ADVANCED DISTRIBUTION MANAGEMENT SYSTEM IN BC HYDRO'S DISTRIBUTION NETWORK

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ABSTRACT

The paper introduces BC Hydro's network operations model and describes how BC Hydro is looking to modernize its distribution network, improve network operations and control capability in order to achieve the goals of its overall Advanced Infrastructure Program. The Advanced Distribution Management System (ADMS), which is being implemented for BC Hydro's distribution network, is a foundational application to support BC Hydro's Advanced Infrastructure Program. The main power applications which are being implemented to transform or advance BC Hydro's distribution network are briefly described.

1. INTRODUCTION

BC Hydro is the third largest electric utility in Canada, providing efficient and reliable supply of electricity to over 94% of British Columbia's population in a technically, environmentally and socially responsible manner. BC Hydro operates 30 hydroelectric facilities and three natural gas-fueled thermal power plants. About 80% of the province's electricity is produced by major hydroelectric generating stations on the Columbia and Peace rivers. BC Hydro generates between 43,000 and 54,000 gigawatt hours (GWh) of electricity annually, depending on prevailing water levels.

BC Hydro's T&D network includes transmission assets, which include 18,000 kilometers of high-voltage wires and 1,300 distribution feeders. The BC Hydro systems used for real-time distribution operations have not evolved significantly since the 1970s. Much of the distribution operations are currently performed using manual work practices.

The distribution network is currently represented on an electronic mimic board where by safety protection guarantees are manually tagged, recorded and displayed for BC Hdyro's load dispatchers. The electronic mimic board offers little or no decision support capability to the dispatcher. The issuance of permits to block reclosing is currently tagged, recorded and displayed within BC Hydro's Energy Management System. In 2007, BC Hydro completed its System Control Centre Modernization Project (SCMP) that consolidated control room functions of the four area control centers and one system control center into a main and hot backup operation centre located 450 Km apart.

A Distribution Management System (DMS) offers significant opportunities to modernize control room work practices and shift from the current practice of manually operating distribution assets to an electronic decision support platform. The DMS technology platform will provide operational information, centralized visibility and control of the distribution field equipment for BC Hydro's Distribution System Operators and Field Personnel.

BC Hydro has also recently undertaken the Smart Metering & Infrastructure (SMI) Program, which is a long-term program for delivering technology and change that has the potential to realize important provincial policy goals and to benefit BC Hydro customers, employees, and stakeholders. It is anticipated that the installation of approximately 1.7 million smart meters and supporting infrastructure will be completed by the end of 2012. Every BC Hydro customer will have a smart meter, making immediate and future benefits to the network energy possible.

In addition BC Hydro has also embarked on a Advanced Infrastructure Program, which is currently a set of projects, management systems, intelligent distribution line and substation equipment, and foundation elements such as the DMS Project that will be implemented over the next five years to enable BC Hydro to continue to provide reliable power, at low cost, for generations and remain in alignment with the BC Clean Energy Act.

The term "Smart Grid" refers to a modern, intelligent electric distribution system that incorporates elements of traditional and advanced power engineering, sophisticated sensing and monitoring technology, information technology, and communications to provide better system performance and to support a wide array of additional services to customers and the economy. Figure 1 provides a simplified outlines of BC Hydro intends on transforming from it current passive network to a more agile and active network.

BC Hydro views the DMS to be a foundational element to its Advanced Infrastructure Program. Key factors driving BC Hydro's Smart Grid considerations include the increased use of Distributed Generators (DGs), including clean and renewable resources (wind, solar), and Distributed Energy Resources (DERs) to provide local power, the aging population and increased competition for workers, the aging distribution infrastructure, increasing customer demand for reliability, enhanced interest in energy conservation and an increase in severe weather events. DMS will also provide the capability to coordinate energy storage and peak load reduction programs. BC Hydro is anticipating an increase in the penetration of DERs within its distribution grid and as such will look to the DMS to coordinate and

control the operations of a large number of DGs which can be great source of distribution network instability.

