TULSA Water and Sewer Department

SCADA System Improvements

Programmable Logic Controller (PLC) Hardware Standards

FINAL

PRESENTED TO

Cindy Cantero
City of Tulsa
Water Pollution Control
175 E 2nd Street, Suite 1400, Tulsa, OK 74103

PREPARED BY

Tetra Tech
7645 E. 63rd St.,
Suite 301
Tulsa, Ok 74133

P: *(918) 249-3909*
www.tetratech.com

TETRA TECH

200-11383-19001
July 9, 2021

CONTENTS

LIST OF TABLES

LIST OF FIGURES

REVISION HISTORY

Version	Date	Description
A	March 25, 2021	Draft Delivered to Client
B	July 9, 2021	Final Delivered to Client

1 PURPOSE – SUMMARY OF INTENT

The Programmable Logic Controller (PLC) Hardware Standards define the preferred hardware, technologies, implementation and related design topics for the selection and design of PLC hardware systems for the City of Tulsa (CoT). The City has selected Rockwell Automation as the preferred PLC hardware manufacturer.

This document will provide guidance to the CoT stakeholders and design engineers on design decisions required to implement both the near-term and long-term vision as they relate to PLC hardware and the overall Plant Control System (PCS). This document will focus on the selection of Programmable Logic Controller (PLC) Hardware and associated components to be included in process control design. Determination of the exact PLC hardware selections and sizing will be determined using the criteria identified herein.

2 DEFINITIONS – TERMS SPECIFIC TO THE DOCUMENT

For the purposes of this document, the following terms and definitions apply.

Table 2-1 Definitions

Term/Acronym	Definition/Description
CPU	Central Processing Unit – contains the executable PLC program for monitoring and control of the I/O.
Distributed I/O	I/O, standalone rack based I/O, field device with parameters that share data with a PLC system.
HMI	Human Machine Interface
I/O	Input / Output Types: DI – Digital Input; DO – Digital Output AI – Analog Input; AO – Analog Output
OIT	Operator Interface Terminal
PCS	Plant Control System
PLC	Programmable Logic Controller
RIO	Remote Inputs and Outputs. I/O that is logically part of a PLC system but is physically located apart from the CPU.
SCADA	Supervisory Control and Data Acquisition
UPS	Uninterruptible Power Supply

3 ROLES & RESPONSBILITIES

The following role definitions provide guidance to clearly identify individuals or groups involved with the design, development, procurement, and programming of a Plant Control System.

System Integrator - The individual or company responsible for providing equipment, materials, and software required to meet the intent of the contract documents. This entity is responsible to perform the commissioning, testing, training, and software services for the equipment required to successfully interface and interconnect associated equipment specified and or designated within the specifications. The individual or company is responsible for ensuring smooth communications between products from different vendors and various components.

I&C Design Engineer - The individual either within CoT or hired by CoT who is responsible for the design of process control system projects. This person identifies the equipment and develops the plan for the changes that will take place. This includes designing the instrumentation changes and can include providing justification for the project, project management, and other tasks.

CoT Personnel - This group includes the supervisor, operations, maintenance, and project PM. This group will provide the overriding decisions required to for the design team and Contractor to provide a complete PLC systems that meets the needs of the project and future goals of the CoT.

4 DETAILED PROCEDURE

4.1 Requirements for Deviations from Standard

Any intended deviation from these standard guidelines shall be discussed with CoT personnel and approved on a project-by-project basis to ensure methodologies are in alignment with CoT's vision. This will provide an opportunity for CoT personnel to consider if updates to the standards document are needed based on any approved deviations.

4.2 Notes for Design Engineer

On a project by project basis, the I&C Design Engineer, through discussions with CoT personnel, is responsible for evaluating and overlooking items found in the standards specifications that are not pertinent to the current project.

5 CONSIDERATIONS FOR PLANT CONTROL SYSTEM (PCS) DESIGN

Key design decisions must be made by CoT personnel during the design phase of a project to provide guidance to the I&C Design Engineer for the development of the detailed design. The selections made are used to develop plans and specifications to meet the needs of each project while adhering to the long-term goals of the CoT.

The overall complexity of the Plant Control System (PCS) is based on many criteria including:

- New or existing construction
- Layout of CPUs within the plant
- Networking of equipment

5.1 New Construction or Upgrade of Existing Facility

New construction differs from an upgrade of existing facilities in significant ways. These two types of projects each have their own distinctive questions to be answered by CoT Personnel and the I&C Design Engineer.

5.1.1 New Construction

A new construction project is either a "Greenfield" plant or the addition of new process areas to an existing plant. Either of these construction projects involves new buildings, processes, PLC control panels, and how they are to be integrated into the overall plant design. There are several key high-level decisions to be made early on in a project that provide guidance.

- How are the PLC CPUs to be distributed (central or distributed)?
- Where would Operator Interfaces be most beneficial to Operators?
- Network topology and media
- Input/Output Module Selection and Wiring

The decisions to the questions above can lead to more detailed questions as the specifics of the project develop. The I&C Design Engineer will work hand in hand with CoT Personnel on these decisions. The I&C Design Engineer should solicit and provide input from/to CoT Personnel during all phases of the design from conceptual to final bid plans and specifications. This can be done through the normal review process at each milestone and additionally using focused workshops.

An example design decision is the voltage selection for discrete input/out modules. The modules come in either 24VDC or 120VAC as the operating voltage of the field contacts that wire to them. The preferred voltage is 24VDC for all new construction. 24 VDC controls provide for less potential shock hazard to maintenance personnel than 120VAC. Since the new process may incorporate some manufacturer supplied equipment that are wired for 120 VAC controls, the PCS will require additional steps such as rewiring power distribution within the panel and/or providing interposing relays transitioning from 120VAC to 24VDC. In lieu of transitioning, the design team may decide to provide 120 VAC modules instead.

5.1.2 Existing Plant Upgrade

These projects incorporate modifying existing plant process areas through expansion or upgrading of the existing PCS. There are three (3) options for upgrading/replacing existing PLC Hardware and their associated control panels. Each of these options allow for the PLC hardware provided to fully meet the intent of the hardware standard or with deviations as agreed upon by the CoT Personnel and I&C Design Engineer.

- Replace entire control panel: Enclosures completely removed due to age, condition, etc. and new panels installed in the same location. There may be scheduling issues with this option.
- Replace only PLC hardware: The panel enclosures remain and the PLC hardware along with other panel desired components are removed and replaced.
- Gut existing panel except for field terminations and add new panels:
  All panel components except for the Field Terminations are removed from the panel(s). New panels installed nearby, and field wiring extended. The old panel becomes a marshalling panel.

Each plant upgrade project is unique and relies heavily on the availability and accuracy of the existing PCS RECORD drawings. If these drawings do not exist or are not relatively correct, the I&C Design Engineer will have to perform detailed site investigations to assess the age/condition/functionality of the control system and document this information in the form of reports using photos, sketches and other means. The site investigation report will be used by CoT Personnel and the I&C Design Engineer to determine which of the three options above is the best option for each area of plant upgrade.

5.2 Distribution of CPUs within the Plant

A primary decision to be made early in the design process is what CPU distribution architecture is provided. There are two (2) distribution choices:

- Centrally located CPUs with local I/O and distributed remote I/O
- Distributed CPUs in each process/area or building with local and/or remote I/O

Centrally located CPUs are recommended for small treatment plants or single building sites. These sites have a single or relatively few buildings in a small area and PLC input and output (IO) counts less than a 1000. An example is a regional lift station or similar facility where the IO can readily be wired back to a central location. For centrally located CPUs applications, the CompactLogix Family of PLC Hardware and the 1769-L33ER processor are recommended. Refer to Appendix 1 for additional hardware information.

Design Note: If extensive highly detailed automatic control is required for the site, the I&C Design Engineer may deem it necessary to upgrade to the ControlLogix family and a smaller memory version of the Series L8 processor to accommodate the comprehensive programming logic and speed.

Distributed CPUs are recommended for large treatment plants that have multiple buildings and several processes spread out across a campus setting. This allows each process or building to be controlled by a local CPU that aggregates the IO and is programmed to control the process(es) in that area. Distributed CPUs require that a communications network, as describe in Section 5.3, be installed so that all plant information and control can be brought back to the operation(s) center. The network communications can become complex. The ControlLogix family of hardware contains more options for integrating with these complex systems. For distributed CPU applications, the ControlLogix family of PLC hardware and the Series L8 processor are recommended. Refer to Appendix 2 for additional hardware information.

Design Note: For some manufacturer supplied processes where they are providing a CPU for their system only, it does not make fiscal sense to have them provide the ControlLogix family of hardware. The I&C Design Engineer may adjust how the manufacturer supplied CPU connects into the PCS network and only require the CompactLogix hardware family.

