Network management for smart grids

Innovative operations centers to manage future distribution networks

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Traditional power networks have been carefully managed at operations centers to ensure adequate power supplies are maintained despite peaks and troughs in demand. Each section of the grid has an operations center that conducts and coordinates various functions including system monitoring, control, crew administration and dispatch. It has been regarded conventionally as "the brain" of the power system, from which operations have been directed.

As distribution systems are gradually evolving into smart distribution systems, the operations centers that control them are evolving to take on new roles to manage such grids. The separate IT systems operating in these control centers are becoming more streamlined, communicating seamlessly to provide an integrated monitoring and management system. More advanced applications and analytical software are providing more sophisticated analyses and automated operations. The control systems of operations centers are not only helping to make the grid smarter but are also helping to improve support for decision makers responsible for operations, maintenance and planning. Such integrated operations centers are helping distribution organizations meet their goals despite ever-increasing challenges.

Conventional monitoring and control systems for distribution networks have in the past been relatively low-tech. Wall boards displaying the system's status were commonplace. These boards could be covered with sticky notes, push-pins, and ad-hoc changes, which may have been difficult to monitor and inflexible. Paper-based maps of the distribution circuits, which were often annotated manually and risked being out of date, were used to direct maintenance work on the system. Paper-based switch orders were used to plan, execute and track scheduled switching on the system. Outage calls were received by operators, with little information to provide to customers about the outages. Paper-based outage tickets were commonly used for tracking customer outages. Communications with field-based crews were conducted by radio. These crews had to supply their location to the operating centers, and the communication of switching, the placement of tags and other operations were made verbally.

This is not to say that distribution operations have stood still over time. As technology and business needs have changed so too have many distribution operations centers. Many Supervisory Control and Data Acquisition (SCADA) systems have been extended from the transmission system to include monitoring and control of medium-voltage (MV) feeder breakers. In some cases, SCADA has been further extended out beyond the MV feeder circuit breaker to equipment such as reclosers, switches and capacitor switches.

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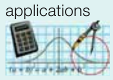
Modern computer-based outage management systems (OMSs) utilizing connectivity models and graphical user interfaces have become more common. An OMS typically includes functions such as trouble-call handling, outage analysis and prediction, crew management, and reliability reporting. At some distribution companies, an OMS can be utilized simultaneously by hundreds of users. It integrates information about customers, system status, and resources such as crews.

1 Deficiencies in today's distribution operations centers for grid management

	Separate IT systems 	Incomplete real-time system status 	Few advanced applications 
Examples	Non-integrated systems for: ■ Customer information system ■ Geographic information system ■ Trouble calls ■ Crew management ■ Switch order management ■ AMI ■ SCADA ■ Mobile workforce management ■ Work management	Lack of: ■ Equipment loading information ■ Status of switches, voltage regulator taps, capacitor banks ■ Location of momentary faults on system ■ Status of distributed resources ■ Customer demand/load	Lack of applications for: ■ Fault location ■ Restoration switching analysis ■ Volt/var control ■ Distribution state estimation
Consequences	■ Inefficient work processes ■ Redundant and/or inaccurate data ■ Longer outage durations ■ Possible noncompliance of work processes with possible safety issues	■ Inefficient equipment utilization ■ Difficult to enable customers to connect distributed energy resources to grid ■ No understanding of automated operations on feeder	■ Longer outage durations ■ Inefficient use of crew hours ■ No chance to reduce customer demand through voltage control at peak times ■ Higher system losses ■ Increased customer complaints for voltage out of range

Status

Despite the progress that has been made, there are still fundamental issues that need to be addressed. The table provides examples and discusses the consequences of separate (non-integrated) IT systems, incomplete real-time system status and the lack of advanced applications in the operations of distribution organizations 1.

The case for change

Within the last few years, several external drivers have helped accelerate the development and expansion of applications for smart grid technology. Drivers for change include society and government, the business environment of distribution organizations and technology.

