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Bringing probabilistic analysis capability from planning to operation

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ABSTRACT

The dynamic behavior of smart grid technologies requires the transition from a deterministic to a probabilistic control paradigm. This necessitates a smoother, better-integrated interplay between the functional roles of planning and operations to leverage the capabilities of probabilistic analysis in both realms. This paper presents two power system probabilistic analysis tools and how they are integrated into the GridOPTICS Software System (GOSS), a middleware platform facilitating deployment of new applications for the future power grid. Case study results show the developed tools provide better prediction of the power system balancing requirements, better transmission congestions management, and better system reliability.

1. Introduction

Power system operation and power system planning are two essential activities in the electric power industry. Power system operation focuses on operating the power system reliably and efficiently. Power system planning's objective is to ensure a reliable supply of electricity to customers economically, while certain security and environmental limits are still enforced. Ideally, these two activities are performed in concert to make the power industry work properly. However, in practice, operation engineers and planning engineers use different models, which represent different system states. Traditionally, the support from either side has not been sufficient to ensure the methods and models are aligned.

Due to the growing complexity of the power system, represented by the fast deployment of intermittent energy technologies, control paradigms, and automation technology at all levels, the management of the nation's power system has progressed to the point where the conceptual lines between operations and planning are becoming blurred. Traditional deterministic models and applications are not sufficient to handle the new grid operation paradigm with increased variability. Some planning-related, probabilistic analyses need to be moved into the operational environment to aid in decision support for operators. This situation brings pressure to incorporate operational planning tools that have predictive capabilities with power system operation tools to enhance grid reliability. Thus, it will result in a smoother, better-integrated interplay between the functional roles of planning and operations.

There are research publications on the topic of probabilistic transmission operation and planning (Li & Choudhury, 2007; Beshir, Jul 1999; Papaefthymiou, 2006). However, there is not much work published about the fusion of operation and planning and showing its benefits. Planning tools with forecast uncertainty can provide better risk management, asset utilization, and more reliable system operation.

This paper presents two use cases that are built on a GridOPTICS Software System (GOSS) framework that supports the fusion of operation and planning. The first use case is built on the Ramp and Uncertainty Tool (RUT). The RUT forecasts generation capacity and generator ramp ranges needed to balance the system one hour ahead with a 5-minute resolution, incorporating uncertainty associated with wind, solar, and load forecast into power system operation. The second use case is based on the Transmission Uncertainty Tool (TUT) for predicting potential congestion and voltage stability problems in the electrical grid. The TUT takes into account different sources of uncertainty, including forecast errors for wind, solar, and load.

The objective of the fusion of operation and planning is to integrate the analysis results from operational planning into the real-time operation, as well as improve planning functions with fresher and

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more accurate information from operation. The framework proposed in this paper provides a vehicle to deploy different power applications from different domains, allowing easy communication and data transfer between applications. Without this type of framework, it would be challenging and inefficient to bridge the gap between applications, especially considering the difficulties of handling non-well-structured data.

This paper is an extension of the conference paper published at the 2015 IFAC Symposium on Control of Power & Energy Systems (CPES 2015) (Chen et al., 2015).

2. Structure and data flow of fusion framework

The objective of the framework is to enable a bi-directional exchange of data between operations and planning environments. This is accomplished via a software middleware platform, the GridOPTICS Software System (GOSS), which enables data analytics, communication, and data transfer between different applications (Gorton et al., 2013). In particular, the functions not only allow the results of traditional operational planning studies to be reflected in relevant real-time tools available to the system dispatcher, but support the initialization of the planning analysis tools with current data from the operational system.

There are five function blocks based on the GOSS framework:

(1) A ramping tool engine to read forecast data from the GOSS database, create predictive ramping capacity data, and archive the output data to the GOSS database;
(2) A transmission tool engine to read forecast and power system data from the GOSS database, calculate probabilistic power flow for selected system branches/buses, and archive output to the GOSS database;
(3) Web-based and map visualization tools to read and display the RUT and TUT outputs from the GOSS database;
(4) The PowerWorld tool (PowerWorld [online]) to present the system status from the operation side and for some analytical functions (e.g., power flow calculation and power transfer distribution factors calculation);
(5) A model conversion tool to convert a node-breaker model (operation) to a bus-branch model (planning).

