

Technical News

Specialists in electrical and automation products, systems and solutions

A photograph of a hospital hallway. In the foreground, a person in light blue scrubs is pushing a gurney with a patient, moving from left to right. The person and gurney are blurred due to motion. In the background, other staff members are visible, also blurred. The hallway has white walls, a light-colored floor, and a handrail on the right side.

**Solutions to prevent overheating
of critical switchgear**

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INTRODUCTION

Overheating is one of the single biggest causes of failure in critical LV switchgear such as Moulded Case Circuit Breakers (MCCBs) and Air Circuit Breakers (ACBs). Modern circuit protection is provided by digital, microprocessor based overcurrent relays which are operated by measuring current flow, not heat. Therefore, abnormal heating caused by loose connection bolts, ventilation failure or worn contacts are usually left undetected by conventional circuit protection devices.

This abnormal heating can lead to pre-mature failure of switchgear and also constitutes a potential fire hazard. Many power critical applications such as data centres, hospitals, utilities and mining sites use technology such as thermal imaging to help identify over heating in switchboards, but this method is only valid during that specific 'snapshot' in time.

Recent developments within microprocessor based circuit breakers provide the option of monitoring the temperature of the contacts and terminals continuously, which can substantially minimise downtime of the installation and reduce the risk of fire.

If an abnormal condition was to occur this information can be communicated to the Building Management System (BMS) to allow the facility managers to plan for preventative maintenance before a critical power outage or even a fire hazard was to occur.

In the following Technical News we'll examine the sources of overheating and the potential solutions to prevent this.



SOURCES OF OVERHEATING

There are several sources that can contribute towards switchgear overheating; all of which can occur while it is carrying its normal full load current. Typical sources of overheating are listed below.

Connections/ Terminals

If any of the copper connections onto the main ACB terminals (Figure 1) are not at the correct torque, this can lead to a potential hot spot. Equipment close to machinery which have reasonable vibration such as generators, pumps, motors or compressors can loosen the copper to copper making surface, potentially leading to a situation where over time an over-temperature could result.

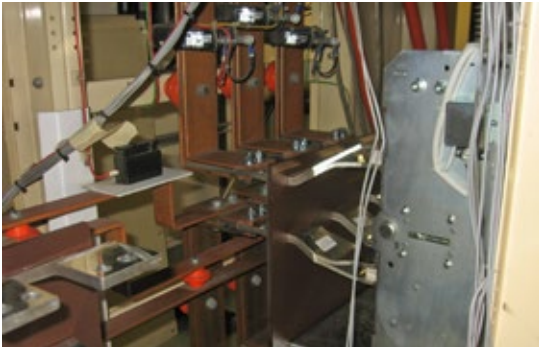


Figure 1 – Rear copper connections to the ACB chassis

Contacts

Depending on the application, over time the fixed and moving contacts of a circuit breaker or switch can be prone to contact erosion. Localised arcing and contact erosion can occur when switching an inductive load such as a motor. Over several cycles, this can lead to an uneven contact surface and contamination build up, thus increasing contact resistance shown in Figure 2.

If a circuit breaker has been subject to lower magnitude faults over its lifetime, i.e. ground faults, this too can result in an increase in temperature at the contact point, which will transfer to the terminals. Therefore, it is imperative that internal contacts, particularly of a main incoming ACB be of a modular design allowing for easy replacement.

