Publishable Summary for 23IND06 Met4EVCS
Metrology for electric vehicle charging systems

Overview

Electrical Vehicles (EVs) are the core of the European Commission's transition plan for the transport sector towards electromobility. The successful integration of EVs requires the deployment of an extensive infrastructure for EV Charging Stations (EVCSs) covering the overall charging needs of the consumers. This project will tackle the challenges of power quality effects on and as a result of EVCSs, and evaluate the associated losses and reliability of metering under actual on-site conditions. The project aims to cover several charging modes, such as direct DC charging at low and high power, smart charging, and bi-directional charging. The project will support the industry needs through the development of a metrology infrastructure for traceable testing of EV charging systems which remains a major bottleneck at the moment. The project will also provide input to OIML TC 12, WELMEC WG 11, and the European Commission (EC) Working group WgMI E01349 for uptake in their guidelines and regulations which will, in turn, support the EV charging industry through standardisation.

Need

The EC has adopted an ambitious roadmap for a competitive and sustainable transport system by 2050. With the expected integration of EVs, EVCSs are a key element in electromobility and, therefore, the Alternative Fuels Infrastructure Directive 2014/94/EU took measures to increase the number of standardised EVCSs. Though EVCSs may be considered simple meters, additional factors, such as grid distortion and dynamic impedance during charging, challenge their reliable operation. In addition, the detailed characterisation of the effects that EVCSs may have on the grid will be valuable to anticipate deteriorating Electromagnetic Compatibility (EMC) or Power Quality (PQ). Therefore, there is a need to characterise on-site local grid conditions in various charging scenarios.

The methods and standards applied in existing EVCS test benches do not reflect representative operating conditions. Also, characterisation of newer charging modes, such as DC charging at low power and ultra-fast charging at high power, smart charging, and bi-directional charging, is not well covered in standards.

Therefore, there is a need for establishing EVCS test benches for both DC and AC, implementing new measurement methods and standards reflecting representative operational conditions at low, medium, and high power levels, following IEC 61851-1. These test benches shall be capable of evaluating (i) metering accuracy and energy transfer efficiency with a target uncertainty of 0.1 %, and (ii) generated conducted emissions up to 150 kHz.

Knowing that the number of EVCSs is growing rapidly, there is a need to develop the metrological infrastructure for on-site verification of EVCS energy metering, in support of legal metrology. On-site verification requires reliable and efficient measurement procedures, based on commercially available equipment capable of handling representative operating conditions and charging scenarios. The uncertainty of the metering accuracy verification is targeted at 0.5 %.

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The project has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

Objectives

The project focuses on the development of metrology capabilities for the traceable evaluation of EVCSs under realistic operating conditions.

The specific objectives are:

1. To define representative on-site operating conditions for EVCSs in terms of local grid disturbances and local grid impedance under live grid operation. For this, dedicated measuring equipment will be developed for measuring local grid disturbances and local grid impedances up to 150 kHz. With this equipment measurements will be performed at, at least, five sites with DC chargers and five sites with AC chargers with a variety of (i) charger brands, (ii) operating modes and (iii) charging power levels.

2. To develop traceable methods and test benches for the characterisation of EVCSs under representative operating conditions for both AC and DC charging in accordance with IEC 61851-1. For AC chargers, the characterisation will be performed at low and medium power, and for DC chargers the characterisation will be done at low, medium and high power. The characterisation involves the evaluation of (i) metering accuracy and energy transfer efficiency with a target uncertainty of 0.1 % (with respect to nominal power) and (ii) generated conducted emissions up to 150 kHz. For AC EVCSs, test benches will be developed for three-phase systems at 230 V up to 100 A and charging power levels up to 44 kW; for DC EVCSs, test benches will be developed for voltages up to 800 V, currents up to 500 A and charging power levels up to 350 kW.

3. To develop the required metrological infrastructure for on-site verification of EVCS energy metering, in support of legal metrology and acceptance testing, with a target uncertainty of 0.5 %. This will include the development of reliable methods for EVCS energy metering evaluation based on commercially available equipment, which have been validated under representative operation conditions, including smart charging and bidirectional energy transfer.

4. To facilitate the uptake of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (IEC TC 69, WELMEC WG 11, OIML TC 12/p 3, EC WgMI E01349), and end users (e.g., EMN Smart Electricity Grids, EMN Clean Energy, EVCS operators, grid operators, EVCS manufacturers).

