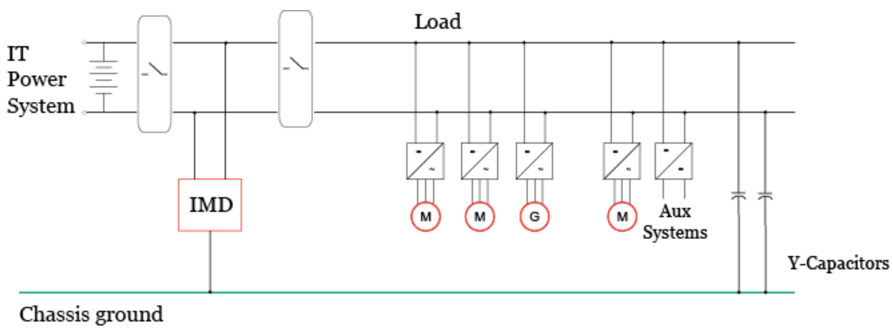
White paper

Ground fault protection for three-phase motors

in unearthed (IT) DC power system



Abstract --- Electrification of transportation relies on high voltage IT (Isolé-terré or Isolated Terra) ungrounded power systems. High voltage batteries are utilized primarily to power motors along with the other control, entertainment and auxiliary systems of the vehicle, vessel or aircraft. Loss of chassis insulation in any of the devices connected to the high voltage system presents a potential hazard that must be quickly identified and acted upon. There are numerous international standards that establish the necessity and function of an Insulation Monitoring Device (IMD) for this purpose. It is essential for system safety that the IMD is capable for providing detection of insulation faults occurring within the motors, after the inverter's power conversion. In this report we will review how insulation faults within a motor exhibit themselves in the IT system and how they are detected by Sendyne's SIM100MOD state-of-the-art IMD.

Keywords: IMD, 3 phase motor, motor ground fault, insulation fault, inverter

Common causes for ground faults in motors is damage to phase conductor's insulation, and internal shorts due to moisture. Fig.1 shows an isolation fault occurring between one the motor phases and chassis.

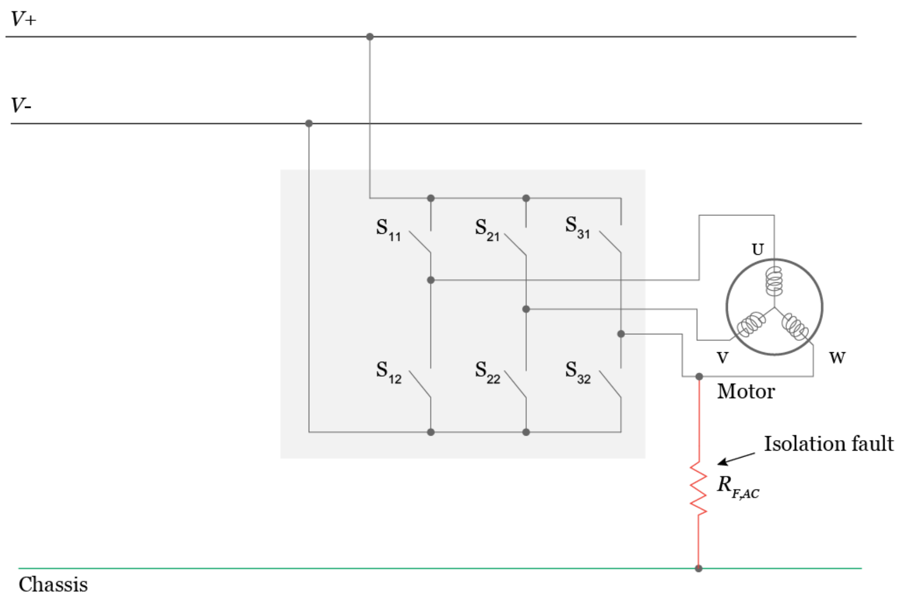


Figure 1: An insulation (ground) fault can exhibit itself in any of the motor phases.

As can be seen in Fig. 1, half of the period in which switch S_{31} is closed (S_{32} open), $R_{F,AC}$ appears connected directly to the positive rail. During the other half period, when switch S_{32} is closed (S_{31} open), $R_{F,AC}$ is connected to the negative rail. The net result is that $R_{F,AC}$ appears connected on both the positive and negative power rails. The current flowing through $R_{F,AC}$ from each of the power rails is a 50% duty cycle square pulse. The equivalent DC resistance between each power rail and chassis is thus $R_{F,DC} = 2 \times R_{F,AC}$. The net result is that a single isolation fault between any of the motor phases and chassis appears as a symmetrical connection with effective resistance values, between each of the power rails and chassis, twice the value of the actual fault resistance.

