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OFFICE OF ELECTRICITY DELIVERY AND ENERGY RELIABILITY

28. NATURAL DISASTER REDUCTION THROUGH TECHNOLOGY

The U.S. electric power sector is a critical part of our society. Virtually all aspects of residential, industrial, and commercial activities depend on safe, reliable, and affordable electricity. Electricity is among the most infrastructure-intensive segments of the energy sector – the electricity grid includes a network of 5,000 power plants with a generating capacity of 800,000 megawatts, 100,000 high-voltage transformers, 63,000 substations, and 158,000 miles of transmission lines. In some cases, this infrastructure is operating at-or-near capacity. Therefore, the potential to be in a supply-shortfall position when affected by a natural disaster has never been greater.

Any prolonged interruption in the supply of electricity would be devastating to the nation. Natural disasters, including major weather events, have caused damage to the electricity infrastructure, resulting in high energy-loss consequences, as well as subsequent public health, safety, and economic losses. For example, hurricanes Katrina and Rita impacted Florida, Alabama, Mississippi, Louisiana, and Texas, resulting in widespread power outages to residential, commercial, and industrial customers. The long-term power outages caused disruption to all parts of society, including inter-dependent critical infrastructure such as communication, oil refineries, pumping stations, pipelines, and gasoline stations.

Reducing the consequences of such disasters has been accomplished by implementing sound emergency management policies that involve close coordination between federal, state, and private stakeholders. Nonetheless, there remain many technological approaches which could decrease vulnerability and accelerate recovery of the electric grid. The most urgent research issues include: (1) advanced power electronics for faster routing of electricity flow and for integration of storage and renewables as buffers, (2) simulation models to assist in recovery measures, and (3) the development of restoration software tools based on advanced sensor data to rapidly ascertain the state of the grid.

Grant applications are sought only in the following subtopics.

a. Vulnerability Reduction Via Advanced Power Electronics—High-voltage/high-current power electronics devices allow precise and rapid switching of electric power to support long-distance transmission. Power electronics are essential for integrating devices such as energy storage, photovoltaic arrays, microturbines, and wind power integration with the local electric distribution system. During abnormal grid operation and interruptions, power electronics can be used as grid shock absorbers, current limiters, and to improve power flow management. Advanced power electronic devices could assist in the recovery from brownouts and blackouts, either short or extended. Therefore, grant applications are sought to develop new power electronic devices to aid in minimizing the impact of, and assisting in the recovery from, natural disasters. These devices must be able to withstand harsh and chaotic electrical perturbations such as frequency fluctuations, erroneous loops flows, large voltage sags and swells, and current surges that can be experienced during a natural disaster.

Questions – contact Imre Gyuk (imre.gyuk@hq.doe.gov)

b. Simulation Models—Grant applications are sought to develop simulation models to improve recovery from disruptions of critical electricity infrastructure, or when possible, preclude such a situation from occurring. The aim is to develop tools that could quickly alert operators and recommend corrective control actions that may be taken to alleviate an existing or potential problem in the system, and return the system to a stable state. Some examples include refined "real-time" tools for contingency analysis; modeling interdependencies; analyzing potential overload and/or short-circuit conditions; and estimating restoration time. Projects with an emphasis on the high-voltage transmission system are preferred. Also of interest are simulators that provide a realistic environment for operators to practice procedures under emergency operating situations.

(**Note distinction between subtopics b and c:** the intent of this subtopic is to develop enhanced decision support tools, whereas subtopic c focuses on providing operational understanding of system status through sensor measurements.)