DMS will require complex real-time integration with a number of systems such as the Geographic Information System, Energy Management System, Outage Management System, Field Crews and Work Management. This will be accomplished using the enterprise service bus technologies (based on the IEC 61850 CIM standard) and in some unique circumstances secure point to point connections. Figure 2 outlines the complexity of the scope of the integration required to enable the DMS. Such DMS is termed Advanced DMS (ADMS).

BC Hydro expects that the ADMS will offer significant opportunities to shift from the current practice to an automated electronic decision support system. The ADMS will provide centralized visibility and control of the distribution assets with enhanced decision support capability that will assist in the day to day operations of the distribution system by contributing to the following value drivers which are aligned with BC Hydro's Long Term Goals and Objectives: 1) **Financial:** provide financial benefits stemming from feeder deferrals, energy conservation, reducing fault locating and restoration times; 2) **Reliability / Customer:** will reduce system CAIDI; 3) **Employees:** the employees will be empowered with enhanced decision support capability; 4) **Safety**: will provide a more secure and safe environment for field personnel; 5) **Alignment with BC Clean Energy Act:** will align with the Clean Energy Act, which calls for the use of innovation and technology and 6) **Environmental:** rapid expansion of energy conservation will result in an incremental reduction in electrical intensity and CO2 emissions.

Section 2 briefly describes the ADMS. The main power applications which will be implemented to transform the BC Hydro's distribution network from levels 1 and 2 to a more agile grid levels 3 and 4 (Figure 1) are described in Section 3. Sections 4 and 5 consist of conclusions and list of references.

2. ADVANCED DISTRIBUTION MANAGEMENT SYSTEM

ADMS that is being implemented in BC Hydro is founded on the common unbalanced distribution network (real-time) Data Base and (real-time) Mathematical Model [1]. Then, following main sets of functions (power applications) are being implemented [2, 3]:

I. Real-Time functions: 1) Network Model, 2) Topology Analyzer and 3) State Estimation [4]. These functions will be executed continuously and will provide centralized visibility of the entire distribution network topology and state.

II. Dispatching Support functions: 1) Optimal Switching Sequence, 2) Under-Load Switching, 3) Fault Management (fault location, isolation and supply restoration) [5] and 4) Large Area Services Restoration. These functions will play a coordinating role to support local automation by providing a centralized calculation engine that will enable efficient and safe control of field equipment for BC Hydro's Operators and Field Personnel.

III. Network Operation Optimization functions: 1) Volt Var Optimization (VVO) and 2) Optimal Network Reconfiguration will be executed automatically in closed loop mode to improve operational performance in areas such as loss and peak load reduction, voltage profiles optimization [6, 7], feeder conditioning, load balancing etc.

IV. Network Operation Analysis functions: 1) Load Flow, 2) Fault Calculation, 3) Relay Protection, 4) Security Analysis, 5) Reliability Analysis and 6) Performance Indices. These functions execution will provide detailed analysis of network states, fault parameters, as well as sensitivity, setting and coordination of protection relays, security of the considered network state, calculation of asset reliability etc.

V. Network Planning functions: 1) Network Reinforcement, 2) Capacitor placement, 2) Network Development Planning [8], 4) Automation Equipment and RTU Placement [9, 10] and 5) Regulation Equipment Planning.

VI. Dispatcher Training Simulator will provide high quality training to dispatchers and operation staff.

3. BASIC POWER APPLICATIONS

The real-time Data Base and on-line Mathematical Model are both used to solve complex calculations for all ADMS power applications. ADMS Mathematical Model is CIM (Common Information Model) compliant. It is based on an extension of CIM with a Catalog of Topologies [1]. It can be stored in all existing major RDBMS's. ADMS Data Base is designed as an open Data Base. This means that after the system is already deployed and put into operation, the user can extend the Data Base structure in order to tailor it to its own needs without any vendor intervention. Both Data Base and Mathematical Model fully incorporate the new level of network automation sophisticated sensing and monitoring technology, including SMI, as well as DGs and DERs. In addition, they are organized to provide a consistent integration with all other systems from the ADMS environment. Some of these systems are: Geographic Information System (GIS), Outage Management System (OMS), Energy management System (EMS), Field Crews and Work Management systems.