Design Note: Some processes have a large quantity of IO that prevents the use of a single PLC rack or module lineup. In these occasions, remote I/O racks are required. The remote I/O racks will communicate with the process CPU via an Ethernet card in the remote rack and Device Level Ring protocol (see example schematic layout below). The remote rack may be internal to the same panel as the CPU rack or in a separate rack located elsewhere in the plant process area.

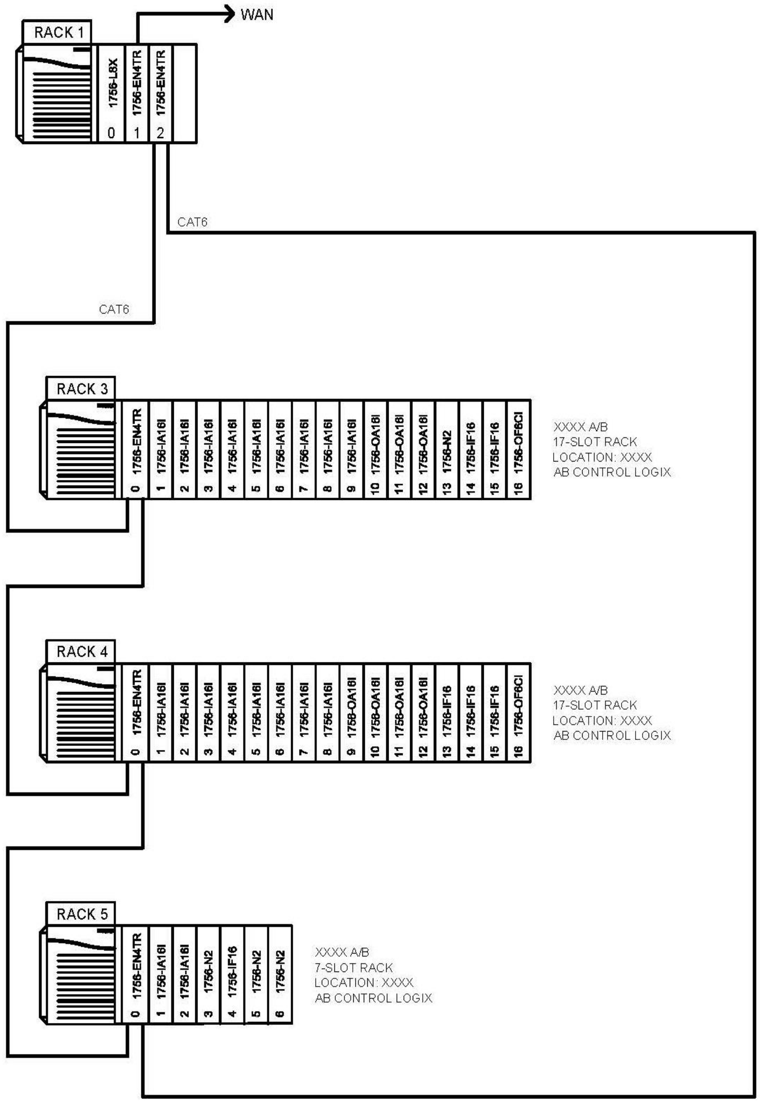

Figure 5-1 DLR Schematic

Design Note: Where a single CPU for a building has a large quantity of IO that prevents the use of a single PLC rack or module lineup, remote I/O racks are required. The remote I/O racks will communicate with the process CPU via an Ethernet card in the remote rack and Device Level Ring protocol. The remote rack may be internal to the same panel as the CPU rack or in a separate rack located elsewhere in the building.

Design Note: For those specific processes or applications that are "Mission-Critical", consideration should be given to implementing redundant PLC CPUs. Redundant CPUs operate as a pair in a "Hot-backup" fashion (see example setup below). There is a Primary CPU and a Secondary CPU that monitor each other continually via a dedicated, high-speed communications link. Both the Primary and Secondary CPUs have the exact same program loaded. The Primary Unit controls the physical IO that are shared by both CPUs. If the Primary CPU fails for any reason the Secondary unit assumes Primary status and immediately takes over all control of the IO and communications. The failed unit can then be repaired or replaced. After the unit has been put back into service, the unit obtains the Secondary status of the pair. It should be noted that the Redundant CPU setup is a specialty layout that requires advanced PLC maintenance knowledge. There are both special programming and communications required. For this specialty setup, the ControlLogix PLC Hardware are required.

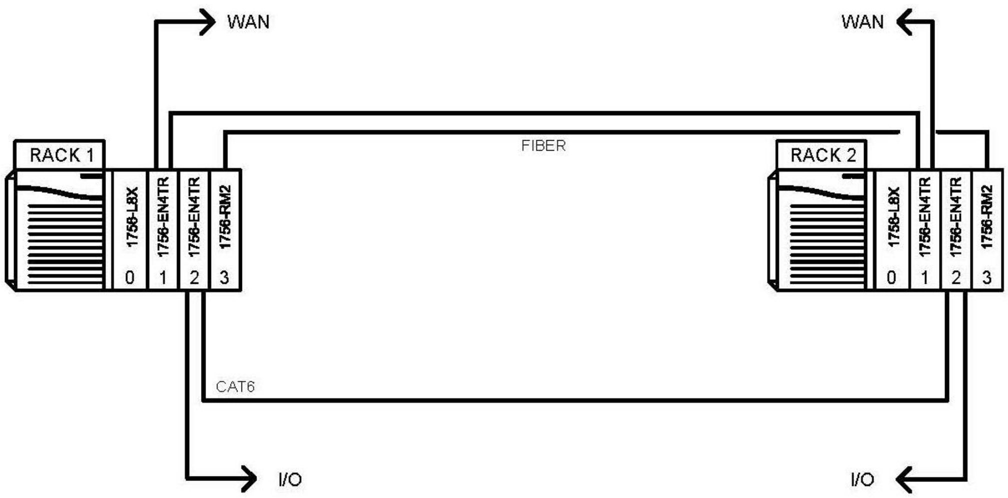

Figure 5-2 Hot Backup Schematic

5.3 PCS Network Design

For the PCS systems that incorporate the distributed CPU and I/O architecture, the network that interconnects them is of vital importance. The design of the PCS network is influenced by several factors:

- How the physical plant facilities are arranged.
- Number of PLCs across the plant to be interconnected
- Number of manufacturers supplied PLCs
- OIT locations desired throughout the site
- Communications required for remote (off-site) facilities such as Lift Stations
- Availability of proprietary manufacturer remote connections for Warranty maintenance

The I&C Design Engineer and CoT Personnel will work together to layout the network to meet the intent of the current project, while allowing for easy modifications to accommodate predicted future projects. Over time as the PCS expands and is upgraded, the network must evolve along with the expansion. The design of a PCS network topology should be a Hybrid network. A Hybrid network combines the different topologies (Ring, Star, Mesh, etc.) and allows for maximum flexibility. Refer to Appendix 4 for a more detailed discussion of the different types of Network topologies and communications media mentioned here.

For distributed CPU architectures, the Hybrid network typically consists of a fiber-optic ring backbone between CPU racks, and Star network connections to manufacturer supplied PLC panels or equipment controllers such as variable frequency drives. The ring involves running fiber optic cable from each distributed CPU to the next unit and finally back to the starting CPU. The ring topology requires network switches that allow for ring communications. Within each building/process a star network can be configured using copper CAT6 or fiber optic cabling to interconnect devices within the building to the network switch.

For distributed I/O architectures, a Device Level Ring should be used. The fiber optic ring is connected to networks switches and CPUs which are Device Level Ring enabled.

Design Note: The fiber optic backbone (ring) cable enters each control panel and is terminated to a Fiber Optic Patch Panel (FOPP) for distribution. The FOPP should be installed in the control panel. The fiber optic cable used to interconnect panels should be 12 strands, minimum. Two (2) strands are used for CPU communications, and the remainder for other plant systems such as security, fire and spares.

Design Note: The fiber optic star cable enters each control panel and is terminated to a Fiber Optic Patch Panel (FOPP) for distribution. The FOPP should be installed in the control panel. The fiber optic cable used make a star connection from the CPU panel to manufacturer supplied panels and ethernet based equipment should be four (4) strands, minimum. Two (2) strands are used for CPU communications, and the remainder are spares.

