EXAMPLE CONTROL NARRATIVE

PUMP STATION

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1 Introduction

This document provides a functional description of the pump station controls and operation. This includes a high-level description of functionality, PID control loops, HMI interface and related hardware. The focus of this document is to define how the actual system operates and is programmed.

2 PLC Hardware

The PLC hardware is manufactured by Horner consisting of a XL6 PLC that has an embedded 6” HMI with touch screen capabilities. The PLC also has built-in capabilities for data logging and serial based communications via multiple communication protocols.

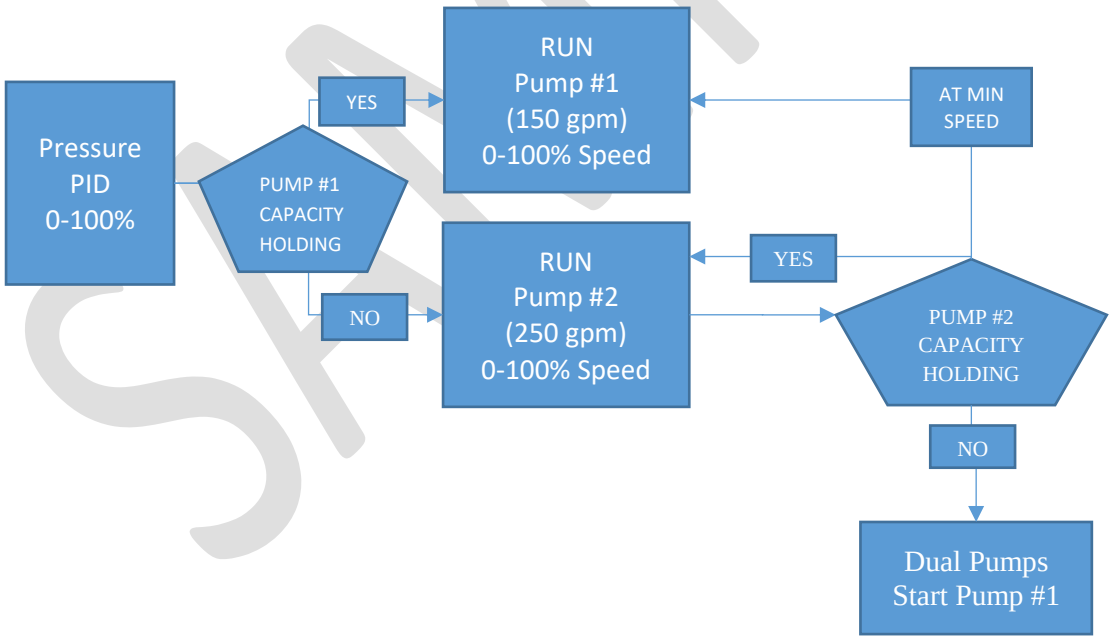
Horner PLC Hardware	Description	QTY	I/O Points
HE-XL105BB XL6 105	PLC with Embedded 6” HMI, 2 Serial, USB, MicroSD, CANBUS, 24VDC	1	12 DI 12 DO 2 AI 2 AQ

3 Control Narrative

This narrative contains two basic sections, the first will describe the overall functionality of the system, and the second contains a control description at the I/O device level. Where the function each device connected to the system is briefly described in table form. Devices are grouped by their I/O type in order of card slot & channel number.

3.1 Pump Station Control

This system works primarily on pressure control using two pumps. The controller will operate these two pumps to accurately maintain a pressure set point. The output from the pressure control PID is considered pump demand speed. Where the PID output regulates the running pump speed. Because each pump has different capacity a staged sequence is used when choosing which pump will be running. Initially only one pump will run at a time and as demand increases the pumps will turn on and off to meet demand. Only at maximum demand will both pumps operate simultaneously. Pump #1 being the smaller pump will operate primarily, and once its capacity is reached and it is no longer able to maintain pressure, the bigger pump #2 will take over to maintain the pressure set point and pump #1 will shut down. If pump #2 is running at 100% and pressure falls below a pressure offset then pump #1 will start and run parallel with pump #2.