Progress beyond the state of the art and results

Definition of representative on-site operating conditions for EVCSs and characterisation of local grid disturbances and local grid impedance (objective 1):

Currently, the most common method of EV modelling is to consider the EV loads as constant power elements without considering the voltage dependency of EV charging systems during the charging process. Several research projects on smart grids are now looking into realistic models representing the realistic behaviour of an EV load to understand the impact of EV charging load, but such models are not yet available nor are the measurement data to support such modelling.

The project will investigate typical EV voltage and impedance patterns as a function of time and state of charge during the charging process, based on on-site traceable measurements at EVCS sites. In some cases, the project will employ an EV load emulator (dummy load) that can simulate these voltage and impedance patterns. The patterns will cover a representative set of the most used EVs, energy transfer modes, and battery capacities.

Development of traceable methods and measurement standards for the characterisation of EVCSs under representative operating conditions for both AC and DC charging (objective 2):

Currently, the characterisation of EVCSs is limited to energy metering based on domestic AC supply meter regulation. Specific aspects of DC metering and aspects of high-power transfer at big charging stations are insufficiently characterised to ensure the reliability of the energy metering and are not fully adequate for estimating the efficiency of the charging stations with sufficient accuracy.

The project will develop the metrological infrastructure for laboratory characterisation of EVCSs including test setups, test methods, test conditions, and reference standards required for traceable characterisation of the energy transfer and energy loss. In some testing scenarios, EV simulators and dummy loads will be used instead of the whole EV. Since facilities for high-power DC charging are still scarce, these will receive extra attention.

Development of metrological infrastructure for on-site verification of EVCS energy metering (objective 3):

OIML TC 12/p 3 has recently produced a guiding document, OIML G 22 “Electric vehicle supply equipment”, but practical technical experience in testing and approving is still lacking in some respects, especially for DC charging applications. Furthermore, its practical implementation is a challenge because some tests require expensive hardware and are very time-consuming. This is not suitable for the fast-growing EVCS market. The project will provide practical technical input to OIML TC 12/p 3 for improvements of the current guide and its successor document on methods for verification of DC and AC EVCSs.

The project will establish the basis for an integrated metrology infrastructure for EVCS metering verification. For this, the project will propose validated simplified test setups and validated simplified test procedures for fulfilling a minimum set of test requirements to verify the EVCS metering accuracy in field conditions.

Outcomes and impact

Outcomes for industrial and other user communities

The project will provide a thorough quantification of high-frequency emissions and distortion caused in the supplying grid, together with feeding an EVCS impedance, improving the knowledge provided by the few existing standards (e.g. IEC TR 60725). This will allow manufacturers to simulate the emissions of their own equipment more accurately, improving the margins to consider during design and production, but also being able to foresee resonance situations for specific grid topologies.

EVCS operators and DSOs can use the results of grid-and-EVCS interaction measurements and modelling for planning a high concentration of EVCSs in the near future. The set of waveforms for distortion and emissions gathered in the project will be evaluated for the influence on metering and losses, providing an indication to many actors (manufacturers, grid operators, consumers) of the cost of distortion as affecting efficiency through losses directly or indirectly through disturbance to metering.

The test benches and test procedures developed in the project for EVCS metering and loss verification will contribute to the lasting metrology infrastructure in the field and provide the various NMIs with testing capabilities to fulfil their market needs. These measurements will help build trust and experience with the technology and further help the EVCS industry, both manufacturers and charge point operators (CPOs), in the widespread deployment of EVCSs. This will also provide guidance as input to the new European legislation on EVCS testing which will in turn facilitate mass production of EVCSs.

This project will provide new insights to the manufacturers and operators on ways to optimise the design of the charging station and emphasise the shortfalls in their current design by investigating the influence of external factors on metering and losses in EVCSs. The outcomes of the project are set to greatly benefit the EV industry and the operators of EV charging stations. The development of a European metrology infrastructure for the verification of the metering and losses in the EV charging infrastructure will further propel the pace of development in the field of EV chargers by reducing waiting times in certification and testing. European consumers will eventually benefit from a good EV charging infrastructure with the added traceability and fair metering of electrical energy. This will increase the level of confidence in the consumers and as a result, support the transition to electromobility in Europe.

