White Paper

How Power Problems Affect PLC Reliability

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Throughout many applications such as oil and gas, wastewater treatment, process control, manufacturing plants and security systems, troublesome localized power pollution is prevalent. A worst case example is offshore and onshore drilling platforms. Variable frequency drives (VFDs) powering large motors throughout the platform reflect large amounts of current and voltage harmonics back onto the platform's power grid. Often they appear as voltage dropouts. Additionally, during the startup of these motors, their exceedingly high initial inrush current demand can be so high it causes a platform-wide low voltage condition sustained for several seconds. Occasionally the harmonics and high current demand conditions create high voltage transients that can cause the complete failure of SCADA equipment power supplies. The costs resulting from lost productivity, equipment maintenance and reduced safety demand that power pollution be mitigated.

The Programmable Logic Controller (PLC) is ubiquitous in process control systems. It is at the heart of SCADA systems monitoring and controlling specialized equipment and systems. Manufacturers design PLCs to be very rugged and robust in an effort to assure longevity, reliability and safety. Yet, like any other microprocessor electronics, their reliability is to a high degree dependent on a reliable source of power. The level of reliability required from a PLC is dependent on the level of reliability demanded by the specific process being monitored and controlled. Some processes may be tolerant of a complete loss of power to the PLC, only requiring the PLC to reboot when power returns. In other applications the PLC must remain fully functional to allow the process to continue and terminate to a known state even after a complete loss of power. Some processes are so critical in nature they require that one redundant, or even two, safety rated PLCs be used. This class of PLC has been designed to never fail through redundancy, or at a minimum, fail only in a predictable, safe way. Typically their hardware, internal software and overall operation has been evaluated and certified by an independent safety agency like Underwriters Laboratories (UL) to established international standards.

The PLC like many other types of microprocessor-based equipment has an internal switch mode power supply. The PLC is typically powered from a standard AC utility source, or in some cases from a 24Vdc power source.

From these sources, the power supply creates tightly regulated DC voltages vital to the proper operation of the PLC's internal CPU, volatile memory chips and all of the other internal PLC electronics. These DC output voltages will stay within regulation over a wide utility voltage range. However, the acceptable voltage range is not infinite. Once the input voltage is out of its normal operational range, the critical DC output voltages will go out of regulation, causing the PLC to malfunction. This typically occurs during low input line voltage conditions (brownouts) or due to momentary or sustained voltage dropouts.

Switch Mode Power Supply Design

To understand these mechanisms one must understand the design of a typical switch mode power supply. Alternating current (AC) utility power enters the supply through an input filter stage having the primary function of blocking unwanted high frequency noise from being transmitted back to the incoming AC power line. The filtered AC power is then rectified to DC and heavily filtered with large electrolytic capacitors. These capacitors also provide a power storage reservoir, allowing the power supply to ride through sub-second utility power dropouts. An acceptable DC voltage level is maintained to power the remaining power supply electronics. The duration of this ride-through time is conditional, dependent on the incoming AC voltage level. Using a 120Vac nominal AC source at its 120Vac level, the electrolytic capacitors are at full storage capacity and will provide enough energy to maintain the maximum ride-through time, while maintaining essential regulated DC output voltages to the PLC's electronics. This typically is over 500 milliseconds. If the manufacturer's stated input voltage range is from 80 to 140Vac, the amount of ride-through time decreases as the AC input voltage decreases from its nominal 120Vac level. In the event the PLC is installed in a location experiencing sustained 85Vac low line conditions, the amount of ride-through time is reduced to almost zero. Should a large motor start-up or any other condition occur that causes the AC line voltage to drop-out for even a few milliseconds, it can cause the power supply output to go out of regulation resulting in a PLC fault or malfunction.

The PLC is not unique in having an internal switch mode power supply. Typically every other switch, router, computer, server and device connected to the SCADA system network incorporates the same type of internal power supply. This includes telemetry equipment supporting the reporting of remote pipeline remote sensors. All switch mode power supply designs are not equal, but every critical device on the SCADA system network is susceptible to fault conditions due to reduced ride-through times. Further, even having a full 120Vac line voltage, should a voltage drop exceed the equipment's full ride-through capability, the same PLC and SCADA networked equipment will incur failures.

