governor speeds under normal operating conditions.

Configure the Default Rate, Fast Rate, and Fast Rate Delay as appropriate for the Inlet/Exhaust Reference ramp.

Configure the Default Initial Value to that which should be applied on power-up of the control.

If desired for control stability, configure an Inlet/Exhaust 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.

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.

Select Use Automatic Decoupling Enable to enable decoupling automatically with Extr/Adm. If deselected, decoupling must be enabled, as normal, after Extr/Adm and with separate HMI/CCT commands, discrete inputs, or Modbus commands.

Inlet/Exhaust 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.

Remote Inlet/Exhaust Settings
If a configurable 4–20 mA analog input will be assigned to remotely position the Inlet/Exhaust Reference, select Use Remote Inlet/Exhaust Control and configure the desired Remote Rate that will be applied. Also configure the Min and Max Inlet/Exhaust Settings that will be used to limit the remote demand.

Turbine Discretes Configuration Screen

The selections on this screen configure the discrete inputs and outputs related to the turbine control.

Turbine Contact Inputs
Four (4) discrete inputs are fixed for Emergency Shutdown, Reset, Raise Speed Setpoint and Lower Speed Setpoint commands. Contact Input #1 for Emergency Shutdown is required and is configured energized to run, de-energized to trip.

There are eight (8) configurable discrete inputs available for the turbine control. Select the appropriate function from the list box as desired—Each function can only be assigned once. If an External Trip Input is used, it must be configured energized to run, de-energized to trip.

For each input, the current status (Open or Closed) is displayed.

Turbine Relay Outputs
Two (2) discrete outputs are fixed for Shutdown and Alarm. The Shutdown output is de-energized when shutdown. The Alarm output energizes when an alarm is active.

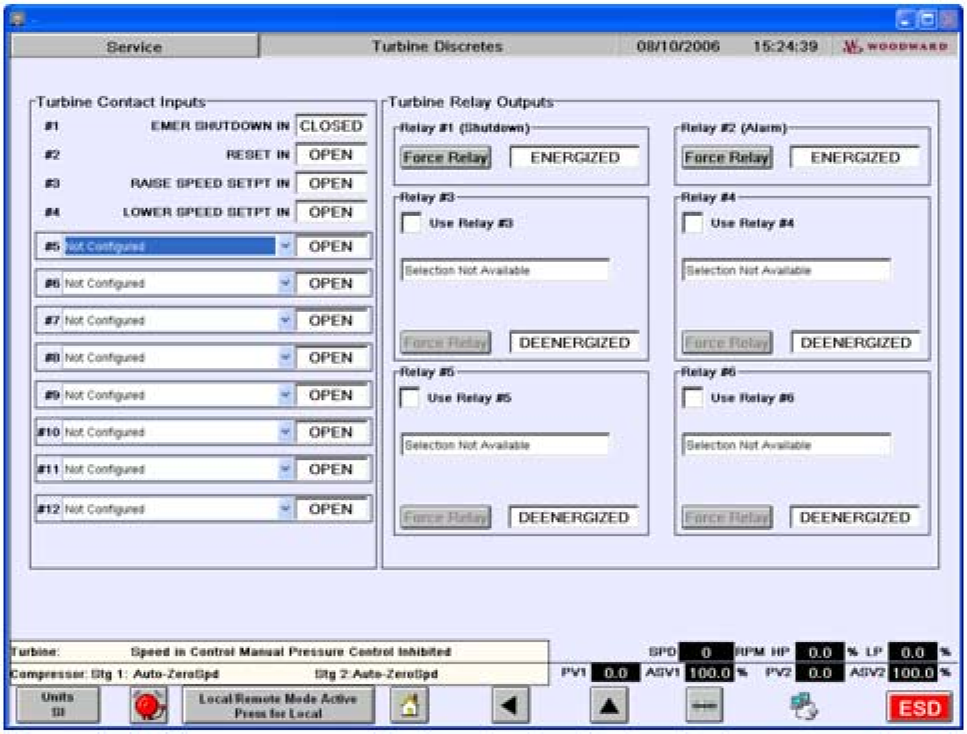


Figure 4-14. Turbine Discretes Configuration Screen

There are four (4) configurable discrete outputs available from the turbine control. Enable the use of the relay drivers as needed and select the appropriate function from the list box. If the Shutdown Indicator is selected, it energizes on a shutdown condition while the Trip Relay de-energizes. Optionally, the output may be configured as a level switch acting on an analog value—If desired select Use as a Level Switch and configure the appropriate On/Off levels.

For each output, the current status (Energized or De-energized) is displayed. For maintenance and testing purposes, the outputs can be forced manually—Select the Force Relay button to open a pop-up, shown in Figure 4-15, that allows momentary and sustained energizing of the output for testing.

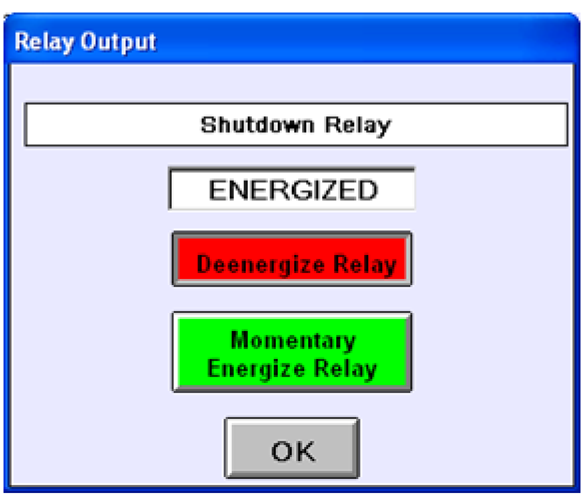


Figure 4-15. Discrete Output Forcing Pop-Up

Turbine Analogs Configuration Screen

The selections on this screen configure the analog inputs and outputs related to the turbine control.

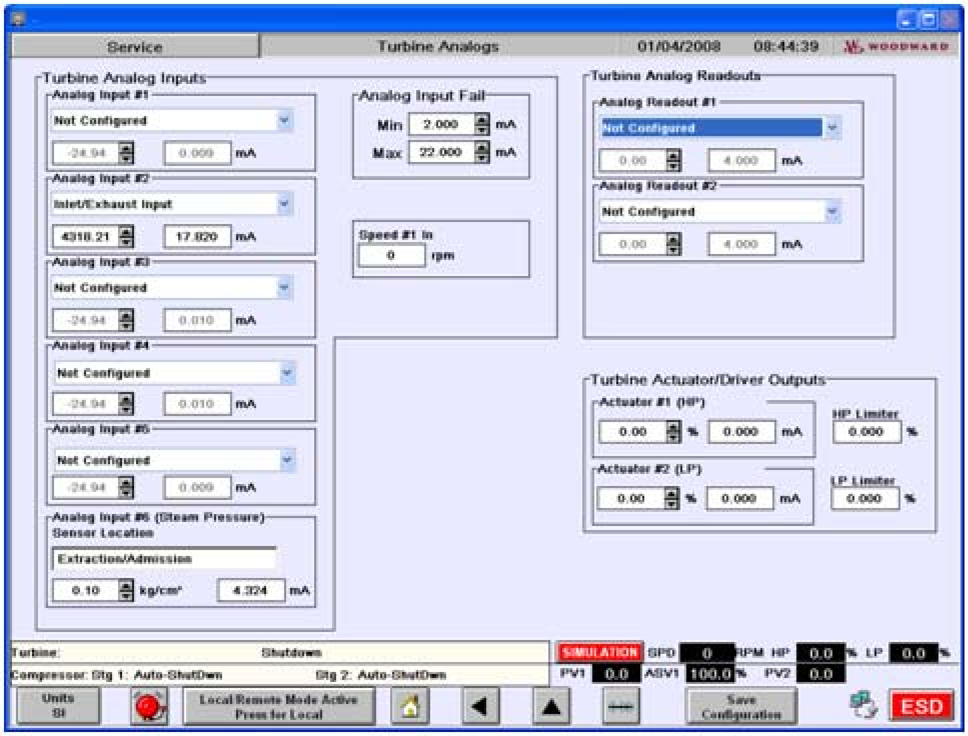


Figure 4-16. Turbine Analogs Configuration Screen

Turbine Analog Inputs

There are five (5) configurable analog inputs available for the turbine control. Select the appropriate function from the list box—Each function can only be assigned once. The value of each input signal, in both engineering units and milliamps, is also displayed.

