Request for Proposals (RFP)

The 2015 International Future Energy Challenge (IFEC'15)

A student competition sponsored by the

The Institute of Electrical and Electronics Engineers (IEEE)

April 30, 2014

Summary of Competition and Proposal Requirements

General Information

Competition Title: 2015 International Future Energy Challenge (IFEC) Student Competition

Topic Areas:

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

(B) Battery Energy Storage with an Inverter that Mimics Synchronous Generators

Period of Competition: May 15, 2014 to July 31, 2015

Challenge Program Awards: In each of the two topic areas there will be a Grand Prize of $10,000 and three additional awards granted at $1,000, $3000 and $5,000 each. The IFEC awards include the following for each of the two topic areas (See IEEE Awards Manual)

- Grand Prize $10,000
- Outstanding Performance Award $5,000
- Best Engineering Achievement Award $3,000
- Best Innovative Design of Power Electronic Converters Award $1,000

Prize requirements: US$10,000 will be awarded as Grand Prize for highest score among entries in each topic area meeting all minimum requirements as confirmed through reports and hardware tests. The remaining prizes will be awarded to the teams who have scored the highest in each of the categories: Outstanding Performance, Best Undergraduate Educational Impact, and Best Innovative Design of Power Electronics Converters.

Intellectual Property and Use of Prize Money:
The International Future Energy Challenge does not restrict the use or protection of inventions or other intellectual property produced by participating teams. There are no special licenses or rights required by the sponsors. However, the Final Test Events in July 2015 will include public

disclosure of each team's technology. Teams interested in securing protection for their inventions should be aware of this date when making arrangements.

The prizes provided to schools are intended to benefit the team members and student team design project activities. There is a Letter of Support (Attachment II) required for submission with the proposal and it should outline the plans of the school in the event that a prize is received.

Outside Support:

Individual schools should solicit project funding from companies, foundations, utilities, manufacturers, government agencies, or other sources. There is no limitation for the sources of project funding.

Eligibility Information:

- **Eligible schools must:** have an accredited or similarly officially recognized engineering program (through the Accreditation Board for Engineering Technology (ABET) or equivalent); be a college or university with engineering curricula leading to a full first degree or higher; have the support of the school's administration; establish a team of student engineers with an identified faculty advisor; demonstrate the necessary faculty and financial support commitments; and demonstrate a strong commitment to undergraduate engineering education through their proposal.

- **University Eligibility Limit: Each university is limited to one topic area; each school can support only one team.**

To confirm eligibility, potential participating schools must submit a Letter of Support (Attachment II) together with a Preliminary Team Information Form (Attachment I) when they submit the proposal.

How to Participate: Participation is on a proposal basis. Those schools that are interested must submit a proposal before the proposal deadline. Proposals will be judged by a distinguished panel of volunteer experts from the IEEE and the industry. Schools with successful proposals will be notified two months after the proposal deadline. Student teams will then carry out the work and prepare hardware prototypes and reports. Deadline for the qualification reports is listed in the time schedule in Page 8 of this document. The reports will be judged by a similar expert panel. The panel will select a group of teams as Finalists based on the qualifying reports. These teams are invited to present their progress to the panel at IEEE APEC conference on March 15-19, 2015, in Charlotte North Carolina, USA. Feedback will be given to the team to improve the system. The team will be invited to a competition event in July of 2015. A Final Report will be due at the competition event.

Please be aware that each of the two topic areas of the 2015 International Future Energy Challenge will be judged separately, against a separate specification set. Each team proposal must address a single topic area.

Judging Panels

Experts from IEEE Power Electronics Society (and others to be announced) and representatives from manufacturers, national labs, independent test labs, utilities, and R&D engineers.

Judging

Student team project results will be judged based on cost effectiveness, performance, quality of the prototype and other results, engineering reports, adherence to rules and deadlines, innovation, future promise, and related criteria. Each aspect of judging will be scored according to a point list and test protocol.

