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# Implementation of Model-Driven Visualizations in Dominion Energy

**H. HUANG [1] [2], X. ZOU [1] [2]**
**H. LIU [2], K. THOMAS [2], S. P. ADAMS [2], T. XIA [2]**
**[1]. Virginia Polytechnic Institute and State University**
**[2]. Dominion Energy**
**USA**

## SUMMARY

The power industry, a fundamental infrastructure in the national economy, has a significant influence on the whole society. In today's power systems, the reconstruction of the power industry has been accomplished with the liberalization of the energy market. To be a competitive electric utility, safety, stability and high efficiency are the most critical aspects.

As power systems develop and expand rapidly, an overwhelming number of devices are deployed in the grid. Due to this increase in devices, it also increases the risk for unexpected faults and interruptions. These failures may cause severe damage. However, Information Technology (IT) with advanced capabilities of data management and calculations would leverage applications in electric utilities in terms of monitoring, data analytics and control. Therefore, it is reasonable to generate a model-driven visualization concept that can efficiently monitor and manage the status of devices and operating conditions in a power system. The concept of Asset Management (AM) based on model-driven visualizations is the optimal method since it can help engineers make decisions for all assets to alleviate risk, reduce costs and optimize profit.

This paper describes two visualization applications: equipment dashboards and one-line diagrams. Both of them are real-time applications which display current snapshots and trend historical data. One-line diagrams that can be automatically generated are an attractive topic for electric utilities since this functionality reduces the labor effort significantly. Equipment dashboards contain various interactive parameters and visual cues of changing states that can help engineers detect abnormal statuses and conditions outside of or nearing operational limits.

## KEYWORDS

Asset management, model-driven visualization, real-time monitoring, time-series database

hhuiy92@vt.edu

# I. INTRODUCTION

With the expansion of power systems and increased usage of advanced information technologies, the categories and quantities of data at various resolutions are increasing dramatically. Simultaneously, changes in the structure of the power grid and generation portfolios are changing the way utilities operate. These growing challenges make it more crucial than ever for utilities to more effectively utilize their amassed data to overcome the growing list of hurdles.

In the transmission network of a power system, reliability and health of devices are very critical because serious incidents may occur due to unpredictable failures and interruptions. These failures might cause damages and even disasters which are negative for the power system operations [1].

Taking advantage of time-series optimized databases for real-time data sources, and robust data models to incorporate static data, data can be integrated from various sources into a common platform. The majority of time-series data is still of the Supervisory Control and Data Acquisition (SCADA) variety, being polled at relatively slow rates from Remote Terminal Units (RTUs) by the Energy Management System (EMS) and Distribution Management System (DMS), or more recently possibly an Advanced Distribution Management System (ADMS). In addition, however, an increasing number of Phasor Measurement Units (PMUs), providing high resolution, time-synchronized, synchrophasor data can be viewed as another critical input for the data platform. This data, however, brings its own challenges due to its storage capacity and high speed processing needs. To leverage all of this data, a suitable data model needs to be developed. Inclusion of static data, such as Global Positioning System (GPS) coordinates, asset information, and more can be interfaced into this data model. Based on their individual business requirements, end users can then either utilize the out-of-the-box tools to visualize data or customize applications with advanced algorithms.

An implementation of model-driven visualization is developed to monitor data from the transmission equipment. The visualization of the data is achieved by polling the real-time data and tracing the historical data, with the aim of supervising the condition of the transmission grid and making decision to maintain the stability of the system.

The rest of the paper is composed of the following sections. The second section describes the definition of AM in power systems. The third section introduces the related software used to implement AM system. In the fourth section, the implementation of AM is explained in detail through software application. The last section concludes the whole paper.

# II. ASSET MANAGEMENT SYSTEM

Asset Management was initially used in financial sectors to manage client assets, but electricity companies require different approaches and more complicated processes for AM. In electricity companies, AM is a complex procedure that makes management and technical decisions in order to minimize cost, optimize performance, and reduce risk exposure for the life of the assets.

In electricity companies, equipment management is a crucial concept within AM. In order to obtain the maximum profit and assure good quality of service, it is necessary to maintain electrical equipment at a high level of safety and efficiency [2]. The historical data and streaming real-time data can help to maintain and inspect the condition of the electrical equipment. Therefore, the availability of good data is the base for optimal AM in power industries [1]. In addition, optimal Asset Management in electricity companies can increase the efficiency [3].

In order to fully understand what an Asset Management System is composed of, it is necessary to know the architecture of the system and how to implement it. The architecture of an Asset Management system is described as below and illustrated in Figure 1 [2]:

- Local systems for monitoring and diagnosis of electrical equipment from substations;
- Software applications for monitoring and diagnosis of electrical equipment in each power substations;
- Systems for transmission of data to a central data processing unit;
- Software application provides information acquisition. It enhances the ability to maintain the safe condition and continuous operation of electrical equipment.

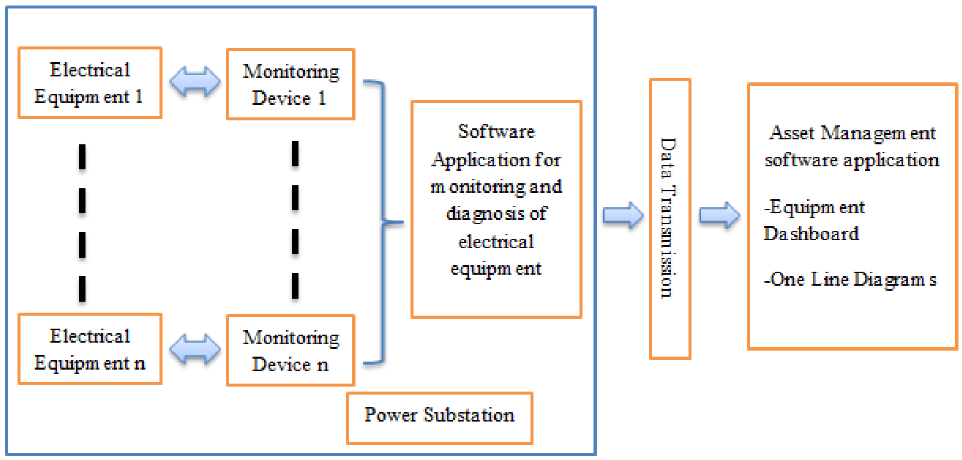

Figure 1 Architecture of Operations Awareness and Asset Management

## III. IMPLEMENTATION OF APPLICATIONS

Model-driven visualizations for AM are implemented through data collection and processing. The OSIsoft PI system is used for supporting applications in this paper and stores and manages real-time data. Several data sources, such as Energy Management System (EMS) /Supervisory Control and Data Acquisition (SCADA), Distribution Management System (DMS) forward data with various resolutions to the PI system. Out-of-box tools, which are applied to build out model-driven visualizations based on the PI system, are PI DataLink, PI Coresight, PI ProcessBook and PI AF SDK. Moreover, CIMSpy, third party software, is utilized to implement one-line diagrams. It is designed to provide information integration and model exchange in power systems and collect EMS topology and data from EMS then generate Common Information Model (CIM)/eXtensible Markup Language (XML) files. CIMSpy provides various features to manage the model and detect incremental updates. Thus, parameters and data are feasible to integrate into the PI system through the standard Scalable Vector Graphics (SVG) files.

Two visualization applications for AM are described in this section including one-line diagrams and equipment dashboards. They are designed to receive real-time data from the PI database model. Then, the data can be processed to accomplish visualizations. The applications implement four key stages to enhance the AM:

- Monitor parameters from different devices (e.g. current, voltage, reactive power etc.) and detect status.
- Generate state reports for a chosen moment.
- Generate diagrams and trends.
- Create maintenance activity with the help of diagrams, [4] and [5].

## A. Auto-Generation of One-Line Diagrams

Auto-Generation of a one-line diagram is an attractive topic for electric utilities since this functionality reduces the human effort significantly. The objective of auto-generation in the model-exploration tool is to enable users to see accurate and clear one-line diagrams which exhibit the underlying relationship within data. Auto-generation of a one-line diagram involves mapping data to graphical components and adapting the graphical elements to present the features of data from various systems.

The critical operation for achieving this goal is to discover the mapping and tuning patterns between the data and the graphical components. Once the template is completed, various types of one-line diagrams can be created to visualize the substation layout and the system operating condition.