Analog input #6 is fixed for the Extr/Adm steam pressure (flow) input if an Extr/Adm turbine is configured. If the turbine type is configured as Single-Valve, this input may be used for an inlet or exhaust pressure input and displayed on the Unit Overview screen.

Speed is displayed, but there is no configuration to perform—All speed input parameters are configured on the Speed Control Configuration screen described previously.

The min and max current levels for Analog Input Failure can also be adjusted from their default 2–22 mA configuration.

Each analog input features a calibration pop-up, shown in Figure 4-17, to allow configuration of the 4–20 mA range values, offset and gain (zero and span) adjustments, and lag filter delay time constant (Lag-Tau). The current engineering unit value is also displayed.

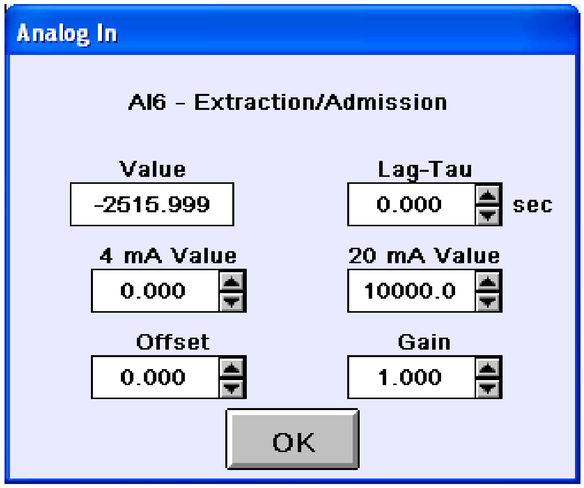


Figure 4-17. Analog Input Calibration Pop-Up

Turbine Analog Readouts

There are two (2) configurable analog outputs available from the turbine control. Select the appropriate function from the list box.

Similar to the inputs, a calibration pop-up, shown in Figure 4-18, facilitates configuration of the 4–20 mA range values, offset, and gain. And, like the discrete outputs, a forcing function is provided for maintenance and testing. Select the Force button to enable forcing—The button will change from red to green. When the button is green, forcing is enabled, and the adjustment pop-up becomes available by selecting the displayed engineering unit value. Stroke the output using the new pop-up to manipulate the engineering unit value. When forcing is completed, select the Force button again to disable.

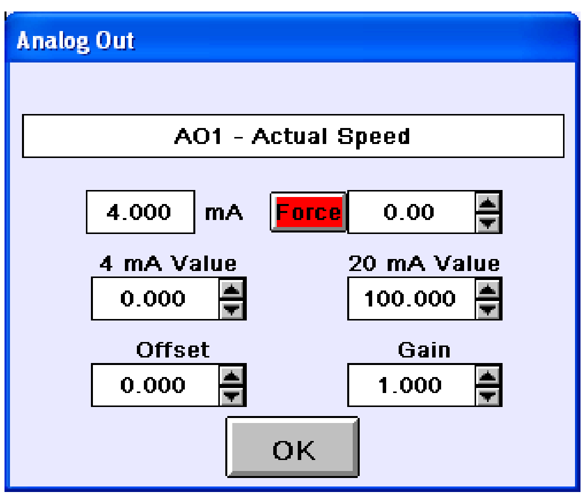


Figure 4-18. Analog Output Calibration Pop-Up

Turbine Actuator/Driver Outputs
The two (2) actuator/driver outputs are dedicated for the turbine's HP/V1 and LP/V2 Steam Valves. The actuator type (4–20 mA or 20-160 mA) can be assigned in the calibration pop-up, shown in Figure 4-19. The Min and Max Current Levels for 0 and 100% valve position can then be adjusted as necessary. Though it is highly unlikely, the Invert Driver Output selection is available for fail-open valve outputs. Select Use Act Shutdown to trip the turbine in the event of an actuator output failure—An actuator failure is defined as a mismatch between the demanded valve position and the current sourced to or returned from the actuator circuit. If desired, configure a dither amount, in milliamps, that will be applied to the output at 25 Hz—If configured, dither should not be visible as movement in the valve. As with other outputs, the actuator outputs can be forced to stroke the valve for maintenance or troubleshooting purposes, but only if the unit is shutdown.

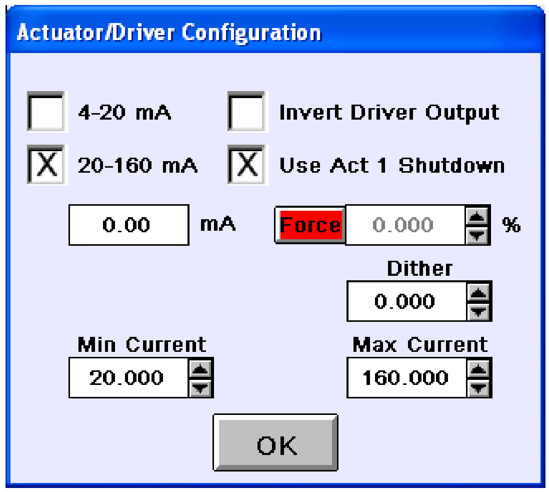


Figure 4-19. Turbine Steam Valve Calibration Pop-Up

Dynamics Adjustments

The Speed, Cascade, Extr/Adm, and Inlet/Exhaust 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, and are displayed by the 505CC-2 as follows:

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

Refer to the sections below for general tuning theory and procedures. See Chapter 5 for specific features of the 505CC-2's turbine control tuning screens.

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 505CC-2's adjustable gains. If the accumulated mechanical gain (actuators, valves, valve linkage, etc.) is very high, the 505CC-2's adjustable gains must be very low to result in a system gain that affords stability.

In cases where a small change in the 505CC-2's output results in a large load change (high mechanical gain) it may not be possible to take the 505CC-2'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% 505CC-2 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 505CC-2 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 with the 505CC-2, 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 505CC-2'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 4–20 shows the typical response to a load change when the dynamics are optimally adjusted.

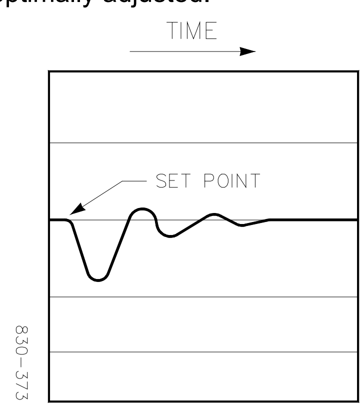


Figure 4-20. Typical Response to Load Change

Chapter 5.
Turbine Operation Overview

Introduction

Operational requirements of steam turbines are as varied as the processes in which they operate. This chapter is intended to provide an overview of turbine operation with respect to the 505CC-2's functionality only. For more complete, process-specific turbine or plant operating instructions, contact the plant-equipment manufacturer.

The HMI/CCT's common screen footer displays status messages and pertinent data for the turbine at the bottom of every screen. To the right side of the footer, speed and steam valve demands are shown. To the left side of the footer is a status message that will indicate the turbine's current control mode and controlling function.