Proposals

Proposals will be judged on the quality of plans, the likelihood that a team will be successful in meeting the International Future Energy Challenge objectives, technical and production feasibility and degree of innovation. Other key criteria are evidence of the school's commitment, capability, experience, and resources to implement their design over the one-year span of the competition. Commitment to excellence in undergraduate education is important, and acceptable proposals will involve undergraduate students as the primary team members. Teams are limited at minimum 4 undergraduate students. Interdisciplinary teams are encouraged. Graduate students are not excluded, but are limited to **advisory role** in the team. The up limit of graduate student participants is **two for each team**.

The impact on undergraduate education is a critical judging criterion. **Proposals are limited to 12 double-spaced pages total, including all diagrams, attachments, and appendixes.** Schools that are invited to participate in 2015 International Future Energy Challenge are expected to adhere to the basic plans described in their proposals. Approval of the competition organizers must be sought for significant changes in plans or engineering designs. **Only one proposal will be considered for each school. Proposals must be submitted electronically in PDF format.**

A. Proposal Objectives

Respondents should express their ideas and plans relevant to their interested topic area. The project should include the construction and operation of a complete hardware prototype. The proposal must address both technical and organizational issues for each phase of the prototype's development and testing. It must contain a realistic project budget, along with a plan to secure the necessary funding. The educational goals, including any course credit provided for work related to the 2015 International Future Energy Challenge, and how the project relates to other efforts within the school and at the regional or national level should be addressed. A Letter of Support from an official of the school confirming a commitment to participate in the competition, and stating the type(s) and level of support for the team's participation in the competition should be attached, and is not counted toward the 12-page limit. Refer to the attachments at the end of this document for a sample.

B. Administrative Considerations and Limitations

This section describes the limitations placed on the proposal. Compliance is mandatory.

Language	Proposals must be written in English.
Length	Proposals are limited to 12 single-sided double-spaced pages of text, figures, and appendixes. The page size must be 8.5" x 11" or A4 and the font size must be no smaller than 10 point. Margins should be at least 25 mm. The Preliminary Team Information Form (Attachment I in this RFP), Support Letter (Attachment II in this RFP) from the school, government entities, or private sector organizations will not count in the proposal length.
Authors	Proposals are to be prepared by the student team in collaboration with the faculty advisors.

Signatures Proposals must be signed by all authors of the proposal (or the student team leader) and the faculty advisor.

Letter of Support Proposals must be accompanied by a letter of support from an appropriate Dean, Department Chair, or other authorized school official. The letter must confirm the school's commitment to participate. It must also state the type(s) and value of support from the institution. School support should match the value of cash and in-kind support from the team's principal sponsors. Additional letters of support from other team sponsors are optional. A sample letter is provided as Attachment II.

Preliminary Team Data Submit one copy of the Preliminary Team Information Form (Attachment I) with the proposal, then an updated copy with the progress reports to the address below. This form does not count in the 12-page limit.

Due Date All proposals must be received at the address below by close of business on **September 15, 2014** for full consideration.

Proposal Submission The electronic copy of the proposal in PDF format must be sent to the respective topic chairs via email, with a copy to the IFEC'15 chairman below:

General Chair: Mark Dehong Xu, Ph.D, Fellow IEEE
Professor, College of Electrical Engineering
Zhejiang University
38 Zheda Road, Hangzhou, Zhejiang 310027 China
Tel: +86-(571) 8795-3251, Fax: +86-(571) 87951625
Email: xdh@cee.zju.edu.cn

Information The volunteer Organizing Committee for the 2015 International Future Energy Challenge maintains a web site at http://www.energychallenge.org/. The site will include the most recent schedule and rule updates, frequency-asked questions, details about judging and scoring, and other team information. It should be checked regularly.