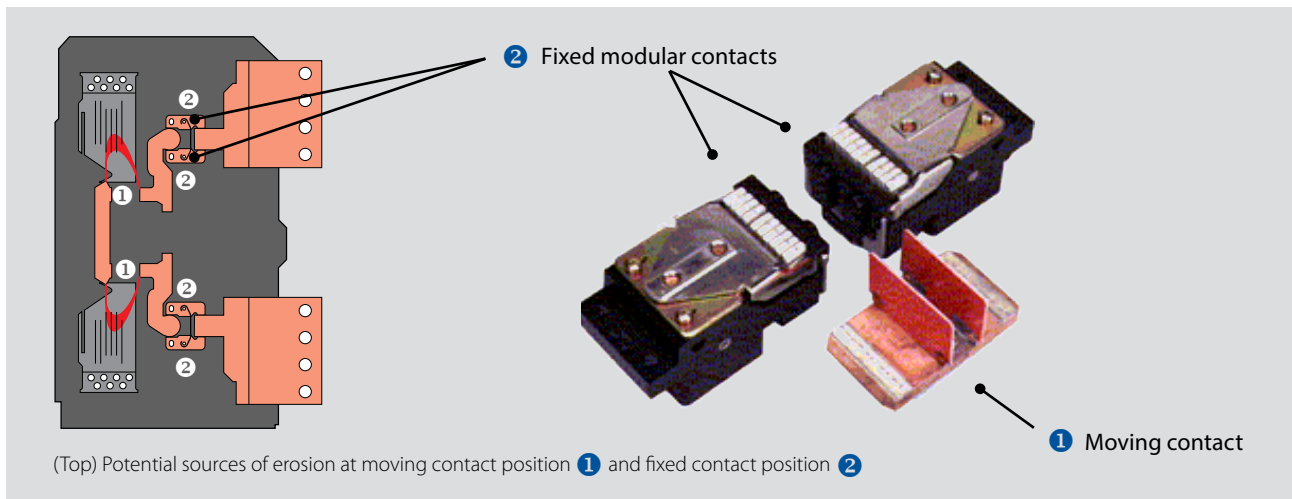
Isolating Clusters

All draw-out switchgear such as an ACB utilise isolator clusters which can be subject to contact corrosion. During a fault condition, the electrical current passes from the connections, through the clusters, then contacts. The isolating clusters are spring loaded and are therefore subject to some degree of slight arcing that can lead to increased contact resistance and will eventually overheat (see Figure 3 below).



Figure 3 - Internal springs from clusters

Often maintenance engineers will replace an existing draw out ACB body with a new body in order to resolve an overheating problem. Unfortunately, all too often they discover that the over temperature was not due to the contacts but actually due to a loss of spring tension in the isolating clusters, which traditionally are inaccessibly located inside the ACB chassis.



(Top) Potential sources of erosion at moving contact position 1 and fixed contact position 2

Figure 2 – Internal contacts of an ACB that can be damaged by continual arcing during switching

Sources of overheating continued....

See the example below in Figure 4, where a combination of poor maintenance procedures and a worn, overheated isolating cluster resulted in a major switchboard fire. This incident occurred at a Western Australian mining site in 2014, resulting in a costly interruption to production and the maintenance worker was badly injured. The official investigation noted that the circuit breaker's clusters had a history of reduced spring tension which lead to the hot joint.



Figure 4 – Fire damaged ACB caused by an overheating cluster

Utilising drawout switchgear that contains the isolating clusters directly integrated into the 'removable body' ensures both the contacts and isolating clusters can be inspected and easily maintained. Figure 5 below, shows the traditional problematic 'cluster in ACB chassis design' compared to the modern, fully maintainable 'cluster in ACB body design'.

De-rating requirements for switchgear

It is a fact that modern switchgear is significantly more compact than in previous generations, and as a consequence tend to operate at higher temperatures. It is not uncommon for Air Circuit Breakers to demand a substantial cross sectional area of copper bus to be connected to its main tags to perform at the rated current. In the case of Moulded Case Circuit Breakers or Air Circuit Breakers, the devices could fail to clear a fault if the contact temperature is not maintained within appropriate limits.

Manufacturer's recommendations must be followed to ensure that the device performs as intended and does not suffer from overheating which will reduce the devices' lifespan resulting in pre-mature and possibly catastrophic failure.