EXPERIMENTAL

Fig 2. shows the experimental setup for measuring the isolation resistance between one of the motor phases and chassis. A resistance of either 40 or 200 kΩ is inserted at different times between the power rails, the phase and chassis. The Sendyne SIM100MOD is connected between the chassis and the power rails *V*+ and *V*-. The resistance that SIM100MOD imposes between each power line and the chassis is 2.7 MΩ. The system under test exhibited a 500 kΩ resistance between the negative rail and chassis. This resistance is in parallel with the 2.7 MΩ resistance of the SIM100MOD exhibiting a total value for $R_{ISO,N}$ of 422 kΩ. The experiment was performed at Columbia University's "Motor Drive and Power Electronics Lab" led by Prof. Matthias Preindl.

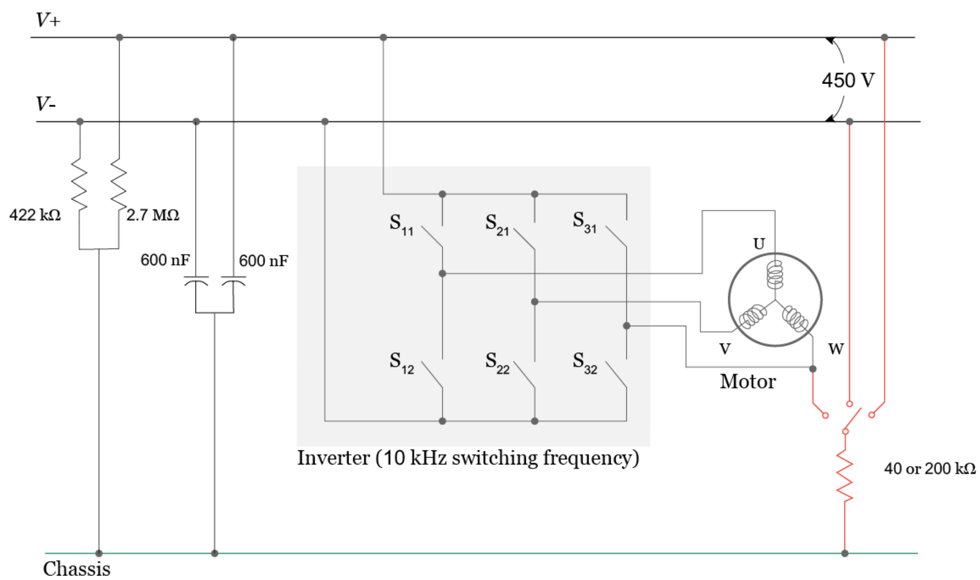


Figure 2: Experimental setup for estimating isolation resistance between a motor phase and chassis.

RESULTS

The results are shown in Fig. 3.

