Selecting the Best Option for Mounting Low-Voltage AC Drives

Jeff Raefield, Power Technical Consultant, Rockwell Automation

Much has been written about how users should mount and wire low-voltage (≤600V) AC variable frequency drives (VFDs). Unfortunately, much of this content is biased, either decrying the shortcomings of competitor products or extolling the virtues of the author’s solution. This paper will seek to provide a more balanced approach, addressing a number of key issues that users should consider when laying out and connecting AC VFDs in either new or existing facilities.

Main Areas of Concern

Environment and safety are two important, yet often overlooked, aspects involved in the use of VFDs. The three basic packaging formats also must be considered: motor control centers (MCCs), group mounted in industrial control panels (ICPs) and standalone wall mount or floor-mounted “cabinet” VFDs. Each of these formats has its own set of inherent risks, benefits and limitations.

Combining all of these elements together makes the selection process less of a black-and-white decision and more of a nuanced compromise. Indeed, how users implement a VFD in one part of a facility may be completely different from a different area of that facility.
Environmental Issues: Handling the Heat

An old adage in power electronics is: Heat x Time = Failure. While there have been significant design and material improvements that have resulted in much higher reliability, heat still remains the biggest enemy. That’s why careful consideration must be given to thermal management when deciding where VFDs should be located and mounted.

All AC power electronic equipment produces heat, mostly from what are called “switching losses” in the power devices themselves. In VFDs, it is power transistors, which are the output devices that make the magic happen. Power transistors are always mounted with a “heat sink” that allows the heat created by the switching losses to be moved away from the transistors themselves as rapidly and efficiently as possible.

If heat is not managed effectively, it builds up in the “junction layers” of the transistors or the silicon structure of the semiconductor itself. This can cause the layers to fuse or melt, at which point they cease to function.

Overheating can also do more than damage transistors. Modern VFDs in smaller frame sizes now use a power structure known as an “IPM”, short for intelligent power module. This component strategy, used by all drive manufacturers, is what allows for smaller, cheaper and faster drives than previous generations. An IPM combines all of the line- and load-side power devices, along with their individual firing circuits, into one compact assembly (see Figure 1) that is then attached to the heat sink. This means that when one component within the IPM is compromised, the entire IPM is no longer functional.

Furthermore, there are hundreds of other smaller discrete components and subassemblies in a VFD. These components all work in concert, meaning overheating affects them as well. Add all of this up, and thermal management should be one of the foremost considerations when deciding how and where to mount VFDs.

Environmental Issues: MCC Mounting of VFDs

When VFDs are installed in an MCC assembly, there are specific UL-845 assembly requirements and test procedures that address the proper thermal management within the entire lineup. Collectively referred to as a “heat rise” requirement, this dictates that the entire assembly must be designed and tested for operation in a 40 C environment without risking failure or compromising the safety of the MCC.

This makes an MCC lineup desirable because it confirms the VFDs will also be in a 40 C ambient environment along with the MCC. This often means that the individual VFDs must use fans to remove their rejected heat into the local air space – a design factor that must be taken into consideration when designing the MCC room airflow requirement. From the standpoint of the equipment design itself, the MCC manufacturer is already required to certify the VFD will not be harmed by being in the MCC lineup, nor will the heat produced by the VFD(s) compromise other equipment in that same MCC. This helps to assure the end user of a properly designed thermal-management system for their VFDs from the start.
Wire management, safety and short-circuit concerns are also most effectively addressed in this format (as discussed later). One limiting aspect, however, is the strict requirement that the entire MCC lineup’s internal temperature cannot be raised beyond the design limits. This means that there is always a limit to the maximum size of VFD that can be mounted into an MCC. As a rule of thumb, this generally works out to be about a 250 A-rated VFD, meaning 200 Hp at 480V. So above 200 Hp, it is generally recommended that VFDs be in their own enclosures with whatever individual cooling means they require, rather than sharing the internal air space with the rest of the MCC. Rockwell Automation has options available for directly coupling the bus bars of the MCC to adjacent large drives, yet keeping the enclosure air spaces separate.