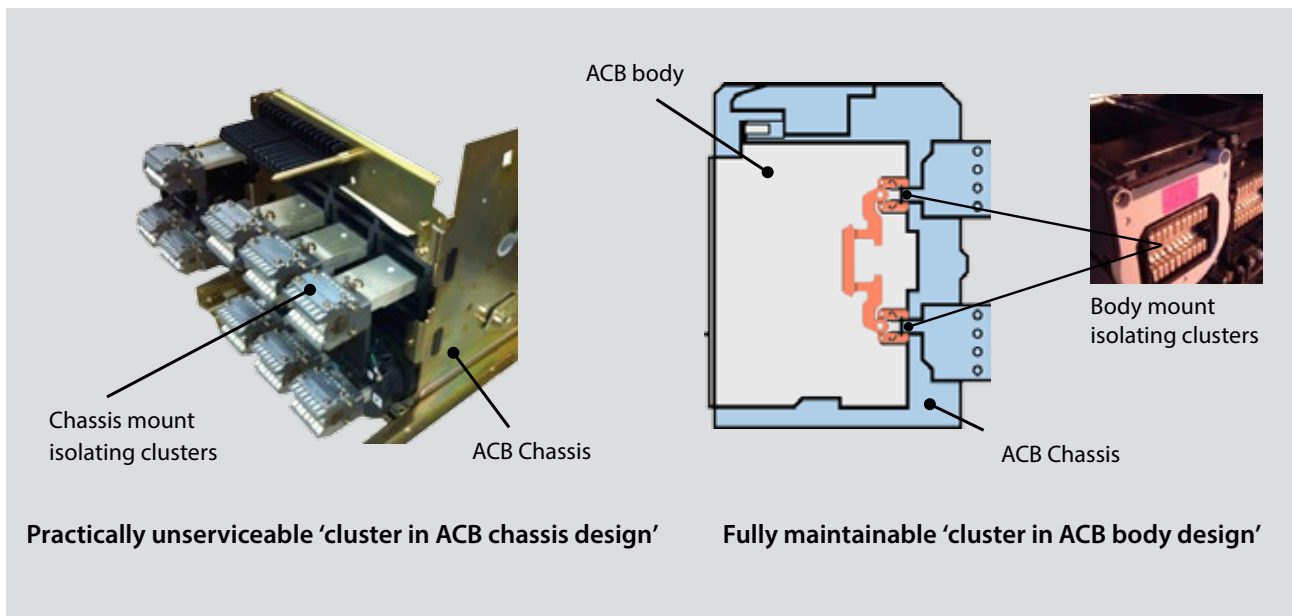


Figure 5 – Traditional 'cluster in ACB chassis design' vs the new modern 'cluster in ACB body design'.

Sources of overheating continued....

Poor Ventilation

Some degree of ventilation is always provided for installed switchgear, having a rating of anything from IP31 to IP43. Several louvres in the switchboard facilitates a degree of air flow in the enclosures; however some designs with higher IP ratings may use fans to provide forced air cooling for switchgear equipment. In particularly dust prone environments (i.e. mining sites) these louvres can become 'clogged' with contaminants, leading to increased thermal stress on components. If left undetected this could result in eventual pre-mature failure of the switchgear.



(above) Clean louvers allow optimum air flow

THERMAL IMAGING - CONVENTIONAL APPROACH TO OVERHEATING

Infrared Thermography is widely used to detect overheating in switchboards. It can be used to detect the problem early before an electrical component heats or burns up.

Infrared scanning of electrical components can help detect loose connections and defective equipment as part of a preventative maintenance regime as shown in Figure 6.

In this picture the MCCBs outer phase is generating excessive heat due to the poor cable connection.

If the switchboard is fitted with inspection windows, then this non-contact method of analysis is useful. However, the majority of switchboards are not fitted with such facilities usually due to cost.

This means in practice the door of the switchboard needs to be opened and the equipment remains 'live' and carrying current to ensure a proper reading is taken.

From a health and safety point of view this is regarded as working while live and therefore substantial risk assessments need to be carried out before this work can be arranged, which can cause disruption.

Another issue with thermal imaging is that it is a "snapshot" in time.

If an overheating problem was to occur in between the thermal imaging period which could be anywhere from one to five years as an example, then the problem would be left undetected and may pose a potential fire hazard.

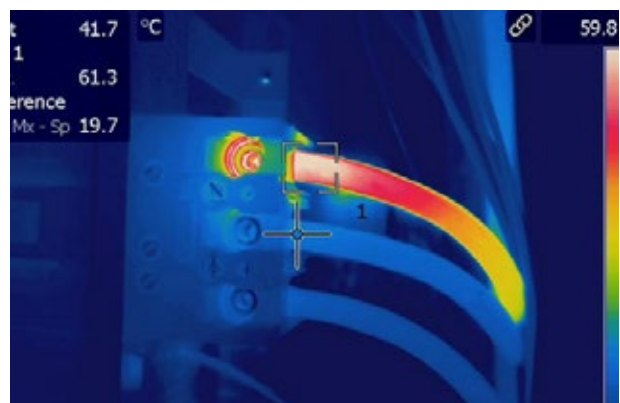


Figure 6 - Infrared Thermography of a 'hot' cable termination

A NEW APPROACH - INTEGRATED CONTINUOUS CONTACT TEMPERATURE MONITORING

NHP are proud to bring a system unique to Terasaki ACBs that provides condition based temperature monitoring as an option. This fully integrated temperature condition monitoring system continually checks for overheating abnormalities that could be due to an issue with the main Conductors, Contacts and Connections as show below in Figure 7.