The data flow of the fusion framework is shown in Fig. 1. All of the functions are integrated on the GOSS framework through GridOPTICS adapters. The adapters provide interfaces that applications can use to connect with GOSS middleware and applications written in different languages, including Java, MATLAB, Python, C++, C#, Visual Basic, and R. The bi-directional dataflow among all function blocks is enabled by the message bus. For the scenarios presented later in this paper, GOSS model conversion functions will be executed to ensure the planning and operational model represent the most up-to-date system information. The visualization tools are able to display the simulation results once they are generated. All inputs and outputs can be saved in the GOSS database for further analysis.

The details of the GOSS middleware platform and the five function blocks are described below (Chen et al., 2015).

2.1. GOSS middleware platform

GOSS is a middleware platform designed for flexible and evolvable power grid applications. It allows fast deployment of applications and enables communication between them. An overview of the GOSS architecture is shown in Fig. 2 (Chen et al., 2015; Chen, Palmer, Fitzhenry, Sharma, Jin, & Huang, 2016).

There are three layers of the GOSS architecture: the application layer, the communication layer, and the data management layer. With these layers, the GOSS framework can separate data sources from different applications and ease application development by providing a unified application programming interface (API) to seamlessly access data from different sources at different locations. Using the GOSS framework, an application can also save data to multiple data stores without dealing with their connection requirements, data format conversions, or query interfaces. Power grid applications developed for different underlying software platforms and installed in different utilities can communicate and interoperate. Multi-organizational data exchange can be accomplished in compliance with security and data-sharing policies between utilities. A grid application example of enabling predictive capability using GOSS can be found in Chen et al., (2016).

GOSS not only supports one-to-one data transfer between applications, but also a publish–subscribe scheme to enable complex application workflows. An application can subscribe to one or more notifications coming from another GOSS instance. With these functionalities, all applications involved in the use case can communicate with each other. These GOSS capabilities build the foundation of this work.

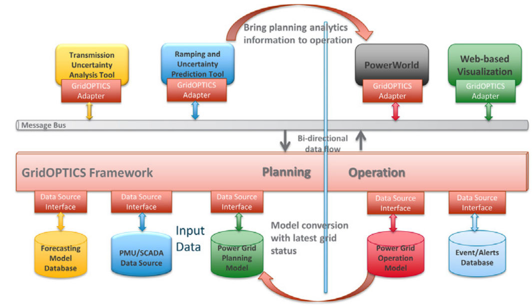

Fig. 1. Dataflow of the fusion frame work.

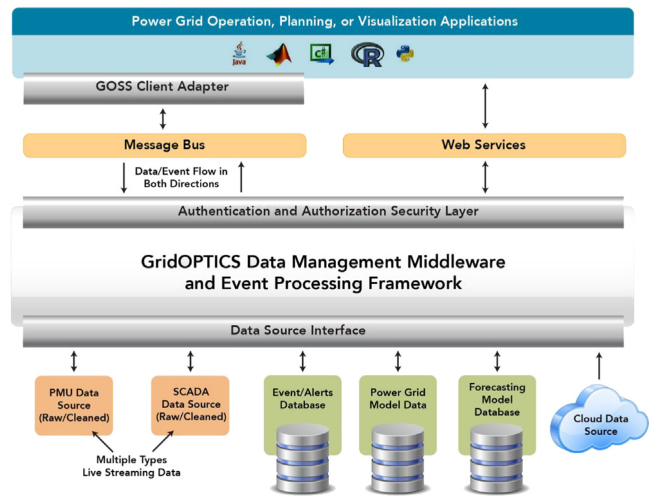

Fig. 2. GOSS architecture.

2.2. Ramping uncertainty tool engine

It is critical to evaluate uncertainties associated with renewable energies and to incorporate the knowledge into the algorithms and operating practices. Work is underway to incorporate renewable energy uncertainties into power system operations (Loutan et al., 2013; Sharma et al., 2012). Multiple efforts have been done to improve the accuracy of the variable generation forecast and to incorporate probabilistic information into power system scheduling and dispatch (De la Torre, Juberías, Domínguez, & Rivas, 2012; Botterud et al., 2013; Wan, Xu, Pinson, Dong, & Wong, 2014; Dvorkin, Pandžić, Ortega-Vazquez, & Kirschen, 2015), and many more. However, these approaches only consider the megawatt imbalances, without taking into account ramp