Application of Advanced Computing Methods to Transmission System Operational Studies at the Bonneville Power Administration

Brian Tuck*. Ramu Ramanathan.**
Terry Doern***

**Transmission Technical Operations,*
Bonneville Power Administration, Vancouver, WA
(e-mail: batuck@bpa.gov).
***Maxisys, Vancouver, WA*
(e-mail:ramu@maxisys.com)
**** DesignTech,Vancouver, WA*
(e-mail: tldoern@bpa.gov)

Abstract: This paper describes a project that will improve response to emergency transmission system conditions by providing Bonneville Power Administration (BPA) operations planning study engineers with the tools to quickly and effectively set System Operating Limits based on current system conditions. Growth of new intermittent renewable resources, smart grid controls, and increased environmental, political, and market demands, are pushing the transmission system to operate with less margin than today. In the future, the data, assumptions, and analysis tools on which today's operational decisions rely will no longer be fast or accurate enough to reliably manage a system operated closer to the reliability limits. This paper describes improvements accomplished by BPA through use of real time data and distributed processing. Initial studies are shown applying distributed processing and real time base cases to an actual contingency event on the BPA transmission system.

Keywords: Power flow, Distributed Simulation, Real Time Model, State Estimation, System Operating Limits, Contingency Analysis, Study Automation.

1. INTRODUCTION

The Bonneville Power Administration (BPA) is a US Department of Energy agency located in the Pacific Northwest. BPA is responsible for the delivery of power from 31 federal hydro projects in the Columbia River basin, with 20,430 MW of generating capability, and operates 15,215 circuit miles of transmission.

The Transmission Technical Operations group at BPA is responsible for providing operational planning studies and other engineering support to real-time transmission system operations. Technical Operations performs near-term system studies for seasonal operating procedures, near-term planned outages, and in response to unplanned outage events.

Traditional operational planning studies are performed using standard bus/ branch, seasonal system planning study cases and off the shelf power flow and transient analysis software running on desktop computers. Contingency analysis, thermal system operating limit calculations, voltage stability, and transient- stability tools are used to compute path limits for seasonal transmission operations planning and in response to unplanned outage events. Grid operation is subject to North American Electric Reliability Corporation (NERC) criteria. This criteria states that each operating condition must meet defined post-contingency performance requirements when a single (N-1) or double (N-2) contingency occurs. Each study therefore subjects a defined operating condition (the base case) to a series of loss-of-element contingencies (N-1 and N-2) and evaluates the performance of each one with respect to the NERC post-contingency requirements. A typical study will evaluate a number of operating conditions in this way, chosen by the engineer as representative of the boundary of the expected operating region, creating a nomogram or other useful representation of the relationship of critical parameters to the System Operating Limit (SOL).

These studies are currently run using seasonal planning cases developed by the region. Seasonal cases are typically 3-6 months old and represent a best guess of "normal" or "worst-case" conditions. Operations engineers typically will modify the seasonal case to represent expected operating conditions for the period of time under consideration, or current operating conditions when running new studies in response to an unplanned outage or other significant event. This can be a lengthy, time consuming process if the generation and load patterns of the operating condition under study differ significantly from those in the seasonal case. When an unplanned outage occurs, it is impossible to adjust the seasonal case to simulate the exact real-time conditions within the short time period necessary to provide system operators with new SOL studies.

In addition, many of the SOL studies are time consuming to run and take too long to be effectively used during emergency conditions. For example, thermal system operating limit studies for one of the interties BPA operates can take up to 24 hours to complete a full suite of scenarios (7,500 power flows). When an unplanned outage occurs, or during critical operating times (such as high load or wind generation), new SOLs need to be evaluated for use during the current or next hour. To meet the time constraints during critical times, many scenarios are not studied simply because the calculation time takes too long – the conditions are superseded before the results are available. Such incomplete analysis poses a potential reliability risk.