Chairs for Topic (A) High-efficiency Wireless Charging System for Electric Vehicles and Other Applications:

Prof. Kevin Bai
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Prof. Wencong Su (Co-Chair)
University of Michigan – Dearborn
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Chairs for Topic (B): Battery Energy Storage with an Inverter that Mimics Synchronous Generators

Prof. Qing-Chang Zhong
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Dept. of Automatic Control and Systems Engineering
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Time Schedule

Calendar Events

April 30, 2014	Request for proposals (RFP) posted.
Sept 15, 2014	Proposals Due
November 1, 2014	Schools informed of acceptance into the competition
Jan 15, 2015	Qualification reports due (Qualification reports must include preliminary experimental results. It is limited to 25 single-column pages total, including all diagrams, attachments, and appendixes).
February 15, 2015	Finalists notified (Selection is based upon likelihood of deliverable hardware, quality of design, and likelihood of success in meeting all the challenge objectives).
March 15-19, 2015	Workshop at APEC 2015, Charlotte, NC, USA
July 6, 2015	Topic A Final reports and working units due (Final reports are limited to 50 single-column pages total, including all diagrams, attachments, and appendixes)
July 13-15, 2015	Topic A Final competition
July 13, 2015	Topic B Final reports and working units due (Final reports are limited to 50 single-column pages total, including all diagrams, attachments, and appendixes)
July 20-22, 2015	Topic B Final competition

2015 International Future Energy Challenge

Organizing Committee

General Chair: Prof. Mark Dehong Xu, *Zhejiang Univ., China*

General Co-Chair: Prof. Jin Wang, *Ohio State Univ., USA*

General Co-Chair: Prof. Junming Zhang, *Zhejiang Univ., China*

Topic A Chair: Prof. Kevin Bai, *Kettering Univ., USA*

Topic A Co-chair: Prof. Wencong Su, *Univ. of Michigan, Dearborn, USA*

Topic B Chair: Prof. Qing-Chang Zhong, *Univ. of Sheffield, UK*

Topic B Co-chair: Prof. Dave Stone, *Univ. of Sheffield, UK*

Webmaster: Prof. Jin Wang, *Ohio State Univ., USA*

IEEE Inter-Society Associate: Donna Florek, *IEEE, USA*

Treasurer: Prof. Jason Lai, *Virginia Tech., USA*

Steering Committee

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Competition Description

Scope: An international student competition for innovation, conservation, and effective use of electrical energy. The competition is open to college and university student teams from recognized engineering programs in any location. Participation is on a proposal basis.

Introduction: In 2001, the U.S. Department of Energy (DOE), in partnership with the National Association of State Energy Officials (NASEO), the Institute of Electrical and Electronics Engineers (IEEE), the Department of Defense (DOD), and other sponsors, organized the first Future Energy Challenge competition. The objective was to build prototype, low-cost inverters to support fuel cell power systems. This competition was originally open to schools in North America with accredited engineering programs. The 2001 Future Energy Challenge focused on the emerging field of distributed electricity generation systems, seeking to dramatically improve the design and reduce the cost of dc-ac inverters and interface systems for use in distributed generation systems. The objectives were to design elegant, manufacturable systems that would reduce the costs of commercial interface systems by at least 50% and, thereby, accelerate the deployment of distributed generation systems in homes and buildings. Final events were conducted at the National Energy Technology Laboratory (NETL) in Morgantown, WV, USA. Speakers from IEEE, DOE, and DOD introduced the competition and interacted with students during the event week. Hardware was tested with an experimental fuel cell at the NETL site. The 2001 Challenge was a success, and is now the first in a biannual series of energy-based student team design competitions.

To continue and expand the 2001 success, the 2003 International Future Energy Challenge (IFEC) was organized as a worldwide student competition. The 2003 IFEC had two topics, a revised topic on fuel cell power conditioning, and a topic for high-efficiency motor drive systems suitable for home appliances. Major sponsors included three IEEE societies, DOE, and DOD. Fuel cell inverter events were again held at NETL. Motor system events were held at Advanced Energy in Raleigh, NC, USA.

The 2005 IFEC had two topics. The inverter topic was revised to incorporate photovoltaic sources and grid interaction, while the motor topic was revised only slightly. Major sponsors included three IEEE societies and DOD, with more modest sponsorship from DOE. Inverter events were held at the National Renewable Energy Laboratory (NREL) in Golden, CO, USA. Motor events were held at MPC Products in Skokie, IL, USA.

The 2007 IFEC had two topics. An integrated starter/alternator and a Universal battery charger system were chosen as the two topics. Major sponsors included IEEE Power Electronics society, and Power Supply Manufacturer Association (PSMA). The final competitions were held at MPC Products in Skokie, IL and Texas Instrument in Richardson, TX.

