



## REFERENCES

1. R. E. Brown, *Electricity Power Distribution Reliability*, 2nd Ed. New York, CRC press, 2007.
2. C.A.Volkman, S.Goldberg and W.F.Horton, "A probabilistic approach to distribution system reliability assessment" in *IEEE Transactions on Power Systems*
3. C.A.Warren, "Distribution Reliability- What is it?", in *IEEE Conference Paper 95B2*, 1995.
4. Teng-Fa Tsao and Hong-Chan Chan, "Composite reliability evaluation model for different types of distribution systems", in *IEEE Transactions on Power Systems*, Vol.18, No.2, May 2003, pp.924-930.
5. A.A.Chowdhury and D.O.Koval, *Power Distribution System Reliability Practical Methods and Applications*, Wiley Publications, 2009
6.  *IEEE Trial-User guide for Electric Power distribution reliability indices*, IEEE std. 1366-1998.  
 University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)
7. R.D. Christie, "Statistical classification of major event days in distribution system reliability", in *IEEE Transactions on Power Delivery*, Vol.18, No.4, October 2003, pp.1336-1341.
8. R.E. Brown and A.P.Hanson, "Impact on two stage service restoration on Distribution Reliability", in *IEEE Transactions on Power Systems*, Vol.16, No.2, November 2001, pp.624-629.
9. R.E.Brown, "Distribution reliability assessment and reconfiguration optimization", in *IEEE Transmission and Distribution Conference*, 2001, pp. 994-999.
10. R.Billinton and R.N. Allan, *Reliability Evaluation of Power Systems*, Plenum press, New York, 1984.

## APPENDICES

### Appendix 1: Summary of the outages- 11kV System

#### SUMMARY OF 11kV LINES- FAILURE AND PLANNED OUTAGES

Average values for 3 years (2007-2009)

