Wind power has adopted a significant role in the rise of renewable power systems, however high wind penetration brings with it technical, economic and regulatory issues. One of the primary concerns for large scale connection of wind power is network operators’ ability to maintain desired frequency and voltage for the network consumers. During faults and outages, operators must rely on spinning reserve and ancillary services from various generators to maintain frequency and prevent cascading loss of load. To enable high levels of wind penetration, it is imperative that wind farms be operated, where possible, as conventional power plants in addition to ancillary services. This can be expensive however, and there is great need for cost effective solutions to better enable higher penetration of wind and all renewables.

1. Connection of Wind Farm using HVDC

Due to the decoupling effect of capacitor in the back-to-back converter, wind turbines may be modelled as DC source connected to Grid-Side Converter in order to simplify the model. For further simplicity, the entire offshore wind farm is represented by one equivalent unit.

2. Control of HVDC link

The Sending-End Converter of the VSC-HVDC keeps a stiff ac bus at the wind farm main platform ($B_{gr}$). This is important to ensure stable control of wind turbine GSCs which used the voltage set by SEC as a reference. The Receiving End Converter of the VSC-HVDC is configured to regulate the DC link voltage level at 640 kV and the AC voltage at the PCC ($B_{se}$). This control scheme allows independent control of P and Q which enables it to perform Fault Ride Through behaviour.

3. Simulation Results

Simulations were run with wind farm output initially set to 300 MW (0.3 pu), with a ramp up in power output beginning at $t = 2s$. Different magnitudes of ramp were achieved as shown in Figures 5a-5f below.

To illustrate the improved ac fault ride-through behaviour of the wind farm when integrated into the mainland grid using a VSC-HVDC link, a symmetrical ac three-phase fault to ground was applied to one of the tie lines that connects bus $B_{gr}$ to the grid as shown in Figures 6a - 6c below.

4. Preliminary Study on Hybrid Converter for SEC

The SEC VSC can be reduced to 1/3 of original rating and connected with two equally rated 12-Pulse Diode Rectifiers in a hybrid topology as shown in Figure 7. This reduces the number of IGBTs used, replacing them with Diodes resulting in a lower cost converter with lower losses.

Simulation was run with ramp up in power output from wind farm of 0.5 pu to 0.9 pu, starting at $t = 2s$. For this brief preliminary investigation into the described hybrid converter design, control of the SEC VSC was as before. It can be seen from Figure 8 that Voltages across capacitors in the SEC of the DC link do not remain balanced with different magnitudes of power flow from the wind farm and additional control is required to achieve this.

5. Conclusion from Results

Figures 6a - 6c illustrate current HVDC technologies ability provide Low Voltage Ride Through (LVRT) support to the network while other ancillary services, such as frequency support, may also be demonstrated. Since the SEC converter, which governs HVDC link voltage, and its controller design remained the same for hybrid design, the DC link dynamics are similar to those seen in Figure 5b.

Therefore it should demonstrate LVRT capabilities but this is yet to be tested through simulations.

Future Work

- Improve SEC control loop for voltage regulation both for offshore AC network and balancing $C_i$ and $C_l$
- Demonstrate LVRT for HVDC link with hybrid converter and investigate capability for participating in frequency restoration services.
- Investigate optimised solution for low cost, high support capability HVDC link for large offshore wind farms.