

# Switchgear temperature monitoring

## Early hot spot detection enabling condition-based maintenance

The hot spot detection in medium voltage switchgears is one of the most crucial condition monitoring functionalities. ABB approach gives very high-level performances if compared with other equipment available on the market due to its lean hardware and software structure. It allows for early fault detection preventing insulation deterioration and lowering risks of insulation faults.

### Introduction

More and more electrical equipment operators rethink their maintenance strategy. It is no surprise, their maintenance budgets have decreased in last years and many technicians with long experience have retired. The time-based maintenance programs which they are running are becoming untenable, they cannot inspect and repair the equipment within scheduled shutdown periods with available resources any more.

It is the right time for the electrical equipment to support new maintenance strategies. The operators have to know the actual condition of the equipment and prioritize the maintenance tasks prior the shutdown period and be prepared for preventive actions during scheduled outage. The embedded condition monitoring systems come into focus. In ABB we see increasing number of tender specifications coming with a requirement for embedding temperature monitoring system into the medium voltage switchgear. It is natural and valid requirement as the experience says one quarter of the switchgear failures is caused by loose joint or hot spot in the switchgear.

### Overheating effects

The temperature of the primary circuits has a dominant influence on the switchgear insulation life. If a loose joint within the switchgear creates a hot spot on the primary circuit, the insulation close to the hot spot can suffer serious deterioration due to excessive heating. The lifetime of the insulation decreases rapidly resulting in weak areas sensitive to dielectric stressing during subsequent operation. As a rule-of-thumb, we can say the insulation lifetime is reduced by half for each rise of 10 deg.C in insulation average temperatures. An aged insulator increases dramatically the switchgear probability of failure in form of an internal arc fault, which can result in long-term power supply outage and huge consequential damages.



Fig. 1 Overheated insulator with surface tracking

Since periodical visual inspections might not accurately estimate the remaining life of insulators, the detection of primary circuit hot spots becomes one of the crucial health condition monitoring tasks, and a key input to implement condition-based maintenance. Let's have a look how we tackled this task in ABB.

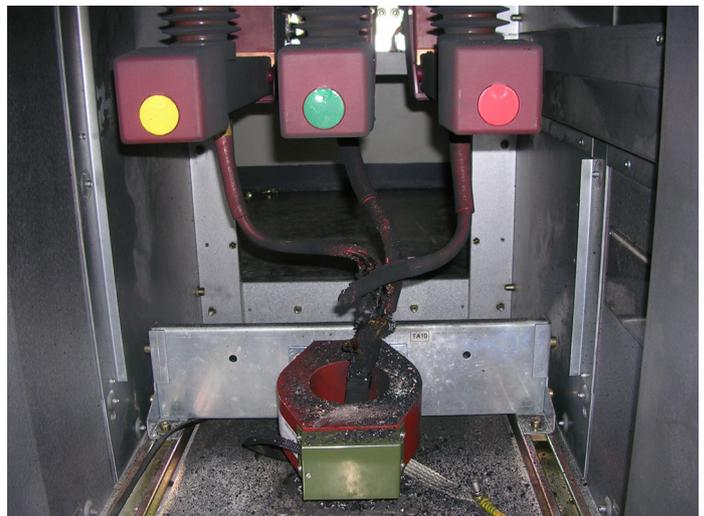


Fig. 2 Overheated cable termination after flashover



Fig. 3 Arc-fault effect on substation

### Failure causes

A hot spot in the switchgear can develop as result of different operational situations, such as:

- Loose joints due to vibrations, unusual operating shocks
- Power cable loose connections as result of severe short circuits and aged clamping arrangement
- Mechanical damage of sliding power contacts during equipment handling outside the panels
- Ablation of contact surface of sliding power contacts due to excess of racking operations above the prescribed limits
- Contacts resistance increase caused by oxidation or corrosion due to unfavorable environmental conditions (humidity, marine ambient, air chemical pollution, etc.).
- Long maintenance intervals due to equipment utilization in continuous process plants.

The points of interest are therefore temperatures on or close to the bolted joints and sliding contacts on primary circuits – see fig. 4. Knowing the temperatures is definitely the first correct task on the road of detecting a hot spot.