System voltage	Class of fault	Outage description	outage type	CEB or LECO	No of failures	Delay hrs.	Avg. Restoration hrs.
11kV	DDLO	Burnt Ddlo Carrier	F	LECO	24.00	22.84	0.95
11kV	DDLO	Broken Ddlo	F	LECO	0.67	0.30	0.45
11kV	EQUIPMENT	Faulty A.R.	F	LECO	2.00	24.43	12.22
11kV	EQUIPMENT	Faulty Ct/Pt Unit	F	LECO	1.00	2.83	2.83
11kV	EQUIPMENT	Faulty Lbc	F	LECO	7.67	7.59	0.99
11kV	EQUIPMENT	Faulty Lbs	F	LECO	8.33	13.25	1.59
11kV	EQUIPMENT	Faulty Sectionaliser	F	LECO	5.00	4.71	0.94
11kV	EQUIPMENT	Faulty T/F	F	LECO	9.67	13.54	1.40
11kV	EQUIPMENT	Faulty Ocb.	F	CEB	13.67	61.48	4.50
11kV	Surge Arrestor	Burnt Lightning Arrestor	F	LECO	27.67	51.37	1.86
11kV	Exreme	Flood	F	CEB	7.00	114.35	16.34
11kV	Line-inherent	Broken Conductor	F	LECO	28.67	119.61	4.17
11kV	Line-inherent	Broken Earth Wire	F	LECO	2.00	0.77	0.39
11kV	Line-inherent	Broken Jumper	F	LECO	4.67	7.20	1.54
11kV	Line-inherent	Broken Preform	F	LECO	14.33	21.07	1.47
11kV	Line-inherent	Burnt Abc	F	LECO	8.00	374.36	46.79
11kV	Line-inherent	Burnt Bolt	F	LECO	2.00	1.48	0.74
11kV	Line-inherent	Burnt Conductor	F	LECO	10.00	14.84	1.48
11kV	Line-inherent	Burnt Conductor Termination	F	LECO	5.33	14.08	2.64
11kV	Line-inherent	Burnt Jumper	F	LECO	16.33	11.06	0.68
11kV	Line-inherent	Burnt Lug	F	LECO	47.33	36.77	0.78
11kV	Line-inherent	Burnt Tail Wire	F	LECO	49.67	38.40	0.77
11kV	Line-inherent	Cracked Insulator	F	LECO	34.67	98.14	2.83
11kV	Line-inherent	Loose Bolt	F	LECO	3.00	3.02	1.01
11kV	Line-interfered	Animal	F	LECO	12.67	11.65	0.92
11kV	Line-interfered	Bat	F	LECO	7.33	4.04	0.55
11kV	Line-interfered	Bird	F	LECO	5.00	2.84	0.57
11kV	Line-interfered	broken 33kv line on line	F	LECO	7.67	25.89	3.38
11kV	Line-interfered	Broken Pole	F	LECO	24.00	282.81	11.78
11kV	Line-interfered	Burnt Ddlo	F	LECO	5.67	6.65	1.17
11kV	Line-interfered	Coconut Branch	F	LECO	88.33	74.24	0.84
11kV	Line-interfered	Consumer Request	F	LECO	6.67	24.67	3.70
11kV	Line-interfered	Crow	F	LECO	42.33	22.70	0.54
11kV	Line-interfered	Fault In Another Fdr	F	LECO	6.00	2.18	0.36
11kV	Line-interfered	Fault In Ceb Area	F	LECO	27.67	26.37	0.95
11kV	Line-interfered	Fire Below Line	F	LECO	2.67	3.02	1.13
11kV	Line-interfered	Internal Faults At Consumer Premises	F	LECO	3.67	31.48	8.59
11kV	Line-interfered	Interrupted For Ceb Work	F	LECO	118.667	212.28	1.79
11kV	Line-interfered	Interrupted For Outside Organisation Work	F	LECO	3.66667	1.82	0.50
11kV	Line-interfered	Kite	F	LECO	11.33	8.00	0.71
11kV	Line-interfered	Lightning	F	LECO	28.00	36.70	1.31
11kV	Line-interfered	Maintenance	F	LECO	31.67	28.41	0.90
11kV	Line-interfered	Monkey	F	LECO	25.33	14.22	0.56
11kV	Line-interfered	Motor Vehicle Accident	F	LECO	27.00	81.62	3.02
11kV	Line-interfered	Operator Error	F	LECO	2.67	1.94	0.73
11kV	Line-interfered	Piece Of Iron On Line	F	LECO	25.67	38.37	1.50

