TRANSMISSION SYSTEM PERFORMANCE REPORT

2014 (First Half)

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 Transmission Licensee is responsible for the safe, secure and efficient operation of the electricity transmission in Sri Lanka. The transmission network in Sri Lanka is operated at 220kV and 132kV to transport electricity from generation points to distribution bulk supply points.

This Transmission Performance Report contains a summary of information and performance statistics of the transmission system for the first half of year 2014 and it compares the performance with year 2013's statistics. The document, moreover, takes account of availability, security of supply and quality of service of the transmission network during the reported period.

All the index and other calculations in this report have been executed based on the data received through LISS (Licensee Information Submission System) and details obtained from CEB Monthly Review Reports.

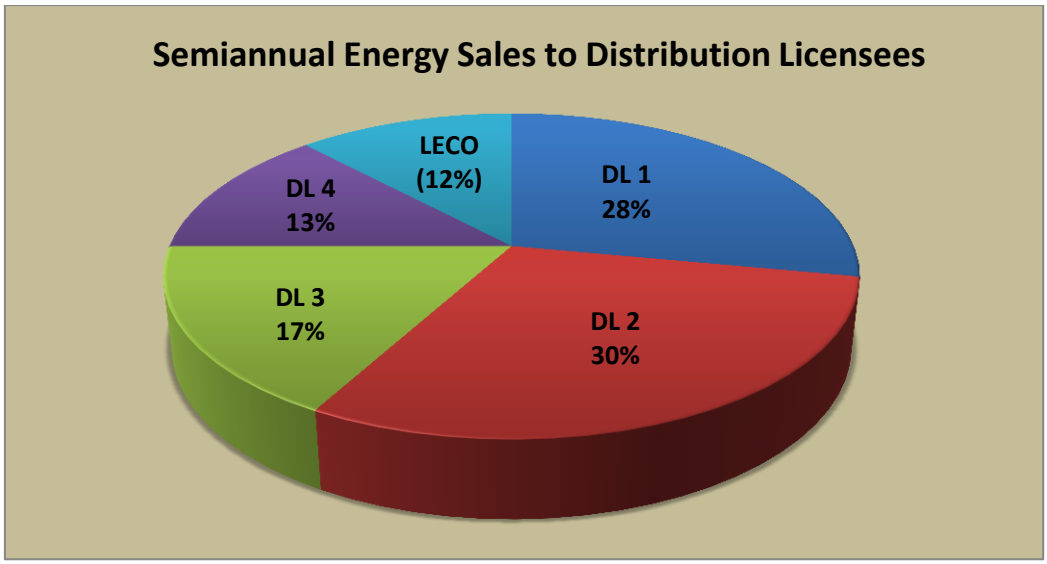
2. Energy Sales

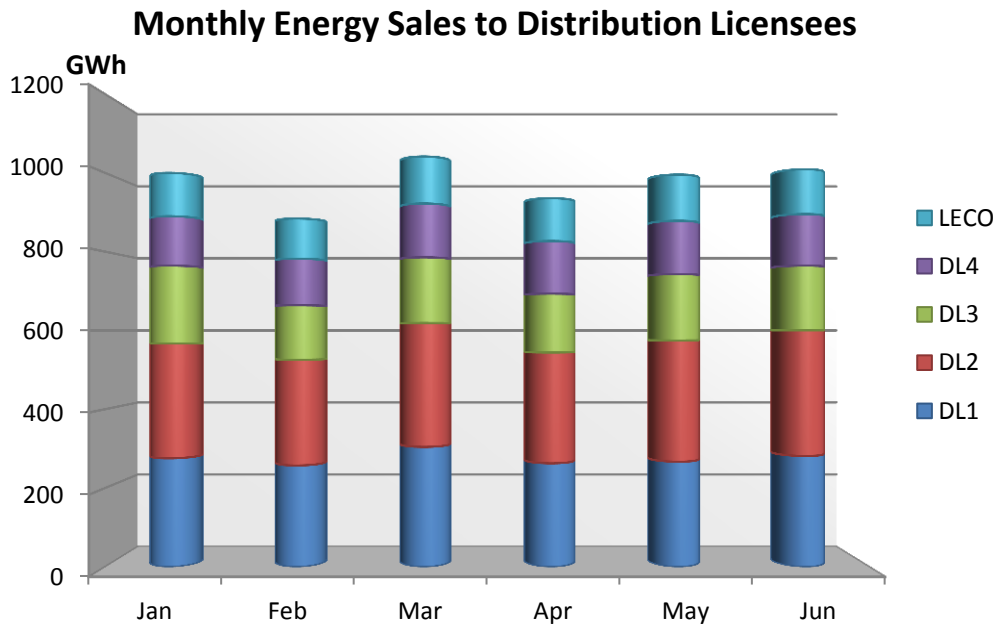
CEB sells the electricity transmitted from generation stations, to the distribution licensees. There are 5 major distribution licensees who purchase the power bulky and distribute among consumers. CEB itself owns 4 distribution licenses for four distribution regions and Lanka Electricity Company (LECO)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

The charts and tables below show the monthly energy sales by transmission licensee (TL) to each distribution licensee (DL) in the first half of year 2014.

Licensee	TL to DL Energy Sales (MWh)					
	Jan	Feb	Mar	Apr	May	Jun
DL1	275,569	257,524	304,508	263,036	267,093	281,504
DL2	291,268	268,026	314,330	280,808	307,608	318,672
DL3	197,417	138,314	166,569	149,212	168,068	164,048
DL4	125,358	118,135	136,451	133,570	135,159	130,796
LECO	109,821	101,626	119,151	108,499	117,197	113,691
Total	**999,433**	**883,624**	**1,041,009**	**935,125**	**995,126**	**1,008,710**

Licensee	Sales by TL (MWh)				
	Day	Peak	Off-Peak	Total	% Total