An often misunderstood restriction to the MCC-mounted drives concept is that the proper thermal management and UL-845 listing of the assembly can only be done by the MCC manufacturers themselves. This means using VFDs that the MCC manufacturer is willing to list (often only their own).

Panel builders, even if they’re certified under UL-508a, cannot add VFDs into an MCC and maintain the UL listing of it. UL-508a panel shops may make modifications to control circuits within an MCC, but they cannot add power devices without short-circuit testing and the heat-rise requirements. UL-845 also dictates that if one unit in an MCC is not listed, the entire lineup is not listed.

All of this ultimately means that the concept of using one brand of VFDs in the MCCs of another manufacturer can only be done if UL listing of the entire MCC lineup is not required. That also applies to placing VFDs into MCCs that are larger than what the UL-845 MCC listing allows. So when a panel builder mounts and wires one brand of VFD into a different brand of MCC, there is no way that assembly can be UL listed – and the listing of the entire lineup becomes null and void. In many areas of the United States, this means the equipment cannot be installed and pass inspection by the authority having jurisdiction. It can also mean that equipment must meet requirements of industrial insurance underwriters that insist on having UL-listed equipment.

**Environmental Issues: VFDs in Industrial Control Panels**

When smaller VFDs are needed for a machine or group of machines that must all run together, one option is to put multiple VFDs inside one enclosure as an industrial control panel (ICP). This system is typically used by UL-508a panel shops, rather than MCC-mounted drives, because they themselves can provide a UL listing of the complete assembly, regardless of the mix of manufacturers used inside. This option has some immediate benefits because the overall space required for multiple small drives can be less than in an MCC format. Other issues, such as power management, safety and connectivity, also can be more easily addressed.

However, there are some environmental issues that must be carefully considered.

Enclosing VFDs inside of an ICP means that users must decide on how the heat will be managed. If the ICP must be sealed – as in NEMA type 12, 4/4X or even sealed 3R where there is no exchange of air – having VFDs inside will often require adding an air-conditioning unit (ACU) to maintain the internal temperature to within the limits of the VFD design. You should follow manufacturer’s data regarding heat rejection for your specific VFD and application, but a general rule of thumb is to estimate that the VFDs will reject approximately 3 percent of the total power going through them as heat into their immediate surroundings.
For example, 12 drives in a sealed box – adding up to a total of 42 Hp at full load – equates to 31 kW of power. And 3 percent of that means the drives, in total, will be rejecting more than 900 W of heat into the box. Industrial ACU manufacturers will often provide simple calculators that pick the size of an ACU based on this heat load, ambient conditions, enclosure type and exposed surface area. Regardless of the outcome, it is important to understand that the ACU must be maintained and monitored to confirm it is functioning. The loss of the ACU can result in the loss of all of the VFDs in short order.

If users can ventilate the ICP, they must make sure that the total volume (CFM) of air exchanged, at the maximum ambient temperature, is sufficient to maintain the internal temperature within the design limits of the VFD (or any other component in the ICP). A quick rule on starting this process is that users must have at least a 10 C delta (difference) between the air used to cool the enclosure and the maximum component temperature. So if the maximum component temperature is 40 C (104 F), the maximum ambient air for ventilation must be no higher than 30 C (86 F). If the ICP is outdoors, this may be difficult to attain. (Note: Most Rockwell Automation VFDs are rated for 50 C. Some can be used up to 60 C and even 70 C with de-rating and added internal (stirring) fans. But most other electronics and even some electromechanical devices are rated for use at 40 C).

If the ambient air being circulated contains dust and/or moisture, filters must be used to mitigate contamination. This introduces a maintenance item because failure to periodically replace filters will result in components overheating. If necessary, automatically warn users of impending filter problems. These features add cost and complexity so they are often omitted, but should be considered when consistent routine maintenance is impractical and/or problematic.