System voltage	Class of fault	Outage description	outage type	CEB or LECO	No of failures	Delay hrs.	Avg. Restorat ion hrs.
11kV	Line-interfered	Pole Erection	F	LECO	87.33	135.59	1.55
11kV	Line-interfered	Pole Shifting	F	LECO	4.67	13.51	2.89
11kV	Line-interfered	Rehabilitation Work	F	LECO	4.33	73.21	16.89
11kV	Line-interfered	Sign Board	F	LECO	4.50	6.83	1.52
11kV	Line-interfered	Squirrel	F	LECO	39.33	21.51	0.55
11kV	Line-interfered	switchgear operated due to O/L	F	LECO	18.00	4.89	0.27
11kV	Line-interfered	T/F Change	F	LECO	21.67	21.78	1.01
11kV	Line-interfered	Tilted Pole	F	LECO	2.33	3.47	1.49
11kV	Line-interfered	To Check Lbs	F	LECO	12.33	7.94	0.64
11kV	Line-interfered	To Check Line	F	LECO	13.00	12.63	0.97
11kV	Line-interfered	to close jumpers	F	LECO	40.33	31.85	0.79
11kV	Line-interfered	To Connect A New T/F	F	LECO	40.67	39.84	0.98
11kV	Line-interfered	To Connect Ug Cable	F	LECO	3.00	1.74	0.58
11kV	Line-interfered	To Cut A Tree	F	LECO	28.33	26.00	0.92
11kV	Line-interfered	To Cut Tree Branches	F	LECO	64.33	38.20	0.59
11kV	Line-interfered	To Disconnect A T/F	F	LECO	3.67	1.36	0.37
11kV	Line-interfered	To Fix H-Connectors	F	LECO	6.00	4.43	0.74
11kV	Line-interfered	To Install A Ddlo	F	LECO	3.00	1.67	0.56
11kV	Line-interfered	To Install L.A..	F	LECO	3.33	4.51	1.35
11kV	Line-interfered	To Open Jumpers	F	LECO	20.67	13.67	0.66
11kV	Line-interfered	To Operate A.R..	F	LECO	1.00	0.08	0.08
11kV	Line-interfered	To Operate Lbc	F	LECO	14.00	4.05	0.29
11kV	Line-interfered	To Operate Lbs	F	LECO	144.00	13.50	0.09
11kV	Line-interfered	To Remove A Sign-Board	F	LECO	6.67	2.60	0.39
11kV	Line-interfered	To Remove A Tree	F	LECO	5.00	8.23	1.65
11kV	Line-interfered	To Remove A Tree Branch	F	LECO	11.33	3.92	0.35
11kV	Line-interfered	To Remove Coconut Tree Branches	F	LECO	3.33	1.12	0.34
11kV	Line-interfered	Tree Branches	F	LECO	79.67	86.99	1.09
11kV	Line-interfered	Tree In Line	F	LECO	88.67	242.38	2.73
11kV	Line-interfered	Tv Antenna On Line	F	LECO	3.33	1.48	0.44
