From: Hantz Presume
Sent: Wednesday, December 11, 2019 12:48 PM
To: Stuart Nelmes
Cc: Bill Barnes; Edward Scrase; Salvatore Minopoli; Chris Root
Subject: RE: Encore/Highview/VELCO meeting

Good afternoon, Stuart.

That you very much for sending the footprint matrix. As we have discussed at the meeting, it would be really helpful to get planning grade cost estimates for a solution alternative that would include a cryogenic energy storage facility. As we have stated, we have considered storage before, and our analyses have indicated that the economics do not work. This is aggravated by the fact that FERC rules do not currently allow recovery under transmission rates. Below is a brief description of the study we are currently performing.

The Sheffield-Highgate Export Interface (SHEI) has experienced occasional congestion, which has resulted in generation curtailments, mostly wind generation. The affected utilities are in the process of implementing three upgrades that are expected to address these curtailment events about 90% of the time. However, there is no headroom for additional renewable generation, and we are currently exploring solutions that would provide about 100 MW of additional capacity. The SHEI limitations are primarily related to low voltage, but once the system is upgraded in the next two to three years, there will be times when the limitations are caused by thermal line loading or even local stability concerns. At a high level, we are testing transmission projects, synchronous condensers, and battery energy storage systems that provide similar levels of system support.

The battery storage option needs to be able to charge 56 MW, which resolves the thermal concerns. We have also found that this storage device needs to be able to inject 51 MVAr of reactive power to resolve voltage concerns. These are minimum values of course. We think that to achieve the 51 MVAr capacity, the battery will either need to be twice as large, i.e. 112 MW, or the battery would need to be coupled with a synchronous condenser, say a 25MVAr machine. I am leaning towards a larger battery recognizing that, to avoid premature degradation, the owner of the storage device would not want to drain the battery fully. Assuming the battery owner maintains a 50% state of charge, the battery size would be 112MW with a 51MVAr reactive power capacity. We also assuming that the battery would have sufficient energy for 4 hours.

Using the 112MW/448MWh/51MVAr battery storage as a description of the storage need, we can think of a cryogenic energy storage device with similar performance characteristics. From our discussions, the Highview techonology appears to be superior to the battery technology in several respects. The Highview storage tanks can be drained frequently without causing premature degradation. This is beneficial because this avoids refurbishments every 5 or 10 years similar to the batteries. We are assuming the Highview machine will have a functioning AVR and will respond to system faults similarly to a traditional generator, such that this machine should improve stability performance.

On the negative side, the efficiency of the Highview technology is less than that of a battery energy storage system. Therefore, we are assuming that the owner and operator of that device will not want to cycle it too frequently. Although, that may be OK because we expect curtailment events and the associated low prices to not occur frequently after the near term upgrades are implemented. We would like to understand the Highview loss figures better. Typical

synchronous condensers are sized as +50/-25 (lagging/leading). How much +/- reactive power can the 50 MW device provide? Can you provide loss curves for the machine, transformer, auxiliary loads, and total for the various modes of operation, such as synchronous condenser mode, charging, discharging, disconnected, and coincident charge/discharge?

Although the efficiency and loss content of the Highview technology appear to be less favorable than for a battery, that may not be a problem, and we would like to understand your view on how that may be the case. One mitigating operating option may be to disable the generator unit entirely until system conditions would benefit from the synchronous condenser. The Highview device may sit idle and totally discharged until there is an impending curtailment event. If this operating regime is utilized, I am assuming losses would be minimized and the effect of the lower efficiency would be lessened. Of course, I suppose that the owner of the Highview device would want to participate in ISO-NE markets, and therefore would have to maintain some state of charge. Because this is a cryogenic process, we would like to understand whether state of charge would be managed similar to a battery to offer the device into the energy, capacity and other markets. This will affect the size of the device.

If you are able to assist us in our review, it would be good to have installation cost estimates, annual maintenance costs, less frequent overhaul costs over a 30-year period, land requirements and any other requirements for an installation that is equivalent to the 112MW/448MWh/51MVAr battery energy storage device described above. It would also be good to have the same information for a different size you believe would be adequate to meet the system needs as described above.

I am happy to meet with you and your team to discuss any questions you may have.

Thank you.

Hantz.