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Software Based Barriers To Integration of Renewables To The Future Distribution Grid

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SOFTWARE BASED BARRIERS TO INTEGRATION OF RENEWABLES TO THE FUTURE DISTRIBUTION GRID

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ABSTRACT

The future distribution grid has complex analysis needs, which may not be met with the existing processes and tools. In addition there is a growing number of measured and grid model data sources becoming available. For these sources to be useful they must be accurate, and interpreted correctly. Data accuracy is a key barrier to the growth of the future distribution grid. A key goal for California, and the United States, is increasing the renewable penetration on the distribution grid. To increase this penetration measured and modeled representations of generation must be accurate and validated, giving distribution planners and operators confidence in their performance. This study will review the current state of these software and modeling barriers and opportunities for the future distribution grid.

INTRODUCTION

The distribution grid was planned to deliver energy from the transmission grid to customer, reliably and efficiently within standards for power delivery, safety, power quality and reliability. Electrical analysis tools that are used to perform capacity and stability studies have been used for transmission system planning for many years. In these tools, the distribution grid was considered a load and its details and physical components were not modeled. Today, the distribution grid is changing to become an active resource with complex modeling needs. The active distribution grid could within the next ten years contain a complex mix of load, generation, storage and automated resources all operating with different objectives on different time scales from each other and requiring detailed analysis. Distributed energy resources (DER) may include both grid level and customer side photo-voltaics (PV), other localized generation types such as fuel cells, and electric vehicles and other energy storage devices such as batteries. The distribution grid itself in the future may have more complex control and visualization needs such as automated switching and reconfiguration and voltage control through new localized and generation based devices rather than traditional capacitors and regulators. There will also be increased measured data sources such as smart meters, distribution synchrophasors and advanced line sensing techniques [1][2]. The utilization of these sources and advanced modeling tools will require data management, and knowledgeable users. The measured data will only be useful with an ability to interpret and utilize it effectively in combination with planning and operation tools.

Barriers to modernization of the distribution system include availability and capabilities of existing planning tools, data availability, model validation and accuracy, particularly inaccurate representation of impedances and loads. This paper reviews and discusses the limitations of distribution planning tools. First we identify three barriers: 1) tools development; 2) model validation and confidence in data; and 3) communication and data transfer between models. Then, we describe each of these barriers in detail with suggestions to how to overcome them. Finally, we summarize our recommendations.

BARRIERS TO DEVELOPMENT IN SOFTWARE

From a planning analysis standpoint, there are numerous barriers to the integration of renewables to the distribution grid. These include:

- Tools development
- Accuracy of measured data sources
- Model data accuracy and validation
- Data transfer between models

We shall review each of these issues in reference to the distribution systems of the future.

TOOLS DEVELOPMENT

Distribution planning tools were developed in response to a need for efficient analysis and digitization of data, but most were developed based on the assumption of one-way power flow, without high penetration of renewables and short time scale control characteristics. Short time scale indicates minutes and hours versus six months ahead planning [3][4]. As the tools may develop to meet the needs of the future distribution grid, the applicability and accuracy of each package must be evaluated.

The current approach in distribution grid planning software development is a combination of accommodating or approximating representations of key components, such as inverters and detailed loads. Current distribution grid planning tools are in a rudimentary stage and although some advanced analysis tools are developed, the need to use them, ability and requirements for analysis on the grid is not well understood.

An effective analysis package for the majority of features required in a future grid has the following features;

- Clear concise user interface
- Displays of results in geographical, schematic, tabular and graphical formats that are highly customizable
- Time series package, with slow dynamic analysis including time delays of key voltage regulating equipment
- Data hooks for measurement devices, including advanced sensors, to enable configuration and validation
- Dynamic package with ability to create custom models and hook into other packages such as Simulink for generic device modeling (inverters, storage)
- Data and model import/export capability for standardized formats

ACCURACY OF MEASURED DATA SOURCES

Distribution planning and operations functionality and time scales for analysis are merging as the distribution system becomes an active resource. The distribution system has more components than the transmission system and therefore more unknowns and potential for error in a distribution system model. Errors in data are more prevalent in the distribution system, and lead to a lack of confidence in analysis and operations, and reluctance to move forward with advanced grid analyses in the simulation environment [5][6].

The future grid with large numbers of distributed generation units including solar PV requires different and more complex analysis and control mechanisms. As the number of distributed generation (DG) installations grows, the grid must evolve to accommodate high penetration levels. The time scales of these sources will influence the development of features of distribution modeling tools from steady state (single point in time), to transient (sub-cycle). Possible data sources required in a future distribution grid scenario include the following;

- DR Metering and Smart Meters
- Transmission and distribution phasor measurement units (PMU)
- Supervisory Control and Data Acquisition (SCADA)
- Grid models and GIS
- Inverter and DG component models
- Weather data
- Economic price signals

Each of these sources, like power systems themselves, have inherently different time scales of importance, for example economic price signaling to demand response could be on an hourly basis, but inform customer behavior and therefore load for short time steps following the economic decision. Weather data for forecasting of short-term variability is on the seconds to minutes scale, grid models and component models require scales from sub-cycle, to seconds to hours and steady state analysis (**Figure 1**). As changes are requested by a future distribution grid planning and management system, knowledge is required on evolving grid conditions, to inform ongoing decisions.

