Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID:**   **194-EH**

Enhancing Renewables Utilizing Generators of Retiring Coal Powerplants

Category: H. Proposals seeking $200,000 or less in funding

Sub-Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 183,301

Proposed Project Time Period for the Funding Requested: June 30, 2021 (2 yrs)

Summary:

Increasing penetration of renewables by retiring coal/gas powerplants affects grid stability. We will research retaining generators of retiring powerplants, supplemented by a small amount of battery storage, to maintain stability.

Name: Ned   Mohan

Sponsoring Organization: U of MN

Title: Professor - UMN

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           Minneapolis   MN   55455

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Interconnected North American Electric grid; Coal and Gas plants throughout Minnesota; Large generators in central powerplants; solar and wind lacking inertia; block diagram of proposed scheme

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

                        _____ If under $200,000, waive presentation?

Enhancing Renewables Utilizing Generators of Retired Coal Powerplants

I. PROJECT STATEMENT

Coal and gas power plants are being retired and are being replaced by wind and solar. If a large fraction of the electricity is generated by renewables that are variable in nature, the stability of the grid becomes a concern. To alleviate this, we will research the use of the electrical generators of the retiring power plants, supplemented by a small amount of battery storage.

Climate change is the greatest threat facing humanity today. This is due to the emission of greenhouse gases such as CO_2, generated from burning of fossil fuels for electricity generation and for transportation. At present, the Minnesota Pollution Control Agency projects that the Minnesota's greenhouse gas emissions will exceed the state's goal for 2025. Therefore, it is essential that existing coal and gas power plants be replaced by renewable sources such as wind and solar, and this renewables-based electricity be used for transportation in electric vehicles and trains.

Several coal plants are to be retired, and some plants are to be converted to natural gas (which has one-half the carbon footprint compared to coal). The ultimate goal ought to be the replacement of as many fossil-fuel burning plants as possible – both coal and natural gas. In addition, two nuclear plants in the state will be retired and no new nuclear plants are to be constructed.

Meeting our electricity need from wind and solar energy is challenging due to its variable nature. Power production can change suddenly if wind conditions change at a wind plant or cloud cover changes on a solar plant. Many companies such as Xcel Energy are planning to combine battery storage with renewables to counter variability of generation to a certain extent. However, if the renewable penetration is to increase significantly (e.g. beyond 50% of the electricity production), innovative solutions are needed to maintain the stability of the electric grid.

For grid stability, all generators on the grid must rotate "in-sync". The massive generators of coal and gas plants on the grid provide a large spinning mass (like a potter's wheel). If many such generators are retired, a sudden change in power production can cause the remaining generators to go out of sync and can lead to grid becoming unstable. Solar and wind power plants to not have any spinning mass and therefore do not help with grid stability.

When coal/gas plants are retired, their generators can be retained (without the turbine) to provide this spinning mass. In addition, these generator can also help maintain the grid voltage at its nominal value by controlling reactive power (different than the real power) that sloshes back-and forth between the generator and the grid. It is also well-known that a small amount of real power injection during changes in power production can be very beneficial in maintaining the electric grid stability. To allow this real power injection, we propose to integrate a small battery bank with the generator.

In retired power plants, to operate these generators without the turbine requires a power electronics converter which is sometimes called a Variable Frequency Drive (VFD). Similarly, real-power injection (or absorption) from a battery bank requires a power electronics converter. The solution proposed here has the following **innovative** components:

1) Reducing the cost by making dual-use of the power electronics converter to start the electrical generator and to use it for real power injection from the battery bank.

2) By distributed energy storage in the locations of retired assets, requiring only small-sizes batteries to maintain the grid stability and to earn frequency-regulation credits. And,

3) Combining the control functions for real-power injection with inertial and voltage support provided by the electrical generator, to minimize the size of the power electronics converter and the battery bank.

The goal of this project is to thoroughly investigate the grid voltage stability and the possibility of participating in the frequency-regulation market of the Midwest ISO (MISO). A model of the electrical grid system will be created using power-system simulation software (such as PSSE) and the behavior of the grid will be studied in detail with and without the proposed inertial support. The results of the study will be made available to utilities for rapid technology transfer.

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II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Modelling of Power Systems and Power Electronics

ENRTF BUDGET: $96,648

Outcome	Completion Date
1. Create a Simulation Model for the Minnesota Electric Grid	August 2019
2. Modelling of Retained Generators	December 2020
3. Model Power Electronic Converters and Transfer Switches	March 2020
4. Design Controllers for Voltage Excitation in Generators and Power Electronics converters for starting the Generator and Real-Power injection	July 2020

Activity 2: Thoroughly investigate various scenarios for disturbances such as sudden power changes at the existing penetration and under increased penetration of renewables

ENRTF BUDGET: $86,653

Outcome	Completion Date
1. Investigate various scenarios for disturbances such as sudden load changes at the existing penetration of renewables	*December 2021*
2. Repeat Activity 1 under increased penetration of renewables	*July 2021*
3. Final Report and the Dissemination of Results by holding a Workshop at UMN	*July 2021*

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding:

Name	Title	Affiliation	Role
Prof. Ned Mohan	Professor of ECE	University of Minnesota	Lead-PI
Dr. Carlos Grande-Moran	Principal Consultant	Siemens PTI	Consultant

B. Partners NOT receiving ENRTF funding:

Name	Title	Affiliation	Role
Pratap Mysore	Consultant	Retired from Xcel Energy	Consultant
Ganesh Velummylum	Senior Manager	NERC	Consultant
Dale Osborn	Consultant	Retired from MISO	Consultant

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

As we progress towards 100% renewable grid, many coal and gas plants will be retired. Under this scenario, keeping the grid stable will require innovative solutions. The goal of this project is to research if the generators of these retired powerplants can be retained and supplemented by a small amount of battery storage.

This research will have extremely significant impact in enabling renewables to reach a large percentage of electricity generation without significant expense. The findings of this research will be shared with the technical community enabling utilities such as Xcel to guide their future plans. It will also lead to further investigations by agencies such as NSF and DOE.

V. TIME LINE REQUIREMENTS:

Year 1:
Create the PSSE Model for the Minnesota Electric Grid; *Convert Generators of Retiring Assets into Synchronous Condensers*; *Model Power Electronic Converters and Transfer Switches*; *Design Controllers for Voltage Excitation in Synchronous Condensers and Power Electronics converters for starting the Synchronous Generator and Real-Power injection*

Year 2:
Investigate various scenarios for disturbances such as sudden load changes at the existing penetration of renewables; Repeat Activity 1 under increased penetration of renewables; Final Report and the Dissemination of Results by holding a Workshop at UMN.

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2019 Proposal Budget Spreadsheet

Project Title: Enhancing Renewables Utilizing Generators of Retired Coal Powerplants

IV. TOTAL ENRTF REQUEST BUDGET [*2*] years

| BUDGET ITEM (See "Guidance on Allowable Expenses")	AMOUNT	
Personnel: Principal Investigator Name: Dr. Ned Mohan Time: One month of summer /year Salary: $22,599 (Year 1), $23,052 (Year 2) Fringe Benefits: 7,571 (Year1), 7,722 (Year 2) Subtotal: $60,943 Responsibility: Overall scientific leadership and project management and will supervise and mentor student researchers supported on this project.	$	157,051
Personnel: Research Assistant (#1) Name: TBD Time: 50% appointment for 12 months Salary: $28,271(Year 1), $28,836 (Year 2) Fringe Benefits and Tuition: $19,458 (Year 1), $19,543 (Year 2) Subtotal: $96,108 Responsibilities: Development of the grid models for software simulations, development and testing of control algorithms and running scenario-based simulations.		
Professional/Technical/Service Contracts: Independent Consultant/Sub-contractor Name: Dr. Carlos Grande-Moran Time: 50 hours (Year 1), 20 hours (Year 2) Salary: $18,750(Year 1), $7,500 (Year 2) Benefits: None Responsibilities: Assisting with development of grid models for simulation	$	26,250
Equipment/Tools/Supplies:	$	-
Acquisition (Fee Title or Permanent Easements):	$	-
Travel:	$	-
Additional Budget Items:	$	-
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$	183,301

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

| SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	
Other State $ To Be Applied To Project During Project Period:	$ -	
In-kind Services To Be Applied To Project During Project Period: Consulting Time Donated: Pratap Mysore 25 hours per year at $100/hour	$ 5,000	*Committed*
In-kind Services To Be Applied To Project During Project Period: Consulting Time Donated: Ganesh Velummylum 25 hours per year at $100/hour	$ 5,000	*Committed*
In-kind Services To Be Applied To Project During Project Period: Consulting Time Donated: Dale Osborne 50 hours per year at $100/hour	$ 10,000	*Committed*
Past and Current ENRTF Appropriation:	$ -	
Other Funding History:	$ -	

Enhancing Renewables Utilizing Generators of Retiring Coal Powerplants

The North American Interconnected System consist of over 200,000 miles of high voltage transmission lines, and 10,000 generators.

Coal and Gas plants are distributed throughout MN
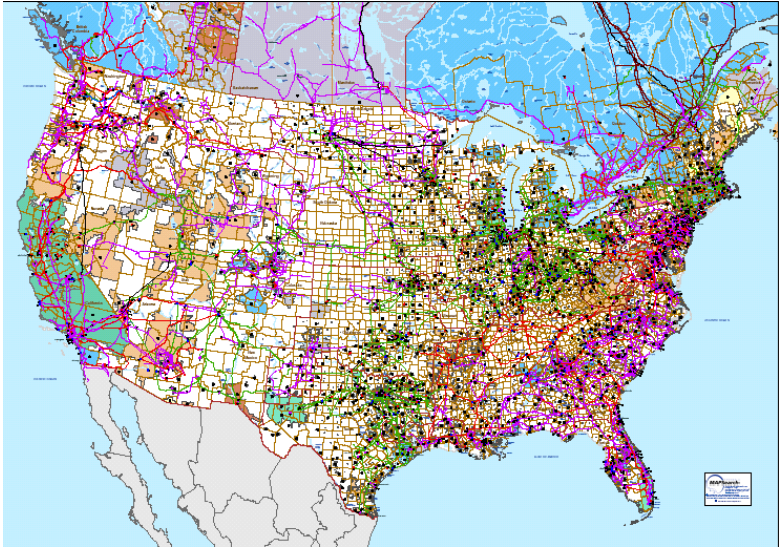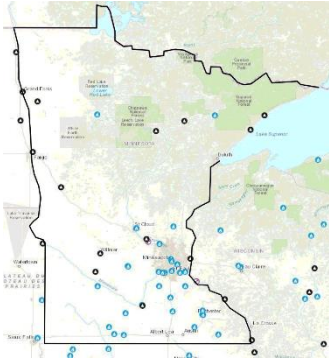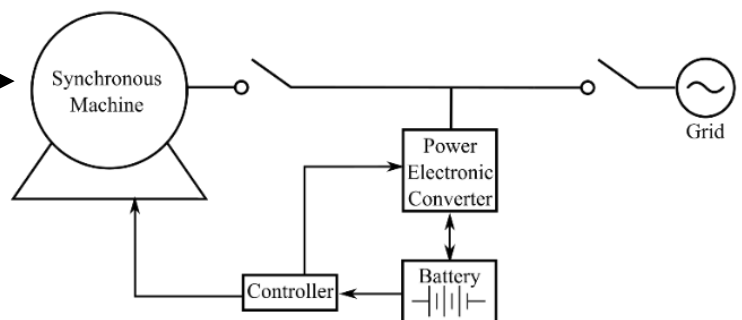

These plants have HUGE generators which help keep the grid stable.
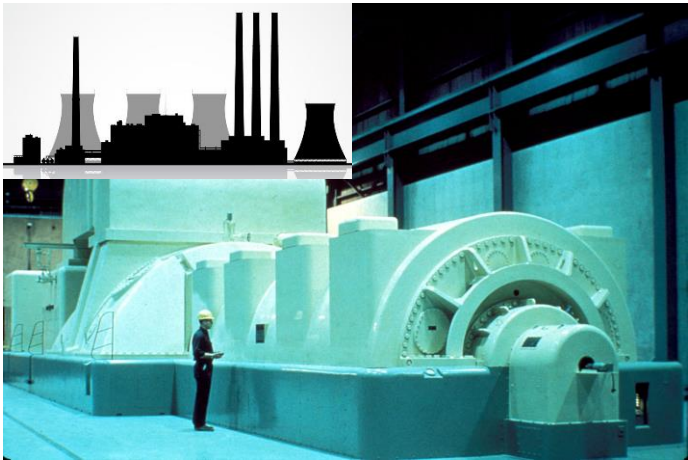
Solar and Wind lack this inertia, so grid stability is a concern

Proposed Solution: Retain the generator of retiring plants, supplemented by small battery storage to keep the grid stable.

