Statement of Program/Practice: The Development and Use of Portable Variable Frequency Drives (VFD's)

Overview:

Electric motors are used in many applications at The University of Texas at San Antonio (UTSA), and at institutions of higher education throughout the Country. Those powering large HVAC machinery, including supply and return fans, are considered critical to UTSA's mission.

VFDs:

VFDs vary the speed of HVAC motors by varying the frequency of the AC current applied to the motor. Unfortunately, VFD's sometimes fail, causing key HVAC system components to shut down, affecting classes, laboratories, and other facilities, sometimes for several days.

Portable VFD units:

Seeing the need to immediately restore critical HVAC systems when VFDs fail, and the high cost of maintaining back-up units, UTSA master electricians, Matt May and Brent Tyroff (Figure 1), set out to develop temporary short notice variable-speed motor control units for use during VFD failures.

Beginning in 2011, they began constructing portable VFDs, and have refined their designs over the years. The latest VFD design resulted in a truly portable VFD built onto a 4-wheel platform truck complete with a service disconnect switch and quick-connector plugs, allowing major HVAC motors to be restored to service within a few hours.

Criteria 1: Institutional Benefits

Flexibility

The UTSA Portable Variable Frequency Drives (VFDs) have proven to be extremely flexible in their application at UTSA (Figures 2 & 3). First, VFDs of various manufacturers can be used that match the application at the university. UTSA has models primarily from ABB, Yaskawa and Robicon among others. They range from 5 to 200 horsepower in capacity and all types have been able to be fashioned into a portable state for application at UTSA (Figures 4 & 5). UTSA has approximately 279 VFD units in service (Table 1).

Safety

All appropriate lock out tag out procedures are used in setting up the Portable VFD. Cam-Lok® power cables are UL listed and designed for temporary power connection situations (Figure 6). Because the VFD function is restored instead of having motors/controls bypassed, both employee safety and safety of equipment and condition of ductwork remain intact.

Cost Effectiveness

The total cost of a Portable VFD is less than $1000 for cart and cables along with the cost of the VFD (which can be $2500-$4500). This cost can significantly offset the price of expedited shipment and administrative costs related to emergency purchase of a failed VFD. This is in addition to energy cost savings by reinstating VFD control versus bypassed manual operation of the motors involved. An additional cost savings attribute associated with portable VFDs, is that they can be re-used in a number of applications covering a multitude of motor sizes.

Timeliness and continuity of operations

Service originally provided by the failed VFD can be restored through the use of the Portable VFD in a matter of hours, usually less than two hours. This allows for near continual operation of motors while replacement equipment is purchased. New units can either be ordered right away or can be appropriately planned, which allows for avoidance of emergency work orders and purchases. The portable VFD can remain in place and operate for an extended period of time.

Criteria 2: Characteristics or qualities that make this program or practice different or innovative

Availability

The UTSA VFDs are unique and innovative in that they solve an immediate emergency need with a low cost and timely solution. We are unaware of the existence of commercially available portable VFDs that can provide this kind of immediate solution for failed VFD systems.

Portability

Portability was an important consideration of the design to make it as easy as possible to locate to the more than 279 possible sites where the Portable VFD may be needed. Several designs for portability were employed including a custom metal rack attached to a standard wheeled cart as depicted in Figure 5.

Ease of Connection

The Portable VFD is easy to connect. It has one set of cables (3) that go to the power connection of the failed VFD through Cam-Lok® power cables (Figure 6). A second set of cables (3) (also Cam-Lok® Power Cables) go to the motor being controlled by the failed VFD. Finally an 8-conductor Beldon wiring cable connects to the building automation system in the same way as done by the failed VFD. The wiring of all these cables is typically done in less than 2 hours by a licensed electrician. Figure 10 shows the overall schematic of the Portable VFD.

Customer Service

The customer service implications of the use of the Portable VFD's are dramatic. These VFDs control systems at the UTSA campus that are critical to our proper functioning as a university. Whether it is for an air handler system that provides comfort heating and cooling for students, faculty and staff or provides for pumping of water and the like, the prompt restoration of that service is necessary for continuity of normal business at UTSA. This also applies to our research areas which depend on proper VFD operation to ensure proper laboratory air pressures as required.

Criteria 3: How this practice can be used by others:

VFD use is extremely common, as are VFD failures. A local manufacturer has expressed interest in marketing the sale of portable VFDs. UTSA has 279 VFD units distributed throughout the tri-campus. Table 1 shows a breakdown of the number of VFDs by building name.

UTSA has performed more than 986 preventative maintenance activities on the VFDs located on all 3 campuses during the last 5 years. However, 236 corrective maintenance work orders were also generated due to various kinds of VFD failures. During this period, the Portable VFD fleet (1) 50 Horsepower, (2) 125 Horsepower, and (1) 200 Horsepower have been deployed to address multiple VFD failures on campus.