Outcomes for the metrology and scientific communities

The test benches developed for the verification of the metering and losses in EVCSs in the various charging modes and the setups and methods for the consistent on-site measurement of EVCSs and EV emissions and distortion by different European institutes will lead to the establishment of an integrated European metrology infrastructure. This upholds the idea of smart specialisation, of an integrated metrology infrastructure of the European area. The devised procedures for the certification and verification are a key step towards the establishment of a common regulation. Knowledge transfer to non-participating NMIs and test institutes will be performed via project workshops and presentations at scientific and industry workshops and conferences.

The project will establish a database for disturbances and impedance measurements that will lead to defining a procedure to evaluate EVCS distortion. For that, comprehensive measurement methods will be defined and validated. Ad-hoc test waveforms, similar to the complex waveforms generated during the EVCS process, will be defined and used to optimise and validate the assessment methods.

The published results in terms of the test waveforms, impedance envelopes, and procedures will serve as a starting point for new and improved research in the field. It is expected that the new measurement and analysis methods, as anticipated, can be reused for similar types of scientific research.

The knowledge of changes in the grid impedance during the EVCS charging will be fundamental for the grid operators to support the impact of EVCS deployment in the near future.

Outcomes for relevant standards

The increased distortion of distribution grids in the near future following the extensive increase of EVCSs and EVs requires revised standards related to PQ issues on public electricity networks. Completing previous results, including the EMPIR JRP 18NRM05 SupraEMI, accurate measurement methods for EVCS disturbances will be proposed for the current standardisation work at IEC SC 77A in relation to the IEC 61000 family standards.

This project will provide three guidelines for metering evaluation and on-site verification of EVCSs to several national and international standard committees dealing with the legal regulation of electricity meters such as IEC and CENELEC TC 13.

Significant input is anticipated for the working groups of OIML TC 12 “Instruments for measuring electrical quantities” for the next revision of the recently published EVSE guide G 22; of WELMEC WG 11 “Utility meters” for the harmonised regulation for EVCSs across Europe through the generated good practice guides.

Longer-term economic, social, and environmental impacts

The wider impact of the project can hardly be underestimated. In general, a harmonised EVCS metrology infrastructure will increase the level of confidence in the consumers and as a result, support the transition to electromobility in Europe.

More specifically, the standards and guidelines resulting from the project will pave the way for a harmonised regulation of EV charging. Such a European or International regulation will have a substantial economic impact as it will enable mass production. Standardised AC and DC metering systems enable international expansion of EV charging networks. They ensure that charging stations can be deployed in multiple countries without significant modifications, fostering the growth of EV adoption worldwide. As EV technology evolves, standardisation allows for easier upgrades and compatibility with new features and improvements. This flexibility ensures that charging infrastructure can adapt to emerging technologies and customer demands. Some of the industries that will benefit from this project are calibration laboratories which provide traceable verifications of the equipment, EV and EVCS manufacturers which will be able to optimise their designs, and EVCS operators that will be able to ensure fair transactions for end users that meet the needs of the European regulatory bodies.

The presence of a reliable EV charging infrastructure with traceable metering is fundamental to the deployment of EVs. This in turn promotes the integration of renewable energy sources which reduces the environmental impact of the energy production process and reduces the dependency on oil and gas.

As an added benefit, the project improves the know-how on metering and losses involved in new and innovative charging modes such as smart charging and V2G charging. These topics are aimed to help mitigate the impact of EVs on grid congestion and reduce electricity generation capacity needs on future grids.

List of publications

No open-access publications have been published yet.

The list will also be available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:	01 July 2024, 36 months	
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Internal Beneficiaries: 1. VSL, Netherlands 2. BEV-PTP, Austria 3. BFKH, Hungary 4. CEM, Spain 5. CMI, Czechia 6. JV, Norway 7. LNE, France 8. MIRS, Slovenia 9. RISE, Sweden 10. TUBITAK, Türkiye 11. VTT, Finland	External Beneficiaries: 12. CIRCE, Spain 13. Elaad, Netherlands 14. EMC-BCN, Spain 15. INM, Republic of Moldova 16. INTI, Argentina 17. ITE, Spain 18. SUN, Italy 19. UNIGE, Italy 20. UPV/EHU, Spain 21. UTwente, Netherlands	Unfunded Beneficiaries:
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