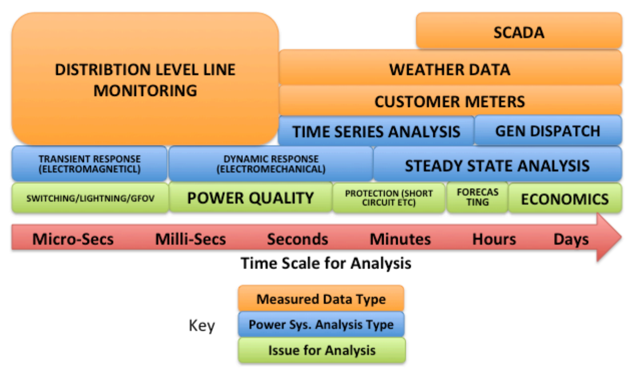

Figure 1: Graph of Data and time-scales illustrating the spread of data requirements at utilities

Data quality from these and future sources for utilities and system planners and operators must improve from current standards, and model validation is an essential and desirable application of enhanced measured data. Data quality should be defined by the latency, accuracy, ease of use, and most importantly availability. The distribution planners and operators must be accurately and timely informed to make the correct choices in both the near and far term. Data quality will translate directly into power systems model accuracy, and quality of the analysis results from the distribution grid analysis tools.

Validation is an iterative process, and circular process, where data sources can validate planning models, and new measured grid data resource (i.e. smart meters and SCADA could be used to help validate advanced distribution monitor data), and validated planning models can inform the correction of operations models. The operations models themselves may be used to then correlate and validate operational measured data from new sources.

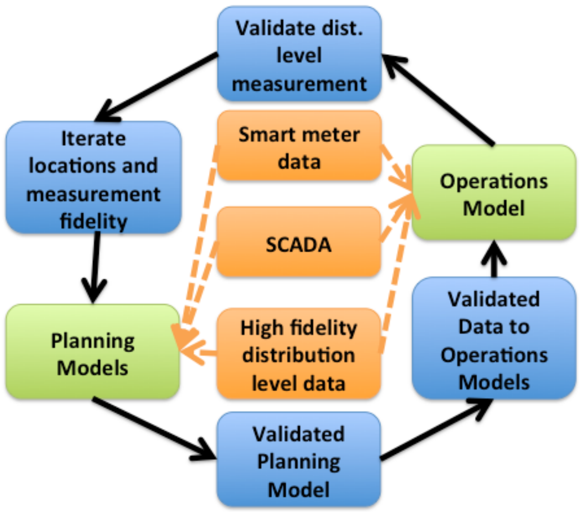

Figure 2: Validation of multiple data sources process to inform operations and planning models

MODEL DATA ACCURACY AND VALIDATION

We have now addressed the abilities and need for various features within distribution analysis and modeling tools, and discussed what features may be present in the future distribution grid that drives the need for more accurate analysis. In this section, we concentrate on accuracy of model data. Accuracy means how closely a tool's performance and output, for example during a fault or generator trip, represents the measured and real world grid behavior. While tools may develop to have many advanced features, they will not be useful if the models are not accurate. The quality of the data input to the models, directly impacts the usefulness of the output. Putting the measurement and modeling portions of analysis together, into a validation and calibration process will enhance the value of grid analysis tools exponentially.

A degree of error in engineering analysis of the distribution system is accepted. Between tools the standard for accuracy is to within 0.5% for voltage and current output at nodes [7]. The impact of errors is practically small at these levels, but when the errors are above this, they can have economic and technical impacts on the grid. An example of impact would be during planning for upgrades and interconnection. A distribution system impact study could indicate, for example, a power quality issue caused by an interconnecting generator. During simulation, a number of items could impact this from conductor type to source impedance, and control strategy for existing equipment. The utility may require the interconnecting generator to install expensive mitigation techniques, which, had the model been correct, would not be necessary. This would limit renewables integration, an important target in many areas for utilities. Conversely, the model could be absorbing some of the impact for the same data accuracy reasons. This can lead to an unplanned power quality issue, which would economically and technically impact customers and the utility. There could be significant impact on safety. Without accurate knowledge of topology, field workers could inadvertently switch into an unknown topology and cause arc flash or overloading. Many of these issues could be solved by validating the distribution models, but until recently data was not available for this function. There are three major modeling data source error sources for electrical distribution modeling:

- GIS data (Equipment, conductors)
- Switching and topology reporting
- Customer and Load Data (aggregate and locational)

Solutions for the accuracy issues include iterative validation, and common data formats for grid data accessible outside the simulation environment.

DATA TRANSFER BETWEEN MODELS

There are a large number of available tools for distribution modeling, with varied applications. Software tools are used for applications such as interconnection of renewables, planning new developments and capital expenditures, and capacity analyses. Often within a utility no single tool is used for power systems analysis spanning distribution planning, operations, protection, renewables integration and transmission. The decision to purchase software is driven by need for a particular application, versus a strategic decision across departments. For example, where a tool may be strong in its detailed analysis of components of load or a particular device, it may not be strong in larger applications such as switching between multiple feeders, and analysis of time series and dynamic impacts for high penetration of renewable resources. While the functionality of the tools is important, the results will only be as accurate as the data input to the tool, state of model validation and results interpretation. Errors are prevalent in all these realms. When the decision to purchase software is made, the user needs to determine what the functions required in their selected analysis are. The user must determine if they need a tool to be all encompassing, for example the component behavior may not be of interest or required, but generation variability. In this example a tool with strength in long-term dynamics would be advantageous.

A key example of the spread of distribution analysis tools at utilities and their application is interconnection analysis. Interconnection analysis is determining the various impacts and ultimately the permissibility of interconnecting a specific distributed energy resource to the grid. Users may attempt to make a particular piece of software fit the purpose they are analyzing, based on the format of data supplied by the utility or interconnecting party, rather than attempting to use a second piece of software. Alternately departments may purchase many pieces of software to fit the data supplied or function required, resulting in duplicative functions.

Numerous types of power systems analysis may be requested by the utility during a system impact or interconnection study. The detail required or requested in this study is dependent on the percentage (of peak load) of renewable capacity installed and requested for interconnection. Currently the interconnection process is not standardized The software selected could include SynerGEE Electric [9], and CymDist [11] for steady state analysis, Aspen Distriview [12] for protection coordination, PSCAD [13] for transient analysis and PSSE [14] for dynamic analysis.

Standardization of the format for moving data, and the model data itself is a key growth area in simulation and analysis packages. High impact conditions such as weather, peaking and minimum loads, and contingency conditions are better managed with combined and integrated planning techniques.

Few power systems software packages exchange distribution and transmission information seamlessly. While distribution systems can often be aggregated and simplified to create an equivalent representation in the transmission format, details are lost for single phase and unbalanced analyses, often essential in renewable integration studies. The previously mentioned lack of communication between network operators and planners, leads to an ever-growing number of software packages being purchased by utilities, therefore reducing efficiency of analysis as users must convert data to and from a new application format. Validated analytical abilities across both the transmission and distribution areas are essential, but software integration is a major bottleneck

All of these models in combination with external inputs such as meteorological data, smart meter data and SCADA produce the complete systems analytical model. A number of data formats have been proposed to standardize how distribution, transmission and other departments store model data. The most prevalent and well developed is the IEC Common Information Model [8][9].

With growing numerous sources of error, validation is essential for modeling and simulation of the distribution system. Key validation points will include recreation of steady state performance, running simulation scenarios for which measured data is available and location sources of error. Dynamic measured response and analysis in selected operations can be used with enhanced measurement to determine if devices are characterized effectively.

CONCLUSIONS

There is a high degree of development work going into commercial and open source analysis tools for the distribution grid. These are developing concurrently with the distribution grid technology itself. There is a need to develop a more holistic approach, taking account of the whole distribution grid and not just application of transmission concepts. The data sources are limited and increasing the availability and integration of measured data into the tools would improve usage and development. Tools are only as useful as their user, and the interfaces must become more intuitive and well understood. Validation of model data would allow the tools to be more accurate and reliable and improve the usage of tools, and allow for more concentration on development rather than questions of accuracy. No single tool can do every job, but transient, and everything else can split the tools. The analysis is becoming more complex with dynamic and steady state concepts becoming mixed, and tools, which address both, are powerful. Transient aspects of the grid are more complex, and separate tools in these areas are adequate. Modeling of detailed components such as inverters is understood well in the three phase balanced realm and transmission tools, but not in distribution systems modeling tools. The high volume of these devices may in the future need more detail control and coordination analysis and generic modeling, with hooks to proprietary aspects is essential. There are many tools that do not communicate or transfer data with each other and standardization of data into common formats such as CIM is a positive step towards this, but adoption of standardized data by the tool builders is required. They are reluctant to share data formats for proprietary reasons, but innovation will grow with a more open source take on formatting of grid models. Developers would be driven to incorporate enhanced features and usability if users were not tied by their original data formats. Cost at utilities would also be reduced for software.

As the distribution system evolves into a more complex, active, controlled and automated resource, the depth of analysis required is evolving also and requires an evolution of modeling tools.

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