The turbine operating screens, available from the Main Menu shown in Figure 5-1, provide access to all pertinent data used by the control to position the steam valves as well as all necessary Operator controls. Screens are shown below as configured for ITCC Mode (See 26451V1 for Control Mode Configuration options)—In Turbine-Only or Compressor-Only Modes, there will be some variation in screen appearance from those shown below.

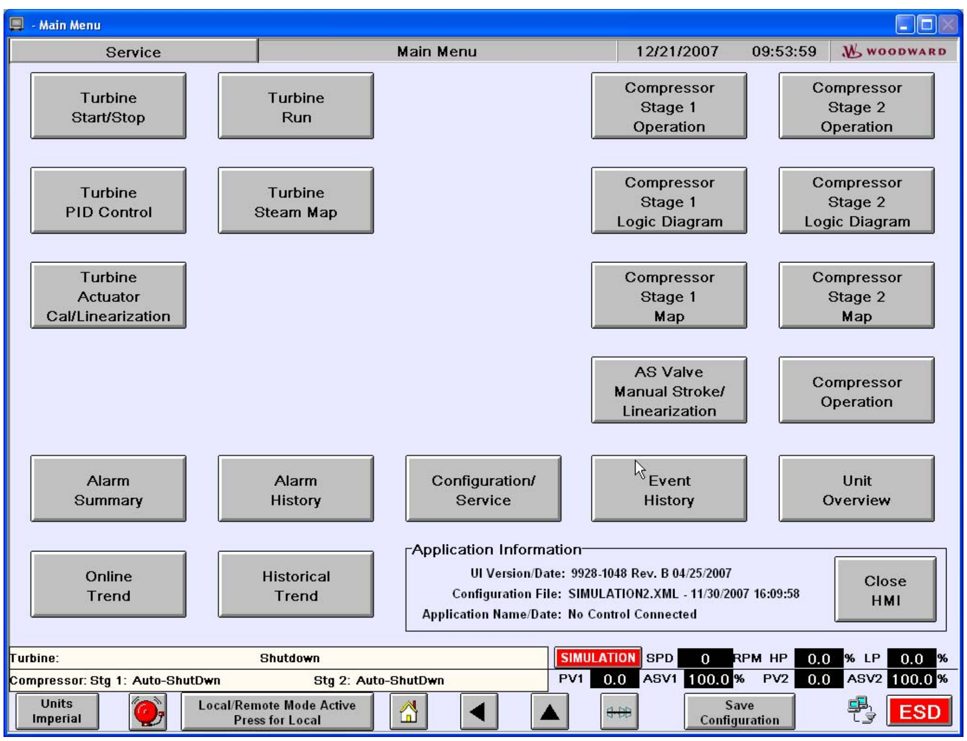


Figure 5-1. Main Menu Screen

Unit Overview

The Unit Overview screen, shown in Figure 5-2, provides a general system view of the turbine and compressor unit, graphically displaying the physical equipment, field measurements, valve statuses, etc. The graphic is dynamic with respect to the specific configuration of turbine type and decoupling mode, I/O selections, compressor layout, etc. No control actions are initiated from this screen. Selecting the turbine or compressor graphics will jump the HMI/CCT directly to those respective operating screens.

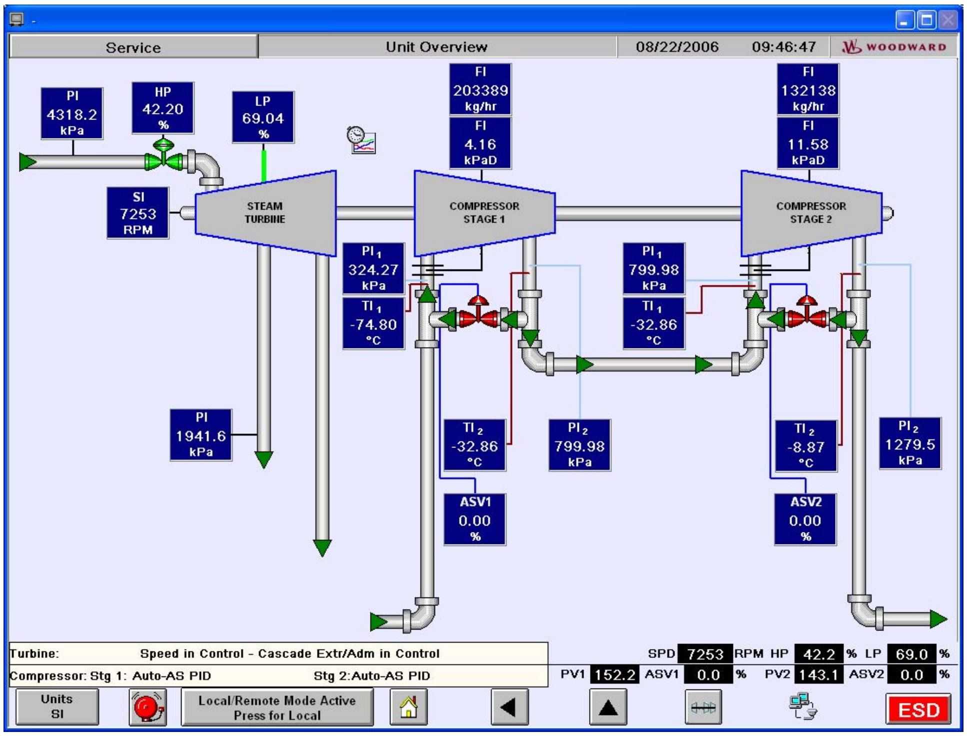


Figure 5-2. Unit Overview Screen

Turbine Operation

Turbine Start/Stop Screen

Refer to the turbine manufacturer's operating procedures for complete information on turbine startup, and Chapter 3 of this manual for a step-by-step procedure, depending on the start mode selected. Figure 5-3 shows the Turbine Start/Stop screen from which the turbine can be started, the speed setpoint and/or valve limiter adjusted, and the turbine's ramp to minimum governor monitored.

The Stop button in the upper left corner of the screen will, at any time, initiate a Normal Stop, or Controlled Shutdown, of the unit.

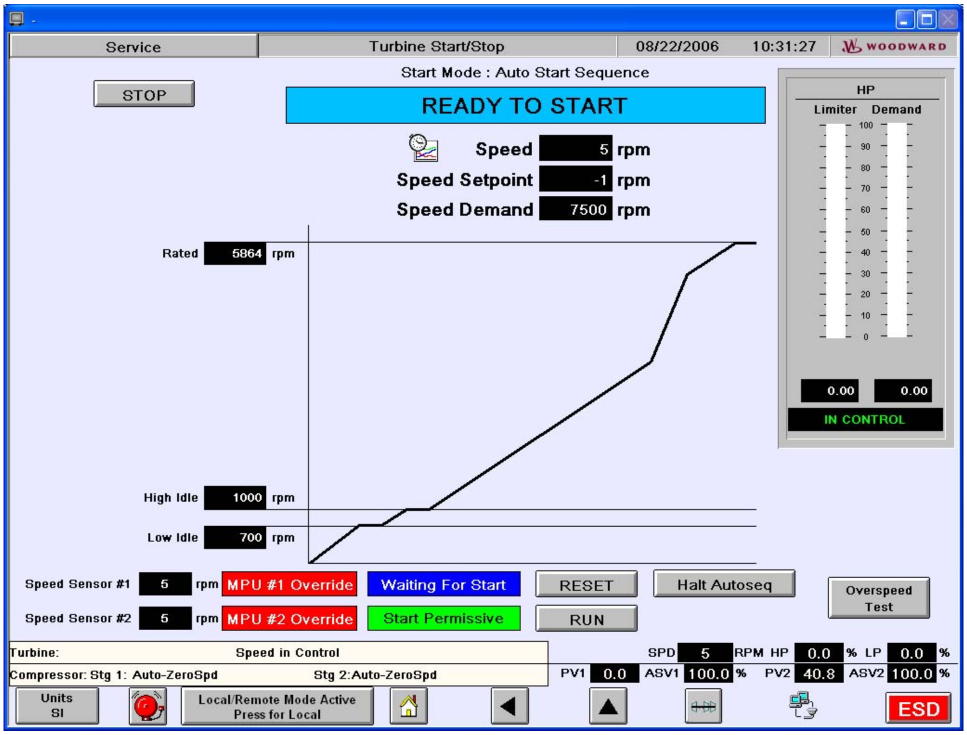
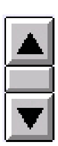


Figure 5-3. Turbine Start Screen

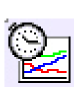
The messages in the upper part of screen indicate the configured start mode and the current status as one of the following:

- Waiting For Reset
- Waiting For Permissive
- Ready To Start
- LP Ramp Up
- Moving To Low Idle
- At Low Idle
- Moving To High Idle
- At High Idle
- Moving To Rated
- Normal Operation
- Controlled Shutdown
- Speed Control In Manual
- Configuration Error

During a turbine start, or at any time during operation, one of these messages will display the appropriate status.



