Chapter 3

3. Steady State System Analysis

3.1. Introduction

The objective of the steady state system analysis is to identify several wind absorption capability levels of the proposed transmission network.

This study was performed based on year 2012, 2014 and 2016 transmission networks proposed in "Long Term Transmission Development Plan 2008-2016" , prepared by the Transmission Planning unit of CEB .(Refer to appendix C and appendix D for the proposed year 2016 transmission map and the year 2016 single line diagram.)

The steady state system analysis was carried out only for 132kV level due to following reasons:

- Both 132kV transmission connections from Puttlam GS to New Chilaw/Madampe and New Anuradhapura have Lynx conductors, with low thermal ratings. Hence there is a possibility of achieving a steady state power transfer limit before stability limit.
- 220kV network around Puttlam PS has been planned to evacuate 900MW coal fired thermal power with approximately 750MW excess capacity. Therefore the possibility of achieving a steady state limit for wind penetration at 220kV level can be neglected.

Transmission Transfer Limit Analysis (TLTG) followed by a Load Flow Analysis were performed to identify the above stated wind power absorption capability levels.

3.2. Transmission Transfer Limit Analysis

Transmission Transfer Limit Analysis is a common approach used to find a limiting solution. It starts with a base case and calculates the sensitivity of flow in monitored elements or groups of elements to a variation in interchange. This technique is often referred to as a distribution factor technique. Once the sensitivity of elements is known, linear projections can be used to estimate permissible interchanges based on thermal limits. P1, P2 and P3 in figure 3.1 represent linear line flow functions of the net import. The horizontal line rating intersects P1 imposing a limit or net import restriction. The TLTG estimates the export limit of the specified subsystem using the above explained technique.

The above approach was initially used to identify 132kV transmission line capacity limitations related to wind power absorption at Puttlam GS.

In the beginning the power system was divided in to two sectors (Study & opposing systems shown in figure 3.2). The transmission lines connecting the two systems above were taken as the interface. Elements included in the study, opposing and interface systems are depicted in table 3-1.

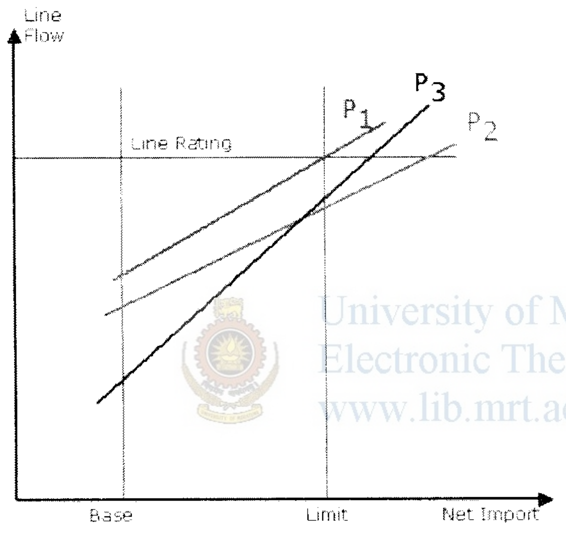

Figure 3.1: TLTG approach

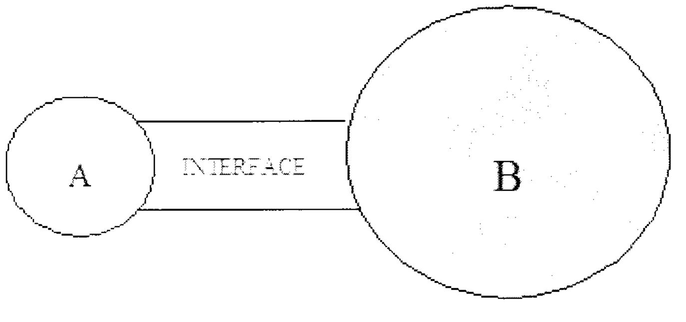

Figure 3.2 : Study system (A) opposing system (B) and interface used in TLTG

Study system [A]	Opposing system [B]	Interface
Puttlam 132kV BB Puttlam 33kV BBs	Rest of the power system BBs excluding BBs specified in A.	Puttlam –New Chilaw 132kV line Puttlam – Anuradhapura 132kV line Puttlam – Maho 132kV line

Table 3-1 : Study, opposing and interface elements for TLTG analysis

3.3. Load flow analysis

3.3.1. Load flow solution

Load flow solution is a solution of the network under steady state condition subjected to certain inequality constrains under which the system operates. These constrains can be in the forms of load nodal voltages, reactive power generation of the generators and the tap setting of a tap changing under load transformer etc.

