Energy Systems Innovation Center (ESIC)
Washington State University
Pullman, Washington

RESEARCH PROJECTS SUMMARY

October 2021

GridAPPS-D Project Support

PI: Anamika Dubey ***Co-PI(s):*** A. Bose

Sponsor: Battelle - Pacific Northwest National Laboratory

Award Amount: $250,000

Project Period: 04/2021 - 03/2022

Summary:

The goal of this work will be to support the GridAPPS-D Year 3+ efforts to evaluate potential future distribution system operating schemes. This includes how various architectures and controls strategies, as they relate to the GridAPPS-D platform, can be leveraged to facilitate future operating paradigms. The first step is a high-level road map of potential architectures, including what is being proposed in different regions and in different disciplines specifically in the control systems community. The roadmap will build on existing DOE activities, such as the Grid Modernization Initiative, but with a specific focus on distribution system operations. Additionally, the road map will include a survey of the key planning and operational challenges which are driving change in the industry. The architecture road map will also examine the exchange of information between the boundary of distribution and transmission systems, and how resources are engaged across this boundary. Along with an evaluation of architecture the work will include an examination and evaluation of a range of control structures. These include, but are not limited to, centralized, decentralized, and hierarchical. Finally, the impact of new technologies and the impact they may have on architectures will be evaluated.

Federated Predictive Analysis For Power Grid Using Multi Agent Models

PI: Arman Ahmed ***Co-PI(s):*** A. Srivastava

Sponsor: Battelle - Pacific Northwest National Laboratory - DGRP

Award Amount: $103,562

Project Period: 1/2021 - 9/2021

Summary:

This research will develop a decentralized scalable multi agent federated prediction/inference event analysis approach, answering following questions: 1. Given different power grid data sets and predictive models, how to enable profiling of raw data sets and predictive models? 2. How to enable and improve/optimize event analysis by making use of individual prediction models for event detection, localization and classification? 3. How to map observed data to decide what's the best prediction model for event analysis? 4. How to develop a federated inference/prediction approach for decentralized power grid analysis in scenarios involving cascading failures etc.?

Grid Supporting Controllers for Enabling 100% Penetration of Inverter Based Resources

PI: Saeed Lotfifard **Co-PI(s):**

Sponsor: Power Systems Engineering Research Center

Award Amount: $70,000

Project Period: 01/2021 - 08/2022

Summary:

Future power systems are envisioned to transition to significant amount of renewable energy. For example, California has mandated 100% renewable energy supply by 2045 and Minnesota has passed laws to move to full renewable energy supply by 2050. New technologies such as HVDC systems will be also integrated into the conventional AC systems forging hybrid AC-DC systems. To assure reliable integration of such a massive amount of renewable inverter-based resources (IBRs), the IBRs should be augmented with grid support capabilities and compatibility features. To this end, this project proposes a multi-pronged research effort as follows: i) Grid Firming Converters: proposing methods to achieve desired voltage and frequency supports from IBRs such as wind and PV farms in the future grid, ii) Grid Forming Converters: developing controls to enable cold start capability of a system with high penetration of renewables, and iii) Resilient Converters: Designing fault ride through capability and post-fault recovery control strategies to avoid massive dropouts of renewables following a disturbance such as what happened in the Western system.

Identification and Mitigation of T&D Operational Security Vulnerabilities in Inverter Dominated Power Systems

PI: Saeed Lotfifard ***Co-PI(s):***

Sponsor: Power Systems Engineering Research Center

Award Amount: $80,000

Project Period: 01/2021 - 08/2023

Summary:

This project seeks to identify operational security vulnerabilities in T&D assets that grid integration of massive amounts of inverter-based resources (e.g. wind and solar generations, HVDC systems and inverter-interfaced energy storages) creates. We will investigate how the likely cascading outages in inverter-dominated power systems will look like as the result of new dynamics and fault responses of inverter-based resources (IBRs). The project will focus on the following three main factors (1) Stability of inverters: we will analyze grid synchronization instability of IBRs and identify conditions that controllers of IBRs negatively affect the stability of the power systems at different operating modes of IBRs (i.e. grid following, grid supporting, and grid forming modes). (2) Protection systems response: we will identify the root cause of protection system vulnerabilities versus penetration levels of IBRs and develop mitigation methods, (3) Dynamic response of loads: we will identify impacts of distinct dynamics of active power distribution systems on transmission systems as the result of large integration of IBRs in distribution systems. According to the identified vulnerabilities, we will propose mitigation strategies. Investigations and mitigation methods will be verified using commercial software such as PSS/E, CAPE, ETAP, PSCAD and realistic power system models.