Below the status message are indications of the current measured speed, the speed reference, and the speed demand from the HMI/CCT. The raise/lower buttons allow manual manipulation of the speed reference, as does the analog demand entry. Select the Speed Demand value to launch a pop-up allowing entry of an analog speed demand.



Select the trend button to jump to a speed trend screen. Refer to Volume 1 of this manual for more information about trend screens.

To the right is the HP/V1 Valve Limiter faceplate, shown in Figure 5-4, which indicates both the Limiter and Demand values in a vertical bar graph. The raise/lower buttons act on the valve limiter and can be used to limit the valve demand at any time. The status will be indicated as either “In Control,” if the speed controller is positioning the valve, or “Lmtr Control,” meaning that the Limiter is clamping the valve demand.

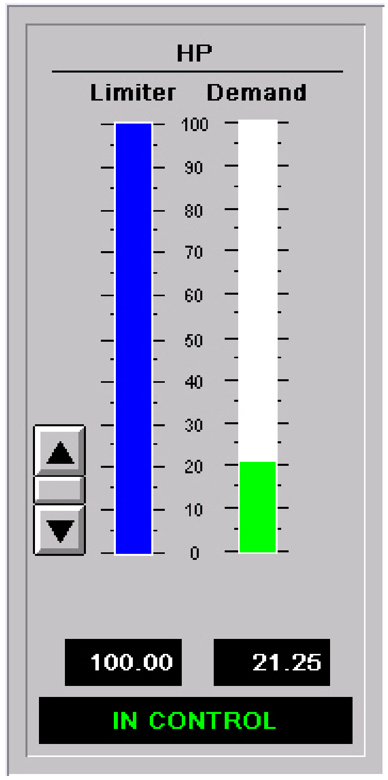


Figure 5-4. Turbine HP Valve Limiter Faceplate

The startup diagram in the center of the screen, also shown in Figure 5-5, is applicable to the Auto Start Sequence. Idle/Rated (Single Idle) or Minimum Governor start methods will display differently. If Auto Sequence is configured, timers will indicate the remaining idle times during the start sequence. Otherwise, the unit will ramp to the targeted start speed of low idle or minimum governor at the configured rate.

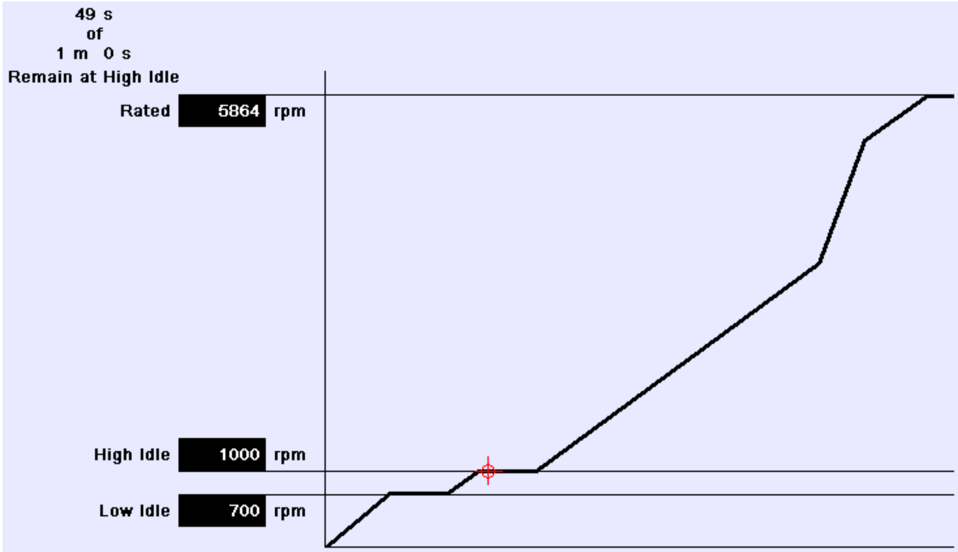


Figure 5-5. Turbine Start Screen Startup Diagram

Individual speed probe measurements are displayed in the lower left corner of the screen. During a start, the low speed measurement must be overridden to allow the unit to come online. A message is indicated as such.

If Auto Sequence is configured, pressing the Halt Autoseq button will halt a start. The unit transfers into Manual Speed Control mode and awaits further commands. If speed is manually raised past an idle setpoint, that idle sequence is considered complete, and resuming the start sequence will continue past that idle. Similarly, if speed is raised manually past the minimum governor setpoint, the entire start sequence will be considered complete and the unit online. Press the Resume Autoseq button to continue the Auto Sequence start.

The following is a typical start-up procedure using the HMI/CCT—Some functions and commands may be initiated through Modbus or remote contact inputs though they are not explicitly defined here.

⚠WARNING

The turbine should be equipped with a separate overspeed protection device that operates independently of the prime mover control devices. This protects against runaway or damage to the turbine and associated equipment, possible personal injury, or loss of life due to equipment failure or human error.

1. Press the Reset button to clear all alarms and trips. If the 505CC-2's Reset Clears Trip Output configurable is selected, the Trip Relay output, if configured, will reset or re-energize after issuing the Reset command. If Reset Clears Trip Output is not selected, the Trip Relay output, if configured, will reset or re-energize only after all trip conditions are cleared.

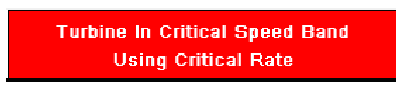
An indicator will display if start permissives are not satisfied.

Once all start permissives (valid turbine configuration; contact input, if configured; speed not in critical band) are satisfied, the green Start Permissive indicator will be visible. If the unit is reset and ready to start, a blue Waiting for Start indicator will also be displayed. The "Ready to Start" message will be displayed as well.

2. Press the RUN key to initiate the selected start-up mode. If a semi-automatic start mode is configured, the valve limiter must be manually increased to open the control valve.

3. During a start, selecting either of the speed raise/lower commands, speed demand, or pressing Halt Autoseq if Auto Sequence is configured, will pause the startup in a manual speed control mode. In this mode, speed can be manually controlled via the raise/lower commands or demand entry, or the start sequence resumed.

4. During a start, a message is displayed when the speed reference is accelerating through a critical speed band, if configured. The start cannot be interrupted or the speed reference paused within a critical band.



5. After the configured start mode is completed, the unit will transfer to its Normal Operation mode, as indicated at the top of the screen. This will generally be at Minimum Governor speed, except for a Single Idle start, which will hold at the configured idle speed. Beyond Minimum Governor, other controls, such as Cascade and Extr/Adm become available on other screens.

Turbine Overspeed Test

The Overspeed Test function is available from the Turbine Start/Stop Screen, shown in Figure 5-3. Select the Overspeed Test button in the lower right corner of the screen to access the Overspeed Test pop-up shown in Figure 5-6.

