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## Foggy Future for U.S. Manufacturing?

Constant Thermal  
Monitoring

A Study in  
Lubrication Selection

Vibration:  
A Big Picture Approach

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# IR: The Next Generation

Constant Thermal Monitoring

by Robert Kern & Ross Kennedy

In a data center or manufacturing facility not so far away, the manager is on a mission to discover every waiting problem before they have a chance to stop the ultimate goal - No Unscheduled Down Time. Yes, we all imagine a perfect universe with no down time, no problems, and no unforeseen equipment issues. Alas, we all know such a universe doesn't exist, so back to reality.

The mission to achieve No Unscheduled Down Time has taken us on an interesting, and relatively speedy, journey. We have come from first having to essentially guess about our machinery's problems all the way to where we are today. But the quest to develop a better understanding hasn't stopped at the technology commonly used today. After all, what manager wouldn't want to know the state of equipment health, today, tomorrow and the next day, with no guessing and no intrusion?

Lets explore where we've come from, where we are, and where we are going.

## The 1st Generation - He who knows it the best...

In the beginning, the person that knew the equipment the best, walked his or her domain just looking, listening and feeling. That person knew the equipment better than they knew own mother. Maybe they could feel the increase in heat radiating from a panel, hear the slower speed of a fan in a cabinet or slower response time from a server. Any little aberration that just didn't seem right sparked investigations to make sure things were just fine. If a problem couldn't be found, well, all they could do was wait and see and hope for more clues instead of a failure.

Of course this method of maintenance was far from perfect, and was dominated by the mottoes "if it ain't broke, don't fix it" and "keep an eye on it". We had to wait for something to break, so we had something to fix. But, at its best, this unscheduled down didn't damage equipment, but

still cost companies in lost revenue. At its worst, this wait and see approach created an environment for damaged equipment, fire or explosion.

Of course, this method was lacking in catching subtle problems before they became larger. It was a huge hazard for the person that had to feel around for a problem, open up panels and attempt to manually measure temperatures. All the data was empirical, subjective, and was done at a "convenient" time. Sometimes when further disassembly was needed, the system had to be turned off and didn't always come back on as expected.

The one thing we learned during this period is that most failures have one thing in common - heat. Or, to be more precise, an increase in heat. If a component is going to fail, the connection will increase in resistance. We will not see a "brown out" of the voltage, but will see an increase in radiated heat. As a connection first begins to fail, the temperature rise may only be 5°, and then a month later another 5°, for a total of 10°. These minor increases in temperature are very hard to detect without comparative data. If we could catch that 1st increase in the temperature before it causes a degeneration of the quality of the connection, we could simply repair it and be fine. So, to advance past the first generation of troubleshooting we needed a better way to quantify the temperature measurements.

## The 2nd Generation - Thermography

To answer the need to collect quantifiable data fast, thermography became



Figure 1 - Just keep an eye on it.

the selected de facto solution.

Even with prices coming down in recent years, thermal imaging cameras are relatively expensive. However, they do collect excellent data, and later that data can be documented, analyzed and corrective action suggested and taken. Small increases in temperature can be documented.

This was a huge step forward. But like most solutions, it has its compromises. While the technician can “stand off” to take the images, the equipment needs to be operational and panels open. The camera cannot see through a panel. If a 10° rise is seen on a panel surface, an object behind the panel could be 50° hotter than the minor “warm” spot. If there is enough of an air gap, and another panel between the heat source and front panel, it’s possible that no noticeable temperature rise may be seen. With the panels open we still put the technician at risk.

Thermography is best performed by a technician familiar with systems like yours and experienced with the thermal imaging camera being used. The correct compensations need to be set and the correct lens used for the data to be accurate. One picture of a large area will not do. Due to both camera resolution and the fact that different points of interest may require different compensation settings, individual pictures will be needed of certain areas of interest. The technician must be diligent for the data to be accurate. The use of a trained and experienced thermographer will yield the best results.

Since thermography can still be intrusive and isn’t free, in some cases it may be performed only once or twice a year. Keep in mind, that infrared surveys should be performed when the system is at full load or at a time when being “exercised” the most.