DL1	965,301	331,594	352,340	**1,649,234**	28%
DL2	1,004,876	373,920	401,915	**1,780,711**	30%
DL3	568,311	213,673	201,644	**983,628**	17%
DL4	432,659	174,036	172,774	**779,470**	13%
LECO	385,592	132,515	151,877	**669,984**	12%
Total	**3,356,739**	**1,225,738**	**1,280,550**	**5,863,028**	





2.1 Transmission Losses

Transmission loss is calculated by taking the difference between 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 an absolute value.

The definition of the transmission losses is defined as;

$$\%Transmission\ Loss = \frac{\sum E_G - \sum E_T}{\sum E_G} \text{X } 100\%$$

Where;

E_G = Total Energy Purchased from generation plants (MWh) during reported period

E_T = Total Energy Sold to Distribution Licensees (MWh) during reported period

- Total Energy Loss in Sri Lankan Transmission Network during first half of year 2014 = **3.7%**
- Total Energy Loss in Sri Lankan Transmission Network in 2013 = **4.5 %**

It can be noted that the transmission loss during the first half of year 2014 has been reduced than it was in 2013.

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

3. System Availability

When considering transmission system availability, it is convention to analyze in terms of transmission system unavailability. The availability of the transmission system components depends 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 unavailability is calculated as a percentage of actual circuit hours unavailable in relation to total possible circuit hours available. Circuit outages that result from both planned and unplanned unavailability are taken into account.

$$\text{System Unavailability} = \frac{\text{The sum of all circuit hours unavailable}}{(\text{No.of circuits}) \text{ X } (\text{No.of hours in period})} \text{ x } 100\ \%$$

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

Transmission System availability of the Transmission Licensee can be assessed through 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 used to measure average Transmission System Availability, are defined below.