Tools for Keeping Your Power ON During Extreme Events

PI: Anurag Srivastava ***Co-PI(s):***

Sponsor: Commercialization Gap Fund/WSU

Award Amount: $37,948

Project Period: 01/2021 - 12/2023

Summary:

Power system operators struggle to keep the power on during extreme events caused by bad weather or cyber-attack, and advanced tools are needed to help them in keeping your power ON. The cost of a prolonged power outage caused by cyber attacks is likely to be included in the range of $36 billion to $156 billion. We are developing software tools for predictive power outage management and decision support during extreme events: CP-TRAM for transmission grid Operators and CANVASS for distribution grid operators. These tools minimize cyberattacks' impact on critical facilities by leveraging power engineering concepts and open source technologies in simulations, machine learning, and data visualization.

DARPA NOMARS Project

PI: Anurag Srivastava ***Co-PI(s):***

Sponsor: Siemens Corporation

Award Amount: $250,000

Project Period: 12/2020 - 03/2022

Summary:

Task 1. Power system – WSU will be supporting the project as subject matter expert and also will be working along with the siemens BU/siemens in modeling and simulation of the Power system. Task 2. Reliability & Risk – WSU will be supporting the project as a subject matter expert and also will be modeling the reliability and risk of the system with Siemens. We will review reliability databases including a) Non-electronic Parts Reliability Data (NPRD) (2016), b) Electronic Parts Reliability Data (EPRD) (2014) and c) Failure Mode / Mechanism Distributions (FMD) (2016) and develop probabilistic reliability and system characteristics based resiliency metric.

AGI GridSandbox

PI: Anurag Srivastava ***Co-PI(s):***

Sponsor: AGI - Battelle - Pacific Northwest National Laboratory

Award Amount: $80,000

Project Period: 08/2019 - 06/2021

Summary:

Task 1. Develop a web-based visual viewer & editor for the communications network configuration. The user should be able to select an existing configuration and the webpage visualizes it. The user can then add, update, and delete nodes and links. This includes configuration of applications on the selected node. Once editing finishes and the configuration is submitted, the configuration should be serialized and sent to the backend for processing. Task 2. Develop the link layer frame structure, transport function, and application layer fragment structures in ns-3 for messages using DNP3 protocol. A comprehensive implementation of the protocol is neither practical nor necessary. The goal of this task is to implement the message structures to support a subset of DNP3 functions that are necessary for our distribution-level use case, which is distributed transactive market clearing.

Source Analysis of Forced Oscillation Mechanisms

PI: Mani Venkatasubramanian ***Co-PI(s):***

Sponsor: Schweitzer Engineering Laboratories

Award Amount: $316,899

Project Period: 08/2020 - 08/2022

Summary:

In this project, we will develop the theory and computational tools for a) analyzing and identifying the source of forced oscillations in a best-case scenario assuming full availability of dynamic models and measurements, and b) gradually reducing the availability of model and measurement information in the formulation toward developing realistic source location algorithms which can be implemented in the near future.

HELICS+

PI: Anjan Bose ***Co-PI(s):***

Sponsor: Battelle - Pacific Northwest National Laboratory

Award Amount: $115,000

Project Period: 08/2020 - 01/2023

Summary:

WSU will build on the existing interfaces between transmission, distribution and communications. The steady state interface requires the interchange of data between the transmission and distribution power flow solutions in an iterative way to align the boundary bus voltages while taking into account the positive sequence model of the transmission interfacing with a three-phase model of the distribution. For the dynamic cosimulation, adding the interface with the communications system to that of transmission and distribution becomes important because many of the controls require the time behavior of communications to be taken into account. Moreover, the communications systems are not necessarily similar as the transmission and distribution SCADA systems are designed quite differently, and so does the data transfer of PMUs and AMI.

