Publishable Summary for 16ENG08 MICEV
Metrology for inductive charging of electric vehicles

Overview

Inductive charging via inductive power transfer (IPT) is a wireless charging technology that will be used with electric vehicles (EVs) in the near future. IPT offers many advantages over traditionally fuelled and other currently available EVs, such as charging whilst in motion, smaller batteries, and high autonomy. Such advantages also support the reduction of carbon dioxide (CO_2) and fossil fuel consumption. However, IPT is still a new technology and accurate measurements of electrical and magnetic quantities involved in IPT technology for the charging of EVs are limited. This project addressed this issue by developing metrological techniques for measuring IPT efficiency to ensure traceability of electric and magnetic measurements with sufficient accuracy for the demands of EV industry.

Need

Air pollution is one of the major environmental concerns in the urban environment. Advancements in IPT can facilitate and hasten the growth of the EV industry directly benefiting the environment in terms of reducing CO_2 emissions and other pollutants. However, IPT is a novel technology and, in certain areas, still under development. Therefore, investment in IPT technologies are needed in order to keep Europe at the forefront of associated research and industry.

IPT requires, among other things, accurate models and measurements that can clearly (i) identify how electromagnetic emissions are compatible with any human exposure and (ii) how to correctly bill the energy transferred on board EVs. However, accurate measurement of electrical and magnetic quantities involved in IPT technology currently represents a challenge. In fact, the signal amplitudes are often as large as those of the energy distribution systems, while the frequency bandwidth involved is much wider. As IPT technology is largely still under development, the corresponding required measurement capabilities have not been realised yet and given the types of application, these traceable measurements are needed before the industry can develop further. For example, the waveform characteristics of the electric quantities that supply the EV inductive charging systems are very specific and require dedicated measurement techniques. Such techniques must also include an adequate calibration of the transducers, especially regarding dynamic charging, where the supply of power to the vehicle involves a transient regime.

Reliable, accurate, traceable electric power, efficiency and magnetic field (MF) measurements are needed for IPT applications. This is not only for manufacturers of EVs or hybrid EVs (including the automotive sector), but their suppliers, associated certification bodies and related electric companies. Such information is necessary for the strict international requirements for EV with respect to accuracy, safety and, in a near future, energy billing.

Objectives

The goal of this project was the development of high-accuracy calibration facilities for the traceability of electric and magnetic measurements with sufficient accuracy for the demands of EV industry. The specific objectives of the project were:

1. To develop and characterise a power measurement unit for static wireless power transfer for on-board measurement with a relative uncertainty in the direct current (DC) circuit of 10^{-3}, the frequencies of the alternating current (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 wireless power transfer system with a relative uncertainty of 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 wireless power transfer, 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 MF meters and gradiometers for 10 kHz to 150 kHz and up to 100 μT and field gradients up to 100 μT/m with both sinusoidal and non-sinusoidal waveforms. The target expanded uncertainty for the system is 5 %. 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 the compliance with the limits indicated by the guidelines of the International Commission on Nonionizing Radiation Protection (ICNIRP) into account.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain and end users and to provide metrology input and pre-normative research to the evolution of relevant international standards

Progress beyond the state of the art

Objective1: A new measurement system called Power Measurement Unit (PwMU) for laboratory and in-field measurements, which improves the ease and ability to characterise WPT charging stations both in field and in laboratory environment, was realised in the project. To calibrate this measurement system, a power standard suitable for measuring electrical powers up to 200 kW, having the characteristics of the power transmitted to EV batteries, not currently available in Europe was realised. Such a power standard is needed for measuring active and reactive power in IPT systems with high accuracy (maximum uncertainty of 10^{-3} relative) for DC current affected by AC power ripple and harmonics up to 150 kHz. This project went beyond the state of the art by also developing a facility for such a power standard and IPT system, which is now ready.

Objective 2: The behaviour and efficiency of the IPT system was estimated through a new model-based approach for the calculation of losses, especially in converters, which is based on the convergence of different modelling approaches validated by measurements, taking also into account the main influence parameters like misalignment. A clear method to assess the efficiency of a static wireless power transfer system through measurements, with a relative uncertainty of 10^{-3}, was set up.