Load flow solution is essential for designing a new power system as well as for extending existing power systems. This analysis requires the calculation of numerous load flows under both normal and contingency operating conditions.

3.3.2. Planning criteria

During the synthesis of transmission development plan, it is targeted to meet the planning criteria to ensure quality and reliable supply under normal operating conditions as well as under contingencies. The adopted contingency level for the planning purposes is N-1, i.e. outage of any one element of the transmission system at a time.

Under normal operating conditions, the equipment (transmission line, transformer and etc.) loading limit is considered as 100% of the respective thermal limit and under contingency situation the allowable equipment loading limit is considered as 120%.

The permitted voltage deviations at any live busbar of the network under normal and contingency conditions are depicted in the table below:

Voltage level	Allowable voltage variation (%)	
	Normal condition	N-1 condition
220 kV	±5%	-10% to +5%
132kV	±10%	±10%
33kV	±1%	±1%

Table 3-2: Allowable range of voltage variations

3.4. Steady state simulation procedure

Two system loading scenarios were considered during the steady state system analysis. They are the day peak and night peak loading scenarios.

Initially TLTG was performed only the for day peak scenario as this becomes more critical when considering branch thermal ratings (i.e. branch thermal ratings are fairly low during day time due to temperature effect). Several transfer limits were identified for each year with a set of network improvements during the TLTG analysis.

Then the load flow simulations were performed for both day peak and night peak loading scenarios to verify the results obtained during TLTG analysis.

Both normal and N-1 operating conditions were considered during the above analysis.

It was assumed that all transmission development proposals that are listed in the "Long Term Transmission Development Plan 2008-2016" would be implemented timely.

3.5. Results and conclusions

Power absorption capabilities identified using the above described method is listed in table 3-3.

Year	Power absorption capability		Network modifications required
	Level	Amount (MW)	
2010	1	50	None
	2	100	Upgrade Puttlam-Pannala 132kV line to operate at 75°C
			Upgrade Puttlam-Madampe 132kV line to operate at 75°C
2012	1	50	None
	2	180	Upgrade Puttlam-Pannala 132kV line to operate at 75°C
			Upgrade Puttlam-Madampe 132kV line to operate at 75°C
			Upgrade Habarana - Anuradhapura 132kV line to operate at 75°C
			Switch off Kelaniya - Kolonnawa 132kV line
2014	1	30	None
	2	190	Upgrade Puttlam - New_Chilaw 132kV line to operate at 75°C
			Upgrade Habarana - Anuradhapura 132kV line to operate at 75°C
	3	360	Re-string Puttlam - New_Chilaw 132kV line using Zebra
			Re-string Puttlam – Anuradhapura 132kV line using Zebra
			Upgrade Habarana - Anuradhapura 132kV line to operate at 75°C
2016	1	120	None
	2	280	Upgrade Puttlam - New_Chilaw 132kV line to operate at 75°C

Table 3-3: Steady state power absorption capability at Puttlam 132kV level

The absorption capabilities depicted in the table 3-3 can be released due to the intermittent nature of the wind resource. The common practice is to consider 20~30% wind resource availability for steady state analysis. Table 3-4 depicts the steady state wind power absorption capability at Puttlam 132kV level without modifying the proposed network and by considering approximately 30% wind availability.

Year	Wind Power Absorption Capability (MW)
2010	160
2012	160
2014	70
2016	400

Table 3-4: Steady state wind power absorption capability at Puttlam 132kV level

Sever steady state limitations were observed during year 2014. The absorption capability of year 2016 system is fairly high. This may be due to the retirement of the Heladanavi generator and the higher local power consumptions.