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The Romanian wireless power transfer network

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Abstract. Wireless power transfer (WPT) is a disruptive technology because it gives up the technology of wire transmission, the only one used in electrical and electronic engineering so far. Although made known since the end of the 19th century through the inventions of Nikola Tesla, WPT became applicable in practice only in the 80s of the 20th century with the progress of power - and micro-electronics. The field is now being studied and applied worldwide for transferred power from a few W up to hundreds of kW, as part of electric mobility and beyond. The fact that numerous researches and applications of the WPT have already been carried out in Romania led to the need for a better collaboration and knowledge which resulted in the creation of the national network of interests - WPT Romanian Network (WPT Rom Net) - presented in this paper.

Keywords: launching Romanian WPT network, goal and objectives, founding members, research field, main applications

1. Introduction

The contactless transmission of electricity or Wireless Power Transfer (WPT) represents a disruptive technology like other historical transitions: from animal to mechanical traction, from vacuum tube to transistor, from incandescent to LED lamp or from film to digital photography a.s.o. Wireless Power Transfer is now recognized as one of the 'Hottest Research Areas in Electrical Engineering' [1] due both to the advantages and practical applications, and to the scientific instruments involved in its development.
This statement best summarizes the particular pursuits in the field. By investigating the IEEE database in this field, it can be noted that during the period 2010-2019 alone [2] over 4500 papers with an annual growth rate (CAGR) of 140% have been published in the world, and there are over 5000 papers, plus over 1400 patents in

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the Web of Science database (former ISI Thomson Reuters Web of Science). These figures are only exceeded by publications in the field of microelectronics. In the IEEEXplore database there are almost 40 papers in the field belonging to Romanian authors, published after 2012 [3].
Indeed, there are many important advantages resulting from the absence of contacts and their wear, the ease of use in aggressive or explosive environments, in air or in water (even salt water), and applications in the most various fields such as: medical, agrarian, military, robotics, electric mobility, etc. The transmission of energy is carried out in the near field (magnetic or electric) at small and medium distances, with an output comparable to the transmission through galvanic contact and with the possibility of simultaneous transmission of energy and data [4]. Due to the different operating principle, both the theoretical bases and the simulation of circuits and fields through numerical methods are essential to the research, evaluation and practical achievement of these systems in order to ensure interoperability, efficiency and the transferred power [2].
The structure and requirements of these systems are complicated when high energy transmission is required, for example for charging electric vehicle (EV) batteries in static or dynamic charging systems. In this case, the limitation of human exposure to the magnetic stray fields [5] is also an aspect requiring important shielding measures.
At present, an important argument for the application of the contactless power transmission is represented by the autonomous driving systems in EV's on highways and in traffic congestion in urban areas.

2. How it came about and what is WPT Rom Net

Considering the perspectives of using the contactless transmission of electricity in the most various technical and scientific applications, the Romanian pursuits in the field (publications, bachelor's degree theses, doctoral theses, etc.), the possibility of adding this field in the curricula for the master's degree, at the initiative of ASTR (Technical Sciences Academy of Romania), Craiova Branch [6] and ACER (Romanian EMC Association) [7], a proposal was disseminated in 2019 to create a network of interest in the field which will become in time a professional cluster to increase the international visibility and access funding sources from the country and from the EU.
Following the discussions, certain ideas and proposals for pursuits have emerged, which were adopted and can be further found, along with the list of participants who have now joined WPT Rom Net.
The public presentation of the goal and objectives of WPT Rom Net was made in important national conferences (MPS 2019, EV 2019, ASMES 2019).
In the end, WPT Rom Net is a voluntary association without legal personality of individuals and legal persons from Romania and from abroad, interested in the research, development and practical implementation of contactless electrical energy transmission.

For the beginning, the activity of the associated members consists in a better knowledge and mutual information about certain achievements, publications, ongoing projects or proposals of jointly achieved projects, to which a Q&A section will be added, with the creation of the Network web page.

2.1. Founding Members of WPT Rom Net

ASTR, Craiova Branch
ACER (Romanian EMC Association)
AVER , Romania
National Institute for R&D in Electrical Engineering ICMET, Craiova
National Institute for R&D in Electrical Engineering ICPE-CA, București
National R&D Institute For Cryogenic And Isotopic Technologies, Rm Valcea
Icpe SA, Bucuresti
University of Craiova (Electrical Engineering Faculty, Automation Faculty,
Mechanical Engineering Faculty)
University of Pitesti, CCIA (Research Center «Automotive Engineering»)
Politechnica University Bucuresti (Electrical Engineering Faculty, Electronic & Telecommunication Faculty)
Technical Military Academy, Bucuresti
MB Naval Academy, Constanta
Indaeltrac SRL, Craiova
Inda SRL, Craiova
Nextrom SRL, Craiova
Tehnoind Electric SRL, Craiova
Terraflux Control Ltd. Iasi
Technical University Cluj-Napoca (Electrical Engineering Faculty)
University " Transilvania"Brasov (Electrical Engineering Faculty)
University "1 Decembrie 1918" Alba Iulia

Discussions are currently being held with entities from abroad in order to join WPT Rom Net.