NORMAL PUMP OPERATION SETPOINTS	PID SET POINTS
Normal Run Pressure Set point (PSI)	Pressure Set Point (PSI)
Minimum Pump Speed (Hz)	Proportional (Kp)
Pump #2 Start at Low Pressure Set point (PSI)	Integral (Ki)
Pump #2 Start Delay Time (sec)	
Pump #2 Stop Speed (Hz)	Pump Transition Set Points
Pump #2 Stop Delay (sec)	Pump #2 Max Start Speed
DUAL PUMP SETPOINTS	
Below Pressure Offset (PSI)	
Start Pump #1 Delay Time (Sec)	

Example:

- Normal Run Pressure Set point: 60 PSI
- Minimum Pump Speed: 35 Hz
- Pump #2 Start at Low Pressure Set point: 45 PSI
- Pump #2 Start Delay Time: 120 sec
- Pump #2 Stop Speed: 40 Hz
- Pump #2 Stop Delay: 15 sec
- Dual Pumps Pump #1 Start Pressure Offset: 10 PSI
- Dual Pumps Pump #1 Start Delay: 15 sec

Pump #1 is running and controlling via the pressure PID to maintain 60 PSI while running at min speed 35 Hertz, demand increases and pump 1 slowly reaches 100% speed. (60 Hz) Pressure begins to drop as pump capacity is exceeded, dropping to 45 PSI. After 120 Seconds, pump #2 turns on and slowly ramps up while pump #1 ramps down. Pump #2 ramps up to ~48 hertz and holds until pump #1 finishes its ramp down. After pump #1 shuts off, pump #2 begins controlling to pressure set point. If demand continues to increase, eventually Pump #2 will reaches 100% speed and pressure begins to drop. 15 Seconds after the pressure reaches 50 PSI (10 psi below the setpoint) Pump #1 starts up and begins controlling to maintain the pressure setpoint.

After time, as demand decreases and Pump #1 begins to ramp down eventually reaching min speed. Pump #1 shuts off leaving Pump #2 running by itself. As demand decreases, Pump #2 eventually reaches its shutdown speed of 40 Hertz (gpm flow should now be within the capacity pump #1) After 15 seconds Pump #1 turns on and ramps up while pump #2 ramps down and turns off. Pump #1 begins controlling to meet the pressure set point.

Pump #2 Max Start Speed setpoint is in hertz. And will limit the starting pump speed during pump transitions. This is to prevent the starting pump from ramping up its capacity before the stopping pump has ramped down.

3.1.1 Run Conditions

Three run conditions exist, Normal and Easy Line Fill and Fire Safety.

Normal

During normal start-up, the pumps will start and stop based on a pressure set point offset. Pump #1 will operate as the primary pump and maintain the pressure set point. If its capacity is exceeded, then Pump #2 will take over until the demand return down to level that Pump #1 can deliver. At which time Pump #2 will stop and Pump #1 will take over.

Easy Line Fill

Easy Line Fill is initiated whenever there is a power failure or if PT-1000 the pipeline pressure transmitter faults. ELF can also be initiated manually from the HMI. When in ELF, PID control is disabled and pump #1 runs and slowly ramping up to an ELF speed set point in Hertz. The system will remain in ELF mode until an ELF pressure set point is reached. After reaching the ELF Pressure set point the system will switch to normal mode enabling the PID pressure controller, and controlling to the PID pressure set point. The ELF pressure set point can only be set to a value equal to or lower than the running pressure set point. While ELF is in control, all shutdowns are disabled.

In addition operators can force ELF run mode at any time by using an on screen HMI button, the system will remain in ELF until ELF pressure set point is reached.

SET POINTS
ELF Complete Pressure (PSI)
ELF Pump Speed (Hz)
ELF Manual (On)

Fire Safety

Fire Safety Mode can be enabled from the HMI by operators with the correct login. When enabled, the larger capacity Pump #2 will start up, ramping down pump #1 and turning it off. The system pressure setpoint is replaced with a fire safety pressure setpoint and the system PID will regulate pump #2 to maintain pressure at the higher fire safety setpoint. The normal HI HI pressure shutdown will be disabled and replaced with the higher fire safety HI HI pressure shutdown point.

3.1.2 Set point ramping

The normal pressure and fire safety pressure set points in the system can be changed from the HMI at any time. Whenever there is a change between set points or a change to an active set point, a ramp rate will control how fast the actual PID setpoint changes to match the new value.

PID RAMP SET POINTS
Pressure PID Set Point Ramp (%/sec)

Alternatively, there is also a ramp rates for the speed demand output to each VFD which will restrict the rate of change on each pumps speed demand signal. The output demand ramps also change depending on conditions, when in ELF mode the output ramp use the ELF ramp rate to ramp from minimum speed to ELF max speed, when in lead lag transition the lead/lag ramp rate is used, and when running normally the output speed ramp is in effect.

SPEED DEMAND RAMP SET POINTS

Pump Output Speed Ramp (%/sec)

Pump Lead/Lag Transition Ramp Rate (%/sec)

ELF Speed Ramp Rate (%/sec)

3.1.3 Timers

Hour Meters

Each pump has its own hour meter which has an optional hours offset and can be reset to zero at any time when logged in. The reset button must be held on for 5 seconds to trigger a reset.

Control Timers

Startup Alarm Delay – Upon startup this setpoint determines how long low pressure and flow alarms are disabled.

