Operating Mission Critical Power Circuits at Low Operational Loads:

The Hidden Danger for High Downtime Cost Organisations

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High downtime cost can be measured in a number of ways. The most common is financial cost. Examples include organizations operating data centers which are mission critical to the organizations core function, such as financial services where downtime can be measured in millions of dollars per hour, in some cases even per minute. Oil & gas is another similar example.

Downtime cost may also include an ecology or pollution cost. Again oil & gas could be included, as well as waste water treatment plants, chemical processing etc. where interruption of the process could result in significant pollution consequences.

A further measure can be safety, i.e. the cause of the downtime could be an explosion and /or fire with risk to human life.

For virtually all of these industries electrical power will be the most critical utility i.e. loss of power will result in loss of core function resulting in significant downtime/safety risk/pollution risk. Consequently, it is common that such organizations will operate a dual power feed, with each being backed up by an Uninterruptible Power Supply (UPS) system. Each power feed will normally be operated at a level below 50% of the total load requirement / system capacity. This is to ensure that in the event one power feed goes down (either due to a planned maintenance, operational reasons or a problem on one feed), the remaining power feed does not exceed 100% of load capacity. As a result, it is usual for such an organization to operate each power feed at levels between 30 > 45% of capacity.

There can be a number of causes of Arc Flash incidents, but the two most common are human intervention e.g. something is introduced which acts as a bridge between phases causing a short circuit. Another common cause is a compromised joint / termination which gradually increases in resistance until it reaches a level where the electrical energy cannot overcome the resistance in the joint. The result is "feedback" resulting in an Arc Flash incident.

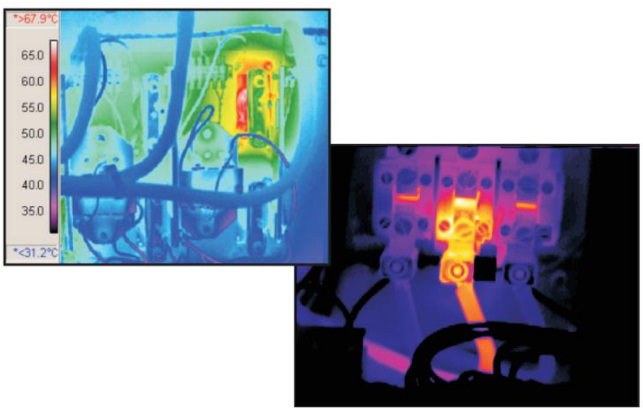
An Arc Flash is an incident of incredible power. Temperatures can reach 35,000◦C, enough to vaporise 1 kg of copper in less than a quarter of a second. When copper transitions from a solid to gas it expands at 65,000 times its volume. The result is a blast travelling at circa 700mph. In the USA alone there are over 10 serious arc flash incidents per day. Globally, it is one of the most common causes of unplanned electrical outage, resulting in millions of dollars worth of business interruption and many serious injuries and fatalities.

High resistance joints / terminations cannot be detected by conventional electrical measurements. Additionally, most mission critical circuits will often be inaccessible when they are energized, preventing physical or optical inspection. However, a high resistance joint can be detected by its increased thermal signature as the electrical energy is dissipated in the form of heat (Newton's Law of Cooling). Thus by measuring the rise of the emitted radiated heat from the joint over the local ambient temperature (Delta T), the fault can be detected. This is the basis of current infrared thermal inspections, which has been internationally recognized.

This risk is recognised by the insurance industry. It is often a mandatory condition of insurance for organizations to undertake an annual Infrared thermographic inspection. In fact, virtually all high downtime cost organizations will now undertake such thermal inspections, as this was the best available non-contact method of thermal inspection which did not require equipment to be de-energized in order to carry out the inspection, an important factor for high downtime cost organizations.

However, an annual thermographic, (i.e. utilizing a thermal camera to provide a thermal "picture" of the target area with the purpose of identifying "hot spots" - see Fig 1), does not resolve some critical factors.

Fig 1: Infrared reveals high resistance 'hotspots'



These can be summarized as:

- Inspecting mission critical circuits on the most critical utility 1 day per year represents less than 1% of the available time. This leaves detection of a problem prior to failure hugely dependant on luck. Current accepted best practise prescribes that mission critical equipment be monitored 24x7.

