DISTRIBUTION SYSTEM RELIABILITY ASSESMENT AND TECHNIQUES FOR IMPROVEMENT.

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by

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DECLARATION

The work submitted in this dissertation in the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree and is also not being concurrently submitted for any other degree

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Prof. Ranjit Perera

ABSTRACT

Although reliability indices were introduced in the past as Key Performance Indicators to gauge the activities of electricity utilities, reliability studies on electricity network are rarely carried out to determine what improvements can be made in the future. The data collected in the past has been only used for manual calculation of reliability indices in the various operating divisions with no attempts made to study & effect improvements based on them.

This study focused on the following,

- A study of the sustained failure indices such as SAIDI & SAIFI making use of the SynerGEE software package for medium voltage distribution network, as an initial computation of indices.

- Comparison of the results with values for reliability indices obtained in practice using past data from operating divisions & their system control centres in the CEB.

- Identification and selection of mitigation techniques in Kalpitiya that is a heavily salt polluted area of the North Western province of Sri Lanka.

- Analysis of the effectiveness of the selected mitigation techniques to improve the reliability level in the Kalpitiya area and a financial analysis to justify the viability of the project.

- Proposing methods for reliability improvement, such as better maintenance practices, policies, augmentation of lines and improvement of switching arrangements.

The tool available in the SynerGEE software package for reliability calculation in the distribution network has not been used effectively in the past for calculations and mitigation planning purposes due to unavailability of proper data base.

In this study the SynerGEE software package has been used to calculate the sustained failure indices such as SAIDI and SAIFI for the medium voltage distribution network of the North Western Province initially with mitigation techniques applied. Further it is recommended that similar studies are conducted in other areas of the CEB as well and techniques applied to critical regions with much benefit to be derived in the future.

ACKNOWLEDGEMENT

First I thank very much Prof. Ranjit Perera without whose guidance, support and encouragement, beyond his role of project supervisor this achievement would not be end with this final dissertation successfully.

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LIST OF ABBREVIATIONS

AAC- All Aluminum Alloy Conductors

ABS- Air Break Switch

ACSR-Aluminum Conductor with steel reinforcement

AR- Auto Reclosure

CAIDI-Customer Average Interruption Duration Index

CAIFI-Customer Average Interruption Frequency Index

CSC- Consumer Service Centre

DDLO- Drop Down Lift Off

DGM- Deputy General Manager

GDP- Gross Domestic Product

GSS- Grid Sub Station

HT - High Tension

LBS- Load Break Switch

LT - Low Tension GSS- Grid Power Station

NWP- North Western Province

PSS- Primary Substation

SAIDI-System Average Interruption Duration Index

SAIFI-System Average Interruption Frequency Index

SIN-Substation Identification Number

SIR -Silicon Rubber

CONTENTS

Annexure

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

The reliability studies on power systems are very important in order to take decisions to develop & rehabilitate the power system to produce a satisfactory service to customers. Much consideration has been given in all countries to improve the reliability of power systems since it has an immense impact on economy of each country. A reliability study committee was appointed several years ago to study and recommend measures to be taken to improve power system reliability & power quality in the Ceylon Electricity Board (CEB) which is the main electricity utility responsible for most of Generation, Transmission & most of distribution of the electricity in the country.

Based on the recommendation of the committee the monitoring of reliability indices, System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average Interruption Duration Index (CAIDI) & Customer Average Interruption Frequency Index (CAIFI) were started at the provincial level by the system planning engineers. However, due to various reasons this attempt to monitor the reliability indices was not successful.

The required data relevant to the failures were recorded in registers at the Distribution control centres that carried details of power outages & scheduled interruptions along with their reasons. However these data are not used for reliability improvement due to improper data recording, inaccurate data etc.

Thus this indicates that extensive work has to be carried out in the future to improve the scheduled maintenance programme to reduce the supply breakdowns and to enhance protection and fault isolation techniques with proper identification of the fault rectification and supply restoration. The objective was to minimize the losses due to unserved energy at the same time improving the service to customers.

There are two major approaches to reliability assessment and prediction:

1.2.1) Traditional methods based on probabilistic assessment of field data.

1.2.2) Methods based on the analysis of failure mechanisms and physics of failure.

This study is particularly based on the 2nd method which is more accurate and useful for failure analysis and finding reasons for failures. The SyenerGEE software package used in this study is also based on the 2nd Method.

The study has been confined to the North western Province (NWP) of the CEB and it includes calculation of the sustained failure indices SAIDI & SAIFI aimed at estimating the reliability to customers in the province

In this project, failure rates and equipment repair times were calculated based on the previous data collected from the provincial control centre of NWP for 2 years and failure rates and equipment repair rates that were calculated for each consumer service centre individually. It was observed that it is fair to calculate them individually due to the following reasons.

Failure rates for the equipment heavily depend on

- geographical location of installation
- Effectiveness of the mitigation techniques
- Influence of the animals such as birds, Monkeys and reptiles
- Skill & Attitudes of the maintenance staff

1.2 Motivation

The outcome of this reliability study will develop a methodology to evaluate reliability indices such as SAIDI, SAIFI & MAIFI using the SynerGEE software. They can be used as guidelines for proper planning of network expansions, maintenance schedules and operating policies. As a distribution planning Engineer of CEB, the author was motivated to select this topic for her study due to above facts.

The concept of reliability is considered as one of the priorities of Electricity utilities in order to improve customer satisfaction. The reliability improvement will help industries and the national economy attracting more investors participating in production process leading to employment generation in the country.

1.3 Objective

The objectives of this study is to,

- Calculate the reliability indices using SynerGEE software package for NWP and compare them with the manually calculated values based on the actual failures recorded by the Distribution Control Centre
- Estimate the effectiveness of mitigation techniques
- Make the recommendations for the reliability improvements

1.4 Scope of work

SynerGEE software package has been used in the CEB for more than 4 years and tools are available to calculate the SAIDI & SAIFI reliability indices although these tools have not been used effectively for the network planning. Tools available in SynerGEE to analyse the system reliability have been studied and it is required to carry out the following activities to run the reliability option in SynerGEE software package.

Following activities are carried out to model the network and to perform the reliability study using SynerGEE Software.

(1) Updating MV distributions maps of North western Province.

(2) Data collection- Equipment failure data , number of consumers for each substation, MV Failures and their causes, data required to calculate failure

rates for exposure Zones & to calculate the effectiveness of mitigation techniques.

(3) Data analysis and calculation-categorized the data to calculate the failure rates and repair time for the equipments

(4) Modelling the MV distribution network in SynerGEE and assigning the failure rates and their repair time to the switch gear.

(5) Assigning in put data to digitized model

- Input data for equipment
- Input data for substation transformers
- Input data for exposure/mitigation zones

(6) Run the Reliability Analysis in SynerGEE.

(7) Proposing reliability improvements to network.

1.5 SynerGEE Software Package.

Reliability is one of a tool available in SynerGEE Software Package to estimate the power system reliability [8]. SynerGEE Reliability is a comprehensive package to aid in the simulation and analysis of distribution system reliability. Delivered on the SynerGEE platform, it is a powerful tool for investigating root-cause and configuration effects on system and customer level reliability.

SynerGEE Reliability brings you the following features and characteristics:

• Zone-based failure rates, repair times, and repair costs with provisions for single- or three-phase lines

• Use of failure rates based on historical outages

• In depth root-cause analysis

• Comprehensive and detailed switching models

• By-phase analysis

• By-cause analysis

• Sectionalizing, reclosing, pickup

• Capacity evaluation

• Unlimited and customizable causes
• Failure rates by category and subcategory
• Mitigation over multiple subcategories
• Comprehensive contingency-based interruption, switching, and pickup plans
• By-phase analysis and results reporting
• Handling of automatic switches and auto-transfer switches

Reliability metrics indicate how well a utility serves its customers. More specifically, they indicate the value that customers realize through their current service. Since quality of service is basic to the long-term health of any utility, reliability metrics are a fundamental concern of engineers, managers, and executives alike. These metrics often affect financial decisions related to long-range and business planning. In addition, as movements toward deregulation and open competition continue, issues of distribution system reliability become even more important.

Chapter 2

Distribution System Reliability in NWP of Sri Lanka.

2.1 North Western Province (NWP)

NWP comprises of Puttalam and Kurunegala Districts. For administration purposes the NWP is divided into 19 AGA divisions. The total land area is 7756 sq. km. The total population in 2004 is 2.18 million. North Western province is one of the fastest developing provinces in Sri Lanka. Where Sri Lankan transport network is concerned many routes linking Northern and Central provinces with the city of Colombo pass through the NWP. As a result the province has a fast economic growth and geographical diversity that has promoted different type of industries established within the province. Agriculture is the main income generator of NWP. Paddy and Coconut based industries are very common. Since the western boundary is demarcated by the sea, several fishery based industries and salt extraction industries have been established over the past. Tourism is a key industry in the coastal belt from Wennappuwa, to Kalpitiya. Several historical ruin kingdoms such as Paduwasnuwara, Yapahuwa etc. and large lakes such as Magalle, Thabbowa etc. and Wilpattu national park are some of the tourist attraction in NWP. Few industries based on minerals such as clay, sand and graphite are located at certain parts of NWP. Large-scale manufacturing industries are established at several Free Trade Zones located at Makendura, Badalgama and Polgahawela. Hence, NWP is providing high contribution for the economic development of Sri Lanka. GDP contribution from NWP is 231,975 million Rupees [13]

2.2 Electricity Distribution Network of NWP

MV network of NWP is fed by five 132/33kV Grid Substations located at Puttalam, Madampe, Mallawapitya, Bolawatta and Thulhiriya. The map of Electricity Distribution Network of NWP is given in Annexure 2.1. The MV distribution is mainly carried out at 33kV except at Kurunegala city limits and coastal belt of Wennappuwa and Chilaw areas. To facilitate medium voltage distribution and to improve the supply reliability of distribution net work in Kurunegala City is carried out at 11kV. In the costal areas designed for 33kV overhead lines are energized at 11kV to minimize the frequent failures due to salt contamination on line insulators. Bare Aluminum conductors ACSR or AAC is used for MV distribution. 33kV distribution is done with Lynx or ELM double circuit express lines from grid substation up to gantries and several Racoon distributors are used from gantries to the distribution transformers. At gantries Auto reclosure are connected to avoid entire feeder tripping due to transient faults. Air break switches are used to sectionalize the MV circuit. Over current and earth fault protection is provided at Grid substation for 33kV feeders. At mid points of MV lines, DDLO switches are used to ensure the isolation of the exact section during the faults. The distribution facilities of NWP MV network are presented in Table 2.1.

Table 2.1: MV distribution facilities at the end of 2006

Item	Unit	Available Installed Quantity
LBS / ABS	Nos.	165
Auto Re-Closure	Nos.	31
Primary S/S Man/Unman	Nos.	01/15
Gantry	Nos.	17
Boundary Meter	Nos.	12
Capacitor Bank	Nos.	5
Distribution S/S i. 33kV LT ii. 11kV LT	Km	 1913 300
33kV O/H	Km	2711.5
33kV U/G	Km	0.12
11kV O/H	Km	275.4

The LV distribution system is 400V, 3 phase, and 4-wire. Bare Aluminum conductors are commonly used for LT distribution but insulated bundle conductors are also used in highly congested areas. Distribution transformer capacity is not allowed to exceed 160kVA other than city in limits. Maximum LT feeder length is limited to 1.8km to ensure the stipulated voltage at the feeder end.

MV and LV network details of each NWP Area is presented in Table 2.2

Table 2.2: Network Details of each Area at the end of year 2006 [4]

Area	Consumers	Substations	LT lines/km	HT Lines/km
Kuliyapitiya	101288	440	3365	547
Kurunegala	95065	458	2207	532
Chilaw	98034	592	4121	891
Wariyapola	77638	390	2866	769
Wennappuwa	61525	333	1284	248
Total	433,530	2213	13843	2987

2.3 Reliability Assessment for NWP Province

Distribution Planning group of region 1 of CEB has started collecting data related to LT & HT break downs failures since 2005 and data are currently available to evaluate reliability of HT network system in NWP. Distribution planning group of region 1 has given a quantitative assessment of outages and sufficient attention has been given to reliability related issues.

To collect the failure data of the distribution network, Provincial Control centre has been established in September 2004 at the DGM (NWP)'s office. The main objective was to monitor and analyse the daily performance of CSCs and thereby improving the supply reliability. Data have been taken from the Distribution Control Centre of NWP for the analysis given below.

Table 2.3 shows the summery of the annual average events occurred during year 2005 & 2006 in NWP.

Table 2.3: Summery of the annual average events -2005 & 2006

	Outage Type	Events Recorded	Effected Consumers	Consumer.hours Lost
1	HT Feeder tripping	77	744807	1561427.9
2	HT Breakdown	212	199001	492505.4

3	Interruptions	59	104739	526934.8
4	LT Breakdowns	2151	70855	341266.9

Definitions for the above mentioned outage types are given below

HT Feeder Tripping - Entire HT feeder is tripped from the Grid substation.

HT break down-HT breakdowns in MV distribution.

Interruption- Scheduled interruptions in MV distribution system.

LT breakdowns- Breakdown in low voltage distribution network.

For the purpose of easy analysis recorded events, affected consumers and Consumer hours lost are pictorially presented in Figure 2.1, Figure 2.2 and Figure 2.3 respectively.

Fig 2.1: Analysis of recorded outages

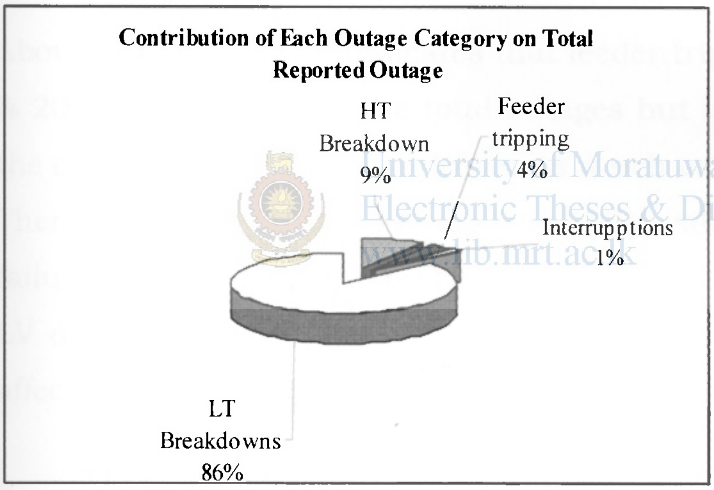


Fig.2.2: Percentage of effected consumers due to different outage categories

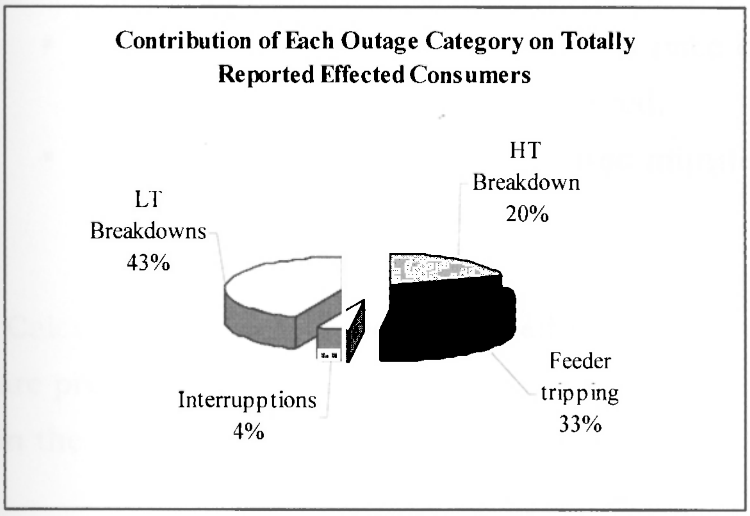
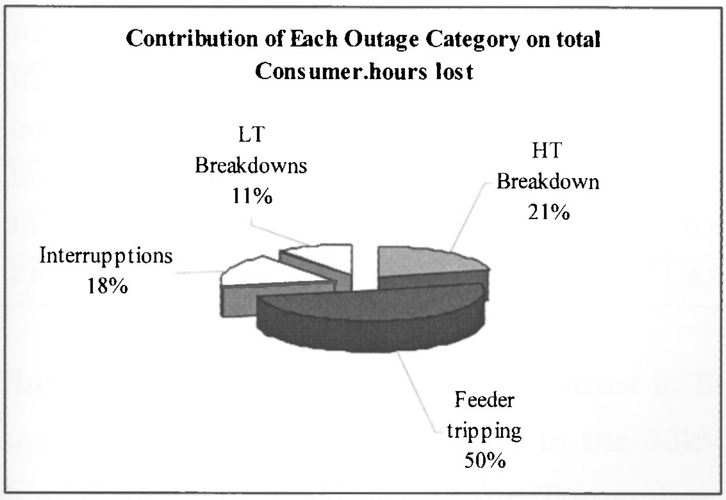


Fig:2.3: Percentage of consumer.hours lost due to different outage categories



Above analysis clearly indicates that feeder trippings reported for year 2005 & 2006 are only 4% of the total outages but it affected as many as 33% of the consumers resulting in losses as much as 50% of the consumer hours. Therefore the main contribution to SAIDI values was from HT breakdown failures as the 33kV and 11kV outages affected thousands of customers. LV outages have limited impact and only a few hundred customers were affected by them.

2.4 Reliability Indices for Year 2005 & 2006

a) Assumptions

Reliability indices are calculated based on the following assumptions:

- Individual breakdowns related to service connection i.e. service wire, meter or cut-outs are not considered.
- Feeder trippings of less than three minute duration due to transient faults are not considered.

