Companies rely on good, scientific practices to maintain their equipment and avoid unscheduled down time. Methods of maintenance range from regular planned services to spot checks. Continuous monitoring of equipment, by its nature, provides the most reliable method of monitoring. If any parameter drifts away from the norm, there is an early alarm which allows time to schedule a corrective procedure, preventing the problem from developing to a point of complete failure. Most machines and equipment have many of their critical parameters covered. There is one parameter, however, that can be the most revealing of the condition of a piece of equipment, but is sometimes the most difficult to measure. And that is heat.

Hot spots
To transfer energy from one place to another, some sort of medium must be used. In the mechanical world this medium could be a drive shaft. In the electrical world a typical example would be a cable or bus bar. In an ideal world you would want energy to be transferred perfectly and efficiently i.e. energy in equals energy out. However, in the real world, there are always some energy losses along the way due to unavoidable influences such as friction or resistance. This lost energy is converted into heat, and either conducted or radiated away into the atmosphere. The plant operator’s goal is to keep this energy loss to a minimum. When transfer mediums are operating as designed, the energy loss that must be dissipated is usually very small and undetectable by conventional equipment. However, when areas of loss become less efficient, they start dissipating more energy in the form of heat - they start heating up significantly, creating so-called hot spots.

This hot spot becomes self-feeding. The generated heat causes further degeneration by increasing the resistance, which in turn leads to more heat. This phenomenon is known as thermal runaway. Usually the hot spot feeds on itself in an exponential fashion until the end result is complete destruction. For the company affected, costly down time could run into millions of rands.

Electrical hot spots
In electrical equipment, the areas of most concern are basic connection points. These include those between busbars, between busbars and switching equipment, and cable termination points. A good connection on a typical busbar connection point typically has a resistance of less than 1 μΩ. The current flowing through such a connection point could be hundreds of amps. The energy lost through this connection point is very small.

Example
For example, with a current of 100 A and a connection resistance of 1 μΩ, P = I^2 x R
= (100)^2 x 0,000001
= 0,001 W
In other words, it’s just one milliwatt of energy - nothing to worry about!
However, this resistance could increase if this connection point degenerates in any way due to factors such as:
- Accidental movement
- Oxidation caused by moisture or chemicals in the atmosphere
- Contraction and expansion causing looseness
- Overloading

What would be the result of a resistance of only 1 Ω?
P = I^2 x R
= (100)^2 x 1
= 10 000 W
In other words, 10 kW of energy!
This is enough to cause complete catastrophic meltdown of the copper connection point in a most spectacular fashion.

Dealing with hot spots
Human inspection
The most cost-effective basic way of dealing with hot spots is human inspection. Placing a hand on safe-to-touch areas like panel doors and feeling for heat, or simply looking at the equipment for areas of discolouration caused by heat are simple ways to determine the condition of equipment. The inspection method is very rudimentary, can be unreliable and also subject to misinterpretation.

Continuous electrical hot spot monitoring
by Gavin Pletschke, Aspercon

It’s all about down time. Lost production is a major threat to any organisation, and the lost production costs are negligible compared to the cost of replacing the failed equipment that caused the down time.
0,9 emissivity? According to figures in infrared hand-held instrument set at if a copper busbar is running at 100ºC, setting on a conventional hand-held Although one can change the emissivity with an infrared hand-held device. Metal objects, on the other measured by a hand-held infrared They can accurately be own energy. They can accurately be measured by a hand-held infrared device. Metal objects, on the other hand, can have emissivity anywhere from 0,01 to 0,9, making it extremely difficult to measure their temperatures with an infrared hand-held device.

Emissivity
Emissivity can be defined as the amount of energy emitted from a target as opposed to that being reflected off the target from another source. This value is expressed as a unit of measure between 0 and 1,0 being a perfect mirror reflecting all energy and 1 being a perfect “black body” emitting 100% energy and reflecting none. Most non-metal objects have emissivity of about 0,9, meaning they emit 90% of their own energy. They can accurately be measured by a hand-held infrared device. Metal objects, on the other hand, can have emissivity anywhere from 0,01 to 0,9, making it extremely difficult to measure their temperatures with an infrared hand-held device.