Construction of a portable VFD unit is cost effective when built in house

The Portable VFD consists of a VFD model (horsepower and specifications matching the replacement) and cables and transport device. Typically, the cables and transport device can be purchased for under $1000 and a typical VFD is $3500-$4500. Figure 7 is the schematic of the Portable VFD which was put together by UTSA Facilities Operations and Maintenance (O&M) personnel.

Connection of portable VFD is simple and safe

The Portable VFD uses two sets of cables (3 conductors each) for the high voltage interface to the incoming power and the motor being controlled. There is an additional 8 conductor cable that is wired to the Building Automation System. These cables are wired in the same manner as the failed VFD which is being supported.

Downtime is reduced to less than 2 hours

On average we can mobilize, make the necessary connections, program the portable VFD and be fully operational in less than two hours. Without the portable VFDs, the process took three to five days. This delay resulted in extended discomfort to facility users and significant interruption of research and other campus activities.

Criteria 4: Demonstration of management involvement and employee commitment

UTSA's Business Affairs and Facilities guiding principles emphasize:

1. Respect
2. Partnering
3. Valuing each other
4. Being Creative
5. Doing the Right Thing

Support for the development of the VFD prototype and system was provided from the highest level within the Facilities Management Department. The VFD program received high priority because of the positive impact the system would have on customers throughout campus. This is especially important because as a department, we are focused on providing excellent customer service. Support, encouragement, financial backing and planning of the VFD prototype and subsequent construction of the 4 (four) VFD units currently on inventory was provided by:

Facilities Executive Management:

David J. Riker, CFM, Associate Vice President for Facilities

Luis Borrero, P.E., Assistant Vice President for Facilities

Belinda Dovalina, CPA, Director Business & Customer Services

Operations & Maintenance Department Leadership:

Enos Jones, P.E., Director of O&M

Chris Miller, P.E., Assistant Director of O&M.

Matt May, Zone Manager, Educational and General Buildings (Master Electrician)

Brent Tyroff, Senior Electrician III (Master Electrician)

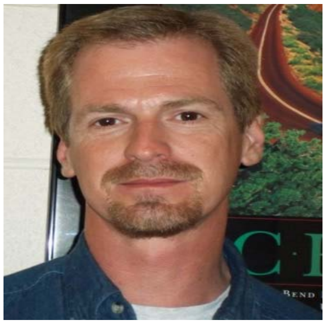
Criteria 5: Documentation of results, analysis, customer feedback, and resulting benchmarks

One of the most compelling results of our use of portable VFDs is that our customers are generally unaware that a VFD failure has occurred because the portable units can be installed before temperatures begin to increase/decrease. We are very pleased with the results of having constructed a "fleet" of Portable VFD units as they have been useful in a variety of failure events. Failures of VFDs are strongly predicted by temperature as illustrated in Table 2:

At UTSA we have VFDs deployed in a variety of circumstances; while we prefer to have them in conditioned spaces, this is often not the case. High temperatures are a key contributor to failure and a survey of work requests over the past 5 years reveals we have had over 231 work orders for VFD repairs many of which could be attributed to heat failures.

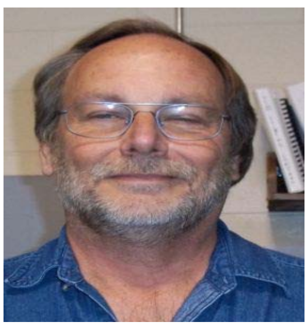
We regard the Portable VFD to be a great insurance mechanism for us to address the inevitable failures in a way that minimizes customer concerns and decreases the financial impact of those failures. It also gives us a flexible platform to use when upgrading VFDs by allowing the existing VFD to be changed out while the Portable VFD does the needed support in the interim.

A recent example of the utility of the portable VFD was the restoration of air handler 76 at the Biological Sciences Building (BSB) on October 7, 2016. The failure of the VFD for this air handler compromised the 2nd floor cooling and air pressure considerations at this 4 story science and research building. The call for service due to the failure came in around 1:30 pm that day and before 3:30 pm that afternoon, full service was restored through the use of a Portable VFD, while new VFD components were ordered. Without the unit, the time needed to return the AHU back into service could have easily exceeded five work days. Another example is the use of a Portable VFD at the Thermal Energy Plant in conjunction with a hot water pump which was driven by a failed VFD (see Figure 8).



Matt May (Master Electrician)

Matt May is the Zone Manager responsible for operations and maintenance of all Educational and General Purpose facilities at the University of Texas in San Antonio (UTSA). A licensed Master Electrician, he is a resident expert on our 13,800 volt power distribution grid as well as 24 volt control systems. Matt has been an electrician for over 25 years with 17 of those at UTSA.



