DISCUSSION PAPER: POTENTIAL BENEFITS OF THE JUAN DE FUCA CABLE TO THE POWER TRANSMISSION NETWORK IN THE PUGET SOUND REGION

INTRODUCTION

Sea Breeze Pacific is proposing an underwater 550 MW power transmission cable, using HVDC Light ® technology,[1] to transmit electrical power across the Strait of Juan de Fuca between Port Angeles, Washington, and Victoria, British Columbia, on Vancouver Island ("Juan de Fuca Cable" or "JDF Cable"). Transmission is planned to be bidirectional. Capabilities of the proposed transmission system have the potential to offer substantial benefits to power transmission functionality in the corridor on the east side of Puget Sound between Olympia, Washington, and the international boundary at Blaine, Washington. This portion of the grid has been termed the "Puget Sound Area and Northern Intertie" ("PSANI").

THE PSANI GRID IS CONGESTED

The Bonneville Power Administration ("BPA") owns and operates much of the transmission infrastructure within the PSANI area. While the BPA is doing the best it can given the physical constraints of the existing transmission infrastructure, transmission paths in the greater Puget Sound region are chronically congested and this situation is only expected to get worse.[2] There are many reasons, but a partial list includes:

- regional growth in population and economic activity;
- new generation sources coming on line and gaining access to the grid;
- tightened standards for system reliability;
- constraints on hydropower operations mandated by the need to protect species listed under the Endangered Species Act;

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[1] "HVDC Light ®" is a proprietary name for a second-generation form of high voltage direct current ("HVDC") power transmission technology.

[2] Challenge for the Northwest: Protecting and Managing an Increasingly Congested Transmission System, BPA, April 2006 ("BPA Congestion White Paper") at 1-2, accessed on June 11, 2009 at http://www.bpa.gov/corporate/pubs/Congestion_White_Paper_April06.pdf; National Electric Transmission Congestion Study, U.S. Dept. of Energy, August 2006 ("DOE Congestion Study") at 31-35; 2006 Annual Report at 13, 15-16, BPA, accessed on June 11, 2009 at http://www.bpa.gov/corporate/Finance/a_report/06/AR2006.pdf.

- growth in the market for energy, especially “green” energy;
- treaty-mandated deliveries of power to British Columbia; and,
- the transmission of energy through the region to markets outside it.[3]

Transmission congestion occurs when flows of electricity must be curtailed to keep the flow levels under the limits required, either by the system’s physical capacity or by restrictions needed to maintain the system’s operational security. Power purchasers traditionally always sought out the least expensive source of energy available to transmit across the grid to the load centers. When a transmission constraint limits the amount of energy that can be transferred safely to a load center from the most desirable source, the service provider must find an alternative and more expensive (or less efficient) source of generation to meet the demand.[4]

Congestion can lead to system instability, especially when transmission levels are relatively high, and it makes the system vulnerable to cascading catastrophic outages.[5] Measures to control excessive power flows include curtailing flows through redispatching generation or rescheduling transmissions.[6] However, there are limits to the effectiveness of such tools, and they come at a price.[7] Adding or upgrading physical transmission infrastructure to increase capacity is another approach that the BPA and others have adopted,[8] but only if the high costs of this remedy can be justified.[9]

The U.S. Department of Energy (“DOE”) identified the Puget Sound region as an “area of congestion” and stated that “constraints limiting desired flows” affect power transactions between Washington and British Columbia.[10] An additional transmission pathway would help ease such congestion, especially if it bypasses the existing paths located on the east side of Puget Sound.

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[3] BPA Congestion White Paper at 7-10. Congestion concerns can be exacerbated further by the need to accommodate the intermittent nature of many renewable energy resources, the use of which is increasing due to the enforcement of renewable portfolio standards aimed at reducing CO_2 emissions from producing energy.

[4] E. Santacana, T. Zucco, X. Feng, J. Pan, M. Mousavi, L. Tang, Power to Be Efficient, ABB, accessed on June 19, 2009 at http://library.abb.com/global/scot/scot271.nsf/veritydisplay/cb8afe88ca4fc8a8c12572fe004dc64f/$File/14-21%202M735_ENG72dpi.pdf.

[5] BPA Congestion White Paper at 4-5.

[6] BPA Congestion White Paper at 11-15.

[7] BPA Congestion White Paper at 13-17.

[8] *See* Final Draft - 2009 Biennial Transmission Expansion Plan, Rev. 2 (“ColumbiaGrid Plan”), ColumbiaGrid, 2009; 2008 BPA Plan - Draft - Transmission Services, BPA, July 2008 (“2008 BPA Transmission Plan”) at 5-6.

[9] BPA Congestion White Paper at 21-22.

[10] *See* DOE Congestion Study at 37-38.