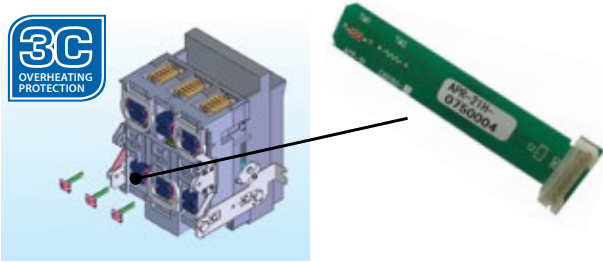


Figure 7 - ACB with integrated thermal sensors

Within the European electrical industry, the Conductors, Contacts and Connections temperature monitoring concept is abbreviated to '3C' and circuit breakers that offer this level of protection are usually represented by the electrical symbol shown in Figure 8.

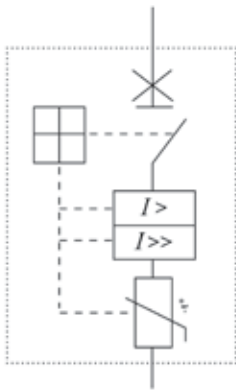


Figure 8 – Electrical symbol indicating a circuit breaker with integrated overload, short circuit and 3C protection.

The status and wear of the contacts is determined by the temperature measurement using NTC (Negative Temperature Co-efficient) thermistors. Self-diagnosis is achieved by direct measurement of physical properties. Each phase of the circuit breaker contact is fitted with its own thermistor. The thermistor will analyse all the three phases continuously every ten milliseconds.

The thermistors used are in a glass encapsulated package, diode outline, with axial tinned Dumet (Copper-Clad Ni-Fe) wire. An example of temperature response to contact resistance (wear) for ACB contact temperature monitoring is shown in Figure 9.

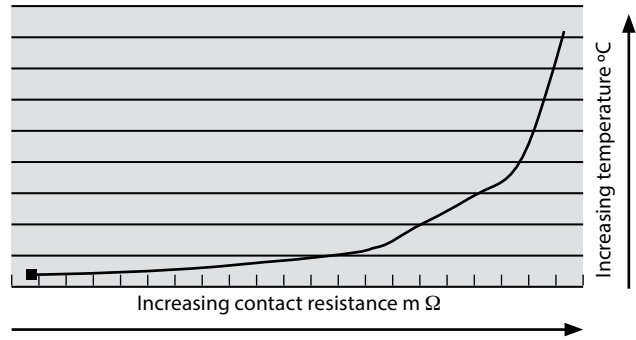


Figure 9 - ACB Contact Temperature vs Resistance

It is important to distinguish between 'direct, continuous measurement' versus 'algorithmic modelling' contact wear indications. The latter are inherently less accurate and therefore more likely to result in false alarms or under protection. Direct continuous monitoring of the contact temperature provides valuable input for preventative and predictive maintenance programs.

Should an abnormal temperature occur the ACBs integrated protection relay will generate an 'Over Heat' (OH) alarm on the integrated local LCD window, close a volt-free output contact and deliver a message to the Modbus network.

To compliment the integrated circuit breaker over temperature protection and extend the level of monitoring to other areas of the switchboard, such as busbar zones, external 3C modules can be used. These external modules use non conductive fibre optics probes which can be fixed directly to a busbar via a special terminating lug.

The temperature is measured by pulsing a laser down the fibre optic cable to a phosphor dot located on the terminating lug. The phosphor dot is excited by the laser and starts to glow. The module then measures how long the phosphor glows (which is linked to the temperature) and then calculates the temperature which can be communicated over the network (see below in Figure 10).



Figure 10 - External 3C module for busbar zone monitoring

This information allows Facility Managers to plan for any necessary maintenance. The implementation of condition monitoring techniques such as this can be equally applied to older installations as well as new builds.

The increase in End Customers considering retrofit solutions to replace ageing switchgear, can also take advantage of new solutions such as this when considering to replace and upgrade their protection and switchgear.

Now that we've discussed some of the theory behind solutions to prevent overheating in critical switchgear, we'll examine a case study where such protection could have helped prevent a catastrophic failure.

CASE STUDY (MARINE INCIDENT INVESTIGATION UNIT 1997 REPORT ISBN 0 642 200 16 5)

On the 23rd of August 1997, the self-discharging bulk cement carrier 'Goliath' was alongside in the port of Devonport, Tasmania, loading a cargo of bulk cement for discharge in Melbourne and Sydney. At about 22:02hrs, the ship's fire alarm sounded due to an incident in the ship's transformer room.