Questions – contact Gil Bindewald (gilbert.bindewald@hq.doe.gov)

c. Restoration Software Based on Advanced Sensors—Sensors are an essential component in the operation and maintenance of energy systems, and advanced sensors could aid in disaster reduction. These sensor networks, located on the transmission and distribution system, would allow control area operators to record the status of the grid prior to a large disturbance and determine line status after a disaster and where generation capacity can be matched with load. Grant applications are sought to develop software tools that use time-synchronized sensor data from all parts of the transmission grid, individually or in combination, to aid operators in restoring full service across a region. The sensor data of interest would be derived from phasor measurement units (PMUs), digital fault recorders with GPS-synchronization, and intelligent electronic devices in substations for time synchronized circuit breaker monitoring. Such sensors could provide information on phase angles to re-synchronize circuits in the system, real and reactive power flows, breaker positions, dynamic line loading conditions, and low-frequency oscillations during the grid restoration process. By operating on these data with appropriate software tools, system operators then could reconfigure electricity flow to restore power to the grid safely and efficiently, while isolating any problem areas.

Questions – contact Phil Overholt (Philip.overholt@hq.doe.gov)

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29. ADVANCED ENERGY STORAGE AND POWER ELECTRONIC SYSTEMS

As energy storage systems continue to advance, two areas have surfaced in which technology advances are needed:

- In battery or electrochemical capacitor strings, slight differences in individual cells can grow over time, leading to premature failure of the system. External circuitry sometimes is applied in an attempt to minimize this problem. Solutions for intrinsic cell balancing, without the use of external circuitry at the cell level, are sought.

- As silicon carbide devices become more available for system level power electronic applications, wire bonding of these devices into circuits is expected to become a reliability issue. Solutions are sought for novel “wireless” bonding techniques to alleviate this potential problem.

Grant applications are sought only in the following subtopics.

a. Intrinsic Cell Balancing for Advanced Energy Storage Systems—In most energy storage applications, individual electrochemical cells and/or capacitors are connected together in a variety of series/parallel configurations to form modules, strings, and ultimately systems. During repeated charge and discharge of the system, differences in the behavior of individual cells can lead to cell imbalances, which can lead to system failure. In many cases, the systems are externally monitored at the cell level in order to minimize abuse of the cells themselves – abuse that can lead to shortened lifetime or, in the worst case, a potentially life-threatening situation (e.g., overcharge leading to thermal runaway and deflagration). As larger and larger systems are built to meet large-scale utility applications, the potential for these imbalances increases significantly, and the complexity of the required monitoring circuits and control software leads to increased costs and decreased reliability. In order to obviate the need for this additional circuitry and electronic monitoring/control of individual cells, grant applications are sought to develop new approaches to cell balancing for batteries and electrochemical capacitors. Possible examples include the use of either intrinsic or external techniques such as overcharge redox shuttles in each cell or module-level circuitry and algorithms to replace individual cell-level systems. Designs and approaches that are applicable to multiple battery and capacitor chemistries are preferred.

Questions – Imre Gyuk (imre.gyuk@hq.doe.gov)

b. Advanced Bonding Techniques for Silicon Carbide (SiC) Switches—Wide band-gap devices such as silicon carbide (SiC) are becoming more attractive to various applications – such as high power motor drives, Flexible AC Transmission Systems (FACTS) controllers, and power conversion systems – because of their increase in performance compared to silicon-based systems. Advantages include lower losses, high operating frequencies, higher operating voltages, and higher operating temperatures. Most SiC devices to date utilize one or more wire bonds to provide the electrical path needed for conduction. These wire bonds are typically made of aluminum or gold wires that are ultrasonically or thermosonically bonded to bond pads on the SiC chip. However, such wire bonds are known to have catastrophic failure mechanisms that occur during high current or high temperature cycling. The wire bonds also add to the overall electrical inductance of the switch and can be especially problematic in high frequency power applications. Consequently, these wire bonds often are considered the weakest link in the overall packaging. Grant applications are sought to develop an advanced wire-bondless approach to high power (greater than 100A and 10kV) SiC packaging. The Phase I project should examine the feasibility of a wire-bondless approach along with the current state of research and development. The potential Phase II project would include the testing and improvement of these devices and the inclusion of these devices into power conversion system for high power applications.