Grid of the Future White Paper

PI: Anjan Bose ***Co-PI(s):***

Sponsor: Lawrence Livermore National Laboratory

Award Amount: $40,000

Project Period: 08/2020 - 07/2021

Summary:

This white paper will have a focus on operations, with much of it looking at issues in control center design for the wide variety of different entities that are involved in transmission system operation. These include reliability coordinators (RCs), balancing authorities (BAs) and transmission operators (TOPs). Issues considered will include the integration of large numbers of measurements from sensors (such as PMUs), operation with a much larger number of controls and renewable generation sources, and the need to maintain situation awareness during a wide variety of different operating conditions including during severe system disturbances. The paper will also consider the needs for future developments in test beds and grid simulators, along with the increased coupling between the electric grid and other infrastructures. Overall this white paper will review and assess the new challenges now facing the operations of the US transmission system, with a focus on what challenges need to be addressed to insure that the grid is prepared for a variety of different conditions that could occur in the next decade or two.

Efficient UltRa Endpoint IoT-enabled Coordinated Architecture (EUREICA)

PI: Anurag Srivastava *Co-PI(s):*

Sponsor: Massachusetts Institute of Technology

Award Amount: $300,000

Project Period: 08/2020 - 07/2021

Summary:

Task 1. Develop a web-based visual viewer & editor for the communications network configuration. The user should be able to select an existing configuration and the webpage visualizes it. The user can then add, update, and delete nodes and links. This includes configuration of applications on the selected node. Once editing finishes and the configuration is submitted, the configuration should be serialized and sent to the backend for processing. Task 2. Develop the link layer frame structure, transport function, and application layer fragment structures in ns-3 for messages using DNP3 protocol. A comprehensive implementation of the protocol is neither practical nor necessary. The goal of this task is to implement the message structures to support a subset of DNP3 functions that are necessary for our distribution-level use case, which is distributed transactive market clearing.

Autonomous, Adaptive, and Secure Distribution Protection (a2SDP)

PI: Saeed Lotfifard ***Co-PI(s):***

Sponsor: US Department of Energy/SETO

Award Amount: $250,000

Project Period: 08/2020 - 07/2023

Summary:

We propose to develop an autonomous, adaptive and Secure Distribution Protection (a2SDP) system to meet the protection challenges created by extra high penetration of PV and other DERs. The a2SDP has the following features: (a) protection of all components of the system via setting-less relays which are the ultimately adaptive relays immune to the known issues of distribution systems with high penetration of DERs, i.e. (1) varying/reduced fault currents and direction and (2) changing topologies and characteristics as resources are switched in and out. (b) detection and protection against down conductors, (c) protection of power electronic interfaces, (d) real time distribution system fault locating, (e) distribution system reconfiguration in real time (fault location, isolation and service restoration (FLISR)), (f) operation of setting-less relays under reduced measurements in case of communication loss, (g) continuous dynamic model validation (feeder, PV, other DERs), and (h) cyber security enhancement by real time intrusion detection and command authentication. The proposed technology will be demonstrated on three feeders with substantial PV penetration (Dominion, Southern Company and Avista), covering three geographical areas with diverse solar patterns.

CAREER: Enabling Operational Resilience in Decentralized Electric Power Distribution Systems

PI: Anamika Dubey ***Co-PI(s):***

Sponsor: National Science Foundation

Award Amount: $500,638

Project Period: 02/2020 - 01/2025

Summary:

The research goal is to activate the resilience services from DERs during the extreme weather event by addressing the aforementioned challenges that limit the operational capabilities of grid during disruptions. Towards this goal, we propose three closely integrated thrusts: (1) Thrust 1 presents risk-based characterization of HILP events that motivates a novel approach for distribution grid planning with DERs that is driven by HILP events and advanced operations, thereby, addressing challenges C1 and C2; (2) Thrust 2 presents a decision-making framework for DER-driven service restoration and active island formation with consideration to grid's operational constraints, addressing challenge C3; and (3) Thrust 3 characterizes graph-theoretic proprieties to quantify the impacts of design parameters (such as droop-settings, time-delays, system losses) on the stability of droop-controlled DER energized islands, addressing challenge C4. Such characterization will inform the decision-making unit to design a restoration plan that admits not only operationally feasible but also stable energized islands.

