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Developing a Distribution Grid Model Data Management Architecture

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SUMMARY

Electric distribution grids are facing changes in how they are utilized, operated, and planned the likes of which have not been seen in decades. Largely driven by the increasing presence of distributed energy resources, distribution systems are transitioning from being one-way conduits of electricity, from bulk system generators to consumers, into two-way energy highways. These changes require utilities to study distribution system behaviour in new ways, in more detail, and more often. The need for power flow-based simulations in planning, protecting and operating the grid is growing, and with it the need for accurate and timely distribution network models.

However, distribution network model data management is challenging for a number of reasons. The very nature of network model data – its size, its multiple sources within the utility, the need to be 'electrically logical' – makes its management difficult. Additionally, the requirements for assembled network model cases vary in terms of time frame, level of detail, scope, type of data and grid state depending on the type of network analysis being performed. This increases the data management challenge. Several factors further magnify the complexity in distribution: the greater volume of data, the quality and organization of data in GIS systems, and the variation and volatility in the distribution application eco-system. Not surprisingly, this has led to a patchwork of vendor and utility-specific data management solutions, which solve limited local problems but follow no overarching data management approach.

To address the need for improved distribution network model data management, EPRI has launched a 'Distribution GIS and Grid Model Data Management' project, a collaborative initiative with the ambitious goal of defining an industry architecture for managing network model data. It is a multi-year, multi-utility initiative which began in the fall of 2017 and will complete in 2020. The architectural development methodology being followed in the EPRI project aligns with the approach used in the IEC's Common Information Model Interface Reference Model (CIM IRM), where business functions (as opposed to specific software applications) are used as the framework for describing the data exchange environment. This

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approach leverages the universality of business processes employed by nearly all utilities in managing the distribution grid to arrive at an architecture with wide applicability.

The EPRI project has developed an initial draft of a high-level functional Reference Model for the architecture. Review and refinement will begin in the fall of 2018 with input and guidance from multiple sources, including utilities, consultants, application vendors and CIM Working Groups.

KEYWORDS

grid model data management, network model data, data management architecture, standards-based integration, Common Information Model

Background

The distribution grid is changing. For decades, the electric system has provided homes and businesses with energy. A networked transmission system has carried power from generators to a primarily radial distribution system supplying customers. And the wholesale market has interacted with transmission-connected generation assuring a balance of supply and demand.

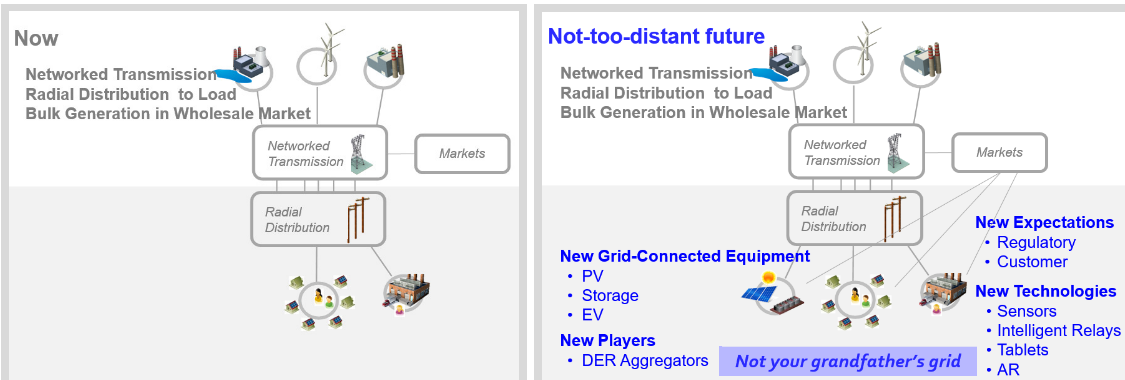

Figure 1 - It's not your grandfather's grid

But today, as illustrated in Figure 1, new distribution grid-connected equipment is turning the distribution system into a two-way energy highway. There are new entities participating in markets using assets not owned by the utility. There are shifting expectations on the part of both regulators and consumers. And all sorts of new technologies provide opportunities and challenges.