Objective 3: In dynamic inductive charging no standards have been established and currently it is arduous to define a clear picture of the characteristics of the electrical parameters to be measured. The project went beyond the state of the art by determining the electrical parameters required for DIPT and proving this information to relevant standardisation bodies for their input into standards. The project also developed a modelling study which provide elements for the extension of the project's results for the realisation of a low uncertainty measurement systems in dynamic IPT (DIPT) stations. The analysis determined that 10^{-2} can be a reasonable target for this type of measurements.

Objective 4: Currently, very limited information is publicly available for the assessment of EV IPT systems from either modelling or measurement data. Whilst manufacturers have modelled their EV designs, these often contain proprietary information and are not publicly available for the development of standards for safety assessment. This project went beyond this state-of-the art by providing the required traceability for MF sensors through a new calibration facility. The project produced validated and comprehensive computer simulations and measurements of human exposure to EV IPT systems, as well as defined new best practice guidelines for field surveys and computational dosimetry for EV IPT systems (static and dynamic) that can be used for future standards on IPT stations.

Results

Objective 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 10^{-3}, the frequencies of the AC transmission being up to 100 kHz – 150 kHz and powers up to 200 kW

POLITO, CIRCE and some project collaborators supplied preliminary recorded waveform at charging stations.

In the case of a resonant circuit, the voltage is substantially a square wave, with an important harmonic content, while the current waveform is a mildly deformed sine wave, with a non-negligible content of the third and fifth harmonics. The voltage and charging current of the batteries are substantially continuous signals, with a not negligible ripple that can even reach 10 % to 15 % of the DC signal. These waveforms were then used by the project for subsequent developments.

The design and realisation of the Power Measurement Unit was completed. This is a new and traceable measurement system devoted to the inductive charging of EVs. The PwMU is able to accurately measure the power absorbed from the batteries, that adsorbed from the electric grid, and the ratio between the two previous quantities (efficiency). Moreover, it is able to determine the magnetic flux density levels in the charging station and to record all the measured values and waveforms. The realisation was achieved at INRIM, with the support of PTB, CIRCE and POLITO with RISE contributing to the preliminary calibration. The PwMU is fully described in [1].

Regarding electrical measurements, the PwMU was calibrated at PTB, where a new reference power standard was developed and realised, with appropriate AC and DC generators, analog-to-digital (ADC) and digital-to-analog (DAC) converters, current and voltage sensors and control software. PTB realised this system with INRIM contributing to the voltage measurement chain [2,3].

The control software of the PTB calibration facility allows the generation of independent waveforms for current and voltage signals and can reproduce recorded real signal waveforms. A correction of the errors of the ADCs and of the current and voltage sensors was completed. The calibration system (within the facility) can perform the calculation of: rms current (i), rms voltage (u), apparent power (S), active power (P), reactive power (Q), waveforms (Fast Fourier Transform; FFT) and quantities are read, stored, and compared with the device under investigation.

The PTB calibration facility was developed for the calibration of the on-board measurement systems and is structured as a phantom power, with two independent circuits for current and voltage, and can be operated with DC plus AC signals up to 150 kHz, simulating electric power up to 200 kW. The calibration facility is now completed, and the new measurement capabilities have been presented to Euramet in order to provide soon a new calibration service.

Objective 1 was fully achieved.

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

Based on the components chosen for the PwMU measurement system (from objective 1), a method was tuned in order to define the accuracy of the power and efficiency on-site assessment. It was clarified that, despite distorted waveforms at the charging stations, it is possible to reach a good target uncertainty of 10^{-3} for the IPT calibration facility, in a wide temperature span between 18 °C and 28 °C [4].

In parallel, the modelling analysis of two static charging stations (CIRCE and POLITO in static conditions) was completed. This was done based on the fact that the efficiency depends on converter losses and on geometric parameters, such as the misalignment. A modelling approach was successfully pursued by Aalto, and a modelling tool (simulator) has been developed at UNISA and UNICAS in order to support the prediction of an IPT system's efficiency performance in any operating condition. The simulator can also quantify the impact of a device's circuit topology, harmonics, and physical and geometrical parameters (airgap, misalignment) on the measurement system. A simplified version of the simulator can be downloaded at the www.micev.eu website.

An electromagnetic numerical model of a complete EV charging system has been created, which includes the transmitter-receiver coils, the shielding structures (e.g. the aluminium chassis), and the ferrite concentrator blocks. The results of simulation models have been compared with the results of experimental measurements, under different steady-state load conditions and has resulted in the validation of the electromagnetic numerical models. Using the results, an equivalent circuit model was then derived and embedded in a system-level circuit model, along with the models of the converters and all the other subsystems of the IPT system. Specifically, a system-level behavioral model of the inverter was developed, tailored for fast simulations in dynamic conditions, and based on a genetic programming approach [5, 6]. Sensitivity of the results was investigated by CNRS using different non-intrusive stochastic approaches considering the variability of different parameters like metal electric conductivity and magnetic permeability, coils length and distance between coils, shift between coils [7], [8].

Objective 2 was fully achieved.

Objective 3 - To define the requirements for a power measurement unit for dynamic wireless power transfer, 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

A literature review of dynamic charging and parameters involved and setup waveform recordings for dynamic wireless power transfer was done by TU Delft and POLITO.

The POLITO dynamic charging system was analysed by modelling. UNISA and UNICAS generated a model of each of the DIPT system's sub-systems. The power loss models of the inverter and rectifier conversion stages adopted for static analyses can also be applied to dynamic analyses, taking into account the vehicle speed and the bandwidth of the DIPT system controls. UNISA and UNICAS used Finite Element Modelling (FEM)-3D to create dynamic models of the coils and other relevant conducting structures (including ferrite shields, and the body of the car) from the IPT system in terms of self and mutual inductances and primary and secondary resistance in different dynamic conditions. Similarly, Aalto modelled the DIPT system using a multiphysics simulation tool. The outcomes of the UNICAS FEM-3D dynamic simulations and Aalto multiphysics simulations highlighted that the coil pair inductances do not significantly change in the dynamic case compared to the results obtained for the static cases, in the range of vehicle speed values foreseen for such applications.

Based on the mutual inductance data provided by UNICAS over a set of the coils positions of interest for the application, UNISA has developed new behavioural models of coils mutual inductance that allow the simulation of trajectories for the vehicle of interest for this application, with the goal of performing power and efficiency analysis. [9]

Simulations based on the 3D FEM approach were also provided as input to CNRS to train its surrogate models. As part of this, the impact of physical parameters on the chassis and misalignment between receiver and transmitter coils was analysed by intrusive stochastic techniques and with the 3D FEM modelling tools in order to build adequate surrogate models for the evaluation of MF close to wireless charging pad, also to assess human exposure [10].

Objective 3 was fully achieved.

Objective 4 - To set up a system for traceable calibration of magnetic field meters and gradiometers for 10 kHz to 150 kHz and up to 100 µT and field gradients up to 100 µT/m with both sinusoidal and non-sinusoidal waveforms. The target expanded uncertainty for the system is 5 %. 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 the compliance with the limits indicated by the guidelines of the ICNIRP *into account*

A new calibration facility for the generation of reference AC MF was realised at NPL. The system is based on two ring coils with a diameter equal to 300 mm. The facility extends the present European measurement capabilities up to 100 µT at (and up to) 150 kHz. To validate the calibration facility an intercomparison was completed and the results were consolidated in a final report. The target relative expanded uncertainty for the new magnetic field standard is better than 5 %.

SPEAG has also setup a calibration system and a new meter for MF gradient measurements up to 100 µT/m and developed a novel method and procedure for evaluating compliance of sources with strong gradient MF such as wireless power transfer systems [11].

Two charging stations were modelled using validated numerical codes. This includes the CIRCE charging station and bus, and a charging station for light vehicles with a car body model supplied by a stakeholder; the Volvo car company. INRIM, NPL and SPEAG have defined the exposure scenario for vehicle occupants and bystanders taking into account areas of higher exposure. SPEAG also generated advanced bio-electromagnetic models of adults, children and infants of a virtual population and subsequently modified the population's postures in order to more thoroughly investigate the human exposure.

The results from the modelling were validated by measurements. The study results, some of which are summarised in [12] and [13], highlighted that the vehicle body appears to be a good shield. The levels of magnetic induction within the light EV are almost negligible, as the MF mainly enters via glazed surfaces. In the case of heavy vehicles, where the source of MF is more significant and where the glazed surfaces of the entrance doors are wider, more significant MF values are found although, so far, the values are much lower than the regulatory limits.

In addition to this, SPEAG developed a new mechanistic model for electromagnetic safety evaluations of electrically short implants [14].

SPEAG, POLITO and INRIM also tested the accuracy of the computational dosimetric results, with reference to human exposure to POLITO's IPT system, in static conditions. The analysis was performed using different anatomical models (i.e. different sizes and posture) and exposure conditions in order to investigate the main origin of local artefacts. The results confirmed that the staircase interfaces between tissues, which are unfortunately unavoidable for voxelised human models, are responsible for most numerical artefacts. The use of an improved filtering technique demonstrated its capability to better assess the results, by removing undesirable outliers and reducing discrepancies between results obtained with different solvers to less than 10 % for 1 mm anatomical model resolution. More details in [15].

Based on the experience gained by the partners involved in the project both from a modelling and a measurement point of view, the MICEV consortium published the "Best practice guide for the assessment of EMF exposure from vehicle Wireless Power Transfer systems" [16] which include the dataset [17].

The guidelines are designed for people who approach the assessment of human exposure in vehicles and around inductive charging stations and they incorporate results and experiences elaborated during the development of the project.

Objective 4 was fully achieved.

Impact

The project hosted a training course on "Wireless Charging of Vehicles - Measurements, modelling, and human exposure," in November 2019 at PTB, Germany. The training course also presented the project's preliminary results to a total of 20 external participants, which included four people from other NMI's, 8 people from other universities, five people from companies including instrument manufacturers and engineering companies and the remaining were students.

A website for the project was created at www.micev.eu and a blog hosted in the project website was populated. The project has been disseminated via a number of different press releases, media interviews and TV and radio clips including ANSA (Italian national press agency), TG Leonardo (Scientific news on Italian National broadcasting RAI3) and Smart City: Materials, Technology and People- at Materials Village - Material ConneXion hub Italia during "Milano Design Week". In addition, the project has published 15 open access publications, a publicly available "Best Practice Guide" and a dataset, and given 28 conference presentations, such as Conference on Precision Electromagnetic Measurements (CPEM 2018 and 2020), IEEE Conference on Electromagnetic Field Computation (CEFC 2018 and 2020), 2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT Automotive) and International Symposium on electromagnetic fields (ISEF 2019), International Conference on Synthesis, Modelling, Analysis and Simulation Methods and Applications to Circuit Design (SMACD 2018 and 2019), IEEE International Conference on Electronics, Circuits and Systems (ICECS 2020), IEEE International Symposium on Circuits and Systems (ISCAS 2020) and MICEV Final Workshop.

The final virtual workshop of the project was organised on a double live channel, on the Zoom and YouTube platforms. The event aroused good interest with over 100 registered participants, 90 actual participants in the live session with a stable average of 65 persons in each instant of the workshop. The workshop remained available on YouTube for deferred viewing, where it has a total (as of March 2021) of over 250 views.

Impact on industrial and other user communities

An advisory Stakeholder Committee has been established for the project consisting of thirteen stakeholders including instrument manufacturers, automotive engineering companies, a local transport company, an electric company and some SME's. The Stakeholder Committee interacts with the project website via the project website and meetings. A car company (Volvo) is also participating in the project as collaborator.

The project has developed new measurement capabilities of direct relevance to accredited laboratories, manufacturers of MF meters and manufacturers of electric current, voltage and power meters. Manufacturers of EVs and their component suppliers, manufacturers of forklift and automatic vehicles in the industrial environment will also benefit from the project's results.

