2011

TRANSMISSION SYSTEM PERFORMANCE REPORT

SRI LANKA

Prepared By:
Public Utilities Commission of Sri Lanka
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1. Introduction

The electricity transmission network in Sri Lanka is solely owned and operated by Ceylon Electricity Board (CEB). CEB is responsible for the safe, secure and efficient operation of the electricity transmission in Sri Lanka. The transmission network is operated at 220kV and 132kV to transport electricity from generation points to distribution bulk supply points.

The Sri Lankan transmission system comprises 794 kilometers of 220kV overhead line circuits, 3102 kilometers of 132kV overhead line circuits, 7 of 220kV Grid Substations and 48 of 132kV Grid Substations and is shown below.

This Transmission Performance Report contains a summary of information and performance statistics of the transmission system for the year 2011. The document, moreover, takes account of availability, security of supply and quality of service of the transmission network.

All the index and other calculations in this report have been done based on the data received through LISS and details obtained from CEB Monthly Review Reports.
2. Energy Sales

CEB sells the power transmitted from generation stations, to the distribution licensees. There are 5 major distribution licensees who purchase the power bulky and distribute among consumers. CEB itself owns 4 distribution licenses for four distribution regions and Lanka Electricity Company (LECO) owns one distribution license.

The charts and tables below show the annual and monthly energy sales by transmission licensee in year 2011.

### BSOB to DL Energy Sales (MWh)

<table>
<thead>
<tr>
<th>Licensee</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL1</td>
<td>232,587</td>
<td>213,415</td>
<td>260,345</td>
<td>234,332</td>
<td>258,341</td>
<td>257,842</td>
<td>264,759</td>
<td>268,780</td>
<td>260,959</td>
<td>268,672</td>
<td>249,121</td>
<td>258,868</td>
</tr>
<tr>
<td>DL2</td>
<td>278,958</td>
<td>217,726</td>
<td>259,653</td>
<td>229,053</td>
<td>255,975</td>
<td>297,775</td>
<td>277,154</td>
<td>279,559</td>
<td>266,250</td>
<td>248,870</td>
<td>248,765</td>
<td>258,434</td>
</tr>
<tr>
<td>DL3</td>
<td>164,463</td>
<td>155,127</td>
<td>193,279</td>
<td>181,494</td>
<td>184,701</td>
<td>171,129</td>
<td>196,528</td>
<td>177,014</td>
<td>181,482</td>
<td>225,004</td>
<td>196,745</td>
<td>201,338</td>
</tr>
<tr>
<td>DL4</td>
<td>109,125</td>
<td>106,988</td>
<td>123,374</td>
<td>107,279</td>
<td>121,025</td>
<td>129,154</td>
<td>122,265</td>
<td>123,011</td>
<td>120,501</td>
<td>121,333</td>
<td>113,309</td>
<td>122,031</td>
</tr>
<tr>
<td>LECO</td>
<td>66,783</td>
<td>88,766</td>
<td>109,471</td>
<td>105,704</td>
<td>109,473</td>
<td>111,214</td>
<td>108,623</td>
<td>110,742</td>
<td>105,463</td>
<td>78,194</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>851,916</td>
<td>782,022</td>
<td>946,121</td>
<td>857,862</td>
<td>929,153</td>
<td>963,767</td>
<td>970,178</td>
<td>959,579</td>
<td>937,815</td>
<td>913,404</td>
<td>918,864</td>
<td></td>
</tr>
</tbody>
</table>

### Sales by BSOB (MWh)

<table>
<thead>
<tr>
<th>Licensee</th>
<th>Day</th>
<th>Peak</th>
<th>Off-Peak</th>
<th>Total</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL1</td>
<td>1,721,063</td>
<td>669,685</td>
<td>637,274</td>
<td>3,028,021</td>
<td>27.5</td>
</tr>
<tr>
<td>DL2</td>
<td>1,748,130</td>
<td>700,452</td>
<td>669,589</td>
<td>3,118,171</td>
<td>28.3</td>
</tr>
<tr>
<td>DL3</td>
<td>1,264,213</td>
<td>497,308</td>
<td>466,783</td>
<td>2,228,304</td>
<td>20.2</td>
</tr>
<tr>
<td>DL4</td>
<td>805,432</td>
<td>320,264</td>
<td>293,704</td>
<td>1,419,400</td>
<td>12.9</td>
</tr>
<tr>
<td>LECO</td>
<td>680,103</td>
<td>254,906</td>
<td>276,395</td>
<td>1,211,405</td>
<td>11.0</td>
</tr>
<tr>
<td>Total</td>
<td>6,218,941</td>
<td>2,442,616</td>
<td>2,343,745</td>
<td>11,005,302</td>
<td></td>
</tr>
</tbody>
</table>

