IMPROVING DISTRIBUTION RELIABILITY THROUGH ELECTRICITY TARIFF AND THEIR FINANCIAL IMPLICATIONS

Dilusha Punsara Nagasinghe

(128877B)

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Department of Electrical Engineering

University of Moratuwa
Sri Lanka

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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

Under price and revenue cap regulations, utilities are encouraged to minimize their costs which may even result low reliability. As the reliability of electricity supply has a very high impact on the country's economy as well as quality of life of people, regulators are required to address reliability at electricity tariff setting. The objective of this study is to identify different approaches the other countries use to provide incentives for distribution reliability improvement through electricity tariff and also to identify potential financial implications such mechanisms may have on the distribution utilities. These aspects are morefully described in Chapter 1.

Chapter 2, 3 and 4, respectively includes an extensive literature review including the distribution reliability regulation mechanisms adopted by India, Philippine, Australia, Hungary and Great Britain, the mechanism identified in the Distribution Performance Standards Regulations (DPSR) of Sri Lanka and a mathematical reliability based pricing model called 'Joint Pricing Model'.

Most of the countries use two incentive mechanisms, to provide incentives to improve the overall reliability of the utility and to compensate individual customers for poor service. Further, incentive mechanism is based on reliability target setting and measuring the utilities performance relative to the targets, where most of the countries set targets based on the historical performance of the utility.

Based on overall reliability, most countries have mechanisms to provide a bonus for achieving the performance targets and a penalty otherwise and to compensate individual customers, all the countries studied use Guaranteed Service Levels (GSL) mechanism, where the customers are entitled to a direct payment if the reliability of their supply is poorer than the GSL. Further, the GSL payment rates are specified in the regulatory instrument (eg. regulation) itself.

Chapter 5 gives the study methodology, which is formulated based on the findings of Chapter 2, 3 and 4. Further, based on the study methodology the financial implications on the distribution utilities under different incentive mechanisms are estimated, using distribution areas of Lanka Electricity Company as an example. The calculations of financial implications are given in Chapter 6.

Chapter 7 gives a summary of the financial impact under each incentive mechanism and a further discussion on the incentive mechanisms. Chapter 8 gives the recommendations based on the study and the future work required in the area of study is given in Chapter 8.

Keywords: Distribution Reliability, Financial Incentives, Tariff, Penalty, Bonus

DEDICATION

To my mother Mrs. Ramya Krunasena

and my father Mr. Ananda Nagasinghe

who made many sacrifices

to make me who I am today.

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LIST OF ABBREVIATIONS

Abbreviation	Description
CEB	Ceylon Electricity Board
ARR	Annual Revenue Requirement
CAIDI	Customer Average Interruption Duration Index
CBD	Central Business District
CI	Number of Customers Interrupted per 100 Customers (100xSAIFI)
CML	Average Minutes without Power per Customer (SAIDI).
DPSR	Distribution Performance Standards Regulations of Sri Lanka
ENS	Energy Not Supplied
GSL	Guaranteed Service Level
LECO	Lanka Electricity Company
MAIFI	Momentary Average Interruption Duration Index
NER	National Energy Rules
Ofgem	Office of Gas and Electricity Markets
PUCSL	Public Utilities Commission of Sri Lanka
SAIDI	System Average Interruption Frequency Index
SAIFI	System Average Interruption Duration Index
STPIS	Service Target Performance Incentive Scheme
WTP	Willingness To Pay

1. INTRODUCTION

1.1. Background

As per the study conducted in 2002, ‘Assessment of Economic Impact of Poor Power Quality on Industry -Sri Lanka, Prepared for United States Agency for International Development under South Asia Regional Initiative for Energy [1], cost of unplanned interruption of electricity supply is 1.06 USD in Sri Lanka, whereas the cost for a planned interruption of electricity supply is 0.66 USD. If the values are adjusted for the per capita GDP growth from 2002 to 2015, the costs will be 3.42 USD and 2.13 USD, respectively. Hence, the low reliability of electricity supply has a significant impact on the country’s economy and also it has a significant impact on the quality of lifestyle of the countries citizens.

Moreover, as per the National Energy Policy and Strategies of Sri Lanka [2], electricity tariff should be cost reflective. That means, the tariff paid by each customer should reflect the true cost the customer exert on the system. Accordingly, at present, the electricity tariff paid by consumers is differentiated based on a number of factors, such as consumption patterns (eg. customer category wise differentiation), level of consumption (eg. domestic tariff blocks), connection voltage, time of consumption (Time of Use tariff), etc. In addition to this, at present, there are vast variations in the reliability of the electricity supply received by consumers living in different areas of the country. It is to be noted that high reliability is achieved through higher investments on the network as well as higher operational and maintenance cost. However, despite the vast differences in the level of reliability, electricity tariff does not reflect this. For example, as per the annual report 2012 of the Ceylon Electricity Board (CEB) [3] the System Average Interruption Duration Index (SAIDI) in 2012 for North Western Province distribution area is 124 hours per year and the SAIDI in 2012 for Colombo Region distribution area is only 0.34 hours per year. However, under present Uniform National Tariff scheme, a customer in Colombo city area and a similar customer in North Western Province are required to bear the same cost for the unit of electricity they consume. In another words, the customers in North Western Province are charged for the high reliability in Colombo city area. This violates the concept of fairness.

Further, the electricity transmission and distribution tariff regulation in Sri Lanka, is based on a mix of revenue cap and price cap regulations [4]. In revenue cap tariff regulation, the maximum revenue an electricity utility can collect from its customers is limited. Similarly, in price cap regulation, the maximum price a utility can charge for a unit of electricity is limited. Further there are regulatory mechanisms that promote efficiency. The ‘X’ factor in transmission and distribution revenue control formulas identified in the Cost Reflective Tariff Methodology of Sri Lanka is an example for this [4]. Reliability cannot easily be priced, so under a price or revenue cap regulations, the regulated intends to increase its profits by reducing costs, even if the cost reductions imply reduced reliability. Hence, if the utilities are not given any incentives to improve the reliability of the system through the tariff, their attempts of cost cutting may result low investments in improvement of the reliability of the network and also low expenditure on maintenance and breakdown rectification, which may reduce the reliability of the electricity supply. Hence, under revenue cap and price cap regulations there should be a mechanism to provide incentives to improve the reliability of electricity supply received by the consumers. Present Electricity Tariff Methodology [4] does not include a provision to provide incentives for utilities to improve the reliability of the electricity supply.

However, as a solution to this in July 2016, the government of Sri Lanka published the Electricity Distribution Performance Standards Regulations of Sri Lanka(DPSR) [5]. These regulations include provisions to regulate the reliability of the distribution systems as well as compensation mechanisms, for poor reliability of the electricity supply received by the consumers. The compensation mechanisms will be in effect after July 2019.

1.2. Identification of the Problem

Reliability of electricity supply of a country has a large effect on the country's economy as well as the quality of life of the citizens. At present, the reliability of the electricity supplied to certain areas in Sri Lanka is at a poor level. However, due to the existing Uniform National Tariff scheme, the consumers are required to pay the same price regardless of the level of reliability of the electricity supply. Also, under the existing price cap and revenue cap tariff regulations in Sri Lanka, utilities strive on cost cutting which may result poor reliability, if the level of reliability is not considered in tariff setting.

1.3. Objectives of the Study

Objective of this study is to identify different approaches of regulating the reliability of the electricity distribution system through electricity tariff setting in order to;

- Provide incentives for distribution utilities to improve the reliability of the system.
- Improve fairness in the electricity price paid by customers.
- Ensure that the financial interests of the utilities are protected.

Under this study, different approaches of providing financial incentives for reliability improvement of the distribution system are studied. Also, the financial implications on the distribution utilities, under each approach are analyzed taking the distribution system of Lanka Electricity Company as a case study.

Reader should note that the Electricity DPSR that came in to effect in July 2016, include regulations on the reliability of the supply through compensation for low reliability. The compensation mechanism will be effective from the July 2019. Under this study, the regulations on reliability included in the DPSR also studied as one of the approaches, to identify level of incentive given to the utility, and fairness on the customers and the financial impact on the utility.

2. LITERATURE REVIEW

Most of the developed countries and also some Asian countries, including some states of India, use financial incentives as a mechanism of improving reliability of the electricity supply. However, such financial incentive mechanism is an end result of the combination of many other best practices. Such as;

- Identifying reliability indices
- Data logging and calculating the indices and reporting by the utility and information reviewing and periodic accuracy checking by the regulator.
- Identifying events exempted from calculation of reliability indices
- Setting reliability performance targets
- Identification of amount of penalties, bonuses and compensation payment rates
- Guaranteed Service Level(GSL) Programmes.

The main objective of the literature review is to identify the financial incentive mechanisms used by different countries as well as associated best practices adopted by different countries for calculating reliability indices, setting performance targets and performance evaluation.

2.1. India- Maharashtra Electricity Regulatory Commission

In most of the Indian state governments, distribution reliability regulation is conducted through the distribution performance standards regulations introduced by the respective state electricity regulatory commission. All of these regulations are based on or similar to the Model Standard of Performance Regulations for Distribution Licensees published by the Forum of Regulators, India [6], [7], [8], [9].

Hence, in the literature review, only the Standards of Performance of Distribution Licensees published by the Maharashtra Electricity Regulatory Commission [7] is reviewed. It is to be noted that in addition to the reliability regulation, Maharashtra Standards of Performance Regulations include performance standards relevant to power quality and commercial quality regulation as well, which are also not reviewed under this study.

2.1.1. Reliability Indices

Maharashtra Standards of Performance Regulations include a set of overall performance indices as well as a separate set of Guaranteed Service Level (GSL) standards for individual customers. The indices are given in the table 2-1 below.

Table 2-1: Reliability Indices- Maharashtra, India

Basis	Performance Indices
Based on overall performance of the utility	(i) System Average Interruption Frequency Index (SAIDI) (ii) System Average Interruption Duration Index (SAIFI) (iii) Customer Average Interruption Duration Index (CAIDI)
Individual performance indices (under GSL scheme)	Rectification time for; (i) Fuse off call (ii) 33kV/ 22kV/ 11kV/400 V Overhead line breakdown (iii) Distribution transformer failure (iv) Underground cable fault (v) Scheduled outage (notified beforehand)

2.1.2. Exempted Events

In calculating the overall performance indices indicated above, the following types of interruptions are not accounted.

a. Scheduled outages;
b. Momentary outages of duration of less than three minutes;
c. Outages due to the failure of the grid;
d. Outages due to cyclone, floods, storms or other occurrences beyond the control of the Distribution Licensee.

2.1.3. Data Logging and Reporting

Distribution utilities are required to maintain data on reliability indices on monthly basis and also to publish the data in their websites. Further, they are required to submit a quarterly report to the regulatory commission. The data collection and calculation of indices is need to be conducted separately for town and cities and also for rural areas.

2.1.4. Reliability Standards

Standards for overall reliability indices are required to be revised every year. But the standards for individual performance indices, GSL standards are specified in the regulations. The GSL standards specified in the regulations are indicated in Table 2-2 below.

Table 2-2: Reliability GSL Standards- Maharashtra, India

Performance Indices	GSLs
(i) Fuse off call	• Four (4) hours (towns and cities) • Twenty-four (24) hours (rural areas)
(ii) 33kV/ 22kV/ 11kV/400 V Overhead line breakdown	• Six (6) hours (towns& cities) • Twenty-four (24) hours (rural areas)
(iii) Distribution transformer failure	• Twenty-four (24) hours (towns and cities) • Forty-eight (48) hours (rural areas)
(iv) Underground cable fault	• Twelve (12) hours
(v) Scheduled outage& notified	• normally not exceeding Twelve (12) hours per day

2.1.5. Compensation for Customers

If the utility fails to achieve the reliability targets, compensation is paid as indicated in the Table 2-3 below.

Table 2-3: Payments under GSL scheme- Maharashtra, India

<table>
<tr><th colspan="2">Performance Indices</th><th>Rate of payment</th></tr>
<tr><td rowspan="5">Individual</td><td>(i) Fuse off call</td><td rowspan="4">50 INR per hour or part there of delay</td></tr>
<tr><td>(ii) 33kV/ 22kV/ 11kV/400 V Overhead line breakdown</td></tr>
<tr><td>(iii) Distribution transformer failure</td></tr>
<tr><td>(iv) Underground cable fault</td></tr>
<tr><td>(v) Notified scheduled outage</td><td>Nil</td></tr>
<tr><td>Overall</td><td>SAIDI/SAIFI/CAIDI</td><td>Nil</td></tr>
</table>

2.1.6. Incentives for Distribution Licensees

The regulator assesses the reliability level of the information submitted by the utility and categorizes the information under the following three reliability grades

- Grade A: Based on proper records with adequate procedures
- Grade B: Data has significant procedural deviations
- Grade C: Unsatisfactory Data

Only if the information is categorized under reliability grade A, the information is further analyzed to check the accuracy. Then, on the basis of the accuracy of the information, if the utilities have achieved the overall performance targets certain percentage (as shown in table 2-4 below) of compensation paid to the customers are allowed under their Annual Revenue Requirement (ARR).

Table 2-4: Accuracy Level and the percentage of GSL payment that can be recovered through tariff- Maharashtra, India

Accuracy Level	& of compensation paid to be recovered through Annual Revenue Requirement
+/-2%	100%
+/-5%	85%
+/-10%	70%

2.2. Philippine

In 2006, Philippine Energy Regulatory Commission introduced Performance Based Regulations, where the distribution price control formula itself includes a provision for the regulation of quality of supply and the regulations on performance incentive scheme are provided in the Rules for Setting Distribution Wheeling Rates. In addition to this, similar to the practice in India, Philippine also has a GSL Payment scheme [10], [11].

2.2.1. Reliability Indices

Table 2-5 shows the indices used for the measurement of overall performance and weights assigned for each index. It is to be noted that, in addition to reliability indices, voltage regulation, losses and service quality indices (with total weight of 0.45) are also taken in to account in the price control formula [11].

Table 2-5: Reliability Indices- Philippine

Basis	Performance Indices
Overall Performance Indices	• SAIFI (0.2) • CAIDI (0.2) • Planned SAIDI (0.15)
Individual Performance Indices (under GSL scheme)	• Customers experiencing interruption periods greater than 30 hours per year • Customers experiencing more than 20 sustained interruptions per year • Customers experiencing outages as a result of secondary system faults, that are not restored within 12 hours • Failure to provide connection on the day previously agreed with the customer.

2.2.2. Exempted Events

In calculating the overall performance indices indicated above, the following types of interruptions are not accounted [11].

i. supply interruptions made at the request of a customer
ii. load shedding due to a shortfall in generation;
iii. supply interruptions caused by a failure of the transmission network;
iv. supply interruptions caused by a failure of a transmission connection asset, but only to the extent that the interruptions were not due to inadequate planning of transmission connections; and
v. widespread supply interruptions due to rare and extreme events. Extreme events are identified using 2.5 beta method.

