METREL®

Application Note

MD line for EV service

Electric vehicles have a new spectre of needs when it comes to servicing. Electrical faults, while essentially rare, can cause serious hazards to both the user and the service personnel. Electrical effects like electrolysis on material contact or battery leakage have to be considered during design.

Regulation for electric cars is currently still weak. The UN regulation UNECE R100 prescribes safety features for the battery, most of which have to be tested by the manufacturer. After the battery is installed, internal systems in the car monitor its status. Few car models allow any kind of electrical testing and consider the on-board monitoring enough. Some tests should still be done in case of a suspected failure.

MD 9070's main strengths are insulation measurement with up to 1000 VDC test voltage, and continuity test with 200 mA test current. It measures TRMS voltage up to 1000 V AC or DC, frequency with or without a VFD filter, resistance, diode test, and tests for continuity with audible signal. It allows for a number of diagnostic and safety tests in cars or elsewhere.

- Testing battery pack's nominal voltage with the voltmeter,
- Faults on PCBs with audible continuity, resistance measurement and voltmeter,
- Controlling signals on electric motors with VFD filtered frequency,
- Testing insulation between any live and any accessible parts while live parts are off,
- Testing continuity of wires,
- Electric motor start-up test with MAX/MIN/AVG recorder and a current clamp.

MD 9272 is an AC clamp with lowest range down to 0.1 µA. It makes it a great tool for leakage analysis. In an EV, leakage is a powerful diagnostic tool at every point in its operation, from charging to driving. Its power functions and harmonic analysis offer additional layers of service. It can perform some functional tests on the inverters and motors, and particularly assure the inverters cause no distortion.

MD 9273 in conjunction with MI 3155

MD 9273 is the upgrade on the MD 9272. It contains all the features in MD 9272 and a number of extras, the main of which is Bluetooth connection to MI 3155 and work in tandem. It can trace inrush current and the application on MI 3155 will draw a graph. On the other hand, MI 3155 can generate a signal into the wiring system that can be traces with MD 9273. Bluetooth also enables easy upgrades of the firmware and the features list will eventually grow.

Optional accessories provided by Metrel that are necessary for some of the mentioned measurements are the A 1734 reference resistance R0, and the A1391 AC/DC current clamp.

Testing insulation on high-voltage busses

The UN regulation UN ECE R100 describes two ways of measuring insulation on high-voltage busses and two for battery modules. High voltage in electric cars is defined as 30 VAC ~ 1000 VAC or 60 VDC ~ 1500 VDC. The first method requires an insulation tester with available test voltage higher than working voltage of the tested bus. This method is only appropriate for high voltage busses when the battery is removed or switched off the measured part. If not, testing voltage and battery voltage are connected in parallel and can be added or subtracted between themselves, making the results unreliable. Some instruments, including MD 9070, won't work in these conditions. For example, MD 9070 always shows an infinite result.

Once the battery is removed or switched off, the insulation on the busses is measured using the high voltage probe and the regular probe in COM socket.econd method uses the vehicle's own DC voltage source. Voltage on the battery output (Vb) is measured, as well as voltages between both of the output poles and the chassis. If the voltage between negative pole and chassis (V1) is higher that the positive-to-chassis (V2), insert a known resistance R0 between the negative pole and chassis. Its value should be close to minimum acceptable isolation resistance. A suitable R0 is available as optional accessory. Measure the voltage (V1') on it.

The insulation resistance is then:

$R_i = R_0*(V_b/V_1' - V_b/V_1)$ *or* $R_i = R_0*V_b*(1/V_1' - 1/V_1)$.

If V2 is higher than V1, put the R0 between positive battery pole and the chassis. The formula is then:

$R_i = R_0*(V_b/V_2' - V_b/V_2)$ *or* $R_i = R_0*V_b*(1/V_2' - 1/V_2)$.

Electrical isolation resistance can then be divided by nominal voltage to get isolation resistance in the sense of UN ECE R100, with unit Ω/V.

Testing insulation on the battery system

Battery system is in the UN ECE R100 referred to as Rechargeable energy storage system or RESS.

Measuring the simulated insulation problem with MD 9070 and reference resistance A 1734.

Insulation is measured on a component basis. When measuring on the battery, it is not possible to use an insulation tester. The working voltage and test voltage get added or subtracted and the measured results are unreliable.

Second method uses the DC voltage from the measured unit. In a similar fashion to the method for busses, voltages negative pole-to-ground (V1) connection and negative pole-to-ground (V2) connection are measured. If V1 is greater or equal to V2, reference resistance RO is inserted between negative pole and ground and voltage V1' measured on it. The isolation resistance is then calculated:

$Ri = Ro*(Vb/V1' - Vb/V1)$ or $Ri = Ro*Vb*(1/V1' - 1/V1)$

If V2 is higher than V1, place the RO between positive pole and ground connection and measure the voltage V2' on it. The isolation resistance is:

$Ri = Ro*(Vb/V2' - Vb/V2)$ or $Ri = Ro*Vb*(1/V2' - 1/V2)$

Electrical value of the resistance can then be divided by nominal voltage of the tested component to get the isolation resistance in sense of UN ECE R100, with unit Ω/V.

