CAR CHARGERS FOR ELECTRIC VEHICLES: A STEP-BY-STEP GUIDE TO AUTOMATED TESTING

Megger

IMPORTANT

This guide is intended to assist engineers and technicians with testing car chargers for electric vehicles. The examples included relate specifically to automated testing carried out with the Megger MFT-X1 multifunction installation tester used in conjunction with the Megger EVX charge point test adaptor. Another version of the guide covers manual testing with other types of test equipment. This can be found at [link].

It is essential that EV charge point testing be carried out only by competent and suitably qualified persons who have experience in electrical installation testing. The information and guidance presented here are not substitutes for proper training in electrical safety and the correct use of electrical test equipment.

In addition, all testing of EV car chargers must be carried out in accordance with locally applicable standards and regulations. The standards and regulations always take precedence if conflicts occur between them and statements made in this guide.

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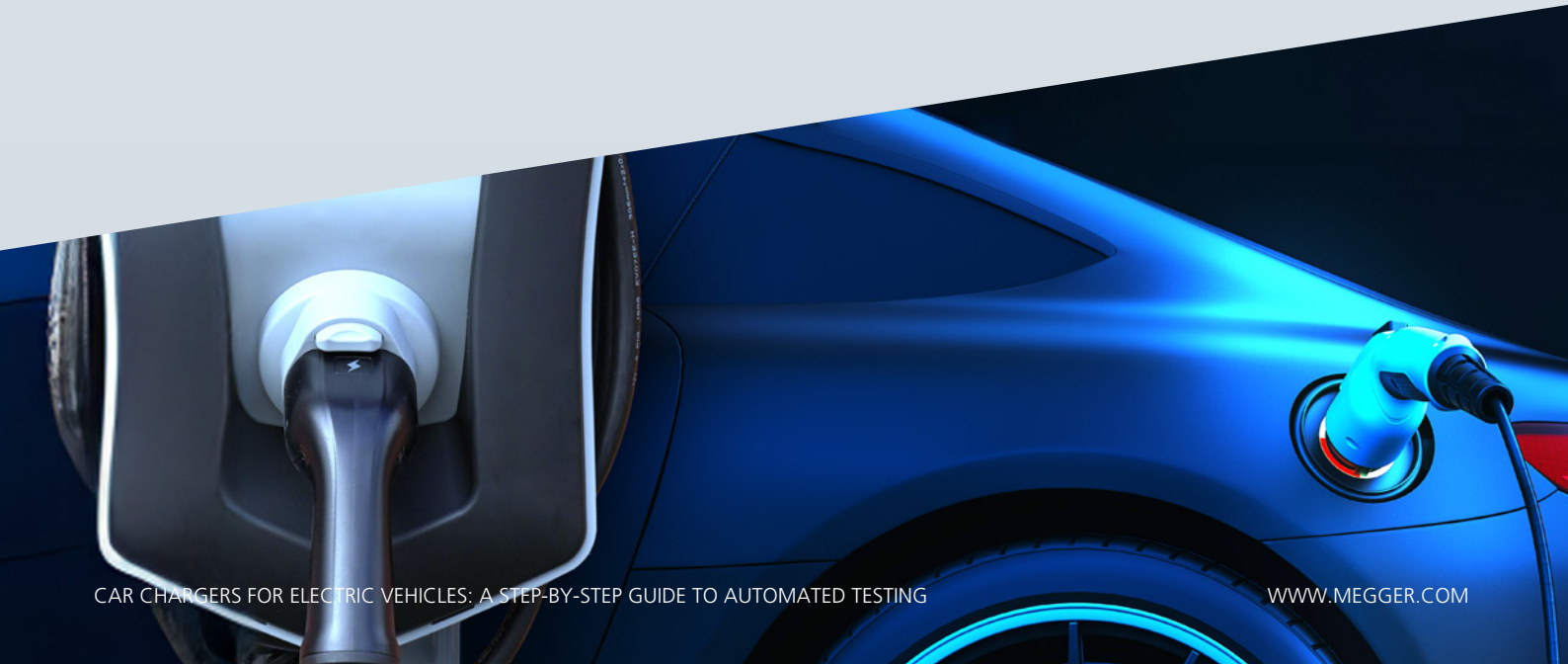
Introduction

The number of electric vehicles (EVs) in use is increasing rapidly in almost every country, resulting in a corresponding increase in the need for safe facilities to recharge their batteries. Providing these facilities is an excellent and growing business opportunity for electrical contractors who are competent in car charger installation, commissioning and testing. Fortunately, much of the work involved is very similar to that needed when carrying out other types of electrical installation. This guide is intended to 'fill the gaps', particularly in relation to testing.