The 2009 IFEC, similar to the previous editions, had two topics. The Integrated Starter/Alternator-Motor Drive for Automotive Applications topic was repeated, a new topic, the Power Wind Turbine Energy Maximizer was included. Major sponsors included IEEE Power Electronics society, Industrial Electronics Society, MPC Products, Monash University, IEEE Power Electronics Society, IEEE Industrial Electronics Society, and Power Sources Manufacturers Association (PSMA). The final competitions were held at Illinois Institute of Technology in Chicago, IL, USA, and in Monash University, VIC, Australia.

The 2011 IFEC had two topics. Topic A focused on low cost lithium ion battery chargers. The final competition of Topic A was held at University of Michigan-Dearborn. And Virginia Tech University of USA won the Grand Prize and the Outstanding Performance Award. Topic B focused on Low Power Induction Motor Drive System Supplied from a Single Photovoltaic Panel for an Emergency Water Treatment Device Maximizer. The final competition of Topic B was held at Federal University of Maranhao, Brazil. Federal University of Maranhao won the Grand Prize and Outstanding Performance Award as well as the Best Technical Presentation Award. Sponsors of this year’s competition include IEEE Power Electronics Society, IEEE Industrial Electronics Society, and Power Sources Manufacturers Association (PSMA).

The 2013 IFEC Competition also had two topics. Topic A focused on highly efficient microinverter for photovoltaic panels. The final competition was held on July 18-19. National Taiwan University of Science and Technology won the Grand Prize and the Best Efficiency Award, Nanjing University of Aeronautics and Astronautics won the Best Engineering

Achievement Award, University of Kassel of Germany won the IEEE IES Best Innovative Design of Power Electronic Converters Award. Topic B was focused on Low power off-line light-emitting diode (LED) driver with long lifetime. And the final competition was held at Zhejiang University on July 29-30. Zhejiang University won the Grand Prize and the Best Efficiency Award; National Cheng-Kung University won the Best Engineering Achievement Award; North China University of Technology won the Best Engineering Design Award. Sponsors of The 2013 IFEC competition include IEEE Power Electronics Society, IEEE Industrial Electronics Society, IEEE Industry Applications Society, IEEE Power and Energy Society and Power Sources Manufacturers Association (PSMA).

2015 Topics and Descriptions: The 2015 competition addresses two broad topic areas:

TOPIC A: High-efficiency Wireless Charging System for Electric Vehicles and Other Applications.

TOPIC B: Battery Energy Storage with an Inverter that Mimics Synchronous Generators.

Detailed specifications, system requirements, and test procedures for each of the two topics are attached and will also be announced through the IFEC Web page.

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 ℃ to 40 ℃ 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.

Team Composition

For each team, the minimum undergraduate student number is four to qualify for the competition. Graduate students are not excluded, but are limited to **advisory role** in the team. The up limit of graduate student participants is **two for each team**.

Financial Support

Each team will receive travel support of $1000 for distance less than 5000km and $2000 for distance of 5000km or above.

References

[1] A. Kurs, A. Karalis, R. Moffatt, J.D. Joannopoulos, P. Fisher and M. Soljacic, "Wireless Power Transfer via Strongly Coupled Magnetic Resonances", SCIENCE, vol. 317, no. 83, 2007, pp. 83-86.

[2]. S.H.Lee and R.D. Lorenz, "Development and Validation of Model for 95% Efficiency, 220W Wireless Power Transfer over a 30cm Air-Gap", ECCE, 2010, pp. 885 – 892.

[3]. Z.N. Low, R.A. Chinga, R. Tseng and J. Lin, "Design and Test of a High-Power High-Efficiency Loosely Coupled Planar Wireless Power Transfer System", IEEE Transactions on Industrial Electronics, vol. 56, no. 5, 2009, pp. 1801 – 1812.

[4]. J.O Mur-Miranda, G. Fanti, Y. Feng, K.Omanakuttan, R. Ongie, A. Setjoadi and N. Sharpe, "Wireless Power Transfer Using Weakly Coupled Magnetostatic Resonators", ECCE, 2010, pp. 4179 – 4186.