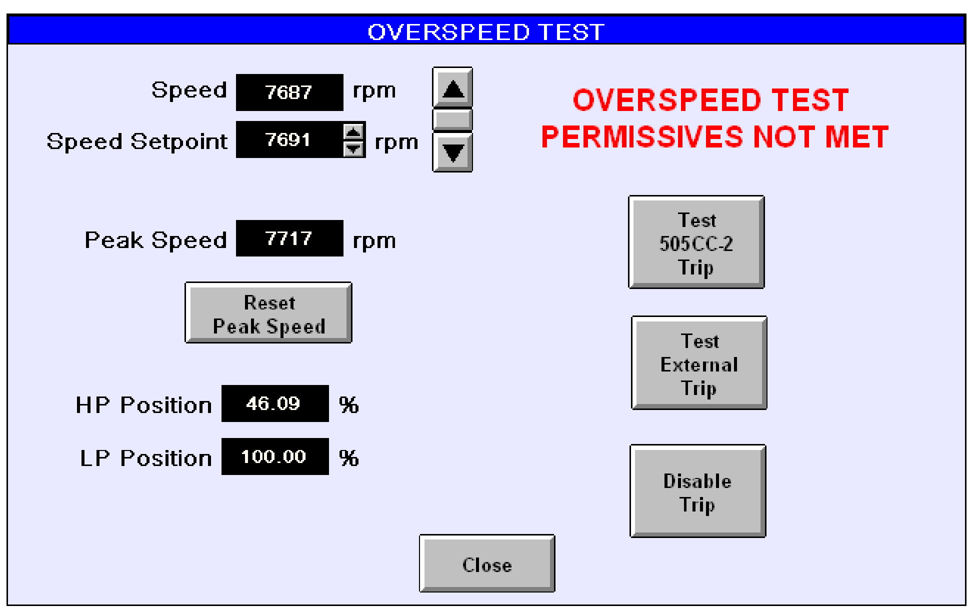
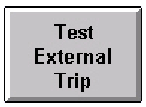


Figure 5-6. Turbine Overspeed Test Pop-Up

The 505CC-2's Overspeed Test function allows an operator to increase turbine speed above its rated operating range to periodically test turbine electrical and/or mechanical overspeed protection logic and circuitry. This includes the 505CC-2's internal overspeed trip logic and any external overspeed trip device's settings and logic. The test can be enabled only after Extraction/Admission and Cascade controls are disabled, if configured, and speed is at the configured Maximum Governor setpoint. Until these conditions are met, a message will indicate "Overspeed Test Permissives Not Met," as shown in Figure 5-6.

Disable all other controllers and raise speed to maximum governor. The "Permissives Not Met" message will disappear, and the overspeed test becomes available. At any time, press the Reset Peak Speed button to reset the peak speed indicator.

Select the Test 505CC-2 Trip button to enable the overspeed test for the 505CC-2's internal overspeed trip. This will permit speed raise commands above maximum governor.



Select the Test External Trip button to enable the test for an external device whose setting is above that of the 505CC-2. This will permit speed raise commands above maximum governor and override the 505CC-2's overspeed trip.

After enabling either of the tests, 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 ramped back to maximum governor. This is the same result as disabling the test via the Disable Trip button.

With the test enabled, raise speed to the overspeed trip level. The unit will trip at the 505CC-2's configured Overspeed Trip Setpoint, unless the external overspeed test was enabled. The peak speed indicator will display the highest measured speed. If both overspeeds are to be tested, the unit can be reset and restarted immediately to proceed with the second test.

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.

If the external overspeed test was enabled, the unit will ramp above the 505CC-2's overspeed trip to reach the external trip point. If the external test is disabled while speed is above the 505CC-2's internal overspeed setting, the unit will trip.

Turbine Run Screen

The Turbine Run screen, shown in Figure 5-7, is the primary turbine operating screen and graphically displays the turbine and compressor train, and provides interfaces to all enabled controllers. The turbine and compressor body schematics are outlined in either blue or white. The latter indicates which piece of equipment is monitored by the current screen. Selecting another piece of equipment, outlined in blue, will jump to that equipment's operating screen. Also displayed at the top of the screen are unit run and trip timers.

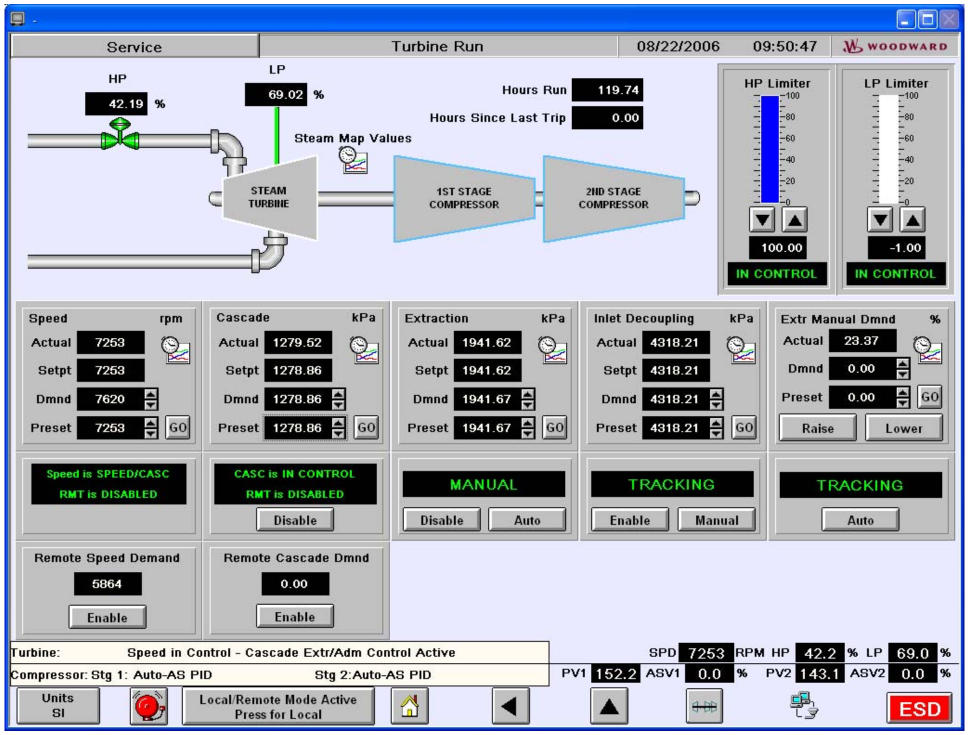
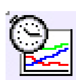


Figure 5-7. Turbine Run Screen



Each available controller may be monitored and manipulated with its respective interface, the appearance of which is dependent upon the turbine configuration and current operating mode. Within each interface is a trend button, which will jump to a trend page corresponding to that controller. Refer to Volume 1 of this manual for more information about trend screens. The speed control interface is shown in Figure 5-8.

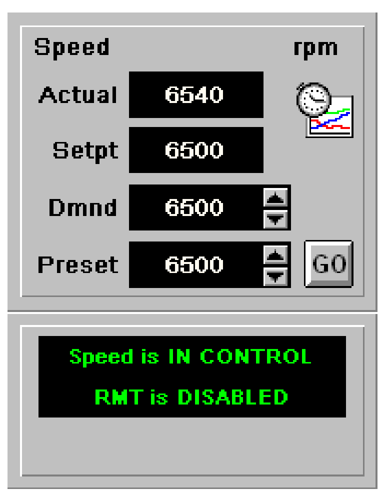


Figure 5-8. Turbine Run Screen Speed Controller

Each control interface displays the measured process variable, current setpoint or reference value, and demand and preset values. The demand value acts as a target for the setpoint. Select the demand value and adjust as desired—The setpoint will ramp to meet that demand. The preset value acts similarly, but the demand is not affected until the Go button is pressed. In other words, the demand value manipulates the reference immediately, but the preset value can be adjusted without affecting the demand or reference until commanded by the Go button.