3.1 Overall System Unavailability – Transmission Lines

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

$$SA_L = \frac{\sum_{j=1}^{NL} H_j}{NL * T} \text{ x } 100$$

Where;

H_j = Unavailable Duration of Transmission Line Circuit "j" (in hours).

NL = Total number of Transmission Line Circuits

T = Number of hours in the reported period.

- Unavailability of Transmission Lines during the first half of 2014 = **0.06 %**
- Unavailability of Transmission Lines in year 2013 = **0.76 %**

- Unavailability of 132kV Transmission Lines during the first half of 2014 = **0.07 %**
- Unavailability of 132kV Transmission Lines in year 2013 = **0.77 %**

- Unavailability of 220kV Transmission Lines during the first half of 2014 = **0.02 %**
- Unavailability of 220kV Transmission Lines in year 2013 = **0.72 %**

Reference for the formula: *National Electricity Transmission System Performance Report – England. Transmission System Performance Report of System Operator For Northern Ireland Ltd.*

3.2 System Transmission Transformers Unavailability

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

$$SA_T = \frac{\sum_{j=1}^{NT} H_j}{NT * T} \text{ x } 100$$

Where;

H_j = Unavailable Duration of Transmission Transformer "j" (in hours)

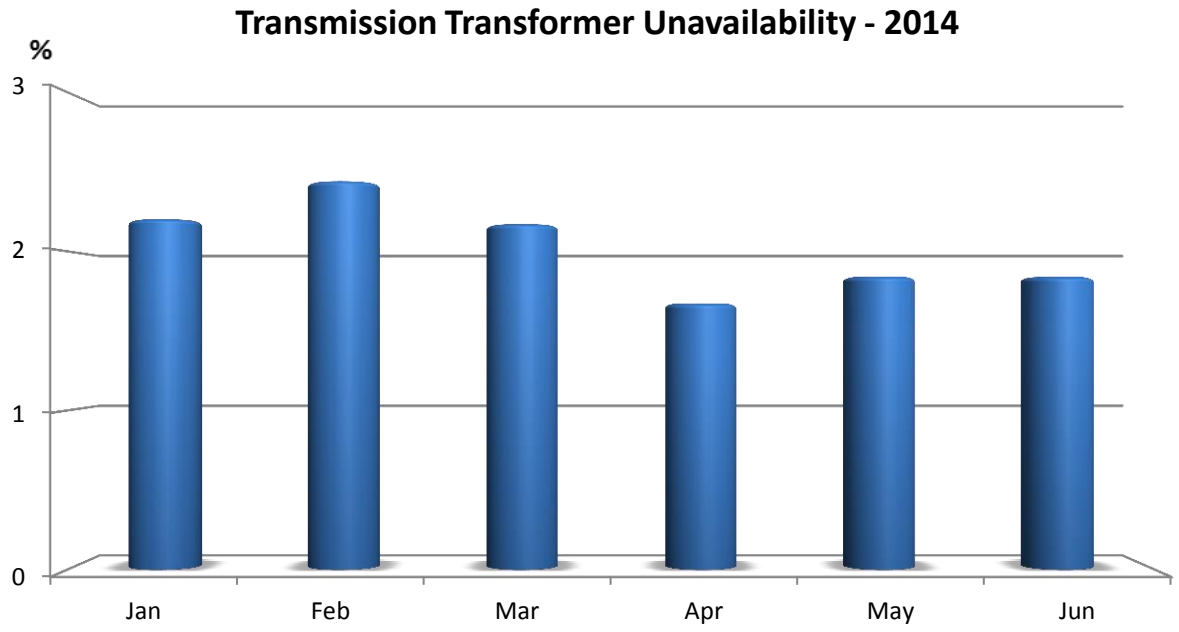
NT = Total number of Transmission Transformers

T = Number of hours in the reported period

- Total System Unavailability of Transmission Transformers for first half of the year 2014 = **2.03%**
- Total System Unavailability of Transmission Transformers in year 2013 = **4.09 %**

3.2.1 Monthly Variation

The chart below shows the monthly variation in total system transformer unavailability.



