Detection and control of insulation faults in electric mobility

Everyone knows about dealing with high voltages in the home. The protective meas-ures provided against electric shock are familiar to most people, especially those measures against direct physical contact. And if one comes into brief contact with AC 230 V, as a rule the only consequence is a "fright". What protective measures must be provided for the 300 - 600 V DC system currently common in a vehicle environment, and the 1,000 V system of the future? Controlling and detecting insulation faults is one of the challenges in vehicles and in charging devices.

Overview

The "fault current" is the part of the current that does not flow back to the source. A fault current is caused in an earthed system by an insulation fault. Depending on the installation, different fault currents are permitted without devices triggering a warning or shut down. Earthed TN/TT systems as are common in the home are generally monitored using a 30 mA residual current device (RCD) of type A (AC and pulse sensitive). Unlike the systems in the home, the first insulation fault in an unearthed IT system does not cause a fault current. As there is no electrical connection between the active conductors and earth (ground), a closed circuit is not made. In this case the first fault is detected with the aid of an insulation monitoring device with the intention of preventing a hazard in the event of a second failure on a different active conductor.

Until it is connected to an earthed charging device, the high voltage system in electric vehicles is also to be considered an IT system. Here the insulation resistance of the system is monitored by an insulation monitoring device (IMD). If the system is connected to a charging device, the installation becomes an earthed system and requires different protective measures on the mains side, e.g., residual current devices (RCD). When it is connected to a charger in the home, the vehicle is an electrically complex source of faults. The residual current devices (RCDs) common these days are then only partially effective. These complex fault currents in the electric vehicle can also be detected and the charging process interrupted if necessary by using AC/DC or pure AC residual current monitoring devices. Here there is also still need for clarification in the standards to provide manufacturers of electric vehicles and charging devices with a safe and compatible concept during development.

Particularly relevant here is "Protection against electric shock in accordance with IEC 60364-4-41 (DIN VDE 0100-410)", e.g. safety precautions, protective measures (shut down of the power supply, protective impedance, etc.), co-ordination of the electrical equipment, special operating and maintenance conditions.

Insulation co-ordination

Insulation co-ordination is a key element for the prevention of insulation faults while an installation is in operation. Improper insulation co-ordination will result in voltage flash-overs or electromigration and the related fault currents. An elementary aspect during the development of electrical equipment is that the insulation is co-ordinated in accordance with IEC 60664 or IEC 61010. A high degree of protection against elec-tric shock is ensured by complying with clearances and creepage distances, as well as the evaluation of the installation location. Possible insulation faults and fault currents are minimised in this manner. Furthermore, attention is to be paid to a minimum leakage capacitance. This capacitance further increases the reactive current in AC systems (drive) and, due to the energy stored, involves a significant hazard on physical contact with shut down DC systems.

Insulation faults can be controlled in the vehicle and in the charging devices. This aspect is ensured during the development of the devices by means of appropriate insulation co-ordination and the design of the on-board electrical system. Additional possible measures (usage of insulation monitoring devices, residual current monitoring devices etc.) are used to ensure safety also in case of a fault.

Insulation monitoring

In unearthed systems only a very low fault current to earth occurs on the first fault, as the circuit is not closed since there is no connection to earth. Here the insulation is monitored using an active insulation monitoring device and insulation faults detected. As a second fault on one of the other active conductors can close the circuit (only then does a fault current flow), the first fault must be detected and signalled as quickly as possible. On the occurrence of the first fault in an IT system, the situation is not initially dangerous. For this reason, as a rule the installation is NOT shut down.

In a typical application in a high voltage on-board electrical system in a vehicle, an insulation monitoring device (IMD) in accordance with IEC 61557-8 is used in the DC link circuit. The IMD can be fitted in the battery or the vehicle. A single IMD monitors the entire, electrically connected high voltage system in the vehicle. A further IMD is installed in DC charging stations. In rare cases also in AC charging stations. It is to be ensured that the IMD on the vehicle side is deactivated during charging using a charger that is not electrically isolated. If two IMDs are active in a system, malfunc-tions can occur.

A possible graph of the insulation resistance over time is shown in figure 1. If the insulation resistance drops below the first warning level, measures can be taken or planned to rectify the problem without shutting down the installation.