One of the stages for implementation of an Asset Management system is generation of the diagrams. CIMSpy is a tool to automatically generate a one- line diagram with clear layout based on artificial intelligence (AI) and advanced algorithms. Users need to be able to visualize the network topology at different levels in detail without overlapping and bending. Figure 2 is an example of auto-generated one line diagram as illustrated below. The diagrams can be also adjusted for clarity and better appearance. The components of diagrams can be easily manipulated through grouping, drag-and-drop, rotating, and resizing. An adjusted one line diagram is illustrated in Figure 3.

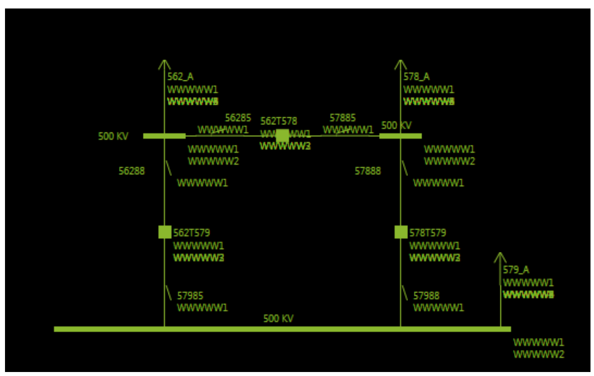

Figure 2 One Line Diagram Auto-Generated by CIMSpy

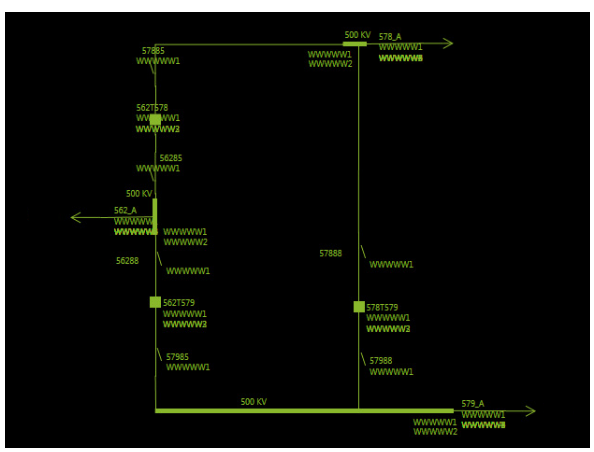

Figure 3 Adjusted One Line Diagram

In addition, CIMSpy unifies models and graphics because auto-generation creates a visually pleasing one-line diagram once the network model is populated with data [6]. Using CIMSpy is an advantageous method for creating one line diagrams due to the significant reduction in engineering effort and cost. In the past, the one line diagrams were created manually by engineers, which is time consuming and expensive. Furthermore, CIMSpy eliminates human error by auto-generating one-line diagrams through advanced algorithms. Diagram maintenance can also be accomplished in CIMSpy in order to keep consistent with updated models. By this Artificial Intelligence tool, an organized and clear layout of one line diagram can be generated, which can help to establish maintenance activity in implementation of an Asset Management [2].

Monitoring of the current state of various assets on the one-line displays, as part of a broader Asset Management plan, can be accomplished by integrating the displays with PI CoreSight. CIMSpy can export one line diagrams into Scalable Vector Graphics (SVG) format. Then, the diagrams are able to be displayed in PI CoreSight, which is a window web server and visualization tool. A data link can be established in PI CoreSight to display up-to-date snapshot measurements and statuses from the PI Data Historian servers for different equipment within the one line diagram. After that, different parameters of equipment can be monitored, such as real power, reactive power, apparent power and more. The streaming real-time data is displayed and continuously updated in PI CoreSight. It has the ability to help power companies detect contingencies and faults in the power systems. And, the historical data is also stored for further analysis. The data and the displays within the PI system data can easily be shared to other users within the same network. Therefore, there is wider usage and it is easier for clients to acquire and share data within the same network. Moreover, PI CoreSight provides movable time ranges for access to historical or forecasted data, and gauges for different viewing options for measurements with known limits. It is easy to manipulate the data for the clients. All these features are illustrated in Figure 4 below.

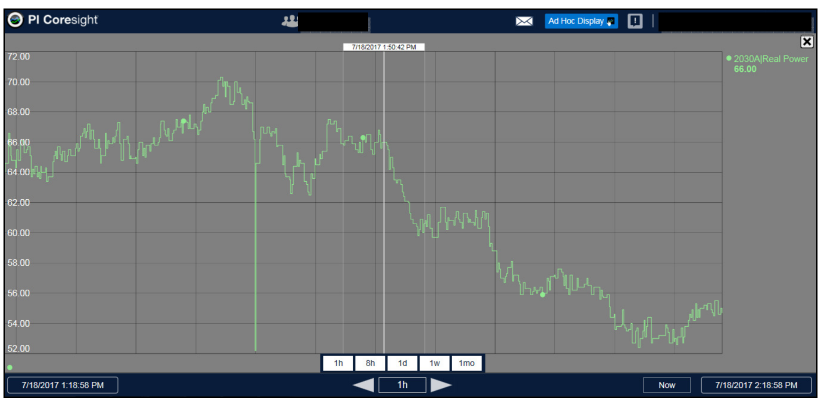

Figure 4 PI CoreSight Data Display

## B. Equipment Dashboard

The development of modern communication systems has made it convenient for engineers to operate and monitor substation equipment. For the operation group, the status of capacitor banks, reactor banks and transformers are of high importance. Taking reactor banks as an example, users find that circuit breaker status, reactive power, voltage and current are helpful in analyzing the root cause of an incident. Other information, such as Load Tap Changer (LTC) positions and synchronized alarms can also be helpful. Taking advantage of PI ProcessBook, users can leverage data-rich visualizations to provide critical data and information to users.

The most essential part of dashboards is the selection of the parameters. As the dashboards were established for the transmission operations group, the parameters for reactor banks as well as capacitor banks were selected according to their needs. These include the status of circuit breakers, voltage, current, reactive power, LTC position and synchronism alarm. The parameters for transformers are the real and reactive power, high and low-side voltages, values for top oil temperature, winding temperature and hydrogen gas in parts per million (PPM). The reactor bank dashboard was created manually in PI ProcessBook initially. However, due to the limitation of PI ProcessBook and the large number of capacitor banks and transformers in Dominion's system, PI Web API and AF SDK, along with web design technologies such as HTML5 and JavaScript are chosen to auto-generate dashboards. A big advantage of web applications over Pi ProcessBook is the performance and flexibility. In the following sections, we will discuss in detail on both approaches to creating custom displays.

### *1. Dashboard built in PI ProcessBook*

PI ProcessBook is a visualization tool that retrieves real-time and historical data from PI servers, which helps clients analyse events with interactive graphical displays [7]. Taking advantage of this benefit, PI ProcessBook can be an appropriate software solution to help create dashboards for a small number of assets that change infrequently. Detail of the reactor banks dashboard is shown in Figure 5.

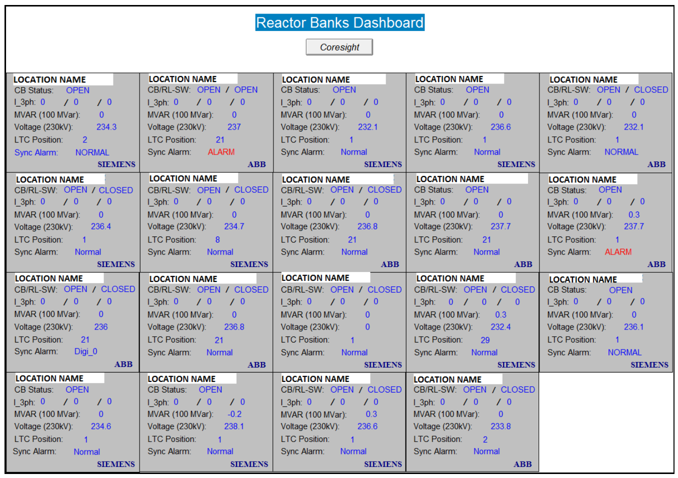

Figure 5 Detail of Reactor Banks Dashboard in PI ProcessBook

Moreover, the dashboard also displays background colour changes for abnormal statuses and flashing text for synchronism alarm warnings. The button below the title is a link to PI Coresight to show the trend of the reactive power for all the locations. The dashboard is a practical tool for the operations group to supervise abnormal statuses and detect faults and interruptions from data analysis. However, it is inconvenient to add a new site into the dashboard. All parameters need to be inserted manually, and it becomes an even greater challenge when a massive number of parameters and equipment is to be integrated into the dashboard.