Citadels

PI: Anamika Dubey ***Co-PI(s):*** A. Bose

Sponsor: Battelle - Pacific Northwest National Laboratory

Award Amount: $495,000

Project Period: 01/2020 - 01/2023

Summary:

The objective of this research is to tap the capability of distribution connected generation assets, specially microgrids to support grid functions during abnormal events. The proposed research will develop a distributed and peer-to-peer control approach to coordinate the operation of multi-microgrids to support bulk grid operation and critical load restoration during extreme events. The research will build upon the existing work on advanced applications developed by WSU for PNNL's GridAPPS-D platform – a platform for the advanced distribution management system (ADMS). WSU is currently implementing two applications to support distribution grid operations using distributed-connected generation resources. These applications are aimed at supporting the distribution grid during normal and abnormal events by utilizing DGs to support feeder voltages and restored critical loads via intentional islanding. However, algorithmically the proposed methods require a centralized decision-making platform such as an ADMS. Owing to the decentralization of the decision-support system in distribution systems that may be collocated with the distribution-connected microgrids and/or at utility-owned DG resources, there is a need to enable distribution decision-making. Moreover, given the emerging challenges for the bulk grid operations, the utility of distribution-connected resources in providing bulk-grid services, especially during abnormal conditions requires attention.

Framework for Simulating Transactive Microgrids

PI: Monish Mukherjee ***Co-PI(s):*** A. Bose

Sponsor: Battelle - Pacific Northwest National Laboratory - DGRP

Award Amount: $110,174

Project Period: 01/2020 - 12/31/2021

Summary:

Advances in electricity generation and storage technologies coupled with declines in cost, the proliferation of smart metering and favourable regulation are inducing a transformation of a large share of electricity consumers in prosumers – producing or storing electricity at home through solar panels, electric vehicles, batteries and other means [1]. In an attempt to empower prosumers, the traditional centralized (top-down) approach of electricity markets are reformed. Californian utilities are aggressively reformulating the current market structures and tariffs to incentivize distributed energy resources (DERs) [2]. The state of New York is implementing its Reforming the Energy Vision (REV) strategy to promote decentralized renewable generation and management and encourage prosumers to actively participate in the electricity system [3]. The changing electricity industry landscape provides an unprecedented opportunity for positive, synergistic interactions via smart prosumer grids. Microgrids which were initially popularized to increase resiliency of power systems, are finding their place in this landscape as economic transactive agents capable of providing a platform not only to incentivize prosumers for energy resources (local generation, flexible load) but also to simplify market regulation and interface with the wholesale system operator [4]. Such prosumer centric microgrids can operate in connection with the main grid providing grid services for bulk power and distribution system operators. The microgrids can also operate autonomously in 'islanded mode' optimizing the prosuming services at the microgrid level and engaging in bilateral trades with other microgrids, prosumers or consumers. The proposal aims at developing a co-simulation

CPS: DFG Joint: Medium: Collaborative Research: Data-Driven Secure Holonic control and Optimization for the Networked CPS (aDaptioN)

PI: Anurag Srivastava ***Co-PI(s):*** A. Hahn, D. Bakken, and Y. Wu

Sponsor: Massachusetts Institute of Technology

Award Amount: $561,000

Project Period: 01/2020 - 12/2022

Summary:

The proposed decentralized/distributed control and optimization for the critical cyber-physical networked infrastructures (CPNI) will improve the robustness, security and resiliency of the electric distribution grid, which directly impacts the life of citizens and national economy. The proposed control and optimization architectures are flexible, adapt to changing operating scenarios, respond quickly and accurately, provide better scalability and robustness, and safely operate the system even when pushed towards the edges by leveraging massive sensor data, distributed computation, and edge computing. The algorithms and platform will be released open source and royalty-free and the project team will work with industry members and researchers for wider usage of the developed algorithms for other CPNI. Developed artifacts as part of the proposed work will be integrated in existing undergraduate and graduate related courses. Undergraduate students will be engaged in research through supplements and underrepresented and pre-engineering students will be engaged through existing outreach activities at home institutions including Imagine U program and 4-H Teens summer camp programs and the Pacific Northwest Louis Stokes Alliance for Minority Participations. Additionally, project team plans to organize a workshop in the third year to demonstrate the fundamental concepts and applications of the proposed control and optimization architecture to advance CPNI. Developed solutions can be extended for range of applications in multiple CPNIs beyond use cases discussed in the proposed work. While the proposed control architecture with edge computing offer great potential; coordinating decentralized control and