Another viable alternative to ventilating an ICP is to use what is called a “flanged” or “fins-out” heat sink on the VFD. This allows the majority of the heat to be expelled into the ambient environment without entering the ICP sealed space at all. The same 10 C temperature delta rule still applies. But this approach may eliminate the need for an ACU, or at least reduce its size and cost if there are other heat-sensitive devices inside. When a standalone NEMA Type 4/4X wall-mount drive is purchased, this is the heat-sink style typically utilized in that design:

![Figure 4 — Flanged VFD for use in dissipating drive heat directly to the outside (rear) of an ICP enclosure](image)

![Figure 4A — Flanged VFD in factory NEMA 4X package](image)
Flanged drive options are not available on all sizes of VFDs because of component limitations. But they are available in Rockwell Automation drives between 1/3 and 250 Hp at 480V. These drives are a good option given the costs of an ACU and the risks associated with ventilation.

Environmental Issues: Wall-Mount/Cabinet-Style VFDs

Wall-mount VFDs, which are placed on facility walls as close to the motor as possible, present the similar and additional considerations as ICPs. In addition to heat, wall-mounted VFDs will typically have fans that push and pull air through the drive housing for cooling. That airflow will be going across not only the heat sinks, but also the printed circuit boards (PCBs) and other somewhat sensitive components inside of the drive. Careful consideration must be given to what else may be present in that ambient air.

Moisture, machine oil, dust, chemicals and even pests that get into the VFD can cause damage or even just build up debris that lowers the cooling efficiency. Even when VFDs are ordered as NEMA Type 12, there will still be fans and filters on larger sizes (over 5 Hp). Again, this introduces the issue of filter maintenance. Some gasses should be avoided altogether because they can corrode the PCBs and connectors. For example, H2S combining with airborne moisture will make sulfuric acid. Rockwell Automation provides what is called "conformal coating" on all PCBs used in its VFDs, but this is not a perfect solution and cannot be used on any removable connectors.

Almost all drives will be rated for use in areas with up to 95 percent relative humidity (RH) noncondensing. Keep in mind there may also be a minimum RH that must be maintained on some drives as well because, if too low, static electricity becomes a problem when the air is moved across the components. This is especially concerning for drives that do not use conformal coating on their boards. Rockwell Automation drives, with all of the boards being conformal coated, are all rated for 5 to 95 percent RH in operation.

At motor horsepower sizes above 400 Hp, VFDs typically become too large to mount on the wall and are built into free-standing structures that bolt to the floor. In these options, often referred to as cabinet-mounted, the amount of airflow needed to keep the heat sinks performing their best becomes too high for simple "muffin fans." They instead require high-volume blower assemblies. And with a high volume of air comes the potential for a high volume of contaminants that, even if present in small amounts, can build up quickly. The only thing that differs from what has already been said for wall-mounted drives is the need for a completely separate air channel for cooling the heat sinks, which is found on the Allen-Bradley® PowerFlex® 755 AC drives.

This helps prevent high volumes of air from mixing with the more sensitive control PCBs and other components. They have their own separate, cooling airflow. However, because there is not much heat in those sensitive areas, the air movement is a fraction of what must flow over the main power module heat sinks. This helps prolong the service life of the VFD and prevent costly downtime while maintaining the high airflow required by the power-device heat sinks.
Environmental Issues: Outdoor VFD Application Concerns

When any VFD is mounted outdoors, special attention must also be paid to direct sunlight exposure. Heat sinks and even enclosure walls will work as heat collectors when exposed to an external heat source, such as solar radiation. So whenever VFDs are mounted outdoors, the best practice is to protect them with some sort of sun shade. This is often a simple shed, lean-to, canopy or even an awning on the side of a building. Pay attention to sun angles as the day and year progresses. Often during the hottest time of the year, if the late afternoon sun moves to hit the enclosure, that is also the time of day the surrounding air is already at its highest temperature.