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)

$$SAFO\_L_{100} = \frac{\sum_{j=1}^{NL} NO_j}{\sum_{j=1}^{NL} LONG_j / 100}$$

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 during the first half of 2014 = **3.10**
- Total System Average Frequency of Outages per 100km during the first half of 2013 = **3.95**

- Average Frequency of Outages per 100km of 132kV lines during the first half of 2014 = **3.75**
- Average Frequency of Outages per 100km of 132kV lines during the first half of 2013 = **4.71**

- Average Frequency of Outages per 100km of 220kV lines during the first half of 2014 = **0.88**
- Average Frequency of Outages per 100km of 220kV lines during the first half of 2013 = **0.88**

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

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.

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

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 in the first half of year 2014 = **2.78 hours**
- Transmission Line Interruption Duration in the first half of year 2013 = **51.9 hours**

- 220kV Line Interruption Duration in the first half of year 2014 = **0.88 hours**
- 220kV Line Interruption Duration in the first half of year 2013 = **0.47 hours**

- 132kV Line Interruption Duration in the first half of year 2014 = **3.2 hours**
- 132kV Line Interruption Duration in the first half of year 2013 = **51.41 hours**

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

3.5 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;

$H_{i,j}$ = Duration of Outage "i", that affected Substation Transformer "j" (in hours)

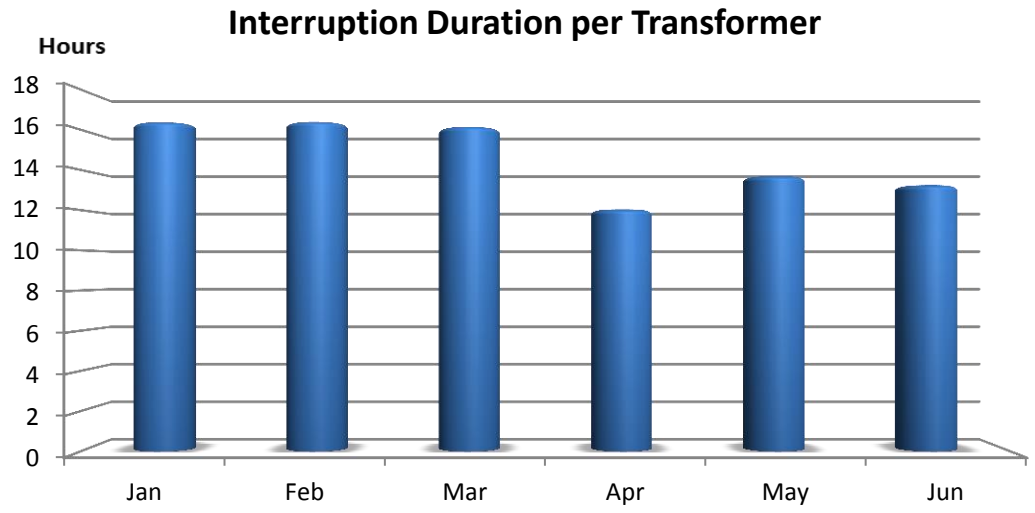
NT = Total number of Substation Transformers

kt = Total number of Outages of Substation Transformer "j" during the reported period

- Interruption Duration per Substation Transformer for the first six months of 2014 = **88.1 hours**
- Interruption Duration per Substation Transformer for the first six months of 2013 = **79.7 hours**