In many countries, legislation and regulatory initiatives have been targeted towards the modernization of the grid. Environmental sustainability and ways of limiting carbon emissions have led to increased interest in smart grids. The increasing costs of new power generation and transmission, both in terms of infrastructure and fuel costs, are also factors influencing technology change. Further drivers for the development and adoption of smart grid technology have been the public's interest to stabilize climate change through greater use of renewables and calls from utilities and governments for improved distributed generation and demand response. From a business perspective, however, distribution organizations are looking to smart grids to help them maintain or improve reliability, increase asset utilization, deal with aging infrastructure and help reduce the impact of knowledge loss as employees reach retirement age.

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Technology has also been a great driver in smart grid development. Communication technology has strongly developed in the last decade. Today distribution companies have the choice between many different solutions. The communication can be based on a dedicated network owned by the distribution organization (eg, SCADA radio networks), or on third-party infrastructure (eg, global system for mobile communications, or GSM, provider networks). Depending on various factors, like required availability and bandwidth, the distribution organization can select the appropriate technology. Whatever the choice, it is certain that additional two-way communication in distribution networks will increase.

There are increasing numbers of distribution equipment with sensing, data processing, control, and communications on the feeder. Automation systems are becoming more common, with smart devices and appliances within a home network. The deployment of this technology will depend upon the development and unification of interoperability standards. The development of such standards is ubiquitous in the United States and Europe.

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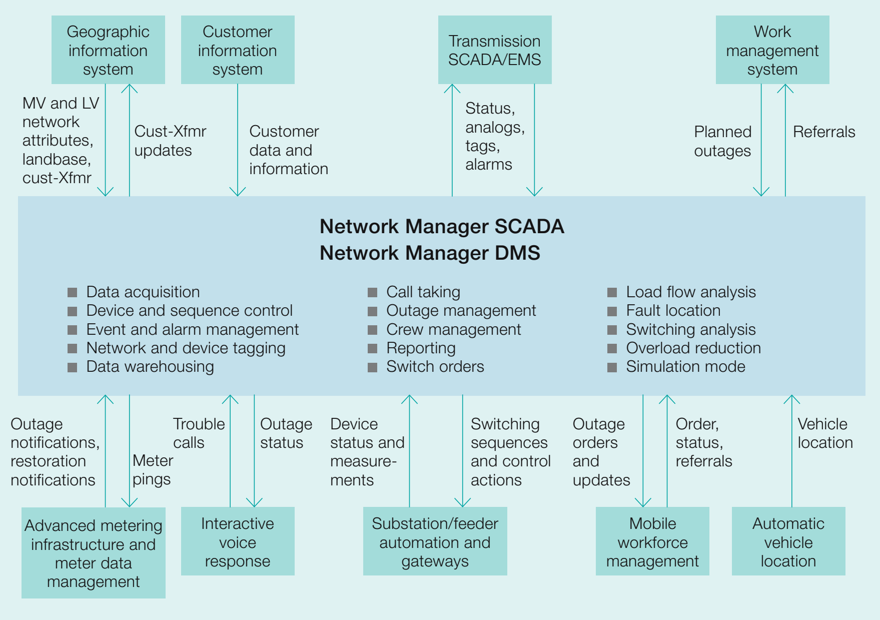
Systems integration

ABB is a leader in the development of smart grids around the world, and has invested time and resources to create the operations center systems that will control smart grids. Three important areas of systems integration are distribution management system (DMS) integration with SCADA, advance metering infrastructure (AMI) integration with the DMS, and the integration of data from substation gateways.

ABB has long been a leader in integrating SCADA at the distribution level with DMS applications. With the smart grid driving more distribution companies to install additional SCADA on the distribution system, ABB continues to improve its integration. Available functionality now includes the transfer of status/analog points from SCADA to the DMS; the sending of supervisory control and manual override commands from the DMS to the SCADA system; an integrated user interface running on the same PC operator console between the two systems; and integrated single sign-on for users.

