Exploiting Emerging Data for Enhanced Load Modeling

Final Project Report

Power Systems Engineering Research Center

Empowering Minds to Engineer the Future Electric Energy System
Exploiting Emerging Data for Enhanced Load Modeling

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Power Systems Engineering Research Center

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Executive Summary

Massive amounts of novel data are currently being acquired and stored as part of ongoing electricity grid transformation efforts. This data will enable discovery of complex system behavior and enable new decision-making processes to realize higher grid reliability, economy, and sustainability objectives. This project presents various mechanisms to systematically exploit the new data, advancing the current understanding of the load.

Part I: Real-Time Dynamic Parameter Estimation for an Exponential Dynamic Load Model (Abur, Northeastern University)

Load modeling has been an important area of investigation due to the importance of loads as part of the network model used in various different power system studies. Dynamic behavior of loads in particular is of special interest in studies involving power system dynamics. This report is also concerned about real-time modeling and identification of dynamically changing loads in power systems. The motivation for the study is the availability of synchronized measurements which can be used to identify the composite behavior of loads behind a measured bus.

An exponential dynamic load model was proposed earlier and was well accepted by several investigators who worked on this topic. This work considers this model and identifies its parameters in real-time by using measurements. An Unscented Kalman Filter (UKF) is used to track the unknown parameters of the exponential dynamic load model.

The report first implements and tests the proposed method using simulated measurements. The method is then applied to actual recorded utility measurements to identify and track the bus load of a utility feeder.

The results suggest that the proposed approach can provide reasonably accurate dynamic loads for on-line applications requiring detailed load models.

Part II: Exploiting Smart Meter Data for Enhanced Load Modeling (Grijalva, Georgia Institute of Technology)

As part of the ongoing smart grid transformation, smart meters have been widely installed producing massive amounts of data and information. One of the critical needs for distribution system operations and planning applications is modeling of the load, in particular, its dependence on the voltage. This study is aimed at using smart meter measurements for enhanced load modeling by using data-mining methods.

The two major barriers for a data-mining-based load model are the load’s time-variant properties and the low resolution sampling rate of the current advanced metering infrastructure (AMI). We address the first barrier through data aggregation and hour partitioning processes. We address the second barrier by introducing the load condition assumption, which justifies the data-mining-based modeling method intuitively from the statistical point of view. Meanwhile, various data-mining and machine learning algorithms are evaluated such as K-subspace method, Davies-Bouldin Index (DBI) and Silhouette Coefficients.
In the first section, we introduce the smart meter deployment on the Georgia Tech main campus as the testbed for the study. We developed an interactive visualization tool, “Smart Grid Plotter”, for easier visualization of the cumulative smart meter database. The visualization tool allows researchers to navigate historical data collected by smart meters for all buildings on campus. Users can further configure and save the desired plot through various parameters on the menu.

In the second section, we propose a novel enhanced load modeling method based on data-mining and machine learning algorithms. The enhanced load model is a time-variant model that writes the load’s active and reactive power usage as a function of both time and voltage. The detailed steps for the new load modeling method are further discussed in details through three aspects: data aggregation, hour partition and the load condition assumption.

In the third section, we further explore the smart meter data for both off-line and real-time utility functions. In the report, we show that as a very important information source, smart meter data (both real-time data and historical data) can be the core of other 18 potential applications when combined with other data, such as weather and GIS information. Two sample applications, refined power flow analysis and dynamic distribution network reconfiguration, are studied to show how smart meter data and the proposed enhanced load model improve power system analysis results and facilitate advanced energy efficiency operations.

In the future, the smart meter data will be more tightly integrated into the vast majority of utility applications for both energy efficiency and reliability improvements. One of the immediate integrations includes a next generation customer information system (CIS) based on smart meter database, weather information and GIS data.

**Part III: Exploiting Weather and Load Recording Data to Enhance Load Modeling (Christy, Iowa State University)**

In Part III, we show a method for calculating the AC motor load using historical load and temperature data. Historical temperature data is now readily available from internet sources, and historical load data is more and more available through various recording means. The concepts have been illustrated using the load for various companies in the PJM interconnection, but the same concepts can be applied at the feeder level or even at the individual customer level.

Estimation of the AC fraction of load was performed using change-point curves and it was shown that separate change-point curves should be constructed for each different system loading state: weekday daytime, weekday nighttime, weekend daytime, and weekend nighttime. Of course, construction of these curves has been programmed so that the process is automated. Furthermore, a straightforward program can be written to estimate the AC fraction of load at any particular time of interest. The steps for this application were shown.

Naturally, the amount of motor load will depend on the outdoor ambient temperature at the time of the event. The higher the temperature, the higher the AC motor load will be. These results use historical load and temperature data to take the guess work out of estimating the AC motor fraction of load.
Project Publications:

