

Letter Requesting Authorization to Establish a Center

This letter is submitted to the College of Engineering and research division of NCSU, to establish Future Renewable Electric Energy Delivery and Management (FREEDM) Center at NCSU. The request is made by Proposed FREEDM Director, Professor Alex Huang, Progress Energy Distinguished Professor of Electrical and Computer Engineering (ECE), on behalf of a group of faculty from the departments of ECE, Chemical and Biomolecular Engineering (CBE), Mechanical and Aerospace Engineering (ME), Computer Science (CSC), Material Science and Engineering (MSE) in the College of Engineering, department of Textile Engineering Chemistry and Science (TE) in the College of Textiles as well as department of Management, Innovation and Entrepreneurship in the College of Management.

1. Center Name

The name of the Center is the Future Renewable Electric Energy Delivery and Management (FREEDM) Center

2. General Statement

The FREEDM Center is being established as an organizational unit to conduct research, education and outreach activities proposed to the US National Science Foundation (NSF) as an Engineering Research Center (ERC). Following a 14-month nationwide proposal selection process, which started with over 300 letter-of-intent submissions by university researchers from across the country, the FREEDM Center has been chosen as one of five (5) proposals nation-wide recommended by the ERC Program Manager for funding. The ERC program is intended to provide substantial and extended support for national centers of excellence in systems driven engineering research of national and global relevance. An ERC Center is initially funded for 5-years, with an additional 5-year support depending on assessment and evaluation of progress towards goals. The FREEDM Center full-proposal is attached for reference.

U.S. annual electric and transportation energy consumption is over 9.4 billion-kilowatt-hours, costing over \$0.5 trillion, (more than 50% from automobiles). Renewable energy utilization in the US is less than 4% and is among the lowest of developed nations - an ominous sign of a looming energy driven economic crisis. Three major factors contribute to this crisis: (1) energy insecurity - most imported oil comes from politically unstable regions; (2) the non-renewable nature of fossil fuels; (3) increased global climate change caused by CO₂ emissions from fossil fuel combustion. To solve these problems, we propose systems level solutions to enable wide spread utilization of long term, secure, sustainable and environmentally friendly electric energy.

The vision for the ERC for Future Renewable Electric Energy Delivery and Management (FREEDM) Systems is an efficient power grid integrating highly distributed and scalable alternative generating sources and storage with existing power systems to facilitate a green energy based society, mitigate the growing energy crisis, and reduce the impact of

carbon emissions on the environment. This is a high-risk, innovative technology for the electric power industry, significantly improving energy security and reliability. Widespread innovation fostered by this ERC will transform the power industry centered on information and post-silicon semiconductor technologies while benefiting from the diverse and well trained job market. We will realize our vision through breakthroughs in fundamental research (system theory, advanced storage, and power devices) and enabling technology development (secured communication, distributed grid intelligence, high-frequency and high-voltage power conversion, and distributed energy storage devices.)

3. Goals and Objectives

The goals for the proposed Future Renewable Electric Energy Delivery and Management (FREEEDM) Center are: Develop fundamental science and enabling technologies leading to the demonstration of the FREEDM System; foster a revolution in innovation and technology in electric power and sustainable energy industries; and to educate a new workforce for the coming green-energy based economy. The FREEDM System will be a research testbed for demonstrating the connection renewable electric energy in a network.

The proposed FREEDM system is a green energy grid infrastructure that will:
Allow *plug and play* of any Distributed Renewable Energy Resource (DRER) such as wind, solar, or geothermal generation component, or Distributed Energy Storage Device (DESD) such as fuel cell or plug-in hybrid electric vehicles, anywhere and anytime;

Manage DRER and DESD through *Distributed Grid Intelligence (DGI)* software;

Have a secure and reliable communication infrastructure backbone parallel to the electric energy network infrastructure;

Have the capability of being totally isolated from the main electric power grid, if necessary, autonomous continuing to operate based on 100% renewable energy;

Have perfect power quality and guaranteed system stability; and

Have improved efficiency, operating the alternating current system with unity power factor.