Dynamic Mimic Diagram (DMD) will replace the old electronic mimic board. It will provide operational information, centralized visibility and control of the distribution field equipment for the BS Hydro's Distribution System Operators and Field Personnel. The DMD will provide two operating views of the network – schematic (dispatcher) and geographic (planning and field crews). The DMD represents the main interface between the user and ADMS. The results

of Topology Analysis power application will be directly presented in DMD application. The application is also used for triggering the power applications execution and presentation of the corresponding results.

State Estimation power application is used for assessment of the (current) network state. In addition to the network state performances (Performance Indices power application), the calculated state is the basis for performing different what-if analyses. The most important of these analyses are ones for validation of different smart grid development scenarios.

Control of voltages and reactive powers is the basic control loop in distribution networks. The Volt Var Optimization (VVO) power application supports this control. It is continuously executed in several modes. The most important ones are: 1) Normal Operation (minimal losses, minimal reactive power taken on from the transmission network and optimal voltage profiles); 2) Energy Conservation (by voltage reduction and/or network reconfiguration), 3) Emergency Mode (decreasing of the active power – peak load).

Fault Management power application consists of three modules: 1) Fault Location, 2) Fault Isolation and 3) Service Restoration – FLISR. The algorithms of all three modules are designed to use all available automation and remote monitored and controlled equipment: Fault Location – fault recorders and indicators, as well as historical data about the frequency of network elements faults; Fault Isolation – automation equipment; remotely controlled switchgear; Service Restoration – ADMS calculation of all possible solutions for service restoration; the selected (the optimal) solution will be performed using the available automation equipment and remotely controlled switchgear; in the event that the optimal restoration solution (or the single possible one) includes network islands then the island's DGs and DERs will be coordinated to restore as much load service as possible, providing the necessary island frequency and voltage control.

The rapid expansion of energy conservation and reduction of CO2 emissions will be significant results of ADMS implementation. This fact is proved by in-field application of the previous variant of DMS described in [11].

4. CONCLUSION

The paper describes how BC Hydro will modernize its distribution network, improve its network operations and control capability in order to achieve the objectives of its overall Advanced Infrastructure Program with following Long Term Goals: 1) Increased financial benefits 2) Increased reliability – reduction of the system CAIDI; 3) Enhanced decision support capability of employees, 4) Increased safety for field personnel; 5) Alignment with BC Clean Energy Act: and 6) Environment protection (incremental reduction in electrical intensity and CO2 emissions).

5. REFERENCES

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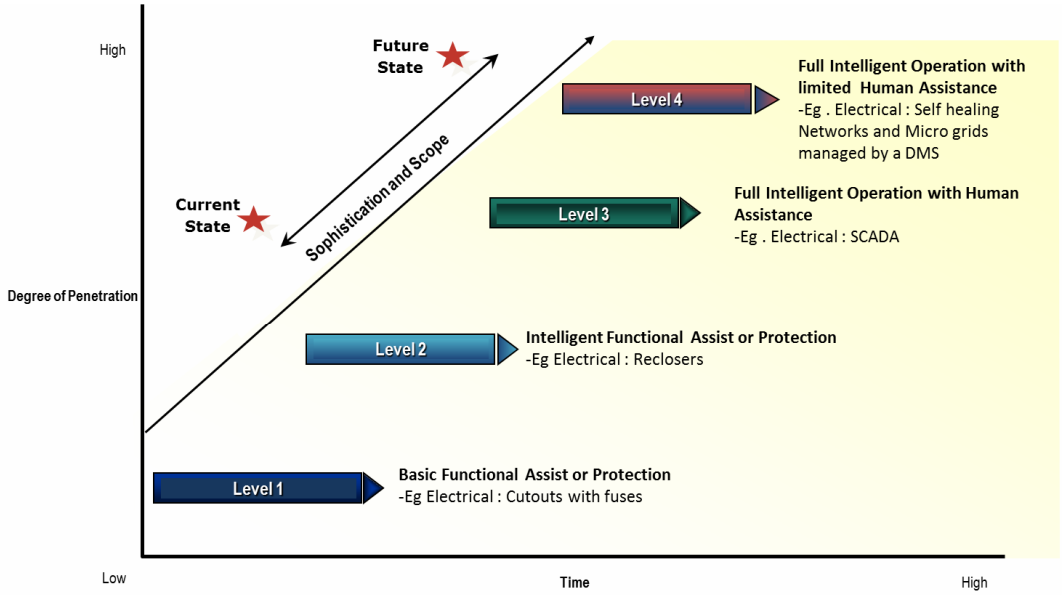