3.5.1 Monthly Variation

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



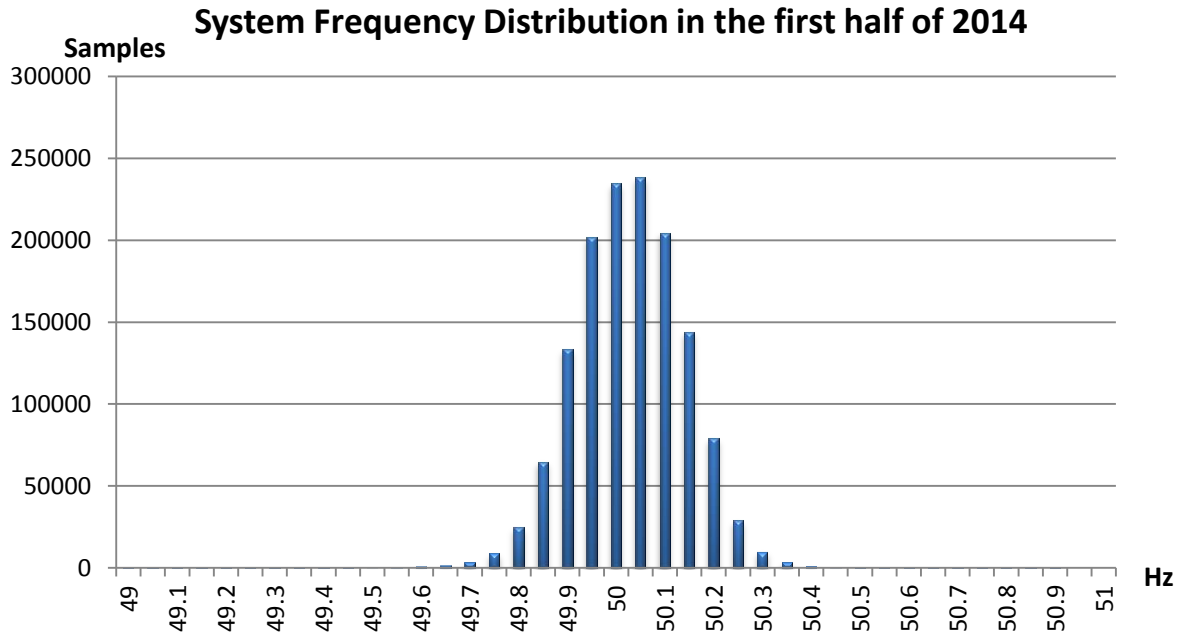
4. Transmission System Power Quality

Quality of a power system service is measured with reference to system voltage and frequency. Power quality indicators show how the transmission line parameters comply with the defined standards and limits.

4.1 Frequency Standard

Frequency variation is the deviation of frequency, beyond a certain range. The nominal allowed 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 faulty 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 during the first half of the year 2014 is plotted below with respect to 1,384,714 measurement samples.



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

During the first half of the year 2014 1,384,714 measurement samples were taken to assess the system frequency and the average frequency value was **50.03Hz**. 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 during the reported period system frequency has been maintained within that normal operating limit **99.9%** of the time. And the system frequency has deviated **0.1%** of the time to the Alert State and **0.0071%** of the time to the Emergency State.

In the year 2014 the system frequency has been maintained within the normal operating limit **99.97%** of the time while the system frequency has deviated **0.03%** of the time to the Alert State and **0.0014%** 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 ranges of variation.

Voltage	Normal Condition	Single Contingency
220kV	± 5%	-10% to +5%
132kV	± 10%	± 10%

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 could be identified that the allowable voltage limits have been violated every month during the reported period. 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 of transformers.

During the first half of the year 2014, out of 139 grid substation transformers, only 2 have been overloaded. The list of overloaded transformers is given below.

- Anuradhapura No.02 Transformer has been overloaded in the month of May with a maximum overloading of 3%.
- Anuradhapura No.03 Transformer has been overloaded in 2 months with a maximum overloading of 21% recorded during the month of June.

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 faulty 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.

$$ENS = \sum_{i=1}^{kt} PD_i * H_i$$

Where;

PD_i = Power disconnected by Interruption "i" (in MW).