For remote network communications to off-site facilities there are several choices:

- Radio (Licensed and/or unlicensed) – radio systems need to have "Line-of-sight" or paths with minimal physical obstructions (tall building, trees, etc.) which impede/reduce radio signal strength below the minimum required. A physical radio survey must be done to confirm paths and antenna heights before installation of any permanent infrastructure (cabling, antennas, masts/poles towers). Depending on the survey results, the initial capital costs of this option can be exorbitant to cover the costs of the antenna towers. The operational costs are low compared to the recurring costs seen for other options. Radio transmission can be negatively affected by weather and other nearby radios.
- Phone/Cable Telemetry – requires modem to connect to the utility lines. System utilizes the phone/cable utility infrastructure to communicate between sites. Data rates provided by the utilities are not prohibitive for communications between remote pump stations, flow equalization basins, and the plant. There are recurring monthly fees based on data usage that are negotiated with the utility.
- Cellular – requires that cellular service (2G, 3G, 4G and now 5G) is available at the remote location. Cellular antennas are typically small and do not require special installations like radio systems. Data rates are generally low bandwidth and do not require 5G. There are recurring monthly fees based on data usage that are negotiated with your local provider. Due to the low bandwidth restrictions, cellular is only recommended for very small sites such as meter or valve vaults located out in the collection system.
- Fiber Optic Cable – installation of a fiber optic cable network in the service area that connects the remote sites back to the treatment plant. This is usually cost prohibitive, unless a process pipe is also being installed between the two sites. The fiber optic cable can then be installed in the same trench as the pipe.

In some instances, a manufacturer provided control system is provided along with their process equipment, and the manufacturer requires/recommends a remote connection to their control system. This remote connection allows the manufacturer to monitor and/or work on the equipment from their service center. Some manufacturers of highly proprietary equipment require this connection for maintaining the warranty. Third party connections to the plant SCADA system are **highly discouraged**. The Engineer should work with the manufacturer to eliminate this connection request.

5.4 PLC Hardware Selection Considerations

In conjunction with the decisions made by CoT Personnel and the I&C Design Engineer for CPU distribution and network topology, the PLC hardware must be chosen. The chosen hardware must seamlessly work with the CPU and the field I/O that will be monitored and controlled. There are several design aspects that should be given consideration when selecting the PLC hardware:

- Physical and environmental conditions
- Electrical Properties of Input/Output modules
- Wiring and Interface requirements of Input/Output modules

Physical and Environmental

- Will the PLC cabinets be located in an Electrical Room or Process Area? This will determine the NEMA Rating for the PLC Enclosure: 3R, 4, 4X, 7 (Explosion-Proof), or 12.
- Will PLC cabinets require heating and/or cooling? The PLC hardware generally has a temperature range: Standard 32 to 140 Deg. F; Extended - (-4…+158 F).
- Will PLC cabinets be exposed to a corrosive atmosphere? Conformal Coating of the PLC hardware modules should be specified for corrosive or damp/wet areas.

Electrical Properties

Since the PLC I/O modules interface directly with the process control equipment (motors, valves, instrumentation, etc.) consideration must be given to voltages and currents that will be seen by the hardware. The selection of the PLC Hardware components will be dependent on the voltages and currents present in the field. The main item that drives selection for discrete I/O is the voltage provided or seen by the PLC hardware. Below are recommendations for discrete I/O hardware voltages. Discrete PLC Hardware have many options; refer to Appendices 1 and 2 for the additional options in the ControlLogix and CompactLogix families.

- PLC Power supplies: 24 VDC is preferred for all new construction. Although 24 VDC is recommended for upgrades also, existing panels may not have DC available and no space for additional power supplies. In this case, the selection of a 120VAC unit would be required.
- Discrete Input modules: 24VDC is the preferred voltage for all new construction. Limiting the voltage seen in the panel, allows for CoT Personnel to work safely on the panel and PLC hardware without the need for special arc flash precautions and personal protective equipment. For upgrades to existing processes, the field equipment that is not upgraded may be wired for 120VAC. In this case, 120 VAC I/O modules would be selected to accommodate this existing wiring.
- Discrete Output modules: There are several types of output modules – relay, isolated and non-isolated. The relay type modules are the preferred option. Relay modules have a dry-contact output that has no specific voltage provided. The relay contacts allow for these modules to interact with either 24 VDC or 120 VAC systems without the need for interposing equipment.

The main item that drives selection for Analog I/O is whether voltage or current is provided or seen by the PLC hardware. Below are recommendations for analog I/O hardware. Analog PLC Hardware have several options; refer to Appendices 1 and 2 for the additional options in the ControlLogix and CompactLogix families.

- Analog Input modules: these modules come as either current (4-20mA) or voltage (1-5 VDC, 0-10VDC) inputs. The 4-20mA current version is preferred, since the majority of field devices provide current outputs.
- Analog Output modules: these modules come as either current (4-20mA) or voltage (1-5 VDC, 0-10VDC) outputs. The 4-20mA current version is preferred since the majority of field devices are current driven.

Process equipment may have instruments that provide signaling different from what is specified above. A common example in the water and wastewater treatment process is temperature monitoring using RTD or thermocouples. The PLC has the capability to directly accept some of these different signals, removing the need for a third-party controller. These specialty IO modules include a wide variety of choices including thermocouple and RTD modules.

Wiring and Interface

Beyond the characteristics of the PLC hardware modules themselves, how they are wired to the field devices and laid out in the panel are important to the overall integrity and safety of the system. The recommended practices for each module are described below. Refer to Appendix 5 for wiring and panel layout examples.

All field wiring should be terminated to subplate mounted terminal blocks inside the control panel and not directly to the PLC IO modules. Terminal blocks shall be individually numbered, colored and grouped per input type. Inside the control panel, analog and discrete wiring shall be run in separate wire ducts, to the extent possible, and when necessary cross at 90-degree angles. Terminal block shall accept a minimum of (2) #14 wires and be rated for a minimum of 300VAC/VDC.

Discrete Input modules: Each individual module shall have the module power feed fused. Discrete inputs from a single piece of equipment shall be grouped together on the same module. A single fuse shall be installed on the panel power feed to the process equipment's discrete input field contacts. Fuse holders should have a Blown Fuse indicator light for ease of troubleshooting.

Discrete Output Module: Each individual module shall have the module power feed fused, if necessary. Install a fuse on the source voltage for each relay output. The relay output contacts are rated for 2 amps. If the control circuit incorporating this relay contact will draw more than 1.5 amps, an interposing relay should be provided. If an isolated or non-isolated module (utilizing transistor outputs) is used instead of the recommended relay output, it is strongly recommended that each individual output whether 24VDC or 120 VAC have an interposing relay wired to it. The interposing relay provides both a level of electrical isolation between the transistor output and the field device to prevent back-feeding of potential harmful voltage, and provide the additional current carrying capacity for the control circuit that a transistor does not provide. Interposing relays shall be double pull double throw, and 120VAC or 24VDC depending on the panel power available. 24 VDC is recommend.

Analog Input module: Each individual input shall have a surge protection device wired in series with the current input. Alternatively, as a less expensive option, fuses can be installed instead of the surge protection device. The surge protection device is recommended as it can withstand multiple surges and maintain the loop operating while continuing to protect the PLC. For the fuse, once it is blown the loop is interrupted until it is replaced.

Analog Output module: Each individual output shall have a surge protection device wired in series with the output. Alternatively, as a less expensive option, fuses can be installed instead of the surge protection device. The surge protection device is recommended as it can withstand multiple surges and maintain the loop operating while continuing to protect the PLC. For the fuse, once it is blown the loop is interrupted until it is replaced.

APPENDIX A COMPACTLOGIX HARDWARE

This Appendix contains the Rockwell Automation PLC hardware options for the CompactLogix hardware family. Each section below lists the individual components required for a complete PLC hardware system. Recommended selections based on the design decisions discussed in the standard are in **BOLD.**

A1 COMPACTLOGIX – 1769 FAMILY OF PRODUCTS

The CompactLogix Family is unique in that is does not require a rack/chassis to physically group the modules. Instead modules are mounted to 35mm DIN rail and slide together. Each module has an electrical bus connector on each side that allows the modules to snap together.

A1.1 Central Processing Unit (CPU)

The CPU is the most critical module of the PLC system since it stores and executes the PLC program. All process control is contained at the PLC level.

Design Note: Provide local hardwired manual control via a motor control center or control panel should the CPU fail.

The **Series 5370 L3 (1769-L33ER**) is recommended.

Features/Options include:

- User Memory: 2MB
- Programming Languages supported: Ladder, Function Block, AOI
- Communications Ports: (2) Ethernet, (1) USB
- Network Topologies Support: Device Level Ring (DLR), Star or Linear; Dual IP Mode - 2 separate IP addresses.
- Ethernet Performance: 10MB/100MB
- SD Memory Card provides non-volatile program backup
- Supports 16 Local IO Modules max.; 2 banks of modules
- Development Software Package: RSLogix5000

A1.2 Communication Modules (Connection of Remote I/O Only)

Model **1769-AENTR** Ethernet communications module is recommended.