![Annual Energy Sales to Distribution Licensees - 2011](image)
2.1 Transmission Losses

Transmission losses can be calculated as the difference between the total electrical energy received from the generating plants and the total energy supplied to all bulk supply distribution licensees. It is usual to express losses as a percentage value rather than absolute value. The losses are measured over a definite period, normally per year.

The definition of the transmission losses is defined as;

\[
\%\text{Transmission Losses} = \frac{\sum E_G - \sum E_T}{\sum E_G} \times 100\%
\]

Where;

- \(E_G\) = Total Energy Purchased from generation plants (MWh) during reported year
- \(E_T\) = Total Energy Sold to Distribution Licensees (MWh) during reported year

- Total Energy Loss in Sri Lankan Transmission System in 2011 = 4.52 %
The chart and table below show the monthly transmission losses in year 2011.

### Transmission Losses in 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>Purchases (MWh)</th>
<th>Sales (MWh)</th>
<th>Loss (MWh)</th>
<th>Monthly % loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>894,279</td>
<td>851,916</td>
<td>42,364</td>
<td>4.7</td>
</tr>
<tr>
<td>Feb</td>
<td>836,008</td>
<td>782,022</td>
<td>53,986</td>
<td>6.5</td>
</tr>
<tr>
<td>Mar</td>
<td>992,212</td>
<td>946,121</td>
<td>46,090</td>
<td>4.6</td>
</tr>
<tr>
<td>Apr</td>
<td>897,231</td>
<td>857,862</td>
<td>39,368</td>
<td>4.4</td>
</tr>
<tr>
<td>May</td>
<td>1,002,217</td>
<td>929,153</td>
<td>73,064</td>
<td>7.3</td>
</tr>
<tr>
<td>Jun</td>
<td>962,667</td>
<td>963,767</td>
<td>-1,101</td>
<td>-0.1</td>
</tr>
<tr>
<td>Jul</td>
<td>1,000,756</td>
<td>970,178</td>
<td>30,578</td>
<td>3.1</td>
</tr>
<tr>
<td>Aug</td>
<td>1,013,857</td>
<td>959,579</td>
<td>54,278</td>
<td>5.4</td>
</tr>
<tr>
<td>Sep</td>
<td>986,247</td>
<td>937,815</td>
<td>48,432</td>
<td>4.9</td>
</tr>
<tr>
<td>Oct</td>
<td>990,229</td>
<td>974,620</td>
<td>15,609</td>
<td>1.6</td>
</tr>
<tr>
<td>Nov</td>
<td>958,081</td>
<td>913,404</td>
<td>44,677</td>
<td>4.7</td>
</tr>
<tr>
<td>Dec</td>
<td>992,625</td>
<td>918,864</td>
<td>73,761</td>
<td>7.4</td>
</tr>
</tbody>
</table>

*Note: Transmission losses were calculated totally based on the energy data received through LISS.*
3. System Availability

The availability of the transmission system is dependent on the number of faults which occur and on the number of outages taken to allow maintenance and construction work to be undertaken. System availability is reduced whenever a circuit is taken out of operation for either planned purposes or as a result of a fault.

System availability is calculated as a percentage of actual circuit hours available in relation to total possible circuit hours available. Circuit outages that result from both planned and unplanned unavailability are taken into account.

\[
\text{System Availability} = \frac{\text{The sum of all circuit hours available}}{(\text{No. of circuits}) \times (\text{No. of hours in period})} \times 100 \%
\]

A circuit is defined as the transmission line, cable, transformer or any combination of these that connects two system bus bars.

Unavailability of the Transmission System is expressed as a function of the Transmission Circuit Outages or Interruptions and is evaluated using indicators that measure the number of outages and their durations. Unavailability Indices could be measured in terms of the scheduled and forced outages separately or in terms of overall outages.

\[
\text{System Unavailability} = 100\% - \text{System Availability}
\]

Transmission System availability of the Transmission Licensee can be assessed thorough Individual Performance Indicators and Overall Performance Indicators. Individual Performance Indicators are used to measure Transmission System availability of each individual Transmission Line and each individual Grid Substation Transformer.