To ensure that a system is being properly loaded, some tests are performed using external load banks. While this is an added expense, external load banks will help ensure that the electrical system is loaded to 40% or more to bring more meaningful results to the thermal images. Load banks have their own dangers. Incorrect wiring of the external load banks could cause damage to the electrical system. Since most systems have one utility feed, a major failure at this point could take down the entire system. Intrusive action like wiring in load banks with external wire runs, coupled with the heat from the loads, increase the odds of personal injury or other unforeseen accidents.

Will an accident occur while the load banks are being disconnected? While the arc flash panels are being reinstalled, or while panel is being closed? If the system was turned off for any of the clean up process, will it turn back on correctly?

While thermography yields results that are very useful, due to the nature of the testing in the once or twice a year scenario, no real trend data is being collected. As loads increase during the year, how are certain electrical components responding? Are any connections degrading due to the increased loads? Was all the periodic maintenance performed correctly? Was the actual thermography survey performed correctly? Was the analysis correct? Much is left to human interpretation.

You may not be sure until next year...or until a failure occurs. If only we could see into the cabinets without opening them.

### **The 3rd Generation - IR Windows**

The need to take thermal images on a timely basis and with the least amount of intrusion has spawned the development of infrared windows. The intention of the IR window

is to allow the thermographer to obtain the thermal images while the cabinet is closed, as often as needed. This greatly decreases the risk factor to the technicians, while decreasing the likelihood that opening or closing the cabinet will cause problems with the systems. Once installed, they can greatly decrease the intrusiveness of the thermography work.

IR windows have come a long way and there are many choices in the market today. Along with so many choices, comes compromise. The types of material and their compromises have been covered very well in past articles, so this particular information will not be covered in this article. But based on the nature of this article, we’ll discuss the highlights.

The IR window should allow the thermographer to take the thermal image while not opening the panels. The goal with the selection and placement of an IR window is that most, if not all, targets should be available for viewing.

IR Windows allow for line of sight, based on the lens used in the thermal camera. Bus bars may cover one another, if there are additional arc flash venting panels installed, bus bars behind them and parts of the circuit breaker will not be available for scanning.

IR windows are made from different materials and each one has its benefits and compromises. Each one will have different ratings for transmission of the available IR signal. The Technician will need to be mindful of this while taking thermal images year to year. The correct compensation will need to be set in the camera for each different thermal window.

One needs to be mindful of the UL or safety ratings of the cabinet into which the IR window is being installed. The addition of an incorrect IR window may invalidate the safety

rating of the cabinet. Make sure to consult the manufacturer of the IR window, the manufacturer of the cabinet, as well as the organization that has approved or listed the cabinet.

### The 4th Generation - Here Today

If we were to start with a clean slate, what would we really want?

Would you want to increase safety by not needing to open a panel and conduct tests live to know a temperature? Would you want to specify the switchgear and electrical panels with the intelligence to take it's own temperature?

Wouldn't it be nice if the equipment let us know when something inside is too hot? Wouldn't it be great to look to see how our equipment fared on the night that a substantial event occurred?

Wouldn't we also want to be able to know for sure that once all the panels were re-as-

sembled after the periodic maintenance was finished that all was still fine?

Wouldn't we like to be able to look at real time data that's been collected from the last 365 days, and substantiate that there is a sound reason to extend a periodic maintenance, so we don't bring down a system unnecessarily? Wouldn't we want to know immediately how the electrical system is handling the latest server upgrades?

We know from experience that problems start out small. When problems are small, they will exhibit a small temperature rise. The worse the problem grows, the more dramatic the temperature rise. As the temperature rise increases, as with a bad connection, the increased temperature causes accelerated oxidation, pitting and carbon build up - further damaging the connection, causing an increase in resistance, which causes an increase in the heat. The cycle continues until we experience

a fire or complete failure. Based on practical experience, the cycle may only take a month, or as much as a year.

If we are lucky, we catch the problem within the thermography cycle established, before it festers to a more expensive repair or a total failure. The bottom line is, the sooner the problem is spotted, the simpler, cheaper, and quicker the repair.

Connections exhibiting a 30° rise, due to added resistance, will hardly register a decrease in current. In fact, in recent testing, a 20 amp branch circuit powering a resistive load with a 50° rise on a connection, barely showed a 500ma change in the load current. How the branch current acts when the source voltage decreases depends upon the load.