4. Organization

FREEDM Center will be a center of excellence housed within the NC State College of Engineering. As described on the front page of the attached ERC full proposal, the leadership team for Center will include a Director, a Deputy Director, an Administrative Director, a Technical Coordinator, a Director of University Education, a Director of

Diversity, a Director of Pre-College Education and Outreach, a Director of Industry and Innovation, as well as Campus Directors for Specific Partner Universities.

The proposed NSF Engineering Research Center (NSF-ERC) will have numerous domestic and academic partners. NC State University (NCSU) will be the Lead institution. The Center Director will be a faculty member from NCSU College of Engineering. The proposed partner universities include: Florida State University (FSU); Florida A&M University (FAMU); Missouri Science and Technology University, Rolla (MUST); and Arizona State University (ASU).

The FREEDM Center will be governed in accordance with a center by-laws and membership agreement. A Council of Deans, consisting of the Deans of Engineering from each partner university will be the governing body for the NSF-ERC. The NCSU Dean of Engineering will Chair the Council of Deans.

Within NC State University, the Center Director will also report to the Dean of Engineering. External oversight and review for the Center will include an Industrial Advisory Board (IAB), a Scientific Advisory Board (SAB) and an Energy Policy Advisory Board (EPAB).

Partners for additional research and education projects may be from Spelman College (SC), Auburn University (AU), Oregon State University (OSU); Virginia Polytechnical Institute (VPI); and University of Washington (UW). International Partners will be from: Aachen University, RWTH (Germany); the Federal Institute of Technology, ETH (Switzerland); the Energy Resources Institute, TERI (India), and the Polish Academy of Sciences, UNIPRESS (Poland).

Affiliated Institutions will include national laboratories and research institutions within the US which do not qualify to receive funds from NSF through the ERC programs, but whom will conduct complimentary research, education or outreach projects in parallel with the FREEDM project. Affiliated institutions may include: Sandia National Laboratories (Sandia-DoE), National Renewable Energy Laboratories (NREL-DoE); National Energy Technologies Laboratories (NETL-DoE); Oak Ridge National Laboratories (ORNL-DoE); and Army Research Laboratories (ARL-DoD).

The proposed initial center faculty members are:

Initial NCSU Faculty

Dr. Alex Huang (ECE) - Center Director

Dr. Mesut Baran (ECE)

Dr. Subhashish Bhattacharya (ECE)

Dr. Mo-yuen Chow (ECE)

Dr. Leda Lunardi (ECE)

Dr. Jay Baliga (ECE)

Dr. John Grainger (ECE)

Dr. John Muth (ECE)
Dr. Veena Misra (ECE)
Dr. Mark Johnson (MSE)
Dr. Doug Barlarge (ECE)
Dr. Xiangwu Zhang (Textile)
Dr. Wesley Henderson (CBE)
Dr. Richard Gould (ME)
Dr. Hoon Hoog (Math)
Dr. Mitzi Montoya-Weiss (MIE)
Dr. Ted Baker (MIE)
Dr. Frank Mueller (CSC)
Dr. Steve Kalland (IE)
Dr. Alex Dean (ECE)
Dr. Srdjan Lukic (ECE)
Dr. Wenye Wang (ECE)

Center research activities will be performed by faculty, graduate students, postdoctoral scientists, undergraduate students and visiting industrial affiliate fellows.

FREEDM Center proposes to establish an industrial consortium, consisting of three membership levels: full, associate and affiliate. Proposed membership level and benefits are described in the Membership Agreement. The consortium will be guided by an Industry Advisory Board (IAB).

