

Three keys to designing safe, reliable and efficient substations for heavy industrial facilities



In May 2013, a Mylar party balloon blew into a substation near one of California's largest oil refineries, causing it to lose power and disrupt normal business operations for at least 12 hours. The power loss triggered unplanned flaring and forced the company to evacuate contract workers at the plant as a precautionary measure.¹

More difficult to quantify was the cost to the company's reputation within the neighboring community. Some residents in the area reported an unpleasant odor in the air following the incident.²

Without the right substation design, the disruption this facility experienced and potential public backlash from environmental concerns could become more common at other heavy industrial plants and more costly as the size and complexity of substations increases.

In oil refineries, for example, power outages can cost up to \$3 million per shutdown, according to the Institute of Electrical and Electronics Engineers Gold Book.

Many traditional substation designs may not meet the long-term needs of heavy industrial environments. These companies need substations that are designed for safety and reliability to protect themselves against unplanned shutdowns and potentially hazardous conditions.

This paper explores three essential substation design principles that ensure reliable operation and minimize the risk of environmental and safety disasters for decades beyond the initial commissioning of the project.

Here are the three key principles heavy industrial users should consider when designing their substations:

- Select the proper substation configuration
- Engineer substations for safety
- Build reliability into the substation design

Select the proper substation configuration

The right substation configuration is the first step heavy industrial firms should consider to ensure their substations can handle their power needs. To accomplish this critical step, manufacturers must understand the system or process they will be powering. They should also understand what the loads will be on the system and how they are expected to perform. This means knowing whether motors are necessary and what types of motors are available, such as synchronous and induction motors.

For example, large motors can cause voltage drop issues if the system is not stiff enough to handle these starting loads. This could lead to power-quality problems, compliance issues with the utility interconnect requirements, tripping of relays to other critical loads, and possibly even damage to expensive motors, compressors or other equipment. When analyzing the system, the substation design can include safeguards to avoid these problems, such as incorporating proper system ratings, capacitor banks, statcoms and/or other equipment to stabilize voltage.

In addition to motor size, substation design needs to consider the type of starting method appropriate for the application. This can include direct-on-line starts, variable frequency drives and soft starts. Starting-method selection is important because it impacts transformer rating selection and the approach manufacturers take toward voltage regulation.

Manufacturers should examine reliability requirements, as well, notes Dustin Prescott, business development manager, industrial substations, ABB.

“In some cases the smallest interruption of power could cost a plant millions by damaging costly equipment or requiring the scrapping of product,” Prescott says. “In these cases layers of redundancy need to be designed into the system.”

Another critical consideration is the type of power delivery available from the utility provider. Industrial users should ask themselves:

- Does the utility provider have a single or dual feed?
- Is the dual feed radial or a loop?
- What is the strength of the utility system (short-circuit rating)?
- What are the terms of the interconnect agreement for voltage drop or power quality?

If these requirements are stringent and the system is fairly weak, then additional voltage support and filtering equipment could be required as part of the total solution.

There are many substation design configurations that will provide the power required. Whether it's a double-bus single-breaker, breaker-and-a-half, a four-breaker ring bus or another scheme, knowing the application and understanding needs will help industrial operations make the best decision on their power needs. Once manufacturers consider their substation configuration, they can begin analyzing different equipment technologies and how they affect the design.

Engineer substations for safety

Petrochemical and oil and gas producers in particular cannot afford to underestimate the need for increased safety, especially after high-profile plant explosions in recent years that caused several employee deaths and injuries. Manufacturers risk increased public scrutiny, fines and more stringent regulations with each catastrophic event.

The substation itself poses many inherent dangers. The purpose of a substation is to step-down high-voltage to medium-voltage usable power for the plant. Employees working on switchgear in this environment are in danger of arc-flash incidents, transformer explosions and other hazards.



Most accidents and injuries occur during routine maintenance. Through substation design and equipment specification, manufacturers can significantly reduce the amount of time technicians need to be in personal contact with the equipment – a significant safety advantage. In some cases, safer equipment may even require lower levels of personal protection equipment (PPE), so technicians can perform their jobs more efficiently. The ability to provide a safer work environment may help manufacturers attract skilled engineers and technicians who are in short supply.

Arc-flash protection

An arc flash is one of the most dangerous situations present in an industrial environment. Arc-resistant switchgear contains the internal arc pressure and directs it to exhaust chambers that safely vent the gases through flaps that push open under arc-fault pressure.

The front doors and rear and side panels of arc-resistant switchgear include designs that ensure they can withstand high pressures until the relief flaps open and pressure subsides. Interlocking flanges and gasket material seal in flames and keep hot gases from igniting flammable materials near the switchgear.

