NATIONAL SCIENCE FOUNDATION
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ARLINGTON, VIRGINIA 22230

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Dear Colleague Letter: Research on Theory and Analytical Tools for Power Networks with High Levels of Renewable Generation

May 19, 2015

Dear Colleague:

With this Dear Colleague letter (DCL), the Division of Electrical, Communications and Cyber Systems (ECCS) of the National Science Foundation (NSF) announces its interest in receiving EArly-Concept Grants for Exploratory Research (EAGER) proposals to support research efforts in developing fundamental theory and analytical methodologies for power networks with high penetration of renewables.

Existing theoretical foundations for electric power networks were developed for traditional infrastructure in which electricity generation is relegated to large utilities that supply power based on accurate forecasts of demand. In the traditional framework, consumers use power and are charged by the utility for their consumption. With the rise of distributed generation (DG), some of which consists of renewable sources such as electric power generated using solar or wind resources, consumers can now also act as producers (hence the new name prosumers), and can sell excess power into the grid.

In classical power network models, the interaction of synchronous generators with the transmission grid and with system loads could be modeled reasonably well, and theory was developed for system stability, dynamic performance, control, reliability, state estimation, economic dispatch, and so on. For example, the theory of power system stability for traditional power networks includes general theorems on local and regional stability, and Lyapunov functions for systems including various types of loads (impedance, constant power). With the steadily increasing presence of nontraditional energy sources in the electric grid, especially renewable sources such as wind and solar, the classical modeling framework and associated analytical methodologies can no longer capture the system dynamics or provide reliable tools for planning, operations and control. Indeed, renewable generation sources may lack the inertia that is inherent in synchronous generators and may require introduction of power electronic controls that significantly change the nature of the network. They also present the planner and system operator with randomness that was not present in classical power generation. Field experience with large-scale deployment of renewable generation has required retrofits after deployment and sometimes policy changes due to unexpected negative impact on stability and power quality.

The purpose of this Dear Colleague Letter is to invite EAGER proposals for research to develop models and new theory for the emerging power grid with high levels of distributed generation from renewable sources. Successful proposals will pursue development of new tools for fundamental understanding of system behavior and control in the presence of volatile renewable energy resources, of prosumers incorporating renewable energy resources, and the expected growth of distributed storage systems. Proposals must contribute to the fundamental understanding of key issues such as modeling, stability, power quality, and implications for choice of control equipment and algorithms. With the volatility of

renewable sources, standard concepts of stability may need to be replaced with appropriate stochastic or risk-based concepts, and proposals addressing stability are free to move away from classical approaches if appropriate. Controls that can be considered include use of intelligent power electronics such as (but not limited to) smart inverters and transformers, as well as pricing incentives and demand response. Proposals should clarify the approach to be employed, the modeling framework to be used, and the qualifications of the researchers both in terms of expertise in power systems and in the applied mathematics to be employed in the research.

VISION

Recent years have seen significant expansion of renewable electricity generation and its integration into the power grid in the US and worldwide. This trend is motivated by several factors, including the desire to reduce carbon emissions in electricity production. While deployment of renewables and new so-called smart grid technologies have proceeded unabated, studies into fundamental systems understanding of the evolving power grid and associated principles for its operation have lagged. Moreover, field experience has shown that high levels of renewable generation can change the behavior of the grid, with potential undesirable effects on stability and power quality. Because of variability and volatility of renewable sources, ancillary services need to be provided, usually by utilities and distribution companies. Economic models for such services and for pricing of renewable generation are currently being discussed in the research community and in industry.

The purpose of this DCL is to encourage the research community to propose seed efforts that will make significant inroads on the fundamental modeling and analysis of the dynamics, performance and control methods for power grids with high levels of renewable generation. Successful research proposals will provide a strong plan for development of theory addressing one or more important issues of interest in this call. Also, research teams must include significant expertise in power systems as well as strength in needed applied mathematics. Proposals can address transmission and/or distribution networks. Efforts that outline purely computational explorations will not be deemed as responsive. Data analysis and computation can play an important role in a proposed research effort, but the overarching goal is to develop analytical understanding and principles that can be generally useful for a variety of power grid architectures and levels of renewable integration. The aim is to seek concepts that can play a transformative role in improving the understanding of power systems with high penetration of renewables.

EXAMPLE AREAS OF RESEARCH

A non-exhaustive list of example areas that could be explored under this program follows:

- Models and fundamental theory for stability of power grids with integrated wind and/or solar sources, taking into account the physical dynamics of these sources as well as their volatility.
- Principles and methodologies to guide renewable source expansion; theory for the effect of placement and level of renewables on power quality, the need for ancillary services, appropriate control mechanisms, and effect on system performance.
- Theory and methodologies guiding sizing and placement of various types of energy storage and reserves in the power grid.
- Theory for the interplay between pricing mechanisms, consumer behavior, and grid performance; and for principles for market design.
- Theory for how randomness of supply and system stability needs should influence the design of controllable demand response (“demand dispatch”).
- Theory for system health monitoring (dynamic security assessment, stability monitoring) for transmission and distribution systems in the presence of high levels of renewable generation.

This list is non-exhaustive, and the items are not mutually exclusive. Fundamental research on other important aspects of grid performance and control in the presence of high levels of renewables are encouraged and welcome.

EAGER SUBMISSION PROCESS

EAGER proposals must be submitted by June 19, 2015, 5:00 p.m., submitter's local time, via Fastlane or Grants.gov following NSF's Grant Proposal Guide (GPG) (Chapter II.D.2) instructions, and should clearly indicate the reason that the proposed work would be appropriate for EAGER support. (As noted in the GPG, EAGER is a funding mechanism for supporting exploratory work in its early stages on untested, but potentially transformative, research ideas or approaches. This work may be considered especially "high risk high payoff," for example, in the sense that it involves radically different approaches, applies new expertise, or engages novel disciplinary or interdisciplinary perspectives.) Please be sure that the title of your proposal starts with "EAGER: Renewables:". Proposals should address the project's long-term vision, specific goals to be accomplished during the course of the EAGER funding, and potential demonstrations to be developed. Proposals can involve more than one senior investigator from the same or complementary disciplines.

For further information, please contact the cognizant Program Directors:

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- Kishan Baheti, ENG/ECCS, rbaheti@nsf.gov

Sincerely,

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