User-Project Proposal:

Use-Project Acronym	**WOLEVET**
User-Project Title	Wireless On-Line Electric Vehicle Energy Transfer
Main-scientific field	Energy Transfer
Specific-Discipline	Wireless Energy Exchange with Electric Vehicle Battery

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Position in Organization	PhD student in UNL

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Position in Organization	PhD student in UNL

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Activity type and legal status of Organization	Higher Education Institution
Position in Organization	PhD student in UNL

** Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)*

Date of submission	*27.01.2012*
Re-submission	*YES_______ 29.06.2012*
Proposed Host TA Facility	*TUS RDS*
Starting date (proposed)	*10.09.2012*

Summary of proposed research (about ½ page)

Prepare a ½ page summary describing the relevance and the scope of the proposed work, and the expected outcome(s)

This project is focused on the design and test of controlled charging of battery when Wireless Energy Transfer is included. An exchange of energy is planned between the AC grid, the battery and the contactless energy converter. The wireless energy transfer is defined as “On-line” because of the varying position of the energy receiver in relation to the energy transmitter. The changing position of the receiver in relation to the transmitter of energy corresponds to the “on-line”, i.e. charging during movement of the electric vehicle (EV) on the road. To experiment this movement the receiver of energy will vary its distance to the fixed charging station. If the experimental equipment succeed to prove the most efficient energy transfer conditions, that will facilitate the integration of EV in micro-grids, adding storage capacity (EV batteries) to the grid.

The existing hybrid energy system in TU Sofia allows for hosting distributed generation from renewable energy sources and it will be possible to combine the wirelessly transferred energy to the battery with that existing hybrid energy system available in TUS RDS. The proposal includes the control and management of the battery in the context of demand side optimization. The intention is to apply the existing knowledge for further development in the contactless energy transfer area, and in the micro grid environment, exchanging practical and scientific experience.

The technical task consists in the design and experimentation of a contactless energy transmitter/receiver in a power electronics infrastructure involving the available high frequency (HF) generator and receiver connected to energy storage system. The design of the future interactive smart on-line energy exchange with the EV battery will be discussed and experimented. The challenge is seen in an on-line bi-directional wireless energy interchange especially considering electric vehicles in movement. This bi-directionality, seen as storing energy in many batteries that are charging and discharging whenever necessary will permit constructing of a future smart grid including many vehicles in movement. The magnetic coupling is one part of the equipment that will be verified theoretically and tested in real power, at least one kilowatt. The battery charger control equipment will be the other experimented block in connection with the transferred energy regulation to the receiver side. The third part of the experiments is

the choice of the power inverter parameters. The main choices are the type of resonance and the switching frequencies of the inverter. The practical choice is made possible through the existence of several different high power inverters in the partner's laboratory in addition to the hybrid energy system.

State-of-the-Art (about 1 ½ page)

Describe in brief (in about 1½ pages) the current knowledge on the subject, citing recent relevant References. Identify any knowledge gaps and their relevance.

Starting from the times of Dr. Nikola Tesla the electromagnetic resonance is applied to transfer wirelessly energy at a distance. The electric/hybrid (EV and HEV) car is becoming necessity in our times due to the foreseen lack of oil, environment pollution problems and growing prices of classical energy production. The batteries of the new vehicles will soon require a large number of charging in different places and moments. It is an urgent need and the knowledge about the resonant contactless energy transfer became very important. The study of the Series Loaded Series Resonant converter places it as suitable for the contactless energy transfer [2]. There are other possible resonant configurations too. The group of Prof John Boys and later Grant Covic from Auckland, New Zealand is working on the subject for long time and holds many patents [3].