Brent Tyroff (Master Electrician)

Brent Tyroff: is the Senior Electrician III assigned to the Educational and General Purpose Facilities Operations Maintenance zone at the University of Texas in San Antonio (UTSA). He is a licensed Master Electrician with over 44 years of progressive experience and supervision within the electrical field. He is a resident expert on our 13,800 volt power distribution grid, and our large-scale generator paralleling systems. Brent has taught at the electrical apprenticeship school for 20 years and is currently teaching journeyman level transformer classes part-time.

Figure 1: Background on Facilities Electricians who developed Portable VFDs

Figure 2 – Portable VFD (latest model)

Figure 3 – Portable VFD (latest model – second view)

Figure 4. - 50 and 125 Horsepower Portable VFD units

Figure 5. - Portable VFD with modified wheeled cart

Figure 6. - Cam-Lok® power cables

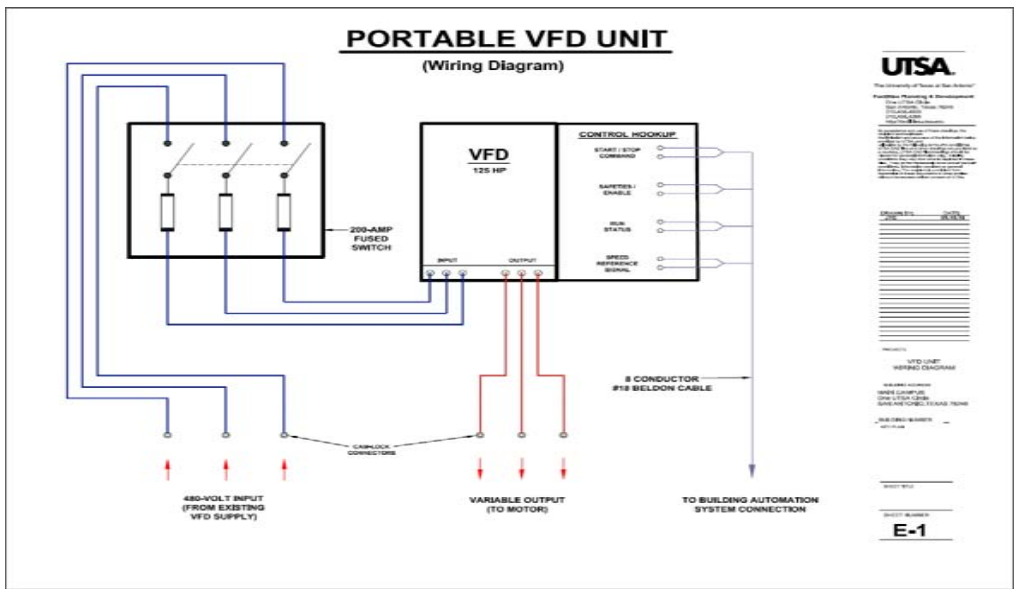


Figure 7. Portable VFD Schematic

Figure 8. - Portable VFD in use at South Thermal Energy Plant serving Hot Water Pump

Building Name	Number of VFDs	
Alvarez Residence Hall	5	
Applied Engineering And Technology	16	
Biosciences Building	8	
Biotechnology Sciences & Engineering	102	
Buena Vista Street Building	21	
Business Building	8	
Durango Building	5	
Engineering Building	8	
Flawn Sciences Building	4	
Frio St North	6	
Frio Street Building	1	
Institute Of Texan Cultures	1	
John Peace Library	7	
Main Building	13	
Margaret Batts Tobin Laboratory Bldg.	11	
McKinney Humanities	11	
Multidisciplinary Studies Bldg.	1	
North Paseo Building	12	
Recreation Wellness Center	26	
Roadrunner Cafe	1	
Scientific Research Laboratory	9	
Scientific Research Laboratory Pump	3	
Total	**279**	

Table 1: VFDs per Building

Drive Temp ˚C	AF	L10 (Years)	MTBF (Years)
50	368.45	28.87	274.00
60	173.18	13.57	128.79
70	84.86	6.65	63.11
80	43.39	3.40	32.27
90	23.04	1.81	17.13

Table 2. Probability of 10% failures (L10) and Mean Time Before Failure (MTBF) of VFDs
(https://www.researchgate.net/publication/261458740 Predictive Reliability Models for variable frequency drives based on application profiles Conference Paper · January 2013 DOI: 10.1109)

About the Author: Enos Jones, P.E., is Director of Operations and Maintenance at the University of Texas at San Antonio, a post he has held for nearly four years. He has held similar posts at Texas State University at San Marcos and Laughlin Air Force Base for a total of over 22 years. He is a registered Professional Engineer in the State of Texas in Electrical Engineering and holds a Master's degree in Computer Science from Texas State University in San Marcos, TX.

Enos Jones, P.E. MSCS