Fact Sheet - April 2019 DOE Award Selections:

Research and Development of the Use of Big Data, Artificial Intelligence, and Machine Learning Technology to Leverage the Power of Grid Sensors

On April 17, 2019, the Department of Energy (DOE) announced the award of nearly $7 million to explore the use of big data, artificial intelligence (AI), and machine learning technology and tools to derive more value from the vast amounts of sensor data already being gathered and used to monitor the health of the grid and support system operations. These projects are expected to inform and shape the future development and application of faster grid analytics and modeling, better grid asset management, and sub-second automatic control actions that will help system operators avoid grid outages, improve operations, and reduce costs.

Below are details about the eight award recipients and the projects.

Performer: Iowa State University of Science and Technology
Partners: Electric Power Group (EPG); Google Brain; IBM
Title: Robust Learning of Dynamic Interactions for Enhancing Power System Resilience
Federal Funds: $1,000,000
Cost Share: $250,000
Total Project Value: $1,250,000
Summary: This project leverages robust graphical learning and PMU data to learn the dynamic interactions of electrical grid components to improve power system resilience, using the team's existing big data and machine learning capabilities. The dynamic interaction graphs learned from unstructured PMU data will be used to extract actionable intelligence for cascading outage modeling, prediction and mitigation as well as anomalous event detection. The main benefits are significant enhancements in system resilience and understanding of anomalous event patterns and cascading outages through unstructured learning from massive PMU data. The outcomes include dynamic interaction graphs, catalogues of anomalous event signatures and patterns, and a cascading outage analyzer. These outcomes will be validated through offline and online benchmarking with EPG's commercial PMU software package. The project results will be available on IBM AI OpenScale's cloud environment. The technical outcomes will also be disseminated in publications, presentations and technical reports.

Performer: Schweitzer Engineering Laboratories, Inc.
Partners: Oregon State University
Title: Machine Learning Guided Operational Intelligence from Synchrophasors
Federal Funds: $600,000
Cost Share: $150,000
Total Project Value: $750,000
Summary: Schweitzer Engineering Laboratories (SEL), in collaboration with Oregon State University (OSU), will extend previous research in both unsupervised and supervised techniques for power system pattern identification, classification, and anomaly detection as well to produce advanced tools for the enhanced reliability, efficiency, and safety of the US power system. The project team perform PMU data preprocessing and mitigation of data anomalies and include work to design procedures and tools to mitigate challenges with PMU data availability and

integrity. The team will then focus on identifying event features and identification of precursor conditions and associated events. A unified research effort will focus on combining technically sound and scientifically robust machine learning analytics with SEL's next generation synchrophasor analytics software. The project team will emphasize development of trustworthy and usable tools in order to advance the state of the art of machine learning in power systems operations.

Performer: The Regents of the University of California
Partners: Electric Power Group (EPG); FortisBC Inc.; Michigan Technological University (MTU); Southern California Edison (SCE)
Title: Discovery of Signatures, Anomalies, and Precursors in Synchrophasor Data with Matrix Profile and Deep Recurrent Neural Networks
Federal Funds: $999,415
Cost Share: $356,430
Total Project Value: $1,355,845
Summary: The goal of this project is to apply proven scalable, multidimensional, and robust big data and machine learning technology on PMU data to identify anomalous events, create a catalog of event signatures, predict asset health, and learn precursors to instability phenomenon. The project team will use the revolutionary multidimensional time series data mining technology Matrix Profile and the corresponding computational algorithms to automatically detect anomalous events and create a catalog of signatures/motifs for each type of events. Second, the project team will use the maximum mutual information theory to train and optimize the structure and hyperparameters of deep recurrent neural networks, which are capable of predicting asset health and learning precursors to frequency, voltage, and rotor angle instability in the national power grids. Third, the unsupervised and supervised machine learning, and data mining technology will be implemented on graphical processing unit (GPU) platforms and validated in off-line and real-time testing environments. The main deliverables from this project are the advanced machine learning and data learning algorithms and software packages, which are tailored for mining large-scale and multidimensional synchrophasor data. The algorithms and software packages will be crucial in enhancing the wide area monitoring, visualization, protection, and control applications. Open-source versions of the algorithms can be downloaded on GitHub or access them through EPG's commercial software packages, which will integrate the advanced data mining and machine learning algorithms.

Performer: Board of Regents, NSHE obo University of Nevada, Reno
Partners: Arizona State University (ASU); IBM; Virginia Tech
Title: A Robust Event Diagnostics Platform: Integrating Tensor Analytics and Machine Learning Into Real-time Grid Monitoring
Federal Funds: $596,700
Cost Share: $149,502
Total Project Value: $746,202
Summary: The project aims to develop a robust event diagnostics (RED) platform that can effectively analyze and discover the information hiding within the PMU data for effective real-time grid monitoring. The developed RED platform will serve as an innovative advisory tool to reliably identify key events and discover new insights about the events and grid characteristics in the PMU data, and contribute to the efficient, safe, reliable operation and design of the nation's