Although the transformer room was filled with quite dense smoke, two of the ship's engineers entered, but then noticed that the smoke was coming from the main switchboard room behind them. The smoke was accumulating rapidly and the men were forced to leave the transformer room immediately, before they could locate the source of the smoke.

The engineers set about shutting down the two running generators. The emergency generator started and placed itself on load. The emergency generator was also stopped by the engineers, because they were concerned that it may energise the main switchboard. Emergency battery lighting was then operating.



(above) Goliath bulk cement carrier

The Tasmanian Fire Service arrived and were shown into the main switchboard room. A crowbar had to be used to open the top door of the No. 2 generator cubicle as the lugs for securing the door in the closed position had melted. The firemen extinguished the fire using CO₂ extinguishers. However, the heat was such that the fire continually re-ignited and it became necessary to use dry powder extinguishers.

The fire destroyed the switchboards' main ACB and its associated control equipment.

Furthermore heat damage had affected the adjacent cubicles in the switchboard resulting in the synchronising panel being rendered inoperative. The remainder of the main switchboard had suffered some smoke damage. Contractors carried out repairs over the next 18 days during which all the ship's circuit breakers were replaced with a Lloyd's approved type.



(above) Damaged switchboard from the Goliath

Summary of the formal investigations findings:

- The source of fire was an internal fault in the generator ACB, a likely result of serious overheating of the centre pole conducting path.
- A previous infra-red examination carried out in Melbourne to detect hot spots on the ship's switchboards, had found no defects.
- Manufacturer recommended maintenance inspections had never been carried out on the ships ACBs.
- A heat detector, located close to the ACB cubicle failed to alarm due to the switchboards' design and layout.

3C circuit breaker temperature monitoring technology is designed to help prevent situations like that seen on the 'Goliath'. Continuous contact temperature monitoring and alarming could have prevented this type of catastrophic failure, avoiding the health hazard posed to the ship's engineers and the costly repair work.

EXAMPLE OF IMPLEMENTING INTEGRATED 3C CONTACT TEMPERATURE MONITORING

Imagine we have a tier 4 data centre that provides 99.995% availability per year to its customers. To maintain such a high level of uptime / availability, the data centre's power and cooling design requires layers of redundancy and furthermore the ability to monitor the integrity of critical infrastructure. Any unplanned downtime will bring serious financial consequences and dissatisfied customers.

In this example the focus will be on the MV/LV switchroom and the Monitor and Control Centre (see Figure 11).

Example Situation:

- The low voltage switchboard contains ACBs with integrated 3C overheating protection and data communication.

- The Monitoring and Control Centre is using the NHP InfoSyte software platform to monitor and report on all critical systems that contain 'smart devices'.
- Due to a 'maintenance issue' the forced cooling system in the switchroom starts to blow dust particles into the LV switchboard. Some of these contaminants eventually make their way inside one of the LV ACBs internal contact system. Over time the electrical continuity of this ACBs contact path reduces due to the contamination and an abnormal contact heating occurs.