Development of Prototypical Communications System Models for Cyber-Physical Resiliency Analysis

PI: Gowtham Kandaperumal ***Co-PI(s):*** A. Srivastava

Sponsor: Battelle - Pacific Northwest National Laboratory - DGRP

Award Amount: $103,151

Project Period: 10/2019 - 09/2021

Summary:

This work supports the simulations and analysis efforts to determine the impact of communications systems on the operations of resiliency based microgrids. This will build on the work of GMLC project 1.4.15 to examine how communications systems with mixed media (e.g. fiber optics and wireless in the same network), and systems with mixed traffic (e.g. control systems operating on the same network as AMI) impact resiliency based controls. The work supports multiple project efforts, including the Microgrid R&D program and the Duke Resilient Distribution System (RDS) project.

Data-Driven Control of DERs & Hybrid PV Plants for Enhancing Voltage Stability Over Multiple Timescales

PI: Anurag Srivastava ***Co-PI(s):***

Sponsor: Power Systems Engineering Research Center/National Science

Award Amount: $220,000

Project Period: 10/2019 - 09/2021

Summary:

This project addresses control & coordination of distribution system assets like DERs and hybrid PV plants with storage to provide real-time active/ reactive power support to mitigate voltage instability in transmission systems over multiple timescales. A novel controller for hybrid PV plants will be developed that delivers the requested P/Q/V to the bulk grid. The control is robust to PV variability and disturbances in the grid and exploits the capabilities of DERs like storage. We will utilize physics-based data driven techniques to develop the control scheme of DERs and hybrid PV plants for mitigating the voltage instability in real-time using measurements from PMUs and micro-PMUs. The hierarchal structure of the distribution topology will be used to effectively train and deploy the data driven controls using message-passing machine learning architecture. The control strategies will mitigate/contain inverter trip cascading during delayed voltage recovery events (seconds timeframe) and ensure a safe stability margin for credible scenarios in the next few dispatching intervals (10 min-1 hr). We will leverage existing Transmission-Distribution (TD) co-simulation platform (PSSE/GridLab-D & OpenDSS) to implement proposed methodologies demonstrating their ability to mitigate voltage instability on practical systems while capturing TSO-DSO interactions. Further validation of the proposed data-driven methods will be done using a hardware-in-loop (HIL) real-time T&D test bed to ensure that controls are effective under noisy measurements & communication delay.

Grid-Ready Energy Analytics Training with Data (GREAT)

PI: Anamika Dubey ***Co-PI(s):*** A. Srivastava

Sponsor: Electric Power Research Institute

Award Amount: $195,000

Project Period: 09/2019 - 05/2021

Summary:

The research goal is to activate the resilience services from DERs during the extreme weather event by addressing the aforementioned challenges that limit the operational capabilities of grid during disruptions. Towards this goal, we propose three closely integrated thrusts: (1) Thrust 1 presents risk-based characterization of HILP events that motivates a novel approach for distribution grid planning with DERs that is driven by HILP events and advanced operations, thereby, addressing challenges C1 and C2; (2) Thrust 2 presents a decision-making framework for DER-driven service restoration and active island formation with consideration to grid's operational constraints, addressing challenge C3; and (3) Thrust 3 characterizes graph-theoretic proprieties to quantify the impacts of design parameters (such as droop-settings, time-delays, system losses) on the stability of droop-controlled DER energized islands, addressing challenge C4. Such characterization will inform the decision-making unit to design a restoration plan that admits not only operationally feasible but also stable energized islands.