In reaction to these changes, utilities are deploying a variety of new and enhanced functionalities in both the planning and operations domains. A number of these are illustrated in Figure 2.

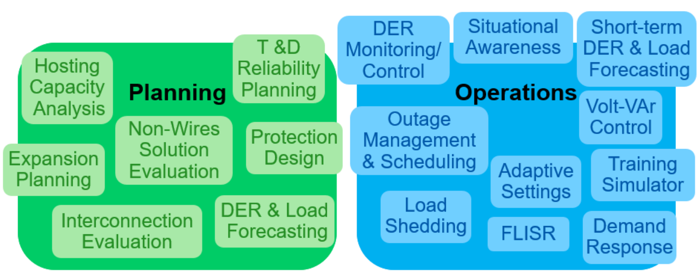

Figure 2 – New or enhanced simulations and analytics

The majority of these functions have, at their core, power flow algorithms that rely on accurate network models as input. In the context of this paper, the phrase 'network model' refers to the data used by a network analysis function, not the simulation itself, and can be defined as:

> *Data representing a simplified view of the electrical grid, including equipment, its electrical behavior and its connectivity, as well as its operating state at a moment in time, which taken together are sufficient to describe a starting point for network analysis.*

The Challenge of Distribution Network Model Data

Network model data is particularly difficult to manage, in part due to the nature of the data itself:

- **It is big**. There are potentially hundreds of thousands of pieces of equipment whose behavior and connectivity need to be modeled.
- **It is diverse.** Network models are made up of multiple types of data which come from different sources within the utility, change with different triggers, and are 'owned' by different entities.
- **It must be electrically logical.** Assemblies of network model data must have the internal consistency and integrity to serve as a valid starting point for a power flow.

Additionally, the multiple purposes for which network model data is used adds further complexity. There is only one electrical grid, but, as Figure 3 illustrates, different network analysis applications need cases representing:

- Different parts of the system
- Different types of data
- Different levels of detail
- Different system states
- Different points in time

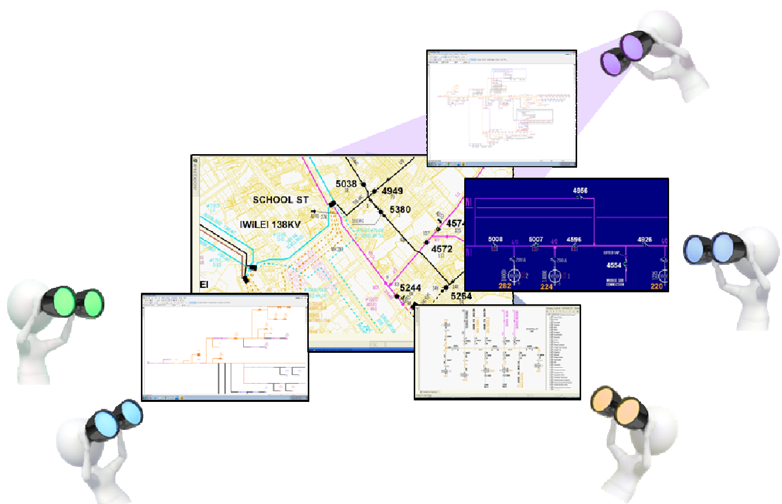

Figure 3 – Different network analysis applications require different views of the network

And the challenge is magnified in the distribution domain by several factors:

- **There is more data.** Distribution network models must represent at least an order of magnitude more equipment than transmission models – a difference that will only increase in the future as models of customer or third-party owned DER become necessary.
- **The distribution world typically views Geographic Information Systems (GISs) as the major source of network model information**. Unfortunately, GIS systems:
    - Often have data quality and completeness issues
    - Usually were originally deployed for purposes unrelated to network model data management
    - Have historically focused on maintaining the 'as built' - a real limitation when enterprise network model needs include 'was', 'as operated', and a plethora of alterative 'will be' grid states

- **The application eco-system is far more chaotic in distribution than in transmission.** There are large numbers of
    - planning and operation tools
    - asset, work management and load forecasting applications
    - visualization and integration solutions

  And they are deployed by distribution utilities in many combinations of usage patterns. The distribution application landscape is also volatile, with product market niches evolving, vendors appearing, merging, and going out of business, and new and enhanced products being developed.
- **The need for comprehensive network model data management is not yet as universally understood in distribution as it is in transmission.** There have been decades of frustration with network model data management silos in transmission. In distribution, however, the ubiquity of the need for network analysis in grid planning and operation, and the attendant need for enterprise management of network model data, are just now starting to be realized.