Features:

- Ethernet Ports: (2) RJ45
- Ethernet/IP Communications Rate: 10MB/100MB/1GB
- Supports Device Level Ring (DLR), Star networks

There is a wide selection of other Allen Bradley communications modules that support other communication protocols:

- DeviceNet – Model 1769-SDN
- Profibus – Prosoft Model PS69-DPM
- MODBUS TCP/IP - connect through the embedded Ethernet port of the CompactLogix 5370 CPU

A1.3 Analog Input Modules

Table A1-1 Analog Input Modules

Model	Description
1769-IF4	4-differential or 8-single-ended
1769-IF4I	4-Channel differential, isolated
1769-IF8	**8-differential** or 16-single-ended

Features:

- Input: Voltage: +/-10VDC, 0-5VDC, 0-10VDC or **Current: 0/4-20mA**
- Resolution: 14 Bits
- Removeable terminal block
- **Built-in HART interface is available.** If HART is desired, the 4-channel option is required – Model 1769sc-IF4IH

A1.4 Analog Output Modules

Table A1-2 Analog Output Modules

Model	Description
1769-OF4	4 Channel Analog Current/Voltage
1769-OF4CI	4 Channel Analog Current/Voltage , isolated
1769-OF8C	**8 Channel Analog Current**

Features:

- Output: Voltage: +/-10VDC, 0-5VDC, 0-10VDC or **Current: 0/4-20mA**
- Resolution: 15 Bits
- Removeable terminal block 1756-TBE (Extended)
- **Built-in HART interface is available.** If HART is desired, the 4-channel option is required – Model 1769sc-OF4IH

A1.5 Digital Input Modules

Table A1-3 Digital Input Modules

Model	Description
1769–IA8I	8-Channel, 120VAC, Isolated
1769-IA16	16-Channel, 120VAC
1769-IQ16	**16-Channel, 24VDC, sink/source**
1769-IQ32	32-Channel, 24VDC, sink/source

Features:

- Input filtering limits the effect of voltage transients that contact
- bounce and/or electrical noise cause.
- Optical isolation shields logic circuits from possible damage.
- Individual channel status indicators turn on or off, which
- indicate the status of each input.

A1.6 Digital Output Modules

Table A1-4 Digital Output Modules

Model	Description
1769-OA16	16-Channel, 120VAC
1769-OB16	16-Channel, 24VDC, source
1769-OB32	32-Channel, 24VDC, source
1769-OW8	8-Channel, Relay (N.O.),
1769-OW8I	**8-Channel, Relay (N.O.), Isolated**
1769-OW16	16-Channel, Relay (N.O.),

Features:

- Individual channel status indicators indicate the status of each output
- Removeable Terminal Block

A1.7 Specialty Modules

Model 1769-IT6: 6-Channel Thermocouple

A1.8 PLC Power Supply

Table A1-5 Power Supplies

	Input Voltage	Current Output
Model 1769-PA2	120/240VAC	2A @ 5V
Model 1769-PA4	**120/240VAC**	**4A @ 5V**
Model 1769-PB2	19-32VDC	2A @ 5V
Model 1769-PB4	**19-32VDC**	**4A @ 5V**

APPENDIX B CONTROLLOGIX HARDWARE

This Appendix contains the Rockwell Automation PLC hardware options for the ControlLogix hardware family. Each section below lists the individual components required for a complete PLC hardware system. Recommended selections based on the design decisions discussed in the standard are in **BOLD.**

B1 CONTROLLOGIX – 1756 FAMILY OF PRODUCTS

The ControlLogix Family is the top of the line model of PLCs from Allen Bradley. It is designed for use in major water and wastewater treatment plants with large IO counts and distributed PLCs. Additionally, it is used for the most demanding applications especially those that require redundant CPUs for Mission Critical processes.

B1.1 Central Processing Unit (CPU)

The CPU is the most critical module of the PLC system since it stores and executes the PLC logic program. All process control is contained at the PLC level. The PLC maintains plant operation.

Design Note: Provide local hardwired manual control via a motor control center or control panel should the CPU fail.

The **Series L8x (558xE)** is recommended.

Features/Options include:

- User Memory: 3MB to 40MB
- Programming Languages supported: Ladder, Function Block, AOI
- Communications Ports: (1) Ethernet, (1) USB,
- Network Topologies Support: Device Level Ring (DLR), Star or Linear
- Ethernet Performance: 10MB/100MB/1GB
- SD Memory Card provides non-volatile program backup
- Development Software Package: Studio 5000 or RSLogix5000

B1.2 Communication Modules

ControlLogix use **Ethernet/IP** as the native communications protocol.

Model 1756-EN4TR is recommended.

Features:

- Ethernet Ports: (2) RJ45
- Ethernet/IP Communications Rate: 10MB/100MB/1GB
- Supports Device Level Ring (DLR), Star networks

There is a wide selection of other Allen Bradley modules that support other communication protocols if needed for the project:

- ControlNet - Model 1756-CN2 (not recommended due to negative hardware version interactions)
- DeviceNet – Model 1756-DNB
- Foundation Fieldbus - Model 1757-FLD2
- **HART** – connects HART enabled analog input/output modules **(recommend specify for all analog modules)**
- Remote I/O – Model 1756-RIO or via Ethernet/IP module

B1.3 Analog Input Modules

Table B1-6 Analog Input Modules

Model	Description
1756-IF6I	6-Channel isolated
1756-IF8	4-differential or 8-single-ended
1756-IF8I	**8 -Channel isolated**
1756-IF16	8-differential or 16-single-ended

Features:

- Input: Voltage: +/-10VDC, 0-5VDC, 0-10VDC or **Current: 0/4-20mA**
- Resolution:16 Bits
- Removeable terminal block1756-TBE (Extended)
- **Built-in HART interface is available.** If HART is desired, the 8 or 16 channel option is required – **Model 1756-IF8IH**

B1.4 Analog Output Modules

Table B1-7 Analog Output Modules

Model	Description
1756-OF4	4-Channel, Voltage or Current
1756-OF6CI	6-Channel isolated, Current only
1756-OF8	8 -Channel Voltage or Current
1756-OF8I	**8-Channel isolated, Voltage or Current**

Features/Option:

- Output: Voltage: +/-10VDC, 0-5VDC, 0-10VDC or **Current: 0/4-20mA**
- Resolution: 15 Bits
- Removeable terminal block 1756-TBE (Extended)
- **Built-in HART interface is available.** If HART is desired, the 8 or 16 channel option is required – **Model 1756-OF8IH**

B1.5 Digital Input Modules

Table B1-8 Digital Input Modules

Model	Description
1756-IA16	16-Channel, 120VAC
1756-IA16I	16-Channel, 120VAC. Isolated
1756-IA32	32-Channel, 120VAC
1756-IB16	16-Channel, 24VDC
1756-IBA16I	**16-Channel, 24VDC. Isolated**
1756-IB32	32-Channel, 120VAC

Features/Options:

- Individual channel status indicators turn on or off, which indicate the status of each input
- Removeable Terminal Block 1756-TBE (Extended)

B1.6 Digital Output Modules

Table B1-9 Digital Output Modules

Model	Description
1756-OA16	16-Channel, 120VAC
1756-OA16I	16-Channel, 120VAC, Isolated
1756-OB16I	16-Channel, 24VDC, Isolated
1756-OB32	32-Channel, 24VDC
1756-OW16I	16-Channel, Relay (N.O.), Isolated

Features/Options:

- Individual channel status indicators indicate the status of each output
- Removeable Terminal Block 1756-TBE (Extended)

B1.7 Specialty Modules

Model 1756-IR6I: 6-Channel Isolated RTD

B1.8 Hot Backup Modules

These modules allow for two processors to work together as automatic backups to each other. One processor will operate as the primary, and the other as a secondary. If the primary were to fail, an automatic switch to the secondary would occur. This allows for the failed processor to be replaced/repaired while maintaining seamless operation of the process.

<u>Required Equipment:</u>

Model: 1756-RM2 (Redundancy Module)

Model: 1756-RMC1 (Redundancy Cable)

B1.9 PLC Power Supply

Power supplies are available in two styles – Standard and Redundant. Standard supplies are integrated into the rack with the other modules. Redundant ones come in pairs and mount outside the rack and are wired to the rack(s). A standard power supply is recommended, along with a spare on the shelf.

Table B1-10 Power Supplies

	Input Voltage	Current Output
Model 1769-PA72	120/240VAC	10A @ 5V
Model 1769-PA75	**120/240VAC**	**13A @ 5V**
Model 1769-PB72	24VDC	10A @ 5V
Model 1769-PB75	**24VDC**	**13A @ 5V**

<u>Redundant Power Supplies:</u>

If the process connected to the associated CPU cannot accept any outage, a redundant power supply may be required. The redundant power supplies offer the same features as the standard power supplies, along with the following:

- Redundant operation
- Automatic chassis load sharing between the redundant power supplies
- Status indicators for visual operating status of the pair

- Solid-state relay for system recognition of supply status when wired to an input module

Table B1-11 Redundant Power Supplies

	Input Voltage	Current Output
Model 1769-PA75R	120/240VAC	75W
Model 1769-PB75R	24VDC	60W

Redundant power supplies require the following accessories:

- Model 1756-PSCA2: Redundant power supply chassis adapter
- Redundant power supply cable (Length = 0.91 m [3 ft])

Standard Power Supplies 1756-PA72, 1756-PA72K, 1756-PA75, 1756-PA75K, 1756-PB72,

1756-PB72K,1756-PB75, 1756-PB75K,1756-PC75, 1756-PH75

Standard Slim Power Supplies 1756-PA50, 1756-PA50K, 1756-PB50, 1756-PB50K

ControlLogix-XT Power Supplies 1756-PAXT, 1756-PBXT

ControlLogix-XT Slim Power Supplies 1756-PA30XT, 1756-PB30XT

Redundant Power Supplies 1756-PA75R, 1756-PA75RK,1756-PB75R, 1756-PB75RK

Redundant Power Supplies Chassis Adapter 1756-PSCA2, 1756-PSCA2K

ControlLogix-XT Redundant Power Supplies 1756-PAXTR, 1756-PBXTR

ControlLogix-XT Redundant Power Supplies Chassis Adapter 1756-PSCA2XT

Redundant Power Supply Power Cable 1756-CPR2, 1756-CPR2D, 1756-CPR2U

B1.10 PLC Racks

The PLC Rack\Chassis provides a physical housing with a communications and power backplane in which the modules slide into.

Table B1-12 Racks

Model	Description
1756-A4	4 Slot rack
1756-A7	7 Slot rack
1756-A10	10 Slot rack
1756-A13	13 Slot rack
1756-A17	17 Slot rack

The rack size shall be selected to contain the required communication and I/O modules, processor, and some spare empty slots. To protect backplanes of the rack where there are empty slots, provide a slot filler module.

Model: 1756-N2 Slot filler

APPENDIX C ANCILLARY EQUIPMENT

C1 OPERATOR INTERFACE TERMINALS (OIT)

Operator Interface Terminals generically refer to two (2) different technologies of graphic display terminals; PanelView, Industrial Computer.

These graphic display terminals allow the operator to monitor and control the process locally. They are distributed throughout the plant site at locations that assist CoT personnel to efficiently operate the processes. Either of the units are mounted directly on the front of the PCS panels.

Industrial Computers are the preferred choice and supplied by either CoT or the System Integrator. For process equipment packages provided by equipment manufacturers if an Industrial Computer cannot be supplied then a PanelView unit is acceptable.

Panel/View

Proprietary Allen Bradley interface terminal that utilizes its own software package to provide the visual interface to the PCS. Due to the proprietary software, the visual interface and security options will be different than the PCS Operator Interface Computers in the control room. These differences can lead to confusion when CoT personnel who normally operate the system from the control room are asked to perform tasks at the remote panels.

The PanelView family offers a wide range of sizes and options. The **Model 5510** is the recommended unit. The features and options include:

- Voltage: 24VDC
- Screen Size: Sizes range: 7” , 9”, 10”, **12”**, 15” & 19”
- Screen Aspect Ratio: 4x3 or **16x10 (widescreen)**
- Screen Input: **Touchscreen only** or Keypad/Touchscreen
- Memory: 1GB, 4GB Flash, SD Card Slot
- Screens/Alarms: 100 screens; 4000 Alarms
- Communication Ports: (2) Ethernet, (2) USB 2.0 – Type A
- Environmental: NEMA Rating: 4, 4X, 12
- Development Software Package: Studio 5000

Industrial Computer

Panel mounted, industrial computers that integrate a personal computer with a touchscreen monitor. The industrial computer utilizes the same plant HMI software package. The Contractor would purchase an additional license of the HMI software used for the plant, and install it on the industrial computer. This allows the remote OITs to have the exact same look and operational controls as what CoT personnel see in the control room.

The Allen Bradley industrial computer family offers a wide range of sizes and options. The **VersaView 6300P Panel PC** is the recommended OIT. The features and options include:

- Voltage: 24VDC
- Screen Size: Sizes range: **15.6”**, 18.5”, 21.5” & 24”
- Resolution: 1920 X 1080 minimum
- Screen Aspect Ratio: **16x9**
- Screen Input: Touchscreen (single touch)
- Processor: Intel Core i7
- Memory: 16 OR 32GB RAM - DDR3 (Sized based on complexity/quantity of system)
- Storage Devices: 1 TB, 2.5-in. SSD
- Connection Ports: (4) Ethernet 1GB, (1) DVI-I, (1) DisplayPort,(3) USB 3.0, (1) Serial RS-232
- Expansion Slot: (1) PCI Express x4 or (1) PCI e x4

- Enclosure Rating: IP65

C2 UNINTERRUPTABLE POWER SUPPLIES (UPS)

A UPS is required for all PLC-based control panels. The UPS provides a steady, conditioned source of power to the PCS equipment. During a loss of plant power, the UPS battery system will maintain power to this equipment for period of time. Each PLC panel should be powered by a UPS. The UPS should be sized to provide a minimum of 30 minutes of backup power at full-load and have reserve capacity of at least 25% for future expansion. The UPS battery backup power is for PLC CPU, operator interfaces, and network equipment only, NOT I/O, panel equipment, or field instruments. The UPS battery backup provides the PCS the ability to monitor the condition of the network and CPU while waiting for the plant power to return. Refer to section 3.3 of this Appendix for UPS wiring recommended to provide a seamless transfer of power between the UPS and plant power.

The recommended UPS is the **Allen Bradley Series 1609 Model 1609-B-1000N** designed for use in industrial control panels. The features and options include:

- Voltage: IN 120VAC; OUT 120VAC
- Power Output: **1000VA (1609-B),** 1500VA (1609-D)
- Battery Type: Sealed Lead-Acid
- Recharge Time: <8 hours to 90% after discharge under full load
- Status/Control Signals : On Battery, Low Battery, Fault, Remote On/Off control
- Optional Communications: **Ethernet** (1609-D)
- Bypass Switch : Allows quick removal of UPS without power loss
- Mounting Options: **DIN Rail** or surface mount.

C3 UPS TRANSFER SCHEME

Introduction

SCADA Panels provide the brains to a plant control system. These panels contain the PLC processor and associated networking equipment to control and monitor the plant systems from multiple locations. The importance of these panels requires prompt notification of power issues preventing the operation of the PLC processors and network.

In order to adequately monitor the power at a SCADA panel, a few items must be supervised. The SCADA system monitors the presence of the plant and an uninterruptible power supply (UPS) power. If either or both sources were to drop out, plant operations need to be promptly notified. The schematic below shows proposed wiring to eliminate the shutdown of a panel’s important equipment from a single source failure. Along with the automatic power switching, logic within the PLC reviews the presence of the two sources to notify when either or both are no longer available. This allows for maintenance personnel to remedy issues prior to a complete power failure of the panel.

Scheme Description

The panel accepts a 120-volt, single phase feed from the plant power. Plant power will directly feed the following items:

- Non-essential items (Example: fan, heater, field instruments, etc.),
- A fused status input to the PLC (refer to second line of the schematic),
- Uninterruptible Power Supply.

The UPS provides direct power to the PLC, HMI, and networking equipment ONLY. Contactor, C-8, monitors UPS power availability. The contactor provides an input contact to the PLC, along with contacts for the switchover scheme. If UPS power were to drop out, contacts from C-8 would automatically switch to plant power to feed the PLC and networking equipment. When UPS power becomes available again, the contactor contacts would switch back to the regulated UPS power.

By monitoring the two power sources we can determine the following situations:

1. Plant and UPS power on – SCADA equipment on UPS power.
2. Plant power on, UPS power off – SCADA equipment on plant power, UPS is either under maintenance or malfunctioning.
3. Plant power off, UPS power on – SCADA equipment on UPS battery power
4. Plant and UPS power off – SCADA equipment are down. This will be seen as a Loss of Communication Alarm.

There is an amber light shown in the transfer scheme wiring. Since most control panels do not have viewing windows into the inside, this light provides plant personnel positive feedback of the power availability to the SCADA equipment without the need to open the panel. This light is push-to-test, such that a person can quickly test to validate the power is out and not a failed light or fuse. The test voltage to the light is shown with the “1” interconnection to the light and to the load side of the UPS power circuit breaker.

Maintenance

The proposed wiring schematic has two inherent benefits for preventative maintenance. The first benefit is the BYPASS-UPS switch wired in series with the UPS Power Available relay. The switch allows for maintenance personnel to test the transfer scheme by selecting BYPASS, watching the transfer to plant power, then selecting UPS to swap back to UPS power. The switch can be used to allow work to be performed on the UPS, while maintaining operation of the SCADA equipment.