2.2.3. Reliability Standards

For each overall reliability index the initial targets for the reliability indices were equal to the particular distribution utility's reliability performance for the last five years [11], after that the performance standards are set adding an improvement to the average annual index for the regulated distribution system for the previous regulatory period, [10]. Further to this performance against the target is measured in discrete steps such that Standard deviation of the annual index values for a Regulated Distribution System for the 10 calendar years leading up to the regulatory period is also calculated and;

a. If the annual index value is higher than two standard deviations from the average it is considered as performance is greatly below the target,
b. If annual index value is more than or equal to 1 standard deviation, but less than 2 standard deviations, above the average it is considered as target is not achieved.
c. If annual index is between or equal to 1 standard deviation above and 1 standard deviation below the average value, it is considered performance as per expectation
d. If annual index is more than 1 standard deviation, but less than or equal to 2 standard deviations, below the average, it is considered as target exceeded
e. If annual index is more than 2 standard deviations below the average it is considered as target greatly exceeded.

Reliability standards for GSL indices are given in Table 2-5 above.

2.2.4. Compensation for Customers

Customers are paid compensation if they have not received the GSL. Total GSL payment is equal to 0.5% of the Annual Revenue of the utility and payment for an individual event is decided based on the total payment, numbers of customers who has historically not received the GSL and weighting allowed for each index and performance target level adopted [10].

An additional allowance (5% of Allowed Revenue) is made over and above the annual revenue requirement for each Regulated Entity, to cover the anticipated average amount that would be payable towards the GSL scheme. The intention of the annual revenue requirement allowance is to allow utilities the option of incurring additional expenditure to avoid penalty situations, or to remain revenue neutral if they maintain current performance levels [10].

2.2.5. Incentives for Distribution Licensees

Price Cap Formula given below includes the S factor, which relate to the performance level of the distribution utility [10].

$$MAP_t = [MAP_{t-1} \times \{1 + CWI_t - X\}] - K_t + ITA_t + S_t$$

Where, MAP_t and MAP_{t-1} are the maximum average prices for year t and t-1, respectively.

CWI_t , X, K_t , ITA_t and S_t are the index for change in Consumer Price Index, efficiency factor, correction factor for revenue over or under recovery in previous year, correction for tax over or under recovery in previous year and performance incentive factor, respectively.

The S factor will allow average price to increase by up to 2.5% if the actual performance exceeds the target value and average price to decrease by up to 2.5% if the performance fall below the target value [10].

However, 45% of the +/-2.5% is based on the distribution utilities performance related to power quality and customer services. Hence, 55% of the +/-2.5% of annual revenue (1.375% of annual revenue) will be at risk based on the reliability performance of the regulated distribution utility.

2.3. Australia

In Australia, certain elements of the distribution reliability are included in the National Energy Rules (NER), and other elements are governed by the state governments and those elements are either in addition to the NER or legacy arrangements that are required to transition to the NER over time. The NER contains a reliability incentive mechanism, which is known as Service Target Performance Incentive Scheme (STPIS) [12], [13].

Similar to the practice in Philippine, in Australia also the reliability performance is linked to the revenue control formula. Further, Australian NER also includes a GSL payment scheme. Further, similar to India and Philippine, NER also includes the mechanism for regulating commercial and power quality, which are not reviewed under this study.

2.3.1. Reliability Indices

Given in the Table 2.6 below the reliability indices used for the measurement of overall performance and payment of GSL [12].

Table 2-6: Reliability Indices- Australia

Basis	Performance Indices
Overall Performance Indices	• Unplanned SAIDI • Unplanned SAIFI • Momentary Average Interruption Duration Index (MAIFI)
Individual Performance Indices (under GSL scheme)	• Frequency of interruptions • Duration of interruptions or total duration of interruptions

2.3.2. Exempted Events

In calculating the overall performance indices indicated above, the following types of interruptions are not accounted [12].

i. load shedding due to a generation shortfall
ii. automatic load shedding due to the operation of under frequency relays following the occurrence of a power system under-frequency condition
iii. load shedding at the direction of the Australian Energy Market Operator (AEMO) or a system operator
iv. load interruptions caused by a failure of the shared transmission network load interruptions caused by a failure of transmission connection assets except where the interruptions were due to inadequate planning of transmission

connections and the Distribution Network Service Providers (DNSP) is responsible for transmission connection planning

v. load interruptions caused by the exercise of any obligation, right or discretion imposed upon or provided for under jurisdictional electricity legislation or national electricity legislation applying to a DNSP.

vi. An event may also be excluded where daily unplanned SAIDI for the DNSP's distribution network exceeds the major event day boundary. Major events are identified by a standard "2.5 beta" method, and the impact of major events is capped at 2.5 beta (The 2.5 beta method involves analyzing five years' worth of daily SAIDI data. The logarithm of each observation is taken and the average (alpha) and standard deviation (beta) of the set is calculated. Any day whose logarithmic SAIDI value exceeds alpha plus 2.5 times beta is classified as an extreme event day.

2.3.3. Reliability Standards

For each overall reliability index the performance target is its average performance in the prior five years. In using the historical performance to set the target, a number of adjustments are made: "major event days" are excluded; and the target may be tightened to reflect the impacts of system investment completed or planned in the current or prior regulatory period [12]. Reliability standards under GSL scheme is given in Table 2-7 below.

Table 2-7: GSL standards for reliability-Australia

Performance Indices	GSL
Frequency of interruptions	• Central Business District(CBD) and Urban feeders – 9 interruptions • Rural (short and long) feeders – 15 interruptions
Duration of interruptions	• CBD and Urban feeders – 12 hours • Rural (short and long) feeders – 18 hours
Total duration of interruptions	• Level 1 – 20 hours • Level 2 – 30 hours • Level 3 – 60 hours

2.3.4. Compensation for Customers

Customers are entitled for the compensation as given in table 2-8 below, if they have not received the guaranteed service level and the GSL payments are not intended to compensate customers for loss suffered as a result of poor service but are intended to be an acknowledgement of poor service [12].

Table 2-8: GSL payments for reliability- Australia

Performance Indices	Rate of Payment
Frequency of interruptions	AUS$80
Duration of interruptions	AUS$80
Total duration of interruptions	• Level 1 – AUS$100 • Level 2 – AUS$150 • Level 3 – AUS$300

While customers experiencing particularly poor performance may receive payments from their distributor in many jurisdictions, some jurisdictions additionally have specific mechanisms to target the worst-performing parts of each system. For example in New South Wales, in addition to standards relating to the average performance of feeders (which we described above), distributors in NSW must also meet laxer standards on all feeders. The interruption duration standards for individual feeders are around 2-3 times higher than the SAIDI standard. Where feeders fail the individual standard, the distributor is required to develop and implement a plan to improve performance.

2.3.5. Incentives for Distribution Licensees

Similar to the S factor in price cap formula in Philippine, the fixed revenue cap formula includes a S factor [12].

$$AR_{t+1} = AR_t \times (1 + \Delta CPI_t) \times (1 - X_{t+1}) \times (1 + S_t)$$

where: AR is the allowed revenue for a regulatory year

ΔCPI is the annual percentage change in the consumer price index

S is the s-factor expressed as a percentage of revenue (or prices)

t is the regulatory year.

As per the S factor, 5% of the distribution utilities revenue will be at risk, depending on their reliability performance.

Even though +5% is set as upper margin of bonus and -5% set as lower margin for penalty, the actual rate at which the reliability incentive bonus or penalty accrues is based on the “value of customer reliability”, expressed as a cost of energy not supplied in MWh. This value is set at $97,500/MWh for central business district (CBD) customers and half this value for other customers. The value of unsupplied energy is used to derive individual incentive parameters for SAIDI, SAIFI and MAIFI. The value of unserved energy and the derivation of individual parameters are based on (Willingness To Pay) WTP studies [13] Willingness to Pay Study is a market survey to identify how much the customers are willing to pay for high reliability.

Further, in addition to providing customers with payments when they experience poor reliability, the guaranteed service arrangements also provide the distributors with an incentive to improve performance: to the extent that performance improves and payments go down over time, the distributor is able to retain the difference between expected and actual payments for the duration of the price control.

2.4. Great Britain

The incentive arrangements for distribution reliability are set by the, electricity sector regulator, Office of the Gas and Electricity Markets (Ofgem) via the licences issued to the Distribution Utilities. But the reliability standards as they relate to customer payments are set out in secondary legislation such that the payments to customers are a legal obligation on the distributors. Changes to the incentive arrangements for distribution reliability are reviewed and announced by Ofgem through a distribution price control review, which it carries out in every five year [13],[14].

2.4.1. Reliability Indices

Given in Table 2-9, the reliability indices used for the measurement of overall performance and the Indices measured under the GSL scheme [13].

Table 2-9: Reliability Indices- Great Britain

Basis	Performance Indices
Overall Performance Indices	• Number of Customers Interrupted per 100 Customers (CI = 100xSAIFI) • Average Minutes without Power per Customer (CML = SAIDI).
Individual Performance Indices (under GSL scheme)	• Respond to failure of distributors fuse • Supply restoration: normal conditions • Supply restoration: multiple interruptions

One notable difference in British overall performance incentive scheme compared to the other countries studied is the performance under indices CI and CML are evaluated separately. So a distribution utility may receive a bonus for the performance of CI while having to pay a penalty for performance under CML.

2.4.2. Exempted Events

Ofgem's methodology for setting the CI and CML targets distinguishes between unplanned and planned outages. Ofgem calculates separate targets for unplanned and planned outages and then combines these targets to produce a single CI target and a single CML target for each distributor for each year of the price control period. In calculating CI and CML targets, unplanned outages on the distribution system and outages caused by distributed generators are given a weighting of 100% whilst pre-arranged outages on the distribution system only have a weighting of 50%. For CI, outages originating on the transmission system or other connected systems are excluded from the targets. For CML, 10% of CML from interruptions on transmission and other connected systems are also included in the CML targets unless the interruptions result from the distributors complying with statutory and/or licence requirements [13].

2.4.3. Reliability Standards

For the first year of the price control period, the CI/CML target was set to be the lower of;

i) the average of the company's actual CI/CML over the last three years and

ii) the CI/CML target for the company for the last year of the previous price control.

The CI/CML target for the final year of the price control was set to the lower of

i) the benchmark figure calculated by Ofgem for last year and

ii) the CI/CML target assigned to the company for the last year of the previous price control.

Where there is a change in the target between the beginning and the end of the price control period, the CI/CML targets change by equal increments each year [13].

The threshold levels for GSL scheme are given in Table 2-10 below.

Table 2-10: Performance thresholds for Reliability GSL scheme- Great Britain

Performance Indices	GSL
Respond to failure of distributors fuse	Within 3 hours on a working day (at least) 7 am to 7 pm, and within 4 hours on other days between (at least) 9 am to 5 pm
Supply restoration: normal conditions	Within 18 hours, otherwise a payment must be made. Where a large scale event occurs then supply must be restored within 24 hours
Supply restoration: multiple interruptions	If four or more interruptions each lasting 3 or more hours occur in any single year (1 April – 31 March)

2.4.4. Compensation for Customers

Customers are paid compensation if they have not received the GSL at the rates identified in the Table 2-11 below [14].

Table 2-11: Payments under GSL scheme- Great Britain

Performance Indices	Rate of Payment per hour
Respond to failure of distributors fuse	£22 (£20) for domestic and non- domestic customers
Supply restoration: normal conditions	£54 (£50) for domestic customers and £109 (£100) for non-domestic customers, plus £27 (£25) for each further 12 hours up to a cap of £218 (£200) per customer where the interruption is part of a large scale event
Supply restoration: multiple interruptions	£54 (£50) for domestic and non- domestic customers

In addition to the GSL scheme, Ofgem introduced a third incentive mechanism, Worst Served Customer Fund, The purpose of the fund is to improve the reliability for customers who have experienced a large number of interruptions over several years. The fund is particularly focused on customers for whom the distributors may not be incentivized to improve their service under the overall performance based incentive scheme because, for example, they reside in an area where supply interruptions only affect a small number of customers. Utilities keep a record of the investments they have made to improve service reliability for these customers. The distributors can qualify for a contribution from their worst served customer fund if they provide evidence that an investment has improved supply interruptions by at least 25% over three years [13].

2.4.5. Incentives for Distribution Licensees

Distributors receive a bonus for performance above the target and are required to pay a penalty for under performance. The incentive rates are defined based on Willingness To Pay(WTP) Studies conducted every year.

2.5. Hungary

2.5.1. Governance

In Hungary, setting service quality standards, monitoring compliance of the utilities to the standards is done by the Hungarian Energy and Public Utility Regulatory Authority (CEER) [15]. Further, CEER is responsible for ensuring that the customers are compensated for low service quality and also that the utilities are rewarded or penalized depending on their performance based on service quality. In addition to reliability of electricity supply, CEER set quality standards for commercial quality and customer services as well. The regulatory mechanism for reliability regulation is defined in the Regulatory Resolution issued in 2005 [15].

2.5.2. Reliability Indices

The regulatory resolution identifies indicators for both continuity of electricity supply and security of electricity supply. The following quality indicators for monitoring and reporting concerning the continuity of electricity supply.

a. Average number of long unplanned interruptions (SAIFI).
b. Average number of long planned interruptions
c. Average duration of long unplanned interruptions (SAIDI)
d. Average duration of long planned interruptions
e. Average duration of long unplanned interruptions relative to the number of affected customers.
f. Average duration of long planned interruptions relative to the number of affected customers.
g. Restoration rate of unplanned interruptions
h. Restoration rate of planned interruptions
i. Average number of transient and short interruptionsr.
j. Number and proportion of customers with the worst supply.

For the security of electricity supply the following indicators are determined in the regulatory resolution.

k. Outage rate: is the ratio of the amount of energy not supplied due to unplanned long interruptions to the amount of available energy
l. Number of medium-voltage unplanned long interruptions in the medium voltage networks per 100 km.
m. Average restoration time in case of medium voltage interruptions: is the ratio of the total restoration time of all unplanned long interruptions to the total number of unplanned long interruptions. It is expressed in the duration (min.) of restorations/number of interruptions/year and calculated separately for the overhead line and cable line medium voltage circuits
n. Average unavailability of the 120 kV lines

However, only three indicators out of the above (only a, b and k) are linked with the incentive mechanism. For some of other indicators, targets quality levels are identified and the other indicators are for monitoring purposes only and both the latter two types f indicators do not have an incentive mechanisms linked with the performance.

In addition to this the regulatory resolution identifies GSLs. If the distribution company fails to meet the level of service required, it must make a payment to the affected customer subject to certain exemptions. Payments under the guaranteed standards compensate for the inconvenience caused by inadequate service. They are not designed to compensate customers for subsequent financial loss. Given below the GSL indicators, relevant to the reliability identified in the regulation resolution [15].

a. Time until the start of restoration of supply in case of a single failure:
b. Time for the restoration of supply in case of failures affecting more than one consumer

2.5.3. Exempted Events

In Hungary the definition of exceptional event included in the regulatory resolution covers the followings:

a. system breakdown;
b. acts of terrorism;

c. any event classified by the regulator as “other event”(e.g. strain exceeding the design requirements).

These events shall be included in the annual reports of the distribution utilities, but can be excluded from the calculation of the quality indicators

2.5.4. Reliability Standards

Overall reliability standards are set based on the average of the past three years. For example that the required performance determined for the three-year average of 2004- 2006 was used as a basis when calculating the requirements for the next three-year periods. In addition the utilities are obliged to meet a predefined annual improvement, the degree of which is higher as long as the difference between the actual performance of the company and the predefined threshold (which is the same for all utilities) is high and decreases as the company’s performance is improving.

