THERMAL MANAGEMENT

Considerations for reducing control panel temperature levels

A persistent problem with power and control panels that causes problems for industrial customers resulting in drop outs and on malfunctions of Variable Frequency Drives and other control assets.

This whitepaper looks at the issues, challenges and solutions to managing thermal levels in control panels.

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HEAT LEVELS

Managing heat levels in control panels that protect VFDs and other sensitive electronics has become an increasingly important issue in industrial applications as a result of several factors relating to the electronics themselves, control panel design and market trends.

As electronics have gotten more powerful they have also shrunk in size. The foot print of a 5HP VFD, for example, has gotten significantly smaller, but its thermal signature has gotten larger.

Smaller more powerful industrial drives

Because of the smaller unit size, panel builders and machine builder are able to pack more control into smaller enclosures than ever before – all in an effort to reduce the panel footprint. This also affords greater flexibility regarding panel location.

Many of these devices – VFDs in particular – lack industrial hardening that makes them more susceptible to problems arising from the higher temperatures they create within the enclosure. While the benefits of cost savings and flexibility of smaller panel sizes are desirable, the negative consequences of higher panel temperatures are not.

There is a growing awareness of the relationship between higher performance controls, higher temperatures and the reliability of VFDs and other controls. Smaller enclosures also reflect a change in design philosophy, from panels that were large enough to effectively dissipate heat, to smaller, more densely packed enclosures that are far less able to dissipate heat with minimal cooling. This change has wrought consequences, some unintended.

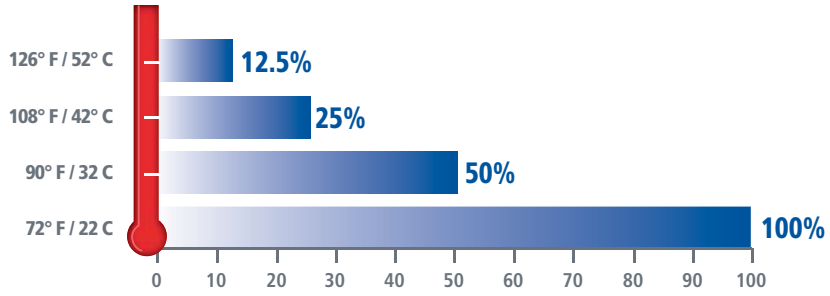
Densely packed panels and higher ambient operating temperatures are therefore almost inevitable. There is a greater awareness of the need for active cooling systems in many applications.

Harsh environments create their own set of challenges as panel ratings can be compromised by ineffective cooling methodologies that rely on unfiltered, unconditioned air being used to manage thermal loads within the panel.

AN UNINTENDED EFFECT ON ELECTRONICS

It's a well-established fact that increased temperature decreases reliability and causes parametric changes in the function of the electronic devices (such as VFDs), some of which are unpredictable.

At 90° F ambient temperature, degradation of sensitive electronics occurs, reducing the life expectancy by 50%. This figure increases as ambient temperature rises, as shown in the following chart. Fortunately, VFDs are typically rated to 104°F, however, real world experience indicates that life expectancy reduction and reduced performance are very real consequences of excessive heat levels.



Source: Digital Equipment Corporation

ELECTRONIC LIFE EXPECTANCY IS REDUCED BY HALF WITH EVERY 18° F RISE ABOVE ROOM TEMPERATURE

Life expectancy of electronics is difficult to calculate. Manufacturer data for VFDs suggest a life expectancy of up to 20 years. The question is whether a VFD will continue to function within normal parameters when exposed to elevated temperatures, or will it exhibit unpredictable parametric changes including drop outs or shutdowns during its lifecycle?

SUMMARY KEY POINTS

- Panels or enclosures continue a trend toward smaller size, as do the components placed in the panel, resulting in higher densities of heat-producing devices.
- The heat generated by VFDs and related power control equipment can no longer be easily dissipated through normal air flow in the control panel.
- Higher temperature in the control panel is a fact of life for many applications, resulting in a new awareness of the problems created by higher temperatures.

PANEL RATINGS

Control panels are designed to operate within a defined temperature range, typically not to exceed 104° F for UL 508A rated enclosures, the most common enclosure rating.

Control panels adhere to one or more of the following standards that govern such things as construction, ingress access, latching, corrosion resistance and other elements of panel design and construction:

International Electrotechnical Commission (IEC) Standard 60529 - these codes reflect an electrical enclosure's ability to protect against access to electrified parts by people, tools, moisture, dust or dirt.