If direct sun exposure cannot be avoided, it is best to use white or other reflective paint and line the inside of the enclosure with foam board or other solid thermal insulation to minimize heat gain from the solar radiation. Venting in Type 3R structures like this should also be done through downward-facing openings to minimize the introduction of moisture from rain or snow.

Proper heating of outdoor-mounted VFDs is also crucial. Users must maintain the VFD internal air temperature to be above the atmospheric dew point, the point at which moisture will condense on surfaces. The dew point varies with RH but a safe minimum value is 40°F (5°C) in cooler areas. In warmer areas with high humidity, this value can be much higher. Local conditions should be checked. This is typically done with enclosure heaters, but they should have adjustable thermostats to avoid leaving them on all the time.

The heating unit should be selected based on the lowest watt density (W/in.²) possible to keep the exposed surfaces safer to touch. Light bulbs have been used for this purpose, but they are too easily broken, and the glass surfaces can be too hot. Also, make sure that the fans are not pulling in cold air at the same time and defeating the purpose if the heater is on in colder conditions.

In addition to avoiding condensation, it is also important to avoid the risk of freezing. Frozen electrolytic capacitors lose their properties and can immediately short or even explode just from being energized in a frozen state (the drive does not need to be commanded to run). The minimum ambient operating temperature of most VFDs is 0°C (32°F). But if power is off, they must never drop below the minimum storage temperature. This value varies by design but is usually -40°C (-40°F) for PowerFlex drives.

If hard freezing is a possibility, use a line isolation contactor ahead of the drive. The contactor is tied to a thermostat that will disconnect power to the drive if the interior enclosure temperature is below freezing for an extended period of time. It will not allow re-energization until it is above the minimum operating temperature. Special care then must be taken when using VFDs outdoors if powered by generators. If the generator is not running, the heaters will not work either.

Insects are an oddly common problem when using a “flanged” VFD outdoors. They can find the warm and protected fins of the heat sinks an ideal place to raise their young, creating nests that block the airflow. Precautions should be taken, such as with screens, to avoid this – even then, routine inspection is a good idea.
Environmental Issues: Prefab Buildings

When there is a large group of drives, MCCs and ICPs, and even switchgear and transformers that need to be mounted outdoors, a site-built structure may not be an option. In these instances, a skid-mounted electrical building or “E-House” may be a viable solution. This is a prefabricated, outdoor-rated metal building specifically designed to house electrical equipment. It is integrated with complete environmental controls, cable trays, communications and code-compliant fire suppression.

The entire assembly is made off-site, and all of the equipment is mounted and interconnected as much as possible. Then the entire unit is tested, verified and shipped to the project site to be placed onto a suitable prepared space, leaving the user with a turnkey solution where they simply connect line and load cables. In addition to solving the environmental issues all at once, it often provides tax benefits to some users.

Safety Issues: General

Safety is another serious concern in deciding how and where to mount their VFDs. This is not pertaining to overall machine safety, per se, but rather to the safety of personnel who must use, adjust and troubleshoot VFDs in a facility. Emphasis on arc-flash safety in particular is driving companies to rethink their approach to VFD safety.

As a general rule, if a system requires opening a door to read or enter data, troubleshoot or make simple changes to programming, then the VFD must be energized. This means technicians will be exposed to whatever arc flash or electrical hazard exists in that enclosed assembly. As a result, they must wear the appropriate personal protective equipment (PPE) to perform these tasks. PPE, such as arc-resistant gloves, can make keypad entry of data very difficult. Also, any exposure to live terminals means workers are exposed to the arc-flash hazard represented by the energy in that enclosure. Older, traditional packaging often does not take this into account. This should be considered when deciding how to mount VFDs.

A final word on general safety for all VFDs: Significant and potentially lethal energy will remain on the DC bus capacitors for a long period of time, even after they are disconnected from the power source. Most VFDs provide some form of indication as to the status of that energy, such as in the form of LEDs or a display that stays active after power is cut. Users should familiarize themselves with all of the safety guidelines in any VFD manual, especially with regard to this issue.