11kV	Line-interfered	Ug Cable Failure	F	LECO	9.00	278.93	30.99
11kV	Line-interfered	Unknown	F	LECO	1306.33	400.07	0.31
11kV	Line-interfered	Wayleaves	F	LECO	3.00	5.68	1.89
11kV	Line-interfered	broken crossarm	F	CEB	3.67	20.04	5.47
11kV	Line-interfered	Switchgear Operated Due To O/L	F	CEB	4.00	1.92	0.48
11kV	Line-interfered	Load Shedding	F	LECO	201.00	387.37	1.93
11kV	Line-interfered	Load Transfer	F	LECO	870.33	173.54	0.20
11kV	Line-interfered	Load Transfer	P	CEB	822.33	182.16	0.22
11kV	line-Planned	Construction Work	P	LECO	150.00	921.96	6.15
11kV	line-Planned	Interrupted For Ceb Work	P	LECO	105.00	688.98	6.56
11kV	line-Planned	Interrupted For Outside Organisation Work	P	LECO	111.00	608.09	5.48
11kV	line-Planned	Maintenance	P	LECO	210.67	1447.01	6.87
11kV	line-Planned	Pole Shifting	P	LECO	23.67	153.65	6.49

**SUMMARY**

System voltage	Class of fault	Outage description	outage type	CEB or LECO	No of failures	Delay hrs.	Avg. Restorat ion hrs.
11kV	DDLO		F	LECO	24.67	23.14	0.94
	Equipment	Faulty A.R.	F	LECO	2.00	24.43	12.22
	Equipment	Faulty Ct/Pt Unit	F	LECO	1.00	2.83	2.83
	Equipment	Faulty Lbc	F	LECO	7.67	7.59	0.99
	Equipment	Faulty Lbs	F	LECO	8.33	13.25	1.59
	Equipment	Faulty Ocb.	F	LECO	13.67	61.48	4.50
	Equipment	Faulty Sectionaliser	F	LECO	5.00	4.71	0.94
	Equipment	Faulty T/F	F	LECO	9.67	13.54	1.40
	Surge Arrestor	Burnt Lightning Arrestor	F	LECO	27.67	51.37	1.86
	Extreme	Flood	F	LECO	7.00	114.35	16.34
	Line-inherent	failures	F	LECO	218.00	366.43	1.68
	Line-inherent	Burnt 11kV ABC	F	LECO	8.00	374.40	46.80
	Line-interfered	Load Shedding	F	LECO	201.00	387.37	1.93
	Line-interfered	Load Transfer	F	LECO	870.33	173.54	0.20
	Line-interfered	Load Transfer	P	CEB	822.33	182.16	0.22
	Line-interfered	failures	F	LECO	2176.14	1768.99	0.81
	Line-interfered	wayleave	F	LECO	283.66	412.51	1.45
	Line-interfered	CEB and other	F	LECO	157.70	296.00	1.88
	line-Planned		P	LECO	600.33	3819.69	6.36

