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Managing Cooling & Building Requirements for Air-Cooled Medium Voltage VFDs

Use conventional and alternative methods to undertake critical practice of heat management.

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Medium voltage (MV) drives are commonly applied to pump systems in water/wastewater, oil and gas, and power generation industries. Two key application considerations that may not have received due attention are how to manage the heat rejected from the drive, and how to ensure the environment of the drive installation.

A typical MV drive is 96 to 97 percent efficient (including isolation transformer, blower fans and auxiliaries). The rest is rejected as heat to the indoor environment, requiring air conditioning and heater (HVAC) systems to maintain specified temperature, relative humidity and air quality levels. HVACs come with capital expenditure (capex) cost, but the variable costs to run, maintain and service have a material impact on the total cost of ownership (TCO) of the variable frequency drive (VFD) installation. These costs may not be understood initially, but can become significant when assessed over a 25-year service life span.

One alternative thermal management implementation eliminates the need for an HVAC and building/E-house to ensure the drive environment. Recent experience and research in electrical enclosure temperature augmentation techniques have enabled MV drives to be moved outdoors. However, due diligence is necessary when selecting them.

Image 1. Net present value calculations of HVAC electricity expense of a 2,500-hp VFD over a 25-year life *(Images courtesy of TMEIC)*

Parameter	Value
Cost of electricity (cents/kWhr)	6.51
Motor HP	2,500
Estimated heat loss	75 kW (3 kW for every 100 hp)
Estimated tonnage required	21.53 tons (0.86 tons for every 100 hp of motor)
kW used by HVAC system	21.53 kW (1 kW for every ton of HVAC, typical)
Drive running hours multiplier	0.75 = 6,570 hours per year (Assume drive runs 75% of the time in a year)
HVAC electricity expense Year 1	$9,206 (6,570*21.53*0.0651)
HVAC electricity expense Year 2 (assume 2% inflation rate in electricity prices)	$9,391
HVAC electricity expense Year 3	$9,578
HVAC electricity expense Year 24	$14,518
HVAC electricity expense Year 25	$14,808
Net present value (NPV) of HVAC electricity cash expense over 25 years (assume 8% return rate)	$116,682 (Above calculation does not include cash outflows due to regular HVAC maintenance or expense due to HVAC change-outs every seven to 10 years)

Why Managing Heat & Ensuring Drive Installation Environment Is Critical

VFDs consist of delicate semiconductors, transistors, capacitors and electronics that are susceptible to extreme high/low temperatures, moisture, humidity and air contaminants. The VFD operator is tasked to control the process, production, labor, raw materials and other costs in their plant. But managing the VFD environment is more challenging. Image 2 shows the heat loss and the associated HVAC tonnage required to keep a 1,000 horsepower (hp) or a 5,000-hp indoor VFD in operation.

The conventional method of managing heat for a typical National Electrical Manufacturers Association (NEMA) Type 1 indoor VFD has been to either package the drive in an industrial control building (or E-house) or install in a motor control center (MCC) room.

However, putting drives in an E-house or an MCC building comes with a price tag. At $550 to $600/square foot (E-house option), one is looking at an additional minimum of $55,000 to $60,000 to host a 1,000-hp VFD (100 square foot E-house). Further, the E-house is subject to expensive site install, permitted load transport, building codes, regular HVAC maintenance and filter changes. Beyond the initial capital capex, the year-over-year operational costs (opex) of HVAC itself, maintenance and replacement every seven to 10 years, materially impacts the TCO for large, air-cooled MV VFDs. Image 1 demonstrates the net present value of electricity expense, and Image 3 shows a picture of an E-house with HVAC units.