Overall System Performance Indices to measure average Transmission System availability and unavailability are defined below.

3.1 Overall System Availability – Transmission Lines

This measures the average fraction of time (expressed in percent) that Transmission Lines are available in service in relation to the possible circuit hours available.

\[
SA_L = \frac{\sum_{j=1}^{NL} H_j}{NL \times T} \times 100
\]
Where;

\( H_j \) = Available Duration of Transmission Line Circuit “j” (in hours).

\( NL \) = Total number of Transmission Line Circuits

\( T \) = Number of hours in the reported period.

- Total System Availability of Transmission Lines in year 2011 = 99.65 %
- Availability of 132kV Transmission Lines in year 2011 = 99.58 %
- Availability of 220kV Transmission Lines in year 2011 = 99.98 %

**Note:** Vavuniya – Chunnakam 1 & 2 (formerly, New Anuradhapura-Chunnakam 1& 2), was unavailable (beyond Vavuniya) during 2011 owing to line damages caused by war conflicts. Therefore those two lines have not been considered for the availability calculation. For outages’ data in December was not available for the calculation.


### 3.1.1 Monthly Variation

The charts and table below show the month by month variation in transmission line availability.

**Transmission Line Availability - 2011**
### 3.2 System Transmission Transformers Availability

This measures the average fraction of time (expressed in percent) that Transmission Transformers are available in service in relation to possible circuit hours available.

\[
SA_T = \frac{\sum_{j=1}^{NT} H_j}{NT \times T} \times 100
\]

Where;
- \( H_j \) = Available Duration of Transmission Transformer “\( j \)” (in hours)
- \( NT \) = Total number of Transmission Transformers
- \( T \) = Number of hours in the reported period

- Total System Availability of Transmission Transformers in year 2011 = 97.84 %
Note: Only the major outages of transformers have been considered for the availability calculation due to unavailability of data of short term transformer outages.


3.2.1 Monthly Variation

The chart and table below show the month by month variation in total system transformer availability.

Transmission Transformer Availability - 2011

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Availability</td>
<td>98.26</td>
<td>98.26</td>
<td>98.26</td>
<td>98.09</td>
<td>97.45</td>
<td>97.07</td>
<td>97.08</td>
<td>97.34</td>
<td>98.03</td>
<td>98.26</td>
<td>98.14</td>
<td>97.92</td>
</tr>
</tbody>
</table>

3.3 System Average Frequency of Outages per 100km of Transmission Lines

This measures the average number of Outages per 100km of Transmission Line Circuits (Expressed in number of outages per 100 km of lines)

\[
SAFOL_{100} = \frac{\sum_{j=1}^{NL} NO_j}{\sum_{j=1}^{NL} LONG_j/100}
\]

Where;

\(NO_j\) = Number of Outages of Transmission Line Circuit “j” during the reported period

\(NL\) = Total number of Transmission Line Circuits

\(LONG_j\) = Length of Transmission Line Circuit “j”
- Total System Average Frequency of Outages per 100km in year 2011 = **4.75**
- System Average Frequency of Outages per 100km of 132kV lines in year 2011 = **5.42**
- System Average Frequency of Outages per 100km of 220kV lines in year 2011 = **2.14**
- Total System Average Frequency of Planned Outages per 100km in year 2011 = **0.21**
- Total System Average Frequency of Forced Outages per 100km in year 2011 = **4.54**

**Note:** *Forced outages’ data in December was not available for the calculation.*

**Reference for the formula:** *Transmission Performance Standards Code of Electricity Regulatory Commission of Jordan.*

### 3.3.1 Monthly Variation

The chart and table below show the month by month variation in total system average frequency of outages per 100km of Transmission Lines.

#### System Average Frequency of Outages per 100km

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Outages</td>
<td>0.28</td>
<td>0.39</td>
<td>0.23</td>
<td>1.28</td>
<td>0.21</td>
<td>0.31</td>
<td>0.46</td>
<td>0.36</td>
<td>0.41</td>
<td>0.46</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Individual Performance Indices to measure average Transmission System unavailability are defined below.