Not surprisingly, given all the above factors, distribution utilities today typically have a fragmented approach to managing network model data. Figure 4 illustrates the situation. There are:

- Distribution applications needing ever more accurate, up-to-date network models (on the right)
- Cases in which the network model data is provided to them (to the immediate left of each application)
- The multiple systems providing input data (on the left)
- The three major types of data exchanged in building distribution network models: physical network model data (blue rounded rectangles), situational data (red rounded rectangles), and design engineering data (purple rounded rectangles)
- Data flows in between sources and cases (arrows) which universally end up being proprietary and 'one off'

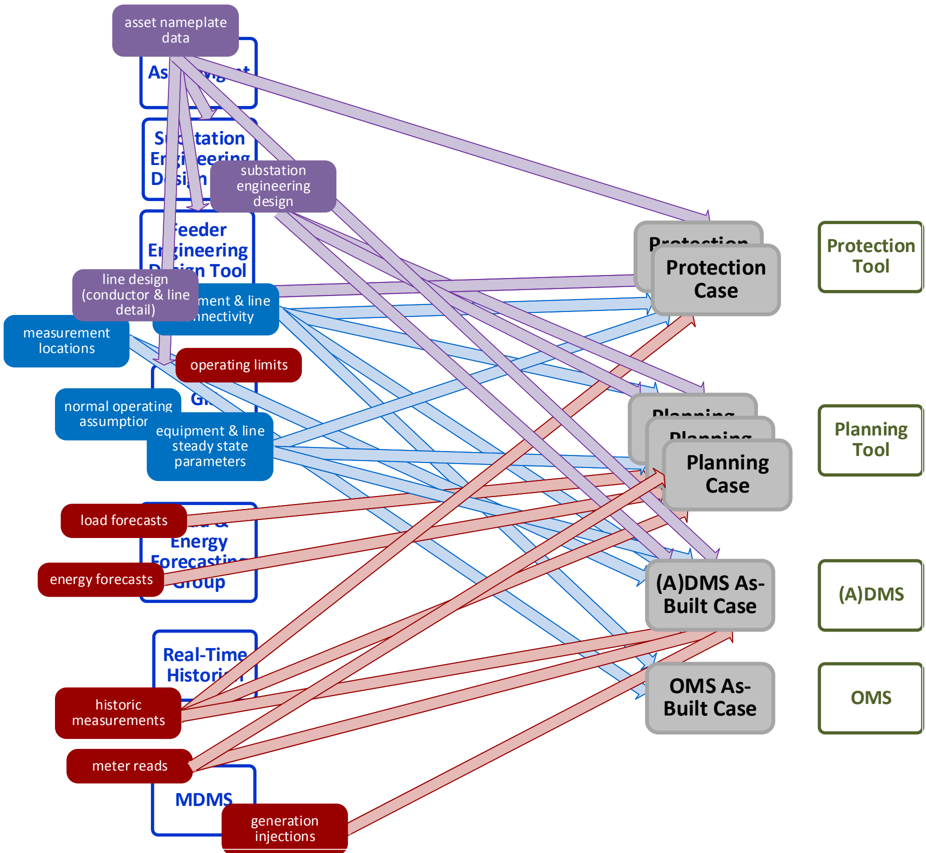

Figure 4 – Today's typical distribution network model data flows

The situation is a natural result of the factors cited above: network model data is inherently challenging to manage, consuming applications need different assemblies of data, and there is great variation and volatility in distribution solution approaches. At both the utility level and at the industry level, there is no real overarching data management architecture for distribution network model data.