BC Hydro's current power delivery system operates at levels 1 and 2 (some level 3 for Transmission).
BC Hydro's Advanced Infrastructure will "advance" its automation by moving to the application of levels 3 and 4.

Figure 1: Advanced Infrastructure Transformation

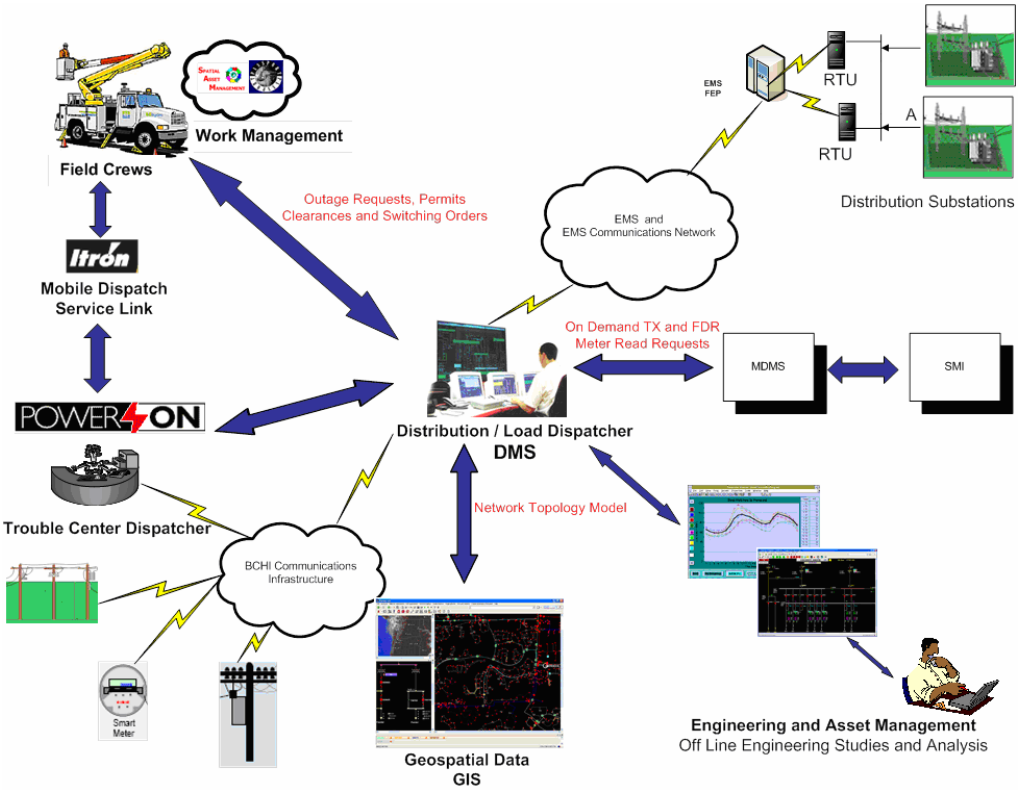

Figure 2: ADMS Scope of Integration