National Electrical Manufacturer's Association (NEMA) Standard 250 - NEMA 250 addresses ingress protection, but it differs in that it also addresses specifications detailing minimum construction, performance and test criteria, corrosion resistance and more.

Underwriter Laboratories® (UL) 50, 50E - is based on NEMA 250 standards. While they address many of the same points, NEMA indicates the design intent but does not mandate compliance via third party testing and on-site compliance visits. A product can be built to NEMA standards but actual performance compliance is at the discretion of the manufacturer. UL certification, however, is formal confirmation that required construction and performance are met after analyses and testing is completed. In summary, both NEMA and UL define standards, but only UL enforces compliance to their standards with third-party testing and inspection.

None of the above standards address issues related to cooling per se. One manufacturer states that its panel mounted A/C units have been tested by TÜV Nord against the latest version of the EN 14511:2012-01. It's unclear whether this testing and standards compliance has had any effect on the impact of higher temperature levels in the panel.

Average ambient temps of enclosures are increasing because of the previously noted observation, and it must be noted that VFD manufacturer data consistently indicate a maximum ambient temperature of 104° F. In fairness to VFD manufacturers, some offer solutions capable of operating at higher temperatures – up to 1220F. But, the question must be asked - at what expense to product life expectancy? In some cases this also means de-rating of the device.

FAILURE – WHAT DOES IT LOOK LIKE?

Outright failure, where a VFD ceases to operate and cannot be re-started, is relatively rare according to personnel familiar with industrial applications. It is not uncommon, however, for board level electronics to fail in extreme cases of prolonged overheating (see photo below).

The more persistent problem is an unexpected shut down, requiring a cool-down period before attempting re-start. While this is usually successful it often times leads to recurring shut down or drop out events. This is the most common situation what will spur adding thermal management.

FALSE SOLUTIONS

Field observations by EECO personnel and partners indicate that some customers, acknowledging heat rise issues in their panels, will on occasion open the panel door and use an external air source such as a free-standing fan to bring the temperature down to acceptable levels. While there's little doubt that this is an effective short term solution to an emergent problem, there's also little doubt that this procedure defeats the panel rating, which was designed to keep out contaminants such as dust and foreign matter.
It is not recommended in any case.

Additionally, this poses a risk to workers who are able to gain unrestricted access to the panel without observing established safety procedures for their facility. Workers may be exposed to live conductors and the electronics are also exposed to potential accidental damage.

TYPICAL APPLICATIONS FOR THERMAL MANAGEMENT

Applications where thermal management is most needed include the following:

- Blast furnaces and foundries
- Heat treating facilities
- Welding process facilities
- Paint ovens
- Any application where PLCs, VFDs and other control and power devices are used in combination.

Rooftop or exterior mounted enclosed VFDs for HVAC, animated billboards and other exterior applications are also worthy of inspection for improved thermal management.

EFFECTS OF SOLAR IRRADIATION

An examination of Weather Bureau data indicates that maximum **ambient air temperatures of 104° F (40° C) are only exceeded in Arizona, Nevada and California** (ref. IEEE C37.26-1986; IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear).

Thus, it's safe to conclude that solar irradiance is a significant contributor to excessive ambient temperatures in certain geographies, at a minimum, and any environment where high levels of solar irradiation are present.

COOLING SOLUTIONS

As noted, approximately 30% of control panels require some type of cooling system to attain optimal operating temperatures. Effective cooling or thermal management solutions must take into account location of the panel, the environment, combined watt loss of the electronics in the panel and space available around the panel.

Commonly used enclosure cooling solutions include the following:

- Air conditioners - are ideal for hot environments where closed loop cooling is desired.
- Thermoelectric coolers (Peltier effects) - ideal for conditions where larger cooling solutions are not practicable and moderate ambient temperatures are observed.
- Air-to-air heat exchangers - useful in moderately cool environments where dirt and other contaminants are present.
- Air-to-water heat exchangers - for high ambient temperature environments where extreme dust and dirt conditions make moving air solutions impractical.
- Direct Air cooling systems (DACS) utilize filter fans, blowers or impellers to manage internal enclosure temperatures. These are best used in moderately warm, clean air environments.
- Vortex coolers rely on compressed forced air and are effective at cooling in hot, dirty or corrosive environments.

With literally hundreds of panel manufacturers in the market and a myriad of cooling solutions, it's difficult to know whether the cooling solution, often times supplied with the machine or equipment, has been engineered to properly manage the heat levels at that location.

Industrial customers have little hard data on heating issues until the effects of higher heat levels are observed.