Under the GSL payment scheme, the standards are defined as below,

a. Time until the start of restoration of supply in case of a single failure: in case of an interruption, which affects only one consumer, the restoration of electricity supply should be started within 4 hours to 12 hours after the consumer’s call reporting the failure was received, depending on the population density of the city and on the time and date of the call (if it is a working day or weekend):
   - in settlements with a population of more than 50 000 the repair shall be started in 4 hours on weekdays, and in 6 hours on weekends and on holidays,
   - in settlements with a population between 5 000 and 50 000 the repair shall be started in 6 hours on weekdays, and in 8 hours on weekends and on holidays,
   - in settlements with a population of less than 5 000 the repair shall be started in 8 hours on weekdays, and in 12 hours on weekends and on holidays,
   - in the outskirts of the settlement the repair shall be started in 12 hours.

If the consumer's call was received after 8 p.m., then the reparation shall be started next day between 7 and 10 a.m. in the inner city and between 7 and 11 a.m. in the outskirts.

b. Time for the restoration of supply in case of failures affecting more than one consumers: the electricity supply shall be restored within 12 hours in case of single and within 18 hours for multiple interruptions after the utility was notified of it (in case of a failure in the Low Voltage network the utility gets the notification by a consumer's call and in case of medium-voltage failures the notification is automatically sent by the SCADA system). In case of interruptions lasting longer than 24 hours, the amount of compensation doubles and after 36 hours it triples. For interruptions longer than 36 hours the affected customers are paid compensation for every additional 12-hour periods. The time for restoration of supply in case of failures caused by an exceptional weather event is determined according to special rules, which will be detailed later in this section.

2.5.5. Compensation for Customers

Initially in case of customers did not receive the guaranteed service level, the customer was required to make a claim from the utility. But from 2009 onwards, the automatic payment system has been gradually introduced by the Hungarian Regulator. In Hungary the value of compensation is 16.67 € for residential customers, 33.33 € for non-residential customers and 100 € for customers connected to the medium-Voltage network [15].

2.5.6. Incentives for the Distribution Licensees

The regulator incentivizes the utility to improve the quality of supply by making the distribution network charges dependent upon the compliance with the requirements defined for the three quality indicators with incentives (Average number of long unplanned interruptions, Average number of long planned interruptions and Outage rate). If a company fails to provide the required standards, its network charges are automatically decreased with the following degree [15]:

- by 1 % for half a year if the deviation from the requirements is between 5 and 10%;
- by 2 % for half a year if the deviation from the requirements is more than 10%.

There is a 5 % dead band, meaning that if the deviation is below 5%, no reduction of the distribution network charges is required.

2.6. Summary of International Best Practices

The summary of the findings based on reliability regulation mechanisms of the five countries reviewed is given in the table 2-12 below.

Table 2-12: Summary of the International Best Practices

Best Practices and Summary Findings	
1	Governance of Incentive mechanism
	The mechanism for provision of financial incentives for reliability performance is specified in secondary legislation (rules, regulations etc.). However, financial incentives are provided through the tariff. In Philippine and Australia, revenue control formula (or price control formula as applicable) contains a provision for reliability performance of the utility, through performance incentive factor (S factor).
2	Reliability Indices
	All the countries studied measure SAIDI and SAIFI (or derived version of the same indices, eg. CAIDI in India& Philippine, CI&CML in Britain) and some countries use MAIFI (Australia), in addition to SAIDI and SAIFI. In Hungary, reliability performance is measured under two categories, continuity and energy security, where SAIDI and SAIFI measures etc. fall under continuity and outage rate (ratio of energy not supplied) etc. fall under energy security. Hungarian regulator requires many other performance measurements as well, which are not connected to an incentive scheme.
3	Exempted Events
	Many jurisdictions studied exclude natural disasters from calculation of reliability indices.

Best Practices and Summary Findings	
	Philippine and Australia use a statistical method to eliminate extreme events from the calculation, which is 2.5 beta method. India, Philippine, Australia and Hungary, eliminates the transmission and generation failures in calculation of reliability indices. Britain in exception from this includes a certain percentage of upstream failures in CML calculation. However, similar to other countries exempt upstream failures in calculation of CI. India exempts scheduled outages also in calculating the indices, where other countries set separate targets for planned and unplanned interruptions.
4	Overall Reliability targets
	All the countries studied have not specified the overall reliability target in the respective regulation. But are provided for determination in every year. In many countries studied, the basis of target setting is the past years average performance of the utility (eg. Philippine, Australia, Great Britain, Hungary), This requirement is explicitly given for the first regulatory period, where incentive scheme is in place. The regulations of Maharashtra-India do not specify a mechanism for setting overall reliability targets.
5	Incentives for the utility to improve the performance.
	In all the countries studied except India, the utilities are required to pay a penalty for not achieving the targets and will be entitled for a bonus, if they performed above the target. However, in India the overall performance indices are not linked to a financial incentive mechanism. However, the utilities are able to recover total GSL payment or part of it through the tariff, upon achievement of the overall reliability targets. Hence, the mechanism can be considered as a one way incentive mechanism, where it is similar that the utilities are given a bonus for achievement of the overall performance targets but not charged a penalty for not achieving the targets.
6	Compensation for Individual Customers for Poor Service

Best Practices and Summary Findings	
	All the countries studied have a GSL payment schemes to compensate individual customers. Also, all the countries studied specify the GSL thresholds in the respective regulatory instrument itself. Except Philippine, other countries has specified GSL payment rates also in the regulatory instrument, where as in Philippine, the regulatory instrument identified total GSL payment as 0.5% of the utilities annual revenue and individual rates are decided every year, based on the total GSL provision and forecast number of GSL payments. Philippine provides an allowance over and above the allowed revenue for recovery of GSL payments, such that the utilities can recover GSL payments through tariff.
7	Recognition for Worst Served Customers
	Great Britain has a third incentive mechanism to improve the reliability for worst served customers, Worst Served Customer Fund. Certain jurisdictional regulators in Australia also specified minimum standards on distribution feeders to identify worst served customers (eg. New South Wales).

3. ELECTRICITY DISTRIBUTION PERFORMANCE STANDARDS REGULATIONS OF SRI LANKA

3.1. Review of Regulations on Reliability

In July 2016, the Government of Sri Lanka published Electricity Distribution Performance Standards Regulations of Sri Lanka (DPSR) [5]. The regulations cover reliability as well as commercial and power quality regulation. This chapter only reviews the regulations related to overall and individual performance related to reliability of supply.

3.1.1. Reliability Indices

Electricity DPSR includes a set of overall performance indices as well as a separate set of individual performance indices. The overall and individual performance indices are given in the Tale 3-1 below.

Table 3-1: Reliability indices- DPSR

Basis	Performance Indices
Overall Performance Indices	SAIDI, SAIFI, Energy Not Served (ENS), MAIFI, separately for; (i) distribution system faults, (ii) distribution planned maintenance programs, (iii) Inter-Licensee distribution system faults (iv) Inter- Licensee distribution system planned programs (v) Upstream (Transmission) failures/maintenance programs
Individual Performance Indices (under GSL scheme)	• Total number of Interruptions owing to distribution system faults per calendar year • Total number of Interruptions owing to planned programs arranged by the Distribution Licensee per calendar year • Total number of Interruptions owing to system faults due to inter-licensee distribution systems per calendar year • Total number of Interruptions owing to planned programs

Basis	Performance Indices
	of the inter-Licensee distribution systems per calendar year • Total number of interruptions owing to failures and planned outage programs of the Transmission System per calendar year • Total duration of Interruptions owing to distribution system faults per calendar year. • Total duration of Interruptions owing to planned programs arranged by the Distribution Licensee per calendar year • Total duration of Interruptions owing to failures of the inter Licensee distribution systems per calendar year • Total duration of Interruptions owing to planned outages arranged in the inter licensee distribution systems per calendar year • Total duration of interruptions owing to failures and planned outage programs of the Transmission System per calendar year

3.1.2. Exempted Events

The regulations exempt following events,

(i) Interruptions due to consumers being disconnected due to defaults by customers or offences committed under the Act.

(ii) Interruptions due to switching off of power supply to avoid catastrophic situations, such as tsunami, cyclones or any dangers to human life etc. that are beyond the control of a Distribution Licensee.

Further, target setting, information collection, and performance evaluation etc. are required to be done, separately for different types of failures as in table 3-1 above.

3.1.3. Reliability Standards

The regulations require the Public Utilities Commission of Sri Lanka (PUCSL) to set the performance targets each year at the determination of electricity tariffs. Further, the regulations require targets to show an improvement each year.

Further, prior to target setting, customers are geographically divided in to four distribution groups, A, B, C and D, based on the Load density, Customer mix, Sales mix, Specific consumption and Extent of the network. The reliability targets (both overall and individual) are required to be identified separately for these customer groups as well as voltage levels.

3.1.4. Compensation for not achieving Individual Performance Targets

A major difference in Performance Standards Regulations of Sri Lanka is that the regulations does not provide for a GSL scheme. Also, the regulations do not specify the rates for compensation payments for individuals as in the other countries studied. But the regulations identifies the following formula to calculate the compensation for customers based on individual performance indices, if the consumers do not get the supply at the target level or below. According to the formula, the compensation is paid to the total hours lost by the customer if either the total number or duration of interruptions has exceeded the target value. This is another difference from GSL schemes of other countries, where payment is made for the amount of index exceeded the target.

$$C_i^{CUST} = \sum_{j=1,J} ID_{i,j}^{CUST} \times \frac{YearEnergy_i}{8760} \times SUPPLYCOST$$

where

C_i^{CUST}	Compensation to be paid by the Distribution Licensee caused to customer "*i*" during the calendar year owing to exceeding the tolerance specified for any Individual Performance Indicator for such customer.
J	Total number of interruptions to customer "*i*".
$ID_{i,j}^{CUST}$	Duration of the Interruption "*j*" to customer "*i*", expressed in hours
$YearEnergy_i$	Energy sales to the customer "*i*" within the calendar year, expressed in kWh.

SUPPLYCOST Weighted average cost of supplying to the customers of the Distribution and Supply Licensee within the calendar year, expressed in LKR/kWh.

3.1.5. Incentives for Distribution Licensees

The regulations do not give the utilities any bonus for achieving the target performance levels. But the utilities are given incentives to improve the reliability in low reliable areas, by requiring them to pay a penalty if the target performance is not achieved. The regulations identified 3 types of penalties,

- Based on SAIDI/ SAIFI performance
- Based on EENS performance
- Based on MAIFI performance

3.1.5.1. Compensation based on SAIDI and SAIFI

SAIDI based compensation, $C_{m,i}^{SAIDI}$, expressed in LKR is calculated as follows,

If the specified level for $SAIDI_m = \overline{SAIDI_m}$,

$$C_{m,i}^{SAIDI} = (SAIDI_{m,i} - \overline{SAIDI_m}) \times \frac{YearEnergy_{m,i}}{8760} \times SUPPLYCOST_{m,i}$$

If $SAIDI_{m,i} < \overline{SAIDI_m}$, $C_{m,i}^{SAIDI}$ will be zero.

SAIFI based compensation, $C_{m,i}^{SAIFI}$, expressed in LKR shall be calculated as follows

If allowed level of $SAIDFI_m = \overline{SAIFI_m}$:

$$C_{m,i}^{SAIFI} = (SAIFI_{m,i} - \overline{SAIFI_m}) \times \left(\frac{SAIDI_{m,i}}{SAIFI_{m,i}} \right) \times \frac{YearEnergy_{m,i}}{8760} \times SUPPLYCOST_{m,i}$$

If $SAIFI_{m,i} < \overline{SAIFI_m}$, , $C_{m,i}^{SAIFI}$ will be zero.

Where,

$SAIDI_{m,i}$ and $SAIFI_{m,i}$:Actual (registered) values for each of such Overall Performance Indices for a particular distribution system grouping "*m*" during the corresponding complete calendar year, for the distribution licensee "*i*".

$\overline{SAIDI_m}$ and $\overline{SAIFI_m}$: Approved specified level for each of the selected Overall Performance Indices for the relevant distribution system grouping *"m"*.

Year Energy $_{m,i}$:Annual Energy sales by the Distribution Licensee "*i*" to its customers in the distribution grouping "*m*" during the year, expressed in kWh.

$SUPPLYCOST_{m,i}$:Weighted Average Cost of supplying a kWh to the customers., expressed in LKR/kWh

Compensation payable to customers based on SAIDI and SAIFI is the maximum out of SAIDI based compensation and SAFI based compensation, calculated above.

$$C_{m,i} = Max\,(C_{m,i}^{SAIDI}, C_{m,i}^{SAIFI})$$

where:

$C_{m,i}$: Compensation in LKR to be paid by the Distribution Licensee "*i*" owing to non-compliance with the Overall Performance Indices for a distribution system grouping "m" as defined in regulation 6.2 , in the corresponding calendar year.

Max ( ): means the maximum of all the values indicated within the brackets.

3.1.5.2. Compensation for ENS

Compensation for energy not served is calculated as shown below.

$$C_{m,i}^{ENS} = \left(\frac{EENS_{m,i}}{ETOT_{m,i}} - \frac{\overline{EENS_{m,i}}}{\overline{\overline{ETOT_{m,i}}}} \right) \times YearEnergy_{m,i} \times CENS_{m,i}$$

If, $\left(\frac{EENS_{m,i}}{ETOT_{m,i}} - \frac{\overline{EENS_{m,i}}}{\overline{\overline{ETOT_{m,i}}}} \right) < 0$, then $C_{m,i}^{ENS}$ =0

Where,

$EENS_{m,i}$	Actual (registered) values of EENS for a distribution system grouping "*m*" for distribution licensee "i" during the corresponding complete calendar year, expressed in kWh.
$\left(\overline{\overline{\frac{EENS_{m,i}}{ETOT_{m,i}}}}\right)$	:Specified ratio of EENS to total energy sales for a particular distribution system grouping "*m*" for the distribution licensee "*i*" during the corresponding complete calendar year
$C_{m,i}^{ENS}$	:Compensation for exceeding the levels specified for EENS, for the disgtribution system grouping "m" for the distribjution licensee "*i*", expressed in LKR
$CENS_i$	:Cost of energy not supplied expressed in LKR/kWh for the distribution licensee "*i*".

3.1.5.3. Compensation for MAIFI

The regulations require the PUCSL to develop a suitable compensation mechanism in respect of MAIFI using the Yardstick regulation, with the results submitted by the Licensees during the implementation period.