Another technology that helps protect against arc-flash incidents is an arc-mitigation relay system. These systems use fiber-optic sensors to detect arc faults. Top-performing relay systems can identify arc faults at the speed of light (2.5 milliseconds) before tripping the main breaker and minimizing an arc-flash incident. Arc relays can reduce arc energy by up to 80 percent in many applications, significantly cutting the risk of injury and property damage.

Many industrial operations are also implementing ultra-fast earthing switches (UFES). UFES triggers a three-phase short circuit to earth in the event of a fault. The extremely short switching time of the primary switching element (less than

1.5 milliseconds) in conjunction with the rapid and reliable detection of the fault ensures that an arc fault is extinguished almost immediately after it arises.

Remote monitoring

With remote-monitoring capabilities plant technicians can perform more predictive and preventive maintenance tasks without entering the substation. Integrated control systems can for the first time consolidate information about the plant operations and the substation in one, integrated view. Newer control systems that integrate substation automation with process automation systems aggregate data using an open standard called IEC 61850.

For example, the ABB distributed control system (DCS) is an extended-automation platform that uses the IEC 61850 standard to aggregate data from process and substation automation systems. The DCS then delivers integrated intelligence from the substation to plant operations. An integrated control system can identify when faults occur, classify them based on severity and notify other systems and parties inside and outside the plant to take necessary actions in real time.

For instance, if the control system detects an arc flash, the situation would be classified as severe. The DCS activates the integrated safety system to take appropriate actions to address the issue, while informing plant personnel of the hazard. The integrated power management system and the burner management systems in the power house will automatically take actions as well to address the problem.

“Without an integrated control system, operators are exposed to more dangers because they have to perform manual maintenance tasks,” says Jeffrey Vasel, North America area sales manager for ABB.

Build reliability and efficiency into the substation design

The party balloon that disrupted the California refinery could have had little or no impact on plant operations if more reliability were built into the substation design.

Manufacturers can improve the reliability and efficiency of their substations with innovative substation designs. Whether it's balloons drifting into the substation, animals chewing on cables or the occasional hurricane, exposed power components are always at risk.

GIS technology

One of the ways manufacturers can eliminate or minimize such costly shutdowns is through the use of gas insulated switchgear (GIS) substation components. Traditional air-insulated substation (AIS) components are not sealed, so they're exposed to the elements, making them more vulnerable to outages and other hazards. GIS protects substation components by enclosing them in aluminum tubes filled with sulfur hexafluoride (SF6 gas). SF6 has extremely high insulating and arc-quenching properties.

A sealed environment is especially critical for process plants located in coastal areas or arctic regions where hurricanes,



floods, wildlife and extreme temperatures can damage equipment and result in an outage.

“When you take these components and embed them into an SF6 gas, you’re completely sealing them so they’re not exposed to the harsh environments of, say, the Gulf Coast, or the harsh pollutants that might be present in a chemical facility,” says Prescott. “It protects the devices and reduces the opportunities for failure and maintenance issues.”

In addition, SF6 gas under pressure is much more dielectric (non-conductive) than air or dry nitrogen. The non-conductive attributes minimize the opportunity of an arc to occur. For instance, open-air disconnect switches can draw an arc when they’re opened. This can create a catastrophic explosion in refineries and petrochemical plants where combustible gas may be present.

GIS substation designs are up to 50 percent more expensive than standard configurations. But GIS systems may carry lower lifecycle costs because they require half the maintenance of traditional systems, Prescott says. With fewer maintenance requirements, GIS designs lower the likelihood of equipment failure and maximize substation power availability. The enhanced protection of GIS also can improve substation reliability by 1,000 percent and cut maintenance and inventory costs because fewer components are required.

Reduced maintenance increases uptime

Advancements in circuit-breaker technology also increase reliability by cutting the number of components industrial users must maintain, which also reduces opportunities for failure. For example, today circuit breakers as large as 550 kV require only one interrupter, whereas in the past this involved as many as four interrupters in series with their mechanical and electrical interconnections. In addition, disconnecting circuit breakers (DCB) eliminate the need for disconnect

switches. Instead of visible break, the DCB solution provides visible ground via its own incorporated ground switch. The elimination of disconnect switches also reduces the overall substation footprint and improves safety.

The use of magnetic actuators instead of spring-drive mechanisms in medium-voltage breakers also increases substation reliability. Magnetic actuators typically have seven moving parts compared with more than 100 in traditional spring-drive mechanisms. Fewer moving parts not only minimize the risk of failure, they’re quicker and less expensive to troubleshoot. “By eliminating parts, you reduce the opportunities for failure and maintenance requirements,” Prescott says.