While these traditional methods have served the purpose in the past, there is a growing need to improve the tools used, both in terms of the fidelity of the base cases with respect to current operating conditions, and in reducing the time it takes for the analysis to be performed. Drivers of this growing need for improvement include a number of factors that are increasingly utilizing the transmission system in ways that are different from historical patterns: increased integration of intermittent resources such as wind generation; greater operating restrictions on conventional generation sources such as coal/ gas (air quality regulations) and hydro (endangered species); changing load patterns and composition (shift from resistive to motor and electronic); and the potential for increasing control of loads through Smart Grid based devices. Many of these changes are occurring quickly, and as system operation shifts away from historical patterns, analysis in real-time becomes critical. One example of the change experienced by BPA is in the area of wind integration. In less than 3 years, 3,000 MW of wind generation has been integrated into the BPA balancing area, with the total energized wind fleet expected to increase to 6,000 MW by the end of 2014. As a non-dispatchable resource, the intermittency adds to the variability experienced across the transmission system through large mid-hour ramps with a characteristic that is largely unpredictable at this time. Additionally, these resources displace an equal amount of conventional generation that has historically been relied on to provide voltage control, stability, frequency response, and remedial actions, thus resulting in a transmission system that continues to experience heavy power flows but with limited sources of operating margin.

This paper reports efforts at BPA to implement a real-time based model and improved analysis tools. Section 2 reviews the problem type and approach; sections 3-5 detail the software, hardware, and test cases used; and section 6 reports the results of applying these improvements to an actual case study.

2. PROJECT APPROACH

As noted previously, the first objective of this project was to provide, in a timely manner, Technical Operations study engineers with a power flow base case that represents real time operating conditions. Ideally, the base case would be provided in a format that is consistent with existing power flow and analysis tools currently in use by the study staff.

BPA has maintained an Energy Management System (EMS) State Estimator since the 1980s. The State Estimator (SE) provides an accurate representation of current system conditions by creating a power flow base case that can be used for system studies. This base case is updated every 10 minutes and represents the same essential transmission system as provided by the seasonal planning case currently used for operations planning studies, with the notable improvements of including real-time generation and load patterns. In addition, the SE generated base case is a "Full Topology" model, meaning that it explicitly models the detailed switch configurations (i.e., Power Circuit Breakers and disconnects). Equipment outages within a substation can significantly change the risk and consequences of a line fault. The typical seasonal base case currently in use is simplified to a "bus/ branch" model. Since this model does not directly simulate the effect of switch status, many of the consequences of these outages are not readily apparent. Retaining the detailed modelling within the substation makes these risks readily apparent to the operations planning engineer.

Despite the availability of these cases, BPA engineers have not used these cases for operational planning studies because the advanced analysis tools required by operational engineers to evaluate system reliability and set system operating limits are not currently available on the EMS. While it would have been possible to improve the tools available on the EMS, we decided early on to retain the current analytical tools and provide a means of exporting the SE case to a format that would make it available for real-time studies as these cases were produced. This approach would retain the specialized analytical tools that have been developed, and are currently in use when performing system studies, while achieving the required fidelity to current system conditions.

To take full advantage of the SE real-time case, and be able to run the full number of scenarios necessary for a complete analysis, there is a need to substantially increase the speed of these tools so that analysis and results can be completed fast enough for real-time operation. The second objective of the project was to reduce the total computation time required for these studies to be run so that the real-time system can be analyzed, and new SOLs could be evaluated, within the limited time constraints of critical operating periods.

Study tools used by BPA engineers include contingency analysis and thermal, voltage stability, and transient studies. Common to all of these is the need to run many different scenarios (usually hundreds) against the same base case, representing system conditions under study. Such a situation, where many independent scenarios can be run at the same time without interdependency in the solution, is a prime candidate for distributed computing techniques when the total computation time of the entire problem set needs to be reduced. Distributed computing is successfully employed in many industries. Because of the types of analysis that are performed, we looked toward distributed processing methods to achieve the necessary decrease in analytical computation times.

The main problems for this effort are as follows: