Should Drives be Specified in Division 15 or 16?

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Recently, Variable Frequency Drive (VFD) manufacturers have seen a trend to move the VFD specifications from the mechanical portion of the specification (section 15XXX) to the electrical portion (section 16XXX). While this trend may stem from concerns about harmonics, it may also be influenced by certain VFD manufacturers who have a vested interest in having the drives specified in section 16XXX. Another reason for this trend may be that mechanical department personnel at consulting firms are often not comfortable with the harmonics issue. It is the writer's opinion that specifying VFDs in section 16XXX can cause unnecessary concerns. This article will document some of the more compelling reasons to place the drive specification in the mechanical or controls section of the specification. This article will also document some of the potential pitfalls possible when installing the VFDs in MCCs (motor control centers). Finally, recommendations for specifiers will be presented.

History

The motor control center (MCC) was first introduced at the turn of the century. MCCs allow the designing engineer to maximize the usage of valuable space by putting motor controls and branch circuit protection in a common enclosure. MCCs also allow the end user to consolidate wiring, simplify installations and keep the electrical controls out of the manufacturing environment. With the advent of solid state electronic controls, it seemed natural to incorporate these new controls into the MCCs. However, MCC's were not designed to house electronics. In the case of VFDs and other heat producing, solid state devices, there are several potential problems that the designer should understand. These pitfalls will be discussed in the following paragraphs.

Why not MCCs?

Today's PWM VFDs all use Insulated Gate Bipolar Transistors (IGBTs) as output switching devices. IGBTs switch 10 to 100 times faster than the previous switches used as VFD output devices. This fast switch "turn-on" time can set up a phenomenon known as standing waves or voltage reflection. Voltage reflection can cause motor end-turn failure in a short period of time. Voltage reflection is a function of the lead length of the power cable between the drive and motor. Voltage reflection can theoretically occur with motor lead lengths as short as 25 feet. Voltage reflection is often predicted by the following formula:

$$L_{critical}\ (feet) = \frac{V_{cable} \times t_r\ (\mu s)}{2} \qquad \text{Formula \#1}$$

Voltage reflection may occur when the length of the motor cable is greater than or equal to the critical length. V_{cable} (sometimes referred to as propagation factor) is the speed that the pulse travels from the drive to the motor in feet per microsecond. The value of V_{cable} depends on the type of conduit or cable tray and other details of the cable installation. V_{cable} is often estimated as 500 feet per microsecond (μ sec); t_r is the rise time of the output pulses from the VFD under consideration.

A recent independent study of 17 different drive manufacturers[i] suggests that t_r may be as short as 0.117 μ seconds. Solving for the critical cable length by substituting this value into formula #1, and using the 500 V per μ second cable default value, equates to 29.25 feet as the critical distance for voltage reflection. Even when mounting the VFDs on the wall, next to the driven equipment, it is not hard to imagine motor cable lead lengths of over 29 feet. Putting the VFDs in the MCCs will almost assure motor cable lengths of over 29 feet in most HVAC installations.

There are several solutions to the problem of long motor cable lead lengths. The most often specified solution is to supply output dv/ dt filters with the VFD. The dv/ dt filters are fairly large and are not easily installed in MCC enclosures. Definite-purpose Inverter-fed Motors can also be utilized when long motor cable lead lengths are unavoidable. If 230 volt power is available on the job site, a 230 volt VFD and 230/ 460 volt motor can be used. When fed with 230 volt power, the 230/ 460 motor will not be susceptible to voltage reflection failure. All of the above listed solutions will cost the owner extra money and can increase the system complexity. These “solutions” will not be required if the VFDs are located close to the driven motor.

To meet local codes, a motor disconnect switch is typically required within sight or within 50 feet of the motor. Most VFD manufacturers can competitively supply a VFD and disconnect switch in a common enclosure. This combination enclosure, positioned properly, will meet the motor disconnect code requirements. If the drives are mounted in the MCCs, the local motor disconnect will probably still be required.

Thermal Considerations

VFDs are heat-producing devices and, as such, need proper cooling and air flow. Most VFDs were not originally designed to be mounted in MCCs. Putting a VFD in an MCC enclosure requires a special MCC enclosure with cooling provisions. Although this can be adequately accomplished by a few companies nationwide, any savings that were expected from reduced wiring costs are quickly eaten up by the special engineering charges and cooling requirements. In the writer's experience, the installed cost of drives in MCCs exceeds the installed costs of wall-mounted drives.

All solid state switching devices generate losses. There simply is not a perfect semiconductor power switch. With the present generation of power output devices, the system efficiencies are typically in the range of 96 to 98 percent. This means that the heat generated must be dissipated within the MCC section. VFD heat loss generated may be calculated using the following formula:

Heat loss in Watts = HP X 746 Watts per HP X (1 - VFD Efficiency) / Motor Efficiency
Formula #2

BTU load = Heat loss in Watts X 3.41 Formula #3

For example, a 15 HP drive with an efficiency of 96% connected to a 90% efficient motor, will yield the following results:

Heat loss = 15 HP X 746 Watts per HP X (1 - .96) / .9
= 11,190 Watts X (.04) / .9
= 497.3 Watts lost

BTU Load = 497.3 Watts X 3.41
= 1,696 BTU's

Since VFD losses are approximately linearly proportional to horsepower, losses can be estimated at 33.3 watts or 113 BTU's per horsepower. For example, the losses on a 30 HP drive would be approximately 1,000 Watts. This may not seem significant, but this is the same as having a 1,000 Watt heater in the enclosure. The challenge, then, is to get the heat out of the MCC bucket without compromising the VFD heatsink design or restricting the drive's cooling air.

Many specifications also call for the VFD manufacturer to supply input line reactors and/or output filters. These are also heat-producing devices and may require large mounting areas. Most VFD manufacturers have pre-engineered designs for placing filters inside of the VFD enclosure. Few, if any, can easily mount and wire these devices in the MCCs. Finally, 12-pulse drives and other forms of harmonic mitigation do not fit well into MCC enclosures. If harmonic concerns are discovered after the installation is completed, it is much easier to retrofit harmonic mitigation devices to free-standing or wall-mounted VFDs than it is to mount and connect these devices to drives inside of MCC enclosures.

Environmental Concerns

In many instances, the MCCs are located in less than ideal environments. Most commercial and industrial building owners have no desire to provide conditioned air for the MCC equipment rooms. Since personnel are not generally expected to work in these rooms, very little attention is paid to the environmental concerns of the MCC area. It is not uncommon for high ambient temperatures to be present in the MCC areas. VFDs only exacerbate this problem. On warm days, the maximum ambient temperature of the VFDs can easily be exceeded. While this excessive heat may not present a problem for the electro-mechanical equipment in the MCCs, it is a potentially large problem for the VFDs in an excessive ambient environment.

Project Coordination

Project coordination is more complicated when the VFDs are specified in section 16XXX. Changes in project scope often do not get transmitted effectively from the mechanical contractor to the electrical contractor. For example, if an air handler unit motor changes from 15 to 20 HP during the course of a project submittal, it is no problem to change from a 15 to a 20 HP starter. Both starters typically fit into the same size MCC bucket. However, changing from a 15 to a 20 HP drive will likely change the physical size of the drive. This may require a bigger

MCC bucket and will assuredly require more CFM of cooling air be brought through the drive enclosed in the MCC.

Changes such as these are obviously very expensive to accomplish in the field. If the MCCs are not yet released, there will still be a time delay while the MCC line-up is re-engineered. In addition to the normal MCC lead time, VFD lead time could also present a problem in later stages of the project.

Other Concerns

Motor control centers have “wireways” in which all the control and power wires are routed. This can present RFI and EMI concerns. All drive manufacturers insist that power wiring (both input & output) and control wiring be run in separate, metal conduits. Installation of the VFDs in MCCs may void the VFD warranty.

The start/ stop and speed control of the VFDs typically comes from the temperature control equipment. The temperature control equipment is not mounted in the MCCs. Mounting the VFDs in the MCC will further complicate the control wire routing and add cost to the installation. Great strides have been made recently in serial communications capabilities between VFDs and temperature control equipment. Placing the VFDs in the MCCs cancels some of the wiring cost savings these new serial communications interfaces have pioneered. In the writer’s opinion, placing all this wiring together in MCC wireways is asking for trouble.

Serviceability of the drive may also become an issue. Placing the drive in an MCC enclosure will typically make the drive components harder to get to, and therefore harder to service or replace. Also, if a drive becomes outdated and the owner wishes to replace the unit with a newer generation of VFD, it is much easier to replace a wall mounted unit than a unit buried in an MCC bucket. The end user also losses his flexibility in this situation. Instead of buying a replacement VFD using owner important criterion such as ease of programmability, serial communications capability, or some other issue, the overriding criterion now is to find a VFD that will fit into the existing MCC enclosure.

