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# The project “Metrology for Inductive Charging of Electric Vehicles”

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**Abstract** — The European metrology programme for innovation and research (EMPIR) is the current main programme for European research on metrology. In 2016, within the EMPIR call, the project “Metrology for inductive charging of electric vehicles” (MICEV) was approved and it started in September 2017. Inductive charging is a wireless charging technology that will be widely used with electric vehicles (EVs) in the near future, offering many advantages over traditionally fuelled and current EVs. The project aims to advance inductive power transfer (IPT) for EV charging by developing metrology techniques for measuring power transfer efficiency and reliable demonstration of compliance with existing safety standards for human exposure. The main research topics are: measurement of the power transmitted on-board, transmission efficiency, requirements for measurements in the dynamic charging, assessment of magnetic field exposure.

**Index Terms** — Electromagnetic measurements, electromagnetic modeling, measurement techniques, metrology, power measurement, uncertainty.

## I. INTRODUCTION

EURAMET is the Regional Metrology Organisation of Europe [1] and promotes the EMPIR programme [2] as an integrated part of Horizon 2020, the EU Framework Programme for Research and Innovation. EMPIR includes many calls on different topics, including health, industry, fundamental metrology and, among others, energy. In the 2016 call on this latter topic the project MICEV was approved and it has recently started. MICEV deals with the measurement of the power transferred on board the vehicle during the inductive charging, evaluating compliance to human exposure standards [3]. The inductive power transfer occurs between two resonant circuits, one under the road and

the other on-board, at the frequency of some, or many, tens of kilohertz, depending on the specific technologies adopted [4]. The peculiar current and voltage waveforms in this specific application require dedicated measurement techniques, which involve an adequate calibration and characterisation of the transducers, especially as regards dynamic charging. In dynamic charging, the supply of power to the vehicle takes place instantaneously, the moment the vehicle is aligned with the coil under the road. It is clear, however, that the transient regime poses non-trivial measurement problems, for instance for the presence of harmonics in the power measurements, and for the effects on the human exposure assessment.

Reliable, accurate, traceable electric power, efficiency and magnetic field measurements are needed for IPT applications, specifically for manufacturers of electric vehicles or hybrid electric vehicles (not only in the automotive sector), their suppliers, certification bodies and electric companies, as they are subject to strict international requirements with respect to accuracy, safety and, in a near future, energy billing. In this project, high-accuracy calibration facilities will be developed to ensure traceability of electric and magnetic measurements with sufficient accuracy for the demands of industry.

## II. MAIN SCIENTIFIC AND TECHNICAL OBJECTIVES

The project has four main objectives, corresponding to four technical work packages (see Fig. 1). The first two objectives concern only the static charging and in particular, the measurement of the power on board the vehicle and the measurement of the power transmission efficiency. The third objective is inherent the requirements for the measurement in the dynamic charging. The fourth deals with the assessment of human exposure to magnetic fields. Here in detail:

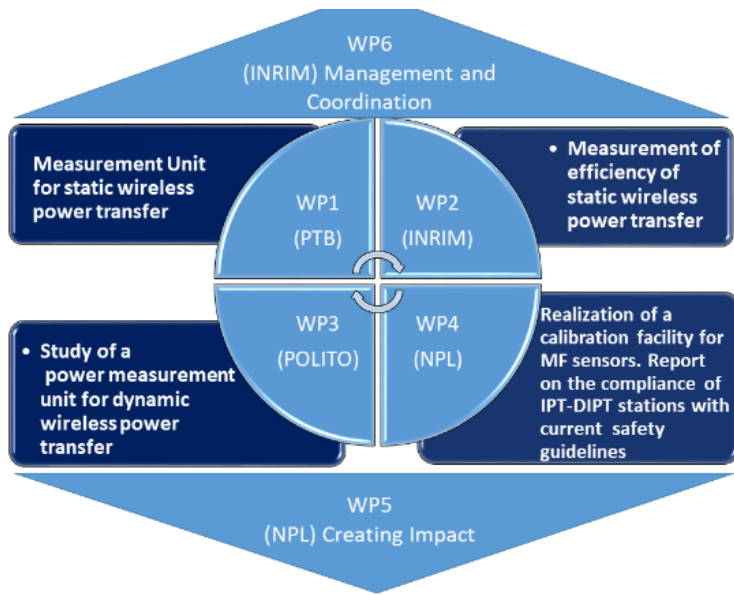


Fig. 1: MICEV project work packages.

1. To develop and characterise a power measurement unit for static wireless power transfer for on-board measurement with a relative uncertainty in the DC circuit of  $1 \cdot 10^{-3}$ , the frequencies of the AC transmission being up to 100 kHz – 150 kHz and powers up to 200 kW.

2. To develop methods to determine the efficiency of a static IPT system with a relative uncertainty of  $1 \cdot 10^{-3}$  and taking the relevant parameters, particularly airgap and misalignment between the coupled coils into account.

3. To define the requirements for a power measurement unit for dynamic inductive power transfer (DIPT), identify the relevant parameters (e.g. traffic conditions, speed, vehicle dimensions, power converter state, coil configurations) and estimate their effect on the measurement of the power transferred to the vehicle and on the system efficiency.

4. To set up a system for traceable calibration of magnetic field (MF) meters and gradiometers from 10 kHz to 150 kHz and up to 100  $\mu$ T and field gradients up to 100  $\mu$ T/m with both sinusoidal and non-sinusoidal waveforms. The target expanded uncertainty for the system is 5 %. Moreover, to develop measurement protocols for the assessment of the human exposure to the electromagnetic fields generated by these technologies, in static and dynamic conditions, taking into account the compliance with the limits indicated by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [3].

### III PROJECT IMPACT

The project partners will operate to facilitate the take up of the technology and measurement infrastructure developed in the project activity by the measurement supply chain and end users and to provide metrology input and pre-normative research to the evolution of relevant international standards.

A power standard suitable for measuring electrical powers up to 200 kW, having the characteristics of the power transmitted to EV batteries, is not currently available in Europe. In the case of DC current affected by AC power ripple and harmonics up to 150 kHz, such a power standard will serve as a basis for measuring active and reactive power in IPT systems with high accuracy (maximum uncertainty of  $1 \cdot 10^{-3}$  relative). Another project output will be a facility, allowing manufacturers of sensors and measurement tools to have their instruments calibrated in this frequency range.

No detailed metrological methodologies for the assessment of exposures from vehicle inductive power transfer systems are available at present, except indications in [4]. Little information is publically available reporting results for the assessment of electric vehicle IPT systems from either modelling or measurements. Whilst manufacturers have modelled their electric vehicle designs, these contain proprietary information and are not publically available for the development of standards for safety assessment.

This project will go beyond this state-of-the art by providing the required traceability for magnetic field sensors and gradiometers for sine wave and distorted waveforms for 10 kHz to at least 150 kHz. The project will also provide validated and comprehensive computer simulations and measurements of human exposure to EV IPT systems, and test protocols for field surveys and computational dosimetry for EV IPT systems (static and dynamic) that will form the basis of future standards for IPT stations.

The project will produce specific theoretical investigations and measurements on power losses in the IPT chain. Future payment systems in public charging systems and stations will take advantage from this research data making it clear what the consumer pays for, the transmitted or received energy.

### IV. CONCLUSION

MICEV project will provide new metrology techniques, standards and industry best practice guides for EV's inductive power transfer measurements. New calibration services for power measurement and for magnetic field sensors will be setup. The project results will contribute to new or improved guides, recommendation and standards. Finally, a boost for this technology will be provided through a proper assessment of the human exposure by excluding hazards for users

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