2.2. The main research activities and practical applications specific to the WPT field

In order to gain a better knowledge, the proposals presented below are general in nature and do not necessarily represent actions that will take place in the WPT Rom Net.
The activity of the associated members consists in a better knowledge and mutual information about certain achievements, publications, ongoing projects or proposals of jointly achieved projects
- Research - development activities

Circuit Theory & Field Simulation – Coupling Topologies – Loose & Tight Coupling – Coupler Coils Optimization – Metamaterials – Interoperability - Micro & Power Electronics – Global & Partial Efficiency – EMC – Environmental and Health Effects – Data Communication and Positioning Methods – Foreign Object Detection – Standardization – Models & Prototypes – Testing & Certification Infrastructure

-The main applications of the WPT are extremely numerous and often irreplaceable by classical technologies

Light & Heavy BEV (Battery EV) & HEV (Hybrid) Road vehicles – Light Urban Vehicle (catenary free) – eMicromobility (scooters & pedelecs) – Plant transport equipment – Brushless Synchron Motors – UAVs (Unmanned Aerial Vehicles/Drone) – AUVs (Autonomous Underwater Vehicle/Robot) – Contact free connectors for aggressive environments – power & data transmission for robot arms – Rotating Radar platforms – Consumer Applications – lighting equipment for explosive environments – Energy Harvesting – Wearables – Biomedical implants and medical devices.
The first steps to increase the visibility of Romanian researches and achievements in the field have already been made through:
-the publication in English, in September 2018, of the first volume of scientific communications entitled "Contactless Power Transfer Research & Development in Romania" as a special issue of the "Annals of University of Craiova - Electrical Engineering Series" [8];
-the achievement by ACER [7] in collaboration with INDA-Eltrac SRL [9] of the first wireless charging system in Romania for the electric vehicle Dacia electron, and this achievement received the ASTR "Stefan Grosu" award in 2019 [10].
This vehicle based on the mechanical structure of Dacia Sandero was achieved by CCIA (the Research Center for the automotive industry) at the University of Pitesti with the support of Renault RTR Romania in 2016 and publicly presented at the EV Show 2017 [11].

The present state of the information necessary to be known when approaching the research and development of high power WPT systems in particular will be presented below.

3. European FP 7 Projects related to EV Charging Systems

The main engine of the WPT development is the battery charging system equipping the EVs / HEVs. That is why virtually all EU FP7 projects related to e-Mobility which have been developed since 2011 and which are mentioned below also refer to the wireless systems.

- **DERri** - Distributed Energy Resources Research Infrastructure with
- **WOLEVET** - *Wireless On-Line Electric Vehicle Energy Transfer*

- **FABRIC** - Feasibility Analysis of on-Road Charging Technologies
- **UNPLUGGED -** Inductive Charging for Electric Vehicles
- **FASTINCHARGE -** Innovative fast inductive charging solution for EVs
- **COTEVOS -** Concepts, capacities and Methods for Testing EV Systems and their Interoperability within the Smart Grids
- **ZeEUS -** Zero Emission Urban Bus System
- **FREVUE -** Freight Electric Vehicles in urban Europe**GREEN eMotion -** Interoperable and scalable technical solutions in connection e-Mobility
- **eCo-FEV** - Efficient Cooperative infrastructure for Fully Electric Vehicle
- **EM-SAFETY –** EM safety and Hazards Mitigation by proper EV Design

So far no entity from Romania has participated in such a project, mainly due to the low visibility of the achievements in Romania. As it results from the analysis of the published results, however, the results of these projects should not be overestimated. The progress made is remarkable, the involvement in the decarbonisation has become a priority for the transition to the electric transportation within the EU, as it results from the titles of the projects, but the solution of some theoretical and practical applied issues is going to be implemented in practice.

It should be noted that the electrification of public and urban freight transportation (currently almost 100% Diesel) is required by the EU Directive in traffic congestion in urban areas. Therefore the focal point of the ZeEUS [12] and FREVUE [13] projects developed during 2013 - 2018 analyzes in detail both the constructive solutions (plug-in hybrid, full electric, battery trolley buses), the fast/slow charging strategies (overnight, terminals or plug-in hybrid) and the charging systems (plug-in, wireless, overhead lines). In Germany, in Berlin and Braunschweig, wireless stationary charging systems have been successfully developed for buses of 200 kW transferred power [14].

A proof of interest for the WPT technology consists in the launching of the EURAMET MICEV project [15] entitled “Metrology for inductive charging of electric vehicles”, during 2017 - 2020, to define more precisely the efficiency and environmental problems of the WPT systems.

4. Overview of the WPT Standards

The most important standards mentioned below are the result of extensive international collaboration. The standards marked as CD (Committee Draft) are versions in the process of being finalized.

