ENHANCED CONSUMER AND GRID MANAGEMENT THROUGH INTEGRATED DISTRIBUTION MANAGEMENT SYSTEMS (IDMS)

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ABSTRACT

The expectations of Smart Grid are increasing the pressure on all aspects of network operations for improved performance. The ability to manage the potential widespread introduction of distributed generation, storage and demand management devices, also referred to as Distributed Energy Resources (DER), requires advanced network-wide analysis and control functions. This paper describes the next generation Integrated Distribution Management System (IDMS) for enhanced utility operational capabilities and end-use consumer satisfaction.

INTRODUCTION

The advancement of worldwide Smart Grid initiatives are being driven by a new paradigm around enabling more active consumer participation in electric grid management. There are numerous pilot programs in progress worldwide to validate the viability of such a paradigm. The progression towards smart meters and advanced metering infrastructure (AMI) as key components and enablers of Smart Grid means that it will become a primary tool for observation of real-time system operation, customer outages and enhanced services including demand response.

The introduction of Distributed Energy Resources (DER) and other smart devices (e.g. smart meters, distribution automation (DA) and advanced sensors) will bring a new level of complexity and benefits to the management of the distribution grid. The requirement for self-healing capabilities across a broad range of field-deployed devices involves a high level of knowledge of the real-time connectivity of the network combined with operational analysis tools that have access to all available information. As the levels of automation of the network increases so does the need for accurate real-time modelling and effective visualization.

The regulatory infrastructure and competitive pressures will demand ever-increasing levels of network performance and reliability, and this coupled with the need to ensure customer satisfaction improvement by automatically detecting customer outages and taking necessary actions to restore customers will require advanced operational analysis tools to simulate, and to reliably and securely operate in a real-time Smart Grid environment [1].

Next generation of Smart Grid distribution management will require tight integration between traditional SCADA, distribution management and outage management whilst also integrating with key enterprise systems to enable coordinated analysis and control of active distribution networks with large scale DER and DA devices.

The following sections describes ALSTOM's Integrated Distribution Management System (IDMS) that includes key functionality for Smart Grid operations based on the **e-terra***distribution* control room IT platform. The IDMS provides an effective platform for the monitoring and supervision of distribution networks, for enhanced utility operational capabilities and end-use consumer satisfaction.

IDMS OVERVIEW

The IDMS platform includes SCADA, distribution network analysis and optimization, and outage management, all sharing a single dynamic network connectivity model and a single comprehensive dispatcher user interface, i.e. a single integrated platform.

IDMS is designed to improve the performance of the distribution dispatchers, enhance their capabilities and allow them to manage the network more effectively, particularly under storm conditions with significant unplanned outages. Key potential benefits to electric distribution utilities and end-use customers include:

- Enhanced utility cost savings through reduced distribution system losses, peak load shaving (demand shifting), and optimized utility operational costs.
- Enhanced utility performance improvements through leveraging and integrating enterprise applications (workforce management, distribution automation, customer information systems, geographic information systems, interactive voice response systems, advanced metering infrastructure and meter data management) for improved crew management and safety, load profiling and forecasting, and integration and management of active DER.
- Improved end-use customer satisfaction through reducing outage times from unplanned outages, improving grid reliability and power quality, and adoption and deployment of DER (e.g. rooftop solar, electric vehicle charging, etc.).

The IDMS platform meets requirements specified for distribution networks that are located in, and operating under, varying geographic and extreme weather conditions. The IDMS provides a high-performance storm-ready platform, as it is very important that these systems are able to continue operations under severe storm conditions, and not just blue sky conditions [2].

IDMS MODULAR FUNCTIONALITY

The figure below provides a high-level overview of the key components within the IDMS platform (in gold), and also key enterprise systems for data integration (in green).

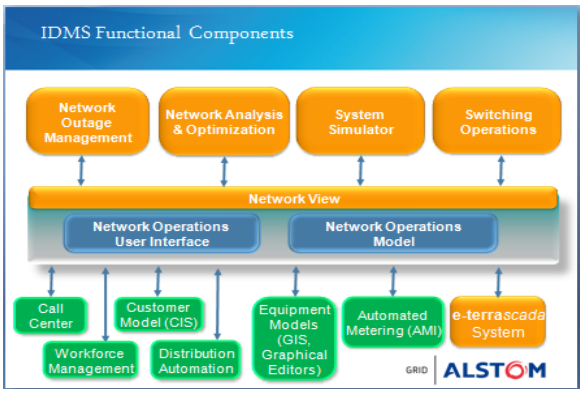

Figure 1 IDMS Modular Components

The Network View module consists of a Network Operations Model combined with a powerful Network Operations user interface, providing the dispatcher with all the key capabilities for viewing and managing the distribution network. The user interface is able to display the Network Operations Model in a range of modes from geographic to schematic or variations.

