WIND TRANSMISSION INTEGRATION STUDY FOR A SMALL ISLANDED POWER SYSTEM

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ABSTRACT

PB's study terms of reference for the wind power integration study for an island power system were as follows:

- *To establish what wind generation the island system could sustain.*
- *To establish the grid strengthening required at the connection substation (22kV or 66kV.)*
- *To establish the integration requirements/specifications for the turbine.*

INTRODUCTION

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 25MW to 50MW wind farm or Wind Power Plant (WPP) at a designated site on the island country in the Indian Ocean. The scope of work for the project included an analysis of the wind generation capacity that the island network could sustain, the grid strengthening and integration requirements for the WPP, and the wind farm specification limits.

WIND INTEGRATION SUTDY

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

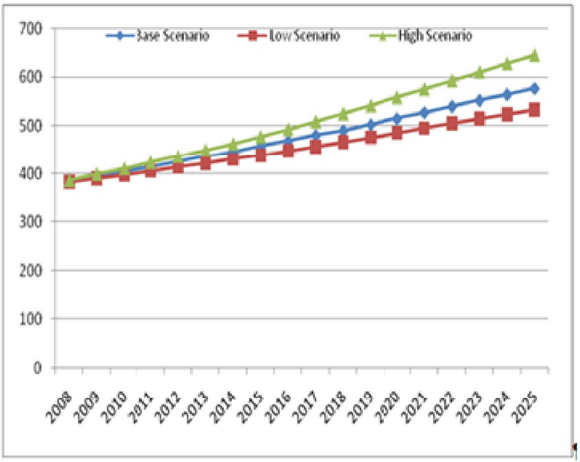

Figure 1: Projected Island Electricity Demand (High, Medium and Low Scenarios)

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

PB's study terms of reference for the wind power integration study were as follows:

- To establish what wind generation the island system could sustain e.g.
  - Governing and frequency response
  - 25MW or 50MW wind power increments
  - Automatic Generator Control (AGC)
- To establish the grid strengthening required at the connection substation (22kV or 66kV)
  - Thermal limits
  - Fault Level and Voltage Stability
- To establish the integration requirements/specifications for the turbines e.g.
  - Fault ride through analysis
  - Wind Grid Code compliance
  - WPP interfaces to the utility system

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 analyzed 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 - 25MW WPP but will not be able to control a 50 MW WPP.
For a WPP of 50MW, 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

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

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

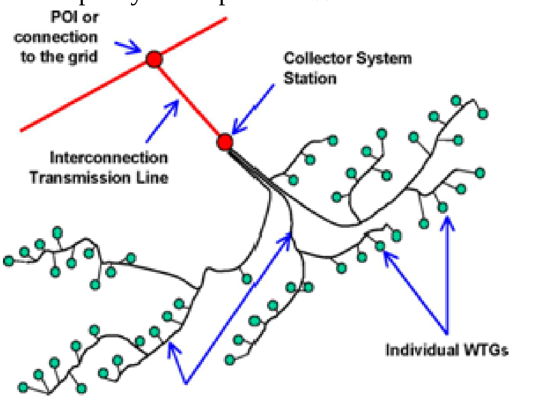

Figure 2: Typical WPP turbine, MV collector and HV interconnection system

Figure 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.

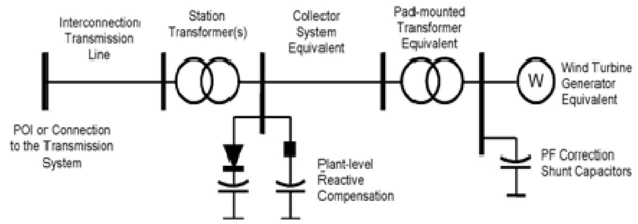

Figure 3: Equivalent Powerflow Modelling

The transmission integration substation includes two voltages viz. 66kV and 22kV, 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 66kV and 22kV transmission integration options and the 66kV 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 22kV and 66kV networks.

The results showed that for the 22kV 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 66kV integration option is more robust than the 22kV as the WPP generator voltage remains above 0.15 per unit for all studied fault conditions.

Figure 4 shows a vendor Low Voltage Ride Through (LVRT) or Fault Ride Through (FRT) capability curve.

