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Eversource's Selection of Synchronous Condenser Technology at Saco Valley

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SUMMARY

Eversource New Hampshire needed transmission system support in the Saco Valley area. A source of dynamic reactive power was needed to support the 115kV bus voltage. No particular technology was favoured and the bid was open to all technologies. Upon examination of all of the technologies bid, and in full consideration of their benefits, a synchronous condenser was chosen. While all the technologies satisfied the basic requirements of the specification, a dozen reasons favored the selection of synchronous condenser as the technology to support Saco Valley.

These reasons are listed in this paper and include capacitor bank switching, system inertia, power system modeling, harmonics, component availability, technology familiarity, overload capability, short circuit strength, temporary overvoltage, output during fault conditions, extended fault clearing, and life cycle costs. While none of these reasons were ultimately as important as voltage performance, each benefit listed above provided incremental performance benefits to the power system or cost of ownership advantages relative to the alternate technologies such that the overall evaluation favored the synchronous condenser.

KEYWORDS

Synchronous Condenser, Dynamic Voltage Support.

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INTRODUCTION

Transmission system reliability studies identified the need for a dynamic reactive device at Eversource's Saco Valley Substation. For the ISO-New England approval of this system upgrade an assumption was made that the dynamic reactive device would be a synchronous condenser, with a capability of 25 Mvar capacitive (overexcited) and 12.5 Mvar inductive (underexcited) and is documented in the approved ISO-NE Proposed Plan Application (PPA). After the PPA approval an investigation of the available dynamic reactive device technologies was made to determine if there was an advantage of any one technology to use for this application. The investigation focused primarily on the Mvar capability and order of magnitude estimated cost. The investigation concluded that all of the technologies could meet the Mvar capability and that the estimated costs were all on par with each other.

A performance based bid specification was developed and sent out to bidders. Subsequently six bid proposals were submitted to Eversource. The bid proposals were narrowed down to three based on cost and then assessed based on non-cost factors. The final decision was for a synchronous condenser supplied by General Electric Company.

HISTORY

The synchronous condenser is the original dynamic reactive power device. Before all the modern power electronics technologies, there was the synchronous condenser. It can be thought of as a synchronous motor without a load. The field of the machine can be varied to produce or absorb reactive power. A small amount of real power is consumed as condenser losses. The reactive power output is quite similar to a generator. There is no prime mover, so no Watts are produced. But just as a generator's field is varied to produce or consume reactive power, so a condenser's field is varied. [1] Modern synchronous condensers can use digital field exciters with IGBT power electronics identical to what one might find on the most modern combined cycle generators. Machine construction techniques have improved since their early applications in the 1910s. It has been suggested that modern synchronous condenser have maintenance costs on par with their SVC and STATCOM counterparts. [2]

EVALUATION

The evaluation considered Eversource's 115kV system specifically in the central and northern areas of New Hampshire. This is a relatively weak part of the system and is part of the Maine-New Hampshire regional interface connecting into the western Maine transmission system.

While all technologies evaluated met the voltage performance requirements, the following reasons were considered advantages of using a synchronous condenser.

Capacitor Bank Switching

A synchronous condenser will strengthen the system and therefore reduce the magnitude of the voltage change (ΔV) upon capacitor bank switching. Reducing the delta V is considered a positive attribute. The voltage change due to local capacitor bank switching is related to the 3-phase MVAR rating of the capacitor bank and the short circuit MVA at the capacitor bank bus. The expected voltage change can be estimated with the following equation:

$$\Delta V = \frac{MVAR_{capacitor}}{MVA_{short\ circuit} - MVAR_{capacitor}}$$

The installation of the synchronous condenser increases $MVA_{\text{short circuit}}$ which decreases ΔV.

More specifically, the addition of the Saco Valley units will decrease the impact of capacitor bank switching at nearby substations with installed mechanically switched shunt capacitors. A power electronic device would not have this effect on the switching of remote capacitor banks.