### *2. Dashboard generated with PI Web API*

For engineers, capacitor banks and transformers are as important as reactor banks. However, most utilities have a much larger fleet of these assets than reactor banks. Due to the restrictions of PI ProcessBook, as detailed in the previous section, developing the dashboard and converting it to a web application may be a better approach. To gain access to the PI server through HTTP, PI Web API is employed in the project, which provides the Representational State Transfer (REST) service to obtain, create and manage time-series asset and event frame data. Combined with the Vue.js library, the new reactor dashboard is illustrated in Figure 6.

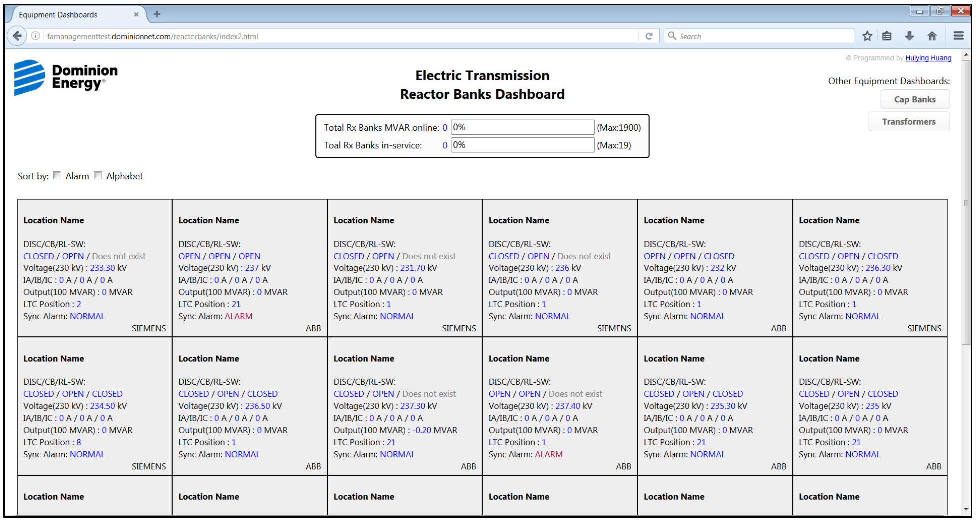

Figure 6 Reactor Banks Dashboard Detail Generated with Web Application

In addition to the functionality that is implemented in PI ProcessBook, the web application also accomplished switching between different dashboards, fleet-wide statistics for certain parameters such as total MVARs, and sorting and filtering functions. This new equipment dashboard circumvents limitations of PI ProcessBook when a massive quantity of parameters is desired since the box for each site is generated automatically. Furthermore, engineers can monitor different equipment in one web page and reduce unnecessary operations. For example, putting nearby reactor and capacitor banks in service at the same time may not be the optimal solution to achieve the end goal of the system operators. . It is challenging to detect such situations without visualization of data. However, engineers can now observe reactive power of reactor banks and capacitor banks to investigate when and why the operators or automatic controllers are operating them at the same time. The framework of each capacitor bank and transformer unit is also presented in Figure 7.

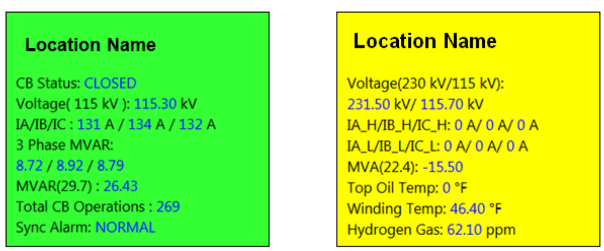

Figure 7 Detail for Capacitor Bank

# IV. CONCLUSION

Model-driven visualizations for AM are important for electric utilities. It may boost grid reliability, improve system efficiency and assist in monitoring the health of critical devices in Dominion's transmission network. It can optimize the equipment utilization and equipment management by allowing operations personnel to immediately make helpful and effective decisions for any unexpected contingencies and fault situations which may cause unwanted damage to the equipment and power systems. The applications improve the ability to monitor real-time data from different data sources. The real-time data can be displayed in various visualization tools, which give users better view and easier manipulation for analysis purpose. Therefore, more useful and proper decisions can be made through historical data and real-time data with the aim of alleviating risk, reducing cost and optimizing the profit for electricity companies.

In this paper, OSIsoft and CIMSpy are used in order to achieve a software application of Asset Management. The ultimate purpose of this paper is to encourage electricity companies to use appropriate software applications to acquire information and perform data analysis to maintain the stability of power systems.

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