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Environmental Solutions

Improving medium voltage VFD reliability and flexibility with environmental controls

Medium voltage variable frequency drives (VFDs) are fairly common in today's industrial plants, largely because they are proven to improve plant and process efficiency, reduce operating costs, and extend the life of critical assets (e.g., large-scale medium voltage motors). However, they contain power circuits and electronic components that, like all electronics, are susceptible to harsh environmental conditions.

Extreme temperatures, water (rain and snow) and air laden with chemical and salt contaminants are also fairly common in industrial settings, and these environmental factors are among the primary causes of equipment failure and reduced longevity. Even a single VFD represents a large capital investment, making environmental protection essential. Placing the VFD outdoors presents obvious challenges, yet integrating it into the plant and the manufacturing process can be problematic for other reasons.

As a result, stand-alone, environmentally controlled enclosures are on the rise – and with some integrators; they're becoming part of the standard drive package.

Figure 1 illustrates the plant requirements typically associated with integrating a new VFD: purchasing a single, stand-alone VFD; incorporating switchgear and other plant-specific components; adding motors or environmental enclosures; providing the plant automation system; and performing balance of plant (BOP) work.

Though few drive vendors are capable of performing all of these services, VFD manufacturers and systems integrators are starting to package the first three into all-in-one systems. The number of medium voltage integrators offering this type of package has rapidly increased over the last few years, as is particularly evident in the oil and gas industry.

Figure 1: Customer Plant Requirements

The burden of responsibility

Nowadays, medium voltage drives are as widely deployed as low voltage drives, and the environmental system approach is becoming popular due to certain advantages:

- Reduced plant engineering responsibility
- Lower administrative cost (one purchase order)
- Lower program management risk (single point of contact)

For many years, plants purchased medium voltage drives solely as stand-alone units or, sometimes, packaged with a motor and additional engineering content. The controlled environment required for optimal VFD performance would be specified by the manufacturer, but the responsibility – and associated costs – for meeting these requirements lay with the end user.

The manufacturer requirements typically entail building a laboratory-like control room, either an electrical equipment house (E-house) or power distribution center (PDC), that is air-conditioned to ensure proper VFD operation and reliability. In addition to allocating sizable floor space for the installation, the end user must also bear the cost of controlling the room's temperature and humidity and ensuring that contaminants (such as dust and chemicals) are minimized or eliminated.

Ultimately, the longevity of the VFD depends on the quality of its environment, leaving the customer with a number of burdens:

- Environmental control: The plant must prepare and maintain a controlled environment before the drive can be installed and commissioned.
- Space distribution and disruption: In addition to the disruption caused by any necessary demolition and construction, a sizeable amount of real estate within the plant must be allocated for the drive.
- Site costs: A dedicated or upgraded HVAC system and corresponding ductwork must be integrated into the plant's infrastructure to provide appropriate temperature control.
- Utility costs: Additional electrical costs for cooling the drive, both upfront and ongoing, contribute to an increased total cost of ownership for the drive system.

Although VFDs have been incorporated into E-houses and PDCs for decades, newer environmental enclosures are helping to relieve users of the burden of VFD installation costs, operating costs and environmental control responsibility.

Integrating environmental control

With the variety of environmental enclosures available today, there is no longer any need to take up valuable floor space in the plant to accommodate drives. Some enclosures even allow the drive to be placed up to 2.3 km (7,500 feet) away from the motor, allowing for additional flexibility in plant design.

In some cases, a medium voltage drive manufacturer can supply a small, environmentally tested shell with a NEMA3R, NEMA4 or NEMA4X rating, allowing the VFD to be placed almost anywhere outdoors at the plant site. This type of enclosure eliminates the requirement for an air-conditioned control room and may require nothing more than a concrete pad and power connections. Note that NEMA ratings apply to low voltages and, when discussing medium voltage applications, the NEMA4 rating is typically referred to as a "Type 4" enclosure or rating. In all respects except voltage rating, the specifications are the same.

Other all-weather solutions include virtually everything needed to integrate a drive into the existing infrastructure without disrupting operations. In addition to not requiring dedicated space within the plant, these larger enclosures generally include integral temperature control, eliminating the need to install and integrate additional HVAC.

Additional features allow operators to easily access main power connections without exposing the drive to external elements, helping to further reduce maintenance and downtime caused by environment-related drive failure.

These all-in-one approaches help minimize the engineering required on the customer's end: All that needs to be supplied is a concrete pad and power cabling. Commissioning is expedited and can sometimes be completed in as little as two days.

Specific all-weather enclosure designs

Environmental enclosures for VFDs typically fall into three distinct categories:

1. A self-enclosed Type 4 VFD cabinet

2. A containerized solution, or "box within a box"

3. A PDC or E-house

The approach taken depends on the plant or site's specific needs, with the goal being to provide maximum flexibility and added value.

Self-enclosed Type 4 cabinet designs

With this approach, standard NEMA style 1 or NEMA style 12 cabinets are replaced with a cabinet specifically designed for outdoor use. These are typically changed to a Type 4 (NEMA 4 rating) and utilize an air-to-air heat exchanger to isolate the internal drive components from the outside air.

In most cases, the internal components include only the VFD, but some designs include an input isolation switch and protective fuses for the VFD circuitry. Note that this is a remote, unmanned location, and the VFD is equipped with Type 4 cabinet with air-to-air heat exchangers.

Free-standing NEMA-style, all-weather drive enclosures with integral cooling offer the maximum protection against external elements. However, care must be taken to specify the VFD rating, because the air-to-air heat exchangers require a 5–10°C temperature difference to operate properly.