IMPORTANT

Setpoint adjustments are ignored until a controller (Cascade, Extr/Adm, Inlet/Exhaust) is enabled. If the controller is disabled for any reason, a demand value may be accepted by the HMI/CCT, but the control will reject the request—Internally, the control's demand will slowly ramp to that entered via the HMI/CCT, but it will not be used as a setpoint for the controller. Once the controller is enabled and the internal demand matches that of the HMI/CCT, demand adjustments will be accepted as normal.

At the bottom of the interface are status messages and control buttons. The speed controller is always enabled, so no Enable/Disable controls are required. Speed control status messages are described below:

In Control	The Speed PID is in control, not being limited.
Critical Band	The Speed Reference is within a configured critical band.
Limited	The Speed PID is limited by the Ratio-Limiter logic.
Speed/Casc	The Speed PID is in control with the Cascade controller active on its reference.

Other controllers generally provide enable/disable and auto/manual buttons as necessary. If the Remote Setpoint feature is configured for any control, an additional graphic below the controller interface displays the current remote setpoint and its enable/disable controls. Reference the Cascade Controller interface shown in Figure 5-9.

In this example, Cascade control is configured with Remote Setpoint, however, neither has been enabled. To enable Cascade control, select the Enable button in the main interface. The status message will change to indicate that Cascade is enabled or controlling. Then, Remote Setpoint may be enabled separately, as desired. Cascade control status messages are described below:

Inhibited	Cascade is inhibited and cannot be enabled.
In Control	Cascade is in control of the speed reference.
Active	Cascade is active but limited.
Enabled	Cascade is enabled but not in control of the speed reference.
Disabled	Cascade control is disabled.

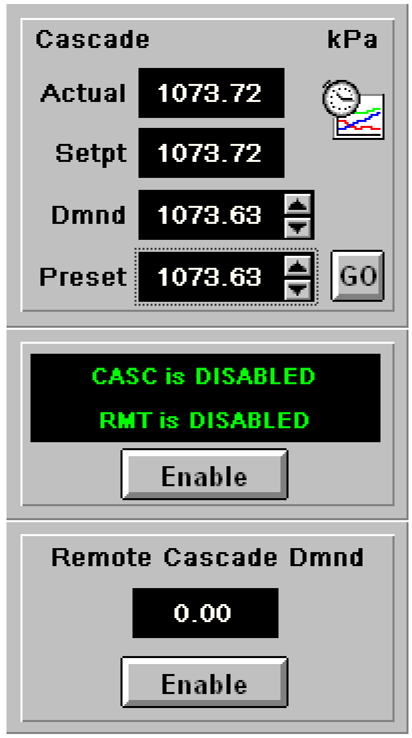


Figure 5-9. Turbine Run Screen Cascade Controller

IMPORTANT	The Cascade Controller is also available if the unit is configured for Compressor-Only Mode, but the Turbine Run Screen is not. In this mode, the Cascade Controller faceplate is available from the Overview Screen.

Similar messages indicate the status of the Remote Setpoint function and other controllers, such as Extraction/Admission and Inlet/Exhaust Decoupling.

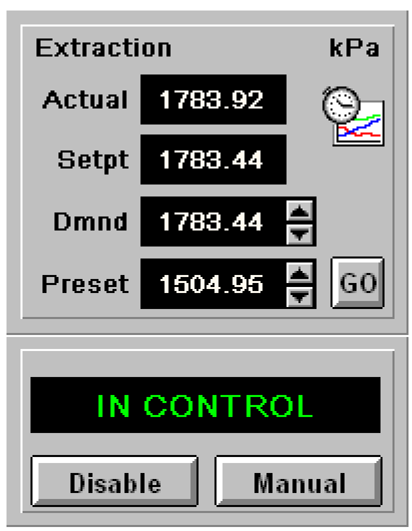


Figure 5-10. Turbine Run Screen Extraction/Admission Controller

The Extraction/Admission and Inlet/Exhaust Decoupling faceplates are similar to the Cascade faceplate shown previously. See the Extraction Controller faceplate shown in Figure 5-10. In addition to enable/disable, a manual/automatic button is provided to transition between automatic, closed-loop control and manual pressure/flow demand. The faceplate for the latter mode is shown in Figure 5-11.

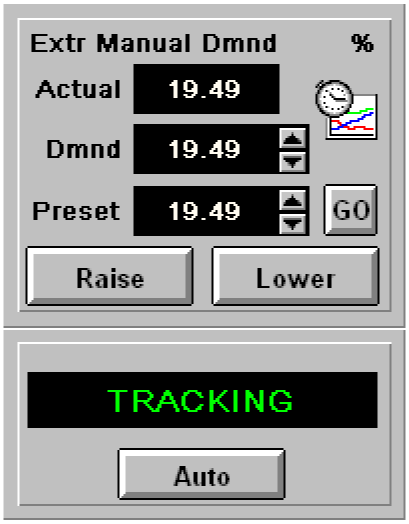


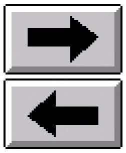
Figure 5-11. Turbine Run Screen Manual Pressure/Flow Demand

The manual demand being sent to the Ratio-Limiter may be adjusted by raise/lower buttons or by direct entry of an analog value. Select the Auto button to return to automatic control.

The Inlet/Exhaust Decoupling faceplate is very similar, but manual control is integrated into the same faceplate, rather than a separate "manual" faceplate.

Turbine PID Control Screen

The Turbine PID Control screen, shown in Figure 5-12, provides typical information for each controller, similar to the Run screen detailed previously, but in a traditional PID faceplate format.



Depending upon the turbine configuration and current operating mode, the number of faceplates may exceed the space available on a single screen. Select the arrow buttons to shift the screen right or left to access additional controllers and limiters.

The Speed Control faceplate, shown in Figure 5-13, is a common example. Select the Dynamics button above the faceplate to jump to the respective Dynamics Tuning screen, detailed in the following section. The process variable and setpoint are displayed in vertical bar graphs, below which the numerical values are indicated. The PID demand output is also shown below. Status messages and Remote Setpoint, if configured, are repeated from the Turbine Run screen, discussed previously.