Calculated reliability indices based on the assumptions mentioned above are presented in table 2.4. The definitions of the reliability indices are given in the Annexure 2.2

Table 2.4: reliability indices of NWP network for year 2005 & 2006

	Reliability Indices					
	SAIDI/hrs	SAIFI	CAIDI	CAIFI	CIII	ASAI
HT Network Breakdown	53.2	11.8	4.5	0.0007853	1273	
HT Scheduled Interruptions	13.3	1.0	13.1	0.0008739	1144	
Entire HT Network	66.4	12.8	5.2	0.0007923	1262	99.2
LT Network	8.1	9.8	0.8	0.006466	155	99.9
Entire NWP Network	74.5	22.6	3.3	0.0032496	308	99.1

The generation and transmission failures in Sri lanka are relatively seldom and more frequent failures occurs in the 33kV MV distribution system and downwards. Table 2.5 shows the Transmission & medium voltage failure contribution to SAIDI & SAIFI indices in NWP for year 2006.

Table 2.5: Contribution from the transmission and distribution network to reliability indices

	SAIDI/hrs	SAIFI
Contribution from the transmission failures	12	1.1
Contribution from the Distribution failures	62.5	22.6

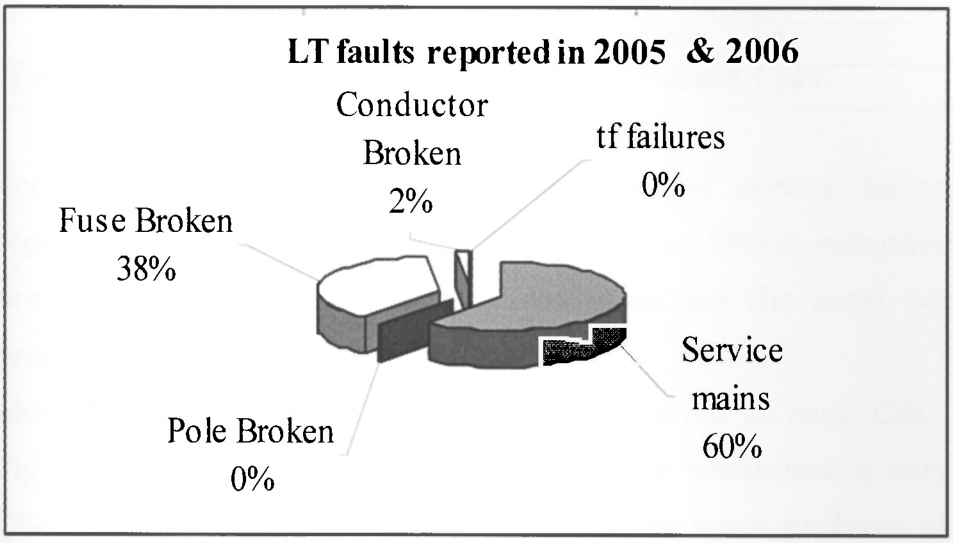
2.5 Causes for system outages

Summary of Average HT & LT breakdown reported to each CSC in the years 2005 & 2006 and judgements of CSC staff about the reasons for breakdown are given below. Apart from that feeder tripping details are also presented.

2.5.1 LT Breakdown details and identified reasons

Average Percentage distribution of LT system faults reported in year 2005 is shown in Figure 2.4

Fig.2.4: Analysis of LT faults



As shown in Fig.2.4, 60% of the reported faults are service main problems and 38% are due to the blown out fuses.

Table 2.6 shows the summery of average LT breakdowns reported to each CSC during the year 2005.

Table 2.6: Summery of Average LT breakdown details for year 2005 & 2006.

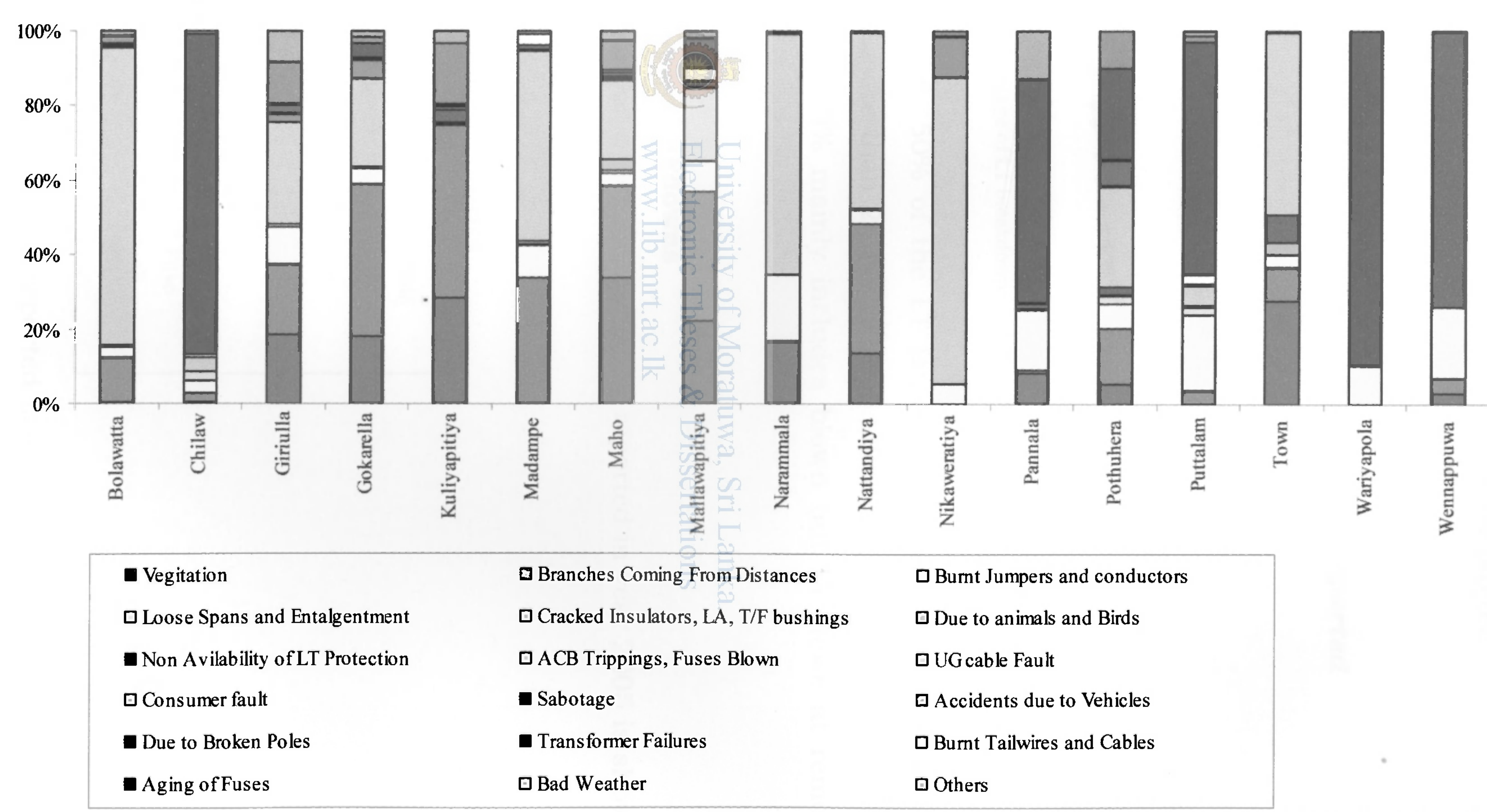
Area	**CSC Name**	**Service Mains**	**Pole Broken**	**Fuse Blown**	**Conductor Broken**	**Transf. Failures**	**Total**
Chilaw	Chilaw	5465	1	1410	27	1	6904
	Madampe	1527	6	724	34	2	2293
	Puttalam	5918	3	1367	54	3	7345
Kuliyapitiya	Giriulla	1516	55	1860	196	0	3627
	Kuliyapitiya	1873	16	2212	68	3	4172
	Narammala	1260	4	1562	44	0	2870
	Pannala	1741	11	1847	194	0	3793
Kurunegala	Gokarella	1764	8	2466	79	0	4317
	Mallawapitiya	1986	2	1720	4	1	3713
	Pothuhera	2125	3	1109	18	1	3256
	Town	2567	18	833	121	3	3542
Wariyapola	Maho	1615	10	998	26	1	2650
	Nikaweratiya	1678	2	882	53	3	2618
	Wariyapola	2133	6	1689	20	3	3851

Wennappuwa	Bolawatta	1311	6	913	22	5	2257
	Nattandiya	1421	0	1400	3	2	2826
	Wennappuwa	1738	8	949	4	5	2721
Total		***37638***	***159***	***23941***	***984***	***33***	***62755***

According to Table 2.6 massive number of service failures have been reported from Chilaw and Puttalam CSCs. When comparing with other breakdown categories service breakdowns are the most common type of breakdown.

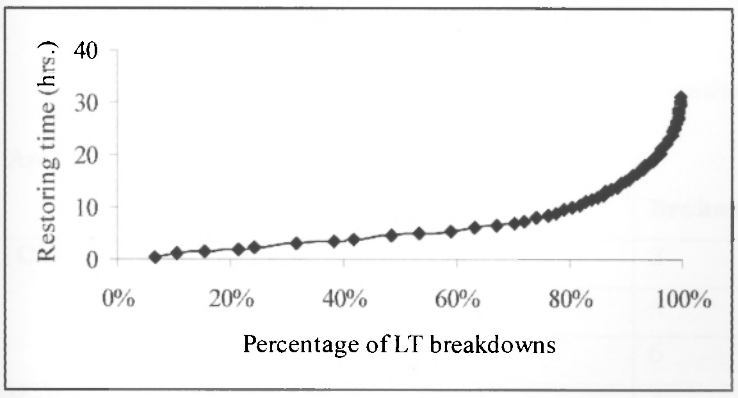
Identified reasons for LT breakdowns reported to each CSC are shown in Fig.2.5. It is observed that the reasons for breakdowns vary from CSC to CSC. As shown in Fig.2.5, way leaves is the main problem of LT failures of CSCs in Kurunegala and Kuliyapitiya Areas. However, aging of equipment installed in the network caused the large number of LT failures in Chilaw and Wennappuwa Areas. In average 66 numbers of LT fuses blow and 103 numbers of service breakdowns are reported in a day.

Fig 2.5 Identified Reasons for LT failures Reported to Each CSC



Fault clearing time vs proportion of total LT faults are plotted and shown in Fig.2.6.

Fig.2.6: Restoring time vs percentage of LT faults reported

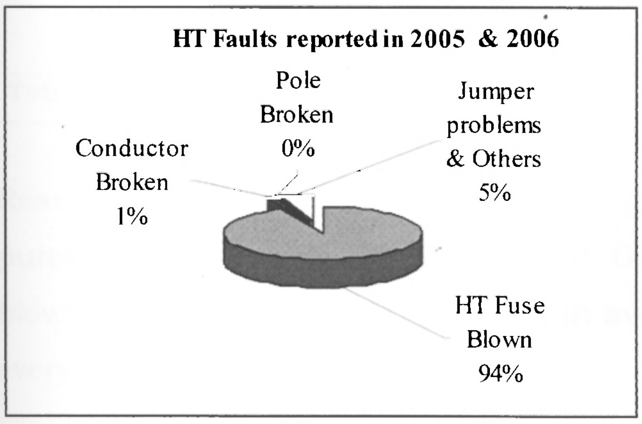


As shown in Fig.2.6, 50% of the LT faults are restored within 5 hours period. However, more than 24 hours were taken to rectify 20% of the LT breakdowns. These 20% mainly includes blown out LT fuses at remote locations.

2.5.2 Details of HT Breakdowns

Percentage distribution of HT system faults reported in year 2005 is shown in Fig.2.7.

Fig.2.7: Analysis of HT faults



As shown in Fig.2.7, 94% of the reported faults are due to the blown out fuses and 5% are caused by improper jumper connections etc.

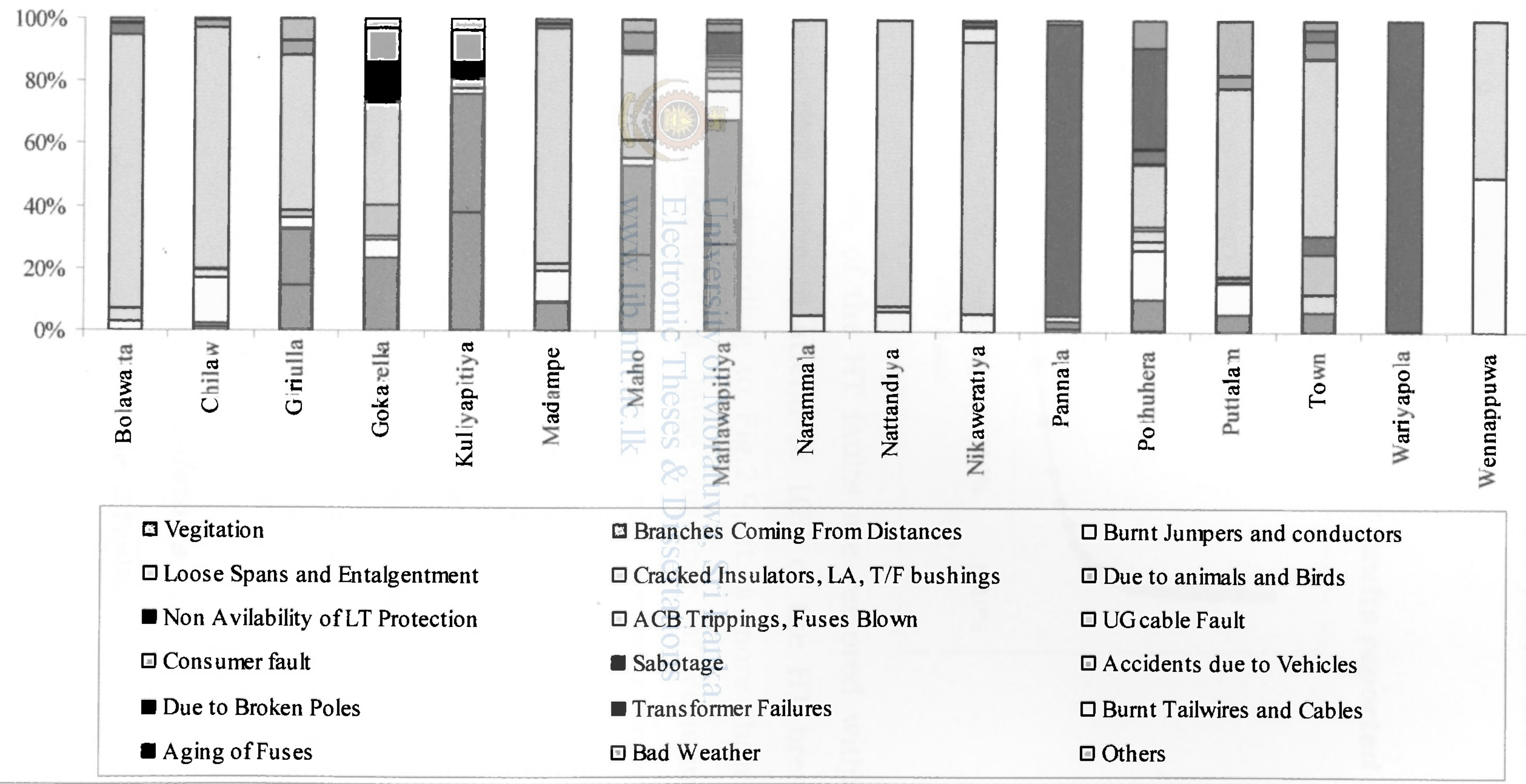
Table 2.7 shows the summery of average HT breakdowns reported to each CSC and deports during the years 2005 & 2006.

Table 2.7: Summery of HT breakdown details

Area	CSC Name	HT Fuse Blown	Conductor Broken	Pole Broken	Jumper problems and others	Total
Chilaw	Chilaw	129	3	1	5	138
	Madampe	95	4	0	3	102
	Puttalam	304	6	2	66	378
Kuliyapitiya	Giriulla	214	4	1	9	228
	Kuliyapitiya	126	9	0	8	143
	Narammala	111	0	0	1	112
	Pannala	152	1	1	2	156
Kurunegala	Gokarella	246	6	4	44	300
	Mallawapitiya	124	0	0	4	128
	Pothuhera	152	3	1	5	161
	Town	31	0	0	2	33
Wariyapola	Maho	137	1	0	1	139
	Nikaweratiya	129	1	0	0	130
	Wariyapola	318	0	0	4	322
Wennappuwa	Bolawatta	92	0	0	2	94
	Nattandiya	53	0	0	0	53
	Wennappuwa	38	0	0	1	39
Total		***2451***	***38***	***10***	***157***	***2656***

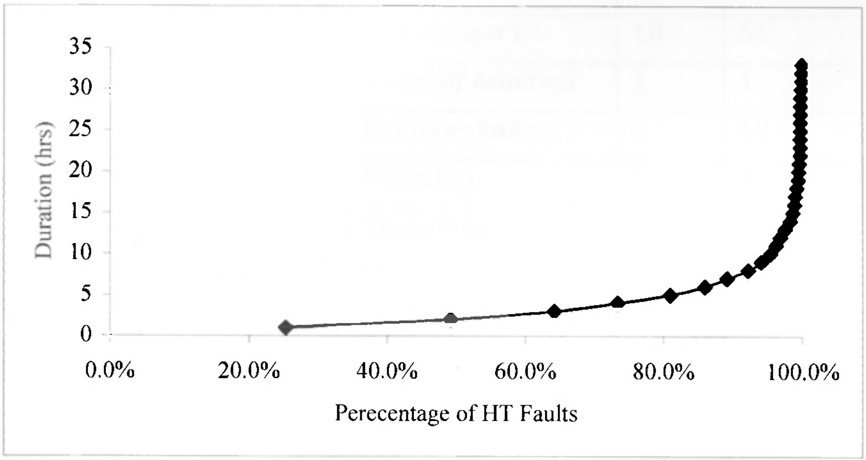
Reasons idenfied for HT failurers are given in illustrated in Fig.2.8. In puttalam, wariyapola, Gokarella and Giriulla areas, a large number of blown HT fuses events are reported in average about 7 HT fuses are blown everyday in 2005 & 2006.

