Grid Signature Library for Classification of Grid Anomalies

U.S. DEPARTMENT OF ENERGY

Published February 2022

Grid Signature Library: An Open Access, Curated, Evolving, and Interactive Big Data Framework for Smart Grid Event Signatures for the Nation's Energy Sector and Critical Infrastructure

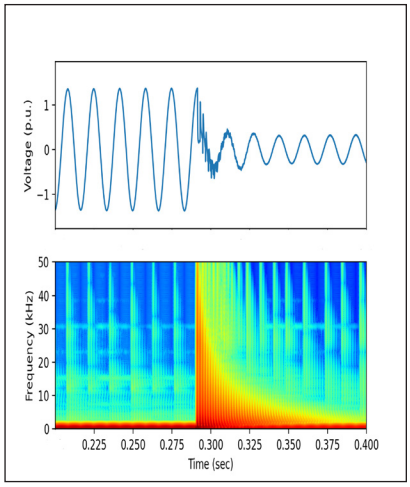
The Grid Signature Library (GSL) initiative at DOE's Oak Ridge National Laboratory (ORNL) and Lawrence Livermore National Laboratory (LLNL) is focused on the development of the well-defined, curated, and free-to-access smart GSL to increase the resilience and swift response against malfunctions of grid infrastructure. The GSL is accessible at https://darknet-01.ornl.gov/apps/siglib

The Challenge

Information and communication technology, automation, and electrical grid networks are being connected to enable the huge information exchange mechanism between advanced metering infrastructure and Internet of Things devices such as sensors that are installed within the existing smart grid systems. Instantaneous multidimensional complex big data generated from two-way information and energy flow (including real-time energy consumption, energy planning, and detection of anomalies and faults) brings new challenges in terms of communications, interoperability, coordination, and management. Such problems can only be overcome with intelligent sensing and prediction machine learning (ML)/ artificial intelligence (AI) frameworks that heavily rely on the use of properly labeled grid data.

Furthermore, adopting and ensuring the success of such an ML/AI framework is only viable by addressing the requirements of the data sets, such as maintaining the confidentiality and reliability of the captured data, proper labeling, and visualization. Suitable data use facilitates in solving problems and increasing grid resilience and performance, which highly depends on converting the raw data into a more comprehensible curated format, as is the case for advancement of image processing, computer vision, and deep learning algorithms.

However, in the power systems industry, few databases have proper event labeling and data access to a publicly available collection of grid signatures that will allow users to interact with grid signature data. Publicly available data sets of grid signatures, such as the DOE/Electric Power Research Institute data set, often lack critical metadata or contain only a single example of an event type, and data formats vary widely across these data sets. Furthermore, because of the dynamic nature of the electric grid structure, data sets should evolve in time to update themselves with new signal waveforms and characteristics, which is a major shortcoming of current data sets.



An example of an AI technique that leverages signature data such as that housed in the GSL is the Power System Neural Network (PSNN) developed at ORNL. PSNN uses spectrograms that provide a simultaneous time-and-frequency view of a current or voltage signal. This method of analysis is commonly used in audio engineering. However, the technique is generalizable to many different fields, including power systems.

The Solution

ORNL and LLNL have partnered with universities and private sector industry partners to develop a framework, the GSL, that attempts to address these challenges. The GSL is an expandable database architecture for power system event signatures from devices that monitor different assets on the power system. The GSL can be used for the development and testing of new ML algorithms for interactive signature identification, matching, and predictive analytics.

Prior efforts have built the foundation of this framework and populated it with more than 900 signatures that provide a common storage platform and standardization scheme for curating grid signature data from multiple sources. Advancements on the GSL will enhance the utility of the framework for use by the larger community by incorporating a hierarchical labeling scheme, improved user interface, and additional signature data from newly deployed sensors from utility sources and software-simulated events.