Before proceeding, there are a few points that need to be explained:

- This guide refers only to chargers for electrically propelled vehicles – that is, electric vehicles (EVs) and hybrids driven by an electric motor powered by a high voltage battery. It does not cover the charging of low voltage batteries in vehicles which use other types of motive power, such as petrol or diesel engines.
- The equipment used for charging electric vehicles is usually called a 'car charger', an 'EV charger' or an 'EV charge point'. Strictly speaking, none of these descriptions are correct, as the charger itself is frequently within the vehicle. A more accurate description is 'electric vehicle supply equipment' or EVSE. However, this description is rarely used other than in standards and regulations, so to make this document easier to read and understand, the description 'car charger' is used throughout.
- Car chargers are usually classified as belonging to one of four 'Modes'. Mode 1, 2 and 3 car chargers supply AC to the vehicle and the AC is converted to DC in the vehicle. Mode 4 car chargers, which are used for high-power fast charging, supply DC to the vehicle. Mode 4 is the only type of car charger where the charger itself is not in the vehicle.
- Mode 1 charging is achieved by connecting a domestic power outlet to the car with a simple lead, essentially an extension lead. Mode 1 charging does not incorporate the safety features of Mode 2 or 3. The safety of this charging mode relies entirely on the safety of the electrical installation, as there is no additional functionality. This mode is becoming unusual and is illegal in many countries. Where it is used, however, the charging circuit should be tested in the same way as any other circuit in the electrical installation – no additional tests are possible.
- Mode 2 car chargers are simply in-line modules that incorporate basic control and protection capabilities. Car manufacturers commonly provide them for charging vehicles from a standard domestic electrical outlet.
- Mode 3 car chargers are currently the most common type. They are fixed items of equipment, often attached to a wall or a free standing post, and they provide a single- or three-phase AC supply to the vehicle. This guide is mainly concerned with testing Mode 3 car chargers.



CAR CHARGERS FOR ELECTRIC VEHICLES: A STEP-BY-STEP GUIDE TO AUTOMATED TESTING

- Mode 4 car chargers are DC chargers. Because they convert AC to DC internally, they incorporate more complex circuit protection than other types of chargers and use power line control (PLC) to manage the charging process. Specialised equipment is needed to test Mode 4 car chargers, and as a result, they are outside the scope of this document.
- Because, for all types of car charger except Mode 4, the charging system is actually in the vehicle, the equipment referred to as a car charger is, in reality, just a special-purpose electrical supply point. It differs from other supply points only because it includes control facilities and, in many cases, additional earth fault protection.
- Like other high power devices, such as electric showers and cookers, car chargers must be fed from a separate circuit that is not shared with any other load.
- Up to the point where the car charger itself is connected, the circuit feeding the charger is the same as any other circuit in an electrical installation. Therefore, this circuit should be installed and tested in accordance with the international standard IEC 60364 or local regulations in force for electrical installations in buildings – for example, BS 7671 in the UK – before the car charger is connected.
- This guide assumes that testing will be carried out using a Megger MFT-X1 multifunction installation tester in conjunction with a Megger EVX charge point test adaptor. If other types of test equipment are to be used, see the step-by-step guide to manual testing, which can be found at [link].
- The design and functionality of car chargers are similar in almost all countries, but there are differences in terminology. This guide is intended to be international in scope, and where these differences occur, they are mentioned and explained in the text.

CAR CHARGERS FOR ELECTRIC VEHICLES: A STEP-BY-STEP GUIDE TO AUTOMATED TESTING

Equipment for testing car chargers

The equipment needed for testing all car chargers (except for Mode 4 types) can be divided into two sections.

First, an electrical test instrument, such as an electrical installation multi-function tester (MFT), is required. This is the same type of instrument used for general testing on electrical installations, including the supply to the car charger, but it needs to have some extra features to test the unique protective devices often used in car chargers.