[5]. X. Zhang, S.L. Ho, and W.N. Fu, "Quantitative Design and Analysis of Relay Resonators in Wireless Power Transfer System", IEEE Transactions on Magnetics, vol. 48, no.11, 2012, pp. 4026 – 4029.

[6]. K. Fotopoulou and B.W. Flynn, "Wireless Power Transfer in Loosely Coupled Links: Coild Misalginment Model", IEEE Transactions on Magnetics, vol. 47, no.2, 2011, pp. 416 – 430.

[7]. T. Imura and Y. Hori, "Maximizing Air Gap and Efficiency of Magnetic Resonant Coupling for Wireless Power Transfer Using Equivalent Circuit and Neumann Formula", IEEE Transactions on Industrial Electronis, vol. 58, no.2, 2011, pp. 4746 – 4752.

[8]. L. Chen, S. Liu, Y.C. Zhou ,and T.J. Cui, "An Optimizable Circuit Structure for High-Efficiency Wireless Power Transfer", IEEE Transactions on Industrial Electronics, vol. 60, no.1, 2011, pp. 339 – 349.

Topic B

Battery Energy Storage with an Inverter that Mimics Synchronous Generators

Vision

- To develop a grid-connected bi-directional battery energy storage system with an inverter that mimics the functions of synchronous generators
- To reduce the overall cost and volume of energy storage systems
- To offer students a challenging opportunity to integrate their knowledge and skills in power conversion circuit theory, control, battery energy management and power systems

Goals

Design and build a battery energy storage system with an inverter that will:

- Have the basic functions of charging, discharging and protection for the battery;
- Meet the desired power quality to the grid/load;
- Improve power density;
- Realize power conversion between the battery and the gird/load with high efficiency;
- Mimic the function of synchronous generators to autonomously take part in the regulation of system frequency and voltage via controlling the real power and reactive power delivered;
- Achieve seamless transfer between grid-connected and stand-alone modes;
- Reduce manufacturing cost.

Background

Renewable generation is a growing component of electricity grids around the world due to its contributions to energy system decarbonization and long term energy security. Most renewable energy sources are location-dependent and experience intermittency, a combination of non-controllable variability and partial unpredictability. These cause a lot of challenges for generation owners and grid operators in the integration of wind and solar generation. One important solution is to adopt distributed energy storage systems. This could postpone the need of network expansion and can be optimized for different kinds of grid services. Energy storage systems could enhance the reliability of power systems and the security of supply and increase the level of the penetration of renewable energy sources.

Grid-connected storage systems can be installed at different voltage levels, depending on the location and the application scenario. The charging/discharging process of energy storage systems introduces different dynamics into the grid, which may lead to heavy burden to the grid and threaten the system stability. How to integrate energy storage systems into the grid so that they can behave similarly as conventional power plants is very important.

The main objective of Topic B is to develop a grid-connected energy storage system with an inverter that can mimic the functions of synchronous generators. It should be able to autonomously deliver the right amount of real power and reactive power according to the grid frequency and voltage or to regulate the frequency and voltage via changing the real power and reactive power delivered. At the same time, the harmonic components of the generated voltage should be maintained low. Moreover, such inverters should also achieve seamless transition between grid-connected mode and stand-alone mode to facilitate the applications in renewable energy and microgrids.

In order to connect an inverter to the power grid, it often needs a dedicated synchronization unit, e.g., a phase-locked loop (PLL). However, because PLLs are inherently nonlinear and so are the inverter controller and the power system, it is extremely difficult and time-consuming to tune the PLL parameters to achieve satisfactory performance. As a result, how to achieve synchronization quickly and accurately is very challenging. The teams are encouraged to get rid of the dedicated synchronization unit and implement the function of synchronization by the controller itself.

Conventional technical challenges to build a normal inverter should also be fully considered, which include power density, efficiency, electromagnetic compatibility and electromagnetic interference (EMC/EMI), reliability, thermal management, safety and cost etc.