5444.18 8097.79



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## Appendix 2: Summary of the outages- LV system

### SUMMARY OF LOW VOLTAGE LINE- FAILURE AND PLANNED OUTAGES

Average values for 3 years (2007-2009)

System voltage	Class of fault	Outage description	outage type	CEB or LECO	No of failures	Delay hrs.	Avg. Restoration hrs.
LV	Line-inherent-ABC	Broken Abc	F	LECO	16.33	58.40	3.58
LV	Line-inherent-ABC	Burnt Abc	F	LECO	48.00	83.09	1.73
LV	Line-inherent-ABC	Burnt T-Off Connector	F	LECO	7.33	4.06	0.55
LV	Line-inherent-bare	Broken Jumper	F	LECO	2.00	2.14	1.07
LV	Line-inherent-Common	Broken Conductor	F	LECO	33.33	134.09	4.02
LV	Line-inherent-Common	Broken Neutral Wire	F	LECO	18.67	44.57	2.39
LV	Line-inherent-Common	Burnt Conductor	F	LECO	5.33	7.95	1.49
LV	Line-interfered-bare	Animal	F	LECO	24.33	14.80	0.61
LV	Line-interfered-bare	Bat	F	LECO	2.67	1.61	0.60
LV	Line-interfered-bare	Bird	F	LECO	1.33	0.67	0.51
LV	Line-interfered-bare	Burnt Jumper	F	LECO	5.33	5.71	1.07
LV	Line-interfered-bare	Coconut Branch	F	LECO	180.00	156.32	0.87
LV	Line-interfered-bare	Crow	F	LECO	17.33	9.34	0.54
LV	Line-interfered-bare	Monkey	F	LECO	26.33	18.81	0.71
LV	Line-interfered-bare	squirrel	F	LECO	20.00	12.30	0.61
LV	Line-interfered-bare	Tree Branches	F	LECO	176.67	227.20	1.29
LV	Line-interfered-Common	Broken Pole	F	LECO	16.33	133.39	8.17
LV	Line-interfered-Common	consumer request	F	LECO	35.33	259.91	7.36
LV	Line-interfered-Common	Faulty Mcb	F	LECO	3.33	2.35	0.71
LV	Line-interfered-Common	fire below line Internal Faults At Consumer	F	LECO	11.33	60.08	5.30
LV	Line-interfered-Common	Premises	F	LECO	6.00	6.24	1.04
LV	Line-interfered-Common	Lightning	F	LECO	19.33	23.05	1.19
LV	Line-interfered-Common	Load Transfer	F	LECO	26.67	58.27	2.19
LV	Line-interfered-Common	Maintenance	F	LECO	48.33	84.59	1.75
LV	Line-interfered-Common	Motor Vehicle Accident	F	LECO	6.00	268.50	44.75
LV	Line-interfered-Common	Pole Shifting	F	LECO	17.67	48.51	2.75
LV	Line-interfered-Common	T/F Change	F	LECO	12.00	19.41	1.62
LV	Line-interfered-Common	To Arrange Alternative Supply	F	LECO	11.33	5.77	0.51
LV	Line-interfered-Common	To Arrange The Feeders	F	LECO	9.50	4.38	0.46
LV	Line-interfered-Common	to check neutral leak	F	LECO	8.33	19.04	2.28
LV	Line-interfered-Common	Tree In Line	F	LECO	84.00	269.18	3.20
LV	Line-interfered-Common	Unknown	F	LECO	687.67	573.12	0.83
LV	Line-interfered-Common	S/S Augmentation	F	LECO	5.67	7.36	1.30
LV	Line-interfered-Common	Wire Contact	F	LECO	26.00	36.12	1.39
LV	Line-interfered-Common	To Check T/F	F	LECO	6.67	2.19	0.33
LV	Line-interfered-Common	To Connect A New Line	F	LECO	12.00	7.98	0.67
LV	Line-interfered-Common	other failures	F	LECO	66.00	84.78	1.28
LV	transformer	Faulty T/F	F	LECO	38.00	293.54	7.72
LV	transformer-accessories	Broken Ddlo	F	LECO	3.00	6.23	2.08
LV	transformer-accessories	Broken Earth Wire	F	LECO	4.00	3.74	0.94
LV	transformer-accessories	Burnt Ddlo Carrier	F	LECO	4.67	3.69	0.79
LV	transformer-accessories	Burnt Fds	F	LECO	59.67	57.74	0.97
LV	transformer-accessories	Burnt Lightning Arrester	F	LECO	4.00	5.14	1.29
LV	transformer-accessories	Burnt Lug	F	LECO	80.33	63.53	0.79
LV	transformer-accessories	Burnt Tail Wire	F	LECO	12.67	19.64	1.55
LV	transformer-accessories	To Change Meter	F	LECO	9.00	4.80	0.53
LV	transformer-accessories	To Check Meter	F	LECO	6.33	3.21	0.51
LV	Line-interfered-Common	Load Shedding	F	LECO	41.00	414.98	10.12
LV	Line-interfered-Common	Rehabilitation Work	P	LECO	9.67	67.20	6.95
LV	Line-interfered-Common	Interrupted For Ceb Work	P	LECO	21.00	145.14	6.91

