Temperature-rise implications when fitting circuit breakers to assemblies

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Different standards are applicable when temperature-rise performance for circuit-breakers and for motor control centres (MCCs) are specified. We need to ask why temperature-rise is such an important variant for correct performance of circuit-breakers. The origins of power losses inside MCCs and dissipation of such power losses are investigated. Real dangers of using a low diversity factor when designing and testing busbar systems for MCCs and the longer term effects on the assembly’s functionality will be discussed.

The purpose of this paper is to touch on aspects related to the so-called ‘Silent Killer’ of LV switchgear and controlgear assemblies (also referred to as distribution boards and motor control centres), which is typically associated with high power losses of installed components, busbars and cables. Excessive power losses usually result in abnormal temperature-rise throughout the assembly. Attention will in particular be focussed on the following:

- Temperature-rise testing of individual circuit-breakers
- Verification of temperature-rise limits of assemblies
- Derating requirements of circuit-breakers when installed inside assemblies
- The escalating effect of temperature-rise of all components fitted in an assembly
- The effect when assigning low diversity factors to circuits inside the assembly.

Problem statement

Circuit-breakers form an integral part of every LV switchgear and controlgear assembly commonly referred to as distribution boards or motor control centres. These devices are subjected to performance tests under ideal conditions not likely to be repeated under field conditions. Circuit-breakers are tested to SANS 60947 requirements and after installation is expected to operate under conditions specified by SANS 1473-1 (SANS 60439-1).

Consulting engineers and LV assembly designers’ role with bringing the above differences in context during the specification, design and tender adjudication phases, will be elucidated. Correct interpretation of the two standards will ensure level playing fields for assembly manufacturers during the tender phase and for users during future upgrading.

The ‘silent killer’

The ‘silent killer’ is the inability of an enclosed assembly to sufficiently dissipate heat to such a level that components and materials fitted to the assembly can operate in accordance with the original equipment manufacturer’s (OEM) prescriptions. It is often not sufficiently considered when designing an MCC that each current carrying busbar, each power cable, each protection device, each control device, each measuring device, each indicating device and each point of connection/contact, generate power losses which must be dissipated by the assembly.

The inability of the motor control centre to dissipate such power losses could have serious consequences on the tripping characteristics during conditions of overload for thermal-magnetic circuit-breakers whereas hydraulic-magnetic circuit-breakers stand indifferent to the effects of localized or general high temperatures inside the assembly.

Fig. 1: Circuit-breaker tested in the open.

For this reason it is of paramount importance that specifiers and users of assemblies have a clear understanding of what is specified by the OEM and how this information should be interpreted and applied when particular sizes of busbars, power and control circuits and a host of other controlgear including circuit-breakers are fitted to enclosures by assembly manufacturers.

The role of the assembly designer

The importance of the verification of temperature-rise limits for assembly systems are often overlooked as a straight-forward type-test with as few components fitted as possible to get it over and done with. This type-test is, contrary to common belief, probably the most important determinant for the functional life of the assembly and its suitability for future expansion. Establishing the highest possible temperature-rise profile of a fully type-tested design, is perhaps the most challenging part for the assembly designer when subjecting the System for type-testing. Assembly manufacturers should have a clear understanding of the heat dissipating properties of different configurations of a type-tested system. This information is crucial to the consulting engineer and in particular to the end user. The consulting engineer would determine future load patterns and will request additional space for future circuits. At this point in time the system designer should have submitted detail to the consulting engineer on required sizes of sections and sub-sections, the size of components and the diversity factors fitted to the enclosure.
of main and distribution busbars and the effect of increased requirements of internal protection and forms of separation.

Performance standards
From the outset, it must be understood that circuit-breakers are tested to SANS 60947-2 whereas LV switchgear and controlgear assemblies are benchmarked for performance against SANS 60439-1. These standards have different installation requirements for type-testing: circuit-breakers are tested in free air whereas verification of temperature-rise limits type-tests of assemblies calls for the assembly to be set up as in normal use. This means that due consideration need to be taken to the specified level of internal protection (IP rating) and the form of internal segregation against which performance verification need to be performed. Forms of separation is arranged between the busbars, functional units and terminals of outgoing conductors and varies from a Form 1 which denotes no segregation, up to Form 4b where all of the above elements per circuit are segregated from each other. Circuit-breaker manufacturers, who effectively have compiled the SANS 60947-1 standard for circuit-breakers, have resorted to the conclusion that the number of permutations of installation and operating conditions are too complex and have “conveniently” resorted to the best alternative – to test the circuit-breakers in free air. To say the least, this decision does not serve the best interests of the user. This is qualified by stating that few assembly designers will correctly derate circuit-breakers and few specifiers will understand the difference to what has been offered.