A Data Management Architecture for the Industry

To address the problem, EPRI has launched the Distribution GIS and Grid Model Data Management project [1], a collaborative initiative with the ambitious goal of defining an industry architecture for managing network model data. It is a multi-year, multi-utility project which began in the fall of 2017 and will complete in 2020. The project currently has a diverse group of 9 utilities participating and is actively seeking additional members.

Initial project activities have focused on doing deep-dives at most of the participating utilities. The purpose of the deep-dives is two-fold:

- To help utilities understand their current data flows at an enterprise level and to envision how an approach founded on an industry data management architecture might be of local benefit
- To ensure that the requirements identified and the architectural solution created by the EPRI project are grounded in real-world understanding

In addition to the main activity of architectural development, several complementary project activities are planned to maximize the value of the architectural work:

- A substantial amount of technology transfer activity will promote industry understanding of and vendor product support for the architectural solution. In the view of the project, vendor implementation of tool interfaces conforming to the architecture is the most effective means of delivering the value of the project to the industry at large.
- Participating utilities will be provided with actionable strategies for improving their GIS data accuracy, their mobile solutions and their grid model data management.
- Project learnings will be contributed to the International Electrotechnical Commission (IEC) Common Information Model (CIM) Working Groups to ensure that there is a solid standard on which vendors, integrators, and utilities can rely in their interface implementations and solution designs.

The architectural design work being undertaken by the project is being informed and underpinned by a variety of earlier learnings including EPRI transmission network model data management work [2] [3] and distribution system modeling work [4], DOE's Modern Distribution Grid Report series [5], Southern California Edison's Grid Modernization Initiative [6], work done by DOE's Grid Modernization Lab Consortium [7], and the ongoing development of the IEC CIM Interface Reference Model (IRM) [8].

Data Architecture Development Approach

The architectural development methodology being followed in the EPRI project aligns with the approach used in the CIM IRM, where business functions (as opposed to specific software applications) are used as the framework for describing the data exchange environment. This approach allows the conversation to move beyond the local decisions that vendors or utilities have made about the functions implemented by specific applications. The dialog can proceed on the basis of the far more universal set of processes undertaken by nearly all utilities as they go about the business of operating the distribution grid.

Leveraging this approach, the business functions performed in planning and operating the grid can be analyzed and decomposed (sub-divided) into smaller and smaller granularity business functions. Ultimately, the sets of data, called business objects, shared between business sub-functions can be identified and their content defined. This concept is illustrated in Figure 5.

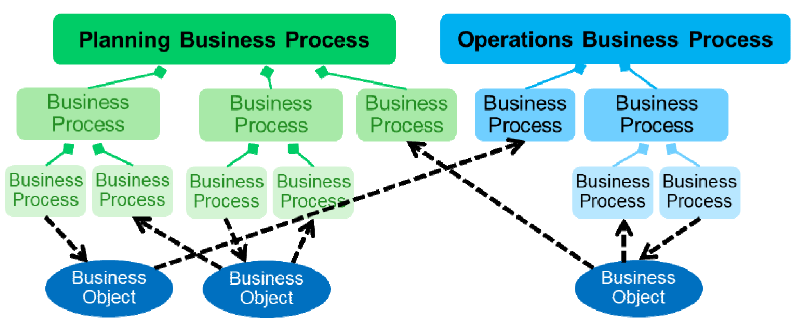

Figure 5 – Business process decomposition and shared sets of data

Business objects defined in this fashion become truly useful to the industry when the structure of their content is defined by an industry information model, like the CIM. Then utilities and application vendors alike have the support they require for designing and implementing truly interoperable solutions.

The EPRI Distribution GIS and Grid Model Data Management project is using a top-down approach, exploring business functions, their sub-functions and relationships. As of the summer of 2018, an initial draft of a high-level functional Reference Model has been created by the project. Review and refinement will begin in the fall of 2018 in a series of face-to-face workshops with utility participants. Continued development will occur over the next year with input and guidance from multiple sources, including:

- Utilities participating in the project, whose insight is sharpened by the project deep-dive experience
- A diverse set of consultants engaged directly in the project
- A substantial number of application and integration vendors who have expressed interest in the project
- A larger group of utilities and integration consultants whose feedback is being solicited
- The CIM working groups currently refining the CIM's IRM.

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