Fig 2.8 Identified Reasons For HT failures Reported to Each CSC



Fault clearing time vs. proportion of total HT faults are plotted and shown in Fig.2.9

Fig.2.9: Restoring time vs percentage of HT faults reported



According to Fig.2.9, 80% of the HT faults are restored within 5 hours period. However, time taken to attend to 10% of the HT breakdowns is comparatively high and according to Fig.2.9, it is more than 10 hours. Since HT failures disconnect a large number of consumers, their contribution on reliability indices is very high. A proper program should immediately be launched to reduce the restoring time of HT faults.

2.6 Feeder tripping details

Table 2.8 shows the summery of average 33kV feeder trippings reported during year 2005 & 2006. The tripping data are enumerated under different fault categories in order to identify the possible reasons for feeder trippings.

Table 2.8: Summery of feeder tripping details

Grid	Feeder	Feeder Name	No of Faults			Manual
			OC	EF (Reclosed)	EF(Not Reclosed)	Tripping
Puttlam	F1	Chilaw/Kalpitiya	36	108	81	173
	F3	Palavi	0	3	14	32
	F4	Anamaduwa	20	52	222	85
	F5	Cement Fac.	1	3	7	14

	F7	Wanathawilluwa	0	0	9	6
	F8	Cement Fac.	2	5	9	12
Madampe	F1	Kuliyapitiya	11	18	260	63
	F2	Bingiriya	15	4	252	109
	F3	Chilaw	8	0	43	99
	F4	Nattandiya I	10	51	26	69
	F5	Voice of America	1	1	2	6
	F7	Keeriyankalliya	6	49	29	127
	F8	Buwalka	1	0	8	8
Bolawatta	F1	Madampe	13	0	13	44
	F2	Makandura	6	3	47	35
	F3	Voice of America	10	1	47	107
	F5	Bolawatta Primary	1	1	3	23
	F7	Pannala	14	160	31	43
Mallawapitiya	F1	Galagedara	25	226	40	66
	F2	Kurunegala Town	7	38	7	48
	F3	Polgahawela	53	9	80	61
	F4	Hiripitiya	16	196	122	44
	F5	Padeniya	40	284	59	29
	F7	Ibbagamuwa	5	143	59	24
	F8	Dodangaslanda	4	64	48	45
Thulhiriya	F1	Polgahawela BOI	1	17	2	10
	F2	Kurunegala	20	97	14	52
	F3	Pannala	17	108	9	33
	F5	Kuliyapitiya	22	96	9	53

Since the feeder lengths are different it is not reasonable to identify the worse feeders just by considering the no of tripping events. Hence, a fault rate (faults per year per 1km length) of each feeder has been calculated and presented in table 2.9 for the analysis to be done on a fare basis.

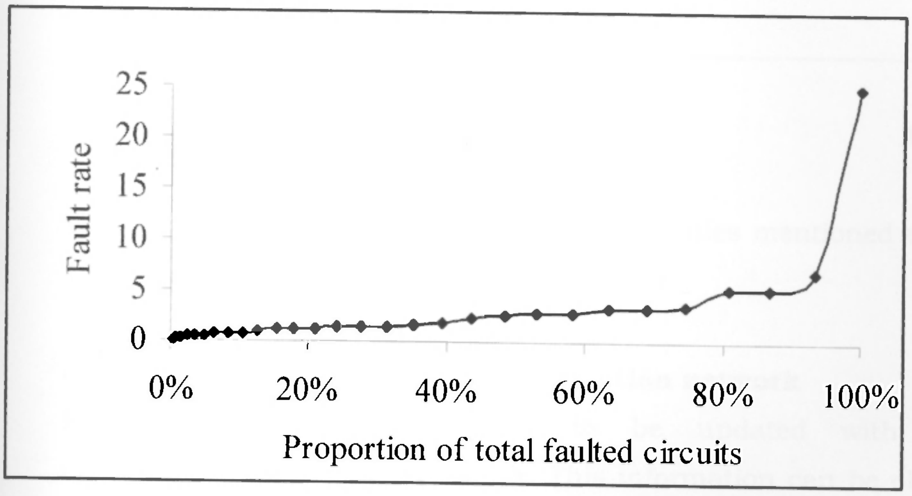
Table 2.9: Fault rate of each feeder

Grid	Feeder	Feeder Name	Feeder Length/km	Fault rate (Faults/km.year)	Rank
Puttlam	F7	Wanathawilluwa	90.9	0.099	1
Thulhiriya	F1	Polgahawela BOI	89.4	0.224	2
Puttlam	F3	Palavi	73.8	0.230	3

Puttlam	F4	Anamaduwa	636.9	0.462	4
Thulhiriya	F5	Kuliyapitiya	237.0	0.536	5
Madampe	F5	Voice of America	7.3	0.548	6
Madampe	F7	Keeriyankalliya	130.7	0.643	7
Mallawapitiya	F7	Ibbagamuwa	283.4	0.730	8
Bolawatta	F3	Voice of America	60.0	0.967	10
Mallawapitiya	F3	Polgahawela	121.3	1.171	11
Madampe	F1	Kuliyapitiya	246.4	1.173	12
Madampe	F2	Bingiriya	219.1	1.237	13
Madampe	F3	Chilaw	37.2	1.371	14
Bolawatta	F2	Makandura	39.9	1.404	15
Mallawapitiya	F5	Padeniya	249.3	1.536	16
Madampe	F4	Nattandiya I	49.2	1.768	17
Bolawatta	F7	Pannala	107.0	1.916	18
Mallawapitiya	F8	Dodangaslanda	48.0	2.417	19
Mallawapitiya	F4	Hiripitiya	124.5	2.683	20
Thulhiriya	F3	Pannala	46.7	2.869	21
Mallawapitiya	F1	Galagedara	98.1	2.966	22
Mallawapitiya	F2	Kurunegala Town	15.2	3.421	23
Puttlam	F5	Cement Fac.	3.2	3.438	24
Puttlam	F1	Chilaw/Kalpiti	61.7	3.647	25
Puttlam	F8	Cement Fac.	3.1	5.161	26
Mallawapitiya	F2	Kurunegala	24.8	5.282	27
Madampe	F8	Buwalka	1.3	6.923	28
Bolawatta	F5	Bolawatta Primary	0.2	25.000	29

The circuits which have fault rates more than 0.5 can be categorized as most unreliable circuits of the system. Special attention should be focused on maintenance and way leave clearance of these circuits to reduce the extremely high fault rates. Out of the worst circuits indicated in Table 2.9, it can be observed that Mallawapitiya F5-Padeniya 33kV feeder has tripped at least once a day.

Fig.2.10: Fault rate vs percentage of total circuits



Proportion of total faulted circuits vs fault rate is plotted for all 33kV distribution feeders and presented in Fig.2.10. It indicates that proportion of total faulted circuits of 75% is having more than 0.5 fault rate. Where breaker operations and supply reliability are concerned, the present situation is not satisfactory and it has to be improved without delay. A Large number of manual trippings requested by operation staff for load transfer has been indicated in Table 2.8. Even though the duration of manual trippings are very short they adversely affect all industries and a means should be found to eliminate them.

Chapter 3

Methodology

The methodology to carry out the main activities mentioned under clause 1.5 of this report is discussed in this chapter.

3.1 Updating the map of MV distribution network

Hard copy maps are needed to be updated with the latest changes/additions to the network. This information can be obtained from the system planning Engineer of NWP. This is required to model the network in SynerGEE exactly like the existing system. It is also required to have the latest updated map of the area printed by the Surveyor Department to identify the exposure zones, required mitigation techniques in the relevant part of the network.

Following data need to be recorded in the map updating process.

3.1.1 Recording of the line route on the map as accurate as possible.

3.1.2 Type of conductor (Lynx, Raccoon), Configuration of the circuit (vertical, horizontal, delta formation etc.) Number of circuits (Single, double, double line etc.) to be recorded.

3.1.3 All network switchgear items like Auto Reclosers, Sectionalizers ABS, LBS, & DDLO need to be recorded with their reference numbers and status (whether open or closed).

3.1.4 All distribution and bulk supply substations need to be recorded with their SIN.

3.1.5 Number of customers for every substation need to be recorded individually.

3.1.6 Network switching arrangements at Gantries, PSS need to be recorded.

3.2 Data collection

Data required to calculate the equipment failure rates, repair time and exposure Zone failure rates & repair time have been obtained from the DCC of NWP. The function of the DCC is described in 3.2.1.

3.2.1 Control Centre Functions

A performance report about daily functions of each CSC is collected by the control centre. The report format is given in Annexure-3.1. At section (a) details of LT failures are mentioned according to the type of breakdown. Similarly section (b) is for HT outages. CSCs should report whether all reported breakdowns have been rectified or if not the number of unattended breakdowns on that particular day. Section (c) is for scheduled outage information. Thereby outage period and affected sections are thoroughly supervised. Section (d) is to mention the ES's judgment of possible reasons for reported HT and LT breakdowns. The special incidents that happened during the particular day have to be mentioned at section (e) which describes about accidents, electrocution, over voltage incidents and so on. Details of the distribution network facilities damaged or repaired on the day have to be mentioned at Section (f) Section (g) is for information about new equipment energization.

Feeder tripping details and peak current flow on feeders have been collected from each Grid substation daily and recorded on the format given in Annexure-3.2. As shown in the format the time of fault initiating, the indication on relay panel about the type of fault, restored time and isolated area are recorded on it. In addition to that the information about manual tripping requested by NWP operation staff for load transfer or scheduled interruptions are also recorded.

At the end of the day control centre in charge has to prepare a summery report for DGM (NWP) that provides the system outage information of the entire province. The format of summery report is given in Annexure-3.3

All collected details are saved in an outage database prepared by the NWP planning division. The database consists of several data tables for different type of outages. e.g. LT breakdown, HT breakdown, feeder trippings, planned interruptions, equipment outages etc. For each outage the database contains the information about date, outage time, restored time, reason for outage as well as no. of consumers affected. The no. of consumers attached to each substation is updated once in a six months period.

Analyzing the available information the reliability indices, SAIDI, SAIFI, MAIFI, CAII, CAIFI are calculated in each month for the province as well as for individual CSCs and feeders. A detailed report is published in each month and it contains breakdown information and reliability indices calculated for LT and HT network for each CSC. Based on the available breakdown information the frequently repeating failures are identified and passed to the respective CSCs to carry out necessary maintenance activities.

Provincial Control Centre is the interface between CEB System Control Centre and CSCs of NWP. CSC staff always consults the provincial control centre for the most appropriate switching sequence for interrupting power supply to carry out immediate breakdown work or to face any contingency situation. At similar occasions, it is the duty of provincial control centre to acknowledge the CEB control centre about power interruptions and get the working approval to interrupt the feeder supply.

Apart from that the control centers is responsible for preparing the correct switching sequence and pass the relevant information to the operation staff at every time when network change is required.

Any abnormal happening in the net work such as electrocution, failure of equipment, accident, over voltage incidents etc control center should immediately inform to the related officers and prepare a channel to pass necessary information between the relevant parties.

3.3 Data Analysis & calculation

Data analysis & calculation can be devided in to 2 group as follows

3.3.1 Calculation of reliability for equipment

3.3.2 Calculation Exposure zone reliability and effectiveness of the mitigation techniques.

3.3.1 Calculation of reliability for equipment

All the HT breakdowns/failures recorded (Refer Annexure 3.4) at the Provincial Distribution Control Centres need to be analyzed and categorized to calculate the equipment failure frequency and repair time for Auto Reclosers, Sectionalizers, Air Break Switches, Load Break Switches & DDLOs.

Data such as pole breakdowns, Line conductor break downs due to way leaves and other failure data related to failure rates calculation & repair time for exposure zones need to be analyzed. These data is required to calculate the failure rate and repair time for the relevant exposure zones.

The accuracy of calculated failure frequency & repair time for the equipment & the failure rates for the exposure Zones are purely based on the accuracy of the data collected by provincial control centre & consumer service centre of NWP.

Breakdowns are categorized and tabulated in table 3.1 as follows:

Table 3.1: Break down categories

category	Type of failure
1	DDLO fuse blown
2	Air break switches /Load break switch operations and breakdowns
3	Auto Recloser trippings & breakdowns
4	Sectionalizer trippings & breakdowns
5	Other breakdowns (Conductors broken, Pole breakdown, jumper breakdown and etc.)

Data can be categorized individually for each CSC wise to calculate the annual failures rate & repair time for the equipment.

1. DDLO fuse blown

Data required for calculating the frequency of annual fuse blown and equipment repair time could be gathered from category 1. The method of calculating the failure rates and repair time for the consumer service centre is shown using the following example.

Example: In Wariyapola area at Nikaweratiya CSC there are 29 x 3 DDLO Switches in the MV network and an average of 72 fuse blown incidents are recorded for years 2005 & 2006. Annual average Total time duration taken for repairing the DDLO is 410 hours.

The equipment failure rates & failure repair time for the DDLOs existing in Nikaweratiya CSC are calculated as follows:

$$\text{Failure Rate} = \frac{F_{total}/Y_{total}}{N_{total}}$$

F_{total} = Total number of fuse blown failures in Nikaweratiya CSC

$N_{total\ DDLOS}$ = Total nmber of installed DDLOs in Nikaweratiya CSC

Y_{total} = Total number of years

$$\text{DDLO Annual Sustained Failure Rate} = 72/(29*3)$$

DDLO Annual Sustained Failure Rate = 0.82 / Year

Therefore Annual Failure Rate for DDLO fuses in the area under the control of Nikaweratiya consumer service centre of Wariyapola area has been taken as 1 f/year.

$$\text{Repair Time} = \frac{T_{AVG-duration}}{N_{total-incidents}}$$

$$\text{DDLO Annual Failure repair time} = \frac{410}{72}$$

$$= 5.69 \text{ Hours / Year.}$$

$T_{avg\text{-}duration}$ - Annual Average time taken for repairing during 2005 & 2006

N_{total} – Total number of incidents recorded during 2005 & 2006

Therefore repair time for DDLO fuses in the area under the control of Nikaweratiya consumer service centre of Wariyapola area is taken as 6 hours.

Same method has been followed to calculate the Annual equipment failure rates for ABS/LBS , Secctionalizers & Auto Reclosures using the data category 2,3 & 4 respectively while the data category 5 has been used to calculate the exposure zones failure rates and repair time. Calculated Result are tabulated in Table 3.2

Table 3.2 shows the generally assigned values for the model and following assumptions have been made in assigning the reliability indices for equipment,

- The repair time for the HT fuses installed with in the 0.5 km radius from the CSC is taken as 1 hour.
- The repair time for the HT fuses installed with in semi jungles & far from consumer service centres is taken as 8 hours.

Table 3.2 : Equipment failure rates and repair time assigned for the model

Area	CSC	Annual Fuse failure frequency	repair time hours	Annual LBS/ABS operation frequency	LBS/ABS repair time	Annual Sectionalizer /AR operation frequency	Sectionalizer /AR repair time
Chilaw	Puttalam	1	6	0.05	8	0.01	8
	Chilaw	0.5	6	0.05	8	0.01	8
	Madampe	0.5	6	0.05	8	0.01	8
Kuliyapitiya	Giriulla	1	6	0.05	8	0.01	8
	Kuliyapitiya	1	6	0.05	8	0.01	8
	Narammala	0.5	6	0.05	8	0.01	8
	Pannala	1	6	0.05	8	0.01	8
Kurunegala	Gokarella	1.5	8	0.05	8	0.01	8
	Mallawapitiya	0.5	5	0.05	8	0.01	8
	Pothuhera	1	6	0.05	8	0.01	8
	Kur. Town	0.5	5	0.05	8	0.01	8
Wariyapola	Mahawa	1	6	0.05	8	0.01	8
	Nikaweratiya	1	6	0.05	8	0.01	8

	Wariyapola	1.5	6	0.05	8	0.01	8
Wenna ppuwa	Bolawaththa	0.5	6	0.05	8	0.01	8
	Nattandiya	0.5	6	0.05	8	0.01	8
	Wennappuwa	0.5	4	0.05	8	0.01	8

3.4 Modelling the network using SynerGEE

SynerGEE Electric is the network analysis Software being used for Distribution Planning MV network needed to be modelled for analysis (feeder by feeder). In this process following points need to be noted [8].

3.4.1 Digitising MV distribution network of NWP model.

a) Scan map sheet (1:50,000 or lower scale rectified map sheet) need to be kept in the background. (Latest map is required for more accuracy of digitizing the network.)

b) Digitizing need to be initiated from the GSS/PSS and to be done outwards till the feeder comes across a provincial boundary or termination. (Refer the updated hardcopy map and follow down each & every feeder.)

All network switchgear items like, Auto Reclosures, ABS, LBS, DDLO, Auto Reclosures & Sectionalizers have to be installed in the digitized network model, in the way that they are physically existing in the network.

c) Since the number of customers per substation is assigned to sections in the model, it is better to have separate sections for separate substations.

d) Each section with number of customers (under Description) with the relevant SIN of the substation attached. If more than one substation is available, multiple SIN numbers are to be entered separating each other with a Comma. Total number of customers in all substations has to be considered as the number of consumers for the relevant section. This is helpful in assigning customers to the sections. Indicate the feeder name under section ID of each section to identify the feeder to which the section belongs.

3.5 Assigning in put data to the digitized model.

Input data can be divided in to 3 categories

a) Input data for the equipment

i) Annual Sustained Failure rates for equipment(f/year).

ii) Sustained Repair time for equipment(hr/year).

b) Input data for substation transformers

i) SIN for the substation.

ii) Number of customer for each substation.

c) Input data for exposure /mitigation zones

i) Annual breakdown frequency for the exposure zone.

ii) Equipment repair time for exposure zone.

iii) Effectiveness of the mitigation techniques.

a) Input data for the equipment

Annual sustained equipment failure rates & repair time are assigned to switchgears have been taken from table 3.2. As shown in the table it has been calculated for every consumer service centre.

b) Input data for substation transformers

i) Sin for the substation

Sin for the transformers is allocated in such a way that it is easy to identify the area and the consumer service centre where the substation transformer is installed.

Example : SIN -MW-001

First letter gives the name of CSC, Second letter gives the name of area.

Number indicates the allocated number for the substation transformer.

Table 3.3 shows letter allocation of SIN for the Areas & Consumer Service Centres.

Table 3.3: Letter allocation of sin number for the Areas & CSCs.