3.2. Comparison with International Best Practices

	International Practices	**Practice provide in DPSR**
1	Governance of Incentive mechanism	
	Incentive mechanism is specified in the regulatory instrument and is monitored and controlled by the industry regulator. In some countries the revenue controlling formula includes a provision for reliability based incentives.	Incentive mechanism specified in the regulations and is monitored and controlled by the PUCSL. Yearly performance target setting is required to be done at the tariff determination.
2	Reliability Indices (for overall performance)	
	SAIDI and SAIFI (or derived	SAIDI, SAIFI, ENS and MAIFI

	International Practices	Practice provide in DPSR
	version of the same) is measured in all the countries. MAIFI is also measured in some countries. Only Hungary use ratio of ENS as a measurement.	It is to be noted that SAIDI and ENS are directly interrelated, where higher the SAIDI, higher the ENS and wise versa. Hence, adding up the compensation based on SAIDI/SAIFI and ENS causes, penalizing the utility twice for the same area of performance.
3	Exempted Events	
	Natural disasters are exempted. Planned outages and also outages due to upstream failures (some countries) are exempted. A statistical method, 2.5 beta method being used to eliminate extreme events(Philippine and Australia)	Natural Disasters are exempted. Separate targets are given for planned outages and outages due to upstream failures. Extreme events are not exempted.
3	Overall Reliability targets	
	Overall reliability targets are not specified in the regulatory instruments. Overall targets are based on the average performance of the past years, specially in the first regulatory period where incentive mechanism activated. After that, the targets are revised based on long terms targets, utilities' investments on reliability improvements or benchmarking methods (eg. Britain)	Overall reliability targets are not specified in the regulations. Mechanism for setting overall targets is not specified in the regulations. For targets to be realistic for the utilities, they should be based on the historical performance of the utility. This requires monitoring the reliability performance of the utility for at least three years, prior to entering in to the incentive scheme, to minimize the impact from extreme events that may have occurred in certain years and also to ensure the

	International Practices	**Practice provide in DPSR**
		credibility of the information reported by the utility.
4	Incentives for the utility to improve the performance	
	Utilities are required to pay a penalty for not achieving the targets and will be entitled for a bonus, if they performed above the target. In India, no penalty or bonus mechanism is linked to overall performance. But the utility can recover the payments made under GSL scheme under the tariff in the achievement of the Performance Targets.	Utilities are charged a penalty for not achieving the targets, but are not entitled to a payment for achieving the targets. This is a major difference from the popular international practice of two way (both penalty and bonus) incentive mechanism.
5	Compensation for Individual Customers for poor service	
	GSL scheme is used by all five countries studied. Payment is made only for the amount of index exceeding the target level. Rates for GSL payments are specified in the regulatory instrument.	No GSL scheme. 10 different reliability indices are identified, for each the targets should be separately set by the utility. As per the compensation formula, if any index has exceeded the target level, compensation is paid to the total number of hours not supplied to the customer. Rate of payment (LKR/kWh) is required to be decided every year. The method is complicated and less understandable to customers compared to GSL mechanism in other countries studied.

4. JOINT PRICING MODEL

The reliability based financial incentive mechanisms followed by other countries are either a direct compensation payment method or a revenue reduction or increase of the distribution utility for not achieving the reliability targets or outperforming the reliability targets or a combination of the two. Even in case of the revenue reduction or increase in the utility, such benefit is passed to the customers of that utility only.

However, in Sri Lanka, due to the presence of Uniform National Tariff scheme, if one distribution utility under performed in reliability and subject to a revenue reduction, the benefit of revenue reduction is not only passed to the customers suffered from the poor reliability, but also are shared with all the customers from other high reliability areas.

Joint Pricing Model [16] introduced in this chapter, provides a mathematical based simple model for differentiating end user electricity tariff based on the reliability. The model comprises of two stages;

a. Differentiating tariff rates based on individual reliability indices, separately based on each index.
b. Combining the differentiated tariff rates, by calculating weights and taking the weighted average.

4.1. Differentiating Tariff Rates based on Individual Reliability Indices- Value Engineering Theory

Value Engineering Theory [16] calculates the change in electricity tariff corresponding to change of one index.

Assuming that original base price P_0 corresponds to average index λ_0 of the total system, the change of reliability electricity price at load point i (ΔP_i) is calculated using the below formula, Where, λ_i is the actual level of the reliability index

$$|\Delta P_i| = \frac{|\Delta \lambda_i|}{\lambda_0} P_0 = \frac{|\lambda_i - \lambda_0|}{\lambda_0} P_0$$

λ can be any reliability index as SAIDI, SAIFI, CAIDI.

Using the above equation, differentiated tariff rates can be determined separately for each index using the below formula.

$$P_i = \begin{cases} |\Delta P_i| + P_0 = \left(2 - \frac{\lambda_i}{\lambda_0}\right) P_{0\,,}\ if\ \lambda_i < \lambda_0 \\ P_0, \qquad if\ \lambda_i = \lambda_0 \\ |\Delta P_i| + P_0 = \left(2 - \frac{\lambda_i}{\lambda_0}\right) P_{0\,,}\ if\ \lambda_0 < \lambda_i \leq \delta\lambda_0 \\ P_{0,min} = \left(2 - \frac{\lambda_i}{\lambda_0}\right) P_{0\,,}\ if\ \lambda_i > \delta\lambda_0 \end{cases} \quad where\ \ 1 < \delta < 2$$

From the equations it can be seen that pricing method is effective reflects the principal of "High quality high price, poor quality low price. $P_{0,min}$ is specified for protection basic earnings of power suppliers, The specific value can determined by the supplier according to the operating costs of the utility [16].

4.2. Combining the Differentiated Tariff rates, by Calculating Weights and taking the Weighted Average- Joint Pricing

There are interrelated relationships between different reliability indices. Joint pricing model calculates weights corresponding to different index and the resulting weighted average price will be the joint price.

Joint electricity price $P = \alpha P_{SAIDI} + \beta P_{SAIFI} + \gamma P_{CAIDI}$

- $P_{SAIDI}, P_{SAIFI}, P_{CAIDI}$ can be calculated using value engineering theory
- α, β, γ can be calculated using a weighing method

In most of the countries studied under the section 2 above has calculated the relative weights between SAIDI and SAIFI and any other index used for the calculation (eg. In Philippine weights assigned for CAIDI, SAIFI and planned SAIDI are 0.2, 0.2 and 0.15, respectively). International best practice of calculating weights is based on a industry survey to identify the relative impact on customers from SAIDI and SAIFI or based on expert opinion. Such weighing methods are subjective weighing methods. However, when such knowledge on the industry is not available an objective weighing method can be used [17].

4.2.1. Multi index Entropy Weighing Method

Multi-Index Entropy Method [16], [17] is an objective weighing method. The weights depend on the amount of information used for the calculation of the weights and also, consistency of the information. The method automatically assigns a lower weightage if the relative dispersion of the set of information is large.

4.2.1.1. Steps for calculating weights

Step 1. Assuming there are 3 indices (eg. SAIDI, SAIFI and ENS) and m alternative values for each index, the index Metrix can be calculated using the below equation.

$$X = \left[x_{ij}\right]_{m\times 3}$$

Step 2. These raw data are normalized to eliminate the anomalies with different measurement and scales. The conversion to standardized matrix transforms the raw data in to common measurable units.

$$\text{Standard index Matrix, } Y_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

Step 3. Then the information entropy is calculated. The larger amount of information, the smaller uncertainty of the system, entropy is also smaller; on the contrary, the smaller the amount of information, the greater uncertainty of the system, the entropy is greater

$$\text{Index information entropy, } e_j = -k \sum_{i=1}^{m} (Y_{ij} \times lnY_{ij})$$

Step 4. Next the Entropy redundancy, which is the diversification of the Entropy, is calculated.

$$\text{Entropy redundancy, } d_j = 1 - e_j$$

Step 5. The index weights are calculated using the entropy redundancy, using the below formula.

$$\text{Index weight, } W_j = d_j / \sum_{j=1}^{3} d_j$$

Using the above formulas the weights (α, β, γ) for each index, e.g. SAIDI, SAIFI and CAIDI can be calculated and the weighted average price gives the joint electricity price (The step by step calculation using the LECO data is done in Section 6.4.4.2).

5. STUDY METHODOLOGY

Flow diagram given in figure 5-1 below shows the study methodology followed.

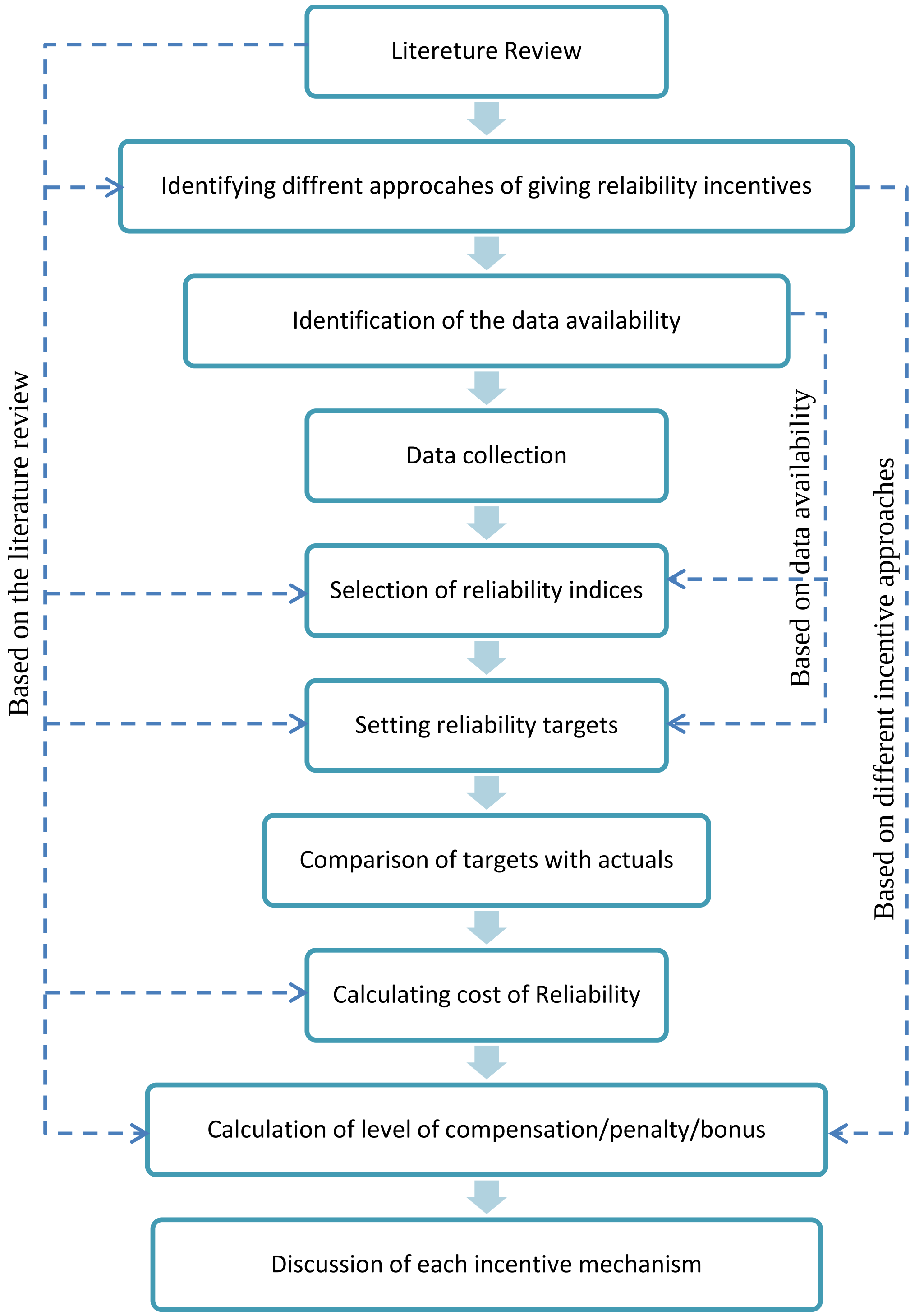

Figure 5-1: Study Methodology

Based on the extensive literature review including international practices and review of DPSR and other approaches of providing financial incentives for reliability reviewed under chapter 2, 3 and 4, the following mechanisms were identified as suitable for Sri Lanka.

(a) Payment of (direct) compensation to Consumers for low reliability of the electricity supply
(b) Changing the utility's Allowed Revenue based on the reliability performance
    i. Some regulators only charge a penalty for utility for not achieving the reliability standards, and
    ii. Some regulators also pay a bonus for achieving the reliability standards, in addition to the penalty for not achieving the targets.
(c) Differentiating electricity tariff rates, based on the reliability.

The following steps, 1-8 were followed to identify financial implications of the incentive mechanisms on the distribution utilities in Sri Lanka and the benefit passed to customers.

Step 1. Identification of present data availability with utilities

Lanka Electricity Company (LECO) has published SAIDI, SAIFI and CAIDI data from 2013 onwards. Certain CEB distribution provinces have also collected interruption data since past few years, but they are not published in consistent manner. Further, in order to calculate the financial implications, it is required to analyze the reliability performance in entire distribution region and hence, the interruption data is required for the entire operating area of a distribution Licensee. Hence, considering the consistency and availability of data, the SAIDI, SAIFI and CAIDI data of LECO for 2013, 2014 and 2015 were collected for the purpose of the study. Further, in order to calculate the differentiated tariff rates under joint pricing model, a large number of data is required. For this, the 3 data set is not sufficient. Hence, for the calculations under joint pricing model, monthly SAIDI, SAIFI and CAIDI data in 2015 was collected.

Step 2. Collecting available data

Annual SAIDI, SAIFI, CAIDI and MAIFI data of LECO for 2013, 2014 and 2015 were available in their website. However, for the calculation of Joint Pricing (Section 4) large number of data was required, for more accuracy. Hence, based on the availability of data, for year 2015, monthly SAIDI, SAIFI and CAIDI data were obtained from LECO.

Step 3. Selection of reliability indices

Based on the international best practices as well as the data availability, SAIDI and SAIFI were selected as the reliability indices for the purpose of this study. CAIDI was not selected as a reliability index because,

(a) All the countries studied use only two out of the three indices SAIDI SAIFI and CAIDI
(b) These three are interrelated, CAIDI is the ratio between SAIDI and SAIFI
(c) DPSR considers SAIDI and SAIFI as reliability indicators, but not CAIDI.

Step 4. Setting reliability targets

Philippine, Great Britain, Hungary and Australia use averages actual performance of the past years as the basis of the reliability target setting. By taking average of several past years, the impacts of bad weather or any other seasonal effect will be minimized. Further, the reliability targets should be challenging to the utilities to achieve and at the same time should be achievable targets to the utilities. Hence, adding an improvement factor to their past years actual will provide both challenging as well as achievable target to the utility.

Step 5. Comparison of targets with the actuals

The targets for 2015 were set based on the averages of 2013 and 2014 and compared with 2015 actuals.

Step 6. Determining unit cost of reliability

Unit cost of reliability varies with the method use. For example, when calculating compensation payment to customers, Cost of Unserved Energy can be used as the cost of reliability and when calculating bonus or penalty the cost reliability is need to be selected based on the revenue of the utility.

Step 7. Determining the financial impact under each incentive mechanism.

The compensation or penalty/bonus or profit/ loss is calculated separately considering the following methods of providing financial incentives.

a. Charging a penalty for not achieving performance targets and no bonus
b. Charging a penalty for not achieving performance targets and paying a bonus for achievement of above the target.
c. Compensation for individual customers for poor relaibility.
d. Differentiating electricity tariff based on the reliability indices (joint pricing model)

All the countries studied in chapter 2, use a combination of two incentive methods, to incentivize the utility (based on overall performance) and to compensate individual customers (based on individual indices/ GSL scheme). Hence, when analyzing the financial implications the combined effect of a&c and b&c is considered.