System Inertia and Future System Operation

The increase in system inertia, provided by the rotating mass of the synchronous condenser will benefit this part of the system by providing kinetic energy exchange between the synchronous condenser and the system during system disturbances (power swings). The proposed power electronic alternative devices do not have this ability, nor was it part of the bid specification. As wind generation connects to this part of the system it provides power, but the inertial response of a windplant differs from that of a conventional power plant since it can be modified by control action. As wind generation develops, it displaces rotating machines that provide conventional inertia that helps enable the transmission system better cope with large disturbances on the system. Compounding this issue is the potential retirement of rotating synchronous generation resources in the area that have this inertia.

Power System Software Modeling

System Planning utilizes simulation software that would require a specific 'user model' for the alternative devices considered. Whereas the synchronous condenser is a standard device, a model is included as part of the software. User models are typically more difficult to maintain and incorporate into future software revisions; therefore it is preferable to have a standard model.

Harmonics

The synchronous condenser impacts the system resonant frequency, making the resonant frequency less problematic. The proposal included a frequency scan and identified the system resonant frequencies. See Figure 1. The synchronous condenser does not contribute harmonics at the dominant system resonant frequency. Power Electronic solutions may require additional filtering and/or control system modifications and will require further analysis and potentially added cost.

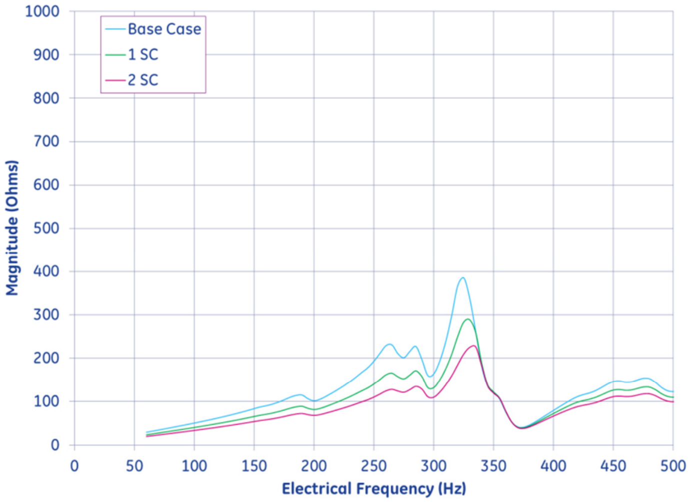

Figure 1.
Frequency scan results at Saco Valley 115 kV with 0, 1, and 2 condensers.

Overload Capability

The synchronous condenser has a capacitive reactive overload capability at depressed 115-kV system voltages (0.80 p.u. V or 92 kV) of 62.5 Mvars for a period of 5 seconds. The power electronic device that was the best alternative would provide a capacitive reactive output of 38.4 Mvars for a period of 2 seconds. During a degraded system voltage the synchronous condenser is more robust than the other options.

Short Circuit Current Ratio

The short circuit ratio is a measure of system strength with respect to a device and its operation. Synchronous condenser operation and performance is generally not dependent on the system short circuit ratio. Some power electronic solutions are dependent on the short circuit ratio for reliable operation. As traditional resources in the area retire, the system short circuit strength will decrease, thereby lowering the short circuit ratio. Also, as system facilities are taken out of service for periodic maintenance, the short circuit ratio is reduced. The operability of the power electronic alternatives was potentially susceptible to various system conditions like variable short circuit ratio. For comparison of the existing system strength, the available short circuit MVA for a strong part of the system is approximately 9000 MVA. In the area of the proposed synchronous condenser it can range from approximately 700 MVA with all lines in, to approximately 300 MVA under line out conditions. This illustrates the relatively weak short circuit capability of the area. Adding synchronous condensers provide approximately 188 MVA to the system strength at Saco Valley.