3.4 Transmission Line Interruption Duration Index (in Hours)

This measures the average time duration per reported period where a single transmission line circuit is not available in service.

\[
UD_L = \frac{\sum_{i=1}^{NL} \sum_{j=1}^{kt} H_{i,j}}{NL}
\]

Where;
- \( H_{i,j} \) = Duration of Outage “i”, that affected Transmission Line Circuit “j” (in hours)
- \( NL \) = Total number of Transmission Line Circuits
- \( kt \) = Total number of Outages of Transmission Line Circuit “j” during the reported period

- Transmission Line Interruption Duration per year 2011 = 30.85 hours
- 220kV Line Interruption Duration per year 2011 = 1.38 hours
- 132kV Line Interruption Duration per year 2011 = 36.8 hours
- Transmission Line Planned Interruption Duration per year 2011 = 29.04 hours
- Transmission Line Forced Interruption Duration per year 2011 = 1.81 hours

Note: Forced outages’ data in December was not available for the calculation.

3.4.1 Monthly Variation

The chart and table below show the month by month variation in interruption durations per transmission line.

**Interruption Duration per Transmission Line**

<table>
<thead>
<tr>
<th>Month</th>
<th>132kV Line</th>
<th>220kV Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>7.11</td>
<td>8.54</td>
</tr>
<tr>
<td>Feb</td>
<td>0.91</td>
<td>1.09</td>
</tr>
<tr>
<td>Mar</td>
<td>0.07</td>
<td>0.28</td>
</tr>
<tr>
<td>Apr</td>
<td>0.9</td>
<td>0.73</td>
</tr>
<tr>
<td>May</td>
<td>0.23</td>
<td>1.4</td>
</tr>
<tr>
<td>Jun</td>
<td>0.62</td>
<td>5.94</td>
</tr>
<tr>
<td>Jul</td>
<td>1.17</td>
<td>4.72</td>
</tr>
<tr>
<td>Aug</td>
<td>4.95</td>
<td>0.04</td>
</tr>
<tr>
<td>Sep</td>
<td>0.04</td>
<td>0.72</td>
</tr>
<tr>
<td>Oct</td>
<td>3.93</td>
<td>7.39</td>
</tr>
<tr>
<td>Nov</td>
<td>6.27</td>
<td></td>
</tr>
</tbody>
</table>
### Outage Duration

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outage Duration Per Line (Hours)</td>
<td>7.11</td>
<td>0.91</td>
<td>0.07</td>
<td>0.9</td>
<td>0.23</td>
<td>0.62</td>
<td>1.17</td>
<td>4.95</td>
<td>0.04</td>
<td>3.93</td>
<td>6.27</td>
</tr>
<tr>
<td>Outage Duration per 132kV Line (Hours)</td>
<td>8.51</td>
<td>1.09</td>
<td>0.02</td>
<td>1.09</td>
<td>0.28</td>
<td>0.73</td>
<td>1.4</td>
<td>5.94</td>
<td>0.05</td>
<td>4.72</td>
<td>7.39</td>
</tr>
<tr>
<td>Outage Duration per 220kV Line (Hours)</td>
<td>0.19</td>
<td>0</td>
<td>0.34</td>
<td>0</td>
<td>0</td>
<td>0.05</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td>0.04</td>
<td>0.72</td>
</tr>
</tbody>
</table>

### Substation Transformer Interruption Duration Index (in Hours)

This measures the average time duration per reported period where a single substation transformer is not available in service.

\[
UD_T = \frac{\sum_{j=1}^{NT} \sum_{i=1}^{kt} H_{i,j}}{NT}
\]

Where;

- \( H_{ij} \) = Duration of Outage “i”, that affected Substation Transformer “j” (in hours)
- \( NT \) = Total number of Substation Transformers
- \( kt \) = Total number of Outages of Substation Transformer “j” during the reported period

- Interruption Duration per Substation Transformer in year 2011 = 188.87 hours

**Note:** Only the major outages of transformers have been considered for the availability calculation due to unavailability of data of short term transformer outages.

**Reference for the formula:** Transmission Performance Standards Code of Electricity Regulatory Commission of Jordan.
3.5.1 Monthly Variation

The chart and table below show the month by month variation in interruption durations per substation transformer.