SERVICE TO THE OLYMPIC PENINSULA ADDS TO THIS CONGESTION

The BPA also owns and operates the transmission infrastructure serving the Olympic Peninsula. The transmission system on the Peninsula currently runs from the BPA's Olympia substation to Shelton, runs northward along the west side of Hood Canal, turns to run westward along the southern shore of the Strait of Juan de Fuca, then dead ends west of Forks. North of Shelton there are no substantial interconnections back to the grid.[11]

At this time peak loads on the Peninsula are around 1200 MW, with the area north of Shelton, including Port Angeles and points further west, accounting for about half of that load.[12] For the most part this power is provided from sources east of the Cascade Mountains. Such power must come west through the "West of Cascades North" pathway, then through the PSANI area towards Olympia along with all the other loads using that pathway, thereby contributing to the congestion.

THE JUAN DE FUCA CABLE OFFERS A SOLUTION TO CONGESTION

As discussed above, providing any additional north-south transmission capacity via an additional, parallel link between southern Puget Sound and British Columbia can only ease congestion on the grid within the PSANI area, improving reliability and increasing capacity. Further, the availability of this route would provide an alternative pathway to serve loads on the Olympic Peninsula, easing congestion and freeing up transmission capacity on the north-to-south pathways east of Puget Sound and on the east-to-west pathway across the Cascades.[13] To realize all these benefits it may be necessary to improve the capacity and robustness of portions of the transmission system between Olympia and Port Angeles. The BPA is considering such measures.[14]

THE JUAN DE FUCA CABLE'S TECHNOLOGY OFFERS ADDITIONAL BENEFITS

By its nature, the HVDC Light ® technology that will be employed for the JDF Cable offers benefits to the functionality of the existing high-voltage alternating current ("HVAC") backbone of the PSANI grid that go well beyond the benefits realized by adding capacity and shifting a portion of the load away from the PSANI grid.

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[11] Olympic Peninsula Reinforcement - North of Shelton Analysis ("BPA North of Shelton Analysis") at 2, BPA, accessed on June 17, 2009 at http://www.transmission.bpa.gov/PlanProj/Non-Wires_Round_Table/NonWireDocs/OlympicPeninsulaReinforcementNonWiresPres3-13-06.ppt.

[12] 2008 BPA Transmission Plan at 7; BPA North of Shelton Analysis at 4.

[13] The ColumbiaGrid study team stated that the JDF Cable would provide "Possible Significant Benefit" (the highest possible ranking) in the "British Columbia to Northwest" transmission path and "Possible Benefit" (the next highest ranking) on the "West of Cascades North" pathway. ColumbiaGrid Plan at 20-21.

[14] ColumbiaGrid Plan at 30; BPA North of Shelton Analysis at 9.

Many Factors Can Impair the Performance of a Transmission System

A transmission network performs best when power flows smoothly and can be ramped up or down in a deliberate and controlled manner. Failures of key transmission components such as power lines, transformers, circuit breakers, or other major infrastructure elements interrupt smooth flow, as do unanticipated surges or collapses of power production at a power source or major surges or collapses in demand at a destination. Such events are commonly referred to within the industry as "contingencies." The internal characteristics of the system and its components can also foster the establishment of self-sustaining oscillations in power flow even in the absence of a major contingency event, or oscillations may be induced or amplified by a contingency. However established, such oscillations are an additional source of perturbations in the flow.

A transmission system can accommodate such variations up to a point, but beyond that it becomes increasingly exposed to catastrophic outages. In order to manage that risk system operators try to maintain flows at levels below the system's theoretical capacity, thereby creating a safety margin, but as noted above congestion reduces the space available for maintaining such a margin before substantial costs arise in terms of dollars or functionality. Contingencies (or the need to allow for their potential occurrence) and oscillations effectively add to congestion. In turn, the factors that cause congestion increase both the risk of contingencies and the extent of the harm that any given contingency can cause.

HVDC Links Within an Integrated Grid Improve Overall System Performance

Conventional high voltage direct current ("HVDC") transmission systems embedded within a grid can improve the overall performance of the grid over and above the additional transmission capacity that they provide. For example, modulation of power flows on an HVDC line has the potential to damp power oscillations in parallel HVAC lines, thereby increasing power transfers and system reliability.[15] The precise controllability of HVDC offers advantages when the control of real power is desirable to manage normal or post-contingency flows on the network, provide increased transfer capability through direct or indirect regulation of flows across critical transmission paths, or provide voltage support to the system.[16] The whole system benefits from HVDC's increased flexibility for scheduling generation to manage congestion.[17] Finally, an

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[15] Increasing WSCC Power System Performance With Modulation Controls on the Intermountain Power Project HVDC System, D.E. Martin, W.K. Wong, D.L. Dickmander, R.L. Lee, D.J. Melvold ("Martin") at 5, IEEE Transactions on Power Delivery (1992).