Temporary Overvoltage

The synchronous condenser can better control temporary over voltages resulting from line fault clearing. An EMTP study indicated relatively high temporary over voltages with harmonics in the area of Saco Valley (1.5 p.u.). See Figure 2. The synchronous condenser is better suited to mitigate the temporary over voltages and harmonics. The alternative technology considered may have required additional harmonic filtering and controls, which could increase project costs.

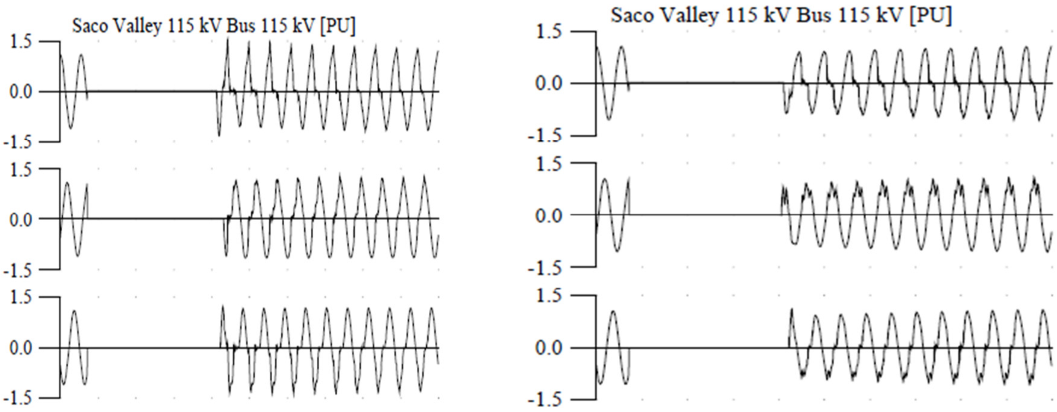

Figure 2.
Temporary overvoltages due to 3-phase fault and clear at Saco Valley 115kV without (left) and with (right) one +25 Mvar synchronous condenser.

Output During Fault Conditions

The synchronous condenser maintains reactive output power during a fault. By maintaining reactive output power during a fault, a more robust dynamic voltage response is realized; this is especially true when dynamic load modeling is considered. A new requirement of the NERC reliability standards (TPL) is to include dynamic load modeling. The synchronous condenser proposal included a simulated dynamic load model scenario. If the power electronics device blocks during a fault, the device reactive power output is zero.

Even without a block, the dynamic performance of different reactive devices with the same nameplate rating is not the same as was demonstrated with a +25 Mvar condenser and a +25 Mvar static var controller (SVC). The synchronous condenser did not lead to any voltage violations during fault recovery while a NERC Catagory B voltage violation was observed with the +25 Mvar SVC. The voltage violation was rectified with a larger SVC, i.e. +50 Mvars. See Figure 3. In this case, the rating of the SVC solution needs to be increased (approximately doubled) to meet the specification which could lead to additional project costs.

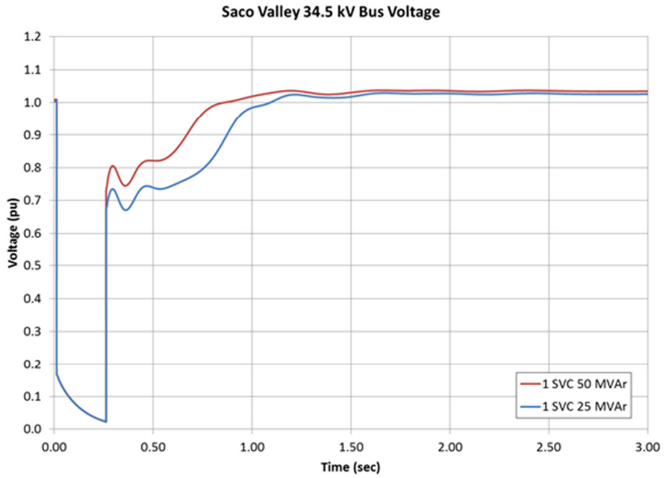

Figure 3.
Fault and clear performance of +25 and +50 MVAr SVCs.