### Interruption Duration per Transformer

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interruption Duration (Hours)</td>
<td>12.9</td>
<td>11.7</td>
<td>12.9</td>
<td>13.8</td>
<td>19</td>
<td>21.1</td>
<td>21.7</td>
<td>19.8</td>
<td>14</td>
<td>12.94</td>
<td>13.36</td>
<td>15.44</td>
</tr>
</tbody>
</table>

3.6 System Average Frequency of Outages per Transmission Line

This measures the number of interruptions per reported period per transmission line circuit of the system.

\[
SAFO_L = \frac{\sum_{j=1}^{NL} NO_j}{NL}
\]

Where;

- \( NO_j \) = Number of Outages of Transmission Line Circuit “\( j \)” during the reported period
- \( NL \) = Total number of Transmission Line Circuits
- System Average Frequency of Outages per Transmission Line in 2011 = 1.55
- Average Frequency of Outages per 220kV Transmission Line in 2011 = 0.85
- Average Frequency of Outages per 132kV Transmission Line in 2011 = 1.7
- Average Frequency of Planned Outages per Transmission Line in 2011 = 0.07
- Average Frequency of Forced Outages per Transmission Line in 2011 = 1.49

Note: Forced outages’ data in December was not available for the calculation.


3.6.1 Monthly Variation

The chart and table below show the month by month variation in frequency of outages per transmission line.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Interruptions</td>
<td>0.09</td>
<td>0.13</td>
<td>0.08</td>
<td>0.42</td>
<td>0.07</td>
<td>0.1</td>
<td>0.15</td>
<td>0.12</td>
<td>0.1</td>
<td>0.15</td>
<td>0.12</td>
</tr>
</tbody>
</table>
4. Transmission System Power Quality

To assess the performance of a transmission system not only the availability but also the quality of the power must be considered. Quality of service is measured with reference to system voltage and frequency. Power quality indicators shows how the transmission line parameters comply with the defined standards.

4.1 Frequency Standard

Frequency variation is the deviation of frequency beyond a certain range. The nominal fundamental frequency range shall be 50 Hz ± 1% in Sri Lanka. The system is normally managed such that frequency is maintained within operational limits of 49.5 and 50.5Hz. Frequency may, however, move outside these limits under fault conditions, or when abnormal changes to operating conditions occur. Frequency deviation indices can be defined to find the number of time or duration that the system frequency goes beyond the allowable range.

CEB System Control unit records the system frequency every 0.25 seconds. To calculate the violations, 10 second mean values have been considered. Frequency distribution in year 2011 is plotted below.
To figure out the extent of frequency excursions, three frequency ranges can be defined as follows:

1. **Normal State**  
The Transmission System frequency is within the limit of 49.5Hz to 50.5Hz

2. **Alert State**  
The Transmission System frequency is beyond the normal operating limit but within 49.0Hz to 51.0Hz

3. **Emergency State**  
There is generation deficiency and frequency is below 49.0Hz

In 2011 the 2,565,704 measurement samples were taken to assess the system frequency and the average frequency value was 50.17Hz. According to the frequency standards the system must be normally managed such that frequency is maintained within operational limits of 49.5Hz and 50.5Hz and in 2011 the system frequency has been maintained within that normal operating limit 99.8% of the time. And the system frequency has deviated 0.19% of the time to the Alert State and 0.01% of the time to the Emergency State.

**Reference to the definitions of frequency states:** Transmission System Performance Report of Bhutan Power Corporation Limited.

### 4.2 Voltage Criteria

Voltage variation is the deviation of voltage in a certain range. Voltage deviations can be identified by monitoring the bus bar voltages of the grid substations. According to the defined standards, bus bar voltage magnitudes must comply with following allowed range of variation.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Normal Condition</th>
<th>Single Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>220kV</td>
<td>± 5%</td>
<td>-10% to +5%</td>
</tr>
<tr>
<td>132kV</td>
<td>± 10%</td>
<td>± 10%</td>
</tr>
</tbody>
</table>

Voltage deviation indices can be defined to find the frequency or duration that the bus bar voltages violate above range.

By analyzing the recorded minimum bus bar voltages it can be identified that the allowable voltage limits have been violated every month. Due to lack of data the frequency and the duration of voltage excursions could not be found.
4.3 Grid Substation Overloading

Overloading of grid substations is defined based on the loading levels of grid substation power transformers. Overloading of transformers must be avoided to avoid overheating, leading to equipment damages and reducing the life time.

