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Thermographic monitoring of electrical assets by enhanced thermal images for feature extraction

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Summary:
Low-resolution infrared (IR) cameras offer a superior alternative technically and economically for a permanent thermal monitoring of critical components in electrical assets. Therefore, a mapping procedure is developed for the combination of an IR and a visual USB camera which delivers a detail-accurate overlay of the thermal on the visible light image representing the so-called enhanced thermal image. The enhanced thermal images support the compartment as well as the component recognition in electrical assets showing the temperatures of regions of interest. Finally, combined with the developed correction algorithm for low-resolution IR cameras, temperature features of those regions of interest can be easily extracted for the condition monitoring of electrical assets, such as maximal/minimal, average and environment temperature.

Keywords: Thermal monitoring, medium voltage switchgear, thermal/IR camera, enhanced thermal image, image mapping.

Introduction

Condition monitoring and diagnostics become crucially important for preventing critical overheating failures of electrical assets such as medium voltage (MV) switchgears. Compared to contacting methods like RFID- or SAW- sensors [1], infrared (IR) thermography provides contactless temperature measurement and is suitable for a permanent installation of online temperature monitoring of MV switchgears. Especially in unknown electrical assets for retrofit, the proper installation of stand-alone IR cameras is quite cumbersome during commissioning since, especially in the cold state, it is uncertain if all components of interest are captured by the thermal IR image. A visual USB camera and the subsequent development of a mapping procedure deliver a detail-accurate overlay of the thermal image on a visible light image showing additionally the physical components of the switchgear. The developed image mapping methods for the combination of a visual USB and a thermal IR camera enable the accurate temperature sensing for extracting the temperature features of regions of interest predefined by the user in the visual image.

Temperature monitoring in MV switchgears

Fig. 1 shows the different compartments and components that have to be supervised for a reliable temperature condition monitoring in MV switchgear applications [2,3].

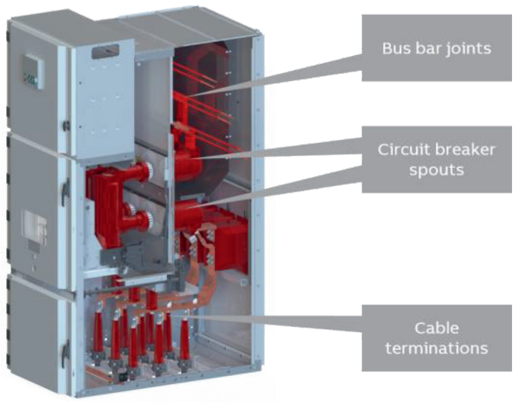

Fig. 1. Schematic view of a medium voltage switchgear panel. Temperature monitoring at the following locations: bus bar compartment (top), upper and lower contacts of the circuit breaker (middle), and cable compartment (bottom).

Enhanced thermal images for temperature feature extraction

The main idea is to provide a detail-accurate overlay of the thermal image on a visible light image which is referred to as enhanced thermal image. Therefore, it is convenient to use a combination of an IR and an USB camera where both lenses possess similar optical characteristics, as for instance similar field of view and fish-eye effect. The image mapping methods are developed by conducting basic tests with both cameras and an uniformly-heated rectangular object with the homogeneous temperature T_{Obj}.

As illustrated in Fig. 2, the mapping method consists of two main steps resulting in an enhanced thermal image as a detail-accurate overlay of the thermal on the visible light image. First, two local coordinate systems are defined in the geometrical center of each image. Then, by considering the fields of view and camera offset, the local coordinate systems of both images are transformed to a common global coordinate system. Finally, both images can be mapped together with respect to the global coordinate system ending up in the enhanced thermal image.

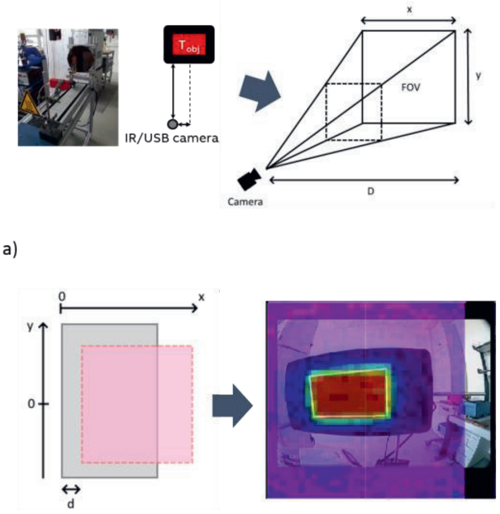

Fig. 2. Overview of the image mapping procedure: a) Schematic measurement setup and determination of field of view for thermal IR image and visual USB image. b) Transformation to a common coordinate system resulting in an enhanced thermal image that is a detail-accurate overlay of both images.

The image mapping method is calibrated with the basic tests performed for the heated block. The calibrated image mapping method is then applied on the use-case of a MV switchgear panel considering the compartment of the breaker spouts.

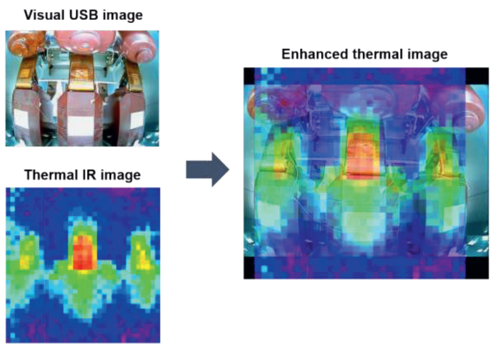

Fig. 3. Demonstration of the image mapping procedure along the section of the breaker spouts of a MV switchgear: Separate thermal IR image, separate visual USB image and enhanced thermal image as overlay of thermal IR and visual USB image.

The enhanced thermal image from Fig. 3 reveals a good agreement between the measured temperature hot spots from the IR image and the individual three phases given in the visual image. The commissioning of electrical assets is now easy to handle since the enhanced thermal image provides the information if all relevant components are fully captured even in the cold state before heating up. Furthermore, the type, topology and compartment of MV switchgears can be identified.

By deriving further mapping methods, we can define the regions of interest to be monitored in the switchgear. As outlined in Fig. 4, the region of interest is manually marked in the visual image with a red rectangle representing the middle phase in the compartment of the breaker spouts. Here, the maximal temperature of the middle phase is automatically extracted as feature. Thus, the developed image mapping methods enable to evaluate semi-automatically the temperature features of the user-defined regions of interest in the switchgear.

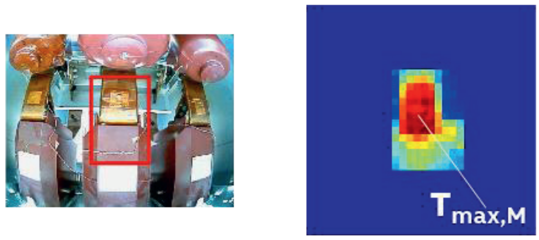

Fig. 4. Temperature feature extraction for the middle phase along the section of the breaker spouts of a MV switchgear.

Conclusion

This contribution introduces algorithmic methods to enhance the overall performance of low-resolution, stand-alone IR camera sensors in failure identification of the thermally monitored electrical asset. By using an additional visual USB camera, the presented image mapping methods allow for a temperature feature extraction from regions of interest and thus support the failure identification during online thermal monitoring of switchgears.

References

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