Regeneration of New AC Power

A good solution to all of these problems is the addition of distributed double-conversion online uninterruptible power supply (UPS) technology. Through its continuous regeneration of new AC power, it provides the highest level of power conditioning and protection. Online UPS technology is ideal for use as a high performance power conditioner in addition to providing long-term battery backup protection. The UPS design topology is very similar to that of the switch mode power supply. The online UPS rectifies and filters the incoming utility or generator power to a steady regulated direct current (DC). Frequency variation, high voltage transients, voltage sags and swells, harmonic distortion, etc. are all removed. The clean regulated DC is then fed to a Pulse Width Modulated (PWM) Inverter stage that recreates clean, tightly regulated, true sinewave AC power. Before drawing power from its internal battery supply, the online UPS also has large electrolytic storage capacitors that allow it to ride-through voltage dropouts. Unlike the switch mode power supply, the online UPS has battery backup capable to power critical SCADA equipment for minutes from its internal batteries to hours and days using extended battery packs.

High-Temperature Industrial Online UPS

Due to the distributed locations and wide range of environmental conditions, a standard off-the-shelf computer-grade online UPS will not be up to the task. Take operational temperature for instance.

The operational temperature specifications for the vast majority of online UPS products on the market today are stated as 0°C to 40°C (32°F to 104°F). These UPS products have been designed for use in an indoor, temperature-controlled environment. Furthermore, they have undergone safety agency testing over the manufacturer's stated operational temperature range and have received a NRTL or Underwriters Laboratories (UL) listing for use over the stated range. As part of the safety agency product evaluation, the temperature ratings of key electronic components, displays, plastics, circuit board materials, insulating materials, and batteries are also verified to remain within their temperature specifications, while the UPS is operating over the entire manufacturer-specified temperature range.

For example, oil and gas operations are often located in some of the most severe operating environments — locations that require a wide operating temperature range of equipment. Installing a commercial off-the-shelf UPS in this type of location is not a wise decision. An industrial UPS (-30°C to 60°C, -22°F to 140°F) is more suitable for operation in this type of environment. These units are manufactured with high-temperature components and designed to operate specifically in harsh environments.

Some online UPS manufacturers offer their UPS products in turnkey systems pre-packaged inside NEMA 3 and environmentally-controlled NEMA 4 rated enclosures. For NEMA 3 rated systems, the UPS must be paired with robust batteries having a wide operational temperature range. This is not the case for environmentally-controlled NEMA 4 systems where 10-year long-life batteries can be incorporated. These turnkey systems are a fast, cost-effective solution to deploying high level power conditioning and backup into harsh rated environments.

UL 1778 and UL 508

Underwriters Laboratories is a nationally recognized testing laboratory (NRTL). The UL safety standard covering UPS products is UL 1778. However, when it comes to installing a UPS into an industrial control system it must be listed to UL 508, as well. UL 508 is the Underwriters Laboratories safety standard covering industrial control panels (ICP) and the equipment suitable to be installed inside them. To receive a UL 508 listing and the authorization to apply the UL 508 listing mark, the equipment manufacturer must resubmit the UPS to UL for inspection and testing against the UL 508 standard in addition to UL 1778. Once found to be in compliance to the UL 508 safety standard, the manufacturer is authorized to apply the UL 508 listing mark to the UPS.

After the industrial control panel has been installed, it is typically inspected by a local code compliance inspector. The inspectors verify the installation and the internal equipment is in compliance with UL 508, which is mandatory. The inspector looks at each piece of internal equipment, specifically for the UL 508 listing mark on the equipment. Should the inspector not be able to verify the listing status of any piece of equipment, including the UPS, it is subject to mandatory removal from the control panel. A few UPS manufacturers have received the UL 508 listing status on their online UPS models. When installing a UPS into an industrial control panel, care must be taken to verify it has UL 508 listing status or any NRTL equivalent.

In conclusion, not all online UPSs are created equal. Only double-conversion online industrial UPSs offer the high level of power conditioning and battery backup protection that oil and gas applications require. Engineers need to research and select UPS solutions that will not only eliminate and protect against power pollution, but also offer long-term reliability in demanding environments.

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