In particular, the project developed a new voltage standard a step-up calibration procedure at INRIM for the voltage transducers used in IPT systems, that can take into account the actual waveforms registered in related applications. Moreover, the project developed a new calibration facility at PTB for calibration of power analysers, suitable for the measurement of power at the frequency levels required by these applications (ripple up to 150 kHz, uncertainty of the reference power standard of the order of 10^{-3} relative). The new measurement capabilities related to the facility will be accessible to companies and laboratories, especially manufacturers of electric current, voltage and power meters and electric companies interested in IPT.

A system for traceable calibration of MF meters was realised at NPL. This facility is suitable for MF up to 100 μT (for 10 kHz–150 kHz, with both sinusoidal and non-sinusoidal waveforms) and is available to accredited laboratories and manufacturers of MF meters. Another facility for MF field gradients calibration (gradiometers) has also been developed at SPEAG.

The project produced 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 by helping to clarify what the consumer pays for, i.e. the transmitted or received energy.

Impact on the metrology and scientific communities

The project has developed a measurement system for the calibration of voltage dividers up to 200 kHz at INRIM. This was realised by a step-up procedure using an amplitude and phase precision comparator. The latter is based on high resolution and high-speed digitisers, equipped with software programs in Labview™ for the simultaneous determination of the voltages on the two channels and their phase differences. The original step-up calibration procedure, together with a new reference voltage resistive capacitive divider for voltages up to 1 kV and bandwidth up to 200 kHz developed during this project, are intended to extend traceability of voltages above 100 V up to (and beyond) 200 kHz [2]. This new measurement system was utilised to calibrate the voltage transducers of the PwMU.

A new phantom power standard was realised at PTB. The facility can be applied for DC currents affected by harmonics determining AC power up to 150 kHz. New CMCs were submitted by PTB to Euramet for AC power measurements in the frequency range between 15 Hz and 150 kHz, for active power, reactive power and apparent power. The target uncertainty in the range of 10^{-3} was met. The new CMCs based on the new PTB standard, will support the research and the use of inductively coupled power transmission systems, the evaluation and further development of the various electrical components, as well as the evaluation of the measured values of the electromagnetic emissions in relation to the actual electrical power. Other metrology institutes will be able to expand their measurement capability in this power and frequency range by tracing them to this standard.

NPL, developed a new calibration facility for measuring the MF, which has extended the measuring range of magnetic induction in Europe, for the low frequency, from 20 μT at 100 kHz up to 100 μT at 150 kHz. The new facility was validated by conducting a successful inter-comparison between three project partners A measuring system for the MF gradient has been developed at SPEAG in the same frequency range.

Impact on relevant standards

The consortium disseminated the guide [16] to EURAMET Technical Committee Electricity and Magnetism (TC-EM), Sub Committee Power and Energy. The EURAMET TC-EM chair disseminated the guide to all the national TC-EM contacts. At least two positive feedbacks were received by the consortium.

IEA is the International Energy Agency. IEA IA-HEV Task 26 aimed to develop a greater global understanding of wireless power transfer systems and interoperability through a focused study of WPT technologies being developed in the participating countries. IEA Task 26 was contacted by CIRCE but Task 26 completed its job before the end of MICEV project. However, the chair of the task provided anyway interesting feedback to the work of the consortium with particular reference to BPG.

IEC CISPR D WG1 committee was contacted by RISE and the chair and secretary found the BPG interesting, so they have circulated it to their expert working group members.

SPEAG represented the consortium in the IEC TC 106 committee. In particular, SPEAG operated IEC TC 106 WG9 "Addressing methods for the assessment of WPT related to human exposures to electric, magnetic and electromagnetic fields", and with the group drafting new standard PT63184 "Human exposure to electric and magnetic fields from wireless power transfer systems". SPEAG provided input in the discussion about new normative document PT63184. WP9 of IEC 106 added a new methodology based on gradient measurements to reduce the exposure overestimation. SPEAG was very active in developing this method and has also developed corresponding instrumentations as part of the MICEV project. SPEAG provided input to the committee working group and presented the BPG to the chair of the IEC TC106 WG on PT63184.

CEI TC 106 is the Italian committee mirror of IEC TC 106, which provided an important feedback and will consider the BPG for the preparation of one part of new Italian national guidelines concerning human exposure to WPT systems. Moreover, CEI TC 106 included INRIM in the Working Group on WPT for the preparation of a first technical report on this subject, preliminary to guidelines.

