# Chapter 5

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## 5. Voltage Stability Analysis

### 5.1. Interfacing standards

Maximum capacity of a wind plant that can be connected to a power system is primarily determined by the electrical system and power quality considerations.

Various countries adopt various standards to limit renewable integrations and to ensure the power quality. A rough rule of thumb to control the power quality has been to keep the renewable power plant capacity in MW less than the grid line voltage in kV, if the grid is stiff .On a weak grid, however, only 10 or 20 % of this capacity may be allowed.

On the other hand, it is convenient to meet the power-quality requirements by limiting the total renewable power rating less than a few percent of the short circuit MVA of the grid at the proposed interface. The limit is generally 2% in developed countries and 5 % in developing countries [14].



Some countries adopt a limit on the step change in voltage a customer can cause when loading or unloading a generating unit. This limit is ±2% in Spain for wind generators.

### 5.2. Voltage stability limit

The voltage fluctuation observed at the point of common coupling (PCC) following a sudden wind farm failure and the grid short circuit level at the PCC were taken in to account to in determining the voltage stability limit for the network during this study.

Since there is no wind interface standard developed for Sri Lanka, the allowable maximum voltage fluctuation is limited to approximately 2% at the PCC and the obtained figure was compared with the grid short circuit level at the same point to obtain a wind integration limit at that point of the grid.

## 5.3. Methodology and results

The voltage stability is considered as a local impact. Therefore it is necessary to identify the system configuration for wind integration in order to perform voltage stability studies.

Initially proper system configurations were identified for each study year and then the voltage stability studies were carried out for the selected configurations in order to identify the voltage stability limit.

Since local impact highly depends on the local loads, both night peak and off peak loading scenarios were appropriately taken in to account during the voltage stability analysis.

### 5.3.1. System analysis – Year 2010

This part of the study aims at obtaining a voltage stability limit for wind integration to the proposed year 2010 network at existing Puttlam GS.

At present Puttalam GS consists of 2x31.5MVA transformers. Holcim cement factory is supplied with power using two dedicated 33kV feeders. Two transformers are operated separately. Year 2010 Puttlam GS arrangement is shown in the figure 5.1.



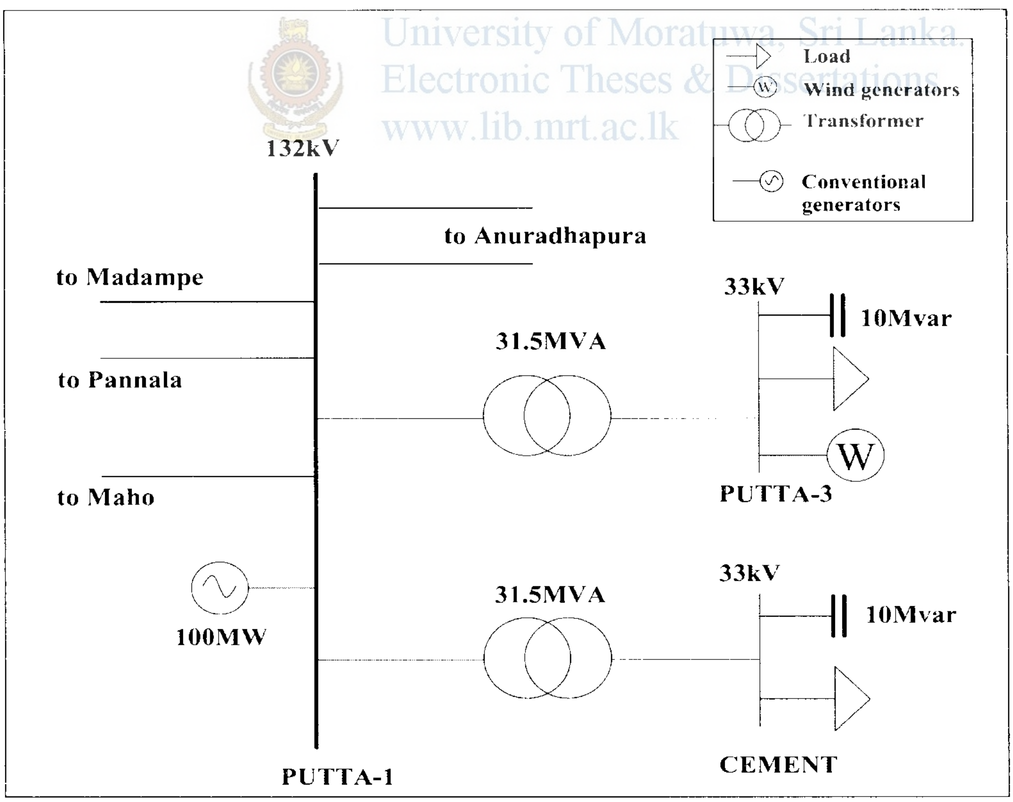


**Figure 5.1: Proposed Puttlam GS arrangement for year 2010**

The impact of wind additions on the 33kV level is analyzed by considering two wind integration levels. They are 20MW and 35MW. Results are summarized in table 5-1.