The benefits of integrating SCADA with DMS include:
- Improved operations by close integration of DMS applications with distribution SCADA
- Increased operator efficiency with one system, eliminating the need to go to multiple systems with potentially different data

2 Systems integration for distribution-grid operations centers



3 Functionality and benefits of advance applications

DMS application	Functionality	Benefits
Unbalanced load flow analysis	Determination of the line currents and node voltages per phase for the entire distribution system, either online or offline in simulation mode	■ Improved system awareness ■ Higher asset utilization ■ Improved contingency planning
Load allocation and state estimation	Intelligent allocation of telemetered or historical measurements over the network to calculate estimated power flows, voltages, and limit violations based on real-time conditions	■ Improved load flow and state estimation calculations ■ Improved notification of overloaded equipment and voltage violations
Fault location	Identification of possible fault locations on system	■ Improved crew efficiencies in managing outages ■ Reduced customer average interruption duration index (CAIDI) and system average interruption duration index (SAIDI)
Restoration switching analysis	Evaluation of isolation and restoration switching schemes	■ Improved operator efficiencies during outages ■ Increased reliability
Distribution Volt/Var control	Monitoring and control of line capacitors, voltage regulators, and load tap changers (LTCs) to reduce peak load and system losses	■ Reduced customer demand at system peaks ■ Lower system losses ■ Improved voltage profiles
Line unloading	Computation and analysis of load transfer options, including overload reduction	■ Reduced thermal-mode failures ■ Longer equipment life due to reduced overloads ■ Higher asset utilization
Remote switching and restoration	Automatic feeder reconfiguration considering network operating conditions	■ Reduced CAIDI and SAIDI ■ Lower system losses

Transmission and distribution

- Integrated security analysis for substation and circuit operations to check for tags in one area affecting operations in the other
- Streamlined login and authority management within one system
- Consolidated system support for DMS, OMS and distribution SCADA

Installation of AMI systems is rapidly increasing, and ABB is developing ways that distribution organizations can leverage AMI data for operational purposes. Interfaces between AMI/MDM (meter data management) and SCADA/DMS have been developed for meter status queries, outage notifications and restoration notifications. Benefits include reduced customer outage durations and more efficient use of field resources. The use of other AMI data in DMS applications, such as interval demand data and voltage violations, is being explored. This would provide additional benefits, such as improved knowledge of system loading and better voltage profiles throughout the system.

In addition, many organizations are increasing the amount of substation automation and substation gateways on their systems. This provides increased access to data in intelligent electronic devices (IEDs) that are installed in substations and distribution systems, many of which have communications capabilities. These include more intelligent recloser controls, switch controls, and voltage regulator controls. Integration of these systems with the DMS provides the benefit of decentralized local control at the substation/feeder level, while providing system optimization through the DMS at the system level. The integration of SCADA and DMS with other systems provides an integrated operations center for managing the smart grid [2].

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Advanced network applications

With its Network Manager™ platform, ABB is leading the distribution industry in the development of advanced applications for distribution system management. Advanced applications use the network model along with the monitoring of the network operating conditions to provide recommendations for optimal network operation. As shown in the table, advanced applications can provide solutions to many challenges that distribution organizations are facing today [3].

