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Analyzing Blackout Events: Experience from the Major Western Blackouts in 1996

Mani V. Venkatasubramanian, Associate Professor, Electrical Engineering and Computer Science, Washington State University

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In the summer of 1996, the western electric grid experienced two major blackouts on July 2, 1996 and August 10, 1996. From the preliminary information available so far, the August 14, 2003 northeastern blackout appears to be somewhat similiar to what was experienced on the western grid on July 2, 1996. I was involved in the post-mortem studies of the two 1996 blackout events as an invited member of the Operating Capability Study Group which was in charge of carrying out those post-mortem studies. The study group included members from all the participant utilities in the western electric grid.

The objective of our study group was to establish the actual sequence of events, and to understand why the initiating events cascaded into large-scale blackouts. Specifically, we wanted to simulate the actual system behavior during the disturbance using computer models of the electric grid. In the present day power system, computer models are commonly used in planning and operation of the electric grid to determine secure operating limits for how much power can be exchanged from different parts of the grid. Roughly speaking, the higher the power transfers, the more vulnerable a power system is towards cascading blackouts. The computer studies then are used to set safe limits for preventing cascading events for normal operation and also under typical outages such as loss of transmission lines and generators. In the model validation studies of the western blackouts, we determined that the models that were used by the utilities in their planning studies before the blackouts were overly optimistic.

The post-mortem analysis itself may be quite challenging since it requires 1) establishing a rough time-line for the switching actions, 2) preparing a model to represent the system conditions at the start of the disturbance, and 3) duplication of the recorded system responses using computer models. Steps 1 and 2 require assembling huge amount of information from different utilities and control areas. I was heavily involved in Step 3, the duplication efforts or the model validation studies for the 1996 blackouts. These studies were facilitated by excellent wide-area synchronized time recordings of the disturbance event that were made available in the Bonneville Power

Administration (BPA) control area. There were three teams mainly in the simulation: 1) BPA, Portland, WA, 2) Powertech Labs, Vancouver, BC, Canada, and 3) Washington State University, Pullman, WA. Several other utilities in the western grid were also strong participants in the discussion and the simulations.

When we carried out the simulations using the standard planning models of WECC, the model showed the system to be operating normally while the actual system had experienced the blackouts. We identified several deficiencies in the computer models and went about improving the computer representations systematically by collecting additional data about the generators and the loads in the western grid. After extensive simulation efforts, the disturbance events were reproduced in the computer models. It was interesting that the three groups could verify the simulations independently at BPA, Powertech and WSU, respectively, giving solidity to the conclusions.

Of the two WECC events, the first one on July 2, 1996, we had shown to be what is called in power system theory as "a voltage instability" and the second one on August 10, 1996 was "a small-signal instability". From initial descriptions, the August 14, 2003 appears to be similar to the July 2, 1996 in being a voltage instability, even though we need a lot more technical details to understand what happened during the August 14th 2003 event.

Nominally, the voltages across the entire power grid are maintained at acceptable values by a variety of controls including at generators, and other switched control devices. When the transmission system becomes highly loaded, such as on hot summer days, if the operating values of transmission line transfers exceed the voltage stability limits, the controls can no longer maintain adequate voltage levels, and the voltages may start to decrease monotonously. This phenomenon is referred to as the voltage collapse phenomenon or the voltage instability phenomenon. Loss of key transmission lines and generators generally push the operation closer to instability limits.

The July 2nd blackout occured on a hot summer day when the loads in the Idaho region were high. It started with loss of two 345 kV lines and subsequent tripping of two Jim Bridger units in the southern Idaho-Montana region. These further stressed the already low voltage conditions in the Boise area, and there was a slow gradual voltage decline for about 25 seconds. Then, suddenly the voltage at Boise that should be nominally around 230 kV, collapsed from 200 kV to 100 kV in about 3 seconds. This sounds similar to what has been reported near Ohio during the August 14 event. Post-mortem studies of the July 2 disturbance showed that the system was possibly operating outside the voltage stability after the initiating Jim Bridger event, and further switching actions stressed the system more and more. The sudden voltage collapse led to loss of considerable load at and around Boise, as well as the gradual tripping of transmission lines feeding into Boise. Within three seconds after the Boise collapse, the voltages on the 500 kV side of the Northwest supporting the Idaho grid, which are nominally around 530 kV had also collapsed dramatically to near 300 kV. This led to the tripping of the critical California-Oregon intertie transmission lines, causing the system separation and the blackout.

More details on the 1996 model validation studies are available in the reports listed below, which were published by the WSCC Operation Capability Study Group. The analysis and post-mortem studies being carried out for the 2003 Northeastern blackout would be even more challenging as compared to the 1996 disturbances, since it affected a larger number of customers

References

Western Electricity Coordinating Council Reports (formerly known as the Western Systems Coordinating Council, WSCC)

1) D. Kosterev, S. Yirga, and V. Venkatasubramanian, “Validation report of the August 10, 1996 WSCC disturbance'', Operating Capability Study Group, Western Systems Coordinating Council, March 1997.

2) R. Aggarwal, R. Daschmans, R. Schellberg, V. Venkatasubramanian, and S. Yirga, “Validation studies of the July 2, 1996 WSCC system disturbance event'', Operating Capability Study Group, Western Systems Coordinating Council, July 1997.

Contact Information

Mani V. Venkatasubramanian
Associate Professor
School of Electrical Engineering and Computer Science
Washington State University
Pullman, WA 99164-2752
Office: (509)-335-6452
Fax: (509)-335-3818
Email: mani@eecs.wsu.edu

Power Systems Engineering Research Center
428 Phillips Hall
Cornell University
Ithaca, NY 14853-5401
Phone: 607-255-5601