White Paper

Redundant Control and Communication for Power Control Systems

ASCO Power Technologies®

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Reliable Power Control Systems (PCS) are essential for many facilities with mission-critical power needs, and reliable Programmable Logic Controllers (PLCs) and Input/Output (I/O) pathways are necessary for proper PCS function. This paper describes basic redundancy schemes for PLCs and I/O pathways.

ROLE OF PLCs IN PCS OPERATION

A PLC consists of a solid-state central processing unit (CPU); an input module; an output module; and a power supply. The CPU executes programmed instructions that are stored in memory. It also evaluates data that comes from sensors or other devices through the input module; and issues control, metering, and alarm signals to other devices through the output module. Examples of PLC and I/O units are shown in Figures 1 and 2.

Figure 1: A General Electric RX3i PLC

Figure 2: A General Electric VersaMax I/O Unit

PLCs control devices such as electromechanical equipment on an assembly line. In PCS equipment, PLCs are used in the Generator, Master, and Distribution Sections of power control switchgear. In *Generator Sections*, PLCs may manage engine-generator signaling, startup, connection, disconnection, and shutdown. Each generator section usually manages one engine; however, two engines are sometimes controlled from a single section. Each generator has its own dedicated PLC, even when two generators are controlled from a single section. Each section can directly control engine power as well as add and shed generators to and from main bus.

Distribution Sections contain circuit breakers that connect elements of power distribution systems to energized bus. They can also connect load banks to test power sources without having to transfer live loads to the backup system. *Master Control Sections* provide overall system control as well as direct control of specific equipment such as transfer switches and utility, tie, and distribution breakers. They may also manage demand by adding and shedding loads. The PLCs in distribution sections typically function as distributed I/O for the Master PLC.

ROLE OF I/O IN PCS OPERATION

The term *I/O* refers to the signals and circuits that comprise data communication pathways between PLCs and the devices they serve. I/O refers to both media and communication protocols such as digital or analog I/O as well as Ethernet over copper or optical fiber. PLCs typically offer removable protocol-specific modules to interface with various monitoring and control systems and devices.

IMPACTS OF FAILED PLCs AND I/O

When PLCs fail, they cannot evaluate information from other devices or execute actions based on device data. If a PLC fails in a Master Section, then a transfer switch may lose the ability to monitor and display device status information or multiple PCS sections could be disabled. If a PLC fails in a Generator Section, users may lose the ability to monitor and adjust equipment settings from its Human Machine Interface. If I/O fails for the same section, a start signal issued by a PLC may never reach the intended engine. Any of these scenarios could result in an outage that can profoundly impact facility operations and mission-critical activities. For this reason, PCS manufacturers offer options for redundant PLCs and redundant IO.

PCS CONTROL CONFIGURATIONS

PCS control configurations vary, in part, according to the level of redundancy specified for their PLCs and I/O. The following narrative describes common configurations and their advantages.

Single PLC and Single I/O

Systems that use single PLCs and single I/O pathways are simple and cost effective, and are used across many applications in many industries. They offer straightforward design and are easy to commission. Because PLCs are designed to withstand harsh environments, they operate reliably without redundant units, as demonstrated by their high Mean Time Between Failure rates.

Although reliable, a malfunction in any single PLC or I/O element could disrupt the operation and availability of a Single PLC/Single I/O PCS system. In addition, power equipment could become unavailable when the system is serviced. Although these systems are robust, a Single PLC/Single I/O configuration should be selected where the impact and cost of downtime can be tolerated.

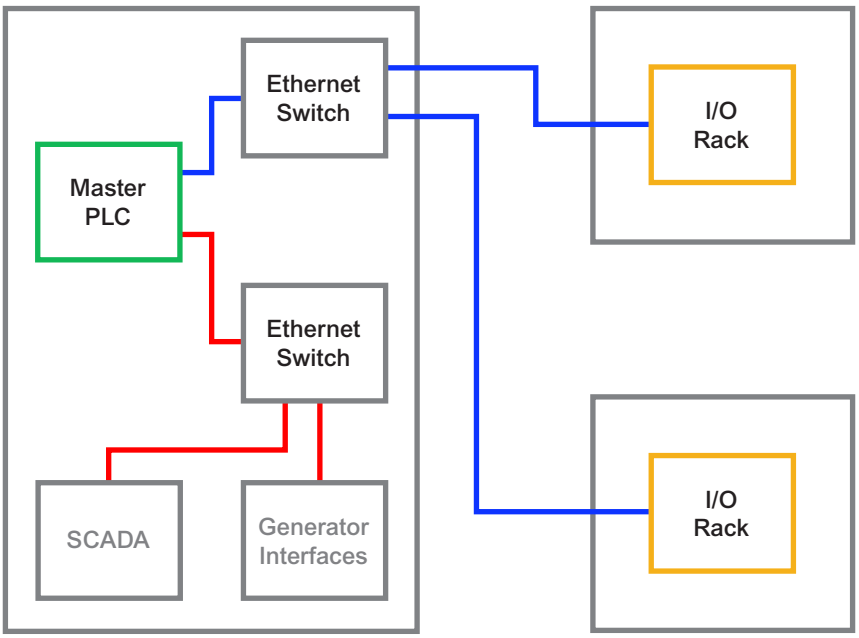

Figure 3: Single PLC/Single I/O

Figure 3 shows a schematic of a Single PLC/Single I/O system that uses General Electric or Allen-Bradley PLCs. Another alternative uses Modicon PLCs that can offer integral I/O redundancy, as shown in Figure 4. While the opportunities to deploy Modicon PLCs are increasing for ASCO PCS products, the remaining diagrams in this paper represent General Electric and Allen-Bradley units.

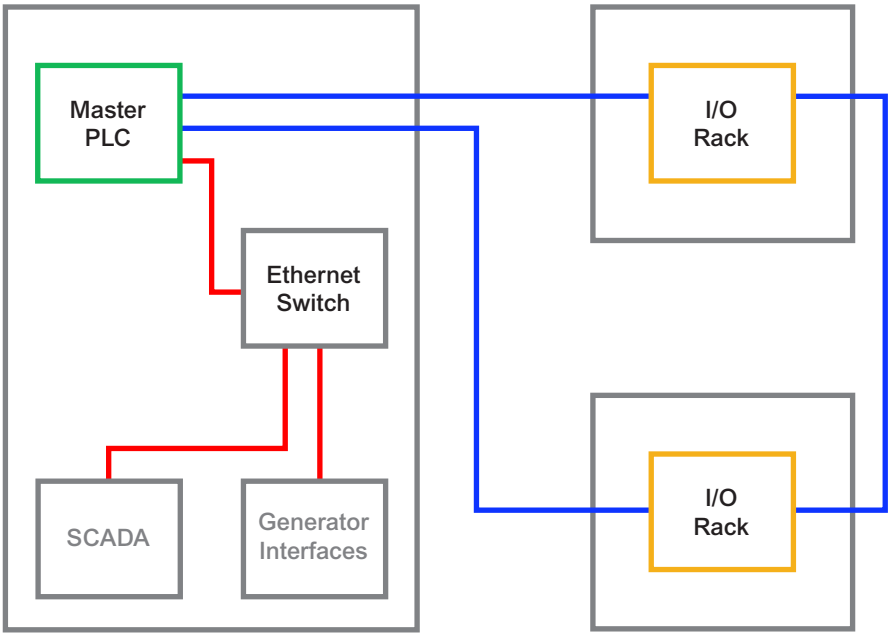

Figure 4: Single PLC/Single I/O Using Modicon PLC

When viewing this document, note that the diagrams illustrate relationships between control components, but may not represent physical arrangements of control systems within equipment line-ups. Figure 5 shows how such a system might be configured within a lineup of PCS equipment.

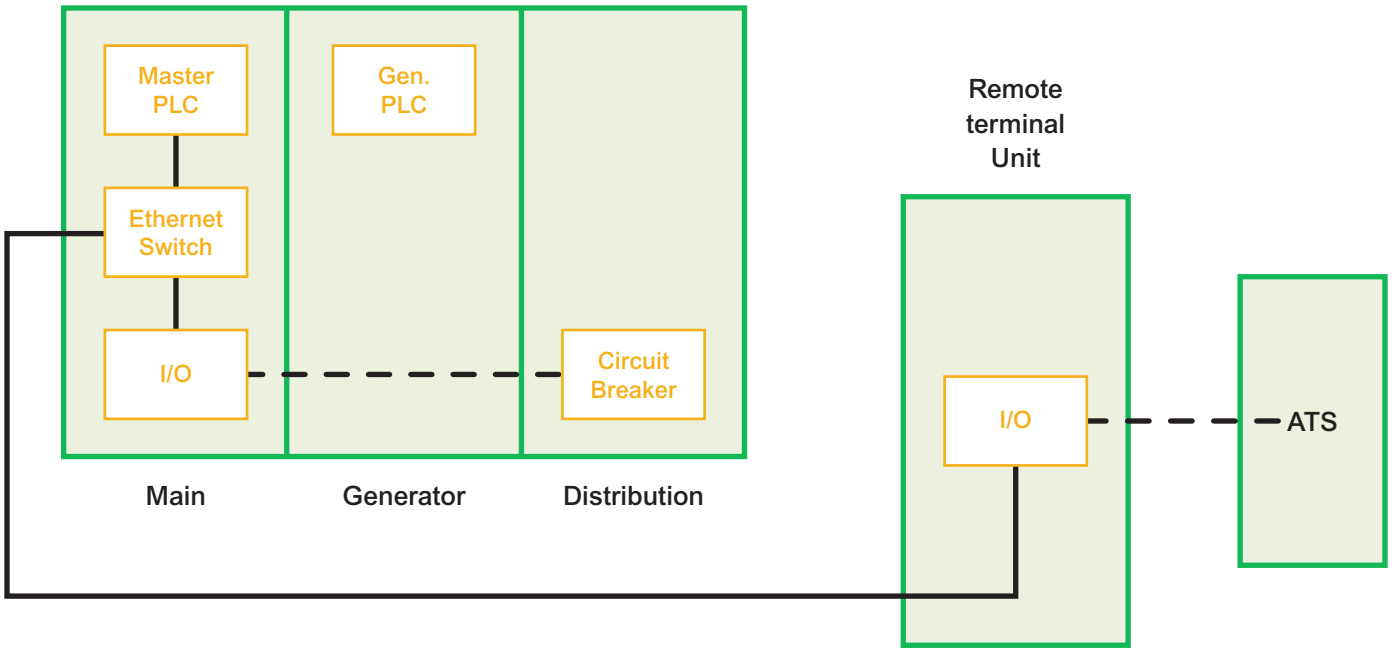

Figure 5: A PCS with a Single PLC and Single I/O Pathways Serving a Remote Terminal Unit

Redundant PLCs and Single I/O

Systems that use two PLCs and a Single I/O pathway offer the first level of redundancy. In this arrangement, each I/O is routed to each of the PLCs, which continually operate in parallel using the same data. If one PLC fails, the other immediately takes over all operations.

An advantage of this arrangement is that facilities gain redundancy in the most complex part of the PCS. The commensurate disadvantage is that a single failure along an I/O pathway can still leave a system isolated from Master Control. Similarly, there is no redundancy if one controller is taken off-line for service. Redundant PLC/Single I/O schemes are often found in healthcare facilities, particularly where ATS control ensures that Priority 1 loads are not dependent on operation of the PLC. The arrangement is shown in Figure 6.

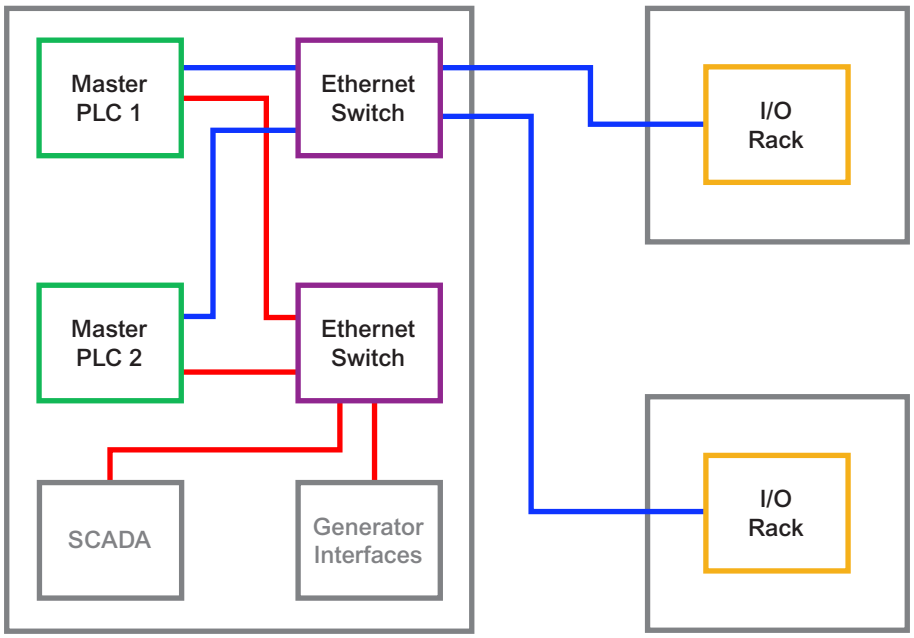

Figure 6: Redundant PLCs/Single I/O

While Redundant PLCs with Single I/O provides a greater level of availability than single PLCs, they do not offer maximum levels of redundancy. For facilities where availability is the highest priority, redundancy for both PLCs and I/O pathways are necessary.

Redundant PLCs and Redundant I/O

To eliminate single point of failure in a PLC system, both redundant PLCs and I/O pathways must be established. In this arrangement, a PCS is fitted with redundant PLCs in control sections and redundant I/O modules are installed in destination equipment. In addition, managed Ethernet switches are used so the either unit can assume the duties of the other if one becomes inoperable.

Redundant PLCs/Redundant I/O is commonly applied at hospitals and other healthcare facilities that are required to provide high levels of power availability. It is also commonly used at data centers that assign great importance on avoiding power interruptions to ensure high levels of service. Redundant PLCs and Redundant I/O is the most common arrangement selected by ASCO customers for their PCS systems. Figure 7 illustrates a Redundant PLCs/Redundant I/O configuration.

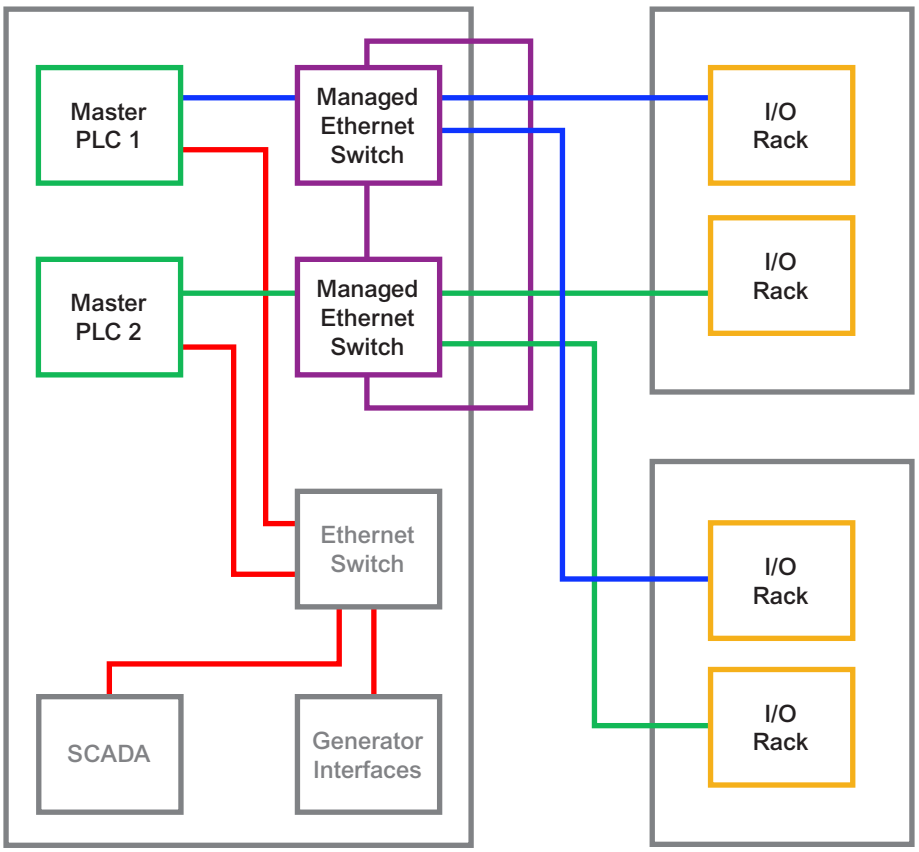

Figure 7: Redundant PLCs/Redundant I/O

Quad-Redundant PLCs and Redundant I/O

The Redundant PLC/Redundant I/O configuration above provides full redundancy for control, network, and communication functions. Using this arrangement, there is only one scenario where redundancy is absent. When a PLC is taken off-line for maintenance, service, or upgrade, the system will lose redundancy for communication, signaling, and control functions for the duration of the event. If an operational disruption occurred during this time-frame, the entire system could still malfunction, leading to a potential outage.

A large majority of facilities can withstand occasional losses in controller redundancy. For those that cannot, quad-redundant PLCs can be deployed to obtain concurrent redundancy and maintainability. While most often used in Tier IV data centers, the advent of modular data centers (where each module has its own power control system) could reduce the number of sites where quad-redundant PLCs will be used. Quad-redundant PLCs are shown in Figure 8.