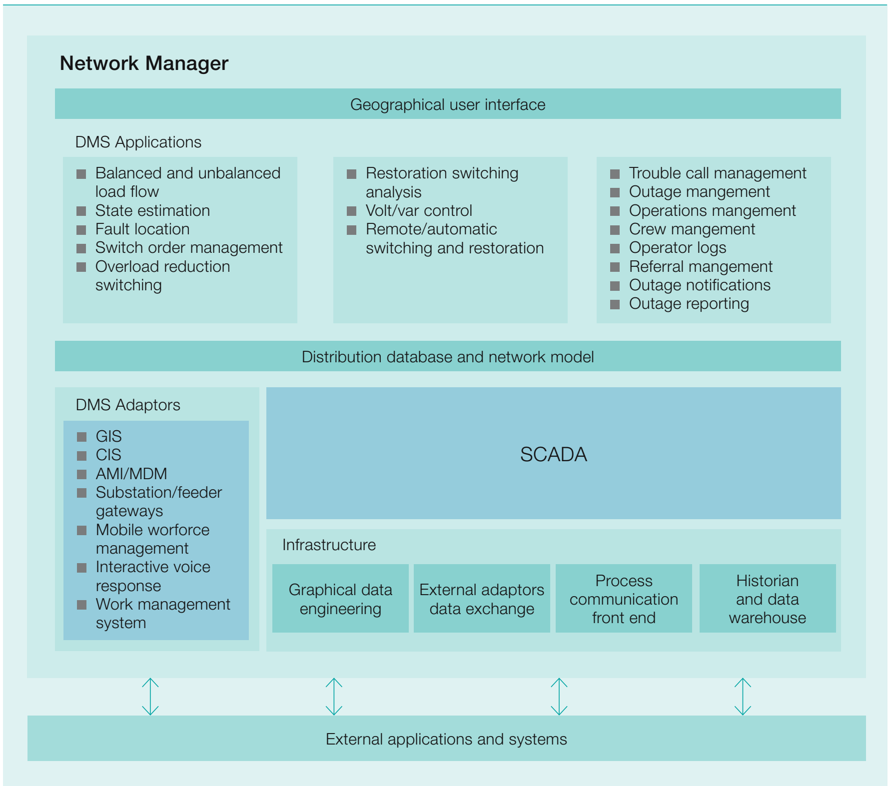
In many cases, distribution organizations choose to leave the operator in the decision loop so that the operator can oversee the system; however, as smart grids evolve, the desire to minimize human intervention will favor a closed-loop or automated approach. In the future, the degree to which the system is automated will be a business decision for each distribution organization.

The operations center

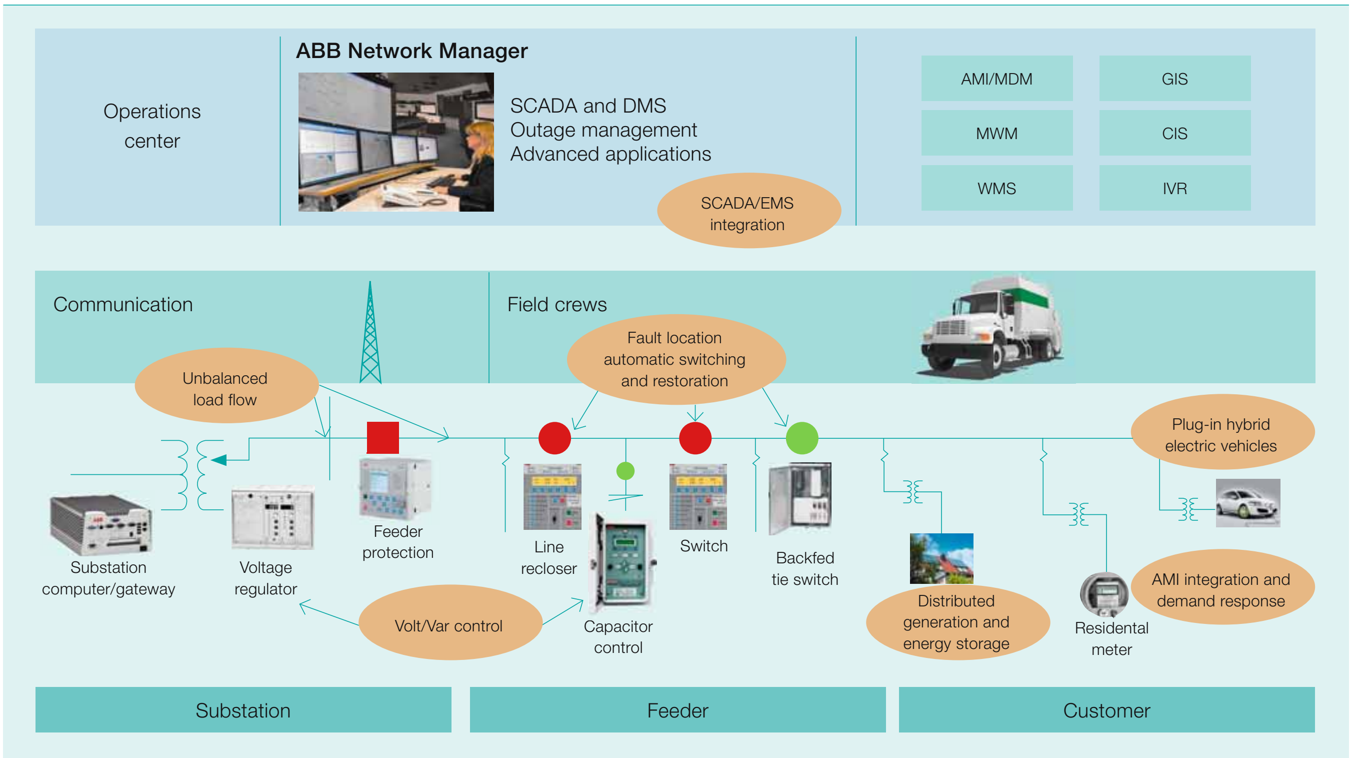
The architecture of a fully integrated distribution operations center is shown in [4]. DMS applications are utilized for the optimal management of the distribution systems with respect to equipment loading, efficiency, voltage control, work management, outage management, and reliability. The DMS applications utilize the distribution database and electrical network connectivity model. The network model is initially created using a one-time data load from a geographic information system (GIS), and is periodically updated from the GIS using an incremental update process.