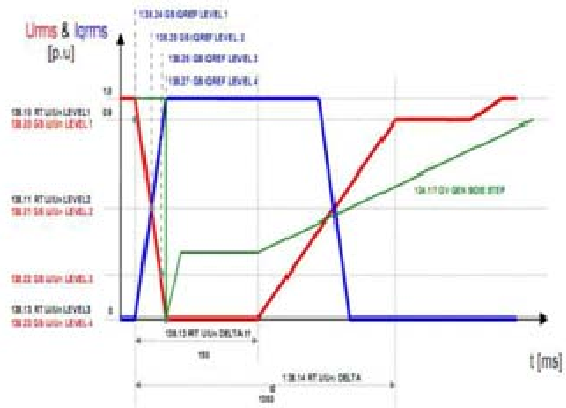

Figure 4: Vendor Low Voltage Ride Through (LVRT) or Fault Ride Through (FRT) capability diagram

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

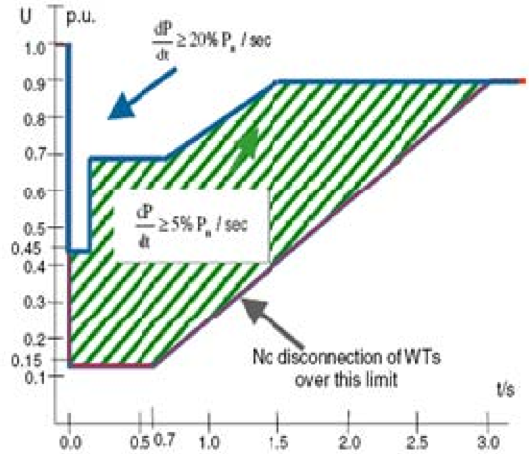

Figure 5: Voltage Limits at Grid Connection During and Following Network Faults (E.ON)

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

Frequency Stability Studies

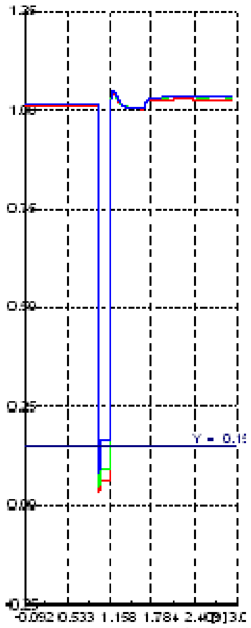

Figure 6: Fault Ride Through Plots at 22kV for a 25MW windfarm

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

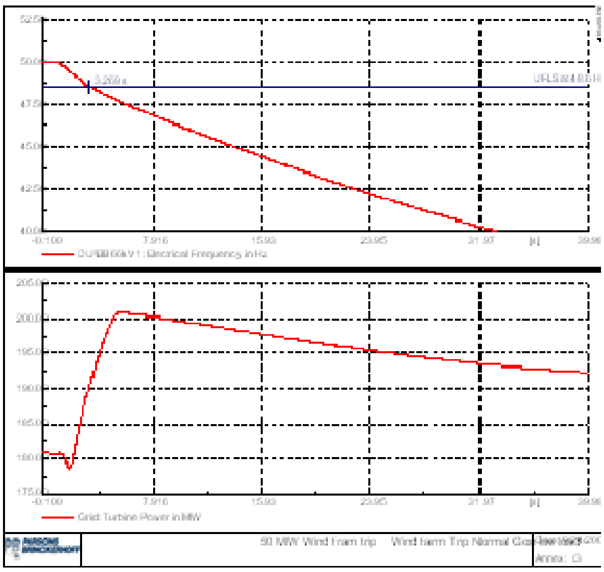

Figure 7: Frequency Stability Curve – 50MW WTG trip

When an extra diesel governing unit of 20MW was added, the system was stable for the trip of a 50MW WPP however Under Frequency Load Shedding (UFLS) was invoked at 48.6Hz.

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.

WIND INTEGRATION SUTDY

- Electricity demand on the island is expected to grow from 388MW to nearly 600MW in the next 15 years.
- The studies show that the existing generating reserve philosophy can control a 20 - 25MW WPP but will not be able to control a 50 MW WPP.
- For a WPP of 50MW, 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 22kV integration option the proposed WPP implementation would not be compliant from a FRT point of view. The 66kV 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 66kV and 22kV transmission integration options and the 66kV option was found to be the best option.
- In terms of frequency stability, the utility system was stable after the tripping of 20MW and 25MW windfarms but not after the tripping of a 50MW windfarm. For a 50MW WPP, when an extra diesel governing unit of 20MW was added, the system was stable for the WPP trip however Under Frequency Load Shedding (UFLS) was invoked at 48.6Hz.
- Implementation of IPP windfarms on the island will be assisted if the island develops a wind grid code

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