Safety Issues: MCC Mounting of VFDs

Perhaps the most persuasive argument for mounting VFDs in MCCs is that the safety will be inherent as part of the overall MCC design. When VFDs are mounted in MCCs, all of the personnel safety issues become common to the entire MCC decision-making process. If a user wants MCCs to be arc resistant, the VFD cubicles must by definition become arc resistant as well. If they opt to deal with the arc-flash risk of the MCCs by locating them in a locked or controlled access area instead, the VFDs end up under that same protection scheme. Beyond the actual arc-flash protection issues, there are other personnel safety issues afforded by MCC mounting.
First and foremost, any VFD’s short-circuit current rating (SCCR) is so inherently low all by itself that it is impractical to consider using them standalone in most industrial environments. A higher SCCR can only be attained when combined and tested in series with specific over-current protective devices (OCPDs).

In an UL-845 MCC unit, a VFD will be required to be in a tested and listed series combination, performed by the MCC manufacturer at a level that meets or exceeds the MCC SC rating. There can be no calculated estimates, procedures or guesswork that suffices for UL-845 listing. They require a full destructive test of every possible configuration of power components in the MCC unit. This assures the user that as long as the overall MCC specification meets the site conditions, every unit within it, including the VFDs, will be certified to be connected to that system.

User access to a VFD via the HMI is, unless otherwise specified, always brought out to the cubicle door in an MCC format. This means that whenever an operator is required to read, adjust, program or troubleshoot a VFD from its display, they will not need to open the cubicle door and expose themselves to the safety hazards inside.

If the MCC is ordered as arc resistant, this can mean that anyone “interacting with the equipment”, as defined in the NFPA 70E “hazard risk category” (HRC) section, will be able to do so with the absolute minimal PPE requirements regardless of the HRC of the MCC with the door open. Even if the optional arc-resistant MCC was not used, an MCC is still providing a safer method of doing the most common tasks associated with using VFDs. This is the same as any wall- or cabinet-mounted VFD, but often contrasts to a large group of VFDs in an ICP, as discussed later.

Another aspect of safe interaction with VFDs is the ability of a technician to kill power to the VFD, both to the VFD itself or to the equipment it is controlling, when doing service work. This means performing a “lock out/tag out” (LO/TO) procedure, in which the controller is de-energized and cannot be re-energized without the technician allowing it. When mounted in an MCC format, every VFD cubicle will end up having its own disconnecting device (circuit breaker or fused disconnect) capable of being used in any number of common industrial LO/TO protection schemes. That disconnect will also only disconnect power from that single unit, not the entire system.

Again, this is often the same for wall- and floor-mounted VFDs, but contrasts with some ICP designs. This aspect of individual LO/TO capability means that if one unit must be disconnected, all other units in the MCC lineup are not affected other than by the process itself, and can be left undisturbed. When unexpected shutdowns cause loss of production revenue, fines for discharges or other economic losses, the risk of those costs must be part of any evaluation with regard to any cost differences in comparing mounting the VFDs in MCCs versus group mounting in ICPs.

In Rockwell Automation MCCs, the SecureConnect™ option can allow a single unit to be removed from the MCC lineup without requiring the entire MCC to be shut down. It does this with a mechanism to remove the stabs from the bus, which is activated from the outside through the closed cubicle door. When the entire MCC bus cannot be shut down, this feature increases the safety of electrical personnel by not requiring a “hot electrical work permit.” A single VFD small enough to use stab-in connections (about 50 Hp and down), can be removed and replaced with a spare without disturbing the rest of the equipment in the MCC lineup or exposing the workers to additional unnecessary risk.