Longer-term economic, social and environmental impacts

The EU is committed to reducing greenhouse gas emissions by 2050 to a level which is 80–95 % below 1990 levels. In the 2050 Energy Roadmap a key goal amongst others will include "no more conventionally-fuelled cars in cities". Actions aimed at increasing the use of electric transport will directly contribute to these objectives and hence this project is centred on EU political strategies concerning transport.

According to "Research and Markets" report 2020 on "Global Electric Vehicle Charging Stations Market Report 2020: 2018-2019 Value and Volume, 2020 Estimates and Forecast to 2027", edited by Meticulous Market Research Pvt. Ltd., the electric vehicle charging stations market is expected to grow at a CAGR of 39.8% from 2020 to 2027 to reach $29.7 billion by 2027; whereas, in terms of volume, the market is expected to grow at a CAGR of 31.8% from 2020 to 2027 to reach 15,025.5 thousand units by 2027.

Based on the charging station type, plug-in charging stations segment is estimated to account for the largest share of the overall electric vehicle charging stations market in 2020. The growth in this segment is mainly driven by the government and automakers initiatives to expand the level 3 plug-in charging station infrastructure. However, the wireless charging stations market is expected to witness rapid growth during the forecast period. The rapid growth of this segment is primarily attributed to the automaker's initiatives for the development of wireless charging stations technology and government funding for the installation of the wireless charging stations.

In the future, payment systems will be widely spread in inductive public charging systems and stations. Therefore, it must be clear exactly what the consumer pays for, in terms of the transmitted or received energy. This project will facilitate the implementation of wireless charging for Evs on public roads and highways, thus providing public assurance on the safety and the cost of using EV vehicles and inductive charging technologies.

List of publications

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[3.] M. Zucca ; M. Modarres ; U. Pogliano ; D. Serazio, "1 kV Wideband Voltage Transducer, a Novel Method for Calibration and a Voltage Measurement Chain," IEEE Transactions on Instrumentation and Measurement, vol. 69, no. 4, pp. 1753-1764, April 2020, doi: 10.1109/TIM.2019.2912589. Link

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[5.] K. Stoyka, R. A. Pessinatti Ohashi, N. Femia, "Behavioral Switching Loss Modeling of Inverter Modules", Proc. 15th International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design (SMACD), 4 pages, Prague, Czech Republic, 2-5 July 2018, DOI 10.1109/SMACD.2018.8434850, Link

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[9.] G. Di Capua, A. Maffucci,K. Stoyka, G. Di Mambro, S. Ventre, V. Cirimele, F. Freschi, F. Villone, N. Femia, Nicola, "Analysis of Dynamic Wireless Power Transfer Systems Based on Behavioral Modeling of Mutual Inductance" Sustainability 13, no. 5: 2556, 2021, Link

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[11.] I. Liorni, T. Lisewski, M. H. Capstick, S. Kuehn, E. Neufeld and N. Kuster, "Novel Method and Procedure for Evaluating Compliance of Sources With Strong Gradient Magnetic Fields Such as Wireless Power Transfer Systems," in IEEE Transactions on Electromagnetic Compatibility, vol. 62, no. 4, pp. 1323-1332, Aug. 2020, doi: 10.1109/TEMC.2019.2924519, Link

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This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:		1st September 2017, duration 36 months + 6 months extension = 42 months	
Coordinator: Mauro Zucca, INRIM Project website address: https://www.micev.eu/		Tel: +390113919827	E-mail: m.zucca@inrim.it
Internal Funded Partners: 1 INRIM, Italy 2 NPL, United Kingdom 3 PTB, Germany 4 RISE, Sweden	External Funded Partners: 5 Aalto, Finland 6 CIRCE, Spain 7 CNRS, France 8 POLITO, Italy 9 TU Delft, Netherlands 10 TÜV-SÜD PS, Germany 11 UNICAS, Italy 12 UNISA, Italy	Unfunded Partners: 13 SPEAG, Switzerland	
RMG: -			