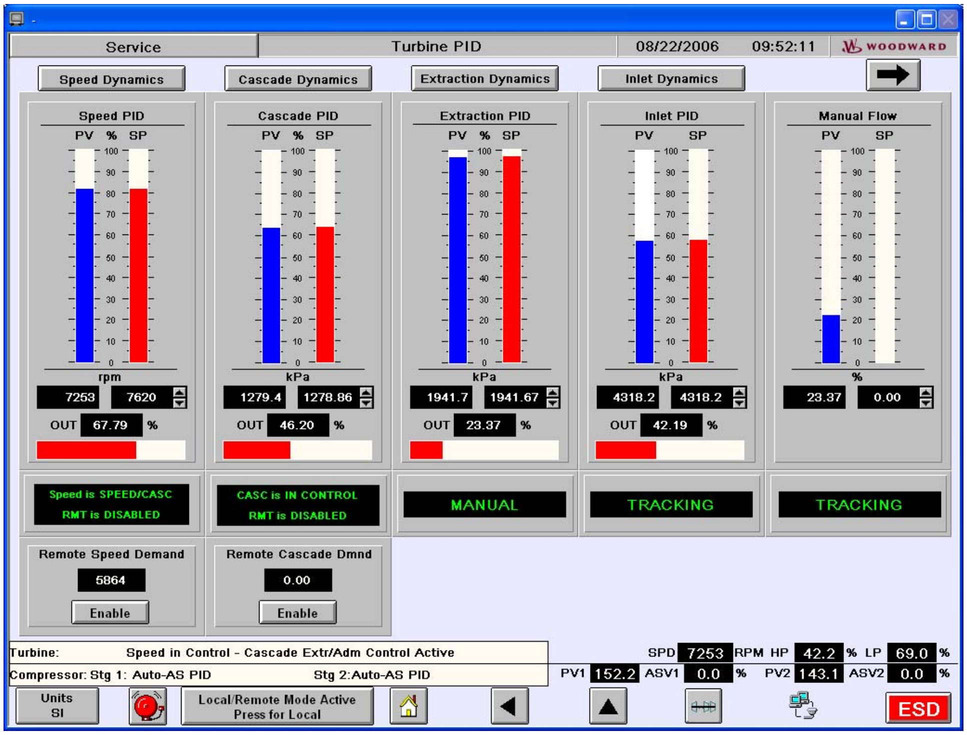


Figure 5-12. Turbine PID Control Screen

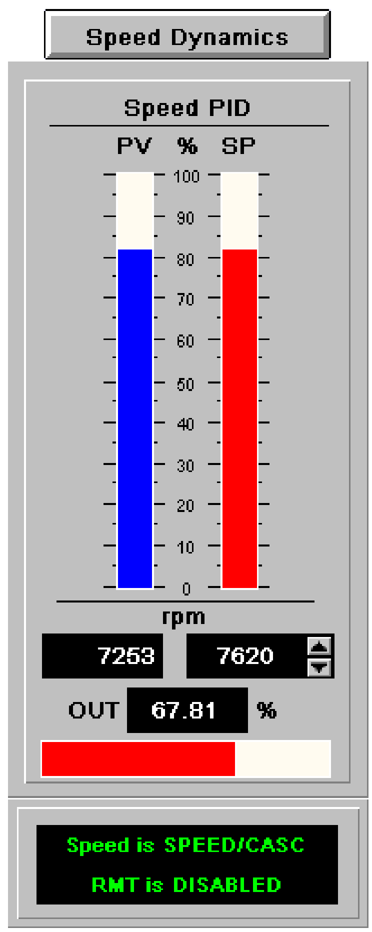


Figure 5-13. Turbine PID Control Screen

Turbine Dynamics Tuning Screens (Speed, Cascade, Extr/Adm, Inlet/Exhaust)

Tuning of the various controllers is available via individual dynamics tuning screens accessible from the PID Control screen shown in Figure 5-12. Select the desired button (available in Engineering or higher login) above the controller faceplate to access the respective tuning screen. The Speed Dynamics tuning screen is shown in Figure 5-14. Similar screens are available for the Cascade, Extraction/Admission, and Inlet/Exhaust controllers.

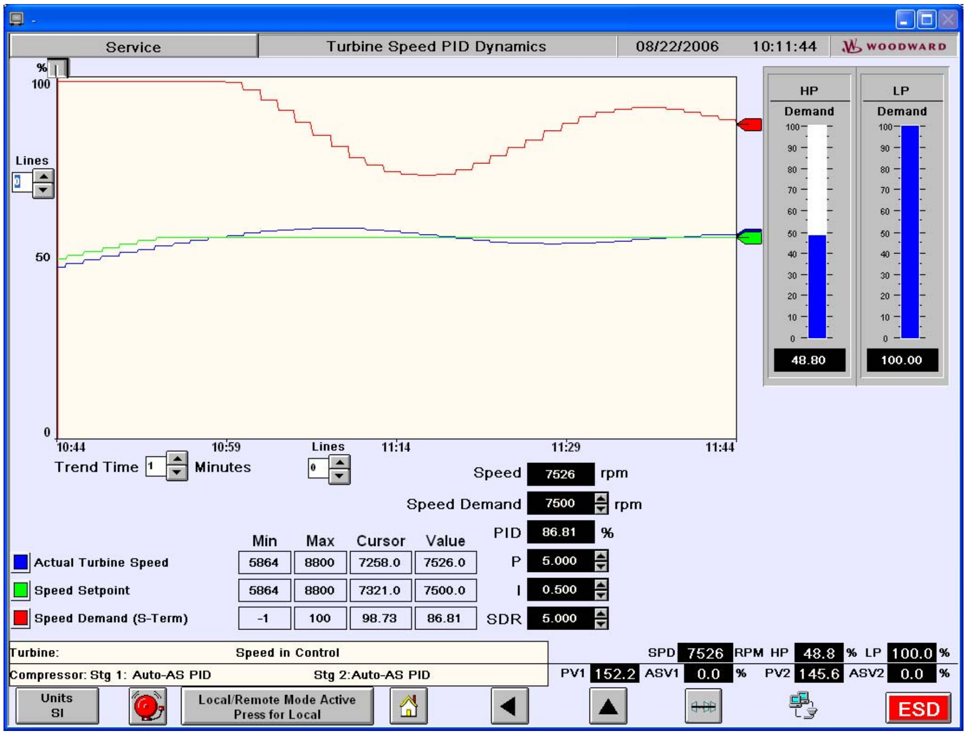


Figure 5-14. Turbine Speed Dynamics Tuning Screen

The trend is configured with pens for the process variable, setpoint, and PID demand output. The trend window can be expanded or contracted in one-minute increments and the number of gridlines adjusted as desired. The crosshair, or cursor, can be moved to any location within the trend to verify pen values at that point. Below the trend, the minimum and maximum Y-axis limits for each pen can also be adjusted. The cursor values and current values are shown for each pen. The demand value to the right can be adjusted to introduce disturbances.

For the Speed controller, if dual dynamics have been configured, a button is available to toggle the tuning mode between Off-line and On-line parameters.

IMPORTANT **The demand value will ramp the reference at the configured rate. If a step-change is desired, temporarily reconfigure the default reference rate to some high value.**

Tune the proportional (P), integral (I), and derivative (SDR) values as necessary to achieve the desired control response (See the Dynamics Adjustments section in Chapter 4 for details on P-I-D settings and general tuning procedures).

Turbine Steam Map Screen

If an Extraction and/or Admission steam turbine is configured, the configured operating steam map is displayed on the Steam Map screen, as shown in Figure 5-15.

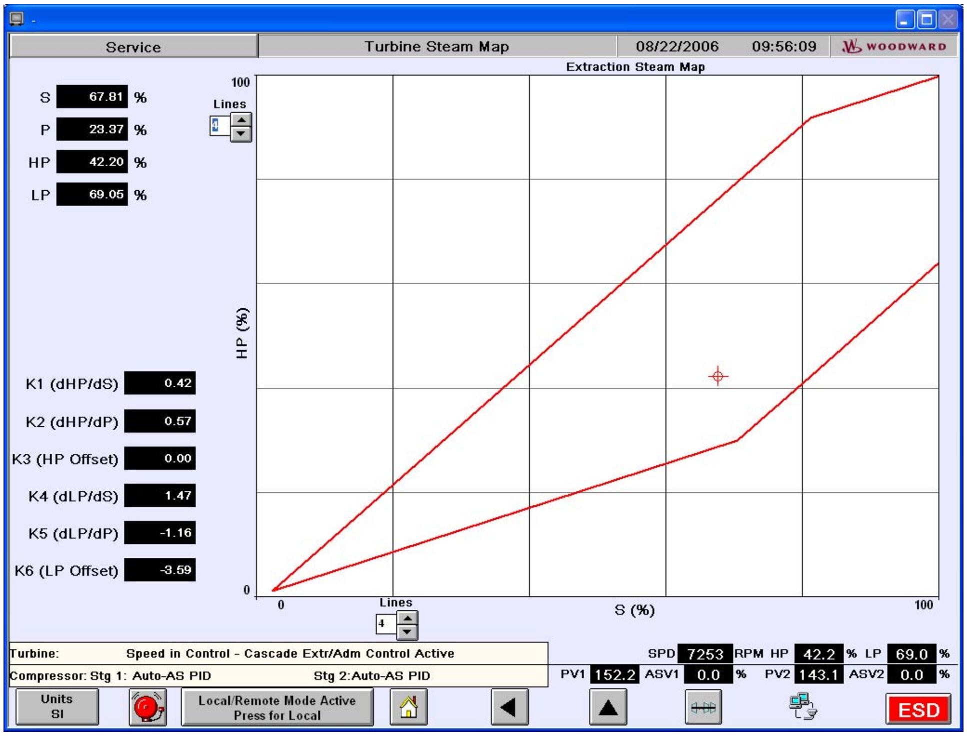
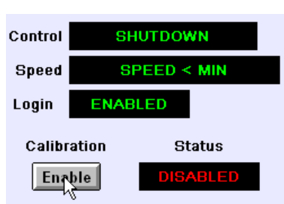