You would naturally think that if the source voltage decreased, the current would decrease



Figure 2 - Unobtrusive installation and the convenience of no maintenance make constant thermal monitoring an attractive option for critical equipment.

as well. So you might think a bad connection within the branch circuit would cause the applied voltage to decrease somewhat, then a corresponding decrease in current should be noticed.

But, this doesn't happen with servers. The Switch Mode Power Supply (SMPS) found in the typical server has a negative resistance characteristic. As its input voltage decreases, its input current increases. Due to the negative resistance of a SMPS, when even a minor voltage drop occurs (say from a connection becoming faulty) an increase in current will be

experienced. This slight change in branch current can easily be interpreted as just additional processor use, or well within the normal range of load fluctuations, not the lurking "bad" connection. Basically, monitoring load current is a great way to know if the loading is what you've planned it to be, but is no measure for the health of the electrical service and the components that make up the electrical service.

If you had data spanning from the last periodic maintenance, and if all the temperatures in the data were fine, there would be no reason to shut down a system, and put a technician into harms way to open panels and check torque. But how would we be able to collect such data?

With constant thermal monitoring, such trend data can be collected in real time automatically and used to substantiate fiscal savings like extending periodic maintenance intervals, monitoring the health of the equipment as loads increase, reducing unscheduled downtime by optimizing scheduled maintenance, realizing the capacity of the system during times of growth.

### The Solution: Constant Thermal Monitoring

The next generation is here: 24 hours a day, 7 days a week, 365 days a year thermal monitoring. Using small infrared

sensors as well as other temperature sensors, each critical item can be monitored in real time.

Such systems can use their own data loop, which provides for a nice back up to the standard building management system (BMS) loop. Or, you can choose to integrate it into current BMS systems.

Once installed, there is no dependency on the settings of a camera or competency of a technician. Protective panels do not need to be removed to check on a protocol data unit (PDU) or piece of switchgear if changes in loadings occur after bringing new loads online. Since data is logged 24/7/365, the data can be reviewed for abnormal transients that would indicate abnormal events in heat or electrical loading of a system.

With the roll out of the blade servers the increased branch loading also reflects back to the switchgear. The effects of the added power requirements normally wouldn't be noted until the next thermography cycle, and it may be too late by then. The same constant thermal monitoring system can be used to monitor and alarm the hot and cold server rack isles.



Figure 3 - Infrared sensor installed on 1 phase of a feeder to a panel.

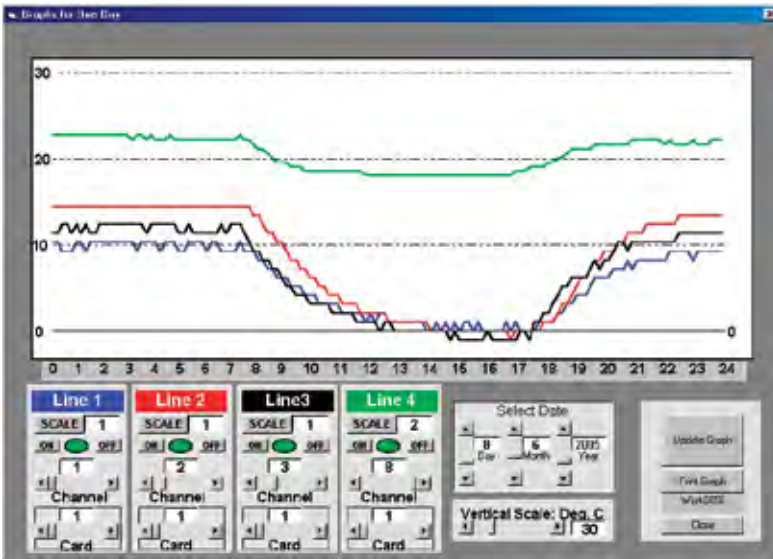


Figure 4 - The Exertherm software has built-in trend graphing, which provides a quick visual of the data.