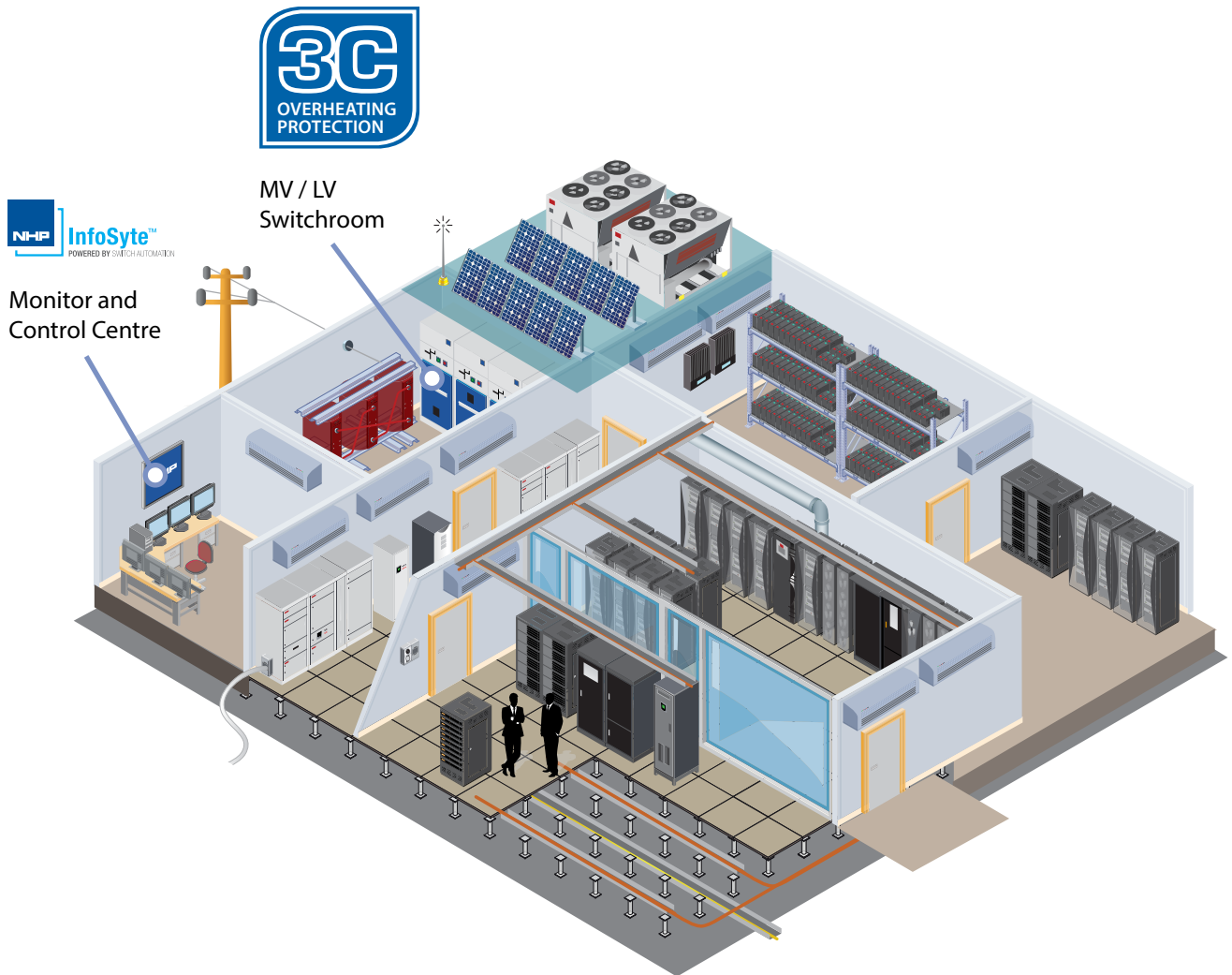


Figure 11 – Example data centre with 3C integrated protection circuit breakers being monitored by the InfoSyte software platform

In this scenario, all 'smart devices' are communicating on the data network and are monitored for status and alarms by the NHP InfoSyte software platform (see Figure 12 below). The ACBs contain integrated 3C overheating protection, therefore contact overheating can be detected by the ACBs trip unit.

This results in an alarm being raised and the NHP InfoSyte monitoring software being notified. Electrical maintenance workers can then plan a shutdown to investigate before any serious downtime occurs.