Continuity

MD 9070 makes its name as basic installation tester also with testing for continuity. Continuity with 200 mA measuring current is mainly used to test the car's PE wire from any higher-voltage device to the chassis. The car is not grounded as in actually connected to the ground, and the chassis is used as voltage reference. That makes it an IT system, and insulation is the more important safety parameter. 200 mA is a standard test current for 230 V appliances and some types of installation, offering a good trade-off between energy spent and accuracy achieved, and it can be done many times even using the regular alkaline batteries to power the instrument.

In a modern car, most devices that work in this voltage class are hidden form the user. Corrosion on high-voltage wires and bolts is however a relatively common problem on some car models and should be regularly checked for. It is however not part of periodic service and is only used in case of problems.

Limit value for continuity required by UN ECE R100 is 0.1 Ω. With this low limit, higher currents or 4-wire method is preferable, but 200 mA can work as a first test.

Audible continuity test with low current works well at short distances and on PCBs as an indicator of connection.

Measuring motor controller with VFD frequency filter

MD 9070 is equipped with a low pass filter for debugging VFD type of drives. VFD is a mainly industrial motor controller. It creates a pulse-width modulated signal to precisely control motor's speed and torque. Motors equipped with it are amongst most energy efficient for variable-torque applications. It is not very common in the cars, but can be found in some models. The pulse-modulated signal is very rich in high-frequency components, making it impossible for the regular multimeter to measure its base frequency and voltage correctly. Particularly TRMS measured voltage can be much higher than true, since the TRMS sensing depends on full heating power of the signal. Signal has to be filtered to the typical base frequencies, usually 30-60 Hz, to be measured correctly. Afterwards, it is compared to values the controller itself provides for debugging purposes, or with its input settings.

MD 9070 ready for insulation measurement

Current measurements

Current can be measured indirectly, with the help of a current clamp with voltage output. While this method takes some brief calculation to get the result, the clamps are a practical way to measure current without breaking the wire, and their attenuation allows measuring very high currents that are found on supply from battery to the motors. In 100 kW car, like medium-sized EV or a more powerful hybrid, more than 100 A can flow. A combination clamp that can sense both AC and DC current is a powerful diagnostic tool, particularly in combination with a recorder of MAX/MIN/AVG values, like one on MD 9070. It is possible to measure electric motor's in-rush current that gives information about state of some components. Real power component (or whole power in DC circuits) can be easily calculated from measured voltage and current. It gives a general overview of the state of the system. For more detail, refer to app note Current clamps on multimeters.

MD 9070 with an extra clamp A 1018

Motors in cars are electronically controlled, so they generally shouldn't pull large in-rush currents. In case of suspected fault in the controller however, the starting current should still be measured.

Leakage current

Combination of a standard multimeter and the extra clamp is nearly never sensitive enough for measurement in mA or even µA range. A specialized leakage clamp like MD 9272 is necessary. The AC charging is the most common source of leakage in a car-and-charger system. Even when there is no problem detected in either the car's or charger's diagnostics, leakage current in PE wire can be considerable, depending on the charger in the car. It should be taken into consideration in charging station design, and carefully monitored for changes over years.

The other source of leakage and distortion are the inverters before the driving motors.

Modern types are electronic and generally shouldn't cause too much trouble, but faults or bad design can cause overheating and damage other parts of the installation or even the batteries. The system has to be tested for leakage, power parameters and distortion. Leakage is measured by turning the rotary switch to Ampere symbol and clamping the relevant wires. Usually, that is the PE for direct measurement, or both live and neutral wires for the differential measurement.

Functional testing and harmonics

Functional test is device-specific and often cannot be done using a measuring device. Part of it however are both power characteristics of the device and its harmonic impact on the surroundings. This can be achieved in a number of ways, but the fastest and simplest is with MD 9272. Measuring current with the clamps and voltage on leads, it covers every parameter necessary, and provides the insight into possible defects that show as lowered power factor or high distortion.

When measuring power features, the test is performed by connecting the clamps around the live wire and the leads between the live and ground. Rotary switch is turned to the sign W. Different further measurements can be reached with the F button.

Testing the leakage current in PE wire while charging the car.

MD 9272 can be used in tight, hard to reach spaces.

Both MD 9070 and MD 9272 are a first-aid type of instruments that provide a fast, easy diagnostic of the vehicle. They can be carried along in the vehicle by the user, or with the field service provider, or even for a quick check when arriving to the garage.

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