With automatic device configuration (ADC), a VFD can be replaced without an overall shutdown in a matter of minutes and automatically reprogrammed by the system. This can be done without the installing electrician needing to know anything about VFDs or programming them, making it a very safe option for workers who may not know everything about all components.
Wire management, another aspect of safety when troubleshooting, is also simplified within an MCC format because all incoming power is coming from bus bars, not additional cables. When something needs to be investigated, this virtually eliminates the time-consuming process of determining if the problem is related to the line- or load-side connections. If something is wrong with the line side, it is more immediately evident by the fact that all units in the MCC would be affected and can be tested at any point in the entire lineup.

Finally, if users are in an area where seismic bracing of equipment is required, most MCCs will have the necessary approvals or ratings required by international and local building codes for seismic withstand. This can make overall project approvals simpler and easier to attain compared to submitting multiple individual wall- or floor-mounted VFDs, or for an entire ICP that has been custom-designed.

Safety Issues: VFDs in ICPs

While it is difficult to judge every panel design in absentia, it is important to understand the potential safety aspects of going with an ICP format for multiple VFDs. First is the issue of getting a proper SCCR from the ICP supplier. The U.S. National Electric Code requires that all ICPs must be marked with a rating plate on the outside showing the SCCR for the assembly, meaning the maximum available fault current (AFC)* to which the system can be connected. AFC is then determined by the utility source capacity, the size and impedance rating of the service transformer, minus the impedance of the circuit conductors between the service and the ICP. (*AFC is also sometimes referred to a prospective short-circuit current or PSCC.)

Unless the end user specifically requires it otherwise, a typical SCCR for an ICP may end up being as low as 5 kA, meaning they cannot connect it to a power system with more than 5,000 A of available fault current. This is just a “courtesy” rating allowed for custom assemblies of untested components. But 5 kA AFC is virtually impossible to attain in an industrial application, especially where 480V service is used. A rating of 30-65 kA is very typical, and occasionally it can be as high as 85-100 kA. Yet when a system is not tested by someone like UL, this is sometimes the only option left available to the ICP builder. If the user doesn’t require it by clearly wording their purchase specifications, some ICP builders will ignore the issue and just use the 5 kA “courtesy” label.

It is possible, using the correct documentation from the VFD manufacturer, to use a specific series combination of OCPD + VFD to attain a higher SCCR rating for that combination, often up to 100 kA as a combination. But the specific devices listed in that documentation must be employed – substitutions are not allowed. In addition, if any other component or series combination of components used in an ICP has a lower SCCR rating than the VFDs, the entire ICP cannot be listed at a value higher than that lowest rating.

For example, even if the ICP builder uses the correct OCPD with a VFD to attain a listed series combination rating of 100 kA, but they used a power terminal block inside that is only rated for 10kA, the entire ICP can only be given an SCCR of 10 kA. That rating is also very difficult to attain in an industrial situation. Therefore, it is imperative for users to be very explicit when having a panel builder make them an ICP by specifying an overall SCCR label at a value that allows the equipment to be installed at the intended location.

Another safety aspect that needs consideration is how the ICP and the equipment it is controlling is going to be used. Arc-flash safety and general LO/TO requirements usually mean the main disconnect of that ICP will need to be opened, locked and tagged in order to work on anything inside or connected to that ICP. Having multiple, through-the-door disconnect devices is extremely difficult to manage. An ICP may make sense compared to an MCC or separate VFDs in the case that if one part of the system is shut down, the entire system must be shut down anyway. This is because the entire group of equipment fed by the controllers within that ICP will be shut down if any unit must be serviced.
On the other hand, if the rest of the equipment can or must continue operating, using an ICP may present an unforeseen safety hazard. Opening the enclosure door to service anything inside of an ICP while leaving everything else operational means the technician must use their established safety protocols for “live electrical work” (often a permit signed by management). This process is seen as onerous by many workers. Also, pressure from management to maintain production goals may lead to unsafe practices being performed, exposing the electrical worker to the hazards. Even if a safety incident does not happen, the entire facility could face fines or work stoppages if these unsafe practices are brought to the attention of safety agencies. So before deciding to utilize an ICP for a group of VFDs, consider those possible consequences.