The Center's research program will be organized into three major thrust levels (system demonstration, enabling technology, fundamental research) which are divided into specific subthrust areas. Each thrust and subthrust will have one faculty leader, and they are responsible to lead the research activities and report to the center director. At the beginning of the center program, a detailed ERC research roadmap has been proposed and will be used to guide the center research program. The research roadmap will be evaluated and assessed on a periodic basis by the Center management, in consultation with the Industrial Advisory Board. In addition courses, training, mentoring and outreach programs supporting the mission of the FREEDM Center will also be developed to address the unique needs research, education and engagement in renewable electric energy delivery and management.

4.1. Fundamental Research Thrust

Post Silicon Devices (PSD) Subthrust: Develop breakthrough devices for next generation of power electronics for renewable energy infrastructure applications;

Advanced Storage (AS): Improve electric energy density and power density needed as electric energy distributed storage resources;

System Theory, Modeling and Control (SMC): Develop a knowledge base and tool set of systems function such that distributed grid intelligence may be reliably and securely utilized in renewable energy power grid systems.

4.2. Enabling Technology Thrust

Solid-State Transformer (SST): Develop cheap, efficient and controllable power electronics which will provide the interface required for distributed energy generation, storage and load devices in an integrated energy device. Such solid-state transformers will be based on advanced post-silicon semiconductor devices, which will efficiently handle power, energy and load in a reciprocal and controlled manner.

Fault Isolation Device (FID): Develop a high power, digitally controlled, fast acting solid state switch which may be used as the enabling hardware component within a integrated fault management device, whose function is to an isolate faults and reclose in a distributed renewable energy system.

Distributed Energy Storage Device (DESD): Develop kilowatt to megawatt class storage device devices capable of deployment in distributed renewable energy network. The purpose of a DESD device is to provide an energy reservoir for balancing between renewable energy generation and electric energy consumption. The DESD subthrust is build upon the scientific advances and discoveries resulting through the Advanced Storage (AS) fundamental science subthrust;

Distributed Grid Intelligence (DGI): Develop the network based decision making systems and protocols which govern the operational needs of power management within a renewable energy hub, as well as and coordinate with other hubs to manage electric power over a wide area. The control system must encode not only operational concerns but also business policies in its decision making, enabling maximum power marketing;

Reliable and Secure Communications (RSC): Develop hardware and software needed to implement these very different communication streams with different levels of reliability and security. *Reliability* refers to the ability to perform and maintain data and control messages within a time constraint that guarantees the correct operation of the system if failures occur in software or hardware. *Security* is the protection of data in transit from any place without modification, corruption, jamming, or delay. This will be addressed over both public (Internet domain) and private (Intranet domain) communication infrastructures.

4.3. System Demonstration Thrust:

To demonstrate the center developed technologies as a system or sub-systems for renewable electric energy network delivery and management in demonstration testbeds.

Integrated Energy Management (IEM): Develop and integrate enabling technologies as a device or series of devices which serve intelligent independently managed devices for the bi-directional control of electric energy across a renewable energy network. Three primary challenges are *recognition and integration of DRER and DSED for plug-and-play capability, development of intelligent power and energy management schemes, and intelligent fault isolation and protection.*

Integrated Fault Management (IFM): Develop and integrate enabling technologies into a device which serves as an intelligent and independently managed circuit breaker for circuit protection within renewable energy electric distribution networks. The IFM will address five fundamental challenges relate to network protection: *intelligent fault identification and location; intelligent fault coordination and reclosing; wide area protection; pre- and post-fault reconfiguration; and advanced metering function.*

5. Need for the Center or Institute

The main motivation for forming FREEDM Center is to provide an organizational unit for a new Engineering Research Center (ERC) funded by the National Science Foundation at NC State, The ERC program is the premier program within the Engineering Division of the NSF, providing up to 10 years of federal funding to investigate nationally compelling, systems driven, engineering research programs. An ERC is a comprehensive program, with specific elements focused on research, education and outreach and engagement. The proposed ERC has been selected following an extensive, nationwide competition, and is intended to serve as a national center of excellence in issues of renewable energy electric grid infrastructure development. The NSF proposal and Reverse Site Visit presentation is attached for reference.