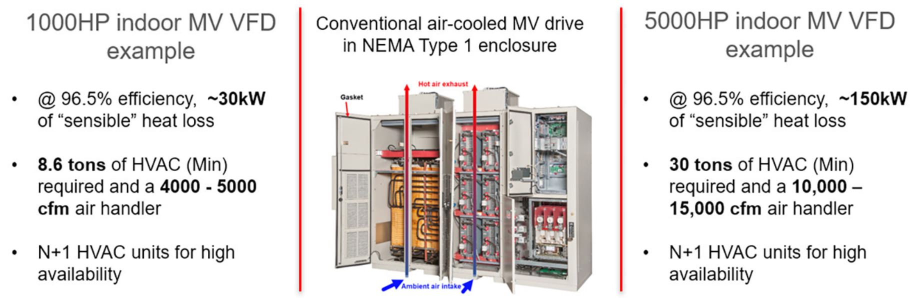

Image 2. Heat loss and HVAC tonnage for a typical 1,000-hp and 5,000-hp indoor MV drive that is air-cooled

Managing Heat in MV VFDs

In the past decade, the MV drive industry has introduced several novel solutions that eliminate or drastically reduce the need for an HVAC building and expand the ambient temperature rating and environment in which the VFD is installed. One such solution is the containerization of indoor MV drives. In this method of managing heat, an indoor rated drive is installed in a NEMA Type 3R rated enclosure (Image 4). This treatment makes it suitable for outdoor use.

The roof of the enclosure is used as a plenum to move air in and out of the unit employing standard VFD blower fans (fans not visible in Image 4 due to top covering). A typical indoor drive is suitable for installation in 32 to 104 F ambient temperature or up to 122 F with derate and max 95 percent noncondensing relative humidity.

To design an outdoor solution for an indoor drive to eliminate the HVAC, the enclosure must be able to maintain the indoor environment of a standard indoor rated drive while being able to withstand extremely low ambient temperatures such as -40 F or high temperatures up to 122 F. The enclosure must also have a strategy to deal with dust and corrosion commonly found in the environment.[1] For the implementation in Image 4, air temperature in the enclosure is regulated using built-in space heaters and exhausting air or recirculating some of the heat rejection from the VFD blower fans back into the enclosure.

The on-board enclosure control unit controls the exhaust and recirculation dampers based on a set-point temperature that is maintained, which is typically above the dew point temperature. Air is sucked in through the roof that is several feet above the ground. Through a combination of twists and turns designed in the roof, most of the dust falls off before entering the drive.[1]

Image 3. VFD E-house showing substantial HVAC units

The benefit of such containerization is that a standard production indoor rated VFD is upgraded to NEMA Type 3R outdoor rating. Further, because the enclosure is classified as a free-standing enclosure, the end user is not subject to real estate taxes, meeting building codes, and drastically reduces on-site work, reducing liability.[2]

Image 5 shows the typical specifications of a containerized solution and shipping method that eliminates expensive permitted load transport. While a containerized solution is one way in which the HVAC requirement can be reduced or eliminated, other methods also exist. Image 6 provides an overview; references 1 and 3 describe several of them in more detail.

Procurement Guidance for Outdoor, HVAC-less Drives

Guide form specifications, data sheets and standards do exist for indoor drives when evaluating between VFD manufacturers.

However, little literature exists on how to assess outdoor drives. While detailed procurement guidance is beyond the scope of this article, what follows are a few key questions one must ask before making a purchasing decision:

- Does the outdoor MV drive have thermal insulation, and what are the R-values for the enclosure walls, ceiling, floor and doors?
- How is dust ingress and condensation controlled?
- What is the temperature rise inside the enclosure and specifically the drive isolation transformer (if supplied)?
- Is the applied enclosure paint commensurate with the environment?
- How about corrosion protection?
- Is the outdoor drive made with standard off-the-shelf components or are they custom parts typically not ordered or manufactured regularly?
- How does the advanced system design (ASD) respond to black start conditions in extreme cold and high humidity?
- What testing was the enclosure subject to for validation?
- What is the reliability of the outdoor power conversion equipment and can the manufacturer corroborate with real-world examples?
- For enclosures with externally mounted blower fans, filters and heatsinks, how reliable are they in various environmental conditions, and what is the typical maintenance?
- What is the typical snow load rating, and how is sleet handled?
- Does the outdoor drive require any additional installation treatment such as a shed, or roof to protect from snow or rain?
- Can the outdoor drive be placed in a 100 percent relative humidity/rainy environment?