If the ICP remains a viable option, the next thing to consider is access to the VFD HMIs. Again, having to open the door of the ICP in order to read or change anything using the HMI will result in exposing the technician to the electrical hazards within the ICP (revisit Figure 3 with this in mind). So, like the MCC option, it is advisable for the ICP design to have all of the VFD HMIs on the front door.

If a PLC or PAC is involved, users can install an industrial monitor or PC on the front door that has access to all of the VFDs through communications options. This can even extend to a PC on the network that is in a different room as the ICP, which can be the safest possible option for users.

Wire management within an ICP, especially with regard to the VFD output cables, is more problematic than many people realize. The output of a VFD can become a somewhat powerful radio-transmitting antenna, emitting EMI (electromagnetic interference) and RFI (radio frequency interference) that bleeds into all of the components and wiring inside of the ICP if not correctly handled. This can affect the equipment’s operation, but also lead to degradation of some types of circuits and instrumentation.

There are very detailed methods of construction and assembly that can be followed by the ICP builder to minimize these risks, but they must be exposed to and trained in these techniques. Rockwell Automation and other suppliers can provide this kind of training, but users may not know if the ICP supplier will have taken those courses. Therefore, it is important for the user to take steps in researching their ICP supplier’s qualifications and expertise in building ICPs that include VFDs.

Finally, unlike MCCs that must pass specific seismic testing and certification requirements, ICPs rarely do. This can lead to unforeseen expenses later in a project when local inspectors insist on seeing certification. Civil engineers (CEs) can offer this as a service, but doing calculations on custom-built equipment can cause delays and increase costs for those services if the CE cannot easily ascertain the weights and centers of gravity of major components. Again, this is something that should be part of the consideration as to how the system is designed and clarified in any specifications.

**Safety Issues: Wall-Mounted and Cabinet-Style VFDs**

Just as with ICP-mounted drives, SCCR ratings of standalone VFDs are an important consideration. If the VFDs can be purchased as combination units, where the main
disconnect and OCPD is included as integral to the VFD package, it should be done that way whenever possible. This solves not only the SCCR issue, but also some of the other electrical safety issues. Using standalone VFDs mounted to the wall or floor fed from remote disconnect/OCPD devices is possible, but the listed series combination must be investigated and adhered to exactly as stated in the UL SCCR documents. This is not impossible to do; it just requires extra steps to do it correctly.

With the integral disconnect and OCPD combination VFDs, the arc-flash and electrical-safety issues will be similar to those of MCCs. The mechanical interlocking with the enclosure door will mean that the door cannot open until the disconnect switch is open (off). If used on machinery where NFPA-79 is a factor, there is an additional safety requirement – the disconnect handle mechanism should be in control of the disconnect device, whether the door is open or closed, without the need for a tool. The use of flange-mounted disconnect switches and circuit breakers satisfies this requirement. However, on smaller drives where there is a rotary, through-the-door disconnect device, a special NFPA-79 handle may need to be specified. This is a smaller, often red, auxiliary handle mechanism attached to the shaft that is only visible and accessible when the door is open.

With cabinet-style VFDs, the disconnect and OCPD option will usually be in an adjacent, connected enclosure. The main enclosure containing the disconnect and OCPD will be mechanically interlocked with all other drive enclosures of the same unit. As the size of the VFD increases and multiple power sections are run in parallel, the interlocking to the main disconnect cabinet becomes even more important because the cabinets will often all look very similar from the outside with the doors closed.

In some cases, if the line terminals of the disconnect device are still live and hot, even with the disconnect open, that means that PPE requirements may still be the same as if the disconnect was closed. This could still be the case if the disconnect is open and there is still almost no danger of accidental contact with live components. The use of a separate enclosure on the cabinet drives allows the service technician to reclose the door of the disconnect section once the adjacent door is open, then use LO/TO on the disconnect while working. This puts the live terminals in a different enclosure than where the VFD components are located.