[16] Planning Issues for HVDC, M. Henderson, J. Gagnon, D. Bertagnolli ("Henderson") at 28, Power Systems Conference and Exposition, IEEE (2006).

[17] Economic Assessment of HVDC Project in Deregulated Energy Markets, S. Wang, J. Zhu, L. Trinh, J. Pan ("Wang") at 2, Electric Utility Deregulation and Restructuring and Power Technologies Conference, IEEE (2008) ("DRPT 2008").

HVDC line is not vulnerable to parallel path flow problems,[18] and its capacity is not affected by congestion on parallel AC systems as long as the sending and receiving ends have strong connections to AC systems.[19]

HVDC Light ® Offers Additional Benefits Beyond Conventional HVDC

HVDC Light ® technology offers additional benefits to routine grid functionality.[20] It can keep voltage stable due to its ability to rapidly control both active and reactive power independently, improving utilization of the AC components of the system.[21] Further, like conventional HVDC it can improve the transient stability of the AC system by damping power oscillations.[22] Its near-instantaneous controllability means that within the grid it behaves like an ideal power generator with a flexible working point and no inertia.[23] The transfer capability of bottlenecks constrained by voltage or transient stability can be increased by more than the rating of the HVDC Light ® system due to its effective damping control and dynamic voltage support.[24] Further, HVDC Light ® does not require the strong connections to AC systems required by conventional HVDC.[25] In short, an HVDC Light ® link enhances the capacity and reliability of the AC components of the system in which it is embedded.[26]

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[18] "Parallel path flows" (also known as "loop flows") are unanticipated flows of power through an interconnected grid due to electricity's property of following the path of least resistance rather than a direct "point-to-point" path from the source to the user. An HVDC line, by contrast, is a true point-to-point link.

[19] Wang at 2.

[20] It is beyond the scope of this memorandum to provide a detailed technical description of HVDC Light ® technology, its features, and its performance. Such information may be found on the Internet, e.g., http://www.abb.com/industries/us/9AAC30300394.aspx?country=US.

[21] *Id.*, Power System Stability Benefits With VSC DC-transmission Systems, S.G. Johansson, G. Asplund, E. Jansson, R. Rudervall ("Johansson") at 1, 3, Cigré Session 2004 (2004); Co-ordination of Parallel AC-DC Systems for Optimum Performance, A.D. Castro, R. Ellström, Y.-J. Häfner, C. Liljegren ("Castro"), GSEE Power Delivery Conference, University of Castilla-La Mancha (1999); Investigation on Applying HVDC Light to China Southern Power Grid, Q. Chen, Y. Zhang, Q. Guo, C. Hong ("Chen") at 1, IEEE DRPT 2008; Study of HVDC Light for Its Enhancement of AC/DC Interconnected Transmission Systems, Q. Zhong, Y. Zhang, L. Lin, Q. Chen, Z. Wu ("Zhong") at 1, IEEE (2008).

[22] Chen at 1; Zhong at 1; Power System Reliability and Transfer Capability Improvement by VSC-HVDC (HVDC Light ®); L. Zhang, L. Harnefors, P. Rey ("Zhang") at 4, Regional Meeting on Security and Reliability of Electric Power Systems, Cigré (2007).

[23] Zhang at 2.

[24] Johansson.

[25] *Cf.* Wang at 2.

[26] AC Grid with Embedded VSC-HVDC for Secure and Efficient Power Delivery, J. Pan, R. Nuqui, K. Srivastava, T. Jonsson, P. Holmberg, Y.-J. Häfner ("Pan") at 4, presented at IEEE Energy 2030, IEEE (2008); *see also* HVDC Light ® System Interaction Tutorial at http://www.abb.com/cawp/GAD02181/C1256D71001E0037C1256D08002E7282.aspx.

HVDC Light ® Offers Additional Benefits During System Emergencies

An embedded HVDC Light ® transmission system will be a very valuable asset during a grid restoration since it will be available almost instantly after the blackout and does not need any short circuit capacity in order to become connected to the grid.[27] An HVDC Light ® system has black start capability and can energize transmission lines to establish an initial voltage, facilitating reconnection of other resources.[28]

CONCLUSION

Any increase in north-south transmission capacity in the greater Puget Sound region can only help relieve congestion on the existing power transmission network. The JDF Cable offers additional benefits as well: it presents an alternative means to ensure reliable service to the Olympic Peninsula, thereby reducing the demand on the grid in the PSANI area; and the HVDC Light ® technology by its nature offers the potential to enhance the grid's robustness, capacity, and ability to recover quickly from outages.

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[27] Johansson at 8.

[28] *Id.*