The Network Analysis module is based on a robust and high performance distribution power flow that allows dispatchers and planning engineers to study the current state of the network, or the expected state in the future. The core analysis engine is the distribution network power flow which supports a fully unbalanced model and is capable of solving for both radial and meshed networks. Network Analysis includes the following analysis functions:

- Distribution Power Flow – this function finds the complex voltages at all nodes and the power flows through all feeder segments in the distribution system.
- Power Quality Analysis – this function is responsible for estimating the quality of service and calculates voltage quality based on accumulated Power Quality Indices to monitor the power quality in terms of the degree of normal and imbalance voltage limit violation.
- Loss Analysis – this function calculates the state (KW, kVAR, Amps, kV, phase angle) from the distribution buses in primary substations to the equivalent load nodes in the secondary of the system based on existing operating conditions. The losses are available per phase for every device.
- Short Circuit Analysis – this function calculates the maximum short circuit current available for various fault types. It automatically finds the highest impedance fault path in the dynamic network.
- Load Model and Forecast – this function estimates the loads on both individual nodes and feeders to support network analysis for future time-frames (study-mode).

The Network Optimizer module provides an enhanced level of analysis that allows the dispatcher to optimize the network configuration and achieve desired goals such as load balancing across feeders and improved feeder voltage profiles. Network Optimizer includes the following analysis functions:

- Load and Volt/Var Management – this function optimizes and coordinates capacitors and voltage regulators to provide reactive power support and maintain system operation within voltage limits [3].
- Fault Location, Isolation and Service Restoration – this function generates a switching sequence to isolate faulted sections and optimally restore service to the non-faulted sections.
- Planned Outage Study – this function is a study tool that provides an automated means of preparing, evaluating and managing planned outages.
- Automated Feeder Reconfiguration – this function optimally restores the network to its normal configuration, unloads overloaded segments and optimizes the location of normally open points.

The Switching Operations module supports the process of switching on the network and interfaces directly to the Network Operations Model. Switching Orders can be created manually or generated automatically by the Network Optimization functions. Key functionality includes:

- Creation, Validation and Execution of Switching Orders which is a detailed set of instructions used to plan and coordinate switching actions in the network.
- Creation and Management of Safety Documents that are formal documents that transfer jurisdiction of a defined section of the network between operations and maintenance staff.

The Network Outage Management module is a combined Trouble Call and Outage Management System. It allows dispatchers to manage unscheduled and planned network outages from within a unified and integrated environment. From the initial notification of a fault, through prediction, crew assignment, and restoration switching to return-to-normal, the dispatcher is able to work from a single set of user interfaces. All the necessary information for each phase of the job is clearly presented in a way that allows the dispatcher to manage each outage efficiently while also staying aware of other network activity.

The Network Simulator module utilizes the same software components, interfaces and user interface as the Real-time IDMS. The simulator includes simulation for smart meters and customer calls. Dispatchers can be trained in both routine and emergency procedures in an environment that accurately represents the behaviour and response of the real system. In addition, the simulator can be used to validate new network models, business processes such as storm restoration programs, and also includes a replay mode for detailed analysis and training purposes.

The IDMS and its modules have been designed to handle major storm situations, by providing high performance and effective tools that support large numbers of dispatchers combined with the ability to easily balance each dispatcher's workload. A comprehensive and flexible record-keeping function automatically provides all the necessary information (reliability and safety indices) for regulatory reporting requirements, reducing the amount of follow-up work required after major storm events.

IDMS SYSTEM ARCHITECTURE

The IDMS has been developed around system scalability, seamless model updates, customizable data interfaces and user interface and cyber security, based on the paradigm of Service Oriented Architecture (SOA).

The IDMS is able to handle very large electrical models by decomposing them into smaller pieces and leveraging state of the art multi-core processors. Updates for these very large models can be applied seamlessly many times per day without disrupting the IDMS functions and operational systems.

The IDMS user interface is tightly integrated using a set of configurable plug-ins within a flexible framework. Each plug-in can be customized according to the specific business processes of the electric utility. The user interface provides seamless navigation and a common look and feel to enhance smart grid operations.

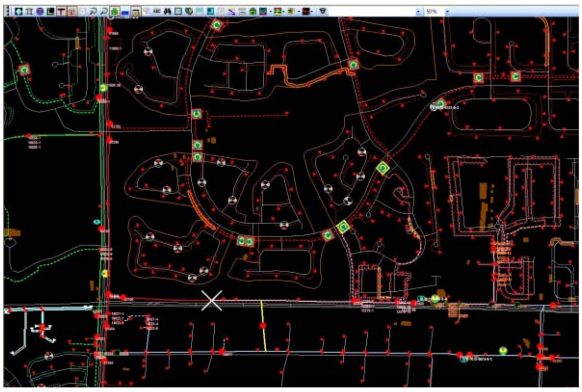

Figure 2 IDMS Network Data View

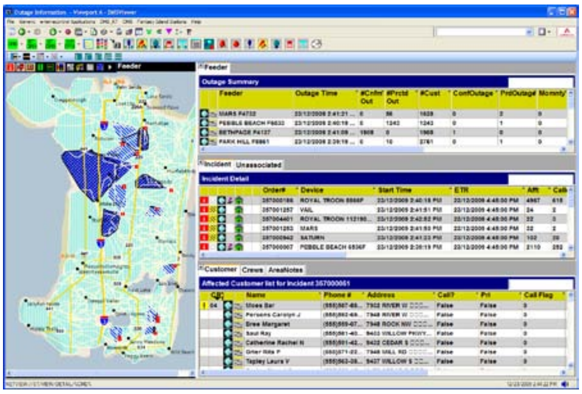

Figure 3 IDMS Customer and Crew Data

A highly configurable data interface framework has been developed by leveraging XML based messaging and Web Services according SOA paradigm. The IDMS uses IEC Common Information Model (CIM) 61968 based messaging to provide a flexible means of interfacing to other IT systems regardless of their internal data structures, thus simplifying integration and maintenance.