On smaller, wall-mounted drives, however, if the facility safety rules require that there be no live terminals in the enclosure when being worked on, then the only option may be to use a non-combination drive and a separate series coordinated disconnect device. This introduces a new safety risk: Without the disconnect switch being mechanically interlocked with the door, the possibility arises of someone being able to open the VFD enclosure door without first removing power. At minimum, signs on the door must be used to warn personnel about this condition but additional protections are advisable.

Other safeguards can be implemented such as electrically operated door interlocks, or captive key interlock systems. Users also can simply install a padlock on the VFD door, with the key to the padlock located inside of the remote disconnect device. This requires users to open that disconnect and attain the key to get into the VFD.

Wire management on all VFDs is very important from the standpoint of EMI/RFI issues as discussed earlier. In addition to that, large VFDs require large cables – often several of them. Cable management, or lack thereof, presents another safety risk. The high weight and stiffness of the cable often leads to poor cable-installation planning and execution. Then, the associated strain on mechanical components can result in warping of structural members, which can lead to possible short circuit and even arc-flash events. If the cables must be disconnected and moved to service the equipment later, reconnection often leads to increasing that strain or causing damage that is not seen until it is too late.
For this reason, Rockwell Automation designs cabinet drives with extra attention to this detail. With the rollout design (discussed below), the installer has full access to a sliding-bus bar connection system that allows simple, straightforward routing, connecting and bracing of multiple large cables per phase – all without having to work around and worrying about damaging sensitive components. After the cables are secured, the power section is rolled back into place and connected. If the power section must be removed later for servicing, it can be done without ever disturbing the power connections or cables.

A final issue on large VFD safety is that they are often very heavy. If maintenance or servicing is required, this can pose an injury risk for technicians attempting to remove or work on them. They will often use tools, jacks or even forklifts in ways that may put the VFD at risk of damage, and may put the workers at risk for injury if the methods are too awkward because of restricted access, or if the method fails. One solution, used with Rockwell Automation cabinet drives, is to use a rollout chassis design. This provides an easy way to remove the heaviest components safely, using a specially designed "truck" assembly that matches up to internal guide rails at the bottom of the VFD cabinet.

Safety Issues: Classified Hazardous Locations

No matter which format is used for VFD-mounting, classified locations (those involving potentially explosive atmospheres) are generally not a suitable environment for VFDs. With the possible exception of E-House packages specially designed for this application, VFDs should be located away from classified areas. Some consider explosion-proof enclosures an option, but the need for thermal management and keypad access for programming can make them very difficult and complex to implement.

One option, a purged-air enclosure system, has been used on small to midsized VFDs in some cases. These systems generally work using a pressurized enclosure package that immediately kills power to the equipment inside if pressure is lost. Even if users kill power to a VFD, significant energy remains on the DC bus, and it could become incendiary in certain circumstances. Special care and attention should be exercised whenever undertaking an application like this.
Summary

Maximizing the success of VFDs requires making the right decisions upfront about how and where they are located and mounted. Often only given cursory attention or even ignored in the face of initial capital outlay, this issue is more important than many realize. Before making a final decision based on cost alone, users should consider the variables listed here and other aspects of current and future use. Accessibility, safety, maintenance and suitability of the installation can make a large impact on not only the long-term costs of ownership, but also the ability to avoid unscheduled shutdowns and the economic costs associated with them.

Using only one particular approach to implementing VFD installations is also rarely the solution. Understanding the nuances of the available options usually results in users employing a combination approach: MCC mounting, group mounting in ICPs, E-House prefabricated buildings, wall-mounting and cabinet-style freestanding individual VFDs. These options provide users with what they need, where they need it.

Visit www.ab.com to learn more about PowerFlex Drives and CENTERLINE MCCs

Please contact us if you’d like more information.
Resources

Please contact the following companies for more information.

**Rockwell Automation**
Stephanie Winterhalter
262.512.2369
sawinterhalter@ra.rockwell.com

**Padilla**
Beatrice Zvosec
612.455.1914
beatrice.zvosec@padillaco.com