Integrated process and substation automation systems also help industrial operations improve reliability and reduce maintenance issues by providing more visibility into substation equipment health. “With an integrated system, industrial operators can easily access information on the health of electrical equipment, recordings from protection relays and the health of circuit breakers,” Vasel says.

The integrated architecture allows industrial users to add plant electrical equipment health to the process control platform’s asset optimization system. This provides users with a single view for all critical process and electrical plant assets. Operators, engineers and maintenance personnel can view asset monitors for process functions, such as instrumentation and heat exchangers, and power equipment (including transformers and circuit breakers) on one screen. The centralized system helps plant personnel prevent plant disruptions and predict equipment failures.

Consider the capabilities of power system providers

All of these options available for industrial substation designs require the expertise of a knowledgeable power systems



provider – ideally a company with an intimate understanding of the equipment, software and communication assets. The power systems provider also should know how the substation connects with the power grid and the industrial plant. Companies with well-established power system solutions can help industrial users optimize their entire electrification system, including connections to a weak utility grid system.

As oil and gas production expands to new unconventional regions, many manufacturers are building plants in rural areas that are not equipped to carry large industrial loads. It is essential that these manufacturers understand how to meet local utilities' grid interconnect requirements.

“By eliminating parts, you reduce the opportunities for failure and maintenance requirements”

Many utility lines located in these regions tend to have low short-circuit capability. With lower short-circuit capacity, the manufacturer's substation must be designed to address a greater voltage drop. The voltage drop could exceed their utilities' requirements and cause issues with plant processes. Relays could trip opening breakers to critical loads. Power quality also impacts harmonics and resonance affecting the type of motors in the plant, as well as how to start these motors. Plants may need to perform system studies to determine if reactive power compensation is needed.

Most process manufacturers are not experts in electrification. Choosing the right partner for industrial substation planning, design, build and commissioning will help process manufacturers avoid potential grid connectivity and supply chain issues that commonly result in costly project delays and late-stage change orders.

Heavy industrial operations should consider a partner that can provide customized turnkey substation systems that efficiently and safely meet the company's power needs, allowing the plant to stay focused on its primary business. “A provider that owns the technology and the equipment knows the best ways to utilize that equipment,” says Prescott.

Many times, local engineering firms are not as versed in the different technologies that exist, says Ulf Andersson, director of engineering, ABB Substations. “They may say that if something worked 30 years ago it will still work today. That may be true, but will it be the best solution for the customer? Will it be as safe or reliable? Can it meet new and anticipated sustainability goals for your facility? You need to analyze it first and look at the different technologies available to make sure it's the best solution for the next 30-or-so years,” he explains.

In addition, manufacturers with on-site substations should consider a supplier that offers ongoing support for the life of the substation, Prescott says. “Instead of industrial firms managing multiple warranties from different manufacturers,

they only have to deal with one contact that can even handle third-party equipment,” Prescott says.

Conclusion

U.S. manufacturing is experiencing a resurgence thanks in part to unconventional energy sources that have created new opportunities for many industries, particularly in the oil and gas, petrochemical and steel sectors. As these facilities expand their capacity, they need more reliable substations to safely and dependably meet their power needs for years to come.

By following the three key guidelines outlined in this paper, manufacturers reduce their risk of commissioning a substation design that doesn't meet the company's critical operational objectives over the course of its active use. To accomplish this, manufacturers should:

- Select the proper substation configuration: Before a manufacturer begins the substation design process, they must have an intimate understanding of the plant's electrification needs and the utility requirements for connection to the power grid. Selecting a power systems provider that specializes in electrification at the asset, system and utility levels can greatly minimize the risk of costly delays and change orders during the design, build and commissioning of these initiatives.
- Engineer substations for safety: On a human level, it's just the right thing to do. But it also better positions the manufacturer as a superior employer in a competitive talent market for the knowledgeable engineers and technicians, who will ultimately manage day-to-day operations of the new substation. Safer substations also save downtime due to loss-time incidents and could reduce insurance rates.
- Build reliability and efficiency into the substation design: By specifying GIS technology, equipment with fewer maintenance requirements and assets that improve power efficiency, plants can minimize power outages and quality issues, increase capacity and reduce operations and energy costs.

As evidenced by major industrial plant disasters over the years, the benefits of protecting employees, plant equipment and neighboring communities may significantly outweigh any upfront cost differentials between a customized and more traditional design for industrial substations. Heavy industrial firms must consider all their options and make the right decision. If something as innocuous as a party balloon can interrupt operations, the risk of not taking an aggressive, proactive approach to industrial substation design seems pretty clear.

References

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² "Torrance Exxon Mobil Refinery Scare Triggered by Party Balloon," L.A. Times, May 30, 2013, <http://articles.latimes.com/2013/may/30/local/la-me-ln-exxonmobil-refinery-balloon-20130530>

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