Wind power transmission integration study for a small islanded power grid

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Parsons Brinckerhoff Africa (PB) was contracted by its client in 2009 to perform a power system study as well as a wind integration study for a 25 to 50 MW wind power plant (WPP) on the utility network.

The scope of work for the project included an analysis of the wind generation capacity that the client’s network could sustain, the grid strengthening and integration requirements for the WPP, and the WPP specification limits.

Wind integration study

Background to the utility power system

Fig. 1 shows the projected demand forecast. Load is expected to grow to nearly 600 MW in the next 15 years.

The utility needs to plan for the expected growth in load, and one power source option in the future is wind power.

Wind study terms of reference

Wind generation sustain capacity for the system e.g.

- Governing and frequency response
- 25 or 50 MW wind power increments
- Automatic generator control (AGC)
- To establish the grid strengthening required at the connection substation (22 or 66 kV)
- Thermal limit
- Fault level and voltage stability

Integration requirements/specifications for the turbines e.g.

- Fault ride through analysis
- Wind grid code compliance
- WPP interfaces to the utility system

Wind data

Wind data provided by the client was analysed. The available data was cleaned and validated. The wind data was subsequently extrapolated to the proposed WPP’s potential hub height of 70 m above ground level.

Wind turbine

All international grid codes require a sufficiently detailed wind model for dynamic studies. Data was not available for a specific wind turbine vendor to populate the dynamic model of the wind turbine. Studies were undertaken using standard wind turbine models.

Regulation reserve, frequency control and spinning reserve

WPP sizes of 20, 25 and 50 MW were analysed taking into consideration the minute to minute variations of the wind speed from the data provided.

Three control scenarios were chosen as follows:

- The existing control philosophy of the utility
- Decreasing the droop at the utility frequency control power station
- Future Automatic Generator Control (AGC).

The studies showed that the existing reserve philosophy can control a 20 – 25 MW WPP but will not be able to control a 50 MW WPP. For a WPP of 50 MW, additional spinning reserve generators are required. Reduction in droop to 1% at the utility’s frequency control power station and the implementation of AGC showed an improvement in the frequency control on the island.

Steady state studies

Fig. 2 shows a typical WPP collector system. Turbines normally generate at around 1 kV and have their own step up
transformers, typically stepping up to 33 or 22kV. MV collector systems are normally in the range of 22 to 33 kV and normally utilise underground cables for aesthetic/environmental reasons.

In this study, the turbine voltage was modelled as 1 kV and the collector voltage was modelled as 22 kV. The reason why 22 kV was chosen was because the nearby transmission substation includes a 22 kV bus and due to the power capacity of the planned WPP.

Fig. 3 shows a typical equivalent model for the WPP and connection. The interconnection transmission line, station transformer(s) and plant-level reactive compensation are represented explicitly. The collector system station, collector system branch, generator step-up transformer and wind turbine generators (WTGs) are equivalenced due to the high number of generators, WTG transformers and cables.

The transmission integration substation includes two voltages viz. 66 kV and 22 kV, so integration scenarios at these voltages were undertaken. Steady state N-0 and N-1 thermal, voltage and fault criteria were studied. Techno financial analysis using capital costs, cost of losses and O&M costs over 20 years was conducted on the two 66 and 22 kV transmission integration options and the 66 kV option was found to be the best option.

Fault ride through studies
Fault ride through (FRT) studies were conducted for the two integration options to determine which option would provide better dynamic response. Three phase and single phase faults with associated fault clearing were modelled on the 22 and 66 kV networks. The results showed that for the 22 kV integration option the proposed WPP implementation would not be compliant as the voltage at the WPP generator busbar drops to below 0,15 per unit for a three phase fault at the utility interface point. The 66 kV integration option is more robust than the 22 kV as the WPP generator voltage remains above 0,15 per unit for all studied fault conditions. Fig. 4 shows a vendor Low Voltage Ride Through (LVRT) or Fault Ride Through (FRT) capability curve.

Fig. 5 shows a voltage l extract from E.ON regulation documents.

Fig. 6 shows fault ride through plots for the 25 MW windfarm option connected to the utility transmission system at 22 kV.

Frequency stability studies
Fig. 7 shows the utility system frequency collapsing for a trip of the 50 MW windfarm with the current regulating reserve and spinning reserve operating scenario.

When an extra diesel governing unit of 20 MW was added, the system was stable for the trip of a 50 MW WPP however under-frequency load shedding (UFLS) was invoked at 48,6 Hz.

WPP interfaces to the utility
PB included an analysis of the interface requirements of the WPP to the utility system. Major requirements include inter alia:

- Wind forecasting
- Telecommunication requirements from power station
- Telecontrol requirements to power station
- High and low frequency response from wind turbine
- Black start shutdown
- Dynamic model of wind turbine
Wind grid code requirements

The island utility has no grid code at present and also does not have a wind grid code. Aspects of various international wind grid codes were used (e.g., Norwegian and Irish) in the analysis.

Conclusions

- Electricity demand on the island is expected to grow from 388 MW to nearly 600 MW in the next 15 years.
- The studies show that the existing generating reserve philosophy can control a 20 – 25 MW WPP but will not be able to control a 50 MW WPP.
- For a WPP of 50 MW, additional utility generators are required.
- Reduction in droop to 1% at the utility's frequency control power station and the implementation of AGC showed an improvement in the frequency control on the island.
- The results showed that for the 22 kV integration option the proposed WPP implementation would not be compliant from a FRT point of view. The 66 kV integration option was compliant.
- Techno financial analysis using capital costs, cost of losses and O&M costs over 20 years was conducted on the two 66 and 22 kV transmission integration options and the 66 kV option was found to be the best option.
- In terms of frequency stability, the utility system was stable after the tripping of 20 and 25 MW windfarms but not after the tripping of a 50 MW windfarm. For a 50 MW WPP, when an extra diesel governing unit of 20 MW was added, the system was stable for the WPP but only under frequency load shedding (UFLS) was invoked at 48.6 Hz.
- Implementation of IPP windfarms on the island will be assisted if the island develops a wind grid code.

References


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Fig. 6: Fault ride through plots at 22 kV for a 25 MW windfarm.
Fig. 7: Frequency stability curve – 50 MW WPP trip.