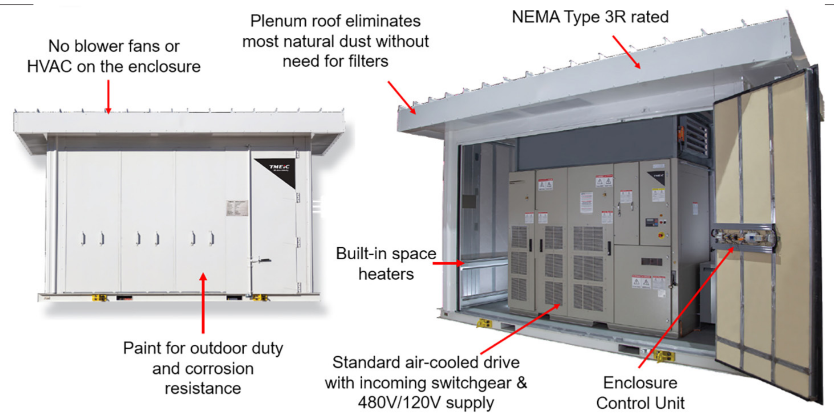

Image 4. Containerized outdoor MV drive

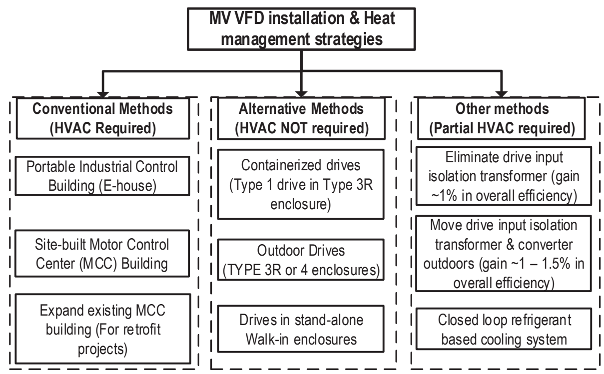

Image 6. MV ASD installation and heat management strategies[1]

Conclusion

Recently, MV VFD operators are under immense pressure to not only control initial costs but also to minimize the TCO. Costs associated with managing heat and ensuring the VFD environment increase the TCO. Containerized solutions are available that have brought down the cost of outdoor power conversion equipment, such as MV drives, and have demonstrated experience in ancillary industries. Appropriate cooling techniques and installation methods must be carefully studied for their impact on capex and opex. Finally, due diligence, site assessment, payback analysis, total installed cost and key questions noted above must be asked before planning to install outdoor drives. ■

Typical Specifications

Enclosure rating	NEMA Type 3R
Temperature rating	-40 deg C → +50 deg C Lower if VFD is running a motor
Voltage	Typical 4.16 kV
Power	Up to 3000HP
Installation site	Outdoor, Non-classified environment
Wind speed	125 MPH
Snow loading	90 lbs/ft^2
Enclosure mounting	Pad, Pier or spot footings
Enclosure lifting	Forklift and provision for crane lift

Image 5. Transport method and standard performance specifications of containerized outdoor MV drive

References

1. Verma, M., Phares, D., Lawrence, R.; "Heat and Harmonics: The most significant concerns in air-cooled MV Adjustable Speed Drives (ASD) & what to do about it?" 2019 Petroleum and Chemical Industry Technical Conference (PCIC), Vancouver, BC, Canada, 2019
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3. Verma, M.; Phares, D.; Grinbaum, I.; Nanney, J., "Cooling Systems of Large-Capacity Adjustable-Speed Drive Systems," in Industry Applications, IEEE Transactions on , vol.51, no.1, pp.148-158, Jan.-Feb. 2015
4. To view the webinar on this topic, visit pumpsandsystems.com/webinar/heat-management-techniques-medium-voltage-drives

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