Questions – Imre Gyuk (imre.gyuk@hq.doe.gov)

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30. HIGH TEMPERATURE SUPERCONDUCTIVITY

Substantial worldwide advances have been achieved in recent years with respect to the development and processing of second generation, high temperature superconducting (HTS) coated conductors (also known as "2G wires"). Highly successful prototype superconducting equipment and devices are being demonstrated. Compared to first generation wires, 2G coated conductors have the potential of providing lower cost and higher performance. These wires also provide the possibility of operation at moderate magnetic fields in liquid nitrogen as well as high fields at lower temperatures. For short laboratory-scale samples, very high current-carrying capacities (over 1,000 A/cm at 77K) have been reported. In addition, pre-commercial coated conductors as long as 600 meters, with current carrying capacity over 170 A/cm, have been demonstrated. Nonetheless, further innovation and development will be needed to achieve the DOE vision for commercial availability of 2G wires that have a cost/performance ratio as low as $10-30/kA-m (dollars per kiloampere-meter) and can be fabricated in practical forms. In addition to wires, further improvements in the efficiency, reliability, and cost reduction of the enabling cryogenic system are needed.

Grant applications are sought only in the following subtopics.

a. AC Loss Reduction in Coated Conductors (ref. 1-4) —Although a number of strategies (filamentization, multi-wire stranding, twisting and transposition) have been shown to reduce AC losses in superconducting wires and cables, all of them have limitations for 2G wires. For example, because 2G wire consists of a continuous layer of HTS, filamentization would require the additional step of physically removing part of the HTS layer. Filamentization difficulties are compounded by the presence of relatively large textured grains, which are contained within certain 2G templates and can range from 30 to 60 microns in size. The presence of these grains may place a lower limit on the width of the HTS filaments; yet, narrow filaments are desirable because they are more effective in reducting AC losses. The twisting and transposition strategy also has drawbacks – the flat tape geometry of present 2G wire does not lend naturally to twisting and transposition, due to mechanical concerns.

Grant applications are sought to develop innovative and cost effective approaches to reduce the AC losses of coated conductors. Approaches of interest include filamentization and substrate modification, including single crystalline round or low-aspect-ratio textured templates.

- With respect to approaches that address the continuous filamentization of the HTS and/or stabilizer, grant applications should develop a potentially cost effective filamentation technique, and determine the influences of such critical parameters as HTS filament shape, arrangement, and geometry on loss characteristics under various operating conditions. Loss characteristics may include properties such as hysteretic, coupling, eddy current, and transport losses, projected over broad ranges of frequencies and field-sweep amplitudes.

- With respect to approaches that address textured substrate fabrication, the substrates either must be single crystalline or must contain well-oriented grains less than five microns in size, with grain misorientation angles less than eight degrees full-width-half-maximum. The substrates also must be suitable for continuous fabrication and be able to sustain a critical current density of more than one MA/cm^2 at 77K self-field. Also, textured templates that have either round or low aspect ratio cross sections are preferred.

Questions – contact Debbie Haught (debbie.haught@hq.doe.gov)

b. High Performance and Reliable 2G Wire Joints—Although superconducting equipment requires long lengths of 2G wires, practical HTS wires are of finite lengths. Consequently, wire joining is required during device manufacturing, installation, and field repair. To ensure safe and reliable operation, high performance joints must have good mechanical and electrical integrity. Due to the different architectures and manufacturing processes of various commercial 2G wires, characteristics of the joints are expected to vary with joint fabrication conditions as well as with the type of 2G wire being used. Also, the asymmetric nature of present 2G wires likely will influence the joint characteristics depending on the joining arrangement (i.e., whether the joints are fabricated in face-to-face, back-to-back, or face-to-back configurations). At present, only limited information on 2G wire joints is available; further information must be developed in order to ensure reliable 2G wire joints for HTS applications.

Grant applications are sought to develop innovative and cost-effective ways to prepare high quality, reliable, joints for superconducting 2G wires, either to one-another or to non-superconducting wires. Approaches of interest must include a detailed determination of the effects of the joining method on the properties of 2G wires –including joint resistance, ac losses, and stability strength – and on the interdependence between these properties prepared under various conditions. The determination of these effects must account for the fact that the wires may have been prepared under various conditions and may have different wire architectures.