- Thermal inspections are conducted externally on the electrical enclosure. It is now common for thermal "windows" to be used to increase the infrared transmission. However, there are many issues with this. Even the best windows material can still only transmit approximately 70% of IR. Other materials can reduce transmission to just 30%. The trade-off for increased transmission is more delicate substrate, often requiring replacement every 5 years. Irrespective of the transmission rate of the window, it requires correlation of the result by the operator. In effect, it is taking an external temperature and attempting to correlate that to a reading internally on the joint itself.

- A further issue is that periodic thermal inspection reports are not "Real Time", they are a "Snapshot". The report is also completely divorced and not integrated with either the BMS/SCADA/EMS computer systems.

- Periodic inspections are not capable of dynamically adjusting the alarm thresholds appropriate to the load being applied to the circuit. This is a fundamental issue, which means that such thermal inspections are not providing the level of protection which organization believe they are.

- This question of load is of paramount importance. In many instances the thermographic scans are conducted during periods of low load, with the result that the inspection is virtually worthless. On dual feed sites it is possible to carry out load switching in order to increase load on the circuits being inspected. However, this is in practise rarely done because of operational pressures.

- Cost is also a major issue. Organizations rarely take all the cost factors associated with periodic thermal inspections, often only counting the charge of the thermographer, and other easily identified direct costs. This is very important, as the true costs are thus not being calculated when comparing periodic inspection v continuous monitoring.

Developments in infrared technology have resulted in the ability to resolve all the above issues and provide an enhanced level of protection to high downtime cost organizations. The development was in small, plastic IR sensors which require no external power source (working like a non-contact thermocouple). This enables the sensors to be placed INSIDE the electrical enclosure with a DIRECT VIEW of the joint to be monitored. The sensors connect to processors which provide the data in a Modbus RTU format, thus making the technology completely vendor neutral.

The majority of high downtime cost organizations operate a dual power feed system, with both feeds protected by separate UPS systems. Thus if one power feed fails, there is a backup power supply available. In consequence, both feeds are normally operated below 50% of the total electrical load capacity, so that in the event one feed has to cope with the entire load, it does not exceed 100% of capacity.

There are operational and maintenance reasons why either specific circuits or an entire power feed may be required to be de-energized and the load transferred to the other power feed. Typical loads on each feed are 25 > 40%. If there is a compromised joint on circuits operating at these load levels, there will be insufficient current to generate excess heat. See Fig 2.

There will thus exist a “Hidden” problem. The joint is unlikely to fail unless the load is increased. However, when additional load is applied e.g. when specific circuits or an entire power feed load is transferred, the joint will escalate in temperature and result in a power outage / arc flash incident.

“There was no method which would enable the operator to verify that no “Hidden” problems existed on circuits operating at low loads, enabling them to switch load with confidence that the action would not cause a potential failure.”

Some operators switch load for short periods. This can result in the joint deteriorating each time load is applied until a point is reached where the joint has deteriorated to a level where when load is applied it results in a failure.

The escalation of temperature to failure limits can be rapid, thus early detection prior to the additional load being applied is of critical importance.

The method employed to achieve this is via the application of continuous thermal monitoring on mission critical circuits, utilizing the new IR sensor technology, combined with the simultaneous measurement of load being applied to that circuit. Software algorithms are then applied to calculate equivalent thermal alarm thresholds applicable to the load being applied.

This enhanced level of protection cannot be achieved via periodic thermal imaging inspections. As an illustration, regulatory bodies prescribe that a ΔT value of 40◦C on a joint = an alarm condition requiring remedial action to avoid potential failure. However, that is at 100% of circuit load capacity.

As the load level is decreased, so the alarm level must be reduced proportionate to the load. A circuit operating at 30% of load capacity has an equivalent ΔT alarm threshold of just 3.6◦C. No thermographic scan would identify this as a potential problem. It is a "Hidden" problem, which could result in failure if additional load is applied.

The LoadMap™ ™ technology identifies the existence of hidden problems on circuits irrespective of the load being applied, and predicts what additional load can be applied before an alarm threshold will be exceeded. This is vital information for organizations with high downtime costs.

Thus while many organizations employ annual thermography scans in the belief they are protecting their mission critical infrastructure, the reality is that they are significantly reliant on luck to detect problems and cannot detect potential problems on circuits operating at low loads. The value of such inspection (on mission critical circuits), is therefore questionable.

Since its recent introduction, thermal mapping technology (LoadMap™) has already received enthusiastic acceptance from global and regional OEM's, consultants, and end user organizations.

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Fig 2: *Below graph shows that operating at 25% load with a Delta T of e.g. 10˚C the temperature rapidly escalates past the 40˚C alarm threshold when load exceeds 50% Delta T rises to 150˚C when operating at 100% load.*