Second, a car charger adaptor is needed, which must mimic a vehicle's connection to the charger. The adaptor may also offer basic safety tests, such as checking for earthing issues and simulating basic error conditions of the Control Pilot (CP) and Proximity Pilot (PP) signals, which are explained in more detail later.

In the case of the EVX adaptor used with the MFT-X1 multifunction installation tester, the adaptor mounts directly onto the tester with a single lead to the car charger – no additional interconnecting cables are required.

The standard type adaptor such as the EVCA210 is connected to the charging outlet of the car charger using a suitable type of supplied connector, and the adaptor connects to the test instrument using the instrument's standard test leads.

Alternatively, a self-contained and simplified car charger checker can be used to verify the functionality and basic safety of a car charger. However, these checkers do not offer the full range of functionality of the MFT and adaptor. Consequently, they are unsuitable for initial verification of a newly installed car charger, but they are ideal for post-installation testing and maintenance. A separate step-by-step guide covering the use of this kind of checker is available. The remainder of this document assumes that tests are being carried out using a Megger MFT-X1 multifunction installation tester plus an EVX car charger adaptor.

Car charger control signals

Two control signals – proximity pilot (PP) and control pilot (CP) - are used to communicate between the vehicle and the car charger. These are set on the adaptor or if using the EVX, automatically by the instrument.

The PP signal indicates to the car charger that a vehicle is connected. One of its primary functions is to ensure that the EV does not drive off while charging is in progress. The PP signal is also used to indicate the maximum charging rate applicable to a particular combination of car charger and EV. Car charger testers need to be able to simulate PP signals.

The CP signal provides information about the status of the charging process, and for the purposes of testing a car charger, the test equipment needs to simulate these CP states:

- State A – no vehicle connected
- State B – vehicle connected but not ready to charge
- State C – vehicle connected and ready to charge; ventilation not required

Optionally the test equipment may also provide:

- State D – vehicle connected and ready to charge; ventilation required

Testing step-by-step

An important note about resetting chargers

Some of the tests described will make the charger trip out because of simulated fault conditions, while others will necessarily cause protective devices to trip. Before proceeding, check carefully that it will be possible to reset the charger or protective device after tripping. Chargers used in non-domestic applications are frequently networked, and supervisor-level access to the network may be needed to reset them. In some cases, however, the charger may offer a maintenance mode to permit local resetting during testing. If this mode is available, it should be used. It is also recommended that in new installations electrical testing should be completed, if possible, before connecting chargers to the network. A further issue relates to protective devices. These are often external to the charger and may even be in another building. It is, therefore, important to know the location of the devices and to be sure that access is available to reset them.

CAR CHARGERS FOR ELECTRIC VEHICLES: A STEP-BY-STEP GUIDE TO AUTOMATED TESTING

Part 1 – Car charger supply connection inspection and testing

- Visually inspect and test the installation up to the point of connection of the car charger. The electrical installation up to this point must comply with local regulations, and testing should be carried out in the same way as any other electrical circuit. Essential tests are loop impedance, voltage drop, continuity of bonding conductor, cable insulation and polarity (phase sequence for three-phase chargers) and RCD testing.

Part 2 – Car charger test adaptor connection

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2


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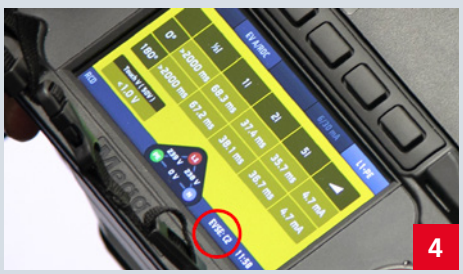
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- Visually inspect the car charger. Look particularly for physical damage to connectors and cables. Replace or repair damaged or defective items before proceeding. 1
- Ensure that the EVX adaptor is correctly attached to the MFT-X1 tester. The adaptor plugs directly into the tester – no interconnecting cables are needed. 2
- Connect the EVX adaptor plug to the car charger. The EVX is now ready to communicate with the charger. 3
- Select the voltage setting on the left rotary dial of the MFT-X1. This will switch on the EVX and the charger.
- Wait a few seconds until the LED on the EVX stops flashing yellow.

