Topic A

High-efficiency Wireless Charging System for Electric Vehicles and Other Applications

Vision

- Increase the wireless charging efficiency for electric vehicles;
- Reduce the overall cost and space of the wireless charging system;
- Achieve highly efficient and safe wireless charging across the large air gap between the charging pad and the vehicle adapter;
- Incorporate practicality, potential manufacturability, and affordability into the competition assessment process;
- Improve engineering education and foster practical learning through the development of innovative team-based engineering solutions to complex technical problems;
- Increase the public awareness of advanced electric vehicle technology.

Goals

Construct a wireless charging system that will:

- Allow wireless charging with superior efficiency for the electric vehicle battery over a certain gap and sliding distance;
- Reduce the overall manufacturing cost;
- Minimize the size and weight of pad and controller;
- Minimize cooling requirements.

Background

The past decade has witnessed a surge in the use of wireless power transfer (WPT) in various electronic devices (laptops, cell phones, robots, PDAs, etc). As a consequence, the potential of the wireless technology has emerged in higher-power applications, e.g., battery chargers for electric automobile systems. Plug and unplug an outdoor high power connector can be a safety concern because of weather conditions and insulation wear Wireless chargers make charging more convenient for the customers. This is especially useful in harsh environments. The U.S Department of Energy has been sponsoring all major research institutes and vehicle suppliers to push the wireless charger to reach marketability for several years. It is expected to see wireless chargers used in the electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) in the near future.

The main goal of Topic A is to develop high-efficiency wireless chargers for electric vehicles and other applications. Currently, resonant topology has been widely used in most wireless charging systems with the wall-to-battery efficiency of less than 90%. Increment of the gapping and sliding distance between coils will significantly decrease the system efficiency and the power capability. For most of the conductive chargers, 94% wall-to-battery efficiency has already been realized. To compete with the conductive charging system and increase the acceptance of the wireless chargers, a high-efficiency wireless charger insensitive to the gapping and sliding distance is a must.

The idea of low power wireless charging has been around for a while, especially for consumer electronics such as laptops, cell phones and toothbrushes. It is still a big challenge to wirelessly transfer a few kilowatts of power over an air gap of inches with high efficiency and safety. This high efficiency can be achieved through innovations in new circuit topologies, optimizations of circuit parameters, optimization of the passive components, and possible implementations of highly efficient wide bandgap (WBG) devices. WBG devices, such as Silicon Carbide (SiC) Metal Oxide Field Effect Transistors (MOSFET) and Gallium Nitride (GaN) Heterostructure Field Effect Transistor (HFET), are expected to have lower on-resistance, lower switching loss and higher junction temperature than their Silicon (Si) based counterparts. The lower power loss and higher junction temperature can bring in the size and cost reduction in the cooling system, whereas the higher switching frequency can result in smaller passive components. At this time, SiC MOSFETs from CREE and GaN HFET from EPC/Transphom are already available in the market. For the Topic A competition, all the teams are encouraged to use active WBG devices in their circuits, however this is not a must.

High-level System Description:

- The proposed wireless charger will be judged against a set of objectives, requirements and characteristics given below:

- The design concept should target a 500 W (continuous) wireless charging system;
- The wireless charger should be able to charge a 48 V battery pack;
- The gap between the vehicle body and the charging pad should be larger than 15 cm;
- Modular or scalable circuit topologies are highly encouraged;
- Utilizations of WBG devices are encouraged, however not a must;
- System switching frequency is not limited; however teams need to evaluate the impact of radiation on human and vehicle bodies;
- The designed charger should adapt to the universal input, i.e., 85 VAC~240 VAC;

Evaluation criteria will mainly include system efficiency, power density and circuit scalability. Competition teams are encouraged to adopt WBG devices in innovative circuit topologies to achieve higher efficiency and size reduction.

Detailed Specifications and Requirements:

(1) Manufacturing cost in high-volume production: less than $100; a cost analysis is required for the final report using the price information on http://www.digikey.com/

(2) Complete coil size: less than 500 mm*500 mm;

(3) Complete power electronics size and weight: less than 1 liter and 1 kg;

(4) Input voltage: single phase universal ac input, 50 Hz~60 Hz;

(5) Output voltage range: 30 V~60 V; nominal voltage is 48 V;

(6) Output power capability: able to charge the battery with 500 W at 36 V~50 V. When battery voltage is lower than 30 V or higher than 50 V, the system will provide 400 W charging power;

(7) Input current total harmonic distortion (THD): less than 5% @ 500 W;

(8) Input power factor: >0.95 @ 500 W;

(9) Overall wall-to-battery power efficiency: higher than 92% @ 500 W and higher than 90% @ 400 W. The distance between the power transceiver and receiver should be no less than 15 cm;

(10) Immunity to sliding effect: teams need to show that the charger can demonstrate 80% of the rated charging capability with 10 cm sliding distance (center to center of the on-board and off-board parts) in any direction;

(11) Voltage display: display of the battery voltage through wireless communication is encouraged;
(12) Ambient temperature: the charger will be tested at room temperature;
(13) Cooling: natural convection;
(14) Acoustic noise: less than 50 dBA sound level measured 1.5 m from the unit;
(15) EMC: The system is expected to meet the EMI requirement specified by EN55022 (CISPR22) Class B. It is preferred to include the EMI test result in the report;
(16) Lifetime: the system is expected to function for at least ten years with routine maintenance when subjected to normal use in a 0°C to 40°C ambient environment; a brief analysis of lifetime in the final report is required;
(17) Minimum interference to the surroundings: during the final tests, the battery pack will be assembled on a solid iron sheet;
(18) Protection: over current, over voltage, short circuit, over temperature, and under voltage. No damage caused by output short circuit; the charger must shut down if the input voltage dips below the minimum input. IEEE Std. 929 is a useful reference;
(19) Safety: the final rules will contain detailed safety information; no live electrical elements are to be exposed when the unit is fully configured; the system is intended for safe, routine use in a home or small business by non-technical customers. Industry safety standards will be required, such as UL 1741-2000.

Final Competition Prototype Testing

In the final test, many tests could be done on an electronic load provided by University of Michigan-Dearborn. However, the battery test is the ultimate integral part of the performance testing.

For each team, the minimum undergraduate student number is four to qualify for the competition. No graduate students are allowed in the competition. However, graduate students could participate in each team as advisors. The graduate advisors should be less than two.

For each team, travel reimbursement is $1000 for distance less than 5000km and $2000 for distance of 5000km or above.