Although one can change the emissivity setting on a conventional hand-held instrument right down to 0,1, it then becomes the operator’s guess as to what the temperature really is. For example, if a copper busbar is running at 100ºC, what would the likely temperature measurement be, using a standard infrared hand-held instrument set at 0,9 emissivity? According to figures published by Rohsenow and Choi in “Heat, Mass and Momentum Transfer”, (Prentice – Hall, 1961), copper has an emissivity of somewhere between 0,05 and 0,6 depending on temperature and surface conditions. If ambient is 30ºC, the actual rise in temperature above this would therefore be 70ºC for the given busbar. Note that 0,05 x 70ºC is only 3,5ºC, and 0,6 x 70ºC is 42ºC.

So the hand-held would therefore display somewhere between 33,5ºC and 72ºC!

Infrared camera technology
Over the last few years, infrared cameras have made an impact on this market in a big way. The camera converts an infrared image and superimposes it on top of a normal image of the target being viewed, giving a very visual and easy-to-interpret temperature image of the target. These images can be captured and referenced and thus are an excellent auditing tool. Thermal camera technology is very expensive however, so many companies prefer to ask independent contractors to do thermal auditing of all their electrical equipment. Shortfalls with thermal audits are that they usually have to be scheduled, and they need to be done in a skilled and organised way. Panel covers must be removed, panel doors must be opened, and equipment must be correctly loaded and online to get the right results.

Inspections are a major inconvenience to a company, interfering with its operations. So naturally they are done only once or twice a year at most, and not always at the best times for inspections. The rest of the year the equipment runs at the same high risk of developing a hot spot without any warning. Even a professionally done, thorough thermal audit, although very useful in picking up problems occurring on the day of the inspection, often do little to prevent a major unscheduled event from happening shortly afterwards.

Continuous monitoring
The only real solution for peace of mind is continuous monitoring. “24/7”, 365 days a year. There is a whole range of small, relatively low cost, infrared sensors that can do the job. The main problem with most infrared sensors is whether they are able to work inside an electrical panel, surrounded by electrical fields and high voltages. Most infrared sensors are active, meaning they must be powered to run their internal electronics, which amplify the very small signals measured by the sensing head. Strong electrical fields can cause all sorts of problems of interference and drift. What is needed is a sensor that is self-powered, immune from electrical interference and is made from plastic as much as possible to reduce the risk of shorts and flashovers. There are sensors available called infra-red thermocouples. These are totally passive, low cost, not affected by electrical interference and don’t drift with time, i.e. they are calibrated to stay true for life. Infra-red thermocouples are ideal for this type of application.

Just like ordinary thermocouples, they generate their own electromagnetic fields from the radiated energy emitted from the source and convert it to a known mV signal that can easily be read by standard thermocouple reading devices mounted outside the area of electrical interference. With these characteristics infra-red thermocouples can be mounted permanently inside electrical cabinets, pointed directly at the potential areas of concern. Live conductors may be safely and easily monitored continuously without the need to open panel doors or take covers off.

Inexpensive standard thermocouple data collection equipment may then be used to monitor the sensors, and alarms can be configured to warn tirelessly for when temperatures are beginning to drift from the norm. Actual temperature information can also be transmitted easily to a central control area for temperature logging, event recording and alarm monitoring. This type of system is easily available now. It is inexpensive, making this solution easily affordable and easily justified against the crippling cost of unscheduled down times.

Additional benefit
The capacity of highly loaded electric power conductors, especially switching and transforming equipment, is limited by the temperature rise characteristics caused by the slight resistive losses discussed earlier. Accordingly, the equipment utilisation capacity is a direct function of the local temperature at critical points in the equipment.

With continuous real time monitoring, critical equipment can be used much more effectively. If the temperature is below operating limits, additional power may safely be routed through the equipment.

Contact Gavin Pletschke, Aspercon, Tel 011 918-8340, gavin@aspercon.co.za