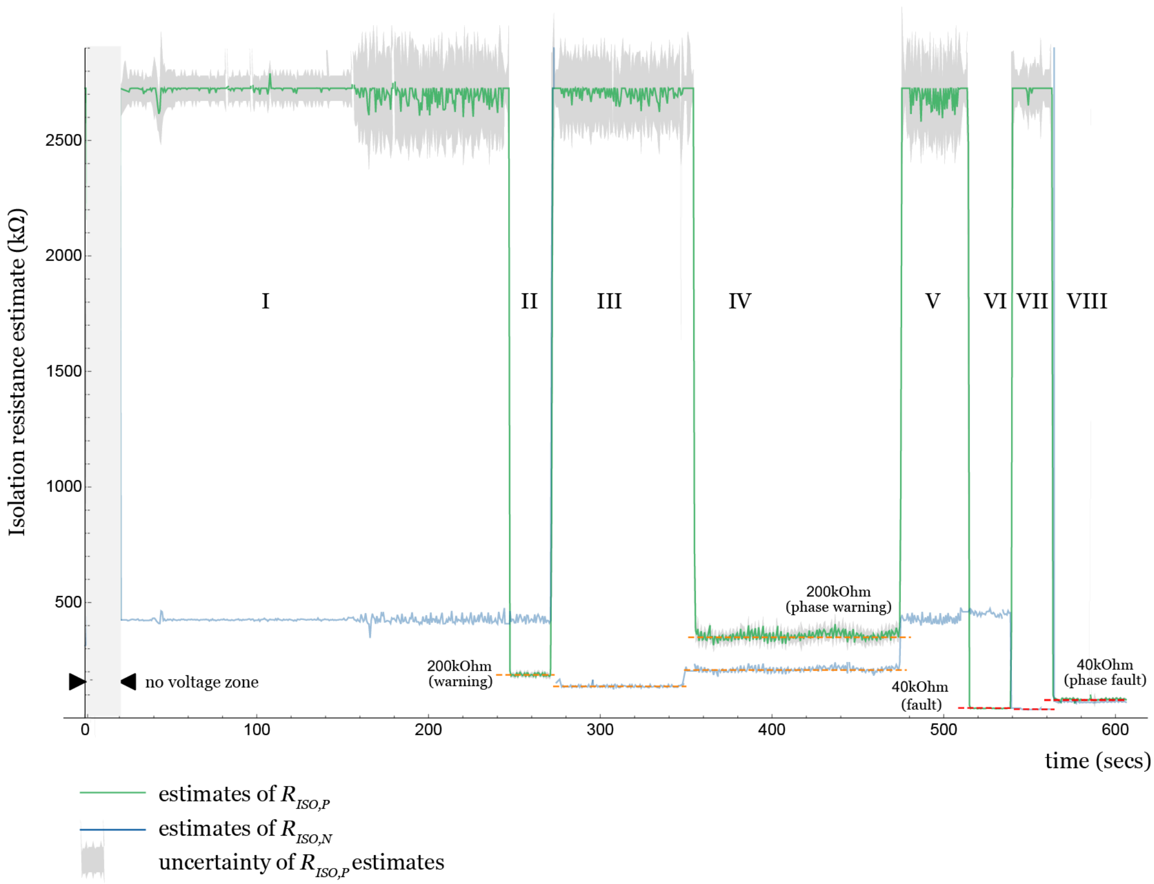


Figure 3: SIM100MOD estimation of isolation resistance between a motor phase and chassis

Estimates by SIM100MOD were read every 500 ms. The chart of Fig. 3 is divided in 8 areas marked I to VIII. The following list describes the experiment setup in each area.

I. No resistance connected. SIM100MOD reports isolation resistance of 2.7 MΩ for the positive rail and 422 kΩ for the negative rail (parallel combination of 500 kΩ and 2.7 MΩ).

II. A 200 kΩ resistance is connected between *V*+ and chassis. SIM100MOD reports $R_{ISO,\,P}$ =186 kΩ (2.7 MΩ // 200 kΩ).

III. A 200 kΩ is connected between *V*- and chassis. SIM100MOD reports $R_{ISO,\,N}$ =136 kΩ (422 kΩ // 200 kΩ).

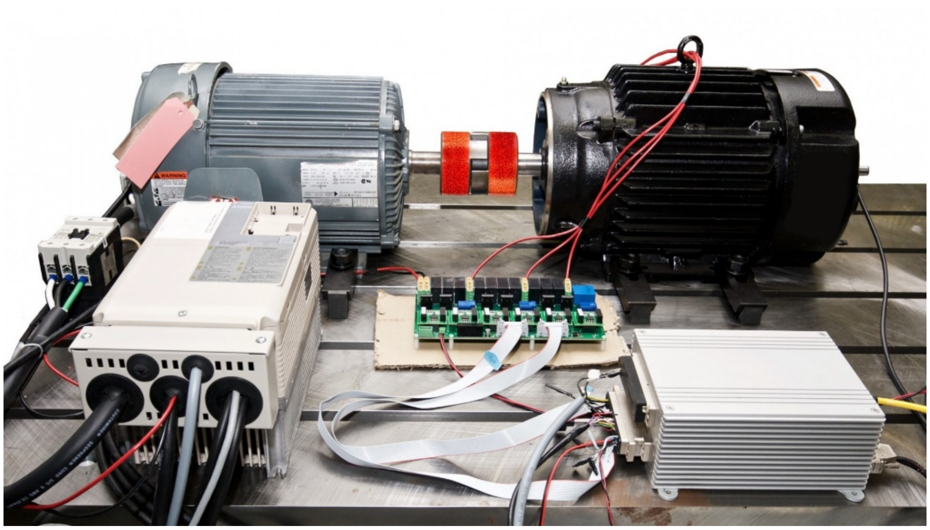
IV. A 200 kΩ resistance is connected between a motor phase and chassis. The SIM100MOD reports $R_{ISO,\,P}$ =348 kΩ (2.7 MΩ // 2x200 kΩ) and $R_{ISO,\,N}$ =205 kΩ (422 kΩ // 2x200 kΩ).

V. No resistance connected. $R_{ISO,\,P}$ =2.7 MΩ and $R_{ISO,\,N}$ = 422 kΩ.

VI. A resistance of 40 kΩ is connected between *V*+ and chassis. The SIM100MOD reports $R_{ISO,\,P}$ = 40 kΩ (2.7 MΩ // 40 kΩ).

VII. A resistance of 40 kΩ is connected between *V*- and chassis. The SIM100MOD reports $R_{ISO,\,N}$ = 37 kΩ (422 kΩ // 40 kΩ).

VIII. A resistance of 40 kΩ is connected between a motor phase and chassis. The SIM100MOD reports $R_{ISO,\,P}$ =78 kΩ (2.7 MΩ // 2x40 kΩ) and $R_{ISO,\,N}$ =67 kΩ (422 kΩ // 2x40 kΩ).



Columbia University's "Motor Drive and Power Electronics Lab" Motor drive system (published with permission from Columbia University)