Area	CSC	ID No:
Chılaw (C)	Puttalam	PC
	Chilaw	CC
	Madampe	MC
Kulıyapitiya(K)	Giriulla	GK
	Kuliyapitiya	KK
	Narammala	NK
	Pannala	PK
Kurunegala (R)	Gokarella	GR
	Mallaw apitiya	MR
	Pothuhera	PR
	Kurunegal Town	RR
Wariyapola (W)	Mahawa	MW
	Nikaweratiya	NW
	Wariyapola	WW
Wennappuwa(P)	Bolawaththa	BP
	Nattandiya	NP
	Wennapuwa	PP

ii)Number of customer for each substation

There are two types of consumers

1. Bulk Supply Consumers.
2. Retail Supply Consumers.

In the case of the bulk supply, it was considered as one customer and Number of customer per substation is divided by 3 and that value is assigned per phase.

SIN and the number of customers assigned to the model is given in Annexure 3.5.

3.6. Reliability Analysis

After assigning the number of customers for each substation, Switchgear failure rates & repair time, failure rates of exposure zones and percentage of effectiveness of mitigation zones are assigned to network, the model is ready to "run" on the Reliability analysis process. As results reliability indices SAIDI & SAIFI are generated.

Once the reliability analysis for the model is run it shows the error messages & warnings to be rectified and on successful completion of the run, it shows the SAIDI & SAIFI feeder wise as well as for the whole system. It is compulsory to rectify the error massages while analysing the warning massages. SAIDI & SAIFI values have been obtained for the whole network or the part of the net work. These reports in SynerGEE can be easily copied to MS Excel/MS Word for easy report generation.

By this way the existing network is modelled and simulated to estimate the reliability of the network.

Exposure zone reliability and effectiveness of the mitigation techniques.

In this chapter the following two topics are discussed in detail.

4.1 Exposure zone reliability estimation.

4.2 Quantification of effectiveness of the mitigation techniques.

4.1 Exposure Zone reliability estimation

4.1.1 Exposure zone categories.

When the reliability of the system depend on the environmental factors such as the type of the weather conditions , way leaves and distance to the sea and geographical location such as Mountains and plains, then weighting factors should be applied to the net work for accurate reliability analysis.

MV network distribution system in Sri Lanka, according to their Exposure Zones can be categorized as follows.

i) Coastal area with sea breeze effect
ii) Coastal area without sea breeze effect
iii) General rural area
iv) Coconut Plantation
v) Thick Jungles
vi) Semi-thick jungles
vii) Paddy fields

i) Coastal area with sea breeze effect.

Corrosion effect due to the salty wind, in the equipment and aluminium conductors are very significant in this type of exposure zones. Kalpitiya & Hambantotha coastal areas fall in to this type of exposure zone.

ii) Coastal area without sea breeze effect.

Except Kalpitiya & Hambanthota area, other coastal areas in Sri Lanka come under this category. There is no sea breeze effect in these areas therefore the corrosion level of equipment and conductors, due to the salty environment is less severe compared to the zones with sea breeze effect.

iii) General rural area.

Most of the rural areas in NWP are coming under this category of exposure Zones. Average failure rates of the equipment and conductors can be observed.

iv) Coconut Plantation.

Some areas inside the coconut triangle come under this category. Conductor breakdowns and DDLO fuses blown are prominent in these areas.

v) Thick Jungles

Jungles with high grown trees and having many branches are classified as the exposure zones with thick jungle areas. Minneriya, Singharaja, Udawalawe areas are coming under this type. Auto Reclosure trippings , Load break swiches tripping are very significant in these areas and the equipment repair time is very much more than the average.

vi) Semi-thick jungles.

Jungles with bushes and average growing trees are classified in to this category. Some areas of Gokarella, Wariyapola and Nikaweratiya are coming under this category.

vii) Paddy fields.

Equipment failure rates and conductor breakdown rates are very low in these areas. Repairing of Equipment broken conductor breakdowns is much easier in these types of areas.

Once the exposure Zones are defined, annual failure rates and equipment repair time for the particular zones can be calculated.

It is required to have a very large number of accurate details in a data base to calculate the annual failure frequency rates and repair time for the exposure zone.

According to the IEEE standards it is required to have at least a 5 year data base to get the reasonably calculated reliability indices for exposure zones. Presently available data base does not produce sufficient information to calculate the zone failure frequency and repair time.

4.1.2 Method of calculating the reliability indices for exposure zones.

In this section calculation of reliability indices for the exposure zone categorized as coastal area without sea breeze effect is discussed in detail.

a. Calculation of Failure Rates & Repair Time for Exposure Zones From the Results of the Survey Carried out by the System Planning Group of NWP.

Questionnaire Prepared by the System Planning unit was distributed among the consumers in Wennappuwa area they were requested to monitor the MV failures for two years and fill the questionnaire. At the end of year 2006 the distributed questionnaire were collected from the consumers by the Wennappuwwa CSC . Questionnaire distributed among the consumers are given in annexure 4.1.

Total number of consumers in this zone is around 800 consumers and feed back was received only from the 242 consumers. The summarized results are given in table 4.1.

Table 4.1 – Summarize result of the survey

Average time taken to restore the power supply (Hours)	Frequency
0.5	1
0.75	1
1	7
1.25	8
1.5	8

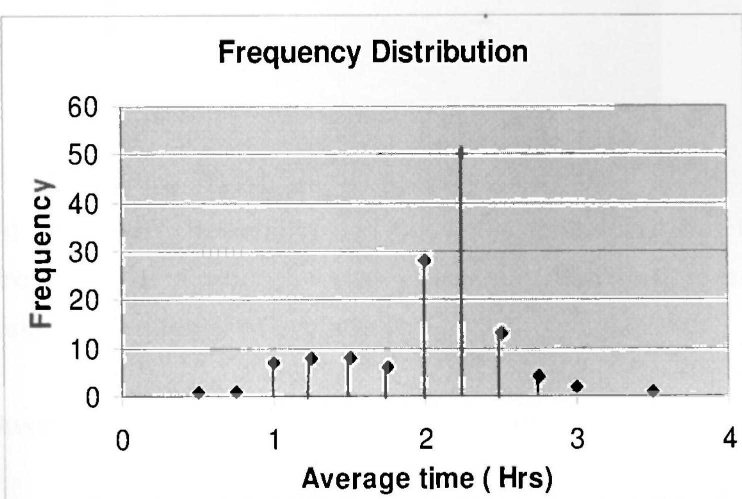
1.75	6
2	28
2.25	50
2.5	13
2.75	4
3	2
3.5	1

Details of the selected zone is given below,

- According to the reliability zone categorization this zone is identified as a reliability zone in coastal area without sea breeze effect.
- Total MV line length in this particular zone is 7.2 km.
- MV failure have been monitored for 2 years to calculated the failure frequency and repair time for the reliability zone -coastal area without sea breeze effect.

Summarized results given in table 41, are plotted as a frequency distribution as shown in figure 4.1 which pictorially represents the frequency of occurrence of MV power failures having the power restoration time between 0.5 hours to 3.5 hours .

Figure 4.1 : Frequency Distribution of MV power failure of the selected area.



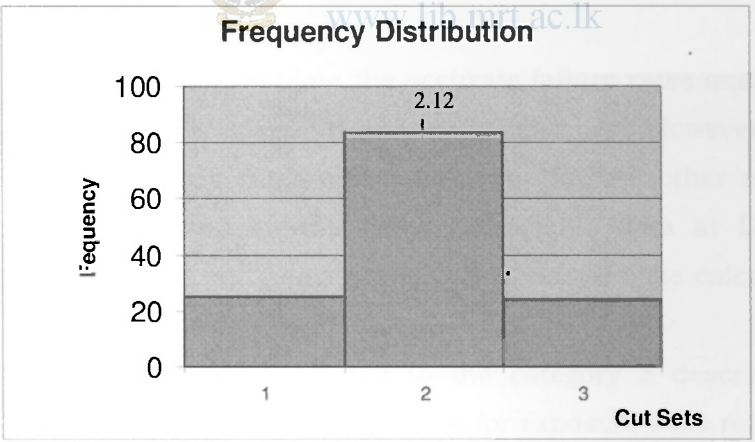
An alternative method of plotting this data is to group sets of data of approximately equal values together. This is convenient as the total number of data is very large and it reduces the amount to be manipulated and produces a pictorial representation that is easier to interpret. Therefore these data could be group in to the cut sets given in table 4.2. [1]

Table 4.2 Cut Sets of average time taken to restore the power supply

Cut Sets	Average Time Taken(Hrs)	Frequency
1	0.5-1.74	25
2	1.75-2.49	84
3	2.5-3.5	24

Frequency distribution of MV power failures against the cut sets are given in figure 4.2 in form of a histogram.

Figure 4.2 : Frequency Distribution of MV power failure of the selected area- Bar Chart



At this point probability has not been considered but this can be deduced from the data and the two frequency distribution using the concept of relative frequency of probability.

Average repair time for this particular reliability zone = 1.75+ (2.49-1.75)/2

= **2 .12 hours**

Therefore, the failure rate, repair time for coastal Zone without sea breeze effect is calculated as follows:

$$\text{Failure Rate} = \frac{F_{total}/Y_{total}}{L_{total}}$$

F_{total} = Total no. of failures

Y_{total}= Total number of years

L_{total} = Total length of MV distribution net work in the particular Zone

$$\text{Failure Rate} = \frac{3/2}{7.2}$$

Failure Rate = 0.21 f/yr per km

As per the figure 4.2

Repair Time = 2.12 hours / yr per km

It is possible to calculate the accurate failure rates and repair time for the other exposure zones in the same manner. However due to the time limitation failure rates and repair time for the other exposure zone were calculated based on the current available data at Distribution control centre and following assumptions are made in the calculation of reliability indices for exposure zones,

- Breakdowns belonging to the category 5 described under clauses 3.3.1 of this report are taken for exposure zone reliability calculation.
- If the duration of breakdown is extremely long due to unavoidable circumstances, the time duration of these type of breakdowns are not been taken into account.
- The practical experience of maintenance staff of the Consumer Service Centres is taken in to consideration.

Reliability indices calculated for different exposure zones are given in Table 4.3

Table 4.3: Reliability Indices for Exposure Zones

Exposure Zone	Failure frequency f/yr/km	Repair time hours / y
Coastal area with sea breeze effect	0.35	2.12
Coastal area without sea breeze effect.	0.21	2.12
General rural area.	0.10	2.50
Coconut Plantation.	0.35	2.50
Thick Jungles	0.25	6.00
Semi-thick jungles.	0.21	4.00
Paddy fields.	0.01	2.50

It is difficult to calculate the repair cost associated with breakdowns. If the detailed records are maintained for every breakdown, such as material cost and labour cost associated with the repair then it is possible to calculate the repair costs of the break down.

Exposure Zones are the tools using which the section failure can be applied to the model. Latest scanned map (1:50,000 or smaller) is put into the background of the model and it categorizes the sections according to their exposure Zones. Stored in the equipment database, an exposure Zone represents a present collection of failure data that can be applied directly to multiple sections, rather than applying an individual data set for each section. All sections assigned to a particular exposure Zone share common values for

- Sustained failure rate per set length of line.
- Repair time.

4.2 Quantification of effectiveness of the mitigation techniques [8].

From data perspective, mitigation Zones are similar to exposure Zones. A mitigation Zone is simply a collection of all the root causes in the system with a percentage of mitigation effectiveness assigned to each. When assigning a mitigation zone to the sub system root causes are considered to be mitigated according to corresponding percentages. Mitigation zones also contain fixed and annual cost data that is used by the analysis for costs calculations, including those based on initial cost versus cost saving due to effective mitigation. However due to the unavailability of data associated with the cost of breakdown repairs, the financial savings are not considered.

For NWP electrical distribution system, Mitigation Zones can be separated as follows:

I. Zones that require for Proper maintenance schedules for Way leave clearing.
II. Zones for Replacement of porcelain insulators with silicon rubber insulators in coastal areas where sea breeze effect is significant.
III. Zones where Insulator washing is required due to coastal spray
IV. Zones where Squirrel cage for monkeys are required in thick & semi thick jungles

Percentages for the effectiveness of the mitigation techniques are selected based on the previous experience of the area engineers & maintenance staff of CEB.

Mitigation zones, root causes and the effectiveness of mitigation techniques applied to the digitized model are given in table 4.4.

Table 4.4 : Mitigation zones and their effectiveness

Mitigation zone	Failures mitigated	Effectiveness of mitigation techniques
Replace the porcelain insulators with silicon rubber insulators in coastal area.	AR & sectionalizer trippings Fuse blown, insulator and conductor break downs	60%

Proper maintenance schedule for Way leave clearing.	AR & LBS operations Fuse blown, conductor break downs	50%
Insulator washing	AR & LBS operations Conductor breakdowns insulator and conductor break downs	20%
Squirrel cage for monkeys	AR & LBS operations Fuse blown	5%

Chapter 5

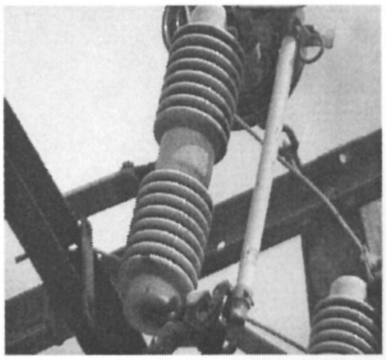
Frequently Repeated Breakdowns in MV Distribution Network and Methods to Reduce them

When the reported outages are analyzed it is noticed that the same breakdown has been repeat again and again due to non rectification of the real reason. The identified reasons for commonly reported breakdowns and suggestions for eliminating them are discussed below.

5.1 Fixing of DDLOs without having minimum clearance with the earthed bodies

DDLOs that are fixed without leaving minimum clearance with the earthed bodies cause earth fault at bad whether situations. As shown in figure 5.1,an extension arm is provided with DDLO set, which can be used in mounting the DDLO base with suitable clearance to avoid flashovers. However, it can be seen that in many DDLO sets this arm has not been used. As a consequence, the insufficient clearance causes sparks at rainy seasons or when birds are sitting on the cross arm on which the DDLOs are mounted.

Fig.5.1: Incorrectly Fixed DDLOs

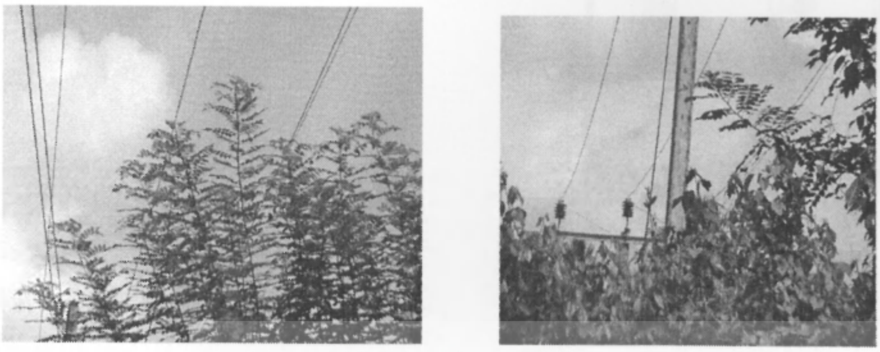


5.2 MV Breakdowns due to way leaves

In MV network majority of the faults are due to way leaves specially in the rural areas . There should be a proper way of managing way leave clearance. Line patrolling has to be done at least twice a year to identify problematic places. Even though way leaves are cleared by contractors there should be a program, monitoring methodology and a feed back system in order to get the maximum benefit out of the huge expenses.

Way leave clearance tenders should be handled with top priority and should not be delayed due to any reason.

Fig.5.2: Tree branches touching MV conductors



5.3 Improper connection of HT jumpers

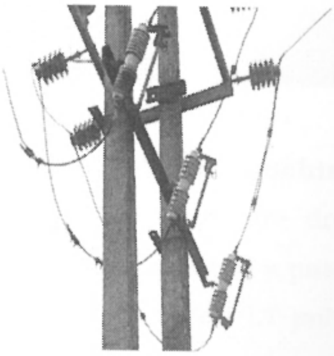
Improper electrical connection of HT jumpers is the main reason for frequent HT breakdowns. Instead of connecting two conductors with a binding wire it is recommended to crimp HT connections.

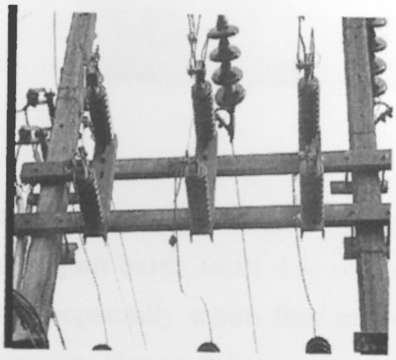
Fig.5.3: Improper electrical connections

5.4 Jumper connections without allowable clearance with cross arms

Jumper connections without having Minimum required clearance with cross arms causes earth fault at bad whether situations.

Fig.5.4: Jumper connections without allowable clearance with cross arms



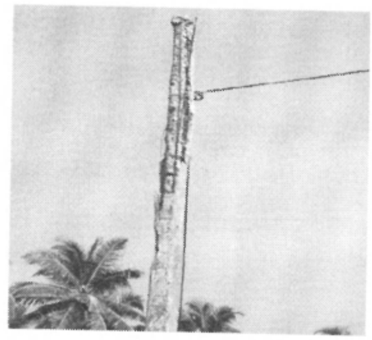


5.5 Corrosion of concrete poles in coastal areas

Concrete poles are not suitable at coastal areas due to corrosion problem. Instead of poles constructed with normal cement, special cement having corrosion resistant characteristics can be used to make concrete poles to be used in coastal areas. Similar cements are widely used today in construction activities in areas close to the sea.

Similarly, timber poles also do not stand for a long period and damages are noticed about three to four years of service at the buried sections. When timber poles are used in coastal areas, it is suggested to cover the buried section of the timber pole with fiberglass cover to avoid direct contact with the wet soil. This will extend the lifetime of the poles. Alternatively corrosion or a similar application that would prevent micro- biological action at ground level can be applied.