Requirements

The energy storage system will be judged against a set of objectives, requirements and characteristics. The basic functions are listed as follows:

- Having the basic functions of charging, discharging and protection for the battery;
- Meeting the desired power quality to the grid/load;
- Mimicking the function of synchronous generators to autonomously take part in the regulation of system frequency and voltage via controlling the real power and reactive power delivered;
- Achieving seamless transfer between grid-connected and stand-alone modes;
- Encouraging performance beyond requirements and the specifications, especially for the efficiency, prototype dimension, design flexibility and performance;

Specifications

Design Item	***Minimum* Target Requirement**
1. Dimensions	Volume less than 1 Litre
2. Weight	Less than 1 kg
3. Manufacturing cost	Less than US$0.5/W
4. Overall energy efficiency	Higher than 95%
5. Input (battery) voltage	48V DC (nominal)
6. Power supplies	Four 12V 40Ah lead-acid batteries will be provided at the competition test site as the only power source to the energy storage system. No auxiliary power supplies will be provided.
7. Output power rating	500 VA continuous
8. Output voltage	AC 230 V (rms) nominal (single phase)
9. Output frequency	50 Hz nominal
10. Frequency regulation	The change of 100% real power corresponds to the change of 1% grid frequency.
11. Voltage regulation	The output voltage should be regulated within ±5% of the nominal voltage, corresponding to ±100% reactive power delivered.
12. Harmonics of the output voltage	Total harmonic distortion (THD) of the output

	voltage should be less than 5% when supplying a standard nonlinear test load (details to be provided) and the THD of the grid current should be less than 5% at the rated power when connected to the grid.
13. User interface	A LED is required to indicate whether the energy storage system is ready for connection to the grid and a switch or button should be provided for grid connection/disconnection.
14. Operation mode	The energy storage system is intended for use as a grid-connected system, which can achieve seamless transition between grid-connected mode (charging/discharging) and stand-alone mode (discharging).
15. Synchronization	Removal of a dedicated synchronisation unit, e.g. PLL, is not required but highly encouraged.
16. EMI	The system is expected to meet the EMI requirement specified by EN55022 (CISPR22) Class B. It is encouraged to include EMI test results in the final report.
17. Protection	The system should shut down if the output current exceeds 5A (instantaneous value). No damage caused by output short circuit and open circuit.
18. Safety	No live electrical elements are to be exposed when the unit is fully configured. The system is intended for safe, routine use by non-technical customers. It is recommended to follow industry safety standards such as UL 1741-2000.
19. Storage temperature range	-20 to 85 ℃
20. Operating temperature	-20 to 50 ℃ The system will be tested at room temperature.

21. Cooling	Natural convection is encouraged.
22. Acoustic noise	No louder than conventional domestic refrigerator. Less than 50 dBA, measured 1.5 m from the unit.
23. Galvanic isolation	Not required but encouraged. A line frequency transformer will be provided to isolate the inverter from the grid during tests.
24. Technical report	It should include the description of the basic principles, design of the system, simulation results, experimental results and cost study for mass production of 1000 units, taking price information of components from RS Components Ltd (http://uk.rs-online.com/).

Final Competition Prototype Testing

The detailed test protocol will be presented to the teams prior to the competition. The test will be carried out at University of Sheffield, UK in six steps: 1) operation in the standalone mode with a local load; 2) synchronization with the grid; 3) operation in the grid-connected mode; 4) Transition between grid-connected and stand-alone modes; 5) battery charge, discharge and protection test; 6) Conversion efficiency test.

Team Composition

For each team, the minimum undergraduate student number is four to qualify for the competition. Graduate students are not excluded, but are limited to **advisory role** in the team. The up limit of graduate student participants is **two for each team**.

Financial Support

Each team will receive travel support of $1000 for distance less than 5000km and $2000 for distance of 5000km or above. Moreover, each team will receive components from RS Components (worth up to GBP250, ordered online at http://uk.rs-online.com/).

References

[1] D. Pavlov, Lead-Acid Batteries: Science and Technology, *Elsevier Science*, Jun 2011.

[2] C. D. Rahn and C.-Y. Wang, Battery systems engineering. *John Wiley & Sons*, 2013.