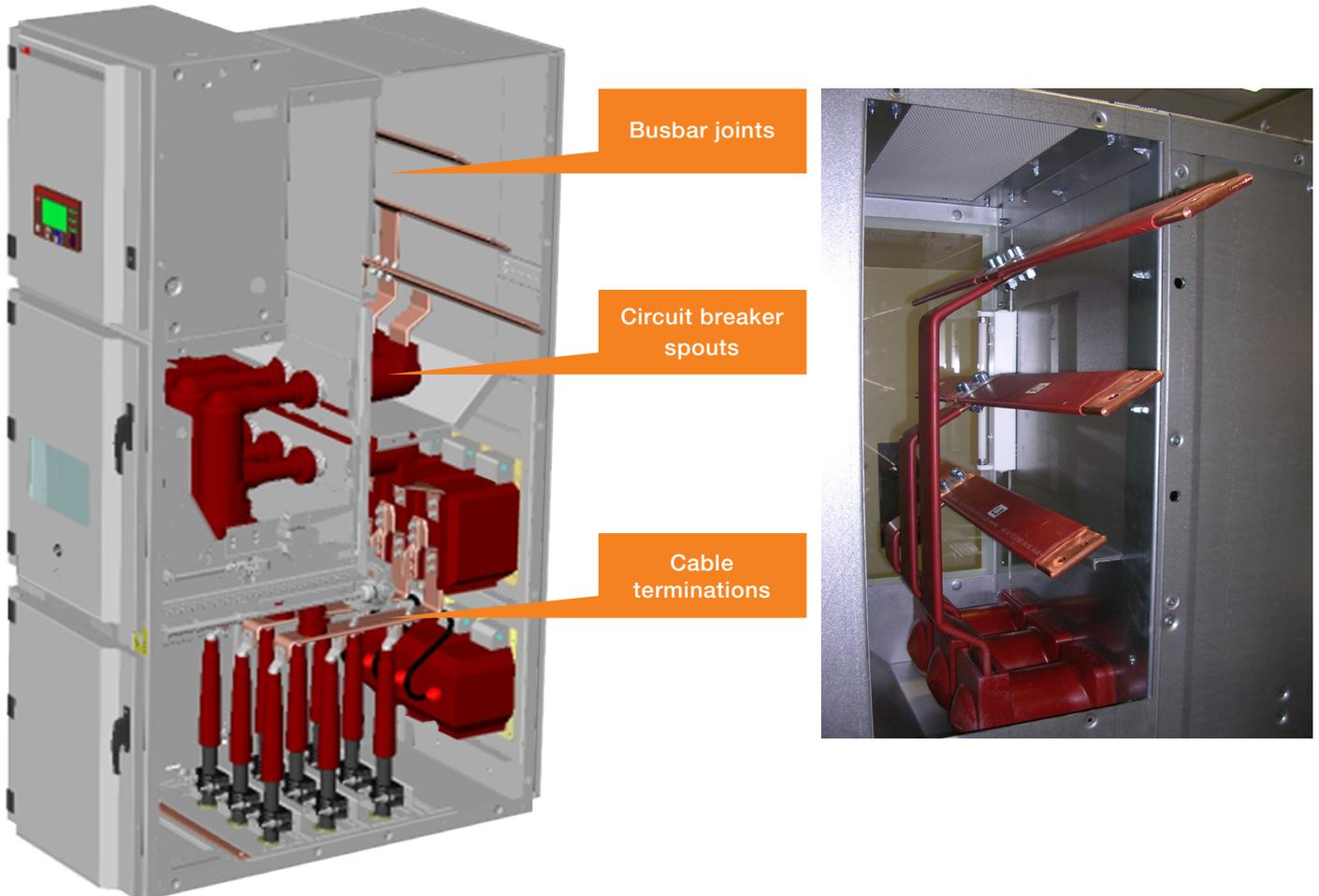


Fig. 4 Areas of interest for hot spot detection. Example of busbar joints in an air insulated switchgear

### Detection algorithm: state-of-the-art

Browsing through available hot spot detection systems on the market we discovered following repeating patterns of the temperature measurement evaluation:

- In basic systems the hot spot is signaled based on temperature delta between the measured object and ambient of the measured object. Usual threshold for alarm is then delta T of 40 deg.C. This method detects fully developed hot spot situations at currents close to nominal of the circuit only, which is already too late for preventing the insulation deterioration (especially for slowly developing faults).
- In advanced systems the temperature values are combined with currents measurement building a complex map of temperature versus current in each point of interest on primary circuit. The delta T threshold for alarms is then dependent on the current. This method allows for more accurate hot spot detection even at low loaded circuits. The main disadvantage is complex data collection and consolidation, need of central data processing and need of tailoring for each specific project. In some of the points (for example busbar joints) the currents cannot be measured and have to be calculated based on the load map of the whole switchboard. One fault in data acquisition or a non-tailored configuration for the specific installation usually compromises the whole system.