ORNL and LLNL will reach out to utility companies to develop a user group. Outreach will include sensing and measurement communities, public utility companies, equipment manufacturers, and academic partners. With the establishment of the user group, the research team will adopt an Agile methodology to regularly engage the user group and solicit feedback and requirements to steer development of new features. Additionally, ORNL and LLNL will work with DOE to encourage partners to upload new, sanitized data, which will be made available in the library to expand its usefulness.

Signature taxonomy that includes underlying event causes (e.g., equipment faults) and waveform anomaly characteristics (e.g., current increase/decrease, single-phase vs. multi-phase, long-duration vs. transient) will be integrated by considering industry standards and electric utility company labeling practices. The labeling taxonomy is designed to be expandable to include any new event types or descriptors of interest to the community.

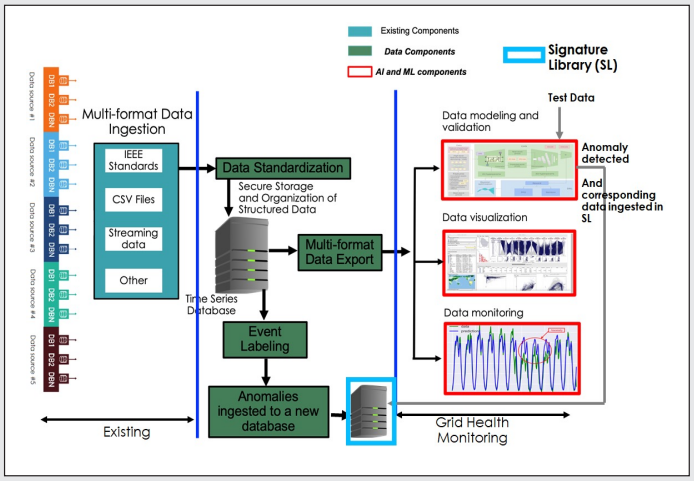
Data captured from high-fidelity research sensors at EPB Chattanooga and other utility companies will also be curated and ingested upon verifying the quality of the sensor output. In particular, concurrent relay data will be requested from EPB Chattanooga to supplement event signatures acquired from the research sensors.

For more information contact:
Sandra Jenkins, Office of Electricity
sandra.jenkins@hq.doe.gov

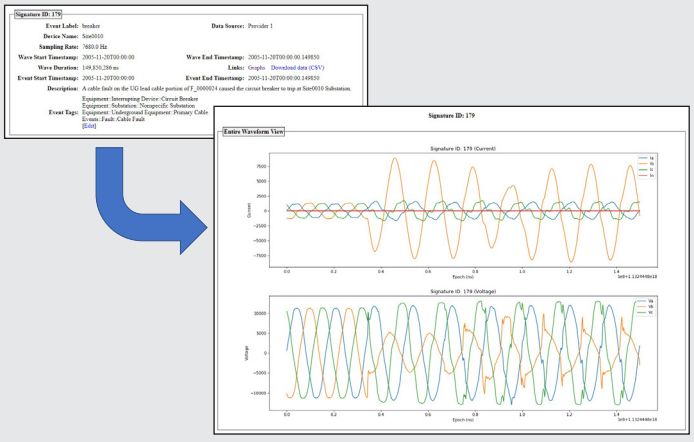
The Mission

Accelerating ML/AI-enabled capabilities of the state of the electric grid is one of the core missions of the DOE Artificial Intelligence and Technology Office. The goal of the GSL is to develop a community resource of curated signature data for use in power system AI algorithm development.

- The GSL houses accurately and precisely labeled power system event signatures
- Signature data is easily accessible, free to use, and publicly available
- The graphical user interface is user-friendly for navigating among data sets and visualizing waveforms
- The GSL will leverage existing mature technologies where possible and practical, such as open-source databases and visualization tools



The GSL framework involves curating the data, ensuring data anonymization, and providing the user-friendly GUI for post-processing.



This image shows an example of the graphical user interface for the GSL.