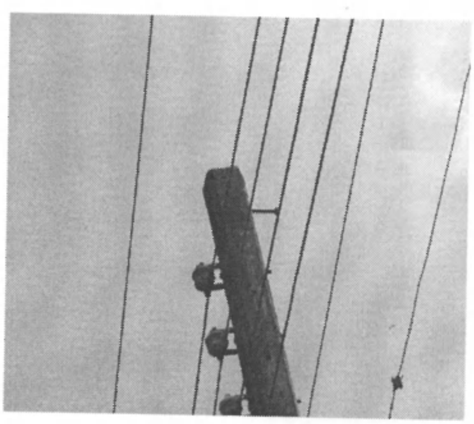
Fig.5.5: Corroded concrete poles at coastal areas

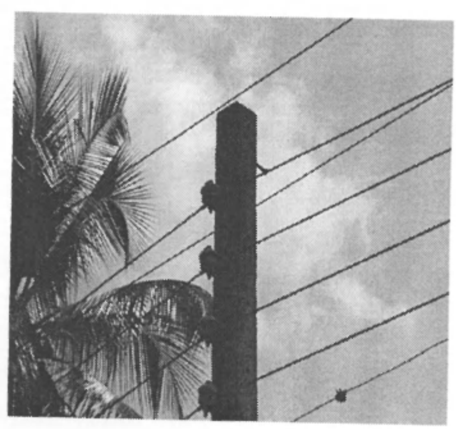


5.6 Sagged MV line touching LT poles

If HT and LT feeders are drawn on the same route but with poles of different heights there is a possibility of having an earth fault due to an HT conductor touching an LT pole. This occurs especially when line currents are high and the HT conductor sag is maximum. Hence it is recommended to use 10m poles instead of mounting both HT and LT on the same poles. When poles with two different heights are used for combined run it is essential to make sure that the sufficient clearance is maintained between HT and LT conductors at all operating conditions.

Fig.5.6: Sagged MV line touch on LT pole

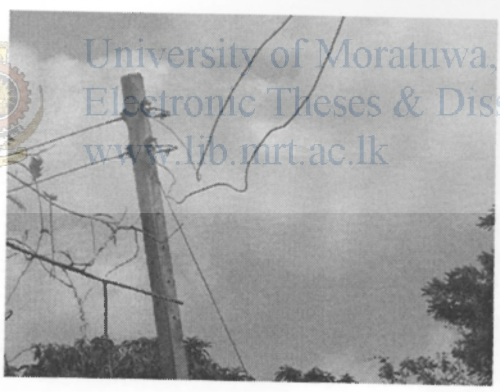




5.7 Improper Electrical connections

It is recommended to use bimetallic clamps, in order to have perfect and durable electrical connections where Aluminum and Copper conductors are joined together. Especially at substations feeders should be connected to the Copper tail wires with bimetallic clamps. Otherwise rusting on Aluminum wire causes high impedance and excessive heating may deteriorate the connection.

Fig.5.7: Improper Electrical connections



5.8 HT or LT conductors are not tensioned properly

If HT or LT conductors are not tensioned properly and resulting loose spans can give rise to faults at windy environment or when birds are sitting on the conductors. Hence it is recommended to avoid loose spans as much as possible. The work of service contractors should be supervised thoroughly to avoid LT loose spans.

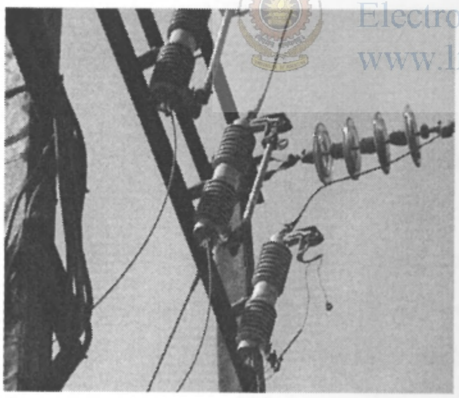
5.9 Insulator pollution due to the contamination of salt, dust or fungus

Insulator pollution due to the contamination of salt, dust or fungus may cause earth faults especially when light rains occur following the drought season. Insulator pollution due to industrial pollutants can be seen at certain industrial areas especially at Puttalam cement factory. Fungus on insulators has been observed at Dodangaslanda, Mawathagama and

Galagedera areas. At Puttalam coastal belt, HT lines frequently develop earth faults in the dawn due to the leakage currents passing through the insulator surface caused by conductive medium formed on insulator disk when salt contaminated on the insulator is combined with water dews. Unlike other coastal areas Puttalam experiences severe drought thought out the year and it would make the situation worse. The present practice is cleaning the insulator surface by hand washing. The cleaning frequency may depend on the raining pattern and the level of pollution.

In order to avoid cleaning insulators by keeping the feeder switched off it is suggested to introduce the new construction standard for heavily polluted areas. For proposed new standard it is possible to evaluate the suitability of using Silicon rubber insulators, double galvanized cross arms or fiber glass cross arms or any other similar materials to avoid frequent tripping due to flashing over.

Fig.5.8 : Damaged DDLO fuse bases



5.10 Usage of incorrect fuse size was the main reason for frequent tripping of HT and LT feeders. The correct fuse size needs to be indicated at the transformer nameplate and the breakdown staff should be educated to refer the nameplate when fuse is chosen for replacement. At many places in the network HT fuses are used not for protection purposes but to isolate the feeder sections when necessary. Hence it is recommended to use short circuited links at these places to short circuit the fuse base. Otherwise improper fuse size may violate the protection coordination principles and unexpected isolation may take place.

5.11 High earth impedance at substations

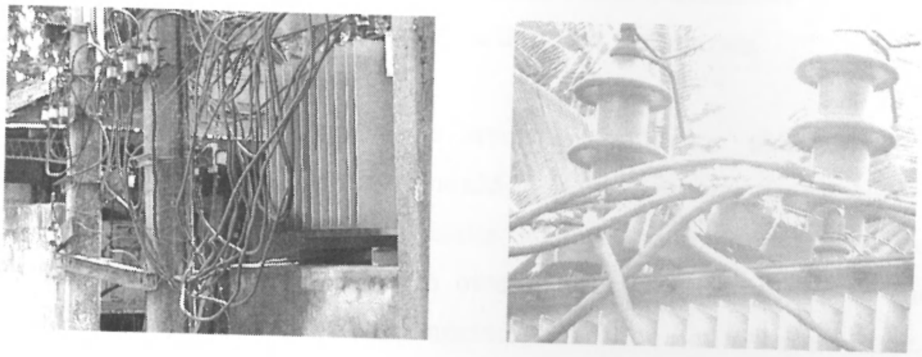
Transformers often fail due to lightening. It is essential to ensure the perfect connection of lightning arrestors to safeguard the transformer. The earth impedance should be checked at least once in a year to make sure they are within the recommended limits. In case of the places with high resistive soil either use of several earth rods or chemical treatment of soil will assist in improving substation earth impedances or use the new earthing system introduce by CEB.

5.12 Two HT circuits are drawn on the same poles

When two HT circuits are drawn on the same pole and one circuit is used as an express line it is recommended to use "T" formation rather than "H" formation. The express line should be mounted on the top cross arm as the top circuit and the bottom circuit can be used as the distributor. Thereby minor breakdowns on the distributor can be rectified without interrupting the top circuit supply. However, the best method is to use a separate line route for the express line as far as possible.

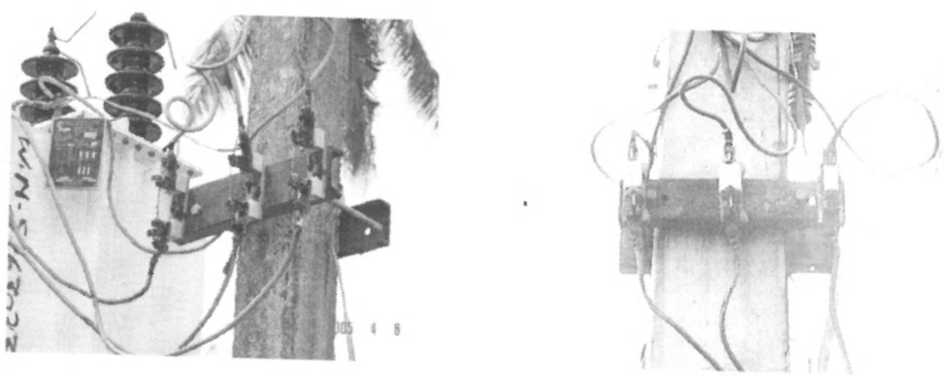
5.13 Failures due to lightning has been increasing in some parts of NWP. The isokeronic level of NWP seems to be higher in the past. Insulator failures due to lightning and subsequent earth faults are common during the rainy season at tower lines running along paddy fields. Therefore it is recommended to fix lightning arrestors at intermediate towers and regular monitoring of tower footing resistance to avoid faults due to lightening. More attention should be paid on maintaining the earth wire of MV tower lines since it is the grounding path for the lighting strokes.

Fig.5.9: Untidy connection of transformer tail wires



5.14 LT cables coming out of the transformer bushing and running up to the LT fuse box should not be allowed to lie on transformer body as it can then obstruct the cooling of transformer oil. Extra force due to the cable weight may be a burden on the transformer LT bushings. Hence it is recommended to use a tray on which cables can be properly maintained and can be fixed in an orderly way.

Fig.5.10: Damaged LT fuse bases



5.15 If either HT or LT fuse base is damaged priority should be given to replace it with a new one. Otherwise loose connections will results in blowing out fuses repeatedly.

5.16 Over voltages are commonly appearing on the network due to touching of LT conductors each other when high currents are passing through them. It is necessary to carry out the system augmentations in time to safe guard transformer damages and conductors heating, sagging and touching due to feeder over loading and unbalance.

5.17 Distribution substation's neutral conductor should be properly earthed and special attention should be paid to ensure the continuity of the earth. Otherwise, when earth faults occur at somewhere in the feeder the disconnected neutral results in over voltage conditions due to the phase voltage appearing at the disconnected part of the neutral conductor.

Chapter 6

Result and Analysis

6.1 Analysis of the Results from the SynerGEE reliability tool.

6.1.1 SAIDI & SAIFI values from SynerGEE reliability tool.

The model was run for the reliability analysis and the results are tabulated in table 6.1 below.

Table 6.1: Results from SynerGEE software package

Grid substation	**Feeder**	**SAIFI**	**SAIDI**
	Name	**Total**	**Total**
	Total System	**12.75**	**38.545**
Bolawaththa	Feeder BOLAF1-Nathandiya	11.978	37.278
	Feeder BOLAF7-Pannala	16.638	33.771
	Feeder BOLAF3-VOA	12.776	28.934
	Feeder NattandiyaPrimaryF2-Marawila	5.593	24.111
	Feeder BolaPrimaryF1-Yikkala	4.252	22.427
	Feeder NattandiyaPrimaryF1-ThalawilaMar	5.336	19.857
	Feeder BOLAF2-Pannala	6.247	12.722
	Feeder LunuwilaPrimaryF2-Hundirapola	1.958	10.641
	Feeder BolaPrimaryF2-Wennappuwa	1.491	5.866
	Feeder Lunuwila Prinmary F1-Marawila	3.464	8.101
	Feeder BOLAF5-BOLA.PRIMARY	0.03	0.18
Puttalam	Feeder PuttalamaF4-Anamaduwa	40.132	57.549
	Feeder PuttF3-Kalpitiya	11.365	34.44
	Feeder PuttF7-Eluwankulama	14.196	32.586

	Feeder PalakudaPrimaryF1-Kalpitiya	4.992	15.542
	Feeder Pudukudirippu Primary-Udappuwa	3.047	14.854
	Feeder PuttF1-Keeriyankalliya	5.53	13.183
	Feeder MangalaelliyaPrimaryF1-Sinnapadu	2.95	12.811
	Feeder MadurankuliyaPrimaryF1-Kadayamot	1.503	7.293
	Feeder ChilawPrimaryF2-Town	1.231	6.612
	Feeder ChilawPrimaryF1-EgodawattaPalliy	0.753	1.883
	Feeder PuttF5-cement	0.551	1.377
	Feeder PuttF8-Cement	0.529	1.323
Madampe	Feeder MADAF4-Nattandiya	13.442	42.906
	Feeder MADAF1-Kuliyapitiya	20.813	37.259
	Feeder MadaF2-Bingiriya	19.087	32.127
	Feeder MadaF7-Keeriyankalliya	13.452	20.407
	Feeder MadaF7-Chilaw	6.737	18.191
	Feeder RajakadaluwaPrimary-Kusala	3.246	15.454
	Feeder MahawewaPrimaryF1-ThoduwawaThala	3.236	13.616
	Feeder KottapitiyaPrimaryF1-karukkupane	1.485	8.258
	Feeder MarawalaPrimaryF1-Iranawila	1.916	4.789
	Feeder MadaF5-VOA	1.646	3.945
	Feeder MadaF8-Bhuwalka	0.278	0.695
Thulhiriya	Feeder THULF2-Narammala	5.654	13.173
	Feeder THULF3-Pannala	11.848	40.503
	Feeder THULF5-Kpitiya	18.799	30.088
	Feeder ThulhiriyaF1- Industril Pol	13.33	36.147
Kurunegala	Feeder Udawalpola Primary F3	1.943	5.153
	Feeder Udawalpola Primary F4	0.634	1.835
	Feeder Udawalpola Primary F5	1.751	5.44
	Feeder Udawalpola Primary F6	0.847	2.159

	Feeder KuruF6-Ibbagamuwa	7.093	19.228
	Feeder YanthampalawaF2-Lakeside	1.314	1.663
	Feeder kURU F7-IbbagamuwaBB	8.787	21.701
	Feeder KuruF1-Galagedera	7.173	14.601
	Feeder KuruF2-Narammala(Town)	4.075	9.111
	Feeder KuruF3-Potuhera	11.234	21.833
	Feeder KuruF4-Maho(Maspotha)	11.153	31.95
	Feeder KuruF5-PadeniyaBB	13.806	32.7
	Feeder Yanthamplawa Primary F1	1.364	1.917

The above SAIDI & SAIFI values are used to identify the unreliable feeders which contribute high SAIDI & SAIFI values in the system.

The Results show that SAIDI & SAIFI values have strong inter-relationship for the sustained type of failures. For the feeders where the SAIFI values are higher than the system SAIFI value, it is observed that SAIDI values are also higher than the system SAIDI value.

SAIFI, SAIDI contribution from the Feeder PuttalamaF4-Anamaduwa, Feeder THULF5-Kuliyapitiya, Feeder Madampe F2-Bingiriya & Feeder Puttalam F7-Eluwankulama are much more significant to the total system while reliability indices contribution.from the Feeder BOLAF2-Pannala & Feeder BolaPrimaryF2-Wennappuwa to the total system are low.

Total feeder length, number of customers & relevant exposure zone for the 4 feeders where the reliability indices are the most significant & the 2 feeders where the reliability indices are very low have been tabulated in table 6.2 for easy comparison.

Table 6.2: Table of Comparison between the feeders of NWP

Feeder name	SAIFI	SAIDI	Total Feeder length Km	Total number of customers in the feeder/system	The most relevant Exposure zone for the feeder
Feeder PuttalamaF4-Anamaduwa	40.132	57.549	636.9	66670	Coconut plantation
Feeder THULF5-Kpitiya	18.799	30.088	237.0	38827	General rural area
Feeder MadaF2-Bingiriya	19.087	32.127	219.1	43285	General rural area
Feeder BOLAF7-Pannala	16.638	33.771	107.0	7777	General rural area
Feeder KuruF2-Narammala (Town)	4.075	9.111	24.8	676	General rural area
Feeder MadaF7-Chilaw	6.737	18.191	37.2	745	General rural area
Total System	15.55	29.864	2986.9	625,000	

The following reasons can be given to explain this situation

a) Total length of these feeders are large

b) The number of customers in the feeder is high.

c) The feeder traveling through exposure zones are having high annual failure rates due to coconut plantations & heavy way leaves.

Example: Feeder PuttalamaF4-Anamaduwa is going through the exposure zones, (coastal area with sea breeze & coconut plantations) where the exposure zone failure rates are having higher values than the other exposure zones . Therefore the reliability of this feeder is less than the total system average reliability.

6.1.2 Comparison of the results obtained from SynerGEE with manually calculated reliability indices in the control centre of NWP.

Table 6.3- SAIDI & SAIFI Comparison Table.

Method of calculation	**SAIDI(hours/Year)**	**SAIFI(Frequency/year)**
Manually calculated Reliability indices for the NWP distribution system	42.0	11.80
Results obtained from the synerGEE tool for the model	38.5	12.75
Difference of the value	3.5(8.33%)	0.95(8.05%)

Reasons for the differences,

It is revealed that the feeders with high frequency of failure also exhibit high failure duration before restoration of supply. High frequency is also due to inherent nature of plantations terrain and bad maintenance. High duration is due to geographic location and low priority given for restoration. However when the actual SAIDI and SAIFI values manually calculated using the practical data remarkably differ from the values obtained from SynerGEE. The following reasons can be given to explain this situation.

a) Major events which have taken unusual long repair time have not been considered during the calculation of equipment failure rates and repair time assigned for SynerGEE software package. However during the manual calculation these type of incidents have taken in to consideration. Therefore manually calculated values should get higher SAIDI and SAIFI values.

b) Breakdown data for MV distribution network in NWP is currently available only for 2 years and the data required to model the NWP MV distribution system was calculated from this data base. IEEE standards [13] recommend to have 5 year data base to calculate the required data to model the MV distribution system. Therefore the calculated values from the 2 years data base may not represent the accurate and reasonable values required to model the system.

c) Manually calculated average SAIDI & SAIFI values for year 2005 and 2006 have been compared with the result from SynerGEE. To have more accurate manually calculated SAIDI and SAIFI values it is required to have physical average of 5 years or more to compare with the result obtained from SynerGEE software package.

6.2 Case Study (Selected Mitigation Technique)

In order to estimate the effectiveness of a selected mitigation technique a case study is done selecting Kalpitiya Feeder. The selected mitigation technique is replacement of Pin Porcelain Insulators with Composite Insulators in Kalpitiya coastal Area to reduce the insulator flash over breakdowns.