Step 8. Evaluation of each incentive method

Based on the calculation of bonuses/ penalties or compensation, separately for each of the aforementioned incentive mechanism, the performance of each mechanism is evaluated considering the incentive for improvement of reliability, benefit (/loss) to individual customer and the fairness of electricity price paid by the customers and the financial impact each method has on the utility.

6. CASE STUDY: LECO DISTRIBUTION AREAS

Under this chapter, the financial implications on the utility and the benefits passed to customers are calculated using the steps 1 to 8 identified under the study methodology in Chapter 5. The incentives are calculated for LECO distribution areas for the year 2015.

Even though LECO distribution areas are located in suburbs, and LECO shows a lower level of interruptions compared to certain rural CEB distribution areas, the financial implications on LECO can be used to depict the financial implications on all the distribution utilities. This is because, the reliability performance is measured compared to reliability targets set for each year and targets are set based on the past year's actual interruption levels of the utility. Hence, in case of a CEB distribution area with a high, level of past SAIDI and SAIFI, the target indices will be also at higher levels (adding an improvement to past years averages), such that the targets are at achievable levels to the utility.

6.1. Performance Indices

LECO has collected and published SAIDI, SAIFI and CAIDI data since 2013. However, CAIDI was not considered as a separate index. The reason is that CAIDI is the ration between SAIDI and SAIFI hence, the variation of CAIDI is described by the variations in SAIDI and SAIFI. Further, all the five countries studied under the literature review uses only two out of the three indices. Further, the Performance Standards Regulations of Sri Lanka do not identify CAIDI as a performance index.

SAIDI, SAIFI and CAIDI data for LECO from 2013-2015 are indicted in the Table 6-1 [18]& [19].

In Table 6-1, it can be observed that there is a significant variations in SAIDI and SAIFI data in 2013 and 2014. This may be due to changes in weather conditions that caused the number of interruptions to be higher or conducting analysis on different basis (eg. consideration of uncontrollable events). In order to avoid the effect from such temporary uncontrollable events, it is required to both adhere to a consistent basis in calculation of the indices and also increasing the number of historical data used for the calculation (eg. in Britain, when the performance targets are set in the first regulatory period, the average of past 10 years performance data was required to be considered). However, due to limited availability of data, for the purpose of this study, only the average of 2013 and 2014 data was considered as the basis for setting the performance targets.

Table 6-1: SAIDI, SAIFI and CAIDI data for LECO for 2013-2015

	SAIDI			**SAIFI**			**CAIDI**		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
Kotte	50.38	27.49	28.56	93	58.65	54.29	0.54	0.47	0.53
Kalaniya	90.48	65.64	67.18	80	90.3	80.34	1.13	0.73	0.84
Moratuwa	43.15	41.61	39.48	97	87.13	118.9	0.44	0.48	0.33
Galle	69.05	60.64	62.71	120	92.27	122.42	0.58	0.66	0.51
Kaluthara	81.74	57.35	53.41	89	87.72	83.45	0.92	0.65	0.64
Negombo	74.47	57.48	67.83	110	102.71	104.95	0.68	0.56	0.65
Nugegoda	46.39	33.48	35.18	110	70.35	85.49	0.42	0.48	0.41
Total LECO	65.27	49.45	50.54	99	84.16	93.12	0.66	0.48	0.54

6.2. Setting Performance Targets

Based on international best practices, separate targets are required to be identified for different customer groups (eg. Urban, rural). However, due to unavailability of such classification of customer groups and the segregation of reliability data among those groups, targets were identified separately for the seven branch areas of LECO (Kotte, Kalaniya, Moratuwa, Galle, Kaluthara, Negombo, Nugegoda), using the average of the actual SAIDI and SAIFI data in table 6-1 above.

In addition to the past data, the below targets set by the PUCSL for 2025 are also considered in setting reliability targets for 2015 [20].

a. SAIDI below 24 Hrs per year
b. SAIFI below 30 times per year

Considering linear improvement of reliability from average level of 2013 and 2014 to 2025, indicated in table 6-2 the performance targets calculated for 2015.

Table 6-2: Performance targets for 2015

	Average 2013 and 2014		Target 2025		Target 2015	
Branch	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI
Kotte	38.94	75.83	24.00	30.00	37.58	71.66
Kalaniya	78.06	85.15	24.00	30.00	73.15	80.14
Moratuwa	42.38	92.07	24.00	30.00	40.71	86.42
Galle	64.85	106.14	24.00	30.00	61.13	99.21
Kaluthara	69.55	88.36	24.00	30.00	65.40	83.05
Negombo	65.98	106.36	24.00	30.00	62.16	99.41
Nugegoda	39.94	90.18	24.00	30.00	38.49	84.70
Total LECO	57.36	91.58	24.00	30.00	54.40	85.83

It is to be noted that when setting performance targets, exempted events should be removed, however, due to unavailability of such segregation of data, exempted events are not eliminated in the performance target setting.

Further, these targets should be separately identified based on the responsibility of interruption. For example, targets should be separately identified for upstream (eg. generation, transmission or inter-Licensee failures) system failures and LECO failures. Moreover, in order to identify the financial impact on LECO, the penalty payable by LECO and upstream systems should be separately identified.. However, SAIDI and SAIFI, data is separately available only for 2015 for the calculation. Hence, the targets for upstream systems and LECO are calculated by dividing the targets calculated in table 6-2 proportionate to the actual SAIDI and SAIFI for Transmission Licensee and LECO for 2015. The targets for calculated for Transmission Licensee (CEB) and LECO are shown in table 6-3 and 6-4 below. For simplification it is assumed that all upstream failures are under the responsibility of the Transmission Licensee. This can be justified on the grounds that the legally the responsibility of maintaining reserve margin and generator dispatch etc. is with the Transmission Licensee.

Table 6-3: SAIDI targets for Transmission Licensee (CEB) and LECO

Branch	Total Target	Actual 2015		Target	
		CEB	LECO	CEB	LECO
Kotte	37.58	7.21	21.36	9.48	28.10
Kalaniya	73.15	54.42	12.76	59.25	13.89
Moratuwa	40.71	18.10	21.37	18.67	22.04
Galle	61.13	38.94	23.77	37.96	23.17
Kaluthara	65.40	27.96	25.45	34.24	31.16
Negombo	62.16	46.80	21.03	42.89	19.27
Nugegoda	38.49	14.28	20.90	15.63	22.86
LECO	54.40	29.81	20.73	32.09	22.31

Table 6-4: SAIFI targets for Transmission Licensee (CEB) and LECO

Branch	Total Target	Actual 2015		Target	
		CEB	LECO	CEB	LECO
Kotte	71.66	31.61	22.68	41.72	29.94
Kalaniya	80.14	65.26	15.08	65.09	15.04
Moratuwa	86.42	73.32	45.58	53.29	33.13
Galle	99.21	100.27	22.15	81.26	17.95
Kaluthara	83.05	66.30	17.15	65.99	17.07
Negombo	99.41	59.20	45.75	56.07	43.34
Nugegoda	84.70	69.00	16.49	68.37	16.34
LECO	85.83	67.25	25.87	61.98	23.84

6.3. Comparison of Targets Vs. Actuals

Figure 6-1 and Figure 6-2 show the graphical representation of comparison of reliability targets set for 2015 and the actual data for 2015.

In figure 6-1, it can be observed that except in Galle and Negombo areas, in all LECO branch areas actual SAIDI is below the target level. Further, LECO as overall has achieved the target performance.

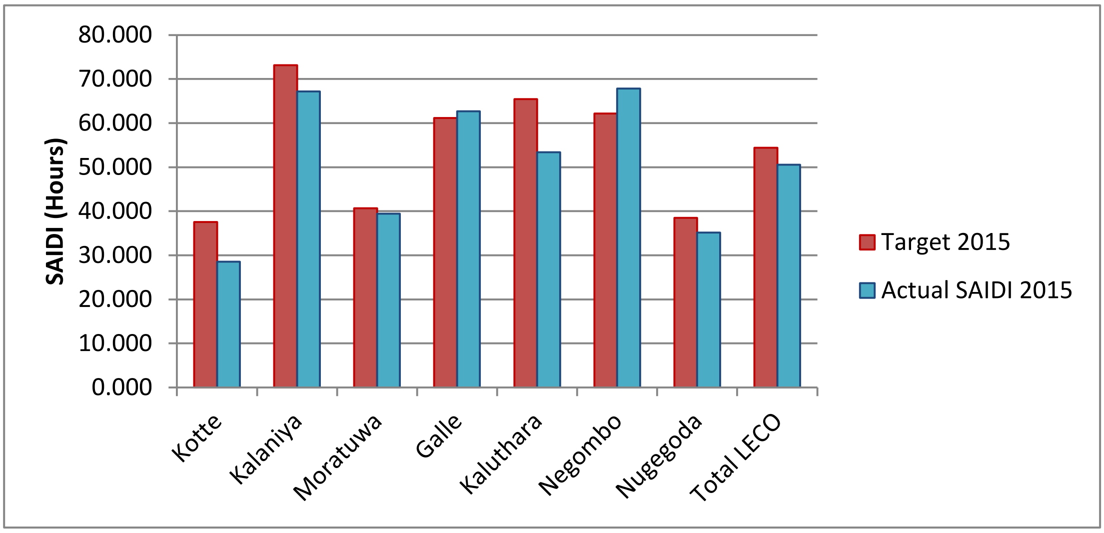

Figure 6-1: Comparison of Target Vs Actual of SAIDI 2015

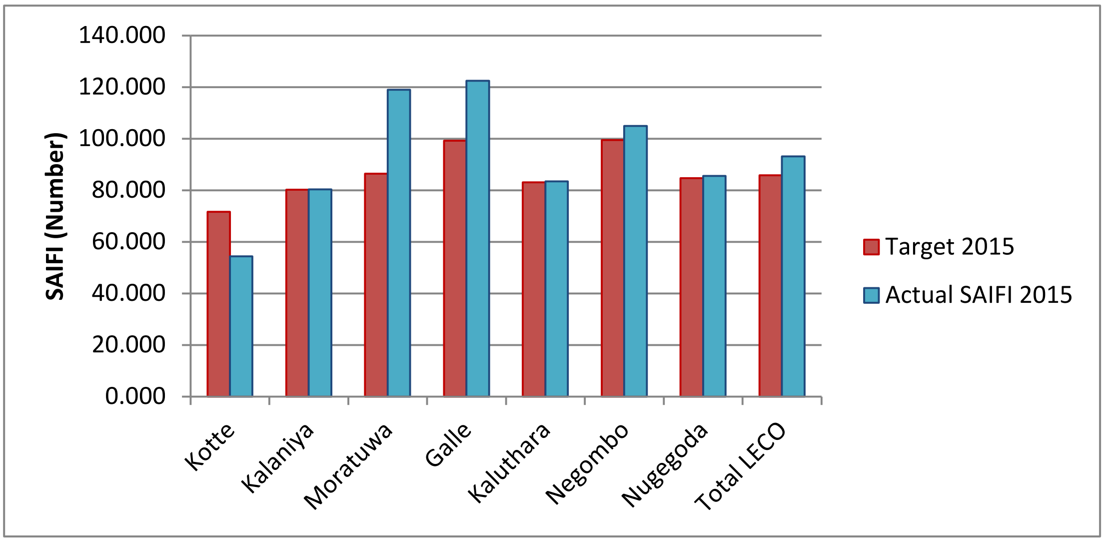

Figure 6-2: Comparison of Target Vs Actual of SAIFI 2015

In figure 6-2, it can be observed that only in Kotte area, the actual SAIFI is lower than the target and in Kalaniya, Kalutara and Nugegoda areas SAIFI is marginally close to the target. But in Moratuwa, Galle and Negombo areas, the SAIFI is higher than the target. Based on these data (as well as the consumer population in each area) the SAIFI of the overall LECO is above the target (hence has failed to achieve the target).

6.4. Determining the Financial Impact under each Incentive Mechanism

6.4.1. Charging a penalty for not achieving performance targets

This is the mechanism identified in the DPSR to provide financial incentives for improvement of overall reliability performance of the utilities, where only a penalty is applicable on the utility for not achieving the targets and no bonus is applicable for achieving the targets. Hence, the SAIDI and SAIFI based compensation formulas given in 3.1.5.1 are used for this calculation.

6.4.1.1. Supply cost calculation

According to the SAIDI and SAIFI based compensation calculation formulas identified in section 3.1.5.1, supply cost of electricity in LKR/kWh need to be determined for the calculation of compensation. The regulations do not specify a method or value for the supply cost, hence for the compensation calculation under this section the supply cost is determined as below.

Figure 6-3 shows the breakdown of 2015 total electricity industry revenue among different business units (generation, transmission, distribution etc.) [21], [22].

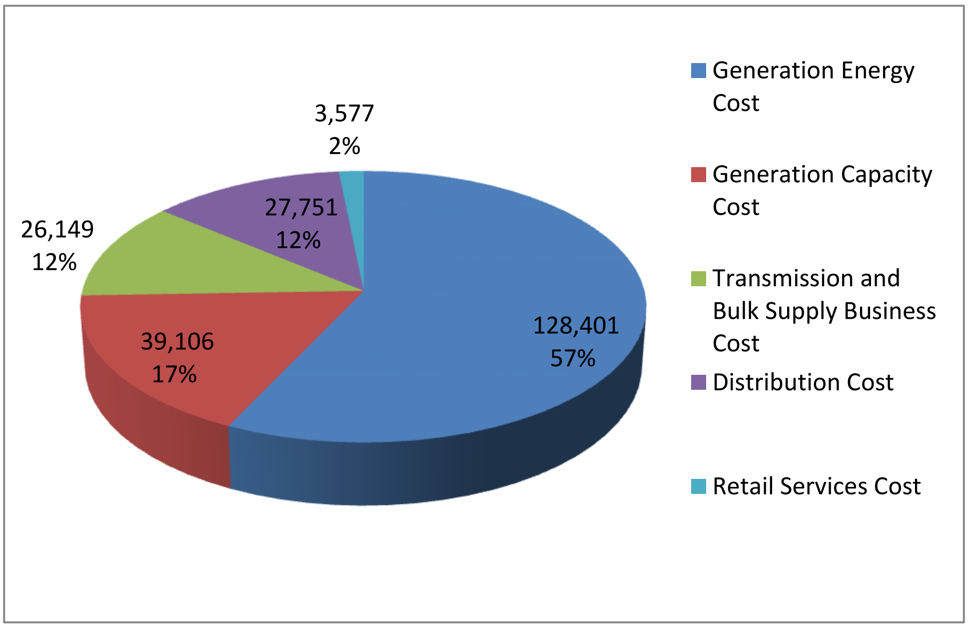

Figure 6-3: Breakdown of 2015 electricity Cost in LKR millions

For this calculation it is considered that this allowed revenue is for the utility to provide the supply of electricity at the target performance level. Hence, if the utility failed to achieve any performance target, it is considered as the total revenue is not effectively utilized. Hence, such amount is taken back as a penalty considering it as an unutilized revenue.

Further, the energy cost passed through to consumers is based on the actual energy cost incurred by the Transmission Licensee in procuring the electricity (adjusted quarterly at Bulk Supply Tariff revisions) [4]. In case of an interruption, the Transmission Licensee is not required to procure the amount of electricity not supplied and hence such cost is not ultimately passed through to the consumers (not included in the revenue). Hence, generation energy cost is not included in calculation of supply cost. Retail service cost (metering and billing) also, excluded from the supply cost calculation as these business unit does not have a direct impact on the system reliability. Considering the direct impact those have on the system reliability, the following cost components are included in the SUPPLYCOST calculation.

