Determination of resistances

Quality of electrical connections in power distribution

Dipl.-Ing. Jürgen Dreier, Product Manager, KoCoS Messtechnik AG, Korbach

On the way from generators to consumers, electrical energy transmission and distribution systems feature a wide range of electrical connections, from simple terminals to complex switchgear devices such as circuit breakers, disconnectors and earthing switches. The reliability and the state of these electrical connections have a decisive influence on the availability, safety and economic efficiency of electrical supply networks.

When high currents are transmitted, the aim is for transfer resistance at connection points to be kept as low as possible. The transfer resistance is affected by a number of quantities und increases with age during operation. A high resistance results in an increase in heat losses, affects longevity and can also lead to a connection being interrupted. By carrying out on-site tests of transfer resistances, a faulty connection can be identified and eliminated.

Figure 1: Electrical energy transmission and distribution systems feature a wide range of electrical connections which have a direct influence on the safety of the system.

The PROMET SE developed by KoCoS Messtechnik AG is a compact, battery-operated ohm meter particularly suitable for such tests. The device features an adjustable test current of up to 200 A. Two current outputs and two voltage measurement inputs allow the resistance to be determined at two measurement points simultaneously. Because the device weighs just 1.5 kg and features a compact housing fitted with a carrying strap, it can even be used in situations where it cannot be put down, for example when working on ladders or hoisting platforms. The powerful lithium-ion battery guarantees operation independent of the power supply even for periods of several hours and longer.

Figure 2: Static resistance measurement on the interrupter units of a medium-voltage breaker with PROMET SE.

Resistance and power loss at the contact point

Even if the connection between two contact surfaces appears to be ideal, the surfaces of contact of the contact pieces are never identical with the size and the surface area for the passage of current. When examined under a microscope, the contact surfaces are uneven and are covered by an isolating impurity layer. During connection, the micro-surfaces which constitute the true contact surfaces are pressed together by the contact force, the current passes through these surfaces. The reduction in the cross-sectional area results in a higher resistance. Because of the higher resistance, more power is dissipated at the contact point and this leads to a rise in temperature. The higher temperature leads to an increase in the specific resistance at the contact point. The power loss at the contact point is dependent on the current and the resistance: $P = I^2 \times R$

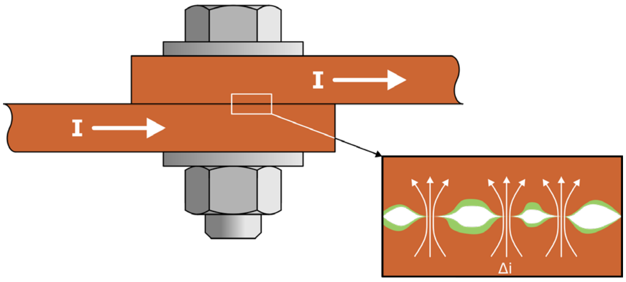

Figure 3: Surface contact at a busbar screw connection showing the true surfaces of contact (green: oxide layer/impurity layer).

As electrical connections age, the resistance of the contact point increases with time. The reasons for this include the reduction in the contact force of the connection, the formation of impurity layers, fretting corrosion and the resulting further temperature rise. The contact force of the contact point drops as a result of a slackening in the tightness of the screw connection and this leads to the surface area for the passage of current becoming smaller. The rise in temperature and external influences accelerate the formation of impurity layers, leading to the growth of oxide layers. With fretting corrosion, which is caused by mechanical displacement or expansion, contacts become misaligned and existing micro-contacts are destroyed. These factors impact on the ageing process and, if the worst comes to the worst, can lead to an interruption of the connection.

Quality factor of a connection

The quality of a connection can be assessed by determining the quality factor. Because there are two voltage measurement inputs, the quality of connections such as screw connections on busbars can be determined quickly and easily using the PROMET SE ohm meter. The quality factor is defined by the ratio of the resistance of the connection over the overlap length to the resistance of the busbar over the same length.

The quality factor K results from the ratio of the resistance of the connection R_{CON} over the overlap length l_{CON} to the resistance of the busbar R_{REF} over the same length l_{REF}.

Testing switchgear devices

Switchgear devices in particular are important components of electricity supply systems and must operate correctly under a multitude of conditions. In electrical energy transmission and distribution systems, switchgear devices are the connection to further parts of an installation. Throughout their operational lives, switchgear devices must constantly be able to connect, interrupt or disconnect operating parts. In the „open" status, they are a puncture-proof disconnection point, in the „closed" status, they carry and control short-circuit currents. Switchgear devices must survive mechanical and thermal stresses during operation without damage. Friction and abrasion influence the performance of the mechanical parts. The contact systems in the current-carrying circuits can deteriorate and thus increase the development of excessive heat. To ensure safe functioning, it is essential to make performance checks on switchgear devices during construction, creation, maintenance and repair.