MV distribution network is in the vicinity of a lagoon with sea breeze effect. Salt is the main contaminator in this area. The salt spray is brought by the prevailing south- west monsoon winds blowing over the ocean and the lagoon.

These porcelain insulators are exposed to salt contamination. Therefore frequent flash over can be observed in the Puttalam Feeder. Past data show that the flash over frequency is having a co-relation with rainfall in this area and an analyse of this relationship is made in clause 6.2.1.

6.2.1. Effect of rainfall on Flash over frequency of MV insulators in Kalpitiya

It is observed that the flash-over frequency is comparatively low during the rainy season where there is abundant rain to wash away salt pollutants. On the other hands flash over frequency increases during the dry season, especially when a slight bristle occurs.

Annex 6.1 shows, operation frequencies of HT DDLOs due to insulator flash overs & way leaves in Kalpitiya consumer service centre area for years 2005 & year 2006 in relation to the rainfall of the month. Rainfall data has been collected from the Meteorological Department. The Data shows that failure frequency has a direct co-relation to monthly rainfall in Kalpitiya area.

Minimum rainfall is recorded during the month of June, July, August & September in year 2005 and the recorded MV breakdowns are a maximum during those months. The same situation can be observed during the year 2006.

During the month of October & November in year 2006 the maximum rainfall has been recorded and failure frequency of HT fuses are in their peaks. To verify this fact, the officer in charge of the CSC was interacted and according to his explanation most of the HT fuses were blown due to the way leaves It appears that this high failure frequency during this rainy season is mainly due to way leaves and coconut branches causing line faults and due to flash over resulting from salt pollution. These observations confirm that, dry months cause insulation flash over due to salt pollution, specially in the event of a slight bristle or dew.

SIR composite insulators have been tested in Kalpitiya area in 1997 [11] and the results show that the performance of the SIR composite insulators are satisfactory even in the heavy atmospheric pollution condition with salt contamination. Therefore it is recommended to use the SIR composite insulators to minimize break down due to insulator flash over.

6.2.2 Comparison of Porcelain insulator with Silicon Rubber insulator

Porcelain has been used as the oldest material for outdoor insulation, and it is widely used around the world. In the polluted environment the development of leakage current causes ·flashover by short circuiting the insulator. This is an acute problem in the transmission and distribution lines exposed to pollution. Some of the methods presently used to overcome these problems are insulator replacement at regular intervals, increasing the creepage distances, insulator washing and greasing or coating. Another method is to replace the traditional insulators by silicon rubber insulator in which high creepage distance can be achieved. Further silicon rubber insulators are hydrophobic in nature and they are not affected by water with salt pollution.

Silicon rubber insulator and referred to as composite insulator as they consist of three parts , namely a metal fitting for the connection to the power conductors and the supporting structure , a fibre glass rod for mechanical strength of the insulator and a housing material for protection of the fibre glass rod and for use as the insulation.

Silicon rubber insulators have many advantages over porcelain insulators and their comparative general capabilities are given in table 6.6.

However, the main drawback of the composite insulator is the surface aging. Under difficult service stress such as corona discharge, UV exposure, chemical attacks etc, chemical reactions can occur on or inside the composite material. This may result in loss of hydrophobicity and other surface degradation for example tracking and erosion.

Table 6.4: Comparison of General capabilities of Insulators [11]

Characteristics	**Porcelain Insulators**	**Silicon Rubber Insulators**
Hydroprobic recovery	No	Yes
Light weight	No	Yes
Contamination Resistance	No	Yes
Leakage current control	No	Yes
Weather Resistance	Yes	Yes
Installation	Difficult	Easy
Resist UV	Yes	Yes
Price of insulator	20 USD	28 USD
Easy transportation	No	Yes
Reliability in the polluted environment	Low	High

Going back to history, the first composite insulators were used on outdoor lines during the mid 1960 period. Since then, there have been many changes in the material composition and design of insulators. Now composite insulators are being used in significant quantities all over the world and their prices are decreasing due to the development of technology.

The most common material used today for composite insulators are silicone Rubber (SIR) and ethylene propylene diene monomer (EPDM). The SIR is used in two forms: room temperature vulcanized (RTV) and high temperature vulcanized. Usually, RTV is used for coating of porcelain insulators whereas HTV is used for composite housings.

6.2.3 Features of MV distribution network Feeder 3 of Puttalam GSS

This feeder is starting from Puttalam GSS and going Kalpitiya as shown in Annexure 6.1. Up to Palakuda the feeder is energized with 33kV and after Palakuda primary the feeder is energized with 11 kV to minimized the flash over breakdowns, and thereby improve the reliability of MV network distribution system. This solution is not the best solution from a technical point of view. It provides higher losses and excessive voltage drops in the distribution system.

6.2.4 SAIDI & SAIFI improvement of Kalpitiya Feeder with SIR insulators.

Considering the fact that the porcelain insulators are replaceable with the SIR insulators in Kalpitiya feeder, only that feeder was run for the reliability analysis in SynerGEE. And the results are tabulated in table 6.7. In the new model exposure zone reliability has improved from o.35 f/year to 0.01 f/year considering that the exposure zone reliability is equal to the zones with paddy field where the exposure zone reliability is normally high .

DDLO Fuse blown frequency has been changed from 1 f/year to 0.5 f/year after installation of SIR insulators.

Table 6.5: SAIDI & SAIFI comparison with both type of insulators

Kalpitiya Feeder	**SAIDI**	**SAIFI**
With Porcelain Insulators	24.47	8.00
With Silicon Rubber insulators	10.69	2.37

SAIDI improvement to Kalpitiya Feeder is nearly 14 hours.

6.2.5 Cost Benefit analysis for replacement of porcelain insulators with SIR composite insulators

a) The following assumptions have been made during the calculation,

i) Reactive Energy losses due to 11kV lines have not been considered

ii) Hardware for the insulators for the both types, Porcelain & Silicon Rubber composite have considered to be the same.

iii) Installation and transportation cost comparison for the both types of insulators have not been taken in to consideration.

IV) Load factor for the Kalpitiya feeder & Palakuda primary is considered as 0.3 as the most of the loads in this area are distributed loads.

v) Effect of the SAIFI improvement of distribution network due to installation of SIR composite insulators have not been taken in to account during the financial analysis as it is difficult to quantify the SAIFI improvement to the economy of the country.

b) Line construction features Kalpitiya Feeder.

- Total line length of the Feeder: 61.7 km.
- Conductor : Racoon conductors (7/4.09).
- Type of insulators : 33 kV Pin porcelain insulators with creepage distance 850 mm and power frequency withstand dry voltage 135 kV and weight 12 kg have been installed presently[7].

As per the Medium voltage line construction standard of CEB the required quantity per 1 km of the following items are as follows

- Number of 13 M RC poles (500 kg): 14 nos.
- Number of Pin insulators (33kV): 43.
- Number of Tension insulators (33kV): 24.

Total number of Pin insulators in the Kalpitiya Feeder: 43 X 61.7=2654 Nos

Total number of Tension insulators for Kalpitiya Feeder } : 24 X 61.7=1481 Nos

c) Calculation of total cost of insulators for the Kalpitiya Feeder.

Description	Porcelain Insulators	Composite Insulators
Current market price for 1. Pin Insulator 2. Tension Insulator	 21 USD 45USD	 28 USD 46 USD
Total cost for 3. Pin Insulators 4. Tension Insulators	 2654x21=55,734 USD 1481x42=16,695 USD	 2654x28=74,312USD 1481x46=17,066 USD
Total cost	**122,379 USD**	**142,438 USD**

d) Calculation of the benefit from the SAIDI improvement

Generation cost per 1 kwh = 6.22 SLR [5]

Assuming 10% operation & maintenance cost = 0.62 SLR [5]

Selling cost of 1kwh to earn 10% profit margin = 7.52 SLR

Therefore profit from 1kWh to CEB = SLR 0.68

Total KVA of the Kalpitiya Feeder =17;535 kVA.

SAIDI improvement to the MV distribution network = 14 hours [Tab 6.7]

Total increase of kWh units sales due to SAIDI improvements } =17535X14X 0.3
=73,647 kWh

(Load factor & power factor are is taken as 0.3 & 1)

Total benefit to CEB from the SAIDI improvement = SLR 73,647 X 0.68
= SLR 50,080.00

e) Calculation Operational & Maintenance cost of Porcelain Insulators in Kalpitiya Feeder

- Annual Maintenance cost for insulators washing and Repairing cost of MV distribution network due to flash over of insulators in Kalpitiya feeder SLR 5350 per km.
- Total cost for Maintenance for the Kalpitiya Feeder= 5350 X 61.7

= **330,095.00 SLR**

f) Calculation of the losses in 11kV Distribution in Kalpitiya Feeder

Palakuda primary is energized with 11 kV. if the presently existing porcelain insulators are replaced with SIR insulators the MV voltage can be increased up to 33 kV. Total length of MV distribution net work is 15 km and the losses due to 11kV MV is calculated below,

Feeder Current of the Palakuda Primary = 222 A

For the Racoon conductor = R +j X= 0.4095 +j0.9339

Therefore the total loss of Power, ΔP = I^2 * R X L

=($222)^2$ * 0.4095 X 15X 3

= 908.16 kW

Losses in 33 kV Distribution

Total loss of energy, ΔP = I^2 * R X L x3

= $(74)^2$ * 0.4095 X 15

= 100.89 kW

If 11kV primary is converted to 33kV the annual energy saving due to the line losses= (908.16 -100.89) X 8760 x0.3 kWh=2,121,505.56 kWh

Annual saving from the line losses

=SLR 2,121,505.56 X 0.68= 1,442,623.4 SLR

g) Calculation of total annual saving from the replacement of Porcelain insulators with SIR insulators

Total annual saving from the Replacement = $\Delta S_{losses} + \Delta S_{SAIDI\ improvement} + \Delta S_{maintenance}$

= 1,442,623.4 +50,080.00+ 330,095.00

= 1,822,798.00 SLR

Total cost of the additional investment for SIR insulators =(142,438-122,379) X115

= 2,306,785.00 SLR

Calculation of additional investments for replacement of 11kV transformers with 33kV transformers

No of 100 kVA transformers in Palkuda primary= 20 nos

No of 160 kVA transformers in Palkuda primary= 17 nos

Additional investment for the replacement Of transformers with 33kV [14] = 20X120,000+17X95,000

= 4 million

Overheads = 1 million

Total investment **= 5 million**

Therefore total additional investment for converting the 11kv feeder to 33 kV =5,000,000+2,306,885= 7,306,785.00 SLR

h) Financial Analysis

- **Calculation of Simple pay back period** = $\frac{7.306.785}{1,822,798}$ years

= 4.00 years

- **Calculation of the viability of the project:**

The following Assumption have been made during the calculation economical life time of the SIR insulator is 15 years

Discount rate is 12%.

Present Value of the Benefit= PV_B=**1,822,798** $\sum_{i=1}^{n}\frac{1}{(1+r)^n}$ ---- (4.1)

In the equation (4.1)

n = economical life time of the SIR insulator is 15 years

r = Discount rate is 12%.

Present value of the benefits of the project, [15]

PV_B= 1,822,798 X 6.810= 12,413,254 SLR

Present value of the cost of the project,

PV_C=7,306,785.00 SLR

Net present value of the project ,

NPV= 12,413,254-7,306,785.00 = 5,106,469.00 SLR.

NPV> 0 therefore the project is viable.

- **Internal Rate of Return of the project**

$PV_C = PV_B$

$$7{,}306{,}785.00 = 1{,}822{,}798\sum_{i=1}^{n}\frac{1}{(1+r)^i},$$

$$4.008 = \sum_{i=1}^{n}\frac{1}{(1+r)^i}.$$

From the table for Present value Factor(PVF), When n=15 years ,

PVF=4.001 for r =24% [15]

Therefore the internal rate of return for the project is (IRR) = 24%.

The above financial analysis shows that the installation of SIR insulators in area exposed to the salt pollution is financially and economically viable. Therefore it is recommended to install SIR insulators in place of Porcelain insulators in the coastal MV distribution network to minimise the breakdowns cause by insulator flash over and to improve the reliability of power supply.

Conclusion and Recommendation

7.1 Conclusion & Discussion

If a proper data base system is maintained for equipment failures and repairs time for the CSC wise or area wise it is very effective to use SynerGEE Software Package to calculate the reliability indices for Distribution Network even at the planning stage. The indices are very useful for assessing the severity of system failures in future reliability prediction analysis.

An important feature of this Software Package is that system weak sections can be easily identified, thereby focusing design attention on those sections of the system that contribute most to service unreliability. It is also possible to estimate effectiveness of the mitigation techniques applied to the system and estimate the cost & benefit to the power utility as well as to the consumer.

The system performance assessment is a valuable activity for three important reasons.

- Establishing the chronological changes in system performance and hence, identification of weak areas and the need for reinforcement could be early achieved.
- Establishing existing indices which serve as a guide for acceptable values in future reliability assessment.
- Enabling previous prediction to be compared with actual operating experience.

The past failure records entered to the data base at DCC in a systematic manner is very important. The failure records without all relevant details such as section failed, course of failure and mode of failure are not much useful for the analysis. Therefore it is recommended to recruit an Engineer to analyze the records sent by the CSCs. These information could be utilized to plan the rehabilitation & maintenance programme for MV Distribution System. Entering the failure data to the data base should be carefully done by a properly trained Data Entry Operator and distribution control centre engineer should closely monitor this data base. This kind of procedure will help to maintain an accurate database.

It is revealed from the study that the time spent for a breakdown, equipment failure rates could be minimized by adopting reliability improving techniques which is discussed under 7.2.

7.2 Proposals for Improvement of the network

In order to improve the system reliability two remedial measures can be taken.

They are reducing the number of outages and reducing the time taken for restoring the supply. The different possible ways of employing these two techniques are discussed below.

7.2.1 Importance of Preparing an Annual Maintenance Plan

A maintenance plan should be prepared annually describing routine maintenance to be attended throughout the year. The outage data collected at the control centre as well as the field experience of the operation staff may be used to find out the maintenance frequency of each MV line. For example, the feeder tripping details indicate that the line insulators installed in the coastal areas of Puttalam district should be cleaned once in six months period. Similarly the vegetation growth rate, rainfall pattern, weather condition and the aging of equipment determine the line maintenance requirements and according to that the annual maintenance plan should be prepared.

Other important activity is to make advance preparation work before planned power interruptions for maintenance or construction activities. Thereby outage time can be optimized and number of consumers affected may be minimized by proper planning and arranging alternative feeding routes. The other advantage of power outage plan is that the public can be notified in advance about power interruptions. Many activities can be planned to be carried out simultaneously at the same interruption period and the supply outage time can be utilized to a maximum.

Both maintenance and outage plan will assist in preparing material and labour allocation as well. Proper planning also assists in optimum utilization of outage time as well as other resources such as material, labour and transport.

7.2.2 Improving workmanship through Training

It is frequently observed that CEB breakdown staff is under trained with respect to safety issues, selection of proper material and tools, efficient and productive ways of completing their day-to-day activities. In order to reduce the number of outages and time taken for restoration all categories of breakdown staff should be trained on outage management techniques such as quick identification of breakdowns and the solution which can be applied permanently repairing the breakdowns in a way so as to prevent frequent repetition of such break downs.

At the same time training will assist them to study new techniques and advance practices in breakdown management. Apart from that the staff may be educated on the importance of neatly recording details of breakdowns and subsequent analysis to identify weak areas. In addition that staff should be trained on the ways of developing personal relationships with customers.

Instead of routine training programs it is suggested to prepare training programs targeting special groups of employees. Each program preferably consisting of several modules, each of which can be independently followed according to the time availability and the requirement of the staff groups. It is suggested to prepare several video documentaries to serve different aspects of training, which would be self explanatory in nature and enabling the trainees to develop their existing skills. If video programs are available the productive training camps can be arranged at the work place itself or even at a CSC. Staff can be motivated for training if the rule is imposed for having the minimum training requirement for them to be eligible for the next promotion.

Not only the internal staff but the outside people willing to get a good knowledge on electrical related technical activities could be trained by the CEB Since CEB is the largest organization in Sri Lanka having the latest equipment and experts on electrical technology. If this method of training is introduced then CEB can enforce contactors to use only such trained staff in contract gangs for CEB work. Perhaps CEB can serve national needs by marketing our expertise on electrical technology in the field of training the electricians.

For each year a large number of students on various disciplines such as technicians, draughtsman, clerical staff, typists etc passing out from the government technical colleges apply and seek an opportunity for training in the CEB. These trainees are at present paid only a government approved allowance during the training period. If proper training programs are arranged then trainees can be employed on a reasonable payment and maximally utilized by CEB for it's development activities. It will be beneficial for both parties and the CEB can get valuable work with reasonable payment to trainees while giving them an opportunity to be trained on specialized work.

7.2.3 Adopting Quality Improvement Techniques

High quality of workmanship of the breakdown staff is a necessary factor to achieve a higher reliability level. Even though the technical staff has been trained to carry out their normal duties there is no assessment on how they apply the knowledge gathered at the training program. Hence it is essential to set up a technical auditing team to evaluate the procedures and practices expected to be followed according to technical specifications and codes as well as the technical construction maintenance standards. Based on the results of the technical auditing, training needs of the staff can be identified. Apart from that the experience of technical auditing can be used to review the technical specifications and standards.

Presently many utilities practice well proved quality-improving method like the 5S concept and quality circles to improve productivity. Some sections of CEB have demonstrated that good improvement can be achieved by adopting these techniques. For example the CSC environment can be well arranged and prepare a consumer friendly environment just by rearranging the different sections and equipments. The stores can be well arranged by placing material on shelves in a methodical order. Properly labeling items will help the staff to find out any equipment with minimum time. Similarly all instructions to consumers and staff can be displayed on the notice board and they will guide consumers. It will avoid embarrassment due to improper communication and irregular practices. The disposable items such as damaged meters, transformers and poles can be arranged neatly without obscuring the staff and consumers. All printed format should be unique at all CSCs and should be printed in both languages. The breakdown vehicle should be equipped with a material box ensuring the availability of minimum stock of material, which is essential to attend breakdowns at minimum time. A tool box should be issued to each linesman and it should be enforced that he carries it at every time when he is called up on to rectify a breakdown. All staff should be compelled to use safety equipment and thereby the accidents can be minimized. Computers should be fully utilized in preparing estimates, stock balance registers, SMC registers etc. These are a few ways where some improvement can be done using productivity improving methods like 5S and quality circles.