- Generation capacity cost – This is the fixed cost component of generation cost. The Transmission Licensee is required to pay this amount to Generators, based on the availability of the power plants and irrespective of energy procured from the plant or not. Hence, this cost becomes unnecessary cost passed through to customers (hence not an effectively utilized revenue) if energy is not delivered to customers.
- Transmission cost- This cost component comprises of three main components (according to the Bulk Supply Tariff Decision of PUCSL [21], [22])
    - Transmission capacity cost- This is the cost of the transmission network, this include the cost relevant to transmission system expansion and maintenance, which directly affect the reliability of the supply.
    - Bulk Supply and Operations Business cost- This is the cost component related to dispatch of power plants. Accurate dispatching can eliminate/ minimize the reliability issues caused by transmission constraints (eg. under/ over voltage) and under/ over frequency of the system.

- CEB Loans- Bulk amount of CEB loans are for system expansion and hence, to enhance reliability.

- Distribution capacity cost-This is the cost of the distribution network, this include the cost relevant to transmission system expansion and maintenance, which directly affect the reliability of the electricity supply to consumers.

Hence, the supply cost calculation will be as shown in table 6-5 below.

Table 6-5: Unit Supply Cost calculation

Cost component	**Amount**	**Unit**
Generation Capacity Cost	39,106	LKR million
Transmission Cost	26,149	LKR million
Total upstream supply cost	65,256	LKR million
Total electricity sales 2015	11,271	GWh
Unit cost (upstream)	5.79	LKR/kWh
Distribution Cost	27,751	LKR million
Total Distribution & supply cost	27,751	LKR million
Unit cost (LECO)	2.46	LKR/kWh

6.4.1.2. SAIDI based penalty

As per section 3.1.5.1 the below equation is used for the calculation of SAIDI based penalty charged on the utility.

$$C_{m,i}^{SAIDI} = (SAIDI_{m,i} - \overline{SAIDI}_{m}) \times \frac{YearEnergy_{m,i}}{8760} \times SUPPLYCOST_{m,i}$$

If $SAIDI_{m,i} < \overline{SAIDI_m}$, $C_{m,i}^{SAIDI}$ will be zero.

Where, $(SAIDI_{m,i} - \overline{SAIDI}_{m})$ is the deviation of actual SAIDI from the target, year energy is the total energy delivered to each area during the year and the supply cost is the cost of supplying unit of electricity calculated in Table 6-5 above.

Based on the supply cost calculation, the penalty calculation is shown in Table 6-6 (negative values are indicated in brackets).

Table 6-6: Calculation of penalty based on SAIDI

Branch	SAIDI Deviation (Hrs)		Supply Cost (Rs/kWh)		Year Energy (GWh)	Compensation (LKR)	
	Upstream	LECO	Upstream	LECO		Upstream	LECO
Kotte	(2.3)	(6.7)	5.79	2.46	183.89	-	-
Kalaniya	(4.8)	(1.1)	5.79	2.46	289.28	-	-
Moratuwa	(0.6)	(0.7)	5.79	2.46	224.41	-	-
Galle	1.0	0.6	5.79	2.46	130.26	84,113	21,832
Kaluthara	(6.3)	(5.7)	5.79	2.46	180.47	-	-
Negombo	3.9	1.8	5.79	2.46	155.16	401,192	76,661
Nugegoda	(1.3)	(2.0)	5.79	2.46	201.05	-	-

6.4.1.3. SAIFI based penalty,

As per section 3.1.5.1 above the below equation is used for the calculation of SAIFI based penalty.

$$C_{m,i}^{SAIFI} = (SAIFI_{m,i} - \overline{SAIFI_m}) \times \left(\frac{SAIDI_{m,i}}{SAIFI_{m,i}} \right) \times \frac{YearEnergy_{m,i}}{8760} \times SUPPLYCOST_{m,i}$$

If $SAIFI_{m,i} < \overline{SAIFI_m}$, , $C_{m,i}^{SAIFI}$ will be zero.

Where, $(SAIFI_{m,i} - \overline{SAIFI_m})$ is the deviation of actual SAIFI from the target.

Table 6-7 shows the calculation of penalty (negative values indicated in brackets).

Table 6-7: Calculation of penalty based on SAIFI

Branch	SAIFI Deviation (times/year)		Supply Cost (Rs/kWh)		Year Energy (GWh)	Compensation (LKR)	
	Upstream	LECO	Upstream	LECO		Upstream	LECO
Kotte	(10.1)	(7.3)	5.79	2.46	183.89	-	-
Kalaniya	0.2	0.0	5.79	2.46	289.28	26,096	2,170
Moratuwa	20.0	12.5	5.79	2.46	224.41	986,317	122,275
Galle	19.0	4.2	5.79	2.46	130.26	838,185	84,485
Kaluthara	0.3	0.1	5.79	2.46	180.47	24,176	3,946
Negombo	3.1	2.4	5.79	2.46	155.16	207,001	31,271
Nugegoda	0.6	0.2	5.79	2.46	201.05	34,705	4,470

The revenue reduction will be the maximum of SAIDI based penalty or SAIFI based penalty (Section 3.1.5.1).

$$C_{m,i} = Max\,(C_{m,i}^{SAIDI}\,, C_{m,i}^{SAIFI}\,)$$

Based on the equation, the actual revenue reduction will be as shown in Table 6-8.

Table 6-8: Actual revenue reduction (penalty) based on SAIDI/ SAIFI

Branch area	SAIDI based compensation (LKR)		SAIFI based compensation (LKR)		Revenue reduction (LKR)	
	Upstream	LECO	Upstream	LECO	Upstream	LECO
Kotte	-	-	-	-	-	-
Kalaniya	-	-	26,096	2,170	26,096	2,170
Moratuwa	-	-	986,317	122,275	986,317	122,275
Galle	84,113	21,832	838,185	84,485	838,185	84,485
Kaluthara	-	-	24,176	3,946	24,176	3,946
Negombo	401,192	76,661	207,001	31,271	401,192	76,661
Nugegoda	-	-	34,705	4,470	34,705	4,470
Total					2,310,670	294,007

As responsibility of Generation planning and maintaining reserve margins are under the responsibility of the Transmission Licensee, it can be considered that all upstream failures (e.g. generation inadequacy and transmission failures) are under the responsibility of the Transmission Licensee (Ceylon Electricity Board- CEB), given in Table 6-9 the financial implications on the CEB and LECO due to the above mechanism.

Table 6-9: Financial Implications on the utility under penalty only method

	Transmission Licensee	LECO
Total Revenue reduction	2,310,670 LKR	294,007 LKR
Total revenue 2015	7,453 (total Transmission revenue 65,256 adjusted for LECO sales (Mil LKR)	2,703 Mil LKR
Revenue reduction as a % of total revenue	0.031%	0.011%

It can be seen that even though the method identified in the DPSR is a penalty only method, the penalty charged on each utility is within the lower limit on revenue reduction adopted by the countries studied under the literature review.

6.4.2. Penalty or bonus mechanism

However, the penalty only method identified under section 6.4.1 above does not incentivize the utility to outperform the target performance. Hence, the utilities will keen on marginally achieving the performance targets and will not tend to improve the reliability in already reliable areas.

Further, the incentive mechanisms in all the countries studied under the literature review in Section 2, except India (where incentives are bonus only), are two way, where utility is charge a penalty for not achieving the target and given a bonus for achieving the targets.

Considering this, using the same equations for calculating SAIDI based Compensation and SAIFI based compensation in section 6.4.1 above, given below the calculation of either penalty or bonus paid for the LECO in 2015 based on SAIDI and SAIFI performance.

6.4.2.1. SAIDI based bonus/ penalty

For the calculation of SAIDI based penalty/bonus the equation used in Section 6.4.1.1. for calculation of penalty is modified as below.

$$C_{m,i}^{SAIDI} = (\overline{SAIDI_m} - SAIDI_{m,i}) \times \frac{YearEnergy_{m,i}}{8760} \times SUPPLYCOST_{m,i}$$

If $SAIDI_{m,i} < \overline{SAIDI_m}$, $C_{m,i}^{SAIDI}$ will give a bonus payment and wise versa.

In the above equation $\overline{SAIDI_m} - SAIDI_{m,i}$ gives the deviation of actual SAIDI from the target and if the utility has over performed, the deviation is positive and if the utility has underperformed, the deviation is negative.

Table 6-10 shows the penalty/ bonus calculated based on the above formula (negative values and penalties are indicated in brackets)

Table 6-10: Calculation of penalty/ bonus based on SAIDI

Branch	SAIDI Deviation (Hrs)		Supply Cost (Rs/kWh)		Year Energy (GWh)	Compensation (LKR)	
	Upstream	LECO	Upstream	LECO		Upstream	LECO
Kotte	2.3	6.7	5.79	2.46	183.89	276,444	348,448
Kalaniya	4.8	1.1	5.79	2.46	289.28	923,377	92,087
Moratuwa	0.6	0.7	5.79	2.46	224.41	83,799	42,080
Galle	(1.0)	(0.6)	5.79	2.46	130.26	(84,113)	(21,832)
Kaluthara	6.3	5.7	5.79	2.46	180.47	748,663	289,775
Negombo	(3.9)	(1.8)	5.79	2.46	155.16	(401,192)	(76,661)
Nugegoda	1.3	2.0	5.79	2.46	201.05	178,249	110,901

6.4.2.2. SAIFI based bonus / penalty

For the calculation of SAIFI based penalty/bonus the equation used in Section 6.4.1.2. for calculation of penalty is modified as below.

$$C_{m,i}^{SAIFI} = (\overline{SAIFI_m} - SAIFI_{m,i}) \times \left(\frac{SAIDI_{m,i}}{SAIFI_{m,i}} \right) \times \frac{YearEnergy_{m,i}}{8760} \times SUPPLYCOST_{m,i}$$

If $SAIFI_{m,i} < \overline{SAIFI_m}$, $C_{m,i}^{SAIFI}$ will give a bonus payment and wise versa.

In the above equation $\overline{SAIFI_m} - SAIFI_{m,i}$ gives the deviation of actual SAIFI from the target and if the utility has over performed, the deviation is positive and if the utility has underperformed, the deviation is negative.

Table 6-11 shows the penalty/ bonus calculated based on the above formula (negative values and penalties are indicated in brackets)

Table 6-11: Calculation of penalty/ bonus based on SAIFI

Branch	SAIFI Deviation (times/year)		Supply Cost (Rs/kWh)		Year Energy (GWh)	Compensation (LKR)	
	Upstream	LECO	Upstream	LECO		Upstream	LECO
Kotte	10.1	7.3	5.79	2.46	183.89	646,358	185,701
Kalaniya	(0.2)	(0.0)	5.79	2.46	289.28	(26,096)	(2,170)
Moratuwa	(20.0)	(12.5)	5.79	2.46	224.41	(986,317)	(122,275)
Galle	(19.0)	(4.2)	5.79	2.46	130.26	(838,185)	(84,485)
Kaluthara	(0.3)	(0.1)	5.79	2.46	180.47	(24,176)	(3,946)
Negombo	(3.1)	(2.4)	5.79	2.46	155.16	(207,001)	(31,271)
Nugegoda	(0.6)	(0.2)	5.79	2.46	201.05	(34,705)	(4,470)

International best practice is to obtain the weighted average of the penalty/ bonus calculated based on different indices. For example in Philippine equal weights are assigned for SAIFI and CAIDI [10]. Based on this assuming that the impact to the customer from SAIDI and SAIFI are equal, the total penalty or bonus is taken as the simple average of SAIDI based penalty/bonus and SAIFI based penalty/bonus.

$$C_{m,i} = Average\,(C_{m,i}^{SAIDI}, C_{m,i}^{SAIFI})$$

Hence, the revenue reduction/ addition will be as shown in table 6-12 below. For clarity, compensation payments are indicated in brackets.

Table 6-12: Actual Penalty/ Bonus based on SAIDI and SAIFI

Branch area	SAIDI based compensation (LKR)		SAIFI based compensation (LKR)		Revenue reduction/ addition (LKR)	
	Upstream	LECO	Upstream	LECO	Upstream	LECO
Kotte	276,444	348,448	646,358	185,701	461,401	267,074
Kalaniya	923,377	92,087	(26,096)	(2,170)	448,640	44,958
Moratuwa	83,799	42,080	(986,317)	(122,275)	(451,259)	(40,097)
Galle	(84,113)	(21,832)	(838,185)	(84,485)	(461,149)	(53,159)
Kaluthara	748,663	289,775	(24,176)	(3,946)	362,244	142,914
Negombo	(401,192)	(76,661)	(207,001)	(31,271)	(304,096)	(53,966)
Nugegoda	178,249	110,901	(34,705)	(4,470)	71,772	53,215
Total					127,553	360,941

Assuming all upstream failures are under the responsibility of the Transmission Licensee (CEB), given below in Table 6-13 the financial implications on the CEB and LECO due to the penalty/ bonus mechanism.

Table 6-13: Financial implications on the utility on Penalty/ Bonus incentive method

	Transmission Licensee	LECO
Total penalty/ Bonus	127,553LKR (bonus)	360,941 LKR (bonus)
Total revenue 2015	7,453 (total Transmission revenue 65,256 adjusted for LECO sales) Mil LKR	2,703 Mil LKR
Revenue addition as a % of total revenue	0.002% (bonus)	0.013% (bonus)

It can be seen that the both Transmission Licensee and LECO earned profits under bonus or penalty method, to penalty only method given in the DPSR.

6.4.3. Compensation for individual customers

6.4.3.1. Supply Cost

Compensation payments for individual customers need to be conducted based on the cost of unserved energy to the customers. For the purpose of this study, the cost of unserved energy used in the Least Cost Long Term Generation Expansion Plan 2015-2034, 0.63 USD/kWh is used [23]. 0.63 USD equals to 85.64 LKR converted at 2015 average exchange rates for 2015 published by the Central Bank of Sri Lanka [24].

6.4.3.2. Compensation calculation

Formula given the DPSR for compensation calculation for individual customer is shown below (refer section 3.4.1).

$$C_i^{CUST} = \sum_{j=1,J} ID_{i,j}^{CUST} \times \frac{YearEnergy_i}{8760} \times SUPPLYCOST$$

Where, the part $\sum_{j=1,J} ID_{i,j}^{CUST}$ gives the total duration of interruptions experienced by a customer. But, at present this data is not available for each and every customer. However, since the overall SAIDI value is available for each branch area, the total financial impact can be calculated using the overall SAIDI.

Hence, total compensation payable for customers can be derived as below.

- Total compensation= $\sum_{i=1,n} C_i^{CUST}$, where n is the total number of customers.
- Hence, total compensation= $\sum_{i=1,n} \sum_{j=1,J} ID_{i,j}^{CUST} \times \frac{YearEnergy_i}{8760} \times SUPPLYCOST$
- The term $\sum_{i=1,n} \sum_{j=1,J} ID_{i,j}^{CUST}$ gives the total customer interruption duration.
- Total customer interruption duration = SAIDI × Total Number of Customers.
- Hence, Total Compensation can be calculated using the below expression

$$\text{SAIDI} \times \text{Total Number of Customers} \times \frac{YearEnergy_i}{8760} \times SUPPLYCOST$$

In other countries compensation is paid only if interruption duration exceeds the target level. Therefore, SAIDI deviation is used for the calculation instead of SAIDI.