| Busbar | Observed voltage fluctuation | |
|---|---|---|
| | kV | % of nominal voltage |
| CEMENT | 0.165 | 0.5 |
| PUTTA-3 | 0.132 | 0.4 |

20MW penetration level at night peak scenario

| Busbar | Observed voltage fluctuation | |
|---|---|---|
| | kV | % of nominal voltage |
| CEMENT | 0.066 | 0.2 |
| PUTTA-3 | 0.755 | 2.3 |

20MW penetration level at off peak scenario

| Busbar | Observed voltage fluctuation | |
|---|---|---|
| | kV | % of nominal voltage |
| CEMENT | 0.198 | 0.6 |
| PUTTA-3 | 0.363 | 1.1 |

35MW penetration level at night peak scenario

| Busbar | Observed voltage fluctuation | |
|---|---|---|
| | kV | % of nominal voltage |
| CEMENT | 0.066 | 0.2 |
| PUTTA-3 | 1.419 | 4.3 |

35MW penetration level at off peak scenario

**Table 5-1: Observed voltage fluctuations at 33kV level of Puttlam GS**

Short-circuit level at Puttlam 33kV busbar is obtained as 258MVA. Wind integration level as a percentage of short circuit level is depicted in table 5-2.



| Busbar | Wind power as % of SCC | |
|---|---|---|
| | Integration level 35MW | Integration level 20MW |
| PUTTA-3 | 13.6% | 7.8% |

**Table 5-2: Wind power as a percentage of SCC – Year 2010**

The maximum voltage fluctuation observed in the 33kV busbar is 4.3% following a sudden drop of 35MW wind plant. Around 2.3% variation can be observed following a sudden drop of 20MW wind farm. 20MW wind integration level is about 7.8% of SCC at PCC. Therefore the maximum wind absorption capability at 33kV level of the existing Puttlam GS is identified as 20MW for year 2010 when considering the voltage fluctuations.

### 5.3.2. System analysis – Year 2012

Voltage stability of the year 2012 network with wind additions into 132kV and 220kV levels was analyzed during this part of study. Year 2012 network arrangement around Puttlam area is depicted on figure 5.2.

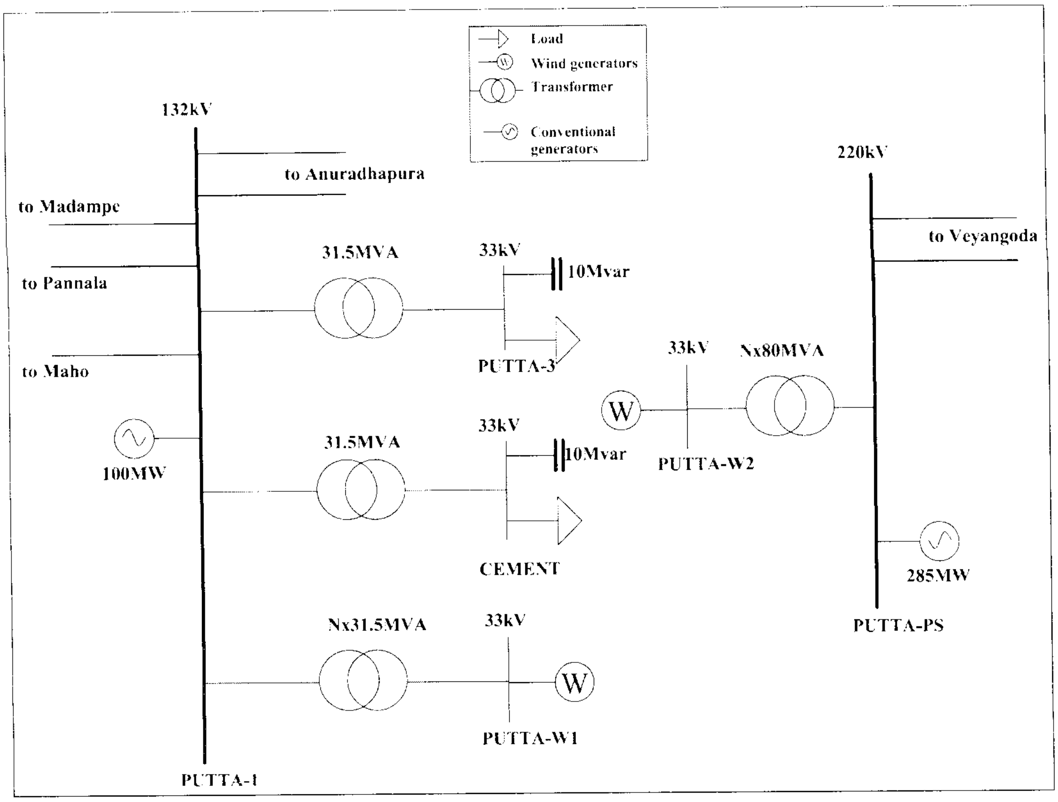


**Figure 5.2 : Proposed network arrangement for year 2012**

85MW and 80MW wind integrations were considered respectively at 132kV and 220kV levels and the results are summarized in the table below.