Collaborative Research: Online Data Stream Fusion and Deep Learning for Virtual Meter in Smart Power Distribution Systems

PI: Saeed Lotfifard ***Co-PI(s):***

Sponsor: National Science Foundation

Award Amount: $200,000

Project Period: 09/2019 - 08/2022

Summary:

The proposed research makes the following major contributions. (1) We design a class of ad-hoc data fusion algorithms that can exploit and extract reliable values from heterogeneous measurement data streams. These algorithms retrieve and identify reliable true values in an ad-hoc manner whenever required, to ensure provable time cost and response time for real-time learning. (2) We devise a class of online stream learning algorithms to estimate virtual measures. These algorithms seamlessly integrate data-driven and physical models to fine-tune model parameters, and perform online model updates only when necessary, to ensure the feasibility over fast measurement data streams. (3) The proposed Virtual Meter closes the loop of interaction between data-driven methods and physics-based methods to provide enhanced estimation of real-time value of loads and states of power distribution systems. To ensure the practical applications of the proposed techniques, we will work with our collaborator Avista to evaluate these techniques with real-world use cases and metrics.

Nonlinear Analysis of Power System Oscillations using Models and Measurements

PI: Mani Venkatasubramanian ***Co-PI(s):***

Sponsor: Power Systems Engineering Research Center

Award Amount: $200,000

Project Period: 7/2019 - 7/2021

Summary:

With the growth of renewable energy sources, the transmission flow patterns are changing in power grids all over the world. Moreover, fast dynamic devices that are built into the newer power electronic based energy interfaces and advanced control systems are interacting with the traditional power grid controls in unknown ways. These complex and nonlinear dynamic mechanisms are impacting on the small-signal and transient stability properties of the power system. This project will focus on the study of nonlinear phenomena in the presence of poorly damped oscillatory modes for understanding the impact of the nonlinearities on transient stability properties. Specifically, the analysis will develop methods to distinguish between supercritical (nonlinear stable) versus subcritical (nonlinear unstable) types of oscillatory behavior. Model based simulation and bifurcation analytic studies will be used to derive insight and theoretical understanding, and the project will then extend the analysis to measurement based algorithms to the extent possible. The project will also work on speeding up time-domain ambient modal analysis methods for reducing their computational burden, and develop efficient methods for processing real-time alarms by combining the estimation results from multiple ambient and ringdown analysis algorithms.

SolarSTARTS: Solar-Assisted State-Aware and ResilienT infrastructure System

PI: Anurag Srivastava ***Co-PI(s):***

Sponsor: University of Utah/US DOE-SETO

Award Amount: $399,863

Project Period: 7/2019 - 6/2022

Summary:

For this collaborative project, WSU will focus on following specific tasks: Task 1: Enhancing real time HIL testbed Task 2: Modeling candidate resiliency enabling algorithms Task 3: Testing and validation of the resiliency enabling technology.

Syncrophasor Analytics for SDG&E

PI: Mani Venkatasubramanian ***Co-PI(s):***

Sponsor: San Diego Gas & Electric

Award Amount: $540,000

Project Period: 05/2019 - 08/2021

Summary:

The project includes research on the following applications based on synchrophasor measurements: a) oscillation monitoring system, b) generator paramter validation, c) transmission line parameter estimation, d) forced oscillation source location, and e) dynamic line rating of transmission lines.

Robust Distributed Control for Power Sharing in Islanded Industrial Microgrids

PI: Anamika Dubey ***Co-PI(s):*** S. Roy

Sponsor: Schweitzer Engineering Laboratory

Award Amount: $267,770

Project Period: 05/2019 - 5/2021

Summary:

This project will outline and address specific challenges in developing distributed control solutions for islanded lossy microgrids, focusing primarily on the power-sharing problem. Challenges are anticipated given the nonconvex three-phase power system models, the need to build distributed secondary controls around fast droop-based local controls, and the constrained and noisy nature of communication channels. Thus, although there is a significant literature on distributed control systems and even their applications to power systems, we expect that new distributed control architectures will be needed for islanded microgrids, which take into account practical considerations regarding distribution-system models (e.g. network losses), legacy controls, and failure-prone communications. We anticipate that these algorithms may draw on recently-developed concepts for input-output dynamic analysis and sparse controller design for linear and nonlinear networks, which were developed in the controls-engineering community.