This means that an internal ambient temperature of 40°C for the VFD components limits the outside ambient temperature to 30–35°C. In many cases where this environmental approach is used, the ambient temperatures can be as high as 50°C, which requires an appropriate derating of the VFD components.

That said, stand-alone VFDs equipped with this type of outdoor cabinet can operate over a wide range of temperatures (-20°C to 50°C), and they provide an additional envelope of safety for the operator, similar to metal-clad switchgear. The drives themselves are typically insulated and equipped with space heaters to prevent condensation.

Air-to-air heat exchangers help filter out air contaminants, although care must be taken with salt air and certain dusts, especially in locations where dust particles are very fine and can clog the heat exchanger's inlet filters. Since these are most commonly used in unmanned locations, a VFD trip due to high thermal conditions can be a particularly costly shutdown.

Type 4 designs accommodate more limited horsepower ratings, ranging from as little as 150 Hp up to several thousand Hp. Larger stand-alone systems (>3000 Hp) have greater cooling needs, so they generally require a containerized solution.

Containerized Solutions

In cases where higher-power drives or a switchgear line-up is required, a containerized solution can be implemented. This design approach is sometimes referred to as a "box within a box," because the VFD is placed in a separate enclosure. This design has the ability to be either Type 3R or Type 4. No special parts or maintenance are required, and no secondary barrier or fence is required around the drive to secure it.

Most of these types of enclosures stand by themselves, are classified as non-walk-in enclosures, and include an independent, third-party structural engineering review for each site. Each enclosure bears stamps for compliance with local and state building codes.

Due to their size, these types of systems can be equipped with more robust heating systems and HVAC systems for a Type 4 arrangement. Type 4 containerized solutions are mostly used in areas where a separate or isolated environment was desired for the VFD, such as sea-proximal locations where corrosive salt-laden air is prevalent.

A containerized solution can integrate several different types of filter systems, from a light industrial filter to heavy harsh-environment or specialty filters, such as those designed to prevent ingress by sea salt and water in off-shore environments.

By implementing environment-specific filters, the VFD never sees anything but clean, cool air, helping it to operate optimally throughout its specified life. This approach has been used on oil platforms where the VFD and its environmental system are located 90 feet above the ocean, using the salt air to cool the unit. The special filtering, which captures the saltwater molecules, is typically designed to last for five years before replacement.

Containerized VFDs can also be easily relocated and the filter system can be upgraded or downgraded if the application or plant requirements change. The entire VFD and its enclosure can be easily lifted and transported as a single unit to a new location in the plant – or an entirely new site. This approach has been used by oil and gas users with portable drilling equipment: They are able to use the drives at one well and then move it 100 miles away to a new well location.

The environmental shell is designed to provide a clean environment for the VFD that can be located anywhere on the plant site. Some drives can be located up to 7,500 feet away from the motor, anywhere an open concrete pad or level gravel area is available and the motor and utility connections can be made.

Power Distribution Centers

When very large or multiple VFDs need to be co-located along with other equipment (e.g., UPS systems, additional switchgear, low voltage power panels or MCCs, even small office space areas), E-houses and PDCs have long been common solutions. Many VFD manufacturers can provide seamless, transparent PDC integration either in their own facilities or in partnership with system integrators who manufacture their own PDCs.

VFD users generally have three options for integration: They can engage their own integrator and order the VFD and other components separately, they can order directly from an integrator who procures the VFD and other equipment, or they can order the complete system through the VFD manufacturer.

As mentioned earlier, ordering everything through the VFD manufacturer can help streamline the process while minimizing administrative costs. The manufacturer handles everything, from procurement and delivery to integration and commissioning, and most already have established relationships with a number of preferred PDC vendors.

When PDCs are used or VFDs are located in existing control rooms, the addition of HVAC systems to cool the VFDs can be expensive and increase the total cost of ownership (TCO) for the entire system. Cooling requirements may also increase maintenance and utility costs over the life of the VFD. For this reason, some VFD manufacturers are now offering air-to-air heat exchangers.

The use of air-to-air HEX units virtually eliminates the need for an HVAC system by removing approximately 95% of the heat load in the control room or PDC. ROI analysis generally indicates a two- to three-year payback in utility cost savings and maintenance costs.

Conclusion

Together, the flexibility, protection and simplicity offered by the full range of controlled-environment solutions available today add up to significant savings. Increased energy efficiency helps drive down utility costs, and the reduced need for maintenance helps minimize those costs – and related downtime costs – as well.

Modular, all-in-one designs virtually eliminate the user's environmental control burdens while delivering greater flexibility, protection, simplicity and savings than traditional stand-alone drives. The selection of an appropriate all-weather drive system is usually based on the drive's Hp rating, auxiliary equipment needs and plant real estate availability.

The environmental control approach also helps to extend the life and increase the efficiency of the VFDs. Controlled-environment drive solutions have been successfully deployed to protect against a wide range of harsh conditions, including:

- Heat, dirt and sand at remote stations in the deserts of West Texas
- Sub-Arctic temperatures (-40°F), snow and ice on the north slope of Alaska
- Air contamination and cold temperatures in the Canadian oil sands
- Salt and shipboard conditions in the Gulf of Arabia

The concept of integrating an expensive VFD asset with the environmental shell continues to evolve, offering a valuable solution for a wide range of applications in the oil and gas industry, chemical plants, municipal water plants and other industrial processes located in challenging and remote environments.

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