| Loading scenario | Observed voltage fluctuation As % of nominal voltage |
|---|---|
| Night peak | 1.4% |
| Off peak | 1.8% |

85MW wind absorption at 132kV level

| Busbar | Observed voltage fluctuation As % of nominal voltage |
|---|---|
| Night peak | 1.4% |
| Off peak | 1.9% |

80MW wind absorption at 220kV level

**Table 5-3: Observed voltage fluctuations at 132kV and 220kV busbars at Puttlam- Year 2012.**

SCC at Puttlam 132kV and 220kV busbars and the wind integration levels as a percentage of SCC are depicted in table 5-4.

| Voltage level | SCC (MVA) | Wind capacity (MW) | Wind power as % of SCC |
|---|---|---|---|
| 132kV | 1075 | 85 | 7.9% |
| 220kV | 1486 | 80 | 5.4% |

**Table 5-4: Wind power as a percentage of SCC – Year 2012**

Results depict that there is a possibility of a slight increase in wind penetration at 220kV level; however there is a frequency stability limit at 90MW. Therefore this study proposes limiting the total wind integration to 90MW and splitting that amount between the above two voltage levels such that 85MW at 132kV level and 80MW at 220kV level will not be exceeded.

### 5.3.3. System analysis – Year 2014

Voltage stability of the year 2014 network with wind additions in to 132kV and 220kV levels was studied in this section. The network arrangement is shown in figure 5.3. The results are summarized in table 5-5:

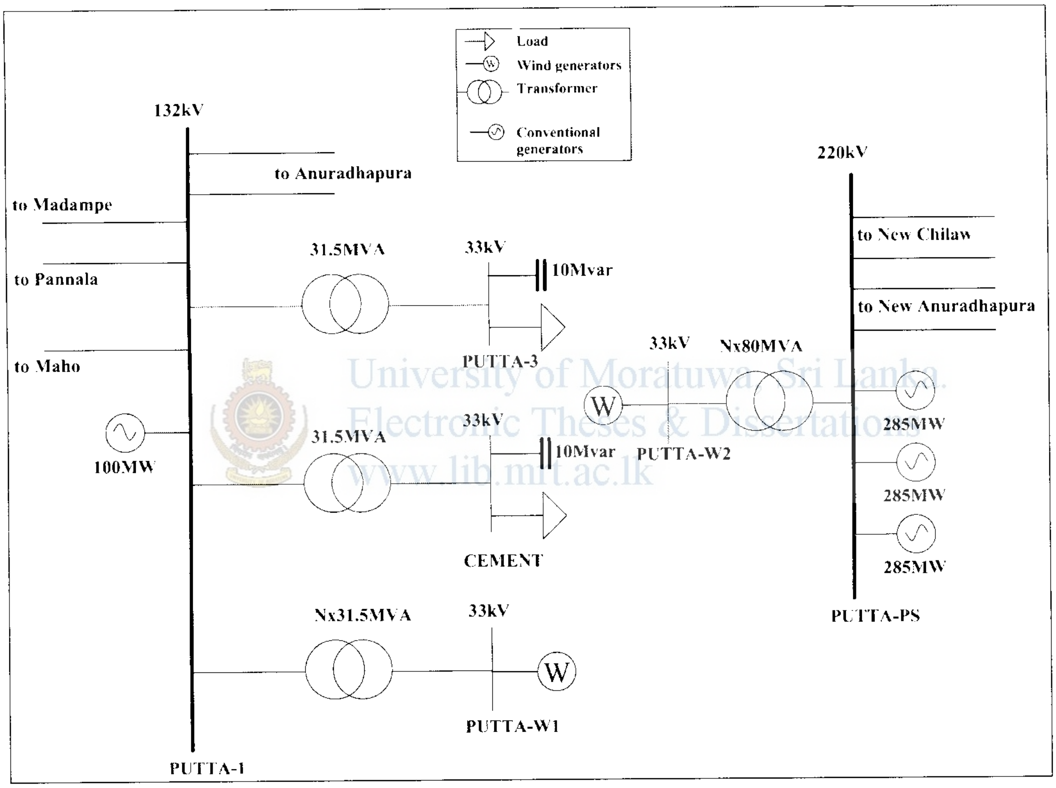




**Figure 5.3 : Proposed network arrangement for year 2014**

| Voltage level | SCC (MVA) | Wind capacity (MW) | Observed voltage fluctuation As % of nominal voltage | Wind power as % of SCC |
|---|---|---|---|---|
| 132kV | 1738 | 90 | 1.8% | 5.2% |
| 220kV | 3506 | 95 | 2.0% | 2.7% |

