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Need for Research: Big Data Applications in Smart Power Distribution Systems

Additional submitted attachment is included below.

Big Data Applications in Smart Power Distribution Systems

Introduction

Penetration of advanced sensor systems such as advanced metering infrastructure (AMI), high-frequency overhead and underground current and voltage sensors have been increasing significantly in power distribution systems over the past few years. According to U.S. energy information administration (EIA), the aggregated AMI installation experienced a 17 times increase from 2007 to 2012. The AMI usually collects electricity usage data every 15 minute, instead of once a month. This is a 3,000 fold increase in the amount of data utilities would have processed in the past. It is estimated that the electricity usage data collected through AMI in the U.S. amount to well above 100 terabytes in 2012***. To unleash full value of the complex data sets, innovative big data algorithms need to be developed to transform the way we operate and plan for the distribution system [1].***

Big data analytics could be applied to improve both short-term distribution system operations and long-term distribution system planning processes. With big data, the sum is always more valuable than parts of the data set. Studying different subsets of the complex distribution system data set leads us to distinct applications. This section proposes promising big data applications for both short-term operations and long-term planning studies. The applications include detection of energy theft, customer consumption behavior modeling, network connectivity and phase connectivity identification, spatial load and renewable forecast, distribution system visualization, predictive asset management state estimation, and distribution system planning.

Research Area 1: Enhanced Distribution System Modeling (E.g., Phase Connectivity Identification)

To operate the distribution system in an efficient and reliable manner, the distribution system operators typically rely on a set of tools and applications including three-phase power flow, distribution system state estimation, three-phase optimal power flow, distribution system restoration, distribution network reconfiguration, etc. All of these applications require an accurate distribution network and phase connectivity model. Although the network connectivity model is mostly accurate, phasing errors are common. Therefore, an accurate phase identification method is in critical need. Pilot testing has been conducted on realistic distribution feeders in Southern California Edison's service territory. The testing results have shown that unsupervised machine learning algorithm has resulted in 95% accuracy in phase identification [2]. Funding support from California is needed to move the technology from limited field testing to large-scale demonstration.

Research Area 2: Distributed Energy Resources Adoption Forecasting Model

Accurate DER adoption forecasting models are crucial to efficient planning in the power distribution systems. Accurate spatio solar PV, energy storage, demand response and energy efficiency program adoption forecasts could results in huge savings from unnecessary distribution circuit expansions. A preliminary model of commercial solar PV adoption model has been developed and integrated into Southern California Edison's distribution planning process [3]. Empirical results show that decreasing solar PV installation costs and government incentive programs are the main forces that drove the growth of commercial solar PV adoption. In the case of Southern California, we also discover that government incentive programs and PV installation costs have a much higher impact on large commercial customers than small commercial customers. However, additional funding support is needed to extend the spatio adoption forecasting model to other types of DERs.

Research Area 3: Robust Distribution System State Estimation

Distribution system state estimation (DSSE) provides the control centers with the information necessary for several of its applications and operational functions. Grid operators are dependent on state estimation to predict the impacts of their decisions in day-to-day operations. State estimation is the application of power flow equations, data from field monitors, and heuristics to measure grid conditions. The applications that rely on state estimation for performing analysis of the distribution grid are numerous and include overloading prevention, outage management, DER dispatch, and integration with transmission operations. With the introduction of AMI data the state estimation algorithms can reduce error by allocating load correctly and thus improving the decision-making capability of grid operators [1].

Research Area 4: Spatio-temporal Renewable Generation and Load Forecasting

Spatio-temporal renewable generation and load forecasting are crucial to reliable short-term power system operations. With rapid penetration of distributed renewable generation in distribution system, the need for accurate distributed renewable forecast becomes critical. For example, as distributed renewable (mostly solar photovoltaic) penetration levels in distribution circuits reach 15% and beyond in Hawaii and Southern California, the distributed generation starts to have significant impacts on distribution systems planning and operation. An accurate spatial joint load and rooftop solar generation forecast could greatly help distribution system operators manage circuit overloading, address reverse power flow and improve circuit voltage profile and power quality. The challenge of producing granular renewable generation forecast lies in the lack of direct rooftop photovoltaic generation measurement as most of the residential solar panels do not have a separate meter. Hence, the solar generation has to be derived from historical load and net load measurements as well as irradiance data collected from local weather stations [1].

Research Area 5: Predictive Asset Management

Equipment Diagnosis: Electric utilities maintain billion dollar asset bases of infrastructure and these systems require regular maintenance. A sample of 34 parent utility companies will require $70 billion in capital expenditures in 2013. To maximize effective replacement of these systems AMI data can be leveraged to predict failure of distribution transformers, underground cable, overhead lines, and voltage regulation devices. Transformer life can be predicted by observing loading patterns throughout the year. The degradation of transformer life is non-linear as the insulation of the transformer breaks down quicker at higher temperatures [1].

References

[1] Nanpeng Yu, Sunil Shah, Robert Sherick, Mingguo Hong, and Kenneth Loparo, “Big data analytics in power distribution systems,” *IEEE PES Conference on Intelligent Smart Grid Technology*, Washington DC, Feb. 2015.

[2] Wenyu Wang, Nanpeng Yu, Brandon Foggo, and Joshua Davis, “Phase identification in electric power distribution systems by clustering of smart meter data,” *the 15th IEEE International Conference on Machine Learning and Applications*, Anaheim, California, Dec. 2016.

[3] Wenyu Wang, Nanpeng Yu, and Raymond Johnson "A model for commercial adoption of photovoltaic systems," to appear in Energy Policy, 2016.