Pressure Low Low Shutdown Delay – Shutdown has a 5-Minute debounce timer

Pressure Hi Hi Shutdown Delay – Shutdown has a 1-Minute debounce timer

Auto Restart Timer/Counter

After a low or high pressure shutdown the system will automatically startup again after 30 seconds. Set points exist to limit how many times the system can auto-restart after a pressure shutdown. If the number of auto restarts exceeds the operator setpoint the system will remain shutdown. Pressing reset button will reset the auto-restart counter.

3.1.4 Pump Selector Switch

Normal Operation will have the pump selector switches set to AUTO. In auto the pump will operate based on system pressure and flow. The OFF position will disable the respective pump and is mainly used for maintenance. The HAND position allows for manual on/off and speed control via the VFD control pad. When in HAND the pump will run under control of its speed dial on the key pad. Turning it clockwise the speed will increase, by spinning it counter clockwise the speed will decrease. *The hand switch is hard wired to close the VFD contactor and enable the forward run command on the VFD. This operation can be VERY dangerous. All control system shutdowns are bypassed and ignored when in HAND and the pump will run at its VFD set speed regardless of system pressure.*

3.1.5 Shutdown Key

A system shutdown is provided to describe the cause and effect of each device and alarm/shutdown conditions and actions taken due to any condition. Please refer the shutdown key for further details on the system shutdowns.

Should the pump #1 or pump #2 trip offline or be turned off the alternate pump will automatically take over and operate to maintain pressure.

3.1.6 Modbus Communications

The PLC has a number communication options. The built in serial port MJ2 is configured for Modbus RTU via RS-232. The serial port baud rate settings by default are 19200-8-N-1. Please refer to the system Modbus Table document for details.

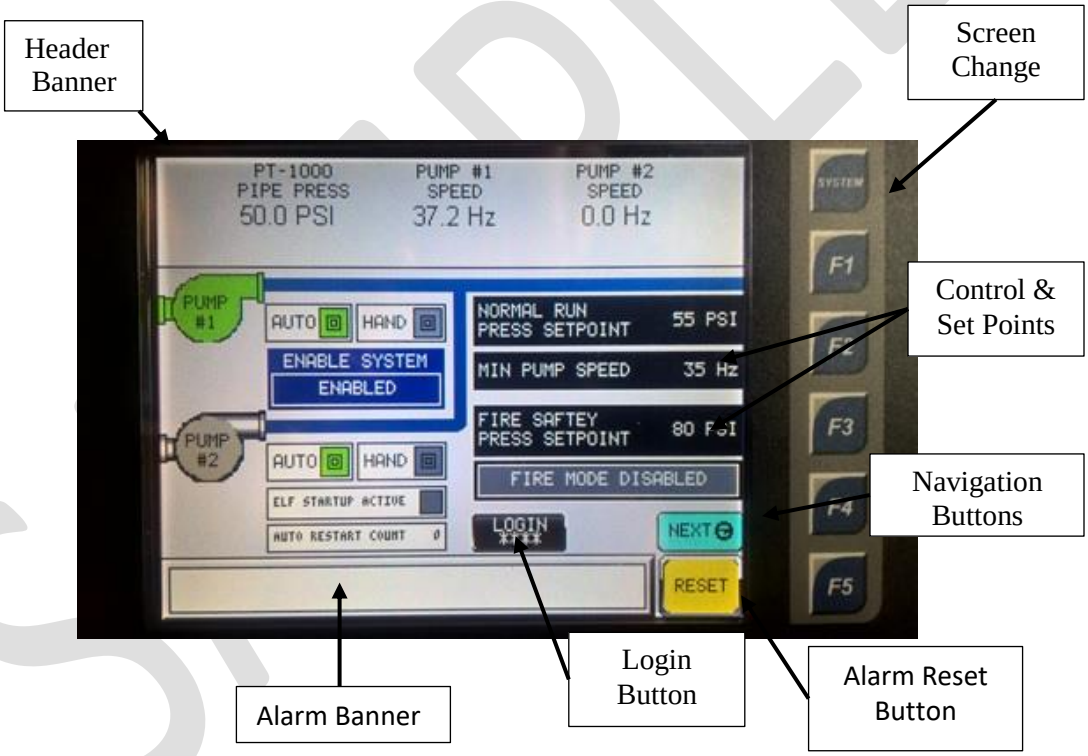
Other communication protocols are available and can be configured upon request. MJ2 can be configured for RS-485 rather than RS-232 upon request as well.

4 Human Machine Interface (HMI)

This system utilizes a 6” color touch screen as an HMI. Navigation through the system is provided using onscreen buttons. Set points and system parameters are available after the operator has input a correct security code, this code is independent of door security keypad. No set points can be changed without a login. Set points always have a black background with white text.