Synchronous Machine — Power Electronic Converter — Grid

Controller — Battery

Prof. Ned Mohan (Project Lead PI) has been teaching and doing research at the University of Minnesota for the past 42 years where he is Oscar A. Schott Professor of Power Electronic Systems and Morse-Alumni Distinguished Teaching Professor. He did his PhD in Electrical Engineering and Master's in Nuclear Engineering, both from the University of Wisconsin – Madison. He has written 5 textbooks and cumulatively they have been translated into 8 languages including Chinese and Spanish. He has graduated 46 PhD students who have gone on to work in iconic companies such as GE, GM, Ford, Tesla, Apple, etc; many of his students are professors at universities such as the University of Wisconsin – Madison, the Arizona State University, Oregon State University, Marquette, etc.

Prof. Mohan's research is focused on increasing the penetration of renewables into the utility grid. He is the Director of the University of Minnesota Center for Electric Energy (UMCEE) which he helped establish in 1981 and that is supported by 6 major utilities in the region including Xcel, GRE and Minnesota Power.

He is passionate about combating climate change and has developed courses that are some of the most popular courses in the Department of Electrical and Computer Engineering. One of these courses is being taught in high schools as well through the College in the Schools (CIS) program at the University of Minnesota. For his teaching and research, he has received many research and educational awards. Prof. Mohan is a Fellow of the IEEE and in 2014, for his achievements in research and teaching, he was elected to the National Academy of Engineering.

Dr. Carlos Grande-Moran (Consultant) is Principal Consultant at Siemens PTI in Schenectady, New York. He works with the Network Consulting Services in the areas of Power System Dynamics and Controls, SSR and Torsional Analysis of rotating machinery, Excitation Systems, FACTS devices and DSP applications, Power system Restoration, Integration of Renewable Resources: Wind, PV, Battery Energy Storage Systems, Biomass and Hydro, Power System Operations, Power System Analysis software and Energy Control Centers, and teaches training courses in dynamic simulation and steady state analysis of power systems.

Dale Osborne (Consultant) was Transmission Planning Technical Director at Midwest ISO. His focus now concerns a sketch of a design of a Voltage Source Converter High Voltage Direct Current Network which would tie part of the Eastern Interconnection, WECC and ERCOT together to exchange Frequency Response, Wind, Solar and Load Diversity. The estimated benefits would more than pay for the annual cost of the HVDC Network with a 1.3:1 benefit to cost ratio. Value Based Planning processes developed by MISO are used to determine the design.

Pratap Mysore was the Director of System Protection in the power delivery group at HDR Engineering Inc. in Minneapolis, MN. He has over thirty five years of Power Systems Protection and Control design experience in the utility and the relay manufacturing area since obtaining his Master's degree in Electrical Engineering in 1976. Prior to joining HDR in 2011, he was Consulting Engineer –highest in-house technical position, at Xcel Energy for twenty three years in maintenance and substation engineering groups. He is actively involved in standards development work through IEEE Power Systems Relaying Committee and is presently the Secretary of the IEEE-PSRC. He has presented tutorials and papers at Minnesota Power Systems Conference and at Texas A&M protective relay conference. Pratap holds Bachelor and Masters degree in Electrical Engineering from Indian Institute of Science, India and is a registered professional Engineer in the state of Minnesota. He is also the recipient of the Twin Cities IEEE outstanding Engineer award in 2000.

Ganesh Velummylum joined the North American Electric Reliability Corporation (NERC) in 2014 as Senior Manager Reliability of Assessment. Ganesh is currently the Senior Manager of System Analysis with NERC. Ganesh has 18 years of experience in systems planning including running load flow, short circuit and stability studies. At NERC, Ganesh directs technical studies conducted by System Analysis Department which includes running load flow and dynamic studies in support of reliability initiatives, event analysis and integration of new technology to the bulk power system. Ganesh worked for Northern Indiana Public Service Company (NIPSCO) as Manager of Electric System Planning, where he oversaw Transmission Planning, Distribution Planning and System Protection Department. During his time at NIPSCO, he had to ensure the safe delivery of 30 MW of Inverter Based Resources (IBRs) which were interconnected to NIPSCO distribution system through the Feed–in Tariff (FIT) program. Prior to this, he worked for Lakeland Electric in Florida as the Manager of System Planning. In this role, he was responsible for Transmission and Distribution Planning, Resource Adequacy and Load Forecasting. Ganesh also has several years of transmission planning experience working for PJM Interconnection, where developed planning models and conducted generation and transmission interconnections studies. Ganesh earned his Bachelor of Science in Electrical Engineering and his Master of Science in Electrical Engineering from Oklahoma State University.