In 2011, out of 115 grid substation transformers 7 have been overloaded. The list of overloaded transformers is given below.

- Anuradhapura No.02 Transformer has been overloaded in 10 months with a maximum overloading of 11% recorded in May.
- Kelaniya No.01 Transformer has been overloaded in 6 months with a maximum overloading of 11.4% recorded in July.
- Kelaniya No.02 Transformer has been overloaded in 3 months with a maximum overloading of 3.5% recorded in September.
- Habarana No.01 & 02 Transformers have been overloaded by 0.6% in September.
- Panadura No.01 & 02 Transformers have been overloaded by 0.3% in October.

5. Security of Supply

Power System security is the ability of the system to withstand sudden disturbances. To secure the supply the Transmission system must be able to deliver the power even under abnormal or fault conditions. The security of supply can be measured by estimating the energy not served to the consumers during loss of supply.

5.1 Energy Not Supplied (ENS)

This gives an estimation of the Energy not supplied to the connected Load due to the Interruptions over a year.

\[ ENS = \sum_{i=1}^{kt} PD_i \times H_i \]

Where;

- \( PD_i \) = Power disconnected by Interruption “i” (in MW).
- \( H_i \) = Duration of Interruption “i” (in hours)
- \( kt \) = Total number of Interruptions during the reported year
• Annual Energy Not Supplied due to all transmission system circuit interruptions = \textbf{1610.1 MWh}
• Annual Energy Not Supplied due to transmission lines interruptions = \textbf{1063 MWh}
• Annual Energy Not Supplied due to transmission transformer interruptions = \textbf{547.1 MWh}

\textbf{Reference for the formula:} Key Performance Indicators of a Transmission System by Oman Electricity Transmission Company

\textit{Transmission Performance Standards Code of Electricity Regulatory Commission of Jordan.}

\textbf{5.1.1 Monthly Variation}

The chart and table below show the month by month variation in energy not supplied to the system due to transmission line and transformer interruptions.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
\hline
ENS Due to Line Outages (MWh) & 7.2 & 16.4 & 30.8 & 411.2 & 75.7 & 8.6 & 287.9 & 0 & 48.2 & 155.4 & 14.1 & 7.5 \\
\hline
ENS Due to Transformer Outages (MWh) & 45.7 & 58.1 & 31.4 & 23.2 & 96.7 & 11.5 & 23.1 & 81.1 & 26.5 & 21.3 & 5.8 & 122.7 \\
\hline
Total ENS (MWh) & 52.9 & 74.5 & 62.2 & 434.4 & 172.4 & 20.1 & 311 & 81.1 & 74.7 & 176.7 & 19.9 & 130.2 \\
\hline
\end{tabular}
\end{table}
6. Transmission System Assets Utilization

Assets which directly involve in Transmission Supply system and are very critical for the secure operation are Transmission Lines and Grid Substation Transformers. Therefore they must be utilized productively by keeping records of their loading capacities.

An index to measure the extent of utilization of system transformers is defined below.

6.1 Transmission Transformer Utilization Factor (UFpk)

This measures the extent utilization of the transmission transformers with respect to their rated capacities. It is the ratio of the maximum load on a transformer to its rated capacity.

\[ UF_{pk} = \frac{\sum_{j=1}^{NT} P_j}{\sum_{j=1}^{NT} C_j} \times 100\% \]

Where;
\[ P_j = \text{Recorded Peak Load of Transformer } “j” \text{ (in MVA) during reported period} \]
\[ NT = \text{Total number of Substation Transformers} \]
\[ C_j = \text{Rated capacity of Transformer } “j” \text{ (in MVA)} \]

- Substation Transformer Utilization Factor = 66.78 %

The table below gives the calculated utilization factors for individual Grid Substations.
Note: All Utilization Factors were calculated based on the peak loads during November 2011.

7. Conclusion

The Report has described and calculated a number of key performance indicators for Sri Lankan electricity transmission system. These indices can be used to measure the system performance compared with benchmarks and to illustrate the historical trends. The indicators for the present technical performance of the transmission system are useful when planning the future developments and taking the corrective actions if necessary to improve system performance and ensure a high degree of reliability of the transmission system.
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