### ABB approach

Trying to avoid the disadvantages of both above mentioned methods, we built and successfully tested new effective algorithm for hot spot detection.

The algorithm does not require information about the current flowing through primary circuit but combines properly two other principles:

- temperatures comparison
- temperatures influence

The first one is based on the fact the currents in 3-phase system are usually balanced and thus the temperatures in all 3 phases should be similar at the same point of interest of the primary circuit. If one or two of the temperatures rises significantly above the other, the algorithm evaluates the situation as possible alarm.

The second one is about the selection of the alarm thresholds, considering the measurement accuracy, the possible natural misbalance in the temperatures of the three phases and the possible ambient temperatures influence. Several temperature rise tests, data from many past tests and simulation of the faults were consolidated to get a reliable and robust setting and to know the limits of this method.

The laboratory results proved that proposed solution can detect hot spot situation also at low loaded circuits from 50% of nominal current and above. The hot spot detection is provided on one switchgear panel level – i.e. you can have the hot spot detection for the most critical circuit only. The alerts warn about abnormal overheating before the temperature level of accelerated aging of insulation is reached.

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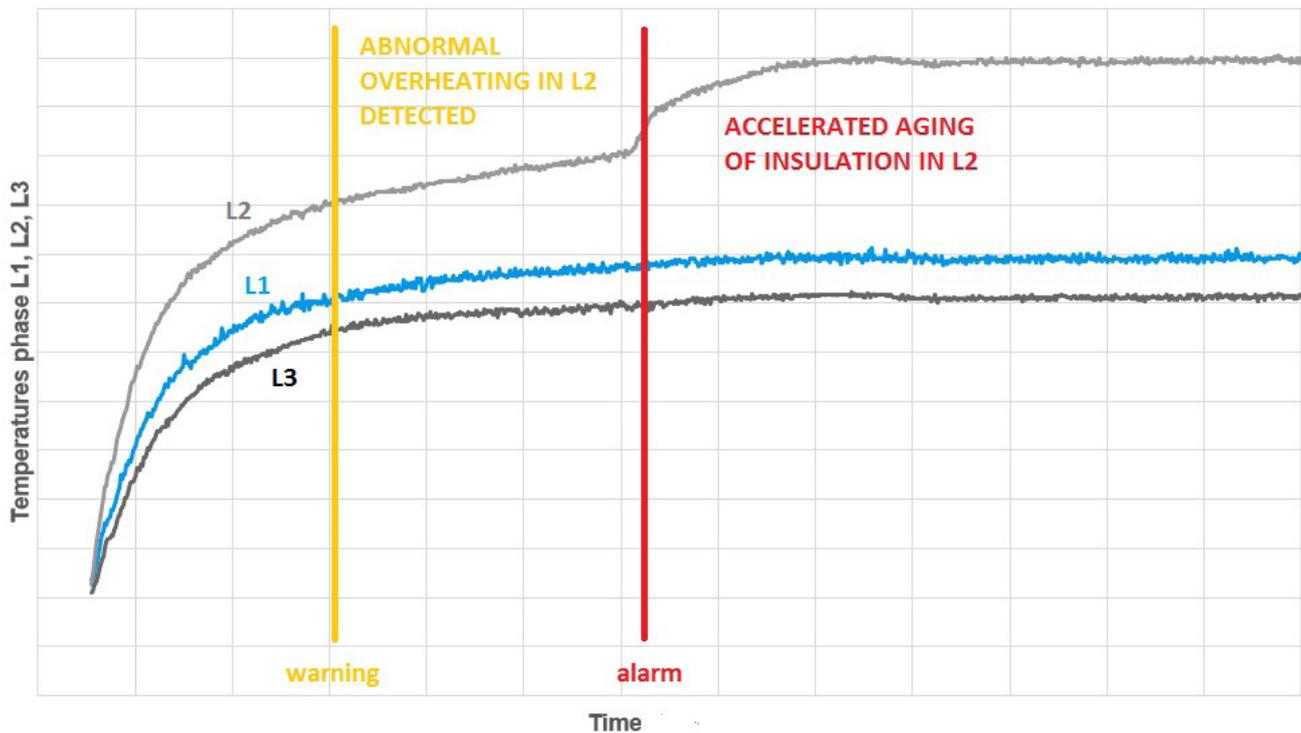


Fig. 5 Principle of detection algorithm - loose cable termination in phase 2 is detected and signaled several hours before evolving to accelerated insulation aging

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