The second benefit is the direct communications between the UPS and the PLC. If the Allen Bradley 1609 series UPS is provided per the PLC hardware standard; Ethernet/IP communications allow for direct PLC access to several additional monitoring variables such as “Remaining Battery Life”.

Side Note: If a UPS from a different manufacturer is provided (not recommended), the unit should be specified to have a communications module utilizing a protocol that is available for the selected PLC processor either directly or via a third-party module.

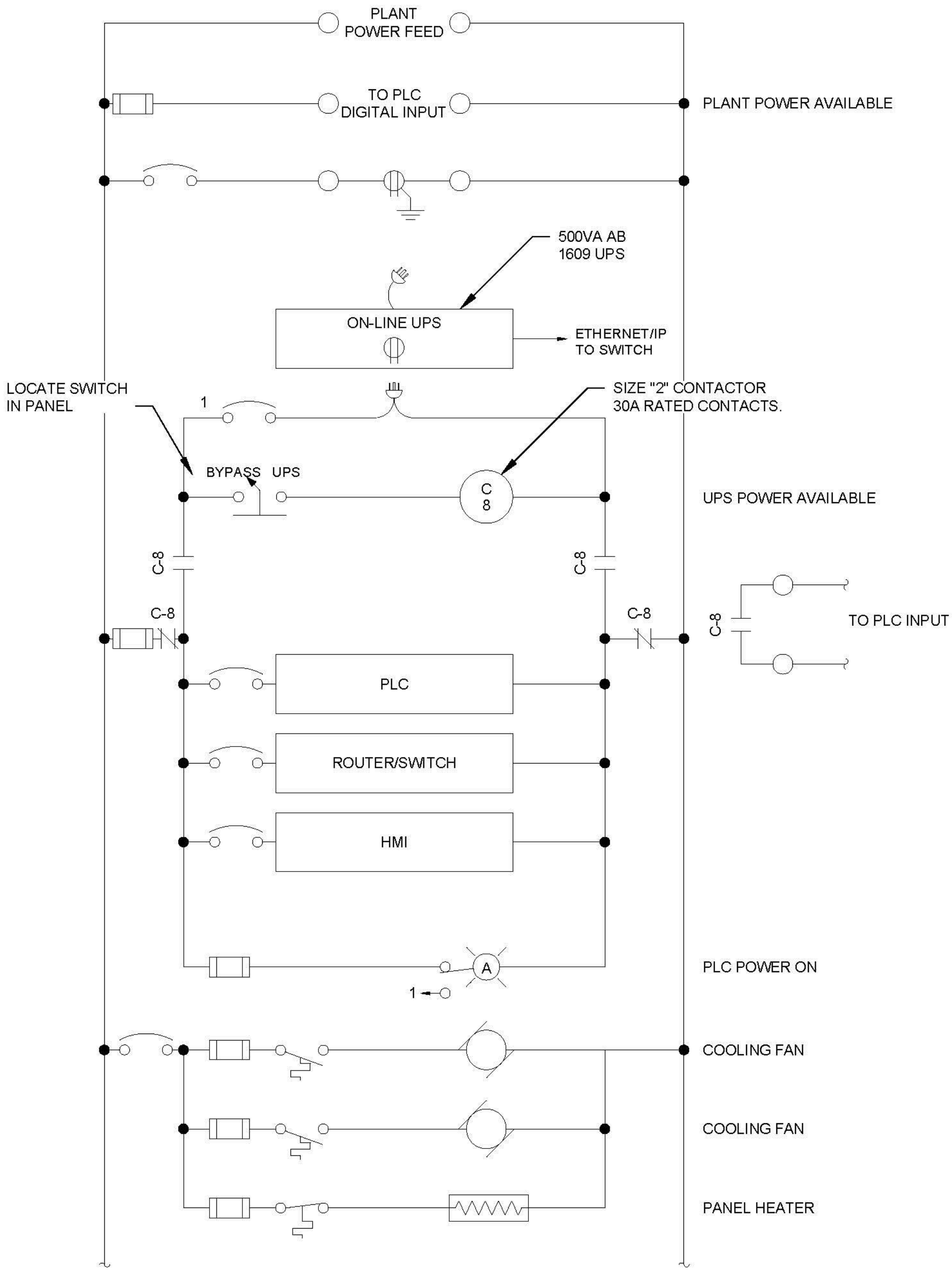

Figure C-3 UPS Wiring Schematic

APPENDIX D NETWORK TOPOLOGIES

Network Topology – the physical layout of the plant network transmission media. The topology must be coordinated with electrical design to ensure the required conduit is shown.

Ring – the physical media forms a “ring” with each PLC connected to the ring. Inherently provides fault tolerance in that if a single break occurs in the ring the communications continues around the ring in the other direction.

Star – can be thought of a “hub and spokes” each PLC is connected to one or more central communications hubs. Loss of the hub causes all connected devices to lose communications.

Linear/Bus -PLCs are connected to each via a common trunk line cable in a straight-line fashion. There is a limit on trunk cable length and number of PLCs that can be connected. Also, dependency on trunk cable in this topology encounters some problem, whole network breaks down.

Mesh – pertains to radio-based systems. Radios are configured to seek alternative paths if a unit goes down.

Hybrid –any combination of the above. This is the preferred topology. The hybrid model allows for the most flexibility for an everchanging system.

Device Level Ring (DLR) - The proprietary communications protocol developed by Rockwell Automation specifically designed to work with and enhance communications of all Allen Bradley products. DLR is a network technology enabling Ethernet ring network topologies at the device level. Unlike a network- or switch-level ring topology that provides resilience to the network infrastructure, DLR technology adds device-level network resilience to optimize communications. When a DLR detects a break in the ring, it provides alternate routing of the data to help recover the network at extremely fast rates. In addition to network recovery performance, DLR technology helps simplify network architecture while still providing the flexibility to connect and coexist with other network topologies. CPUs with dual Ethernet ports equipped with DLR technology connect directly to neighboring nodes and form a ring topology at the end devices.

Network Transmission Media – the physical infrastructure over which communications take place.

Fiber Optic Cable – Fiber Optic cable is the preferred media to run between buildings or long distances since it is not susceptible to electrical interference and has virtually no bandwidth restrictions. Fiber cable can be run overhead or underground in conduits/ductbanks. It can have an armored jacket and be direct buried. All fiber optic cabling shall be Single-mode:

- Core Diameters: 9 um.
- Number of Fibers: 4 minimum or as listed on Drawings.
- Cladding Diameter: 125 microns.
- Wavelength: 1310 nm Band
- Maximum Attenuation: Less than 0.35 dB/1,310 nm.
- Operating Temperature range: -60 to +85 degrees C.

Single-mode is the required fiber type for plant PCSs. Single-mode fiber has a similar capital cost as multi-mode fiber; however, the equipment to connect the fiber to is more expensive. Engineer shall coordinate with the plant IT department to determine what equipment will utilize single mode or multi-mode transmission; regardless the cable is single-mode.

Copper Cable – Copper based ethernet cable is the preferred media for short runs between panels or equipment within a building. Copper based cable should not be used for the media between buildings due to distance and high probability of electrical noise interference. Ethernet cables are rated: CAT5e, **CAT6,** CAT6a, CAT7. CAT6 is recommended as a minimum since it supports data rates up to 1GB. Ethernet cables come as either **Shielded** or Unshielded. Shielded cables have a foil liner that runs the length of the cable to minimize crosstalk and interference.

Radio – Licensed or Unlicensed. Licensed radios require FCC approval and have higher power rating (5W) versus unlicensed (1W). Radio systems also have associated infrastructure costs to install antennas and towers. Radio systems require physical(not just software) radio survey prior to installation to verify that the radio paths are unobstructed, that the antenna heights are sufficient and power levels are adequate.

Cellular – requires cell phone service and has recurring monthly fees.

Communications Protocol – the system of rules that allow two or more devices in a communications system to transmit information via any physical transmission media**.** The protocol defines the rules, syntax, semantics and synchronization of communication and possible error recovery methods. Ethernet TCP/IP is the preferred protocol for all communications.