Also all categories of the staff should be given an opportunity to get involved in improving productivity of their day-to-day activities by forwarding solutions they could suggest through experience. A quality circle is the well-known management technique widely used aiming to collect ideas of all categories of staff for improving quality and productivity and it is a well proven method of management by opinion Quality circles can be set up at every division to collect ideas of all categories for the development of normal activities.

In order to make these concepts popular among the staff a competition should be arranged annually among all divisions of the province with rewards for the best office and the best idea.

Preparation of customer service standards will be the initial step in achieving the quality certificate. It is time for CEB to document suitable service standards policies and establish the achievable quality target based on the existing system performance. Where outage management is concerned the target may be the best SAIFI, SAIDI values to be achieved based on provinces with the best performance. It is high time to introduce the system productivity and quality-improving program aimed at more reliable system.

7.2.4 Employing Advance Technology

Adaptation of advance techniques in maintenance and construction of CEB facilities is one way of improving system reliability. The following proposals describe how the system reliability can be improved by introducing advance technology.

(a) For coastal areas Copper conductors and all Aluminium Alloyed Conductors (AAAC) show very high resistance to corrosion compared with ACSR conductors. Hence it is suggested to use such conductors for LT distribution in coastal areas.

(b) Similarly HT lines in coastal areas are subject to frequent earth faults due to salt contamination and fallen conductors. The present practice is to construct 33kV lines and energize them on 11kV. However, long distribution with 11kV overhead conductors cause large voltage drops and heavy energy losses. Hence it is suggested to use polymer insulators and AAAC conductors that are corrosion resistive in order to reduce frequent earth faults on HT lines in coastal areas due to salt contamination as well as due to corroded and fallen conductors.

(c) Network switching can be done using load break switches in place of Air break switches; hence the network switching can be done without interrupting the supply. These results in improving the MAIFI value significantly.

(d) It is time to introduce hot line maintenance technique for HT maintenance activities. Hence, power interruptions made for maintenance activities can be totally eliminated.

(e) New technology such as fault indicators, auto reclosers, sectionalizers should be introduced in efficient fault identification and fault isolation. Thereby the faults can be identified with minimum time and the outage can be limited to minimum number of consumers. A further step can be brought forward by introducing distribution automation techniques with fault indicators and autoreclosers. Hence, their operation details are automatically sent to the control room and remote operations are made possible depending on the requirement. Thereby time taken for fault identification and subsequent switching operations can be reduced significantly.

(f) Application of thermal vision techniques to identify defective points in distribution line is very popular in utilities operating overhead network for power distribution. This technique is widely used as a preventive maintenance technique. It is suggested to introduce such techniques to identify weak points in the network in advance prior to their development in to serious faults leading to break downs.

(g) An Advance communication network is essential to exchange information among system operators. Present communication system has disadvantages such as not being powerful enough to cover the entire NWP. If this internal communication network can be upgraded to cover the entire province then all breakdown vehicles, CSCs, grid substations and the control centre can be linked together and operational information can be passed between them effectively. Hence, the time taken for restoration can be reduced and reliability indices can be improved through efficient system operations. Since CEB communication facilities such as towers are abandoned at certain locations of NWP it is proposed to carry out feasibility study for rehabilitation of the existing communication facilities and developing them to cover the entire province.

(h) Establishing a Research and Development division may facilitate to introduce and develop new technology applications using local expertise with minimum cost. For example the feasibility of developing necessary hardware and software for remote monitoring and operation of distribution facilities such as air break switches, auto reclosers, boundary meters, relays, fault indicators and retrofitting them into the existing facilities should be investigated. Distribution automation solutions can easily be developed with local expertise and at minimum cost to suit our requirements. A necessary support can be taken from local universities or local R and D institutions such as Auther C. Clerk centre.

(i) When primary transformer fails it would take more time to replace it. If mobile primary unit can be made by mounting a transformer and other accessories on a truck, it can be used to feed the network until the faulty transformer is repaired or replaced. Thereby outage period can be minimized.

7.2.5 Asset Management

Asset management is an important concept in maintenance work. The asset database has all information about the distribution facilities installed in the network. By referring the database it is possible to obtain the information about the equipment type, spare part list, age of the equipment, maintenance history, dimensions, nameplate data, installed location etc. Asset management database is a very useful tool in maintenance activities. At present it is not practiced within the distribution region. Hence, it is necessary to collect the information and prepare a database and initiate the asset management task. It will improve the productivity of maintenance and assist in improving system reliability.

7.2.6 Re-introduction of commissioning reports

When new construction is completed it is essential to have a system to issue a commissioning report. The construction division should energize the system and should produce a commissioning report to verify that the construction work has met the required standards. The present practice is to hand over the constructed and completed work only by counting the material installed. Hence, actions have been taken to enforce commissioning reports for all construction work in order to reduce possible breakdown in the future due to the incompliance with construction standards.

7.2.7 Formulating the operational code of practice for distribution network

At present scheduled power outages are not carried out in a systematic way. It is necessary to formulate a methodology to issue work permit for carry out maintenance and construction activities in distribution equipment. To avoid hazardous situations and ensure safety of public, employees and equipment installed in the network it is essential to prepare a methodology to isolate the network. It should describe the responsibility and duty of each party and all steps should be well documented in order to identify the locations, equipment and persons related to each outage at a later stage.

Similarly at serious outage conditions such as one transformer going out of service substation at the grid there should be an emergency plan describing the way of maintaining supply to essential loads by changing feeding arrangements.

At present several industrial zones are available within NWP and these places should be given high reliable supply at all possible situations. The way of maintaining high reliable supply at any contingency situation can be ensured only if there is a contingency plan for network operations.

Hence, a code of practice should be prepared to cover all those aspects.

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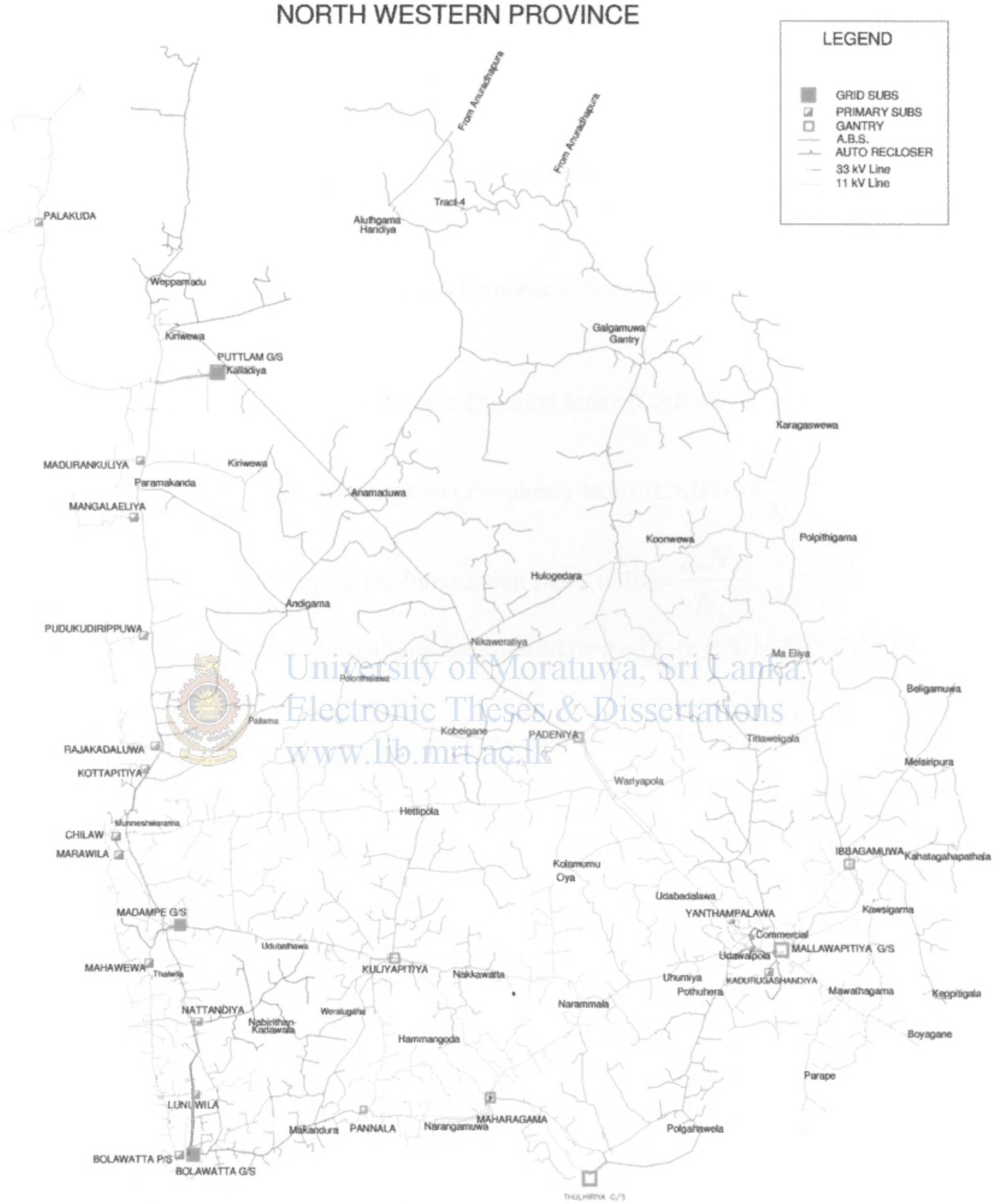
NETWORK MAP

NORTH WESTERN PROVINCE



Annexure-2.2

Definitions of Reliability Indices

The definitions of electricity distribution system reliability indices as given in IEEE standard number P-1366 are summarized below.

a. System Average Interruption Duration Index (SAIDI)= $\frac{\sum(r_i \times N_i)}{N_T}$

b. System Average Interruption Frequency Index (SAIFI)= $\frac{\sum(N_i)}{N_T}$

c. Customer Average Interruption Duration Index (CAIDI)= $\frac{\sum(r_i \times N_i)}{N_T}$

d. Customer Average Interruption Frequency Index (CAIFI)= $\frac{\sum N_0}{N_T}$

e. Customer Interrupted per Interruption Index (CIII)= $\frac{\sum N_T}{N_0}$

f. Average System Availability Index (ASAI)= $\left[1 - \left(\sum(r_i * N_i)/(N_T * T)\right)\right] * 100$

g. Momentary Average Frequency Interruption Index (MAIFI)= $\frac{\left(\sum ID_i * N_i\right)}{N_T}$

Where,

r_i = Restoration time in minutes,

N_i = Total Number of Customers Interrupted

N_T =Total Number of Customers served

N_0 =Number of Interruptions

T = Time period under study

ID_i =Number of interrupting device operations

Annexure-3.1

DAILY REPORT ON THE PERFORMANCE OF C.S.C

Date (DD/MM/YY) : From 8 a.m. of (....../....../...........) to 8 a.m. of (....../....../..............)

Area : ....

C.S.C. : ....

Prepared by : ....

Weather Condition (Fair/Windy/Rainy/Stormy/..)

01. Details of LT Breakdowns

Type	No. of breakdowns to be attended today	No. of breakdowns to be unattended today
Service mains (Loose Connection)		
Service mains (Service wire Problems)		
Service mains (Cutout Problems)		
Service mains (Meter Problems)		
Pole Broken (Natural/Accident)		
Conductor Broken		
Fuse Blown		

Fuse Blown:(Substation Names and Sin. Number)

Sub. Name	Sin No.	Sub. Name	Sin. Name

02. Details of HT Breakdown

Type of Breakdown	Location	Name of the ABS/LBS/DDLO Opened for isolation	Grid Name	Feeder No.	Time of	
					Failure	Reset
Pole Broken	1................... 2................... 3...................					
Conductor Broken	1................... 2................... 3................... 4................... 5...................					
Fuse Blown	1................... 2................... 3................... 4................... 5...................					
Other (Jumpers Open/Conductor Touching etc.)	1................... 2................... 3................... 4................... 5...................					

03. Failure analysis

Reason for Failure	LT	HT	Reason for Failure	LT	HT
Vegetation			Consumer Fault		
Branches coming from distance			Sabotage		
Burnt jumpers and Conductors			Accidents due to vehicles		
Loose span and entanglement			Due to broken poles		
Cracked insulators, L/A and Transformer bushings			Transformer failures		
Due to animals and birds			Burnt tail wires and cables		
Non availability of LT Protection			Aging of fuses		
ACB trippings, fuses blown			Bad weather		
UG Cable fault			Others		

04. Details of HT scheduled interruptions

Interrupted Feeder No.	Feeding Grid	Interrupted Section	Interruption Scheduled at		Interruption Given at		Interruption Requested by
			From	To	From	To	

05.Details of Over Voltages/Fire/Electrocution/Accidents or any other special incidents

Incident	Reported Time	Type (Over Voltage/Firel/Accident/Electrocution)

06.Details of Equipment (Failed/Rectified/Replaced) today

Equipment Type (TF/LBS/Auto Recloser/Arrestor)	ID No.	Location	Report Date and Time	Rectified or Replaced by

07.Details of energized jobs (PCB/DCB/SA/ADB/Bulk Supply/...........................)

Job Name	Job Type (PCB/DCB/SA/ADB/Bulk Supply/Cost Paid/Chinese/RE)

08.Any Assistance (Material/Gang/Vehicle/Tools) immediately required to ES/CSC/from other

Type of Support (Material/Vehicle/Gang/Tool)	Details of Work	Relevant Branch

Annexure-3.2

DAILY REPORT ON 33kV OUTAGES

Date:............................

Name of ES:.......................................

GSS	Feeder No	Feeder Name	Fault				Manual					Isolated Section
			Start ring Time	Ending Time	Duration (Min)	Type EF/OC/Other	Starting Time	End Time	Duration (Minutes)	Request By	Reason	

Annexure-3.3

Provincial Monitoring Center – North Western Province

Daily Report on …………………

1. Details of breakdowns

CSC	LT failures				HT failures		
	Reported		Unattended		Reported today	Unattended today	Reason
	Service Connection	Sub Station	Service Connection	Sub Station			
Kuliyapitiya C.S.C							
Giriulla C.S.C							
Narammala C.S.C							
Pannala C.S.C							
Wariyapola C.S.C							
Nikaweratiya C.S.C							
Maho C.S.C							
Kurunegala C.S.C							
Gokarella C.S.C							
Mallawapitiya C.S.C							
Pothuhera C.S.C							
Chilaw C.S.C							
Puttalam C.S.C							
Madamape C.S.C							
Wennappuwa C.S.C							
Bolawatta C.S.C							
Nattandiya C.S.C							
Bingiriya							
Anamaduwa							
Kalpitiya							

2. Interruption details

C.S.C	Interrupted feeder	Interrupted section		Appro. No.of t./fs	Interruption scheduled at		Interruption given at		Interruption given to
		From	To		From	To	From	To	

3. **Tripping details**

33kV FEEDER TRIPPING IN GRID SUBSTATIONS NORTH WESTERN PROVINCE										
GSS	**Normal current**	**Feeder**	**Feeder Name**	**Peak Currant**	**Peak Time**	**O/C**	**EF**		**Manual**	**Total**
							A/ R	**Others**		
Puttalam	120A	F1	Chilaw							
	75A	F3	Kalpitiya							
	180A	F4	Anamaduwa							
	115A	F5	Cement Fac.							
	30A	F7	Wanathawilluwa							
	85A	F8	Cement Fac.							
Sub Total										
Madampe	205A	F1	Kuliyapitiya							
	160A	F2	Bingiriya							
	80A	F3	Chilaw							
	80A	F4	Nattandiya I							
	40A	F5	Voice of Ameri							
	160A	F7	Keeriyankalliya							
	115A	F8	Buwalka							
Sub Total										
Bolawatta	145A	F1	Madampe							
	160A	F2	Makandura							
	145A	F3	VOA							
	280A	F4	Negombo I							
	60A	F5	Bolawatta Prima.							
	210A	F6	Negombo II							
	140A	F7	Pannala							
	70A	F8	Veyangoda I							
	110A	F9	Veyangoda II							
Sub Total										
Mallawapitiya	138A	F1 / H5	Galagedara							
	112A	F2 / H6	Kurunegala town							
	104A	F3 / H7	Polgahawela							
		F4 /H11	Hiripitiya							
	148A	F5 /H12	Padeniya							
	67A	F6 /H13	Spare							
	162A	F7 / H4	Ibbagamuwa BB							
	45A	F8 /H14	Dodangaslanda							
		F	Maho BB							
Sub Total										
Tulhiriya	79A	F1	Industrial Zone							
	45A	F2	Kurunegala							
	65A	F3	Pannala							
	223A	F5	Kuliyapitiya							
Sub Total										

4. **Reasons for Changes in Feeder Current.**

Grid	**Feeder**	**Reason**

5. **Grid outages/ Total failures**

Grid	Starting time	Energized time	Duration

6. **Energized Jobs**

CSC	Job Name	Type PCB/DCB/ADB/Bulk	Job No

7. **Major Incidents**

CSC/Grid	Incident	Reported Time	Action taken

8. **Details of equipment (failed/rectified/replaced) today**

Equipment	Voltage	Location	Reported date And time	Rectified or replaced by

9. **Reliability Information**

Type of Outages	No. of Events	Effected Consumers	SIDI Information	SAIFI Information
LT				
HT				
Feeder Tripping				
Interruptions				
Total				

Prepared by : - ....

Approved by : - ....