[3] Q.-C. Zhong and T. Hornik, Control of power inverters in renewable energy and smart grid integration. *Wiley-IEEE Press*, 2013.

[4] Q.-C. Zhong, P.-L. Nguyen, Z. Ma, and W. Sheng, “Self-synchronised synchronverters: Inverters without a dedicated synchronisation unit,” *IEEE Trans. Power Electron.*, vol. 29, no. 2, pp. 617-630, Feb. 2014.

ATTACHMENT I

2015 INTERNATIONAL FUTURE ENERGY CHALLENGE
PRELIMINARY TEAM INFORMATION FORM
TOPIC (X)
Submit with Proposal

NAME OF UNIVERSITY:

CORRESPONDING ADDRESS (PLEASE INCLUDE NAME):

TELPHONE:
FAX:
EMAIL:

FACULTY ADVISOR(S):

Name	Department	E-Mail
______________	______________	______________
______________	______________	______________

PRELIMINARY TEAM MEMBERS:

Name	Major Field of Study	Degree and Expected Graduation Date
______________	______________	______________
______________	______________	______________
______________	______________	______________
______________	______________	______________
______________	______________	______________
______________	______________	______________
______________	______________	______________

ATTACHMENT II

LETTER OF SUPPORT

Submit with Proposal

[The letter below is a typical sample and should not simply be copied. Please send a letter with similar content on your university letterhead.]

For Topic (A) High-efficiency Wireless Charging System for Electric Vehicles and Other Applications:

To:

Prof. Kevin Bai
Kettering University
Department of Electrical and Computer Engineering
hbai@kettering.edu
Flint, Michigan 48504, USA

For Topic (B) Battery Energy Storage with an Inverter that Mimics Synchronous Generators:

To:

Prof. Qing-Chang Zhong
University of Sheffield
Dept. of Automatic Control and Systems Engineering
q.zhong@sheffield.ac.uk
Mappin Street, Sheffield, S1 3JD, UK

Dear International Future Energy Challenge Coordinator,

Our university has organized a student team to participate in the 2015 International Future Energy Challenge. Our proposal for the topic ***(X)*** is enclosed. A Preliminary Team Participation Form is attached, listing our contact person, the faculty advisor(s), and some of the students who plan to be involved. The team will keep an eye on the Energy Challenge web site for detailed rules and other information. We understand that we will be notified whether we have been accepted to participate by November 1, 2014. If we are accepted, we agree to have our student team perform the design tasks and prepare the reports and hardware prototypes required for the competition. Our school is prepared to support the team with the following resources:

- A final year project course, ***XXX***, has been authorized to provide engineering students across several disciplines with the opportunity to include this project in their curricula. Laboratory space has been arranged for this course.
- A faculty advisor, Prof. ***XXX***, has been identified, and has been formally assigned to teach the project course and to advise the student team as a portion of his/her regular duties.
- A graduate student assistant has been identified to help manage the student team and to supervise direct laboratory activity. This student is supported with a Teaching Assistantship, which represents a funding commitment of our university of approximately ***$X.***
- The student team will be provided with an appropriate level of technician and machine shop support to assist them with package preparation and assembly. This assistance represents a funding commitment of approximately ***$X***, and we consider this as a matching commitment for any in-kind support received from external sponsors.
- In addition, we will provide limited funds to help secure special parts and equipment, with a total commitment of up to ***$X.***
- The student team will be encouraged to secure outside sponsorship. Our university strongly supports all these efforts, and will match any outside cash support 1:1 up to an additional total of ***$X***.

In the event that our school receives prizes from the competition, we are committed to using approximately X% of this money for scholarships for the student team members. The remainder of the funds will be added to our Team Design Program fund, which supports this and similar projects through sponsorship matching, travel funds for participation in competition events, and other direct costs of large team design projects. In the event that our team creates new inventions in the topic area, our university also provides the possibility of assisting with organization of a start-up company.

We understand the importance of student team projects in the engineering curriculum and look forward to our participation in the 2015 International Future Energy Challenge.

Sincerely,

(Head of Department, Dean of Engineering or similar school official)