FINANCIAL IMPACT

The financial effect of a VFD failure on a typical manufacturing process is illustrated below:

Downtime. Shutting down a manufacturing process can cost thousands of dollars per hour. And while costs vary, with larger manufacturing environments experiencing higher costs downtime is a reality. One EECO customer reported that downtime costs for a critical machine averaged $8,000/hour.

REPLACEMENT COSTS. The following scenario illustrates typical equipment replacement costs:

COMPONENT	TYPICAL COST	NOTES
1 - 2HP VFD	$792.86	460V 3PH
2 - 2HP VFD	$2,064.62	460V 3PH
3 - 50W Power Supplies	$177.33	85-264VAC input, 24V output. 2.5A
1 - 1.5kVA Transformer	$297.60	480V Primary, 208Y/120 Secondary. 3PH.
Labor Estimate	$1,500.00	Installation in existing enclosure
Total Estimate	**$4,832.41**	

- Other costs such as labor, lost productivity or spoiled goods are not included.
- The uncertainty of whether the process will operate as designed after a failure cannot be calculated, but should be considered.
- The addition of a cooling unit, at a cost of ~$2,000, can eliminate the need for component replacement, assuring no downtime and continued operation. As noted above, one hour of downtime could easily exceed the cost of component replacement.

THE MARKET

- According to the electrical enclosure market leader, Hoffman/Pentair, the company has sold over 200,000 A/C units in the past seven years nationwide. Thus thermal management is a large problem, not confined to one area or industry.
- The average life expectancy of an A/C unit is 7-10 years; therefore life cycle replacement of the cooling unit itself is also a consideration for older installations.
- When thermal audits were conducted of various industrial facilities in the Southeast, as many as 70% of the installations needed some type of thermal management solution.

SUMMARY OBSERVATIONS

- On average, 30% of control panels are experiencing overheated VFDs and other components. In some industries the incidence of overheating is much higher.
- Elevated temperatures of as little as 18° F above room temperature reduce the life of electronic equipment by 50%.
- When thermal audits were conducted of various industrial facilities in the Southeast, as many as 70% of the installations needed some type of thermal management solution.
  - In our example, a $2,000+ investment in thermal management can eliminate the need for replacement of power and control equipment.
  - Downtime costs running in the thousands of dollars per hour can quickly justify a thermal management solution.
- Control panels can also be retrofitted with effective cooling solutions.

A FEW CUSTOMER EXPERIENCES WITH THERMAL MANAGEMENT

Bakery Equipment OEM Take Proactive Approach

A large OEM located in the Southeast who exports baking equipment worldwide, faced with the possibility excess heat levels in their control panels, determined that they needed to calculate in advance thermal management requirements that would work anywhere in the world. After consulting with their engineering team, this equipment builder determined that closed loop A/C systems would be deployed with every machine sold. The cost of travel, machine downtime and other costs were calculated in arriving at the decision to ship control panels with cooling systems. After making this design change they have cut machine downtime, while avoiding the costs associated with field service.

Paper Mill Opts for Closed Loop Cooling

A large paper products mill experienced overheating in their control panels, which led in turn to drives malfunctioning. The initial solution was to open the control panel doors and blow ambient air into the panels in an effort to reduce heat levels. After tiring of drive malfunctions and the inevitable cool down and restart process, local engineering determined that a closed loop A/C system was the best solution to assure uninterrupted operations. A closed loop cooling system, which does not rely on ambient air, keeps out dust and dirt and maintains +/- 10F temperature range.

Tobacco Products Plant Solves Filtration and Cooling Problems

Some thermal management solutions need to address more than cooling. A tobacco products plant was experiencing frequent clogging of filters in their open loop type control panel cooling solution. This meant that maintenance personnel spent considerable time cleaning filters to avoid drive overheating and malfunctions. Engineering analysis indicated that a Peltier type, or thermoelectric cooling system, would most economically solve the dust problem. Space limitations favored a low profile solution, which is an advantage of Peltier coolers. After installing the closed loop Peltier cooler, maintenance time was dramatically reduced and the customer realized a very cost effective solution.

Lumber Mill Keeps the Optimizer Running with Cooling

Sawing raw lumber to the high precision standards required by today's customers and doing so efficiently requires an advanced sawing system called an optimizer. A Virginia based lumber mill was dealing with frequent periods of downtime on this most critical machine due to an overheated drive enclosure. An aging variable frequency drive could not easily be replaced without significant automation system changes, changes that the mill was not ready to undertake. The mission critical VFD had already failed and was in in need of repair. After making the repairs, a closed loop A/C solution was retrofitted to the drive cabinet. The result was restored operation of the optimizer system and extended the usable life of the existing system, obviating the need to completely replace the automation system.

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