IDMS CYBER SECURITY

A critical feature the IDMS is its ability to interface smart meters, distributed communication and control pathways, and open standard based networks that are the foundation of the Smart Grid. However this creates cyber security challenges including consumer data privacy and potential cyber attacks to the electricity grid through the open network. Consumer data privacy issues must be addressed by all systems to enable consumer and political acceptance. The ultimate defence of cyber threats is built-in data privacy, integrity, availability and system resilience in Smart Grid and IDMS applications.

The IDMS has been developed with this philosophy in mind. The embedded business and security intelligence effectively isolates and mitigates cyber attacks, and will prevent the propagation to other levels in the hierarchical communication and control pathway, thus safeguarding the overall stability of the electricity grid from cyber attacks. IDMS includes access control, data confidentiality and integrity as core built-in features using information security standard technologies to ensure interoperability with other business systems.

ALSTOM continues to support and actively participate in multiple standards development process and industry workgroups, e.g. NERC CIP, WS-Security, DNP3 Secure Authentication, IEC 62351, etc.

IDMS INTEGRATION WITH AMI-MDM

With the recent surge of interest to implement smarter management of distribution systems has come a focus upon using the new capabilities for widespread monitoring and control at the level of energy consumers and DER as provided by AMI and MDM systems. ALSTOM is actively deploying IDMS projects that integrate with AMI and MDM systems to enhance the performance of the Network Outage Management and Volt/Var optimization functions and simultaneously expand the utilities' business case for implementing AMI and MDM.

AMI is being used to enhance the Network Outage Management function in several respects:

- Power-off notifications from individual meters are received by exception, to augment customer calls associated with un-planned outages. Using these automatically generated messages allows the Network Outage Management function to more quickly determine the extent of an outage and predict with more certainty which protective devices have opened as a result of faults. This in turn leads to a faster overall restoration process and improved performance indices.
- Power-restoration notifications are similarly used to visualize and track the life-cycle of outages.
- As outage restoration activity occurs, individual meters are automatically pinged to verify energization and communication status. This allows the utility to ensure that power has been completely restored to a neighborhood before the trucks move to another location.
- Individual meter pinging to detect load-side voltage can be used as a mechanism to avoid crew dispatches to single premise outages when the problem appears to be inside the premise.

Volt/Var Optimization, running in a fully automated mode, incorporates AMI data to expand upon the field observability and control provided by classic distribution SCADA:

- The function proactively queries for near-real-time voltage measurements from a small set of smart meters on each feeder where Volt/Var control is active. These measurements are used to check that the existing circuit voltage is not already too close to operational limits before issuing new controls that could result in violations. With today's AMI communication bandwidth, care must be taken not to overwhelm the system so a select set of strategic bellwether meter voltage measurement points are dynamically selected. As the near-real time distribution state estimation problem is continuously solved, tracking changes in connectivity and loading, new bellwether meters are selected by recalculating what points on the circuit will be at the lowest voltage.
- Another way AMI data is being used is by subscribing to low voltage brown out alarms that are reported as exception messages. These inform the Volt/Var control function when meter locations are approaching a low voltage limit. This will typically happen to groups of meters in close electrical proximity and again provides a warning to the Volt/Var control function that no further voltage reduction should be done for a given area. It is also a safety mechanism notifying the application that the network is not behaving in the expected way. This could be the result of an asset modeling error or incorrect switching status. Whatever the case, it is a trigger to investigate the problem and in this manner AMI will be helping to focus and refine the process of maintaining an accurate model.

There are a variety of areas where AMI data that has been processed through an MDM will be very useful for network analysis. The calculation of pseudo-measurements for the individual consumer load points for distribution state estimation can make good use of MDM load profiles which are automatically created and sanitized by the validation and estimation functions of the MDM. The fact that these historical load profiles are produced automatically, directly reduces the burden of maintaining an accurate model. Furthermore, the MDM based historical load profiles are good for directly supporting off-line power flow studies where there is no SCADA data allocation available. As AMI communication bandwidth increases, load and voltage measurements from smart meters will be used directly in the state estimation problem, reducing the need to calculate pseudo-measurements.

SUMMARY

The advent of Smart Grid and introduction of smart meters, AMI, DA and DER have created a fast moving change within distribution systems operations and automation. To effectively manage this will require a new integrated paradigm and this can only be accomplished through a well designed IDMS platform based around smart grid data standards and architecture. The IDMS platform has been developed to enhance distribution grid performance and improve end-use customer satisfaction, and provides a platform to enable true Smart Grid capabilities and enhanced end-use customer satisfaction.

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