The Series Loaded Series Resonant (SLSR) power converter is becoming again popular after it appeared in the late 60-s and early 70-s in the works of F. Schwarz and other authors [2]. This happened first because of its Zero Voltage Switching (ZVS) characteristics, popular since early 90-s and now it happens because of the growing necessity for contactless power transfer applications. The operation of SLSR power converter is already analyzed in many articles, e.g. in [2] but to obtain a rapid reaction of this circuit, without exceeding or not reaching the required values at the output, remains a problem. The existence of stored energy in the resonant reactance elements (inductance and capacitance) makes the direct control of the power switches quite difficult, especially when the circuit elements are not ideal (contactless energy transfer). Many articles are published, aimed at resonant converters control. Those works usually include calculation of normalized phase-plane trajectory as in [4]. The suggested calculations are complex and even more complex calculation block (implemented as FPGA) is shown by A. Moradewicz et al. in [7].

All the known methods of calculation are not reacting immediately to the energy demand of the resonant tank as they measure and control the resonant current. The future faster response control circuits that pays attention not exclusively to the resonant current but more to the resonant capacitor voltage is presented in [10] and the next publications of S. Valtchev and his team.

The instant energy control as described in the referred articles is allowing safer operation of the transmitter of energy, but there is still a lot to do for the bi-directional energy transfer, where the charged vehicle is supposed to be capable to give back energy to the common grid. An inverter of this sort will be heavier and more sophisticated than the simple rectifiers or boost (unidirectional) converters that the battery chargers have now. The control of the bi-directional energy exchange is expected to be similar to the already known solutions but will be necessary to involve a faster interchange of information. This kind of new electric energy grid will necessitate a new information grid, similar to the mobile network although much faster.

One of the main new functions will be to recognize and authorize the car to receive or to deliver energy passing near the transmitter cells and to continue this interchange with the next cell. This problem is similar to the requirements that other smart grid versions will ask from the information technology. The switching speed of the energy management infrastructure is also a difficult restriction task if the efficiency is to be kept at acceptable level. We need to take into account that the simple transformer invented in 19th century still remains the most efficient electric equipment, although some good results of wireless energy transfer were achieved by S. Valtchev in 1996: 97% of efficiency for 17 kW transfer. This efficiency was achieved by the so called "rotary transformer" converter with short distance transmitter/receiver and for the on-line charger is still far from being achieved.

As referred in [1], the unit sales of wireless EV chargers in North America will reach about 10,000 in 2014 and increase to more than 132,000 units by the end of the decade. The US company Evatran, which is targeting home users, announced charging devices compatible with both Nissan Leaf BEV and Chevrolet

Volt PHEV and converters adaptable for the Tesla Roadster and older Toyota RAV4 EVs. The company installed last month its Plugless Power unit at Google's headquarters, where low-speed EVs are used to take workers and visitors around.

Fig.1. Differently mounted wireless chargers [1]

Meanwhile, the WiTricity Corp. based in Watertown, Mass. is banking on its relationships with larger companies (and MIT of course) to take a leadership position in the industry. The company last year started working with Delphi Automotive, General Motors' former auto parts division, on developing a wireless electric-vehicle charging system that uses magnetic resonance between a floor-mounted charging source and a vehicle. The different positioning of the charger in public and private places is shown in Fig.1.

As usually all the publicity in USA comes for marketing of products that are still in development. Quite a long time S. Valtchev and other colleagues from Coimbra university are trying to buy the announced products and still no one company sold the charger. This does not mean that the above mentioned companies will not produce the chargers. What is said here signifies that EU has to take the challenge.

Inductively coupled power transfer is based on the principle of electromagnetic induction at high frequency. The on-board receiver and the ground based charging station in Fig.2 show how the AC power is supplied to the EV through inductive energy transfer, i.e. magnetic induction coupling. A solution for the inductive charger of a bus (Daejeon, Rep. Korea) is shown in Figure 3. A soft-switching parallel converter is used for this application as this solution is not sensitive to the parasitic inductance of the connecting cables and the transformer. Although the conductive charger has a lot of definitive advantages such as simplicity and high efficiency, the inductive charger is safer and easy to use under any weather conditions. The main drawbacks of the contactless charger are the high investment cost and the inevitable higher losses.