Assuming all upstream failures are under the responsibility of the Transmission Licensee (CEB), compensation payable to customers is calculated in Table 6-14.

Table 6-14: Financial implications on the utility on compensation payment for customers

Branch	SAIDI Deviation (Hrs)		No of customers	Supply Cost (Rs/kWh)		Year Energy (kWh)	Compensation (LKR)	
	CEB	LECO		CEB	LECO		CEB	LECO
Kotte	-	-	67,544	85.64	85.64	2,723	-	-
Kalaniya	-	-	77,065	85.64	85.64	3,754	-	-
Moratuwa	-	-	94,588	85.64	85.64	2,373	-	-
Galle	1.0	0.6	92,961	85.64	85.64	1,401	1,247,779	763,946
Kaluthara	-	-	73,688	85.64	85.64	2,449	-	-
Negombo	3.9	1.8	83,799	85.64	85.64	1,852	5,932,382	2,670,331
Nugegoda	-	-	56,886	85.64	85.64	3,534	-	-
Total	-	-	546,530	85.64	85.64	2,497	7,180,161	3,434,277
% of AR							0.10%	0.13%

All the countries studied in chapter 2, use a combination of two incentive methods, to incentivize the utility (based on overall performance) and to compensate individual customers (based on individual performance indices/ GSL scheme). Hence, when analyzing the financial implications, the combined financial effect under overall performance incentive method (Section 6.4.1 or Section 6.4.2) and financial effect under individual compensation method (6.4.3) need to be considered.

Hence, Table 6-15 shows the total financial implications on the utility if individual compensation is paid together with the penalty method and Table 6-16 shows the total financial implications on the utility if individual compensation is paid together with the penalty or bonus method.

Table 6-15: Financial implications on the utility when penalty is applied on top of compensation payment for individual customers

	Transmission Licensee	LECO
Total penalty/ Bonus	(9,490,831) LKR (loss)	(3,728,284) LKR (loss)
Total revenue 2015	7,453 (total Transmission revenue 65,256 adjusted for LECO sales) Mil LKR	2,703 Mil LKR
Revenue reduction as a percentage of total revenue	-0.13%(loss)	-0.14%(loss)

Table 6-16: Financial implications on the utility when either penalty or bonus is applied on top of compensation payment for customers

	Transmission Licensee	LECO
Total penalty/ Bonus	(7,052,608) LKR (penalty)	(3,073,336) LKR (penalty)
Total revenue 2015	7,453 (total Transmission revenue 65,256 adjusted for LECO sales) Mil LKR	2,703 Mil LKR
Revenue reduction as a percentage of total revenue	-0.009% (loss)	-0.013%(loss)

6.4.4. Differentiated electricity tariff based on Joint Pricing Model

Under this subsection, the end user tariff is differentiated using the Joint Pricing Model Identified in Section 4 above.

6.4.4.1. Differentiating tariff rates - Value Engineering Theory

As per the Section 4.1, the equation for calculation of change in electricity price corresponding to changes in the reliability indices are given by the below formula.

$$|\Delta P_i| = \frac{|\Delta \lambda_i|}{\lambda_0} P_0 = \frac{|\lambda_i - \lambda_0|}{\lambda_0} P_0$$

In the above equation it is assumed that the original base price (P_0) corresponds to average index value (λ_0) of the total system, where, λ can be any reliability index as SAIDI, SAIFI or CAIDI.

However, for the purpose of this study, it is assumed that,

a. The average cost of electricity corresponds to the target reliability level, not the average reliability level as specified in the model.

   If average reliability level is considered, the losses to the utility due to non-achievement of the target in certain areas is neutralized by the profit gain from the other highly reliable areas. Hence, no incentive is given to the utility.

b. Only 2% of the supply cost calculated under table 6-5 above is linked to the reliability performance.

   This is to ensure that the utility is not making unnecessary losses and no unnecessary cost is passed to the customers. In other countries, only certain percentage of allowed revenue (eg. 2% in Philippine) is varied based on the performance of the utility.

   Further, only of the revenue components directly related to system reliability (described in Section 6.4.1.1) 2% is varied based on the reliability performance. Hence, the total unit selling price of electricity does not vary by 2%. According to the calculation given in Table 6-17 only 1% of the selling price will be at risk, based on the reliability performance.

Table 6-17: Calculation of component of unit cost vary with the reliability

	Cost (LKR/kWh)
Unit cost of upstream system (refer table 6-5)	5.79
Unit LECO cost (refer table 6-5)	2.46
Total (upstream cost+ LECO cost)	8.57
2% of Total	0.17
Average unit cost 2015	19.96
2% of total of upstream and LECO cost as % of 2015 average cost (equals to average selling price)	1%

Based on the calculation in Table 6-17, the above equation is modified as below.

$$|\Delta P_i| = \frac{|\lambda_i - \lambda_0|}{\lambda_0} P_0 \times 1\%$$

Electricity price based on SAIDI is given by the below equation, where SAIDI.and $\overline{SAIDI}$ indicate actual and target SAIDI value.

$$|\Delta P_i| = \frac{|SAIDI_i - \overline{SAIDI_i}|}{\overline{SAIDI_i}} \times 1\% \times P_0$$

The differentiated tariff (P_o+$|\Delta P_i|$), based on SAIDI is calculated in Table 6-18.

Table 6-18: SAIDI based tariff differentiation

	Actual SAIDI 2015 (hrs) $SAIDI_{m,i}$	Target SAIDI 2015(hrs) $\overline{SAIDI}_{m,i}$	Average Unit cost 2015 (P_0) (LKR)	Differentiated Tariff (LKR)
Kotte	28.56	37.577	19.96	20.00
Kalaniya	67.18	73.145	19.96	19.97
Moratuwa	39.48	40.709	19.96	19.97
Galle	62.71	61.132	19.96	19.96
Kaluthara	53.41	65.405	19.96	19.99
Negombo	67.83	62.159	19.96	19.95
Nugegoda	35.18	38.486	19.96	19.98

The change in the electricity price based on SAIFI is given by the below equation.

$$|\Delta P_i| = \frac{|SAIFI_i - \overline{SAIFI_i}|}{\overline{SAIFI_i}} \times 1\% \times P_0$$

Where $SAIFI_i$ and $\overline{SAIFI}_I$ are actual and target for the area i.

Hence, the SAIFI based differentiated tariff (P_o+$|\Delta P_i|$) is as shown in table 6-19.

Calculations in tables 6-18 and 6-19 are conducted for the average selling price of electricity for LECO in 2015. The same way, actual end user tariff rates can be differentiated.

Table 6-19: SAIFI based tariff differentiation

	Actual SAIFI 2015 (no.) $SAIFI_{m,i}$	Target SAIFI 2015 (no.) $\overline{SAIFI}_{m,i}$	Average Unit cost 2015 (LKR)	Differentiated Tariff (LKR)
Kotte	54.29	71.659	19.96	20.00
Kalaniya	80.34	80.136	19.96	19.96
Moratuwa	118.90	86.423	19.96	19.90
Galle	122.42	99.214	19.96	19.92
Kaluthara	83.45	83.055	19.96	19.96
Negombo	104.95	99.414	19.96	19.95
Nugegoda	85.49	84.705	19.96	19.96

6.4.4.2. Calculation of weights using Entropy Method

Since, larger the information used for the calculation of weights, higher the accuracy of weights are, monthly SAIDI and SAIFI data of LECO for 2015 used for the calculation of weights under entropy method [16], [17].

Step 1 For m load points and 2 index, index Metrix is given by, $X = [x_{ij}]_{m\times 2}$

Table 6-20 shows the index matrix of each branch area, contained of SAIDI and SAFI data of 12 months of 2015.

Table 6-20: Entropy Method- Step 1

Month	Kotte		Nugegoda		Kalaniya		Moratuwa		Galle		Kalutara		Negombo	
	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI
Jan	1.3	2.0	1.3	5.0	6.1	7.0	2.7	5.0	2.9	8.0	2.3	7.0	6.8	6.0
Feb	1.4	2.0	1.7	4.0	5.0	5.0	4.3	9.0	1.5	5.0	3.7	8.0	4.6	6.0
Mar	2.0	6.0	2.6	7.0	4.7	5.0	4.3	7.0	10.6	15.0	5.5	8.0	9.5	7.0
Apr	0.8	4.0	1.9	5.0	5.4	6.0	3.4	11.0	4.3	9.0	7.3	13.0	3.3	9.0
May	2.3	5.0	4.1	9.0	6.3	8.0	3.8	15.0	5.4	16.0	5.0	8.0	6.5	10.0
June	2.6	7.0	2.6	7.0	5.2	10.0	3.2	12.0	5.7	20.0	7.3	6.0	7.0	14.0
July	2.5	5.0	3.1	9.0	4.9	6.0	2.3	7.0	4.9	10.0	3.2	2.0	4.3	7.0
Aug	1.3	3.0	1.8	9.0	3.2	6.0	1.4	9.0	1.9	5.0	1.5	4.0	3.1	7.0
Sep	3.3	6.0	4.9	12.0	8.2	8.0	7.4	13.0	8.5	11.0	6.0	6.0	7.4	11.0
Oct	3.9	4.0	6.9	8.0	6.5	8.0	2.5	9.0	5.1	8.0	3.6	4.0	6.1	8.0
Nov	5.4	7.0	2.9	6.0	3.0	4.0	1.7	12.0	5.0	7.0	6.0	9.0	2.1	7.0
Dec	1.7	4.0	1.4	6.0	8.7	7.0	2.5	8.0	6.9	10.0	2.1	9.0	7.4	12.0

Step 2: Standard index Matrix , $Y_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$

Standard index matrices calculated for each branch area is shown in Table 6-21

Table 6-21:Entropy Method- Step 2

	Kotte		Nugegoda		Kalaniya		Moratuwa		Galle		Kalutara		Negombo	
	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI
Jan	0.05	0.04	0.04	0.06	0.09	0.09	0.07	0.04	0.05	0.06	0.04	0.08	0.10	0.06
Feb	0.05	0.04	0.05	0.05	0.07	0.06	0.11	0.08	0.02	0.04	0.07	0.10	0.07	0.06
Mar	0.07	0.11	0.08	0.08	0.07	0.06	0.11	0.06	0.17	0.12	0.10	0.10	0.14	0.07
Apr	0.03	0.07	0.05	0.06	0.08	0.08	0.09	0.09	0.07	0.07	0.14	0.15	0.05	0.09
May	0.08	0.09	0.12	0.10	0.09	0.10	0.10	0.13	0.09	0.13	0.09	0.10	0.10	0.10
June	0.09	0.13	0.07	0.08	0.08	0.13	0.08	0.10	0.09	0.16	0.14	0.07	0.10	0.13
July	0.09	0.09	0.09	0.10	0.07	0.08	0.06	0.06	0.08	0.08	0.06	0.02	0.06	0.07
Aug	0.05	0.05	0.05	0.10	0.05	0.08	0.04	0.08	0.03	0.04	0.03	0.05	0.05	0.07
Sep	0.12	0.11	0.14	0.14	0.12	0.10	0.19	0.11	0.14	0.09	0.11	0.07	0.11	0.11
Oct	0.14	0.07	0.20	0.09	0.10	0.10	0.06	0.08	0.08	0.06	0.07	0.05	0.09	0.08
Nov	0.19	0.13	0.08	0.07	0.05	0.05	0.04	0.10	0.08	0.06	0.11	0.11	0.03	0.07
Dec	0.06	0.07	0.04	0.07	0.13	0.09	0.06	0.07	0.11	0.08	0.04	0.11	0.11	0.12

Step 3: Index information entropy, $e_j = -k\sum_{i=1}^{m}(Y_{ij} \times lnY_{ij})$, where k is entropy coefficient. k = $\ln 12^{-1}$= 0.4024

Information entropy calculated for each index, for each branch area is shown in Table 6-22

Table 6-22: Entropy Method- Step 3

Kotte		Nugegoda		Kalaniya		Moratuwa		Galle		Kalutara		Negombo	
SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI
0.95	0.97	0.95	0.98	0.98	0.99	0.96	0.98	0.95	0.97	0.96	0.97	0.97	0.98

Step 4: Entropy redundancy, $d_j = 1 - e_j$

Entropy redundancy is calculated in Table 6-23

Table 6-23: Entropy Method- Step 4

Kotte		Nugegoda		Kalaniya		Moratuwa		Galle		Kalutara		Negombo	
SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI
0.05	0.03	0.05	0.02	0.02	0.01	0.04	0.02	0.05	0.03	0.04	0.03	0.03	0.02

Step 5 : Index weight, $W_j = d_j / \sum_{j=1}^{3} d_j$

The weights calculated for each index (SAIDI and SAIFI), for each branch area is given in Table 6-24

Table 6-24: Entropy Method- Step 5

Kotte		Nugegoda		Kalaniya		Moratuwa		Galle		Kalutara		Negombo	
SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI	SAIDI	SAIFI
0.65	0.35	0.75	0.25	0.60	0.40	0.70	0.30	0.58	0.42	0.54	0.46	0.66	0.34

6.4.4.3. Combining the differentiated tariff rates-Joint Pricing

There are interrelated relationships between different reliability indices. Under Joint Pricing Model, differentiated tariff rates based on reliability indices, calculated in Tables 6-18, 6-19 and the weights corresponding to each index calculated in Table 6-24 are used to calculate the weighted average price, which is the joint electricity price/ reliability differentiated electricity price.

Hence, Joint electricity price is calculated using the equation below.

$$P = W_{SAIDI}\, P_{SAIDI} + W_{SAIFI} P_{SAIFI}$$

Where, W_{SAIDI} and W_{SAIFI} are the weights assigned for SAIDI and SAIFI, respectively and P_{SAIDI} and P_{SAIFI} are the electricity tariff differentiated based on SAIDI and SAIFI, respectively.

Table 6-25: Calculation of Joint Pricing

	P_{SAIDI}	P_{SAIFI}	W_{SAIDI}	W_{SAIFI}	Joint Price	% Change	Profit / Loss
Kotte	20.00	20.00	0.65	0.35	20.00	0.20%	7,307,026
Kalaniya	19.97	19.96	0.60	0.40	19.97	0.04%	2,279,134
Moratuwa	19.97	19.90	0.70	0.30	19.95	-0.08%	(3,368,732)
Galle	19.96	19.92	0.58	0.42	19.94	-0.09%	(2,449,024)
Kaluthara	19.99	19.96	0.54	0.46	19.98	0.08%	2,900,479
Negombo	19.95	19.95	0.66	0.34	19.95	-0.07%	(2,024,854)
Nugegoda	19.98	19.96	0.75	0.25	19.97	0.05%	2,049,577
Total							6,693,605

For calculation profit or loss to the LECO and upstream separately, separate targets, separate prices and also separate weights required to be calculated. However, for the purpose of this calculation, the total profit/ loss to the system under Joint Pricing is divided among Transmission Licensee and LECO, as per the ratios calculated based on the under/ over utilized revenue of the utility. Under/ over utilized revenues based on SAIDI deviations is calculated in Table 6-10 above and under/ over utilized revenues based on SAIDI deviations are calculated in Table 6-11 above.