HT breakdown failure records at the DCC

Annexure 3.4

CSC Name	Date	BD-Ref No	HT Fuse Blown	Conductor Broken	Pole Broken	Others	Breakdown Type	Grid Name	Feeder No	Location	Failed time	Reset time	Con. effected
Anamaduwa	7/27/2006	HT/5817/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D930 DDLO	10:50:00 AM	2:30:00 PM	281
Anamaduwa	12/11/2006	HT/6998/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thalakolawewa CHB22	9:20:00 AM	10:10:00 AM	476
Anamaduwa	11/10/2006	HT/6774/06	0	1	0	0	Conductor Broken	Puttalama	F4 Aanamaduwa	D925	10:00:00 AM	10:45:00 AM	315
Anamaduwa	10/4/2004	HT/838/04	1	0	0	0	Fuse Blown			Ihala Ibawewa	8:29:00 PM	10:27:00 PM	
Anamaduwa	10/9/2004	HT/853/04	1	0	0	0	Fuse Blown			Uriyawa DDLO	7:00:00 AM	11:00:00 AM	
Anamaduwa	10/9/2004	HT/854/04	1	0	0	0	Fuse Blown			Andarawewa DDLO	4:30:00 PM	5:35:00 PM	
Anamaduwa	6/2/2005	HT/2654/05	0	0	0	1	others	Puttalama	F4 Aanamaduwa	Mahauswewa A/R	2:50:00 PM	3:40:00 PM	1318
Anamaduwa	5/28/2006	HT/5264/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D931 Sirigala	4:45:00 PM	5:10:00 PM	267
Anamaduwa	12/22/2004	HT/1494/04	1	0	0	0	Fuse Blown			12/22/04	12:00:00 PM	1:10:00 PM	
Anamaduwa	12/14/2004	HT/1422/04	0	0	0	1	Others			B/Jumper Wadigamangawa 33kv	12:05:00 PM	5:35:00 PM	
Anamaduwa	12/14/2004	HT/1421/04	1	0	0	0	Fuse Blown			Panavitiya T/DDLO	4:30:00 PM	8:00:00 PM	
Anamaduwa	10/13/2005	HT/3570/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Wadigamangawa DDLO	10:00:00 AM	3:50:00 PM	1
Anamaduwa	10/13/2005	HT/3571/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Perun Kade Jumper	10:20.00 AM	5:30:00 PM	137
Anamaduwa	5/27/2006	HT/5254/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thalakolawewa DDLO	6:00:00 PM	6:40:00 PM	476
Anamaduwa	5/27/2006	HT/5253/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Wembuwewa DDLO	4:00:00 PM	5:30:00 PM	1
Anamaduwa	7/25/2006	HT/5800/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Kottalakemiyawa DDLO	8:10:00 AM	10:50:00 AM	189
Anamaduwa	9/22/2004	HT/695/04	1	0	0	0	Fuse Blown			B/J at Anamaduwa Town	3:00:00 PM	3:30:00 PM	
Anamaduwa	11/26/2006	HT/6902/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D933	7:30:00 AM	11:30:00 AM	1326
Anamaduwa	9/8/2004	HT/614/04	1	0	0	0	Fuse Blown			Paramakanda Junction T/DDLO	5:20:00 PM	6:00:00 PM	
Anamaduwa	9/9/2004	HT/625/04	1	0	0	0	Fuse Blown			Burnt Jumper at Paramakanda Junction	9:00:00 AM	10:35:00 AM	
Anamaduwa	11/27/2006	HT/6908/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D1383	6:10:00 AM	2:00:00 PM	91
Anamaduwa	9/19/2005	HT/3362/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Siyambalagashena DDLO	11:40:00 AM	5:20:00 PM	561
Anamaduwa	10/8/2005	HT/3520/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thalakolawewa DDLO	7:20:00 AM	8:45:00 AM	415
Anamaduwa	9/19/2004	HT/692/04	1	0	0	0	Fuse Blown			Sangattikulama L/DDLO	7:15:00 PM	8:30:00 PM	
Anamaduwa	5/25/2006	HT/5229/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Uriyawa D931 DDLO	4:15:00 PM	5:00:00 PM	267

Anamaduwa	9/25/2004	HT/725/04	1	0	0	0	Fuse Blown			Uriyawa T/DDLO	9:30:00 AM	10:35:00 AM		
Anamaduwa	7/17/2006	HT/5738/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D931 DDLO	5:30:00 PM	6:00:00 PM		267
Anamaduwa	7/11/2004	HT/73/04	1	0	0	0	Fuse Blown			Anamaduwa Town T/DDLO	7:30:00 AM	8:10:00 AM		
Anamaduwa	9/26/2004	HT/736/04	1	0	0	0	Fuse Blown			Palamakanda T/DDLO	10:30:00 AM	10:55:00 AM		
Anamaduwa	7/1/2005	HT/2672/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thonigala DDLO	2:00:00 PM	3:00:00 PM		11
Anamaduwa	7/19/2006	HT/5749/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Kelewewa DDLO	2:25:00 PM	3:30:00 PM		2
Anamaduwa	9/19/2005	HT/3361/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Heenagama DDLO	9:00:00 AM	11:15:00 AM		268
Anamaduwa	11/25/2004	HT/1328/04	1	0	0	0	Fuse Blown			Pallaveliya Junction T/DDLO	2:00:00 PM	2:45:00 PM		
Anamaduwa	10/18/2005	HT/3617/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Mahauswewa A/R	6:10:00 PM	6:45:00 PM		1318
Anamaduwa	7/16/2004	HT/136/04	1	0	0	0	Fuse Blown			T/DDLO	8:10:00 AM	9:30:00 AM		
Anamaduwa	12/9/2006	HT/6981/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D929	8:25:00 AM	10:00:00 AM		428
Anamaduwa	1/9/2006	HT/4300/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Anamaduwa A/R	11:00:00 AM	11:20:00 AM		1318
Anamaduwa	5/7/2006	HT/5078/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D931 DDLO	1:35:00 PM	2:00:00 PM		267
Anamaduwa	5/27/2006	HT/5252/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Welewewa DDLO	9:05:00 AM	2:40:00 PM		1
Anamaduwa	5/6/2005	HT/2194/05	0	0	0	1	others	Puttalama	F4 Aanamaduwa	Nawagatta A/R	6:20:00 AM	7:35:00 AM		3305
Anamaduwa	5/19/2006	HT/5172/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Kottalakemiyawa J/B	8:35:00 AM	12:10:00 PM		189
Anamaduwa	11/25/2004	HT/1327/04	1	0	0	0	Fuse Blown			Wadigamangawa DDLO J/Burnt	3:30:00 PM	4:00:00 PM		
Anamaduwa	5/2/2006	HT/5054/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Sangattikulama	6:25:00 PM	7:00:00 PM		168
Anamaduwa	10/28/2006	HT/6645/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D925	7:50:00 AM	10:00:00 AM		315
Anamaduwa	5/1/2006	HT/5049/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thattewa D930 DDLO	12:15:00 PM	1:00:00 PM		281
Anamaduwa	10/24/2005	HT/3673/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Uswewa DDLO	8:15:00 PM	9:10:00 PM		1318
Anamaduwa	9/7/2005	HT/3253/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Porankade DDLO	1:20:00 PM	3:10:00 PM		137
Anamaduwa	10/29/2006	HT/6652/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D929	7:30:00 AM	11:30:00 AM		428
Anamaduwa	5/1/2005	HT/2142/05	0	0	0	1	others	Puttalama	F4 Aanamaduwa	Mahauswewa A/R	11:45:00 AM	12:15:00 PM		13
Anamaduwa	7/11/2005	HT/2763/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Andigama DDLO	6:20:00 AM	11:00:00 AM		173
Anamaduwa	12/8/2004	HT/1403/04	1	0	0	0	Fuse Blown			Ihalauswewa L/DDLO	8:35:00 AM	10:05:00 AM		
Anamaduwa	10/11/2005	HT/3543/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Nawagattegama DDLO	6:15:00 AM	2:50:00 PM		307
Anamaduwa	12/7/2004	HT/1397/04	1	0	0	0	Fuse Blown			H9' Village T/DDLO	8:30:00 AM	10:50:00 AM		
Anamaduwa	8/17/2005	HT/3083/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Ihalauswewa DDLO	8:20:00 AM	10:20:00 AM		1318
Anamaduwa	5/25/2006	HT/5228/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Uriyawa D931 DDLO	3:20:00 PM	3:50:00 PM		267
Anamaduwa	4/13/2006	HT/4929/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thonigala DDLO	11:10:00 AM	12:10:00 PM		267
Anamaduwa	5/1/2005	HT/2141/05	0	0	0	1	others	Puttalama	F4 Aanamaduwa	Mahauswewa A/R	9:45:00 AM	9:55:00 AM		1318

Anamaduwa	12/4/2004	HT/1371/04	1	0	0	0	Fuse Blown			Sangattikulama	9:10:00 PM	11:40:00 PM	
Anamaduwa	8/13/2004	HT/359/04	1	0	0	0	Fuse Blown			Poravitiya	7:25:00 AM	9:50:00 AM	
Anamaduwa	12/6/2006	HT/6966/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D925	1:00:00 PM	3:00:00 PM	315
Anamaduwa	12/6/2004	HT/1387/04	1	0	0	0	Fuse Blown			11-9 Village Mahauswewa T/DDLO	1:00:00 PM	2:30:00 PM	
Anamaduwa	12/5/2004	HT/1381/04	0	0	0	1	Others			Anamaduwa Milewa	7:45:00 AM	11:40:00 AM	
Anamaduwa	9/15/2005	HT/3333/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Sangattikulama DDLO	9/15/2005 7:25:00 PM	9/16/2005 9:20:00 AM	237
Anamaduwa	5/27/2006	HT/5251/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Nawagathimegama DDLO	8:45:00 AM	11:30:00 AM	283
Anamaduwa	5/24/2006	HT/5216/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Aththikulama DDLO	10:50:00 AM	1:00:00 PM	91
Anamaduwa	10/3/2005	HT/3450/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Thonigla DDLO	12:45:00 PM	12:45:00 PM	17
Anamaduwa	3/4/2005	HT/1908/05	1	0	0	0	Fuse Blown			Madawakkulama DDLO	4:30:00 PM	7:10:00 PM	173
Anamaduwa	7/3/2006	HT/5616/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Water Pump DDLO	8:20:00 AM	10:50:00 AM	1
Anamaduwa	10/4/2005	HT/3457/05	1	0	0	0	Fuse Blown	Puttalama	F5 Cement Fac	Andarawewa DDLO	10/4/2005 7:25:00 PM	10/5/2005 9:15:00 AM	1
Anamaduwa	3/11/2005	HT/1979/05	1	0	0	0	Fuse Blown			Andigam/ Madawela DDLO	3/11/2005 9:10:00 PM	3/12/2005 10:15:00 AM	173
Anamaduwa	3/11/2005	HT/1980/05	1	0	0	0	Fuse Blown			Thonigama DDLO	8:00:00 PM	8:15:00 PM	174
Anamaduwa	1/21/2005	HT/1649/05	1	0	0	0	Fuse Blown			Tonigala Junction	6:45:00 PM	7:00:00 PM	
Anamaduwa	3/13/2005	HT/2017/05	1	0	0	0	Fuse Blown			Thonigala DDLO	10:40:00 AM	12:05:00 PM	174
Anamaduwa	7/14/2005	HT/2796/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Talkolawewa DDLO	3:35:00 PM	5:00:00 PM	415
Anamaduwa	12/15/2005	HT/4119/05	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	Sembukuliya DDLO	7:10:00 AM	9:45:00 AM	26
Anamaduwa	3/6/2005	HT/2025/05	1	0	0	0	Fuse Blown			Punavitiya DDLO	3/6/2005 8:00:00 PM	3/7/2005 10:00:00 AM	1017
Anamaduwa	1/25/2005	HT/1669/05	1	0	0	0	Fuse Blown			Uriyawa DDLO	4:00:00 PM	4:55:00 PM	
Anamaduwa	6/24/2006	HT/5528/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D930	3:50:00 PM	5:20:00 PM	281
Anamaduwa	3/9/2005	HT/2077/05	1	0	0	0	Fuse Blown			Sangattikulama	3/9/2005 5:30:00 PM	3/10/2005 8:40:00 AM	237
Anamaduwa	9/6/2004	HT/585/04	0	0	0	1	Others			J/Broken at Rabawewa	9:50:00 AM	3:50:00 PM	
Anamaduwa	7/25/2004	HT/201/04	1	0	0	0	Fuse Blown			Uriyawa T/DDLO	8:40:00 AM	12:25:00 PM	
Anamaduwa	2/17/2005	HT/1827/05	1	0	0	0	Fuse Blown			Thonigala	10:10:00 AM	11:20:00 AM	
Anamaduwa	7/13/2006	HT/5700/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D931	11:10:00 AM	12:40:00 PM	483
Anamaduwa	9/3/2006	HT/6183/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D929	6:15:00 AM	12:30:00 PM	428
Anamaduwa	7/15/2006	HT/5725/06	1	0	0	0	Fuse Blown	Puttalama	F4 Aanamaduwa	D931	9:40:00 AM	10:15:00 AM	483
Anamaduwa	7/10/2006	HT/5665/06	0	1	0	0	Conductor Broken	Puttalama	F1 Chilaw	DDLO D933	10:30:00 AM	2:40:00 PM	4807
Anamaduwa	7/10/2006	HT/5664/06	1	0	0	0	Fuse Blown	Puttalama	F1 Chilaw	D933 DDLO	10:30:00 AM	2:40:00 PM	4807

Sin numbers and number of consumers assigned to the substation

Consumer Data for Wennppuwa area. **Annexure 3.5**

sin number	Total number of customers
PP111	382
PP113	195
PP114	345
PP115	245
PP116	86
PP117	1
PP118	271
PP119	1
PP120	1
PP121	1
PP122	416
PP123	1
PP124	90
PP125	264
PP126	272
PP128	220
PP129	833
PP130	104
PP131	374
PP132	367
PP133	859
PP134	7
PP135	1
PP136	198
PP137	626
PP138	1
PP139	513
PP140	334
PP141	374
PP142	13
PP143	269
PP144	153
PP145	567
PP146	93
PP147	586
PP148	684
PP149	253
PP150	203
PP151	563
PP152	1
PP153	1
PP154	1
PP155	1
PP156	1
PP157	1
PP158	1
PP159	274
PP160	190
PP161	263
PP162	1
PP163	735
PP164	383

PP165	233
PP166	327
PP167	239
PP168	596
PP169	126
PP170	174
PP171	115
PP172	1
PP173	428
PP174	398
PP175	95
PP176	201
PP177	254
PP178	214
PP179	1
PP180	375
PP181	237
PP301	271
PP302	133
PP303	175
PP304	93
PP305	1
PP306	200
PP307	36
PP308	1
PP309	1
PP310	1
PP311	1
PP312	167
PP313	1
PP314	1
PP315	310
PP316	296
PP317	173
PP318	1
PP319	185
PP320	1
PP321	283
PP322	122
PP323	159
PP324	398
PP326	1
PP327	291
PP328	75
PP329	1
PB001	1
PB002	320
PB003	461
PB004	226
PB005	226
PB006	269
PB007	146
PB008	1
PB009	295
PB010	166
PB011	57

PB012	312
PB013	1
PB014	311
PB015	1
PB016	222
PB017	156
PB018	299
PB019	323
PB020	320
PB021	1
PB022	233
PB023	101
PB024	222
PB025	328
PB026	242
PB027	311
PB028	180
PB029	155
PB030	237
PB031	267
PB032	290
PB034	290
PB035	111
PB036	365
PB037	1
PB038	192
PB039	405
PB040	291
PB041	126
PB042	322
PB043	277
PB044	295
PB045	23
PB046	160
PB047	471
PB048	526
PB049	170
PB050	103
PB051	118
PB052	276
PB053	58
PB054	236
PB055	137
PB056	254
PB057	481
PB058	193
PB059	185
PB061	10
PB062	245
PB063	168
PB064	137
PB065	1
PB066	116
PB067	1
PB068	187
PB069	1

Annexure 4.1

බිඳවැටුම් ශීඝ්‍රතාව ගණනය කිරීම හා නිරාවරණ කලාප ප්‍රතිසංස්කරණය කිරීම සඳහා දත්ත එක්රැස් කිරීම (2006 වසර)

පාරිභෝගිකයාගෙ නම :

පාරිභෝගිකයාගේ ලිපිනය :

ප්‍රාදේශීය කලාපය :

පාරිභෝගික සේවා මධ්‍යස්ථානය :

නිරාවරණ කලාප :සුළගේ බලපෑම සහිත මුහුදුබඩ පලාත් / සුළගේ බලපෑම රහිත මුහුදුබඩ පලාත් / පොල් වගාවන් / වී වගාවන් / ඝන වනාන්තර / ආරක්ෂිත වනාන්තර / සාමාන්‍ය ග්‍රාමීය පලාත් / නාගරික පලාත්

මධ්‍යම රැහැන් වෝල්ටීයතාවය : කි.වෝ. 11 / කි.වෝ. 33

වැඩිසැර බිඳවැටුම් විස්තර

බිඳවැටුම් ආකාරය	* සිද්ධිය වූ මාසය	බිඳවැටීමට හේතු	විදුලි සැපයුම නැවත ලබාදීමට ගත වූ කාලය
(1) කණු බිඳවැටුම	1. 2. 3. 4		
(2) රැහැන් බිඳවැටුම	1. 2. 3. 4.		
(3) වෙනත්			

* සිද්ධිය වූ නිවැරදි දිනය අවශ්‍ය නොවේ.

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පාරිභෝගිකයාගේ අත්සන.

Annexure 6.1

Correlation between rainfall and operation frequency of HT DDLO

Operation frequency of HT DDLO for year 2005

2005	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall in mm	65.7	43.8	73.3	175.8	18.2	7.4	19.9	0	3.3	170	324.5	88.1
No of incidents	4	5	4	1	4	6	7	3	4	2	1	7

Operation frequency of HT DDLO for year 2006

2006	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall in mm	128.9	35.3	229.3	64.7	85	5.3	2.2	5	118.6	497.8	275.2	73.5
No of incidents	2	0	4	4	6	5	4	5	5	16	7	4

Puththalama Grid substation- Kalpitiya Feeder

Project Name

Annexure 6.2

March 26, 2000 08:59 AM

Scale: (1 in = 6119.7 Feet)