electric system. The RED platform will be equipped with key functionalities that can take into account the PMU data losses and quality degradation and provide a scalable approach to diagnose and visualize real-time power system conditions. Specifically, the data quality assessment and completion component of the RED platform leverages tensor analytics tools to detect the bad PMU data and recover the bad/missing PMU data based on the spatiotemporal characteristics of the PMU data, which will provide an innovative tool for PMU data management. The recovered data will be used for early detection and localization of potential fault events, which will provide an early warning tool to the operator for grid operation and management. The proposed robust event classification using adversarial machine learning will yield deep learning of PMU data and generate robust and accurate event classification against potential adversaries or noise and perturbation in PMU data. All the functionalities of the RED platform will be offered to the operator via an interactive user interface, which will enable the operator to make informed decisions and respond in a timely manner. IBM will implement the innovative data analytics tools developed in this project on the RED platform and make it a stand-alone advisory tool. The successful implementation of the RED platform is expected to make a significant economic impact and potentially save the billions of dollars due to lack of effective real-time diagnosis.

Performer: General Electric Company
Partners: GE Grid Solutions
Title: PMU-Based Data Analytics using Digital Twin and PhasorAnalytics Software
Federal Funds: $999,887
Cost Share: $249,972
Total Project Value: $1,249,859
Summary: The project team will explore and evaluate General Electric's (GE's) commercial toolsets Digital Twin and PhasorAnalytics to identify, classify, evaluate, and validate features and signatures for the events applications with the aim of enhancing grid reliability, security, and efficiency. The Digital Twin platform is a horizontal data driven software with industry proven analytics and model library which can predict, describe, and prescribe the behavior of an asset or process via physics and AI/ML models. The featured module in the Digital Twin Platform includes Big Data Toolkit, feature engineering framework, multivariate timeseries temporal modeling, and early warning. PhasorAnalytics is a state-of-the-art synchrophasor engineering analysis package that has dedicated synchrophasor data ingestion, visualization, and domain knowledge-based analytics. Bringing them together to analyze the DOE provided dataset will maximize the use of data-driven and domain knowledge driven analytics for insight extraction. The key result of this project will be a set of identified features and insights with a fully validated PMU-based data analytics platform, including: (1) identified new events not shown in the event log or state estimator; (2) guidance on feature-based real-time load modeling and monitoring, asset health monitoring, cybersecurity monitoring, provided relevant features can be found in the DOE-offered datasets; (3) validated insights and signatures for industry-wide reuse; and (4) a commercialization plan to integrate the validated insights and analytics into GE's PhasorAnalytics software.

Performer: Siemens Corporation, Corporate Technology
Partners: Siemens Digital Grid; Siemens Industries and Drives (Mindsphere); Southern Methodist University; Temple University
Title: MindSynchro
Federal Funds: $700,000
Cost Share: $313,882
Total Project Value: $1,013,882
Summary: The project will demonstrate the detection of relevant grid events based on data-driven analytics applied to phasor measurement units (PMU) data and other complementary grid data. Machine learning methods will be employed for time series classification with the goal of detecting the occurrence of events and their precursors. Siemens Big Data platform MindSphere will be used for implementation and testing of the analytics solution. Services available in the platform will be leveraged and new applications will be developed to suit the specific needs of the project. MindSphere provides the resources and scalability required for processing extensive industrial datasets such as the one associated to this project.

Performer: Ping Things, Inc.
Partners: None
Title: Combinatorial Evaluation of Physical Feature Engineering and Deep Temporal Modeling for Synchrophasor Data at Scale
Federal Funds: $864,000
Cost Share: $275,000
Total Project Value: $1,139,000
Summary: The project will train and evaluate event and anomaly detection, classification, and real-time inferencing neural models and report on their performance when employed on live PMU data streams. The goals of the project are (1) identify physical features that can be extracted from PMU time series data, temporal neural topologies that best model events and anomalies, and the hyperparameters that optimize model behavior during both training and operation; (2) compare and contrast the performance of models trained on individual PMU streams, multiple streams, and whole networks; and (3) produce production ready data transformation and inferencing utilities for immediate use on the grid. This project will develop a hierarchical suite of inter-related deep neural models on individual and multiple synchrophasor data streams.

Performer: Texas A&M Engineering Experiment Station
Partners: OSIsoft LLC; Quanta Technology, LLC; Temple University
Title: Big Data Synchrophasor Monitoring and Analytics for Resiliency Tracking (BDSMART)
Federal Funds: $1,000,000
Cost Share: $696,560
Total Project Value: $1,696,560
Summary: The project will utilize Big Data Analytics (BDA) to automate monitoring of synchrophasor recordings. This will improve assessing events that may affect power system resilience. The proposed BDA will be used to automatically extract knowledge leading to event analysis, classification and prediction, all used at different stages of the grid resilience assessment: operations, operations planning, and planning. The project's techniques are based on their past work performed at the Texas A&M Engineering Experiment Station (TEES) on

automated classification of faults, location of faults and instability detection using neural network and machine learning classifiers and predictors, and the latest innovations in BDA techniques developed by Temple University. The team will engage Quanta Technology experts experienced in the utility interaction to interpret the PMU data files to be utilized in the process. They will facilitate industry feedback leading to the development of metrics for evaluation of the proposed solution. Additionally, the project proposes a novel solution for predicting future events based on historical PMU data by extracting the sets of precursors and analyzing the development of PMU observed disturbances over time.