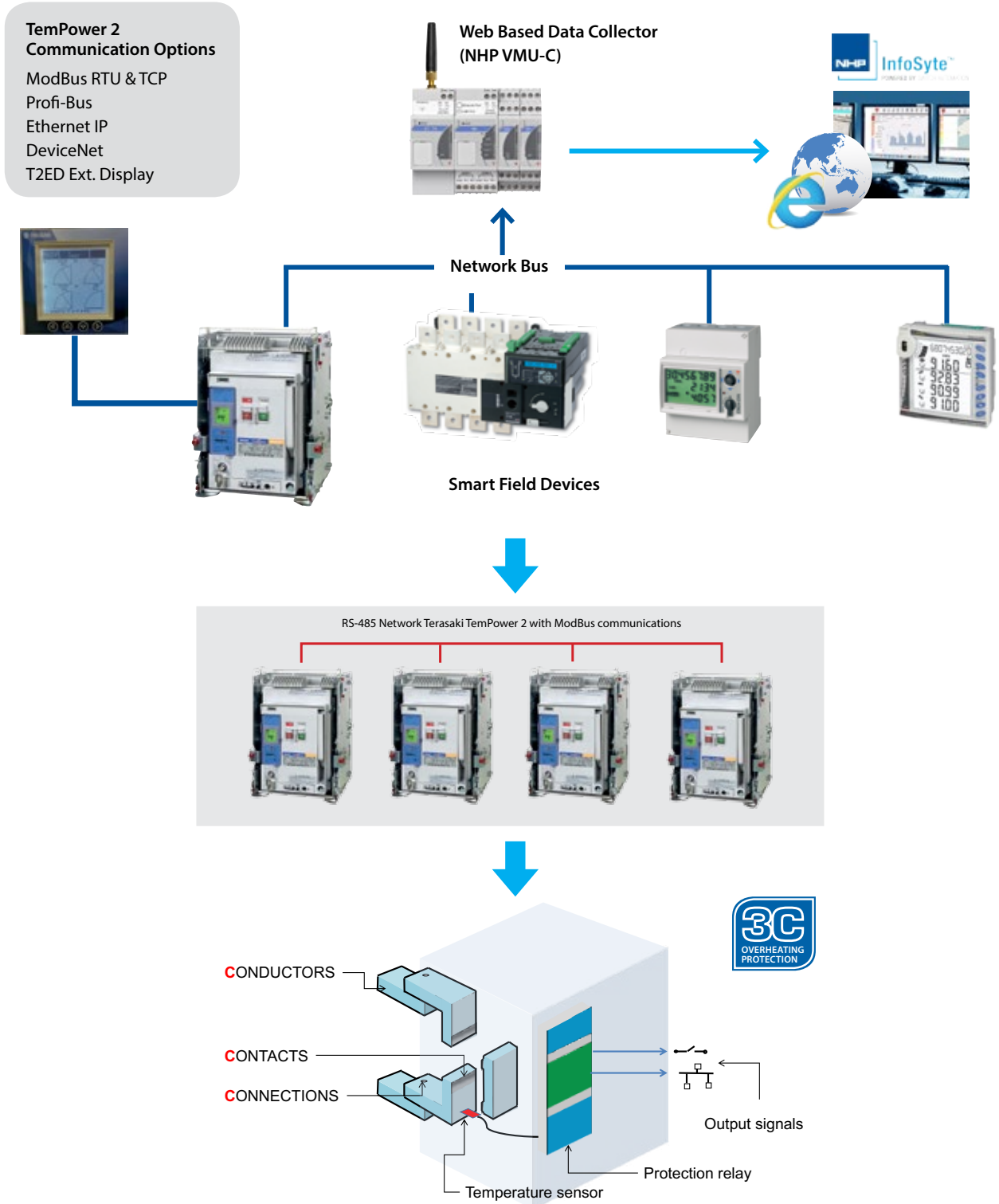


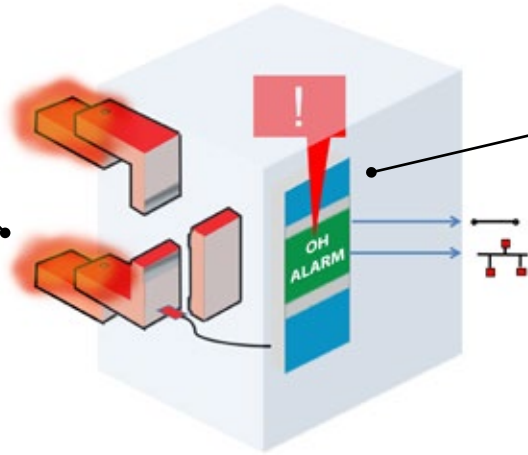
Figure 12 – Smart devices which are monitored over the data network via NHP InfoSyte, and all ACB's in the switchboard are 3C overheating protection enabled

Implementation example continued....

3C overheating protection detects the abnormal temperature within the contact set and activates the alarm (both relay contact and via the data communications network) as per Figure 13.

The ACB trip unit can be configured by the site engineer to 'trip' the ACB of just 'Alarm' (i.e. no trip, just notification) if overheating occurs, avoiding the stoppage of any critical processes.

Abnormal temperature



OH Alarm ACTIVE – Monitoring and Control Centre notified via InfoSyte system. ACB details such as past trip and alarm history could be displayed as well.

COMMUNICATION NETWORK

“Hi maintenance team, we have an ACB over temperature alarm. Can you please arrange a shut down and investigate ACB 002.”