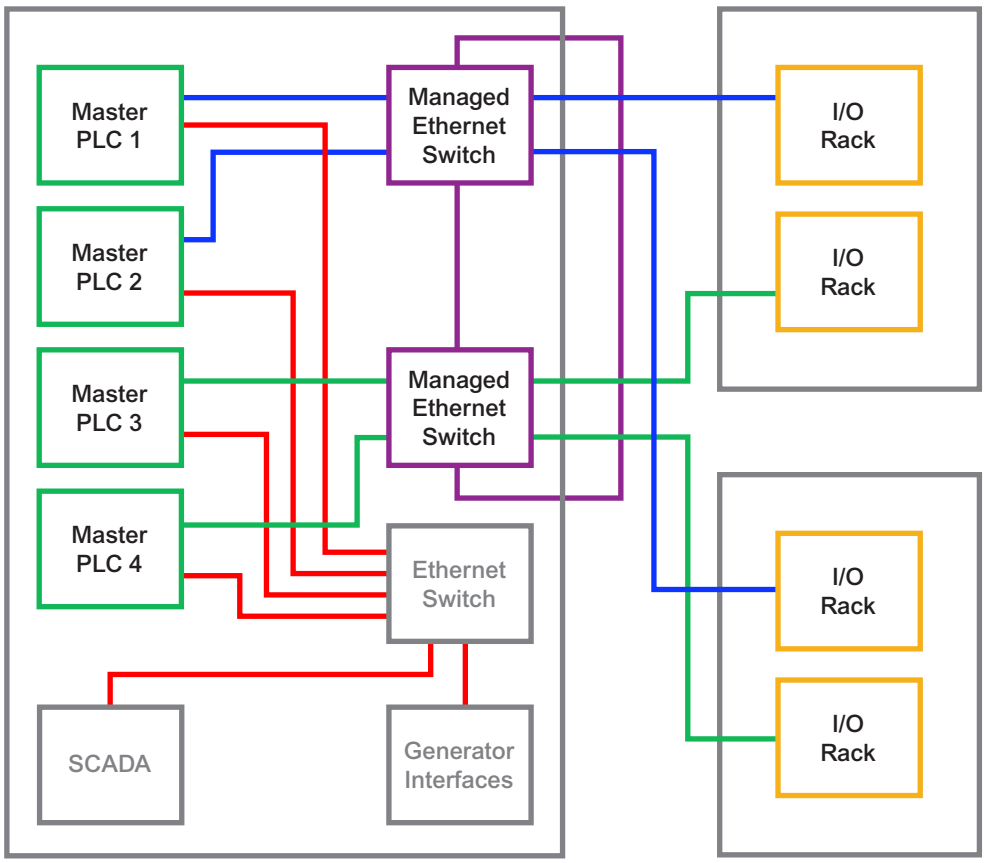

Figure 8: Quad-Redundant PLCs/Redundant I/O

REDUNDANT COMPONENT OPERATION

A redundant component can assume operation from a faulty component of the same type. For instance, if one of two redundant I/O modules fail, the alternate unit will assume the functions of the first. Likewise, a redundant controller can assume operations from another faulty controller to ensure continued system-level control. These transitions are “bumpless” – controllers can assume operation in less than one second, and I/O devices assume control immediately.

In a system with quad-redundant PLCs, any of the four controllers can assume operation at any time, regardless of their location. However, PLC 1 typically controls the system. In the event of an operating anomalies, control is sequentially transferred to PLC 2, PLC 3, and PLC 4, as necessary. Typically, PLCs do not assume control unless another PLC cannot continue to function properly.

EQUIPMENT LOCATION

One consideration for redundant PLCs regards their placement in equipment line-ups. When placed alongside each other in the same section, dual or multiple PLCs could each be affected by the occurrence of a physical threat to the equipment. For instance, if water from a pipe leak were to infiltrate a Master Control Section equipped with four redundant Master PLCs, all units could easily experience water damage, resulting in an outage. Splitting quad-redundant PLCs into two pairs and installing each pair in sections located at opposite ends of a power room reduces the chance that all four units will be affected by the same event. This arrangement is also helpful for minimizing impact on control availability during equipment maintenance.

SUMMARY

Single PLCs and I/O provide reliable service in power control systems. Nevertheless, redundant PLC and I/O equipment can be provided where the highest levels of reliability are required. While Single PLC/Single I/O configurations are best for applications requiring low cost, Redundant PLC/Single I/O and Redundant PLC/Redundant I/O configurations further improve reliability and availability. For the minority of facilities that require concurrent redundancy and maintainability, Quad-PLC/Redundant I/O configurations can be specified.

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