When disconnecting the contacts in a high-voltage circuit breaker, a high-energy switch arc is created. It is necessary for circuit breakers to be able to extinguish short-circuit current arcs within a fraction of a second. For this purpose, circuit breakers feature extinction systems or extinction chambers. The arc contact establishes the first contact during the closing operation and has the last contact touch during the opening operation. The contacts wear during normal switching operations and also when short-circuit currents are interrupted. If the contacts are in poor condition, the circuit breaker becomes unreliable. A high contact resistance within a switchgear device leads to high power loss coupled with thermal stress and possible serious damage to the switchgear device. Problems, such as high transfer resistance resulting from poor connections, can be identified by measuring contact resistance.

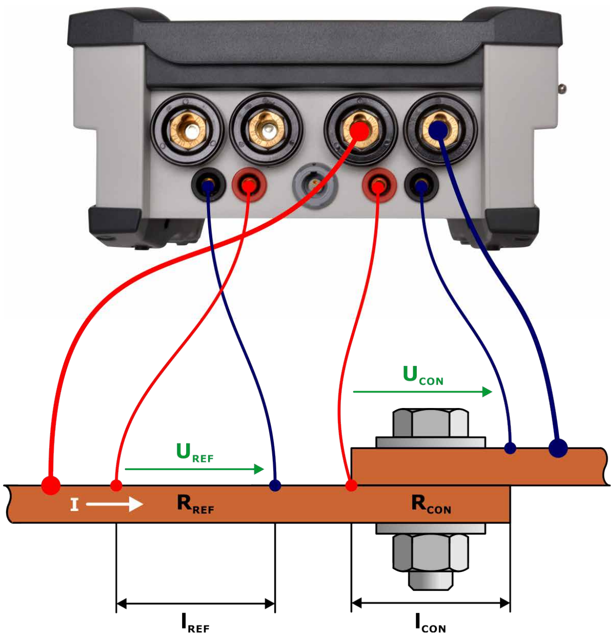

Figure 4: Connection of the PROMET SE ohm meter for measuring the quality factor on a screw connection.

Static and dynamic contact resistance measurements

For the static resistance measurement, the contact resistance is determined when the interrupter unit is closed. However, this measurement does not give an indication of the internal state, especially of the arc contacts. An assessment can be made by an internal inspection of the contact, but it is very labour-intensive and time-consuming. To simplify analyses of circuit breakers, the dynamic resistance measurement was introduced. The contact resistance is dynamically measured via a close-open operation. The contact characteristic and the arc contact can be reliably determined via the measurement results. During this switching operation a high test current is applied and the voltage drop is measured. The measurement of the complete switching operation shows the resistance characteristic of the entire contact travel.

The transition to the arc contact is clearly visible. If the travel is measured, the length of the arc contact can also be determined. The diagram of the resistance characteristic and the length of the arc contact provide an insight into the internal status of the interrupter units without having to open the main contact chamber. When used in combination with an ACTAS switchgear test system, the PROMET SE ohm meter can carry out dynamic contact resistance measurements on three poles and on several interrupter units per pole simultaneously. This means that the measurement can be carried out on all the contacts of a switchgear device in a single operation. This eliminates time-consuming connection and disconnection procedures and ensures that the measurement is carried out under identical conditions, allowing direct comparison of the contact resistances with one another.

The flexible handling of the PROMET SE with battery operation as a stand-alone measuring device and in combination with an ACTAS switchgear test system for static and dynamic resistance measurement make this universal measuring device particularly suitable for portable use in switching stations and industrial environments where high-precision determination of resistances in the micro-ohm range is required.

Figure 6: PROMET SE on a high-voltage breaker with two interrupter units.

Figure 5: Evaluation of a dynamic resistance measurement with PROMET SE in combination with the ACTAS P360 switchgear test system

Conclusions

When considering the distribution of electricity, it is important to bear in mind that losses occur as a result of poor connections and that generators of electricity have to provide additional power in order to compensate for these losses. When making an electrical connection, care should therefore be taken to minimise the consequences of ageing and to create a low-maintenance and reliable connection.

By determining the transfer resistance or the quality of a connection during installation and maintenance of high-current connections and switchgear devices, it is possible to verify that the connection has been made correctly and thus achieve a reduction in electrical losses, an increase in longevity and an improvement in system safety.

Sources

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[7] KoCoS MESSTECHNIK AG, Korbach: www.kocos.com

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KoCoS Messtechnik AG
Südring 42
34497 Korbach, Germany
Phone +49 5631 9596-40
info@kocos.com
www.kocos.com