High Voltage Power Electronics Technologies for Integrating Renewable Resources into the Grid

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Just as diversified generation helps to ensure the security and independence of the American energy supply, diversified transmission technology helps to ensure the optimal, safe, and reliable delivery of electric power to end users. This white paper will evaluate existing technologies used for integrating renewable resources including both conventional and voltage-source converter based HVDC transmission technology and FACTS compensation devices for AC infrastructure expansion.

From the beginning, we want to emphasize that the reliance on one particular technology or approach may not be optimal or reliable and, perhaps, multiple hybrid configurations of the technologies mentioned can be utilized most effectively. Texas, in fact, is taking this approach and much can be learned by observing the trends in Texas. The state's generation portfolio consists of traditional fossil generation sources such as coal, petroleum, and natural gas, low-carbon resources such as nuclear generation, and renewable generation, most notably, wind power. Texas also boasts a wide variety of transmission diversity, with the inclusion of AC transmission, FACTS compensation, and HVDC applications.

In July 2007, the Texas Public Utility Commission approved plans for the expansion of the state's transmission networks. These plans, shown in Figure 1, include enough transmission capacity to transfer 25GW of new generation across the state. In addition, the state's legislators have worked in conjunction with the Electric Reliability Council of Texas (ERCOT) to identify and designate eight Competitive Renewable Energy Zones (CREZs) within the state. These zones have been shown to be highly suitable areas for the development of renewable energy generation. As Texas plans for the addition of more generation, including as much as 10 GW of additional wind turbine capacity, it is concurrently committed to the expansion of its transmission grid and supporting technologies.

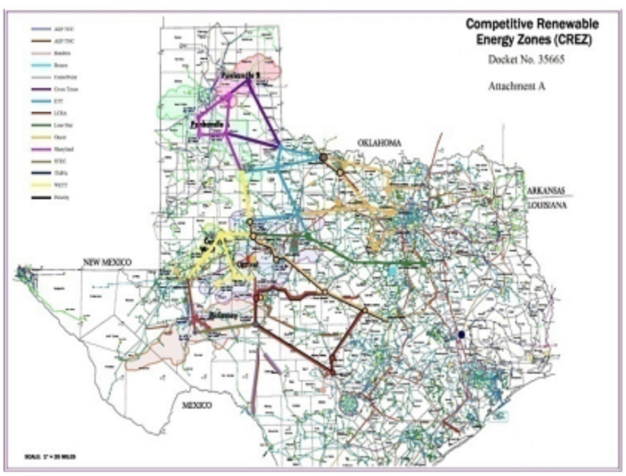

Figure 1: Texas Transmission Additions to Accommodate New Renewable Generation Resources

The predominantly high voltage AC transmission network of today has served the electric power industry needs very well over many decades. However, with the new paradigm taking place related to exponential growth in green and renewable energy resources, much of it located at further distances from load centers, relevant disadvantages begin to arise in terms of AC network interconnections. For example, AC cable transmission suffers from excessive reactive current drawn by cable charging capacitances. This issue increases cable losses and reduces power transfer capability but also requires dynamic reactive shunt compensation (i.e., SVC or STATCOM FACTS device) to absorb excessive reactive power and avoid overvoltage. AC transmission also becomes economically unsuitable for long distances. Long transmission of interconnected generation can lead to issues associated with sub-synchronous resonance (SSR) and sub-synchronous torsional interaction (SSTI) that often require series compensation of the lines in the form of both fixed series capacitors and dynamic FACTS series controllers. In addition, wind turbines located further out at sea where the wind gusts are strongest will require economic feasibility and system planning studies well in advance of construction plans in order to determine the optimal transmission technology.

With the increased amounts of renewable generation resources penetrating the grid, key areas such as voltage instability, reactive power consumption, voltage regulation and voltage sags in the existing system will need to be monitored and resolved with advanced transmission technologies such as HVDC backbone systems and AC systems with FACTS compensation to achieve the needed capacity and system security. HVDC technology has the advantages of transmitting power over long distances at 2 to 5 times the capacity of an AC line of similar voltage rating, interconnecting two AC systems together to resolve stability problems, and control of power flow rapidly and accurately. FACTS devices provide increased capacity by allowing maximum operational efficiency of existing transmission lines, account for greater voltage stability and power flow control, thus improving grid reliability and security. FACTS build intelligence into the grid by being able to respond to system disturbances and help with gridlock constraints. Finally they have been predicted to reduce expenditures on the network by 30% and are less expensive to implement compared to new transmission lines.

There are two classes of HVDC technology, Current Source Converter (CSC)-HVDC and Voltage Source Converter (VSC)-HVDC technology. CSC-HVDC is a proven and pioneered technology but has not been a focus in research and development by leading industry developers such as ABB and Siemens. VSC-HVDC has been the technology being developed and implemented in practice by the two international companies listed previously. Table 1 provides a quick comparison of both technologies.

Attributes	CSC-HVDC	VSC-HVDC
Converter Technology	Thyristor valve with Grid Commutation	Transistor valve with Self Commutation
Max Converter Rating	6400MW, +/-800kV (overhead line)	1200MW, +/-320kV (cable)
Reactive Power Demand	50% of Power Transfer	No Reactive Power Demand
Reactive Power Compensation & Control	Discontinuous Control (Switched Shunt Banks)	Continuous Control (PWM embedded in Converter Control)
Independent Control of Active & Reactive Power	No	Yes
System Losses	About < 1%	About < 0.5%
Multiterminal Configuration	Complex and Limited to Three Terminals	Simple with No limitations

Table 1: Comparison of CSC-HVDC and VSC-HVDC Technologies

VSC-HVDC improves many dynamic-occurring issues on the electric grid such as voltage instability. Inadequate reactive power support from generators and transmission lines leads to voltage collapse and perhaps blackouts in extreme contingencies. An advantage of VSC-HVDC converter technology compared to CSC-HVDC is that it does not consume reactive power and can supply reactive power to the grid independent of its active power transmission. VSC-HVDC reactive support capability is maximized when the grid voltage is low, which is useful if there is progressive voltage depression. Both a SVC and STATCOM, significant FACTS devices, also are used to improve voltage stability issues as well as improve the dynamic performance of the grid.

As was the case at the turn of the 20th century, a justification in using AC compared to DC infrastructure will need to be evaluated as the current electric grid begins to make drastic changes in the United States. In 2006, EPRI published a presentation that established a few points that made the case for DC applications in the 21st century. The relevant points for this discussion that were mentioned stated that we are indeed living in an era of electronics (conversion processes due to DC equipment), era of the micro-grid (distributed generation systems that produce DC power) and an era focusing on integration ease (storage devices to deliver DC power). The future transmission and distribution research and development needs would include the selection of HVDC systems or, when appropriate, AC expansion with FACTS compensation devices for specific applications to promote optimal grid performance and system economics.

References:

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