Clean Energy Fund II

PI: Anjan Bose ***Co-PI(s):***

Sponsor: Avista Corporation

Award Amount: $200,000

Project Period: 02/2019 - 12/2021

Summary:

Data Sensing: High resolution input data is required to obtain a detailed prediction of the building performance. High resolution information about hourly weather information, building geometric and HVAC description (such as multi-zone airflow and extensive HVAC specification capabilities) are required to assist calibration. This task mainly concentrates on the application of specialized software and hardware tools (e.g. Power Quality meters for high resolution end use power data) to gather and analyze data over short period in order to calibrate building models along with existing long term data. Model Calibration: In order to use the building models with any degree of confidence, it is necessary to calibrate the Building Energy Performance Simulation Model (BEPS) with the measured building performance data. This task involves using suitable calibration algorithm to get reasonable agreement between the measured and simulated data. It also involves incorporating model parameter uncertainty in the building models in order to predict the 'equifinality' of the simulation models.

Bilateral Contract Design and Retail Market Development for Flexible Electric Power Systems with Residential Demand-Side Participation

PI: Anamika Dubey ***Co-PI(s):***

Sponsor: Sloan Foundation

Award Amount: $249,785

Project Period: 01/2019 - 12/2022

Summary:

Specifically, the project objectives are to (1) estimate the customer's willingness-to-pay for electricity at the granularity of individual household using recently developed choice-experiment type estimation; (2) translate each customer's willingness-to-pay to bilateral contracts in the form of load reduction or short-term load curtailment; and (3) develop strategies for a profit-seeking aggregator to bid in the wholesale market while simultaneously maximizing the current and future value of the demand response contracts and ensuring the satisfaction of critical operating constraints for the power distribution systems.

Input-Output Metrics for the Power-Grid's Swing Dynamics

PI: Mani Venkatasubramanian ***Co-PI(s):***

Sponsor: Power Systems Engineering Research Center

Award Amount: $100,000

Project Period: 01/2019 - 12/2020

Summary:

New technologies are providing new opportunities for wide-area control of poorly-damped oscillations in the bulk power grid. A foundational need in wide-area controller design is the assessment of input-output channel properties of the power system dynamics, in addition to its internal or modal properties. The purpose of this project is to undertake a comprehensive analysis of a suite of input-output metrics for the system dynamics, from both numerical and graph-theoretic perspectives. The metric analysis will then be used to develop model-reduction techniques that maintain key input-output properties, and to support estimation of channel properties from ambient synchrophasor data.

GridAPPS-D Project Support

PI: Anamika Dubey ***Co-PI(s):*** A. Bose

Sponsor: Battelle - Pacific Northwest National Laboratory

Award Amount: $250,000

Project Period: 12/2018 - 02/2021

Summary:

The goal of this work will be to support the GridAPPS-D Year 3+ efforts to evaluate potential future distribution system operating schemes. This includes how various architectures and controls strategies, as they relate to the GridAPPS-D platform, can be leveraged to facilitate future operating paradigms. The first step is a high-level road map of potential architectures, including what is being proposed in different regions and in different disciplines specifically in the control systems community. The roadmap will build on existing DOE activities, such as the Grid Modernization Initiative, but with a specific focus on distribution system operations. Additionally, the road map will include a survey of the key planning and operational challenges which are driving change in the industry. The architecture road map will also examine the exchange of information between the boundary of distribution and transmission systems, and how resources are engaged across this boundary. Along with an evaluation of architecture the work will include an examination and evaluation of a range of control structures. These include, but are not limited to, centralized, decentralized, and hierarchical. Finally, the impact of new technologies and the impact they may have on architectures will be evaluated.

FW-HTF Theme 1: Collaborative Research: Augmenting and Advancing Cognitive Performance of Control Room Operators for Power Grid Resiliency

PI: Anurag Srivastava ***Co-PI(s):*** A. Bose, A. Hahn, S. Lotfifard and P. Whitney

Sponsor: National Science Foundation

Award Amount: $1,394,337

Project Period: 10/2018 - 9/2023

Summary:

Goals of this proposed project are focused on augmenting cognitive performance of the human operator through human-focused decision support tool and better training during these extreme events through following carefully designed tasks to: i) analyze cognitive flexibility (CF) and performance of power grid operators during extreme events ii) augmenting cognitive performance of human operators through advanced machine learning based decision support tools and adaptive Human-Machine system, iii) CF-driven improved training simulators for advancing cognitive performance of human operators for enhanced grid resiliency. CF is the ability to use feedback to redirect decision making given fast changing system scenarios.