**SUMMARY**

System voltage	Class of fault	Outage description	outage type	CEB or LECO	No of failures	Delay hrs.	Restoration hrs.
LV	Line-inherent-ABC		F	LECO	71.67	145.54	2.03
	Line-inherent-bare		F	LECO	2.00	2.14	1.07
	Line-inherent-Common		F	LECO	57.33	186.60	3.25
	Line-interfered-bare		F	LECO	454.00	446.75	0.98
	Line-interfered-Common		F	LECO	1119.50	1974.22	1.76
	transformer		F	LECO	38.00	293.54	7.72
	transformer-accessories		F	LECO	183.67	167.71	0.91
	Line-interfered-Common	Load Shedding	P	LECO	41.00	414.98	10.12
	Line-interfered-Common	Rehabilitation Work	P	LECO	9.67	67.20	6.95
Line-interfered-Common	Interrupted For Ceb Work	P	LECO	21.00	145.14	6.91	



University of Moratuwa, Sri Lanka.  
 Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

### Appendix 3: Summary of the outages- 33kV system

APPENDIX-3

#### SUMMARY OF FAILURE AND PLANNED OUTAGES STATISTICS OF 33kV SYSTEM Average values for 3 years (2007-2009)

System voltage	Sub name	affected pss	Outage description	out age type	CEB or LECO	No of failure/year	Delay hours	Avg. restoration hrs.
33kV	Gs Matugama	Ambalangoda	33Kv Supply Failure To Pss	F	CEB	199.5	54.7	0.27
33kV	Gs Ratmalana	Angulana	33Kv Supply Failure To Pss	F	CEB	70.5	25.5	0.36
33kV	Gs Aniyakanda	Aniyakanda	33Kv Supply Failure To Pss	F	CEB	54.0	25.0	0.46
33kV	Gs Bataduwa	Beligaha	33Kv Supply Failure To Pss	F	CEB	253.5	50.4	0.20
33kV	Gs Matugama	Bentota	33Kv Supply Failure To Pss	F	CEB	24.0	27.7	1.15
33kV	Gs Kotugoda	Bopitiya	33Kv Supply Failure To Pss	F	CEB	7.5	8.2	1.10
33kV	Gs Dehiwala	Boralessgamuwa	33Kv Supply Failure To Pss	F	CEB	91.0	18.8	0.21
33kV	Gs Sapugaskanda	Dalugama	33Kv Supply Failure To Pss	F	CEB	75.5	28.5	0.38
33kV	Gs Sapugaskanda	Dalupitiya	33Kv Supply Failure To Pss	F	CEB	49.5	21.6	0.44
33kV	Gs Bataduwa	Dickela	33Kv Supply Failure To Pss	F	CEB	149.5	29.5	0.20
33kV	Gs Jayawardanapura	Ethul kotte	33Kv Supply Failure To Pss	F	CEB	75.0	22.0	0.29
33kV	Gs Matugama	Fullerton	33Kv Supply Failure To Pss	F	CEB	56.0	29.8	0.53
33kV	Gs Bataduwa	Gonapinuwala	33Kv Supply Failure To Pss	F	CEB	276.5	84.6	0.31
33kV	Gs Kotugoda	Ja ela	33Kv Supply Failure To Pss	F	CEB	95.5	90.1	0.94
33kV	Gs Panadura	Kalutara	33Kv Supply Failure To Pss	F	CEB	66.0	31.4	0.48
33kV	Gs Matugama	Kaluwamodara	33Kv Supply Failure To Pss	F	CEB	37.0	25.5	0.69
33kV	Gs Ratmalana	Katubedda	33Kv Supply Failure To Pss	F	CEB	76.5	24.0	0.31
33kV	Gs Kolonnawa	Kolonnawa	33Kv Supply Failure To Pss	F	CEB	13.5	9.8	0.73
33kV	Gs Pannipitiya	Maharagama	33Kv Supply Failure To Pss	F	CEB	83.5	20.7	0.25
33kV	Gs Ratmalana	Manikkawatta	33Kv Supply Failure To Pss	F	CEB	99.5	28.4	0.29
33kV	Gs Panadura	Molligoda	33Kv Supply Failure To Pss	F	CEB	74.5	22.6	0.30
33kV	Gs Kotugoda	Negombo	33Kv Supply Failure To Pss	F	CEB	86.0	20.8	0.24
33kV	Gs Jayawardanapura	Nugegoda	33Kv Supply Failure To Pss	F	CEB	121.0	19.1	0.16
33kV	Gs Panadura	Pallimulla	33Kv Supply Failure To Pss	F	CEB	73.0	18.1	0.25
33kV	Gs Panadura	Panadura	33Kv Supply Failure To Pss	F	CEB	123.5	23.7	0.19
33kV	Gs Matugama	Payagala	33Kv Supply Failure To Pss	F	CEB	73.0	39.4	0.54
33kV	Gs Biyagama	Peliyagoda	33Kv Supply Failure To Pss	F	CEB	153.0	51.8	0.34
33kV	Gs Bolawatta	Periyamulla	33Kv Supply Failure To Pss	F	CEB	73.0	45.5	0.62
33kV	Gs Kotugoda	Seeduwa	33Kv Supply Failure To Pss	F	CEB	131.5	40.2	0.31
33kV	Gs Ratmalana	Thelawala	33Kv Supply Failure To Pss	F	CEB	25.0	37.0	1.48
33kV	Gs Jayawardanapura	Udahamulla	33Kv Supply Failure To Pss	F	CEB	107.0	18.5	0.17
33kV	Gs Biyagama	Wwattala	33Kv Supply Failure To Pss	F	CEB	27.5	30.3	1.10