  Note: If the LED continues to flash yellow for more than 30 seconds, this indicates that the EVX is not communicating with the M FT-X1. Refer to Section 5.2 of the EVX user guide for more information.
- The EVX will now send a CP state sequence of A, B, and C to the car charger. This sequence is automatic and shown at the bottom of the MFT-X1 display as the EVSE state. 4
- The car charger should lock the connector in place and the MFT-X1 will display the single- or three-phase voltages at the charger output. For three-phase chargers, the phase sequence will also be displayed. The display should indicate a C2 state.

  Note: Some car chargers have a start-up delay of up to five minutes. This is usually indicated by no voltage on the instrument's display and the status code C1 displayed. Most of these chargers have a 'start charging now' button. Pressing this should immediately switch the charger into charging mode (State C2).

CAR CHARGERS FOR ELECTRIC VEHICLES: A STEP-BY-STEP GUIDE TO AUTOMATED TESTING

- Test PE and CP error mode. Make sure that the MFT is in voltage mode and that the MFT is displaying State C2. Then press Hotkey 2 to select CP error or PE error. The charger should be disabled and the MFT should show its output as 0 V. On releasing the Hotkey, the charger should return to State C2, and the voltage at its output should return to normal. The test should be repeated for both CP and PE errors.

- Test for PE earthing issues. Make sure that the MFT and EVX are connected and communicating. Switch the MFT-X1 to loop impedance mode and use Hotkey 5 to select the L-PE option. Check that the voltage widget triangle shows mains voltage (typically 230 V AC in the UK). Then touch, but DO NOT PRESS one of the red TEST buttons. If there is a problem with the PE bonding, the MFT will display a warning screen, and live testing will be inhibited. If no warning is displayed, it is safe to proceed with live testing.

  Note: The PE earthing test inhibit function can be disabled. See the EVX user guide for more information.

- The tests carried out so far have verified that the basic functions of the car charger are working correctly. The remaining tests are standard electrical tests that would be performed on almost any type of electrical installation. These tests should have already been performed up to the point of connection of the charger to the supply system, but they should now be repeated at the output of the charger. This is necessary because the charger may include additional protection devices, such as RCDs (GFCIs in the USA) and RDCs, which must be tested and will certainly include switching devices, such as contactors, that may add significantly to the total loop impedance.

- Before proceeding, determine the type of earth fault protection used with the car charger. In many cases, primary protection will be provided by a 30 mA type A RCD (residual current device) in the circuit supplying the charger, which works in conjunction with a 6 mA RDC-DD (residual direct current detecting device) within the charger. Alternatively, a 30 mA type B RCD, either within or outside the charger, may be used on its own, without an RDC-DD. All of the earth fault protection devices will need to be tested to verify correct operation. The type of device(s) fitted will affect the type of tests used.

WARNING: The following tests are live circuit tests. Appropriate procedures and precautions for live circuit testing must be observed at all times.

- Measure loop impedance. Loop impedance is measured in the same way as it would be on the MFT-X1 without the EVX adaptor, but note that the EVX limits the functionality of the MFT-X1 to those tests appropriate for use on EV chargers. The outline test sequence is as follows. For further details, refer to the MFT-X1 user guide.
  - Select the loop test function on the left rotary knob of the MFT-X1. The charger should switch to State C2, and output voltage should be indicated in the voltage widget on the MFT display.
  - Press Hotkey 1 to select Z.
  - Press Hotkey 5 to select the circuit connection you wish to test:
    - For chargers rated 7 kW or less, select L1-PE, or L1-N.
    - For chargers rated more than 7 kW, use Hotkey 5 to select L1-PE, L2-PE or L3-PE for earth loop impedance testing, or L1-N, L2-N or L3-N for Live to Neutral testing.
  - In addition, on 3 phase chargers you can select L1-L2, L2-L3 or L1-L3 for multi-phase testing. Press Hotkey 4 to select either 3 wire or 2 wire testing.
    - For L-PE tests ALWAYS use the 3 Wire option. For All other tests use the 2 Wire option.

- For testing L-PE circuits in chargers fitted with and RDC-DD (most chargers), select RDC EV or if a type B RCD is fitted select RCD on Hot Key 2. If testing L-N or L-L circuits, select NO RCD.
- Press the TEST button. The MFT-X1 will display the loop impedance for the circuit being tested. If the correct mode is selected the RCD/RDC should not trip.

- If an internal RCD or RDC trips during the loop impedance test, the car charger output will be disabled. If the RCD in the supply to the charger trips the charger will switch off. If it's an RCD, reset it. RDCs should reset automatically. The EVX will attempt to reset the charger by sending the state sequence C, B, A, B, C. It will continue to do this until the charger returns to State C2.

- Test the protection devices. Car chargers fitted with either a type B RCD, or a type A RCD and an RDC-DD, can be tested with the EVX. The EVX provides automatic test sequences for RCD and RDC testing, but if necessary, these can be modified in the SETTINGS RCD tab. Refer to the MFT-X1 user guide for more details. The test sequence is as follows:
  - Select the RCD test function on the left rotary knob of the MFT-X1. The charger should switch to State C2 and an output voltage should be indicated in the voltage widget on the MFT display.
  - Use Hotkey 2 to select EV A/B or EV A/RDC, depending on the devices protecting the EV charger.
  - Use Hotkey 5 to select L1-PE, L2-PE, L3-PE as required.
  - Press the TEST button. The MFT-X1 will start the test sequence testing the RCD at ½xI, 1xI and 5xI, followed by the RDC ramp test.
  - Each time the RCD trips, reset it. The EVX100 will automatically return the charger to State C2. RDCs will generally reset automatically.
  - At the end of the test sequence, the MFT-X1 will display the complete test sequence results.
  - After all devices have been reset, the EVX should return the charger to State C2.

  Note 1: RDC trip time can be up to 10seconds and is not generally recorded. However, the trip current (<6mA) is important. The RDC test, indicated with a ramp in the display, applies a current ramp test up to 6mA and holds that current for 10seconds. The RCD should trip between 3mA and 6mA. If it fails to trip in 10seconds the RDC has failed.

  Note2: In North America, RCDs are usually known as GFCIs (ground fault circuit interrupters) or, specifically when used in chargers, CCIDs (charge circuit interrupting device).

  Note 2: Some car chargers isolate all terminals when tripped, including the earth terminal. The voltage on the earth terminal may cause the MFT-X1 to show a PE error. If this happens, contact Megger technical services for further advice.

- After completing tests, ensure the car charger is reset, if necessary, and returned to normal operating mode. In particular, be sure to exit maintenance mode if this has been used, and to properly refit any covers that have been removed to gain access to, for example, protective devices.

CAR CHARGERS FOR ELECTRIC VEHICLES: A STEP-BY-STEP GUIDE TO AUTOMATED TESTING

Certification

In some markets, certification may be required or even mandatory to verify that car chargers have been tested and shown to comply with relevant standards and regulations. Even when this is not the case, professional record keeping and documentation are highly desirable. Megger makes this easy with its CertSuite Installation software, which automatically captures test results from the MFT-X1 and produces professional quality reports and certificates at the touch of a button. CertSuite Installation is compatible with portable devices using the iOS and Android operating systems, and it is also available in a version that will run on all popular web browsers.

Calibration

Instruments with up-to-date traceable calibration should be used for the certification of new installations. While calibrated instruments are not essential for routine checking of car chargers, they are highly recommended as otherwise it is impossible to be confident about the accuracy of the results obtained. Recommended calibration intervals vary, but the instrument manufacturer will be able to provide dependable advice.

Resetting protective devices during testing

Testing the RCD or RDC in a car charger will necessarily trip the protective devices protecting the charger and the user. Protective devices may also be tripped accidentally if an incompatible loop impedance test is selected. Before testing the charger, ensure that access to the protective devices is possible so that they can be reset once they have tripped. These devices may be found in the charger itself, such as the RDC, or on the circuit supplying the charger, in the distribution board or in a locked control room.

Domestic chargers should not present any issues but public access, commercial and company installations may be connected to a back-office network or linked to an app on a mobile device. In these cases, it may be necessary to discuss the need for access with the network owners before work commences, as the charger, once tripped, may not reconnect for some minutes or even hours.

If a charger does not reset during an RCD or RDC tripping sequence, it is rarely (if ever) the fault of the instrument. It is almost certainly the charger or back-office system that is preventing it from resetting. Chargers and installations vary considerably in this respect, but if all other methods fail, it may be possible to force the charger to reset by turning off the power to it, waiting a short time, and turning it on again. This should, however, always be a last resort. Contact the car charger manufacturer for additional advice.

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