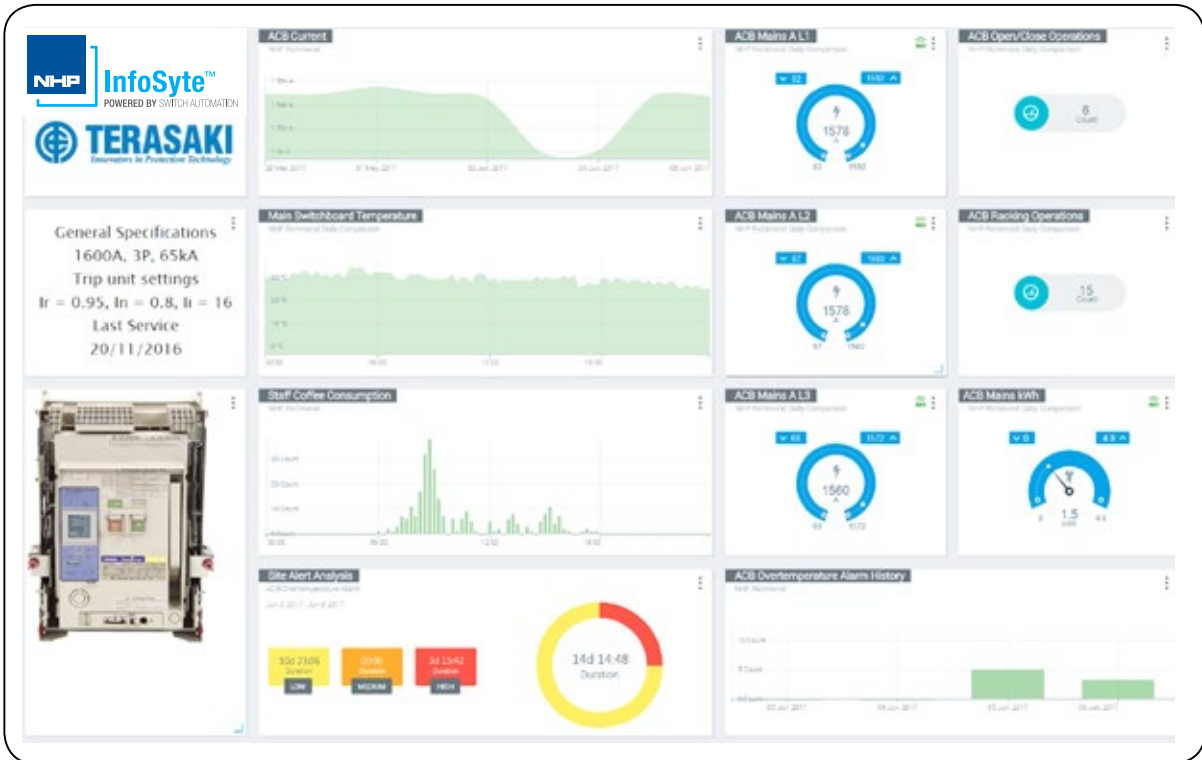
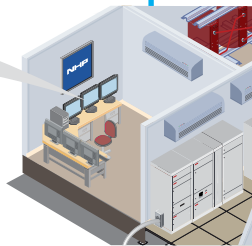


Figure 13 – Example contact overheating notification report via NHP InfoSyte

DATA CENTRE - 3C CIRCUIT BREAKER OVERHEATING PROTECTION CASE STUDY

Terasaki recently installed ACBs and MCCBs incorporating the 3C over temperature technology into the data centre of a multi-national blue chip manufacturer in Merseyside, UK.

The Rosebery Group used Terasaki's 3C overheating protection in the switchboards for the 12 megawatt data centre (pictured below). The following Terasaki products were used:

- 16 x Air Circuit Breakers with overheating protection, integrated display and data communication
- 16 x plug-in Moulded Case Circuit Breakers with overheating protection, and data communication

"Data centres have a constant, non-cyclic, high load which tends to increase over time. Many overheating problems in electrical panels are caused by this type of load profile combined with a faulty connection. Terasaki's contact monitoring system is a good solution because it is based on actual temperature measurement, so it protects the connections as well as the circuit breakers."

- Gary Burgon, Technical Director, Rosebery Group.



Figure 14 – Switchboards installed into the 12MW data centre which incorporated 3C overheating protection



SUMMARY

LV switchgear is one of the areas that is perhaps overlooked when carrying out maintenance schedules in any installation. This is often due to pressures to avoid plant shutdowns.

Neglecting routine maintenance can lead to unplanned outages and any increased temperature of switching devices can also lead to a potential fire hazard. There are many technologies available today which can help detect abnormal temperature conditions in a switchboard, however most of these have significant limitations.

The information gathered by a circuit breaker with integrated 3C overheating protection can help the facility manager develop predictive maintenance plans and minimise downtime. To avoid switchgear running 'abnormally hot', condition monitoring techniques, such as 3C contact temperature monitoring should be considered.

Further Information:

Contact your local NHP specialist to discuss how a customised industrial automation and Terasaki TemPower 2 ACB solution with integrated 3C protection can be implemented on your site.

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