Extended Fault Clearing

The synchronous condenser will remain synchronized for close in faults well in excess of typical 115-kV breaker failure clearing times. Study results demonstrated that for a close in fault, the synchronous condenser maintains synchronism for faults not clearing until 84 cycles, well beyond the typical breaker failure clearing times for this part of the 115-kV system, which are on the order of 15 to 20 cycles. See Figure 4. The effect of an extended fault clearing event on the alternative device would likely be a temporary shutdown of the device until the system voltage recovered.

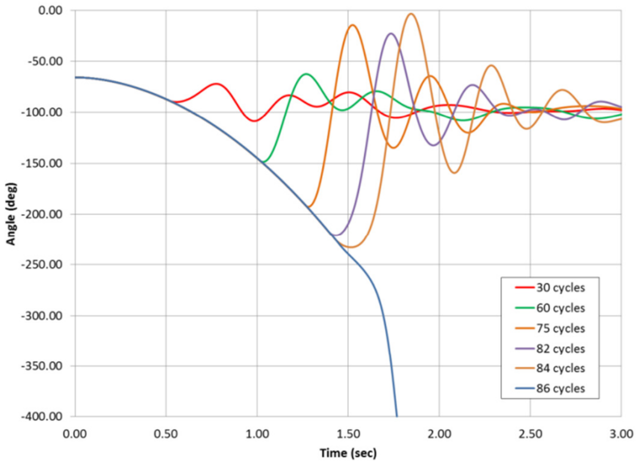

Figure 4.
Rotor angle for Synchronous Condensers 1 and 2 during a 3-phase, 115kV bus fault at Saco Valley.

Component Availability

Every component for the synchronous condenser design has an equivalent replacement from more than one manufacturer and is considered ‘off the shelf’. The power electronics devices considered, have components that are propriety with a sole vendor, and in some instances replacement components are custom manufactured, which may not be readily available during an outage.

Familiar Technology

Technology and equipment associated with the synchronous condenser are well understood and enable greater selection of third party contractors to provide support and services. The power electronic options require certain skill sets not as common among contractors.

Life Cycle Costs

The bid specification called out for a 20 year service life. The bid proposals provided cost adders to account for preventative maintenance, spare parts, and equipment overhauls, etc. to meet this condition. Past experience with electronic devices and voltage sourced converter technologies presently installed on the New England system have demonstrated that the maintenance programs and spare parts can become a significant cost adder in maintaining an expected level of reliable operation for multiple years. This added cost can accumulate and be in addition to the original bid price.

CONCLUSION

Eversource had several technology choices available for their Saco Valley dynamic reactive power device. Studies indicated that when considering only the voltage performance, any of the available technologies would suffice. As the costs of all the different technologies were reasonably close, Eversource examined other system benefits as a means of selecting the technology for Saco Valley. A total of twelve different reasons were found favoring the synchronous condenser. These range from power system performance enhancements to parts and ease of maintenance. Each application is unique with different system needs, and different challenges. It is therefore difficult to claim one technology is always better than another. At Saco Valley, a technology that was once considered obsolete has once again been chosen as the best option.

BIBLIOGRAPHY

[1] Paul E. Marken. (2015, April). Synchronous Condenser 2.0. *Transmission & Distribution World.* [Online]. Vol. 67, No. 4 p20. Available: http://viewer.zmags.com/publication/ddb5a72f#/ddb5a72f/22

[2] P. E. Marken, M. Henderson, D. LaForest, J. Skliutas, J. Roedel, and T. Campbell, "Selection of Synchronous Condenser Technology for the Granite Substation," presented at IEEE PES Transmission and Distribution Conference and Exposition, New Orleans, LA, April 2010.