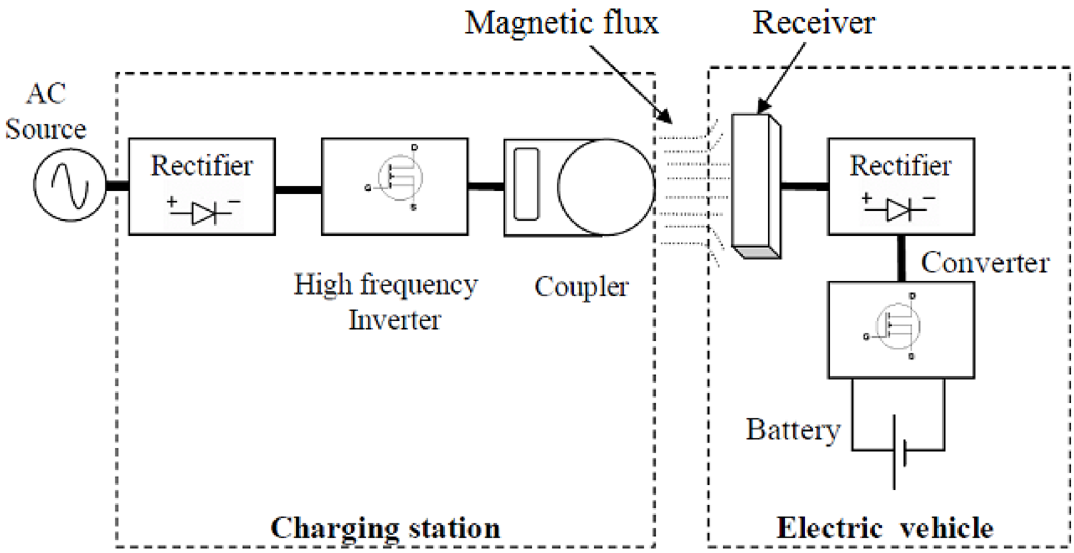

Fig.2. The main blocks of the inductive charger [5]

Summarizing, the basic blocks are shown in Fig.2. The AC supply voltage is rectified and converted to a high frequency AC (tens or hundreds of 100kHz) within the charger station. Based on the resonant processes this high frequency power is transferred to the EV side by induction. Finally the receiver converts the high frequency AC power into a DC power for the battery charging.

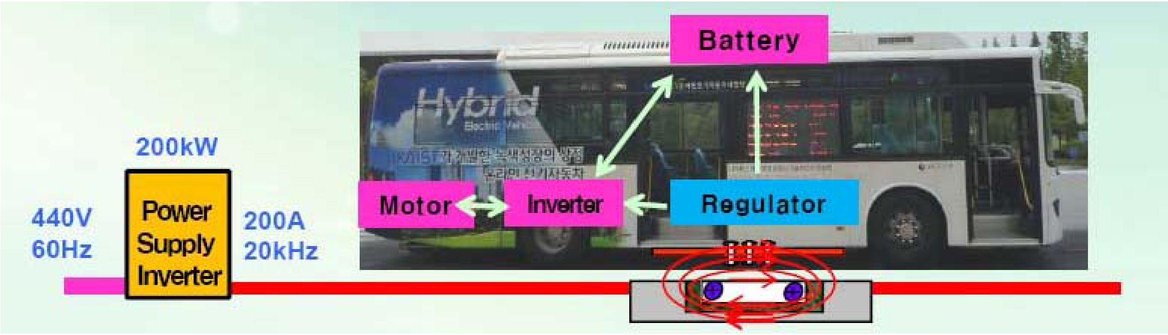

Fig.3. The bus charging station from 440V 3 phase line in KAIST, Rep. Korea, [6] and [10]

Wireless On-Line Energy Exchange will permit to apply more efficiently the energy, in combination with all the other proposed smart grid ideas. In general, involving the electric vehicles in an on-line energy and information exchange will allow to achieve several main goals:

- Optimization of the battery charging, monitoring of the car battery from the central brain of the micro grid, improving the total quality of the energy by storing energy in the batteries;
- Improvement of efficiency of the EV as the necessary energy will be possible to be taken from the nearby source of the grid. In this case the battery size will be drastically reduced. This is very important as the price of a propulsion battery is now roughly 80% of the EV price;
- The environment requirements will be easier to meet as the smaller battery means fewer cells and hence lower pollution;
- Some other possible achievements as the “peak shaving” will be probably met;

The main problem of the inductively coupled power transfer remains the magnetic coupling between the “charging station” and the “electric vehicle” as Fig.2 shows. The “converter” that charges the battery is another problematic block since the batteries require special attention during their charging. The third problematic block that is to be well designed is the “high frequency inverter”. It must be a soft-switching (resonant) converter for many reasons including to avoid the electromagnetic interference. The problems to solve through this project with the available and planned equipment may be defined as:

1. The optimized charging of the battery when the wireless transfer of energy is involved is difficult: the energy source does not have stabilized parameters, to monitor the battery from the distance and to include that battery in the micro grid is a problem.
2. The best construction of inductors that guarantees a good magnetic coupling and best efficiency is still not finalized. It will be necessary to wind several differently shaped high frequency inductors probably of Litz wire.
3. The inverter loading: parallel or series, the resonant frequency, the switching frequency, the characteristic impedance, all the parameters of the “high frequency inverter” are not decided yet and the fight for every one percent of efficiency continues.

References

[1] http://www.autoobserver.com/2011/04/siemens-enters-fragmented-wireless-charging-market.html

[2] Valtchev, S., J. B. Klaassens, *Efficient Resonant Power Conversion*, IEEE Trans. IE, vol.37, No.6, pp.490–495, 1990.

[3] Wang, C.S., O.H. Stielau, and G.A. Covic, *Design Considerations for a Contactless Electric Vehicle Battery Charger*, IEEE Trans. on Industr. Electronics, vol. 52, no. 5, pp.1308-1314, 2005.

[4] Rossetto, L., *A Simple Control Technique for Series Resonant Converters*, IEEE Trans. PE, vol.11, no.4, pp.554-560, 1996.

[5] http://www.d-incert.nl/wp-content/uploads/2010/12/Pavol-Bauer-Groningen-Presentatie.pdf

[6] Sungwoo Lee; Jin Huh; Changbyung Park; Nam-Sup Choi; Gyu-Hyeoung Cho; Chun-Taek Rim; *On-Line Electric Vehicle using inductive power transfer system*, 2010 IEEE Energy Conversion Congress and Exposition (ECCE).

[7] Moradewicz, A., M. Kazmierkowski, *FPGA Based Control of Series Resonant Converter for Contactless Power Supply*, IEEE International Symposium on Industrial Electronics ISIE, Conf. Proc., pp.245-250, 2008.

[8] Dias, Joao Victor Pinon Pereira; Kim, Hyungchul; Jang, Donguk; *Computer model for railway inductive power supply using **Valtchev** model*, 2011 International Conference on Electrical Machines and Systems (ICEMS), DOI: 10.1109/ICEMS.2011.6073510.

[9] http://www.youtube.com/watch?feature=player_embedded&v=ksCgpqMgcZI.

[10] Mi-Hyun Park; Eun-Gyeong Shin; Heung-Reol Lee; In-Soo Suh, *Dynamic model and control algorithm of HVAC system for OLEV® application*, 2010 International Conference on Control Automation and Systems (ICCAS).

[11] Valtchev, S., K. Brandisky, B. Borges, J. B. Klaassens, *Resonant Contactless Energy Transfer with Improved Efficiency*, IEEE Transactions on Power Electronics, vol. 24, No. 3, pp. 685–699, 2009.

Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest (2-3 pages)

Provide a detailed description of the objectives of the proposed activity, the way these objectives will be fulfilled through the proposed work, as well as indications on the expected outcome and the fundamental scientific and technical value and interest of the proposal. Specify the type of TA infrastructure (distributed generation simulator; domotic house; etc.) and the test setup. With the understanding that these aspects will be discussed with the TA infrastructure after approval of the proposal and specified in the Agreement to be signed between the TA infrastructure and the User team, indicate the number of tests to be carried out and their sequence, the response quantities to be measured through the instrumentation, etc. Describe any special requirements for equipment, standards, safety measures, etc. Point out any shortcomings, uncertainties and risks for the fulfillment of the project objectives, as well as the means to mitigate relevant risks.