A key part of the integrated distribution control system is the integration of the different IT systems used in the operation of distribution systems. This includes the SCADA system as a key element of data collection and system control. The trend is for distribution companies to expand SCADA systems past the distribution substation and onto the feeders, providing improved situational awareness and control of the distribution system. Interfaces to other systems include AMI and MDM systems, and substation/feeder gateways and data concentrators. The architecture of how data is transmitted between field devices and the integrated operations center will vary among distribution organizations. There may even be several approaches within a single utility. Whatever the

[4] The architecture of a fully integrated distribution operations center



5 An integrated distribution operations center overseeing the distribution grid



approach, such data transmission is critical for increased operational awareness.

Future operations center

The integrated operations center will be a key to the smart distribution grid. ABB continues to increase the functionality of operations centers to meet distribution organizations' technical and business requirements. A vision of the smart distribution grid utilizing an integrated distribution operations center is shown in 5.

In a general sense, the operation of distribution systems will become more complex. Additional amounts of distributed generation and energy storage will impact the magnitudes and directions of power flows on the system and may vary over time. Demand response, either controlled by the electricity provider or the consumer, will also impact power flows and voltage profiles. In addition, there is already an increasing trend to place additional intelligence in devices on the distribution system, such as intelligent electronic devices (IEDs), substation computers and gateways, sensors, and advanced meters. Some of these devices will result in additional local control actions, further increasing the complexity of distribution systems' operation.

Even in the presence of increasing amounts of decentralized intelligence and control, the integrated operations center will be a centralized way of overseeing and coordinating the entire system. It will not be practical or even desirable to transmit all data and information to centralized systems in the integrated control system. Instead, to ensure the optimal operation of the system, the systems in the integrated distribution operations center will only collect and act upon the particular data and information that is passed to it.

Meeting the challenge

Smart distribution grids will require innovative operations centers for effective system management. ABB has been continuously working to define and develop integrated operations centers for smart distribution grids, including advanced integration of existing systems and the development of new applications. Smart grid operations will provide a comprehensive view of the distribution system, including system status and monitoring, control, outage response, planned work, optimal equipment loading, improved control over distributed generation, energy storage and demand response resources. The integrated distribution operations center will help distribution companies in their mission to meet the goals of customers, owners, employees and society.

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Reference

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