- IEC PAS 63095-Parts 1,2,3: Ed. 1.0, 2017 The Qi wireless power transfer system
- IEC 61980-1, Electric vehicle wireless power transfer (WPT) systems – Part 1: General requirements;
- IEC 61980 -2 Ed.1, (CD) Electric Vehicle Wireless Power Transfer (WPT) Systems – Part 2: Specific requirements for communication between electric road vehicle (EV) and

infrastructure with respect to wireless power transfer (WPT) systems;
- IEC 61980 - 3 Ed. 1, (CD) Electric Vehicle Wireless Power Transfer (WPT) Systems – Part 3: Specific requirements for the magnetic field wireless power transfer systems;
- ISO 19363:2017 Electrically propelled road vehicles — Magnetic field wireless power transfer — Safety and interoperability requirements;
- SAE J 2954: 2019 Wireless Charging of Electric and Plug-in Hybrid Vehicles
- SAE J2954/2 Heavy-Duty Wireless Power Transfer Overview - in preparation
It should be noted that the SAE standard [16] takes into account the whole set of problems that will ensure the industrialization of the WPT transmission systems in EVs, namely: interoperability, frequency band, electromagnetic compatibility, protection of living beings against the magnetic stray fields and last but not least the optimization of the inductive coupler design.

5. Working frequencies of the WPT systems

The general rule that governs any WPT system regardless of whether it is intended for data or power transfer is its non-conflicting co-existence with radio communication systems, which is why ITU's so-called ISM frequency band for industrial, scientific and medical equipment was established [17], covering fixed frequencies from 6.78, 13.56, 27 MHz, up to 2.4 GHz and above. Frequencies of this order of magnitude are used for magnetic resonance power transfer systems [18].
Instead, by international consensus, for the high power WPT, the 10 - 100 kHz non-ISM frequency band is used, namely:
1. 20 - 38 kHz for electric buses with charging powers of 100 – 300 kW;
2. 40 - 58 kHz for light EVs for charging powers of 3 - 22 kW;
3. 85 ± 0.5 % kHz adopted by consensus by SAE J 2954 for achieving the interoperability of the WPT systems
For the projects achieved so far in Romania, the frequency range 2 was mostly used, except for very low power systems (5 - 15 W). The transition to range 3 is going to be made for all subsequent projects.

6. Power ratings and working distances for the WPT systems

The transmitted power is defined as the power effectively transferred to the load [15]. The following power ratings for the WPT equipment are: WPT1 = 3.7 kW, WPT2 = 7.4 kW, WPT3 = 11 kW and WPT4 = 22 kW. The most applications that will be developed within the WPT Rom Net will probably be the low-power ones (5 - 150 W) used for power tools, scooters & pedelecs, laptops & tablets, medical work stations a.s.o.
Both IEC 61980 and SAE J2954 define the vertical distance over which the power has to be transferred with 85 % higher efficiency. This vertical distance is in

practice circa the ground clearance of a given EV. These classes are: Z1: 100 – 150, Z2: 140 – 210, Z3: 170 – 250 mm.
In the case of WPT systems for low power, vertical distances depend on the application and are usually between 3 and 15 mm.

7. Dosimetry and magnetic field exposure levels assessment

Beside the power level, the magnetic field (MF) emissions of the WPT system have a minimum for the perfect alignment of the coupler coils (zero offset) and increase with increasing offset. Instead of performing the MF measurements for perfect alignment, which is difficult to achieve in practice, ISO 19363 [19] and SAE J2954 [15] define a maximum permissible offset of ±75 mm (in the driving direction) respectively ±100 mm (perpendicular to the driving direction). Under these conditions, the limit of 27 μT allowed by ICNIRP [5] should not be exceeded.
An issue still unresolved is whether the value indicated above affects people who have a pacemaker; however, it will be taken into account that WPT systems have MF emissions in very limited areas around the vehicle (in the near field the magnetic component decreases proportionally by $1 / d^3$ and as a result they are considered localized sources of magnetic field [20].

8. WPT Rom Net next steps

WPT Rom Net intends to take the following actions for the next immediate period:
-Electing a network coordination committee;
-Creating a website (in Romanian and English) to ensure the visibility of the network, including an e-mail address; for the moment, on ACER website, an access point to the network's activity was created at http://www.acero.ro/wpt.html)
-Posting the partners' achievements on the website;
-Further publishing of "Special Issue on Wireless Power Transfer", in English, in the Annals of the University of Craiova, at 2 years' intervals;
-Initiating external contacts;
-Proposing dedicated workshops in important conferences in the country (ICATE, ATEE, OPTIM, MPS)
-Supporting local communities in creating opportunities for the practical application of the network's achievements

9. Conclusions

WPT Rom Net was publicly launched in 2019 as a voluntary association without legal personality of individuals and legal persons from Romania and from abroad, interested in the research, development and practical implementation of wireless electrical energy transmission The activity of the associated members consists in a better knowledge and mutual information about certain achievements, publications, ongoing projects or proposals of jointly achieved projects.

Being convinced that "the future will be wireless", a large number of universities, research institutes and companies in our country have become founding members of WPT Rom Net.
There is the conviction that WPT Rom Net will provide solutions for reducing the carbon footprint in traffic congestion in large urban areas for the generalization of the electric transportation and driverless technology.
The paper aims to draw the attention of local communities and potential investors to the applications and benefits of the wireless transmission of electricity in all human activities.

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