Figure 5-15. Turbine Steam Map Screen

At any time, the current turbine operation will be displayed by the dynamic cursor within, or on a limit of, the drawn steam map. The current S-Demand (speed/load), P-Demand (Extr/Adm Pressure), HP Valve demand, and LP Valve demands are indicated, along with the configured map's K-values. No operating actions are required or available on this screen—It merely provides an instant picture of current turbine operation and performance.

Turbine Actuator Calibration & Linearization Screen

Actuator calibration and linearization may be performed from the screen shown in Figure 5-16.



Calibration is only available with an active shutdown, speed below minimum, and security login level at Engineering or higher. If the unit is shutdown, but reset and ready for start, the calibration permissive is not met—Initiate an ESD to generate a shutdown condition. Once these permissives are satisfied, calibration may be enabled.

Select the Enable button to access the calibration function. Then select the desired actuator, HP/V1 or LP/V2. The calibration panel becomes available, as shown in Figure 5-17, to facilitate manual stroking of the selected actuator via raise/lower buttons. Additional commands, Go Min and Go Max, will force the actuator to its lower and upper limits. Stroke the actuator as desired and compare the demand value with the actual position of the valve. Adjust the minimum and maximum current values if necessary.

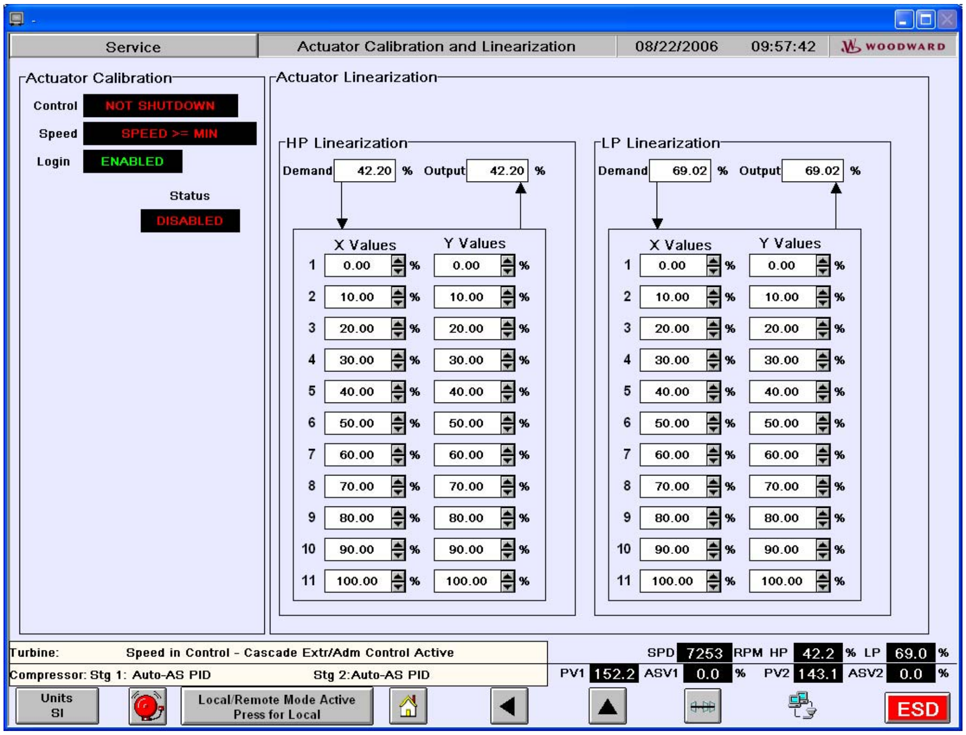


Figure 5-16. Turbine Actuator Cal/Linearization Screen

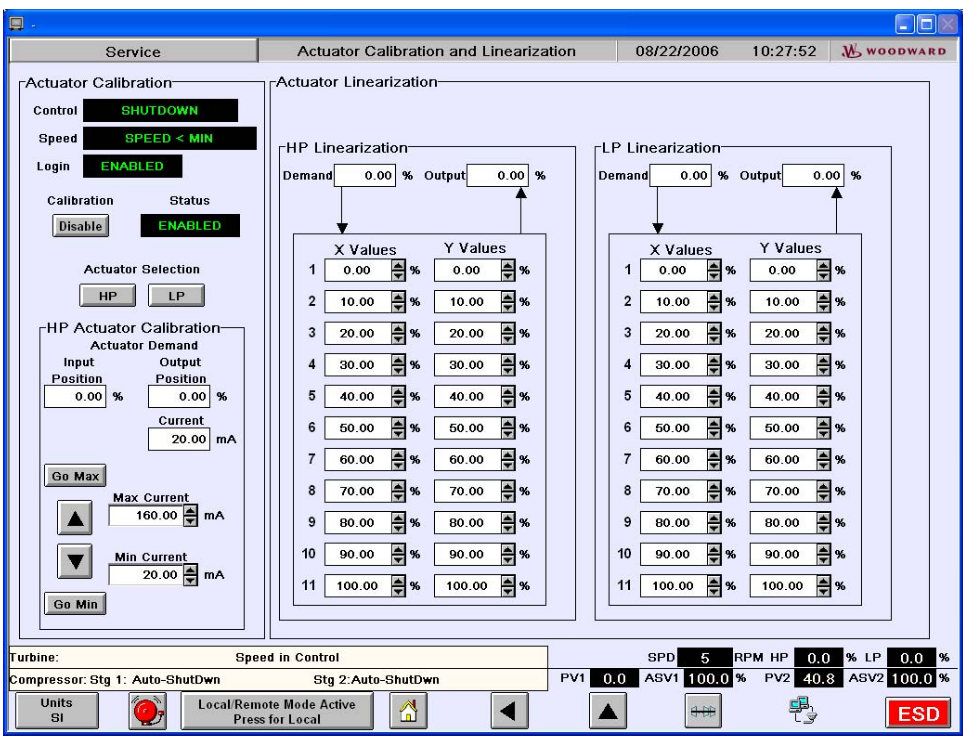


Figure 5-17. Turbine Actuator Cal/Linearization Screen

WARNING

The Trip & Throttle Valve(s) must be closed, and verified, before calibrating the valve output(s). If a calibration is performed while a Trip & Throttle Valve is open, there exists a possibility of turbine runaway, possibly resulting in serious equipment damage, personnel injury, or loss of life.

Linearization must be performed with the unit running, so the requirements for shutdown and minimum speed, noted above for calibration, do not apply. The security login, however, must also be Engineering or higher. The characterizer is an eleven-point curve, which translates demand from the control to the actual valve output. This characterizing curve linearly interpolates between points. That is, if the current demand falls between two X-values, the output will be proportioned between the corresponding Y-values. The X-values are adjustable but are usually left to their default ten percent (10%) increments for simplicity. If they are modified for some reason, they must remain in ascending order. At any given demand, the output can be adjusted by manipulating the two Y-values bounding the current output. Note, however, that changing a Y-value affects the output both above and below it. Modify this curve as necessary to achieve the desired valve characteristic.

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