APPENDIX E **SCHEMATICS**

E1 PANEL LAYOUTS

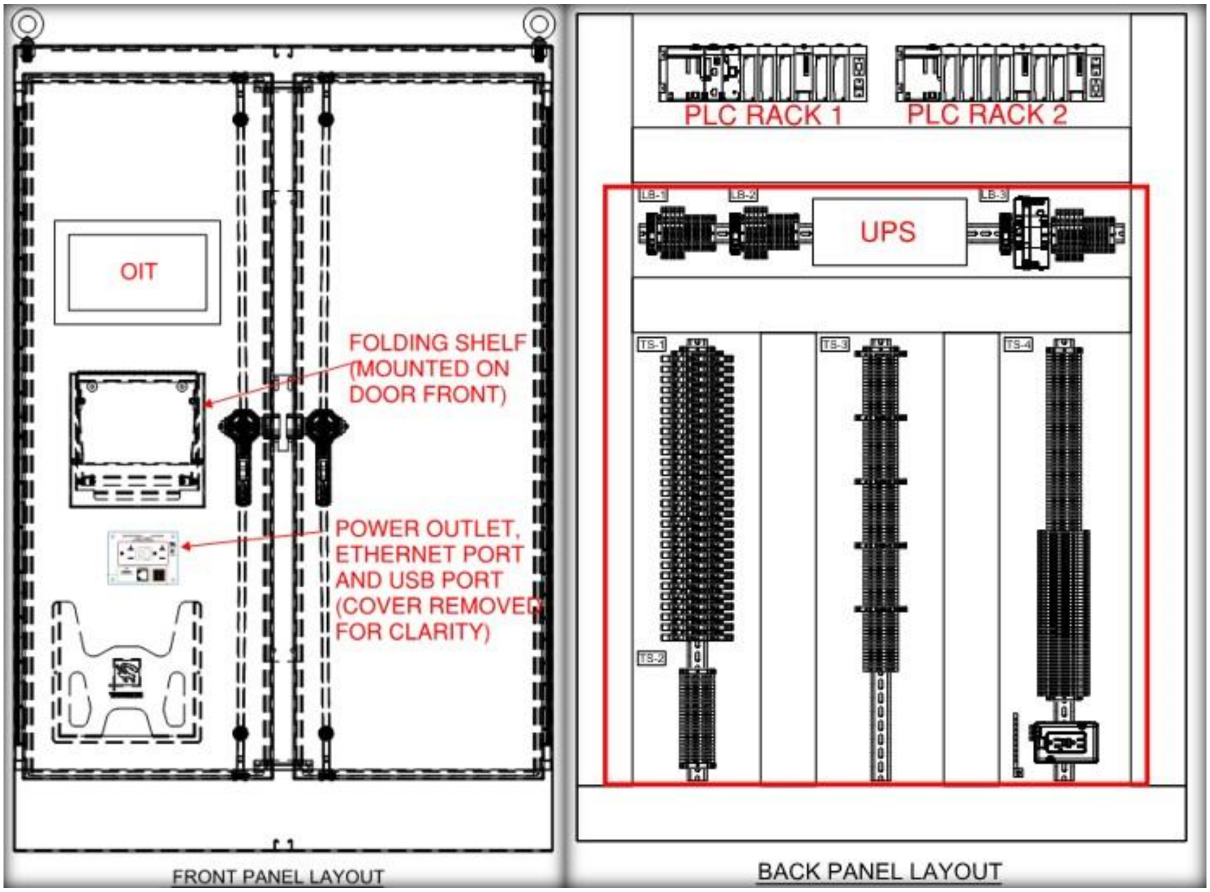

Figure E-4 Panel Layouts

E2 DIGITAL INPUT/OUTPUT WIRING

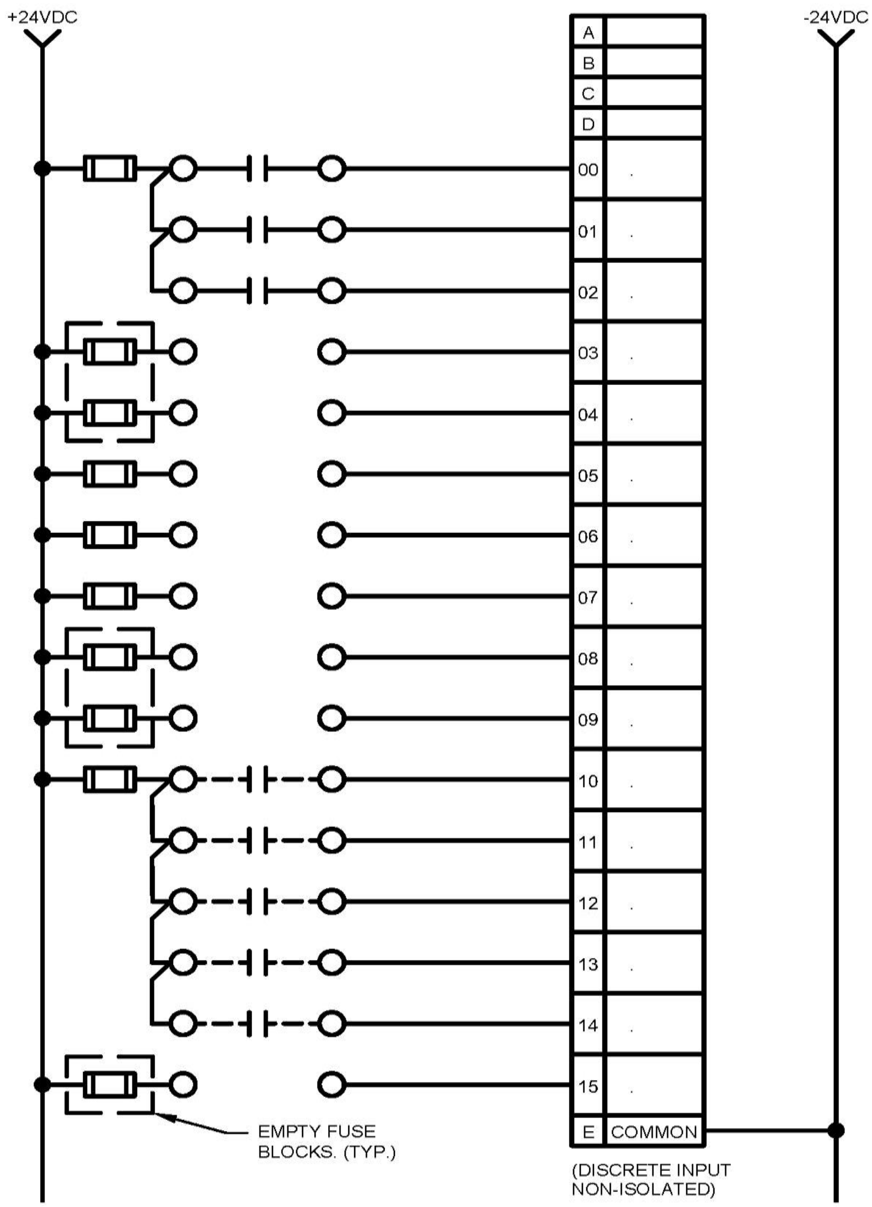

Figure E-5 Digital Input Modules