NC State will be the Lead University in the FREEDM Center, with partner academic institutions from across the United States and around the World.

In addition to the core NSF support, an industrial consortium will be established. 64 companies have provided letters of intent to join this industrial consortium. Successfully converting these companies to full members will immediately vault this Consortium to one of the largest ERC industrial programs in the nation.

This Center will immediately be a source of pride for the NC State community: bringing prestige, ranking, external industrial partners, international visiting scholars and world-wide visibility to our campus as a leader in addressing an urgent global challenge.

Para-phrasing a recent commentator discussing the issue of energy research: “Energy research needs to be the Apollo Project of the emerging generation. The FREEDM Center will be NC State’s, North Carolina’s and the USA’s Moon-shot.”

6. Similar Units

As far as we know, there is no center of excellence with a unified mission of research, education and outreach like FREEDM Center in the UNC system.

The Research Triangle Energy Consortium (RTEC) will be an innovation partner of the FREEDM Center. RTEC is a collection of complementary programs focused broadly in areas of energy science and technology from across the Research Triangle region, RTEC has initially formed between Duke, UNC, NC State and Research Triangle Institute. The RTEC Director has agreed to serve on the Energy Policy Advisory Board of the FREEDM Center.

7. Support

Basic support for the FREEDM Center comes from the National Science Foundation's Engineering Research Centers program. A budget of \$18.8M for the initial 5-year period has been proposed, with a 5-year extension period of a comparable level to be considered. Additional supplemental funding from NSF may be expected for complimentary Research Experiences for Undergraduates (REU); Research Experience for Teachers (RET) and International Programs. An industrial consortium will be established, for which 64 external companies or organizations have provided letters of support. The planned membership levels are: \$50,000 (full), \$15,000 (associate) and \$2,000 (affiliate). Support from the industrial consortium is expected to reach up to \$1.25 M annually. Significant support is also expected from the following additional sources:

- 1) Supplemental funding from FREEDM industry members;
- 2) FREEDM Center contracted research;
- 3) a 'FREEDM Fund' with a capital fundraising target of \$25M during the course of the NSF support. The FREEDM Fund is intended to provide sustaining support for the research, education and outreach programs of the FREEDM Center beyond the term of support by the NSF ERC program.

8. Space and Capital Equipment Requirements

During the NSF proposal phase, the FREEDM Center has shared administrative and research facility with the existing Semiconductor Power Electronics Center (SPEC), located in Partner I building on Centennial Campus.

In the NSF proposal, the Dean of Engineering has committed to 20,000 sq. ft. of newly constructed space for the ERC in the Centennial Science Center, to open on Centennial Campus. This new Center home will include approximately 15,000 sq. ft. of ERC headquarters office and low-bay lab space as well as 5,000 sq. ft. of dedicated high-bay lab space to house the 1MW FREEDM System demonstration site.

As transitional space during construction of this proposed new headquarters, the headquarters space for the ERC leadership team, support staff, and graduate students will be located in the 8,000 sq. ft. of space currently occupied by SPEC. Faculty researchers will be located in the Monteith Research Center (MRC), a 100,000-sq. ft. engineering research laboratory facility housing the NCSU Nanofabrication Facility, the Photonics Laboratory, the Analytical Instrumentation Facility, the Solar Center, and the Advanced Dielectrics Laboratory - all cutting-edge, shared laboratories that will support the Center's research agenda. These and the existing centers of excellence and cyber infrastructure will minimize the need for new equipment in the Center's initial years of operation.

The FREEDM Center has been recommended for funding by the ERC program manager of the National Science Foundation. As a financially significant, premier program for the NSF, Final Award Authority rests with the NSF Director, upon recommendation by the Director of the Engineering Division and ERC Program Manager. Such selection is pending: the proposed FREEDM Center Director has been un-officially notified that such award may be made within 45 days. Establishment of an organizational unit for the FREEDM Center as a Center unit is essential for NSF to complete this award to NC State University.