Table 6-26: Ratio Calculation

Under/ over utilized revenues based on				Weights		Weighted Average Under/ over utilized revenues		Ratio	
SAIDI (Table 6-10)		SAIFI (Table 6-11)							
CEB	LECO	CEB	LECO	SAIDI	SAIFI	CEB	LECO	CEB	LECO
276,444	348,448	646,358	185,701	0.65	0.35	405,914	291,487	58%	42%
923,377	92,087	(26,096)	(2,170)	0.60	0.40	543,588	54,384	91%	9%
83,799	42,080	(986,317)	(122,275)	0.70	0.30	(237,236)	(7,227)	97%	3%
(84,113)	(21,832)	(838,185)	(84,485)	0.58	0.42	(400,823)	(48,146)	89%	11%
748,663	289,775	(24,176)	(3,946)	0.54	0.46	393,157	154,663	72%	28%
(401,192)	(76,661)	(207,001)	(31,271)	0.66	0.34	(335,167)	(61,228)	85%	15%
178,249	110,901	(34,705)	(4,470)	0.75	0.25	125,011	82,058	60%	40%

Table 6-27: Profit/ Loss to CEB and LECO

Total Profit/Loss	Ratio		Profit/ Loss	
	CEB	LECO	CEB	LECO
7,307,026	58%	42%	4,252,970	3,054,056
2,279,134	91%	9%	2,071,852	207,282
(3,368,732)	97%	3%	(3,269,149)	(99,582)
(2,449,024)	89%	11%	(2,186,397)	(262,627)
2,900,479	72%	28%	2,081,601	818,877
(2,024,854)	85%	15%	(1,712,089)	(312,765)
2,049,577	60%	40%	1,237,360	812,217
Total Profit/Loss			2,476,147	4,217,458
Profit/Loss as a percentage of total revenue			0.033%	0.156%

Based on differentiated tariff approach, CEB earns a profit of 0.033% of the revenue and LECO earns a profit of 0.156% of the total revenue.

7. COMPARISON OF RESULTS AND DISCUSSION

7.1. Comparison of Results

Table 7-1: Comparison of financial implications to the utility under each incentive mechanism

	Individual performance	Overall performance		Combination		
	Compensation	Penalty only	Penalty/ Bonus	Penalty+ Compensation	Penalty/ Bonus& + Compensation	Differentiated Tariff
Profit/ (loss) to CEB as % of Revenue[1]	(0.10%) (loss)	(0.03%) (loss)	0.002% (profit)	(0.13%) (loss)	(0.09%) (loss)	0.033% (profit)
Profit/ (Loss) to LECO as % of Revenue	(0.13%) (loss)	(0.01%) (loss)	0.013% (profit)	(0.14%) (loss)	(0.13%) (loss)	0.156% (profit)
Benefit to poorly served customer	85.64 (LKR/ kWh loss)	N/A	N/A	85.64 (LKR/ kWh loss)	85.64 (LKR/ kWh loss)	About 0.1% low tariff[2]

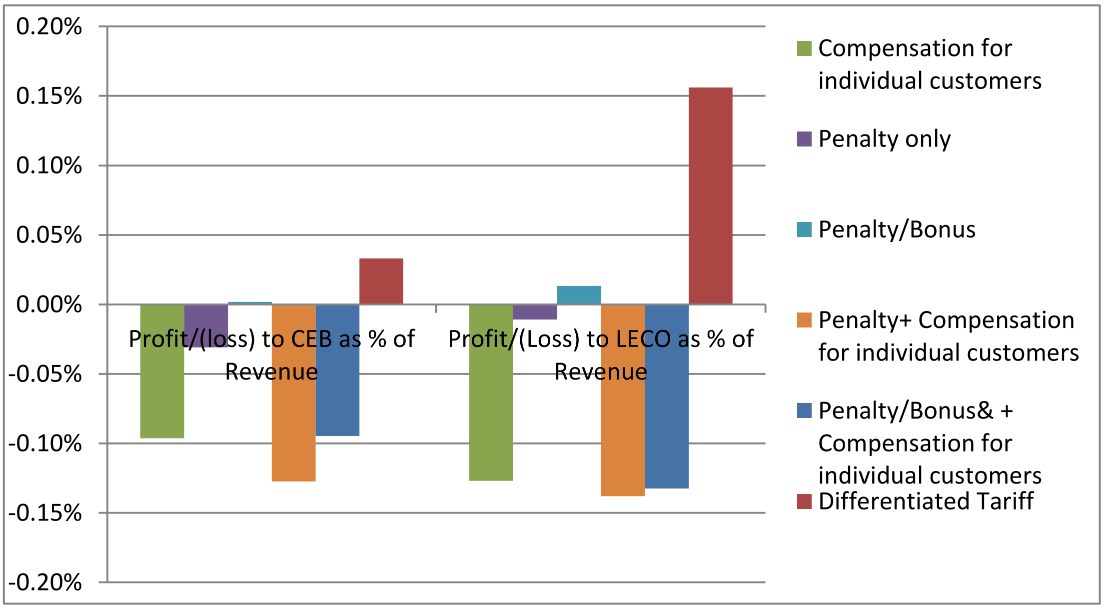

Figure 7-1: Comparison of Financial Implications

[1] Total Transmission revenue 65,256 Mil LKR, adjusted for LECO sales only(7,453 Mil LKR)
[2] The % reduction in tariff depends on the reliability of the living area. There is a % increase in tariff in high reliable areas.

Table 7-1 shows the summary of the financial implications under each incentive mechanism. Figure 7-1 shows the graphical representation of the same.

Under all methods, the estimated financial implications on the utility are about 0.15% of the total revenue of the Utility and hence, the financial losses/ profits to the utility are within the internationally adopted levels of revenue at risk based on the overall reliability (1%-2%).

The estimated loss to LECO, based on implementation of, reliability regulations in DPSR-SL is 0.14 % and the estimated loss to Transmission Licensee is 0.13% of the total revenue. Hence, the implementation of Reliability regulations in DPSR-SL will not significantly adversely impact on the utilities.

The losses to CEB and LECO can be further brought down to 0.09% and 0.13%, respectively, if the two way incentive method (penalty or bonus method) is used to provide incentives on overall reliability.

A significant part of the revenue losses to the utilities are due to payment of compensation to individual customers, compared to overall performance incentive methods. It is more than 0.1% out of 0.15% when the two methods are implemented in together.

Under differentiated tariff mechanism, in LECO areas, both Transmission Licensee and LECO has earned profits.

However, it is to be noted that the above financial implications are depend on the reliability targets and reliability cost use for the calculations. The mechanisms are morefully described in discussion section below.

7.2. Discussion

7.2.1. Individual Compensation Mechanism

Percentage loss to Transmission Licensee due to individual compensation is 0.1% and percentage loss to the LECO is 0.13%. Form Table 7-1 and Figure 7-1, it can be observed that, individual compensation has caused a higher loss compared to overall performance based incentive mechanisms. For the calculation of individual compensation under this study, individual SAIDI targets were set equal to overall performance targets. However, internationally, individual targets are set looser than the overall targets. Hence, by varying the target level, the regulator can control the loss to the utility.

It is to be noted that the above individual performance based incentives are calculated using the method specified in the Sri Lanka DPSR. This method is less understandable to customers and also requires a lot of administration work as every year, supply cost and performance targets for each and every customer need to be identified separately for 11 different indices. This may lead to customer disputes with utilities as well. However, internationally most popular practice is GSL mechanism, where, both rates for payment of compensation and targets are specified in the regulatory instrument.

7.2.2. Penalty Only Mechanism

Since, penalty is charged based on the overall performance of the utility, the method should be used in combination with a programme to compensate individual customers. Hence, when analyzing the financial implications on the utility, the total financial implication, due to penalty and individual compensation need to be considered.

Hence, with penalty for overall performance, the total loss to the Transmission Licensee increased to 0.13% and loss to LECO increases to 0.14%. The losses stay within the limits of revenue variations used in other countries (eg. Philippine:+/- 2.5%, Australia: +/- 2%). However, the total losses are also dependent on the unit rate of electricity (SUUPLYCOST) and the performance targets used for the calculations. The regulator can control the losses to the utility by controlling the values use for *SUPPLYCOST* and performance targets. For example *SUPLLYCOST* can be determined based on a certain percentage of allowed revenue such that the maximum possible losses to the utility will be that amount.

However, the penalty only method has the major disadvantage that the method does not provide an incentive for utilities to improve the performance in already reliable areas. That means, the utilities will be focused on marginally achieving the performance targets and not to outperform the targets. When the performance of a certain utility is close to the target level, the utility resist investing on reliability improvement as it does not give a return to the utility. Further, the method has the disadvantage of low fairness on customers as due to the uniform national tariff system, the penalty charge on the utility (revenue reduction) is shared among all the consumers in Sri Lanka and even the customers in highly reliable areas, will get benefitted from this.

7.2.3. Penalty or Bonus Mechanism

Under this method also, when analyzing the financial implications on the utility, the total financial implication, due to both penalty/bonus and individual compensation need to be considered.

Hence, with penalty for overall performance, the total loss to the Transmission Licensee due to payment of compensation has reduced to 0.9% and losses to LECO stays at 0.13% (insignificant profit). The losses stay within the limits of revenue variations used in other countries (eg. Philippine:+/-2.5%, Australia: +/- 2%). However, penalty/bonus method has caused the utility more revenue neutral. Similar to 7.2.1, the total losses are dependent on the *SUPPLYCOST* used for the calculations as well as the target set by the utility. The regulator can control the losses/profits to the utility by controlling the value use for *SUPPLYCOST* or the performance targets. For example the SUPPLYCOST can be determined based on a certain percentage of allowed revenue.

Further, due to the payment of bonus, it encourages utilities to perform even above the target performance. The method has this advantage compared to penalty only method. Also, under this method, the utilities become more revenue neutral and hence, more protects the financial interests of the utilities. Also, this is the method widely used internationally. However, due to the uniform national tariff mechanism in Sri Lanka, this method also has the disadvantage of lower fairness to customers.

7.2.4. Differentiated Tariff under Joint Pricing Model

Under joint pricing model, a customer live in Kotte branch area, due to the SAIDI and SAIFI levels above the targets, requires to pay 0.2% higher tariff than the average tariff. Where a customer living in Galle area, where both actual SAIDI and SAIFI levels are below the target levels, requires paying the tariff 0.1% lower than the average tariff.

Further, under this method, both CEB and LECO receive an overall profit (compared to the overall loss under all other methods). This is because, even though the utilities has outperformed the SAIDI targets and lag behind SAIFI targets, the weights calculated under Joint Pricing Model (Table 6-25), has assigned higher weight for SAIDI. Further, these profits (CEB- 0.033% and LECO 0.156%) are within the internationally used 'revenue at risk' levels.

Moreover, the tariff rates of individual customers depend on the reliability level of their area, hence, this method is not required to be implemented together with a programme to compensate individual customers. Further, the method provides incentives for utilities to improve the performance in low reliability areas as well highly reliable areas. Also, the method eliminates the disadvantage of low fairness due to the Uniform National Tariff.

For this study only 2% of the revenue components of the utility that directly related to reliability are varied based on the reliability performance (Section 6.4.4.1). The incentive level and the impact on the customers can be controlled by the regulator by changing this percentage.

Hence, compared to other methods joint pricing model stands superior. Also, administration cost will be lower compared to individual compensation payment methods. However, due to the low understandability of the method, this may be less acceptable to customers. Further, no international examples were available for this method.

8. RECOMMENDATIONS

Based on the international best practices as well as considering the level of incentives it provides for the utilities, the best method for providing incentives for overall performance improvement is to provide a bonus for achieving the performance targets and a penalty for not achieving the targets. However, since, the mechanism included in the DPSR is penalty only method, it is recommended to implement this method as an initiative and transform to penalty and bonus method, eventually.

Internationally most popular practice for compensating individual customers is GSL mechanism, where, both rates for payment of compensation and targets are specified in the regulatory instrument. The mechanism given in the DPSR for compensation of individual customers (case by case determination by the formula) is a complicated method and less understandable to customers. Hence, similar to GSL mechanism, having predetermined hourly rate (which is more understandable than kWh rate to customers) is recommended. For example if the duration of interruptions to customer exceeds 30 Hrs per year, the customer to be paid for each hour at rate of 100LKR. For this, without amending the regulations, in the compensation formula, $C_i^{CUST} = \sum_{j=1,J} ID_{i,j}^{CUST} \times \frac{YearEnergy_i}{8760} \times SUPPLYCOST$ (Section 3.1.4) a single hourly rate can be introduced for the expression, $\frac{YearEnergy_i}{8760} \times SUPPLYCOST$.

Internationally accepted method for setting reliability targets (specially in the first regulatory period, where reliability incentive scheme is introduced) is based on past 3-5 years average performance of the utility. Given that even at present most distribution utilities in Sri Lanka do not calculate the reliability indices, by the timeline given in the DPSR (June 2019), credible data for at least 3 years will not be available. Hence, it is recommended to the PUCSL to monitor the performance indices reported by the utilities for at least 3 years, prior to implementation of the incentive mechanisms specified in the DPSR.

It is recommended to set a maximum value for the penalty charge on the utility based on the overall performance (eg 1%-2% of the revenue), therefore the financial interests of the utility is protected. Also based on the performance of the utilities, the regulator can vary this maximum value. Eg, Higher percentage for poorly performing utilities.

Since significant amount of revenue loss is caused by individual compensation, it is recommended to set individual performance targets looser than the overall targets. For example, target interruption duration level for individual customers to be set 2-3 times higher than the equivalent overall reliability targets.

It is recommended to pay the individual compensation based on the cost of unserved energy, calculated based on a Customer Willingness to Pay (WTP) Study (market survey on how much customers are willing to pay for high reliability Understanding the value of reliability to customers). It can also provide the information needed to determine whether or not a distributor's allowed revenues reflect acceptable levels of reliability or if customers would be willing to pay more if reliability was enhanced.

In the DPSR, the formulas for calculation of SAIDI and SAFI based compensation (Section 3.5.1) is based on the amount of energy the utility failed to deliver (ENS) due to not achieving the SAIDI or SAIFI targets, respectively. The DPSR identifies ENS also as a separate index for calculating the compensation. Hence, adding up the compensation based on SAIDI, SAIFI performance and ENS performance causes, penalizing the utility twice for the same area of performance. Therefore, it is recommended to introduce a weighing system based on the relative importance of the each index on the customer reliability.

It is recommended to eventually, introduce 'S Factor' (eg. Philippine, Australia) to the Revenue Control Formula, similar to the 'X factor for efficiency' in the present revenue control formula (refer Sections, 2.2.5 and 2.3.5)

9. FUTURE WORK

This study does not cover commercial quality and power quality regulation mechanisms, which is equally essential part of the quality of supply. DPSR and also the countries studied under Section 2 also include incentive mechanisms for power quality and commercial quality. The same approaches identified in this study can be used to identify the impact of power quality and commercial quality regulations. However, in order to get an idea about the financial impacts on the utility due to their quality related performance, the impacts under power quality and commercial quality are required to be studied.

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