Objectives and expected outcome:

The objectives of the proposal are to include a wireless energy transfer into the existing hybrid experimental system in TU Sofia. The charging of a real size traction accumulator battery by energy transmitted wirelessly through a high frequency inverter will be done bi-directionally in the way to charge the battery from the grid, from the photovoltaic source or through the magnetic induction and to discharge back the battery into the AC grid. The battery charge controller and the high frequency inverters to be experimented are available or will be prepared for the experiments. The main problems to be investigated:

1. Applying the existing equipment, to optimize the battery charging process, monitoring the battery from the point of view of the available micro grid, and to experiment the battery charging from wireless energy.
2. To experiment several inductor constructions that are expected to have good magnetic coupling applying the previous knowledge and to prove the most efficient coupling.

3. To experiment several resonant and switching frequencies of the inverters that are available or possible to modify having as a main goal the efficiency of the energy transfer. The rectifier on the receiver side will be varied depending on the frequency to be experimented. The equipment is either available or the team of S. Valtchev will supply.

Case study:

- Preparing a design and construction of the magnetic coupler for contactless charging at different distances between the transmitter winding and the receiver winding
- Preparing for exchanging the types of inverters (applied as transmitters of energy) among the available high power high frequency inverters in TU Sofia
- Preparing the rectifier and the regulator of the battery charging
- Preparing the necessary measuring equipment
- Executing the tests on the several different configurations
- Drawing conclusions about efficiency and the best possible regimes

The system configuration

Having in mind that the great part of the required equipment is available to the TU Sofia team, the user of DERri infrastructure has to bring mostly the knowledge and almost no equipment. Some small exceptions are the available windings, rectifiers etc. The experimentation is expected to be prepared by TU Sofia implementing a smart energy system based on the available installation, to prove by practical measurements the inclusion of the wireless charger into a hybrid energy system. For this we propose the realisation of the following new circuit involving also the adapted and existing equipment:

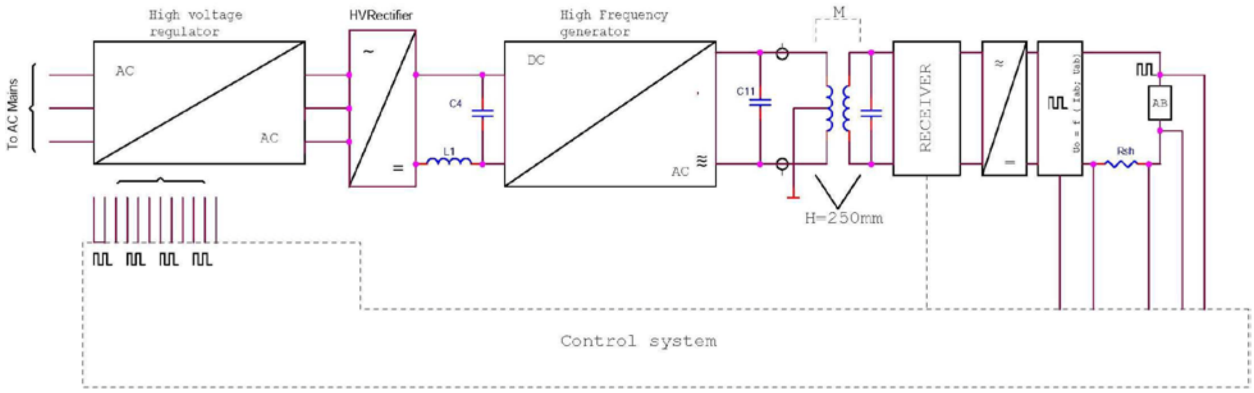

Fig.4. Proposed circuit for the wireless energy transfer

The block AB is the rechargeable Accumulator Battery available in the Power Electronics Laboratory of TU Sofia as part of the Hybrid power system. The energy will be taken from the AC mains by the “high voltage regulator”. After this block the energy follows to the high voltage rectifier which supplies the necessary high voltage, after filtering to the block of the high frequency generator. This functional block is the above mentioned inverter that delivers the energy to the transmitting resonant loop. The inverter may not be only one as the laboratory possesses various inverters of the at least one kilowatt power that generate at 200 kHz, 440 kHz, etc. Those inverters are used now for induction heating technological processes. The distance between the transmitter and receiver coils is marked as 250 mm but it is not fixed yet, as was already mentioned above. It will be part of the experiments to change that distance. The secondary resonant loop is connected to the “receiver” block which involves all the necessary matching circuits that depend on the type of resonance implemented. The rectifier is another block that will be exchangeable as the different operational frequencies have different requirements. The block marked with the symbol of a pulse train is involved in the feedback and “control system” block is taking care for the correct charging of the battery. The main hybrid system equipment already existing in the lab will be the basis of the experiments.

Technical aspects and value:
There is no global solution but practical “step-by-step” movements to achieve a better cooperation between the electric vehicles and their batteries with the grid. It is necessary to make our first small steps in the technical aspects of the wireless energy transfer practical implementation.
We see the following technical aspects, that will result in added value:

- Efficiency measurements that will show the correlation between the resonant loops construction and variation in distance, keeping the best efficiency
- The battery management, keeping the charging process as healthy as possible
- The exchange of the inverters, the variation of the operational frequency, the different rectifiers will be tested in order to make conclusions about the simplest and most efficient energy transfer.
- The control of the resonant inverters, the topologies and the electromagnetic coupling was part of the user team activities since long time as seen from the published works. Now it will be possible to join the knowledge to the available equipment in TU Sofia.
- By this cooperation it is expected to present scientific and technical publications and to implement interesting solutions in practice

The next global field of research will be:

1. To develop the scale of parameters of inverters and proper “antennae” in the frame of the requirements that we expect to gradually increase
2. To include many controllable consumers and renewable energy producer expected to be part of the information and energy integration in the “smart grids”.
3. To create the models for simulation of “smart grids devices” with many small consumers / generators including wireless charger integrating

In fact, the proposal will be useful for the both: wireless energy transfer technical solutions and for the grid concept development.

Originality and Innovation of proposed research – Broader Impact (1-2 pages)

Demonstrate the originality and innovation of the proposed work and the impact the expected results will have on current and future research or practice, public safety, European standardization, competitiveness, integration and cohesion and on sustainable growth.

The wireless interchange of energy and interchange of information concerning the energy aspects, as much as possible and permitted is a very recent idea and some of the involved technology is possessed partly by the user team. The induction heating technology that is part of the TU Sofia works is close to that area of knowledge too. The induction heating is not new but to apply the induction heating equipment in the energy transfer was not done yet. The experiments that may be executed by the available equipment will give knowledge to both sides in the more efficient contactless energy transfer area that is really new.

We would like to have a wider cooperation to make more rational the use of electric vehicles, reducing the size of the batteries once a wider and smarter grid permits to have on-line energy supply, reducing the pollution, making better the quality and the efficiency of the grid.

The contribution of the project we see in the future decisions made upon concluding the efficiency measurements. The more efficient energy transfer will create the possibilities for the inclusion of the wireless charging of the EV batteries.

The optimization models and techniques are expected as a future impact of the project once the scientific, technical and technology problems are discussed during the cooperation. Starting from a smaller although still unsolved energy transfer problems we would be capable to integrate in the future energy system of Europe the installations with wireless energy transfer with bi-directional flux of energy too.

The contribution of the project we see in a “system” point of view: the smart grids will help the future generations to live in a better and “greener” world.

The optimization models and techniques are seen as a future development of the project once the scientific, technical and technology problems are discussed in this project. Starting from a smaller size models (not sufficiently optimized now) we would be capable to integrate the energy system with the wireless energy transfer involving bi-directional flux of energy.