Finally, according to a recent market share study[ii], three out of the top four VFD players in the HVAC market do not even manufacture MCCs. According to the same study, these four players account for approximately 80% of the VFDs sold into the HVAC marketplace. However, some of the major motor control companies are able to offer engineered specials for drives in MCCs. These motor control companies represent a small fraction of the VFDs installed in the HVAC market.

Some of these companies attempt to get their VFDs specified in the MCC sections to gain a competitive advantage at the bidding stage. By providing a packaged price for switch gear, MCCs, VFDs, and other control equipment, they can effectively stifle open competition. As contractors will attest, the VFD "break-out" price in these package situations often leads to pricing "games" from the package suppliers. None of the above issues helps with the owner's desire to get a competitively priced, reliable VFD installation. There are other pitfalls associated with placing drives in MCCs, but the issues just described are viewed as the most important issues.

OK, so drives do not belong in MCCs -- then what is the problem with section 16XXX?

In addition to the coordination required between the contractors, further coordination difficulty can be anticipated in start-up coordination, control coordination, and lack of system understanding. The electrical contractor may have less understanding of how the fans and pumps are supposed to operate than the mechanical contractor. One of the main reasons that VFDs were put into the mechanical portion of the specification 20 years ago was for single source responsibility. This advantage is lost by specifying drives in section 16XXX.

New Trends

There is a trend among HVAC consultants to have the temperature control contractor supply and coordinate the VFDs. This makes good sense from several standpoints. First, the control contractor has electrical experience and understands RFI/ EMI issues. Most control contractors also have at least a casual familiarity with harmonics. Also, the control contractor has a good understanding of the sequence of operation of the mechanical system. For example, if a VFD vendor bids the project without regard to such items as Electro-Pneumatic (EP) relays or damper end switch contact receipts, the control contractor will probably catch the mistake before the units are ordered.

The control contractor also knows when the system is ready to be commissioned. Often the VFD certified start-up engineer is called by the mechanical contractor to start-up the VFDs, only to arrive at the job site and discover that the control wires have not yet been pulled or connected. Having the control contractor coordinate the VFD start-up insures that, when VFD start-up personnel arrive on the job site, the VFDs are ready to be commissioned. Finally, temperature control personnel are typically still calling on the owner after the first year. The mechanical contractor's incentive to keep the owner happy may expire with the job warranty. The control contractor has a vested interest in continuing to call on, and service, the owner.

Recommendations

Because of the above concerns, the writer does not recommend specifying drives in MCCs or in section 16XXX. The VFDs belong in the mechanical or controls portion of the specification. It is recommended that the consulting engineer have their electrical department help their mechanical department write the specifications. If the consulting firm is concerned about harmonics or other electrical issues, they should also have their electrical department review the VFD submittals.

Finally, the specifier may want to consider moving the VFDs to the controls portion of the specification (especially on projects with new building controls). The controls supplier will then be responsible for purchasing and coordinating the VFD systems. It is also recommended that the consultant firm get help with the VFD specifications from a local VFD representative who provides good support and has a proven track record.

About the author:
Michael R. Olson is a Commercial Applications Engineer with ABB Industrial Systems. Mr. Olson has extensive experience in the HVAC, Water/Wastewater Treatment, and Chemical markets. He has been applying adjustable speed drives to these and other markets for over 16 years. Mr. Olson has been published numerous times in trade journal articles discussing energy savings and the proper application of adjustable speed drives. He has a General Engineering degree from the University of Illinois and a Masters of Science in Engineering Management degree from the Milwaukee School of Engineering.

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[i] A. Mansoor, K. Phipps, and R. Ferro, "System Compatibility Research: Five Horsepower PWM Adjustable-Speed Drives," Electric Power Research Institute - Power Electronics Applications Center, April 1996
[ii] P. Benoit, D. Clayton, and A. Chatha, "AC Drive Outlook for North America - Market Analysis and Forecast Through 2002," Automation Research Corporation, October 1997

(caption)

NEW BERLIN, WI – Wall-mounted Variable Frequency Drives are easy to operate, keep cool and service. The installed cost of a VFD also is less than the installed cost of a drive in a Motor Control Center.

(caption)

NEW BERLIN, WI – Most Variable Frequency Drives were not originally designed to be mounted into Motor Control Centers. Doing so requires proper cooling and air flow. "Wireways," through which all the control and power wires are routed, can present RFI and EMI concerns. And space constraints of MCCs make drive components harder to get to, service and replace. Additionally, the installed cost of drives in MCCs exceeds the installed costs of wall-mounted drives.