Test set-up for circuit-breakers
As can be seen in Fig. 1, a circuit-breaker is tested in the open with all possibilities for heat dissipation through conduction, thermal radiation and convection [1]. Test conductors and busbars act as heat sinks with optimum cooling possibilities for the circuit-breaker during temperature-rise tests conducted to SANS 60947-2. It is also of interest to note the length and conservative current densities of the test conductors as indicated by Fig. 2. Ambient temperature is used as the yard stick for determining the maximum temperature-rise for circuit-breakers tested in free air to SANS 60947. Verification of temperature-rise limits of components fitted to an assembly system shall be in accordance with the OEM’s instructions considering the inside temperature of the assembly. The implications of these different yard sticks are placing severe restrictions on the rated operating temperature ranges of circuit-breakers when installed in an enclosure.

Specifiers are often guilty of not taking derating requirements into consideration when enquiry documents are drawn up. The effect of this is that tenderers will offer circuit-breakers of specified current instead of offering up to 125% larger units as required by the OEM when the circuit-breakers need to be installed in an assembly. An appeal is made to designers and specifiers to insist on correctly sized circuit-breakers offered in quotations. Responsible assembly manufacturers are often placed at a disadvantage when correctly sized circuit-breakers are included in their quotations.

Power losses inside enclosures
Temperature-rise testing of the busbar system and components fitted to an assembly places the components, and in particular protection gear, in a total foreign environment to what it has been tested against when determining its performance characteristics. By evaluating Fig. 3, it is evident to what extent the circuit-breaker is placed under severe stress by own and adjacent heat losses imposed on it.

A 1250 A circuit-breaker could dissipate as much as 800 W at rated current. It is not uncommon to see two or three of this size circuit-breakers installed in a single Section. Achieving optimum heat dissipation properties through verification of temperature-rise limit tests, have resulted in extensive packing densities of components fitted to sections and sub-sections. This requirement has been brought about by ongoing premiums being placed on available space for services installations.

Diversity factors applied
The rated diversity factor of an assembly or a part of the assembly having several main circuits, is the ratio of the maximum sum of the assumed currents of the main circuits divided by the sum of the rated currents of all the main circuits or the selected part of the assembly. This factor can be any value as assigned by the Manufacturer. Even if no values of diversity have been stated, the SANS 60439-1 allows very conservative diversity factors. The effect of these values are that busbar current ratings could be severely under-designed leaving no space for future expansion of the assembly. The following could serve as an example by using some conventional values:

From Fig. 4 it can be seen that the main circuits should theoretically be designed for minimum busbar current ratings of 850 A and 1 400 A respectively. These values represent the full load current which can be delivered by the
A 500 kVA transformer. With stated diversity factors, as allowed by SANS 60439-1, the main circuits could be designed with busbar current ratings as low as 680 A and 980 A respectively and it could still qualify as a performance type-tested LV assembly to the SANS 60439-1 Standard. It is crucial that Specifiers understand what the longer term constraints of such an assembly design will have on any requirements to add new circuits to the assembly. Type-test reports should be scrutinized to ensure that unrealistic low diversity factors have not been assigned to main circuits. It is recommended that a value of 0.8 should be regarded as the lowest assigned diversity factor during verification of temperature-rise limits. Designs utilizing low assigned and tested diversity factor circuits will certainly not be suitable for some types of circuit-breakers which require specific oversized busbars for enhancing heat dissipation of the circuit-breaker power losses. Fig. 5 provides some insight on the placement of components to arrive at similar temperature-rise profiles. Assembly manufacturers should rather be encouraged to perform verification of temperature-rise limits also at unity values. This will provide a clear indication of the worst case heat dissipation capabilities of the assembly system.

Consequences for the user

Insufficient de-rating of circuit-breakers for installation inside enclosures, assigning low diversity factors and the different methods of testing circuit-breakers, further add to additional temperature-rise after installation. The following are typical examples:

- The circuit-breaker’s rating plate indicate a current rating which is not truly the current it can carry when installed in an enclosure. In later years, the plant engineer could simply look at the rating plate of the main incomer circuit-breaker and arrange that additional circuits be added to the assembly which may not even have been de-rated in the first instance.
- LV switchgear and controlgear assemblies are often ordered without any evaluation of the type-test reports where low diversity factors may have been assigned.
- Circuit-breakers are replaced at a later stage with others which have much higher power losses.

Conclusion

Specifiers and users are urged to gain a good understanding of the specific operational conditions and requirements of the assembly system. High forms of separation, high IP ratings, process load cycles, switchroom ventilation, humidity and ambient temperatures all play a significant role in temperature-rise inside the assembly. Detailed evaluation of type-test reports must be made during the tender adjudication process. It is important to note that all motor control centres and distribution boards must be tested to SANS 1473-1 when installed at a point of the supply where the prospective short-circuit rating is higher than 10 kA.

An approved Energy SETA course on design and type-testing requirements for motor control centres exists. Ms. Janice Stoddart of SABS-NETFA can be contacted at (011) 316-2005 or stoddaj@sabs.co.za for further information.

References


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