Proposed Host TA Infrastructure/Installation – Justification (about one page)

Specify the type of TA infrastructure (e.g. distributed generation simulator; domotic house; etc.) and if possible which one of the 13 TA Infrastructures in DERri may better serve the scope of the proposed research. Justifications should be provided on the grounds of the test set-up, testing method, equipment, past experience in relevant subject, etc. State whether the TA User team intends to deliver to the premises of the TA Infrastructure parts or components to be tested at the TA User’s expense and responsibility, or to cover the whole or part of the construction/adaptation cost of the specimens to be tested.

After an analysis of DERri partners, we see the possible cooperation with TU Sofia because of the existing battery charging installation included in a hybrid micro grid system and various induction heating equipment of relatively high power. This is the reason to apply some ideas for Wireless On-Line Energy Exchange from our part and we expect a good further cooperation.
TUS-RDS (Bulgaria) – Possibility for cooperation between PEL, RES and ACSL laboratories.

Synergy with ongoing research (about ½ page) –

Provide information on any concurrent research project with the same or similar subject with the one proposed. Describe the synergy (if any) that will be sought between the existing and the proposed project.

Our team is one of the basic developers of this technology and as an example it is possible to mention the cooperation in PhD students’ and MSc students’ teaching between our group and the Institute of Systems and Robotics in Coimbra, Portugal. In the same time we are in the nucleus of the consortium around Prof. Szumanowski from the Warsaw Polytechnics University and Prof. Sun from Beijing Institute of Technology involving also other specialists in electric vehicles from Aachen in Germany, Torino in Italy, Madrid in Spain, etc. Having in mind the whole world, it must be said that Korean Advanced Institute of Science and Technology from the Rep. Of Korea, many institutions from USA and other world players are making new projects and have many millions of investment, public and private. At the conference PCEEE, “Portuguese Conference for an Energy Efficient Economy”, during the special day of Electric Mobility, http://pceee2012.isr.uc.pt/pceee/Evento_Especial.html, tens of different electric vehicles were presented, test-driven by the participants and EV propulsion batteries problems were discussed. It is clear that EU is interested but the investment is still lower than other players can afford. For example, the space located energy systems not only exist as idea. Already contracts for space energy are signed in USA. In 2009 already, the US Corporation Solaren signed with the California Energy Company a contract to supply 200 MW of electric power produced in space from the beginning of 2016. This energy should be transferred wirelessly to the Earth surface. Some colleagues applied for FP7 EU projects aiming EV battery charging but it is not known if the projects will be approved. The team of S. Valtchev has an internal project on wireless charging with some enterprises in Portugal and the Institute of Systems and Robotics.

Dissemination – Exploitation of results (about ½ page)

Describe the means through which the results to be obtained from the proposed project will be diffused and made broadly known.

The results from the experiments will be made known to the scientific world through the conferences in which the team of S. Valtchev participates or organizes: DoCEIS, INTELEC, Powereng, ISEV, etc. and through publications in scientific journals, e.g. IEEE Transactions on Power Electronics.

Time schedule (about ½ page)

Provide an indicative time-schedule for the proposed work and a target starting date.
Target stat date (D1): -to be agreed-(gatherings of 1 week each)

Activity/Month	***0***	***1***	***2***	***3***	***4***
State of the art	Done				
Agreement on tasks with partners		1 week			
Design of model		1 week			
Practical cooperation				1 week	1 week

Practical experimentation in the frame of 2 week 8 days starting in September 2012.

Description of the proposing team (as long as needed)

Give a short description of each member (organization and persons) of the proposing team including publications, experience in test campaigns and role in the proposed project.

Team Members

1. Stanimir Valtchev, Auxiliary Professor, Universidade Nova de Lisboa (UNL)
2. Elena Baikova, Assistant Professor, IP Setubal and a PhD student in UNL.
3. Luis Filipe Romba Jorge, engineer, Vocational Secondary school teacher, a PhD student in UNL.
4. Rui Alexandre Neves Medeiros, a PhD Student in UNL.