Resilient Alaskan Distribution system Improvements using Automation, Network analysis, Control, and Energy storage (RADIANCE)

PI: Anurag Srivastava ***Co-PI(s):***

Sponsor: Battelle - Idaho National Laboratory

Award Amount: $360,000

Project Period: 01/2018 - 12/2020

Summary:

WSU will contribute to this project by providing resilience metrics-based framework for quantifying performance of the Cordova grid with multiple networked microgrids. New resiliency metrics and combination of multiple non-commensurable metrics will be developed as part of this project. The metrics will be used for resilience analysis. This resilience metrics framework will be used for establishing a baseline for the Cordova grid and performance improvements will be quantified against the baseline.

PMU: UI-ASSIST: US-India collAborative for smart diStribution System wIth Storage

PI: Noel Schulz ***Co-PI(s):*** A. Bose, A. Hahn, C. Horne and A. Srivastava

Sponsor: US Department of Energy/EERE

Award Amount: $7,500,000

Project Period: 10/2017 - 10/2022

Summary:

The overall objective of this project is to evolve the future distribution grid that will allow the continuing increase of Distributed Energy Resources (DER) penetration towards a carbon-free electricity system. The research proposed here leads to the fully conceptualized Smart Distribution Grid that optimally utilizes Grid Storage. The development is then actualized using nine different test beds, and finally validated with field demonstrations at 10 different sites.

AGGREGATE: dAta-driven modelinG preservinG contRollable dEr for outaGe mAnagemenT and rEsiliency

PI: Anurag Srivastava *Co-PI(s):* A. Dubey

Sponsor: US Department of Energy

Award Amount: $1,500,000

Project Period: 05/2017 - 06/2021

Summary:

Objectives of the proposed research are to improve the observability and controllability of the distribution system specifically to improve system modeling for outage management and enhance system resiliency using controllable DER. The following technical objectives are addressed to develop the proposed architecture: Objective 1 – Improving System Modeling for Outage Management System: Data-driven models will be developed for reduced distribution system model while preserving controllable DERs. The models will be integrated into the existing fault detection, isolation, and restoration (FDIR) architecture to improve system outage modeling with enhanced controllable assets. Objective 2 –Controllability and Observability of Distribution System: Using non-linear quasi-static model for distribution systems, voltage-current controllability and observability methods will be developed. The system model will be reduced by mathematical analysis for enhanced observability and controllability of DERs. Metrics will be developed and used to measure the controllability and observability of a distribution system with DERs. Objective 3 – Architecture for DER-based Restoration and Outage Management: The proposed research work will advance the state-of-the-art outage management architecture by: 1) developing novel feeder restoration algorithms using DERs and Microgrids, 2) improving feeder response using DER control approach for real-time power balance and voltage regulation in the restored network, 3) improving outage management and outage modeling using real-time distribution system models and accurate load and DER models, and 4) specifying cyber security requirements for a resilient outage management

Development of an Open-Source Advanced Distribution Management System (ADMS)

PI: Anamika Dubey ***Co-PI(s):*** A. Bose

Sponsor: Battelle - Pacific Northwest National Laboratory

Award Amount: 532,902

Project Period: 08/2016 - 02/2021

Summary:

As part of the Department of Energy Office of Electricity Delivery & Energy Reliability (DOE-OE) Grid Modernization Laboratory Consortium (GMLC), Pacific Northwest National Laboratory (PNNL) has been tasked with leading the Advanced Distribution Managements System (ADMS) Platform Program. In this program PNNL will build an open-source ADMS platform to overcome the barriers to ADMS deployment; the open-source platform will be called GridAPPS-D. The GridAPPS-D platform will facilitate the integration of operational systems, provide a testing and evaluation framework to quantify benefits, and provide an extensible development environment that is open-source and accessible to all industry stakeholders. Additionally, the GridAPPS-D platform will be repeatable at other laboratories, Universities, and vendor facilities to ensure that the project develops capabilities that benefit the largest possible number of industry stakeholders.