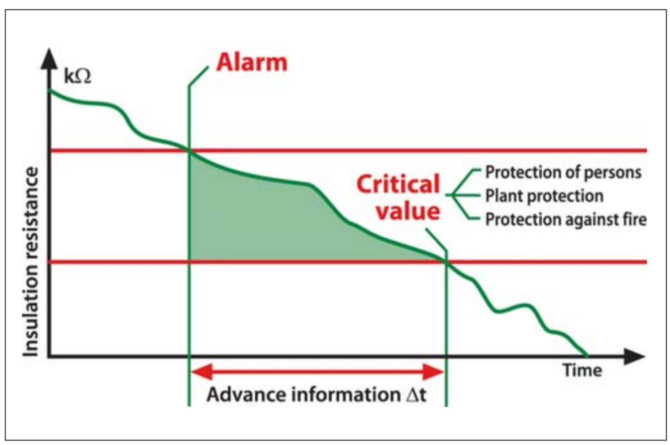

Figure 1: Early warning in IT systems (source: Bender).

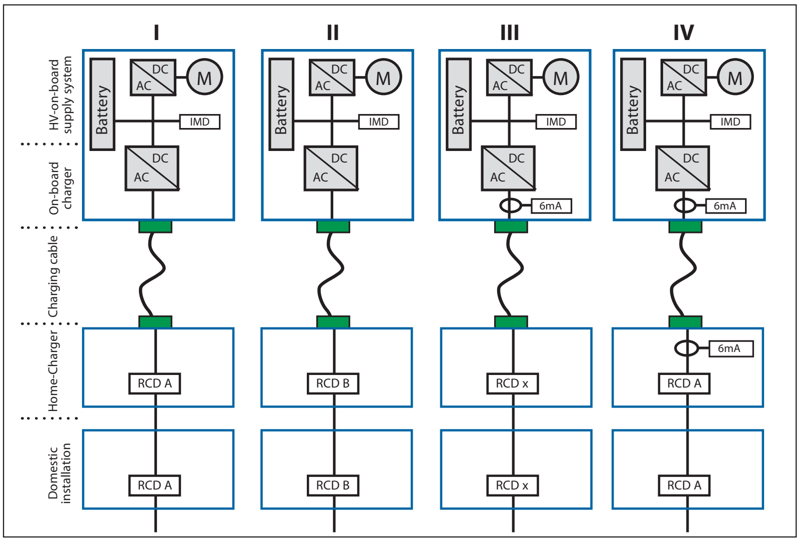

Figure 2: Example illustration of the protective measures against DC faults caused by faults in the electric vehicle (source: Bender).

Residual current measurement

Residual current measurement is used in AC charging modes 1 - 3 for fault current detection. As a rule RCDs of type A are used in the charging station. If a DC fault current is superimposed on an RCD of type A, the characteristic is displaced until the RCD is eventually rendered completely "blind". In this case the protective function is no longer effective. In the standards it is assumed that an RCD of type A will malfunction from a DC fault current of 6 mA. Appropriate measures to safeguard the function are to be taken. One possible measure is the electrical isolation of the charger in the vehicle. It is also possible to detect very low fault currents of a few milliamps in the DC range with an expanded residual current measurement by using an RCMU (Residual Current Monitoring Unit) and to interrupt this fault current by shutting down the charging process to protect the RCD of type A. A further possibility is the usage of an RCD of type B (AC/DC sensitive), here it is to be ensured that an RCD of type A is not included in the installation downstream, as then a fault current of DC 30 mA would be possible without the RCD of type B triggering, however the type A would have already ceased to function correctly. If this issue is not noted, fault states occurring in the vehicle may have an effect on the safety systems in the entire house and disable the fault current protection in the house.

I. **The vehicle has an electrically isolated charger.** DC faults can therefore be excluded. The usage of RCDs of type A is possible.

II. **The vehicle has a charger without electrical isolation.** RCDs of type B are required. Here it is to be ensured that an RCD of type B is also used in the installation in the house.

III. **The vehicle has a charger without electrical isolation.** The 6 mA DC monitoring and shut down is in the vehicle. As such charging at "other charging stations" without a type B RCD is possible.

IV. **The vehicle has a charger without electrical isolation.** The 6 mA DC monitoring and shut down is in the vehicle and in the charging station. As such charging at "other charging stations" is possible and the charging stations can charge vehicles with unknown "on-board chargers". ■

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