H_i = Duration of Interruption "i" (in hours)

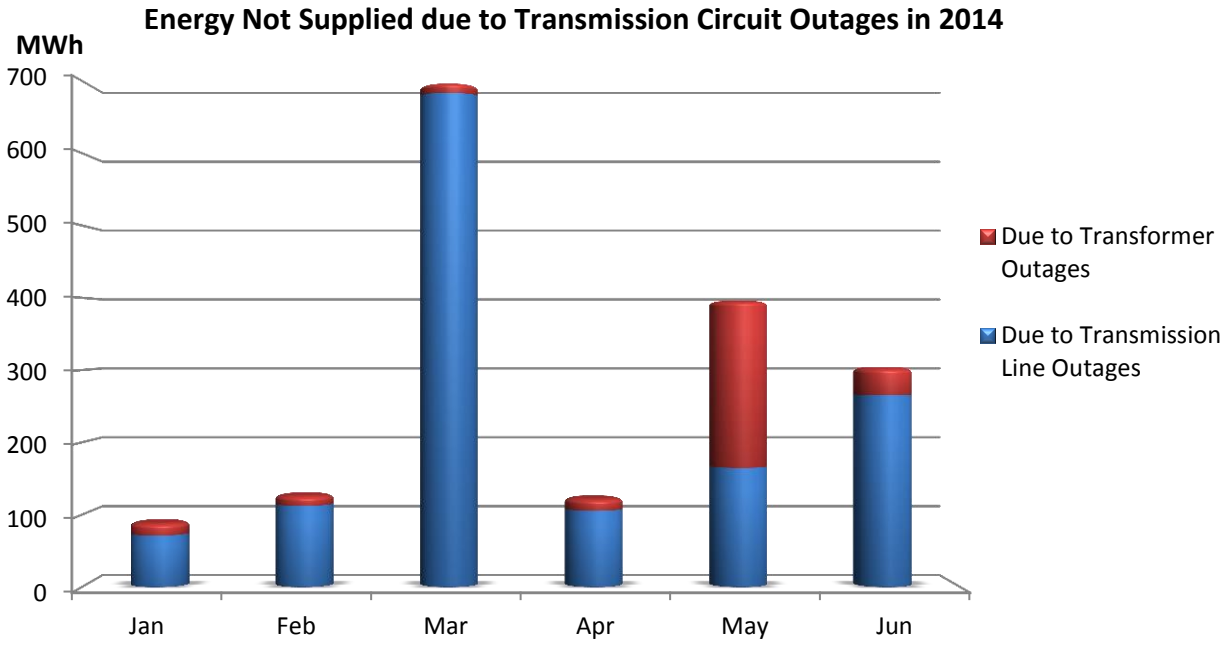
kt = Total number of Interruptions during the reported period

- Energy Not Supplied due to all transmission system circuit interruptions in 2014= **1733.6 MWh**
- Energy Not Supplied due to all transmission system circuit interruptions in 2013= **1399.8 MWh**
- Energy Not Supplied due to transmission lines interruptions in 2014= **1402.1 MWh**
- Energy Not Supplied due to transmission lines interruptions in 2013= **1171.1 MWh**
- Energy Not Supplied due to transmission transformer interruptions in 2014= **331.5 MWh**
- Energy Not Supplied due to transmission transformer interruptions in 2013 = **228.7 MWh**

Note: *Above estimations are only for the first six months of years 2012 and 2013.*

5.1.1 Monthly Variation

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



6. Conclusion

Compared to the transmission line availability year 2013, it can be perceived that the availability has improved in the first half of year 2014 as a result of less outages occupied during the first half of year 2014.

Unlike in year 2013, only one substation has been overloaded in the first half of year 2014. In year 2013, six substations have been overloaded while only Anuradhapura Substation transformer No.02 and 03 have shown overloading during two months in the first half of year 2014.

Compared to the Unserved Energy due to transmission line interruptions during the first half of year 2013, it can be perceived that the estimated amount of Unserved Energy has been increased during the first half of year 2014.

The Report has moreover 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.