Questions – contact Debbie Haught (debbie.haught@hq.doe.gov)

c. Cryogenic Technology for Superconductors—In order to realize the benefits of superconducting equipment, HTS wires must be maintained at temperatures well below ambient. Potential applications for these superconductors will most likely be realized if the operating temperature can be maintained economically in the range 63-83K. To economically achieve and maintain these temperatures, further development in thermal insulation systems (cryostats) and refrigerators (cryo-coolers) is needed.

Grant applications are sought to develop flexible cryostats (ref. 5-6) that are suitable for HTS electrical cable that might be placed underground or underwater. These cryostats should offer superior performance and lower price compared to today's commercially available products. For comparison, current flexible cryostats are manufactured in 100 m lengths, have a price of approximately $500/m, admit heat at the rate of 1-3 W/m, and suffer increased heat loads at bends in the cable. Also the getters used in the vacuum region of these cryostats have lifetimes significantly shorter than the 20-30 year HTS cable lifetime the utilities expect and improved getters are needed as a getter reconditioning or replacement for a long, underground HTS cable is difficult. Cryostats for future HTS cables must be much longer (kilometers), have a reduced price ($200/m), a reduced rate of heat invasion (e.g., less than 1 W/m), minimize performance degradation at bends and have improved getter lifetimes. Proposed cryostats must have the potential to satisfy most or all of these requirements.

Grant applications also are sought to develop efficient, reliable and cryo-coolers (ref. 7). These cryo-coolers should have the potential for unattended, maintenance-free operation for at least 10 years, and be able to function in an underground ~~and/or underwater~~ environment. Proposed approaches must offer the prospect of future price reductions to less than $50/watt at 65K.

Questions – contact Debbie Haught (debbie.haught@hq.doe.gov)

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OFFICE OF FUSION ENERGY SCIENCES

31. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS

An attractive fusion energy source will require the development of superconducting magnets and materials as well as technologies that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and materials will need to be substantially advanced relative to today's capabilities in order to achieve safe, reliable, economic, and environmentally-benign operation of fusion energy systems. Further information about research funded by the Office of Fusion Energy Sciences (OFES) can be found at the OFES Website (URL: www.ofes.fusion.doe.gov).

Grant applications are sought only in the following subtopics:

a. Plasma Facing Components—The plasma facing components (PFCs) in energy producing fusion devices will experience 5-15 MW/m^2 surface heat flux under normal operation (steady-state) and off-normal energy deposition up to 1 MJ/m^2 within 0.1 to 1.0 ms. Refractory solid surfaces represent one type of PFC option. These PFCs are envisioned to have a refractory metal heat sink, cooled by helium gas, and a plasma facing surface, consisting of an engineered refractory metal surface or a thin coating of refractory material that minimizes thermal stresses. The materials being considered include tungsten and molybdenum alloys. Grant applications are sought to develop: (1) innovative refractory alloys having good thermal conductivity (similar to Mo, at a minimum), resistance to recrystallization and grain growth, good mechanical properties (e.g., strength and ductility), and resistance to thermal fatigue; (2) coatings or specialized low-Z surface treatments of refractory alloy armor for improved plasma performance; (3) innovative refractory-metal heat sink designs for enhanced helium gas cooling; (4) efficient fabrication methods for engineered surfaces that mitigate the stresses due to high heat flux; and (5) joining methods, for attaching the plasma facing material to the heat sink, that are reliable, efficient to manufacture, and capable of high heat transfer – these new joining techniques may be applicable to either advanced, helium-cooled, refractory heat sinks or present-day, water-cooled, copper-alloy heat sinks.

In addition, grant applications are sought to develop new or improved *in situ* diagnostic techniques to monitor the health and performance of operating PFCs and plasma edge conditions. A carefully selected combination of