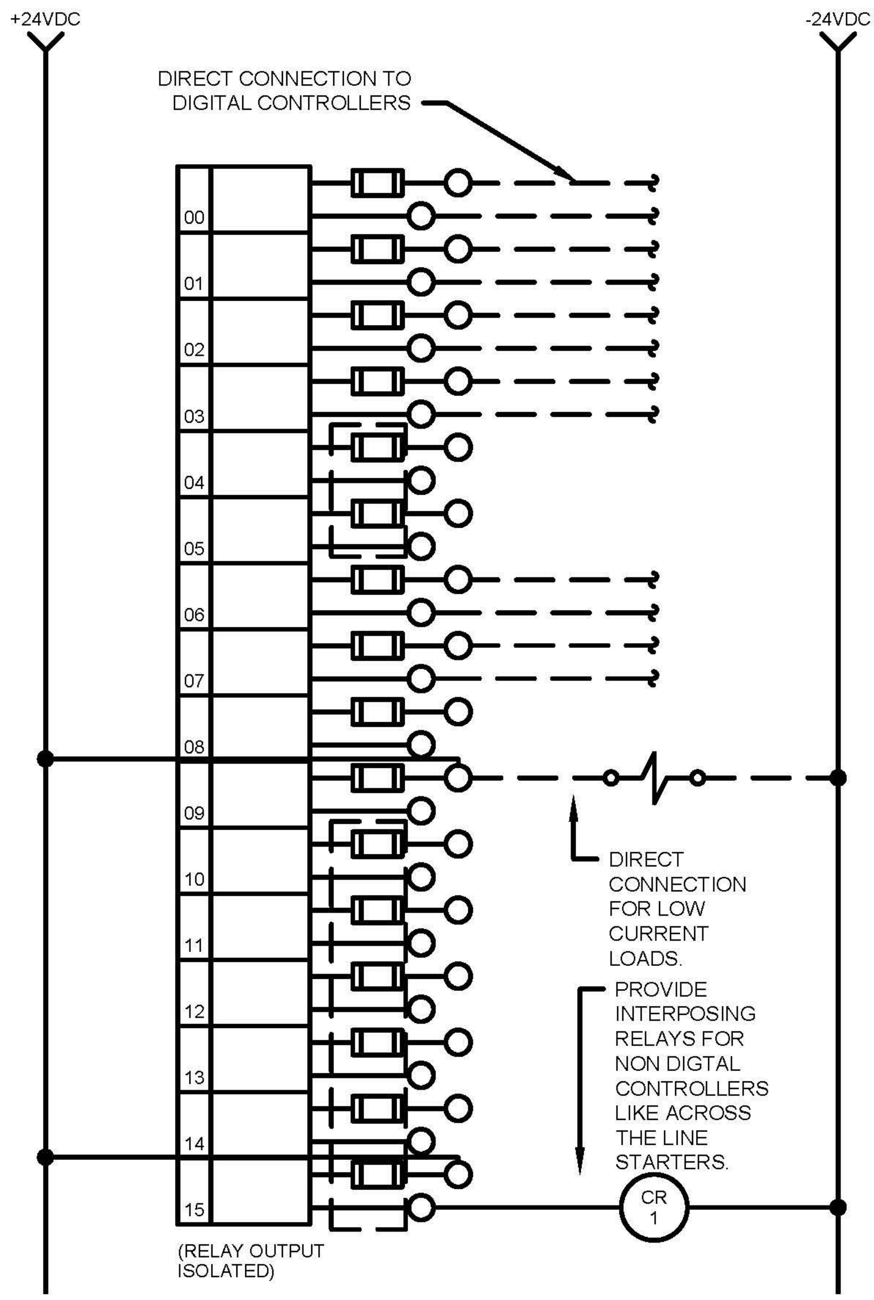

Figure E-6 Digital Output Module

E3 ANALOG INPUT/OUTPUT WIRING

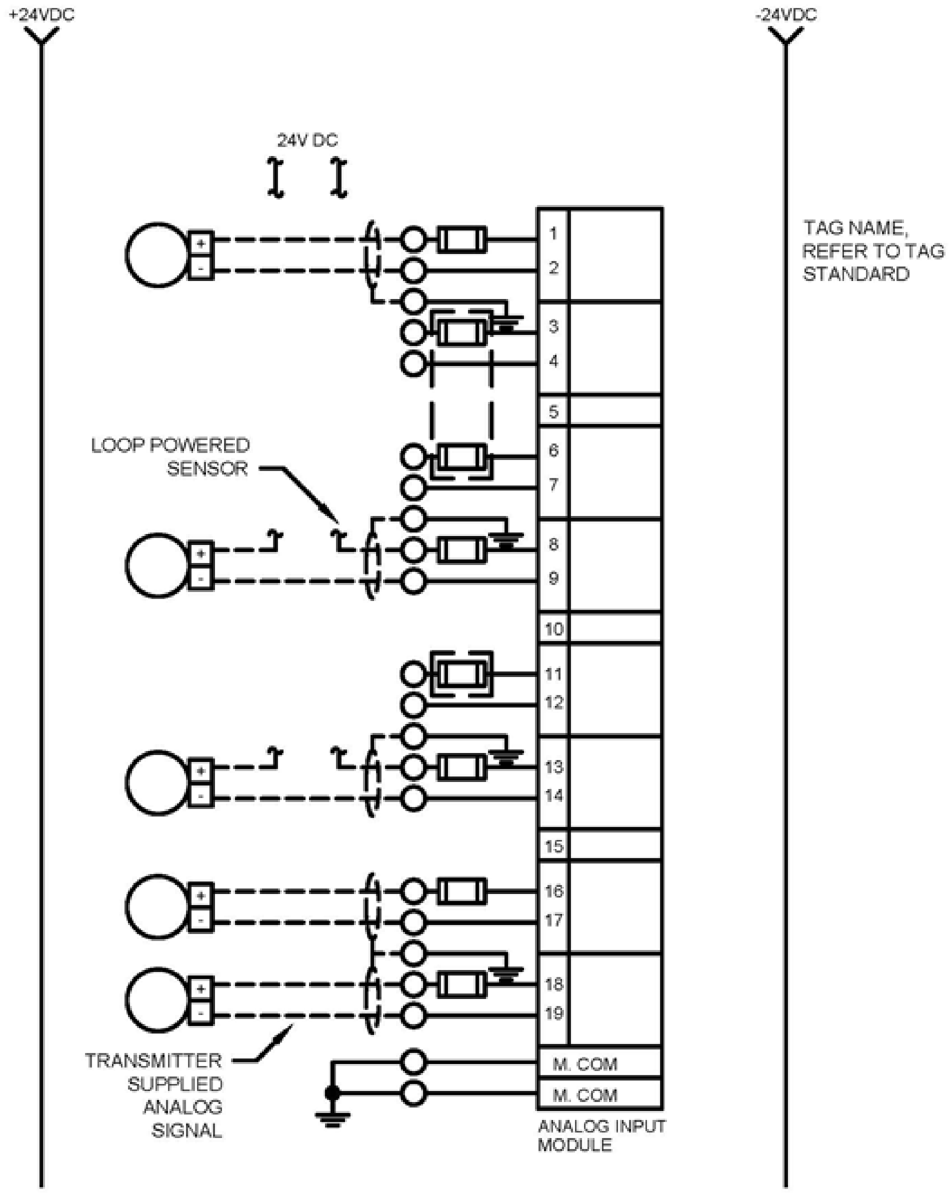

Figure E-7 Analog Input Module

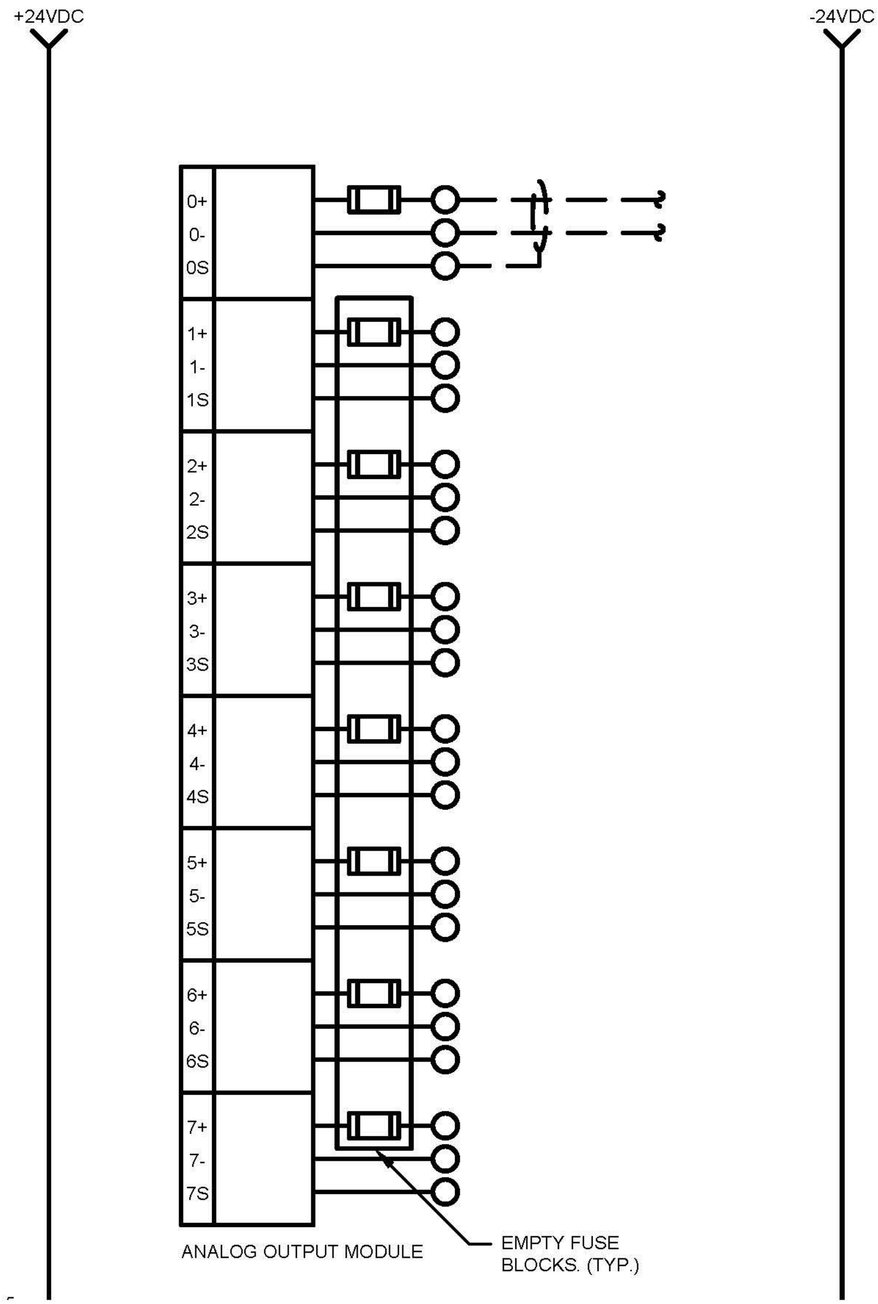

Figure E-8 Analog Output Module