4.1 Overview

The main overview screen is the default screen displayed on the HMI, it will indicate the current run state of the pumps and has some operating set points along with the pressure and flow. The header banner displays relevant run time data and is displayed on all screens. The alarm banner and navigation buttons are always displayed. No set points can be modified unless an operator has logged on to the system***. Side screen buttons like F1 – F5 also change screens, press F5 to access the configuration screens, while F1-F3 cycle through the main overview screens.***

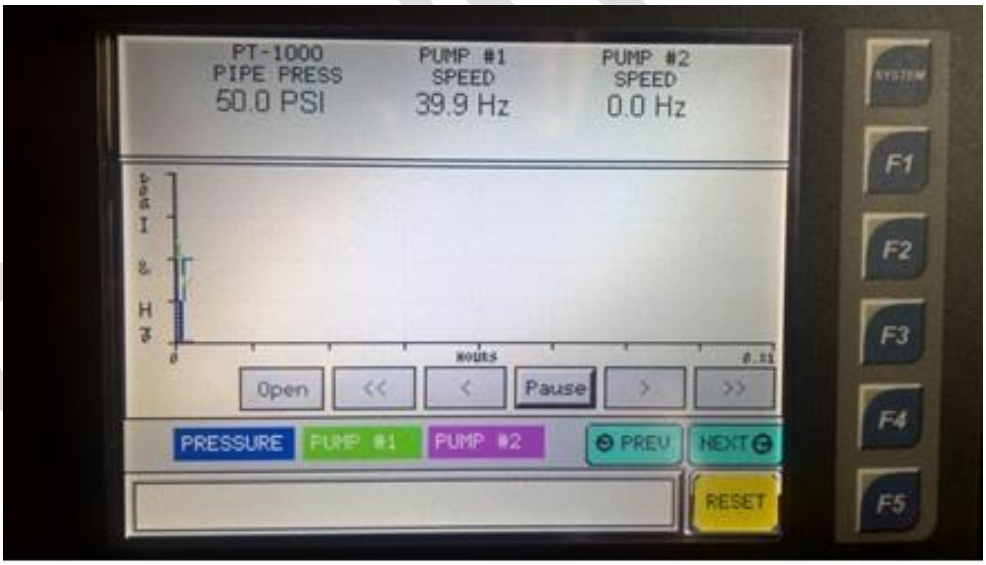


4.1.1 Control

The control displays the current status of the PID control loops. PID setpoints for proportial and integral terms are available for tuning.

4.1.2 Trends

Trending screens display an x/y trend of runtime data and will display pressure vs flow vs pump speed.



4.1.3 Alarm Banner

Two on screen alarm areas exist, an active alarm banner displays the current active alarms while an alarm history page displays a complete history of every alarm. Each alarm is date and time stamped. Pressing the active alarm banner will pop up an alarm control display which allows for

acknowledgement of alarm. Pressing the reset button will reset/clear any alarm conditions which have returned to normal. The Alarm History is found on the main config screen.

4.1.4 Configuration

Access to the configuration pages requires the input of a user access code. After entering the correct code the operator can adjust set points for pump pressure along with other system timers and parameters like transmitter scaling and alarm and shutdown set points. The default passcode to access the configuration pages is 911.

4.1.4.1 Analog Input Scaling & Alarms

Analog inputs (4-20mA) have options for min/max engineering unit scaling, as well as setpoints for alarm and shutdown limits. Setting any LoLo, Lo, Hi, HiHi, limits to a value of -555 will disable that particular limit.

4.1.4.2 Digital Input & Digital Output Forcing

Digital input status screen displays the raw input status of the inputs. The digital output screens not only display the output status but allow for output forcing. An operator must first enable the force for each channel then toggle output on/off.

4.2 Timers

The timer configuration page contains the set point for Lead pump runtime in days. Along with a set point for a startup delay timer which will disable certain alarms like the Low Low shutdowns for Pressure and Flow until the pumps have been running for the specified amount of time. Pump hour meter settings are also found here.

4.3 Rates

Various ramp rates for setpoint changes are configurable.

4.4 Logins

When logged in using the 911 password or via the engineer account, passwords can be updated and changed. Three users exist, two operators and one engineer. Each can be assigned a name and password.

4.5 Datalog & Alarm Log

By default, the system will data log the system status saving to CSV file on a MicroSD card. A new CSV file is created every day and a sample is taken every 15 seconds. The follow variables are in the log with a date and time stamp. The MicroSD card can be removed at any time and the CSV files can be copied and opened on a computer with any application like Microsoft Excel. Alarm logs are also saved to CSV automatically.

- Pipeline Pressure
- Pump #1 Run Status
- Pump #1 Fault
- Pump #2 Run Status
- Pump #2 Fault
- Pump #1 VFD Demand
- Pump #2 VFD Demand
- Digital Input Status'
- Digital Output Status'