The Data Acquisition Cards to which the sensors are wired can be mounted either in equipment cabinets or external to the switchgear. Each card accepts 8 sensor inputs, and there is a choice of data cards. One type communicates using an ExerTherm data loop and works with the ExerTherm software to manage the system, (this can also provide alarm status flag

The available mounting systems provide for a flexible mounting option that's comprised of all non-conductive high temperature material. Since the IR sensors are totally passive and require no bias voltage or current, they never require re-calibration.

In electrical equipment, connections, and components (all known as a target) it's more important to know the temperature "rise" being experienced. The "temperature rise" is the effect of the losses within the "target". For a connection, the losses are a result of the resistance in the connection. As previously discussed, the higher the contact resistance, the higher the losses, so the greater the temperature rise.

Thus, in thermal imaging, the accepted method of temperature measurement for electrical equipment is Delta T ( $\Delta T$ ), i.e. the rise above ambient (surrounding air temp), of the target equipment being measured. The ExerTherm IR sensors employ exactly the same method.

### Not Just For Data Centers

Although data centers were used as the pri-

These high-density blade servers aren't less efficient power wise, they just occupy less space. So they emit more heat per cubic foot due to their density, compared to the old, larger server configurations. When "more" servers are installed into one rack, the result is an increase in the BTU's generated (dissipated heat) from the same rack and an increase in current draw from the branch circuit. So keeping an eye on these hot and cold isles becomes just as critical as the electrical components (PDU's, UPS's, & Switchgear).

to existing systems through the supplied dry contacts). Another type of card communicates directly to the likes of Modbus and other key protocols (i.e. Profibus), utilizing existing bus cabling, and providing supervisory control and data acquisition (SCADA) system compatibility. The system can also be web enabled via Ethernet connection enabling access from intranets, or even combined with the latest wireless data transfer technologies to provide continuous monitoring of critical equipment in remote locations. The system can easily be retrofitted during a suitable shutdown, installed during new construction, and be expanded as required in either case. Easy expansion enables progressive installation in critical sites that only have partial system shutdowns.

While new to the USA, continuous thermal monitoring in critical switchgear has been proven over the past 5 years via numerous successful installations in blue chip multinationals located in the UK, utilizing patented IR technology. Since these small IR Sensors are non-conductive plastic, passive, (requiring no external power), and with unsurpassed mean time between failure, they can be placed inside critical enclosures without concern. Certain switchgear manufacturers in the US are already working to offer OEM installation of this system, which provides trend data and independent alarms from each sensor.



Figure 5 -Sensors installed on 200Amp disconnect.

many example of where constant thermal monitoring is being used, ExerTherm has many more applications than just monitoring the electrical system, HVAC system and temperature of a data center. Any facility or manufacturing plant that is focused on achieving greater uptime and getting the most from their scheduled maintenance can benefit from this technology.

Monitoring electrical distribution equipment for manufacturing plants will not only maximize uptime, but also maximize safety and minimize damage. Many of the large scale manufacturing plants use much more power than a data center. This potential energy that could be unleashed during a failure or arc flash can damage not only the electrical distribution equipment, but also very expensive robotic and manufacturing machinery, not to mention injuring any personnel that may be in the area.

There are many applications within manufacturing machinery. In high cycle rate and or close tolerance machining, minor bearing wear can increase the rejection rate. Bearings starting to wear will exhibit an increase in their operational temperature. If left unnoticed, loss of critical tolerances will cause rejects, and eventually a catastrophic failure in the machine. This failure will lead to more expensive repair and an extended down time. The same can be said for motors, gearboxes and pumps as well. So this technology can literally be applied to most large scale manufacturing/processing plants and shipping fleets.

A larger cruise line company has deployed ExerTherm on their modern vessels. These floating cities on water not only generate and distribute the power for their small city, but for their electric propulsion. Loss or damage of electrical equipment or drive components is much more than just unscheduled down time for this industry. Like data centers and large scale manufacturing, the consequence will not only be additional costs, but also a significant loss of profit. Continuous thermal monitoring provides a solution which substantially mitigates that risk.

## Conclusion

The power to monitor any component of electrical junction or device is now available. Not only to monitor it, but also to record its profile over time, which gives us a level of information we have never had before.

We can now know what occurred in the past, what's happening today and predict what's going to happen in the future. Finally giving us the power for true Predictive Maintenance. So, maybe that mission of No Unscheduled Downtime is within reach after all.

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