**Table 5-5: Observed voltage fluctuations and SCC at 132kV and 220kV busbars at Puttlam- Year 2014.**

Even though we observe only 1.8% voltage variation at 132kV level, there exist critical network limitations at 132kV network, which limits the absorption capability at 132kV level. This 90MW integration at 132kV level will only be feasible assuming 20% average continuous wind output, especially during day time.

### 5.3.4. System analysis – Year 2016

Voltage stability studies were carried out to year 2016 network. The network arrangement is shown in the figure 5.4. It has been found that 220MW of wind power can be integrated into year 2016 power system at Puttlam area. The summary of the voltage analysis is depicted in table 5.6.

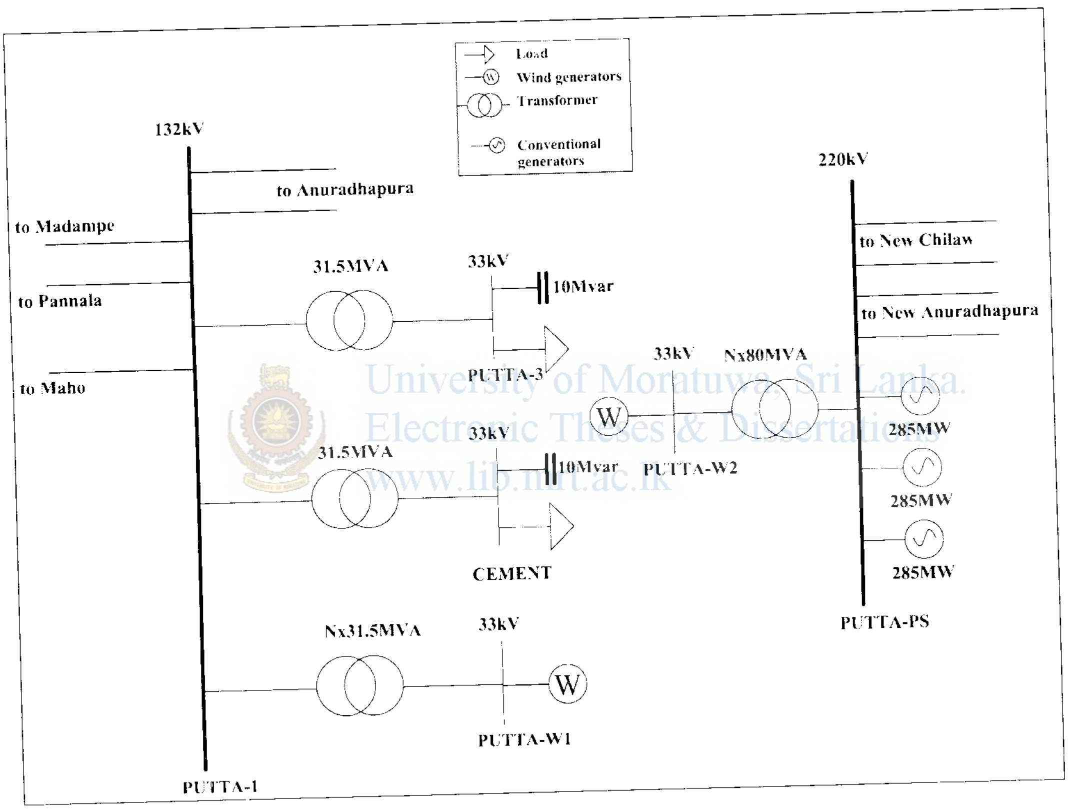



**Figure 5.4 : Proposed network arrangement for year 2016**

| Voltage level | SCC (MVA) | Wind capacity (MW) | Observed voltage fluctuation As % of nominal voltage | Wind power as % of SCC |
|---|---|---|---|---|
| 132kV | 1486 | 90 | 2.0% | 6.1% |
| 220kV | 3849 | 135 | 2.4% | 3.4% |

**Table 5-6: Observed voltage fluctuations and SCC at 132kV and 220kV busbars at Puttlam- Year 2016.**

There are no frequency stability or steady state violations observed for the above wind penetration levels. Therefore the wind interconnection limit at 132kV and 220kV levels at Puttlam substations is identified as 90MW and 135MW correspondingly for year 2016 network.