Stanimir S. Valtchev (IEEE: M'93, SM'08) was born in Lovetch, Bulgaria in 1951. He received his B.S., M.S. Degree from the Technical University (TU) of Sofia (awarded as the best of the year) and received his Doctor's Degree from Instituto Superior Tecnico (IST) in Lisbon, all in Electrical Engineering. He worked in the Institute for Medical Equipment / Sofia until 1977 when he was admitted as a Researcher in the TU (then VMEI – Sofia), initially in the Industrial Electronics Laboratory, then in the Manipulators and Robots Laboratory (also as Assistant Director of the Centre of Robotics). During 1987 and in the period 1991-1992 he was with the Laboratory for Power Electronics at the Delft University of Technology in the Netherlands, where he was appointed "Universitair Docent", i.e. Assistant Professor (1987). Since 1988 he was Assistant Professor in TU Sofia, Bulgaria, and taught several courses on Power Supply Equipment and Power Transistor Converters to graduate and post-graduate students. He was the Deputy Dean responsible for the international students of TU Sofia during 1990-1994. After 1980 he worked on high-frequency resonant power converters and published in numerous conferences and journals, receiving the IEEE Meritorious Paper Award in 1997. In 1994 he was invited in Portugal to lead a project of a new soft-transition power converter, and afterwards he has taught various subjects in different universities and has consulted various institutions in Portugal and in the Netherlands. He is currently Auxiliary Professor in the Universidade Nova de Lisboa, Portugal. His research interests include the power converters (esp. high-frequency, soft-switching and resonant), energy harvesting, contactless energy transfer, electric vehicles and batteries, bio-harvesting and biosensors, etc.

Students of S. Valtchev:

Elena Nikolaevna Baikova, born 1958, has a MSc Degree in Electrical Power Systems and Grids completed in 1981 with distinction in the Moscow Power Engineering Institute, MEI (duration 5.5 years). Granted the degree Master of Science in Electrical and Computer Engineering in December 1997 by decision of Incorvuz under Articles 1 and 5 of the UNESCO Convention. Granted the equivalence degree in Electrical Engineering and Computer 19/03/99 by order of the Scientific Council of the Instituto Superior Técnico, Technical University of Lisbon. Recognition of the Master's degree in Electrical and Computer Engineering from Universidade Nova de Lisboa in February 2009. Since September of 2009 is a PhD student in Electrical and Computer Engineering at the Faculty of Science and Technology, Universidade Nova de Lisboa. Since March 2000 is an assistant Professor in the Superior School of Technology of Setubal Polytechnic Institute.

Luis Filipe Romba Jorge, 61 years, PhD student, Bachelor of Electronic and Telecommunications from Instituto Superior de Engenharia de Lisboa, Degree in Electrical Engineering and Automation Systems from ISEL Instituto Superior de Engenharia de Lisboa, Master's degree in Renewable Energy - Electric Conversion and Sustainable Development from the Faculty of Science and Technology, Universidade Nova de Lisboa. Professional activities start from occupation as technician in radio, radar and navigation equipments in the Portuguese Air Force for seven years. There followed a long period, nearly thirty years, in Xerox Portugal where developed several activities related to the technical and marketing having completed this period as a National Technical Specialist and Trainer. In the last six years have been a teacher in electricity and electronics in vocational education, now in the Institute of Technical Education, in Lisbon, Portugal.

R**ui Alexandre Neves Medeiros,** born in 1986, PhD student of Electrical and Computer Engineering at the Faculty of Science and Technology, Universidade Nova de Lisboa. Specialization in Energy. MSc finished in 2011 in Electrical Engineering and Computers. The main interests are the wireless transmission of energy, power converters, energy storage devices and electric vehicles.

PUBLICATIONS:

[1] Valtchev, S., J. B. Klaassens, *Efficient Resonant Power Conversion*, IEEE Trans. IE, vol.37, No.6, pp.490–495, 1990.

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