System voltage	Sub name	affected pss	Outage description	out age type	CEB or LECO	No of failure/year	Delay hours	Avg. restoration hrs.
33kV	Gs Matugama	Ambalangoda	Interrupted For Ceb Work	P	CEB	2	14.9	7.47
33kV	Gs Ratmalana	Angulana	Interrupted For Ceb Work	P	CEB	1	5.8	5.79
33kV	Gs Sapugaskanda	Aniyakanda	Interrupted For Ceb Work	P	CEB	4	29.7	7.42
33kV	Gs Bataduwa	Beligaha	Interrupted For Ceb Work	P	CEB	1	4.7	4.71
33kV	Gs Matugama	Bentota	Interrupted For Ceb Work	P	CEB	7.5	68.3	9.10
33kV	Gs Sapugaskanda	Dalupitiya	Interrupted For Ceb Work	P	CEB	5.5	49.8	9.06
33kV	Gs Sapugaskanda	Dalupitiya	Interrupted For Ceb Work	P	CEB	2	11.1	5.57
33kV	gs bataduwa	Dick ela	interrupted for ceb work	P	CEB	2	10.8	5.38
33kV	Gs Jayawardanapura	Ethul kotte	Interrupted For Ceb Work	P	CEB	1.5	10.0	6.67
33kV	Gs Mathugama	Fullerton	interrupted for ceb work	P	CEB	1.5	13.0	8.66
33kV	Gs Kotugoda	Ja ela	Interrupted For Ceb Work	P	CEB	9.5	80.9	8.52
33kV	gs panadura	Kalutara	interrupted for ceb work	P	CEB	4	32.7	8.17
33kV	Gs Matugama	Kaluwamodara	Interrupted For Ceb Work	P	CEB	3	24.7	8.24

System voltage	Sub name	affected pss	Outage description	out age type	CEB or LECO	No of failure/year	Delay hours	Avg. restoration hrs.
33kV	gs pannipitiya	Maharagama	interrupted for ceb work	P	CEB	0.5	4.4	8.85
33kV	Gs Ratmalana	Maiyokkawatta	interrupted for ceb work	P	CEB	1	6.0	6.04
33kV	gs panadura	Molligoda	interrupted for ceb work	P	CEB	3	22.4	7.47
33kV	Gs Panadura	Pallimulla	Interrupted For Ceb Work	P	CEB	0.5	3.8	7.58
33kV	Gs Panadura	Panadura	Interrupted For Ceb Work	P	CEB	0.5	3.4	6.75
33kV	Gs Matugama	Payagala	Interrupted For Ceb Work	P	CEB	2.5	21.3	8.51
33kV	Gs Biyagama	Peliyagoda	Interrupted For Ceb Work	P	CEB	7	62.4	8.91
33kV	Gs Kotugoda	Seeduwa	interrupted for ceb work	P	CEB	4	37.1	9.27
33kV	Gs Ratmalana	Thelawala	Interrupted For Ceb Work	P	CEB	2	16.7	8.34
33kV	Gs Jayawardanapura	Udahamulla	interrupted for ceb work	P	CEB	0.5	2.8	5.63
33kV	Gs Biyagama	Wattala	Interrupted For Ceb Work	P	CEB	6	47.0	7.83



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)



## Appendix 4: Summary of component failure rate and downtime of outages

### SUMMARY OF COMPONENT FAILURE RATES AND DOWNTIME OF LECO DISTRIBUTION SYSTEM

Component no	System voltage	Outage type	Class of fault	Line type	Component nos	Unit	Utility	no of failures per year	(Total downtime per year)	$\lambda$ (failures/year/unit)	r(duration-hours per outage)
1	33kV	F	Source		32	nos	CEB	2,921.00	1,023.20	91.2813	0.35
2	11kV	F	OCB	Faulty Ocb.	128	nos	CEB	13.67	61.48	0.1068	4.50
3	11kV	F	Auto Recloser	Faulty A.R.	24	nos	LECO	2.00	24.43	0.0833	12.22
4	11kV	F	Load Break Switch	Faulty Lbs	471	nos	LECO	8.33	13.25	0.0177	1.59
5	11kV	F	Load Break Cutouts	Faulty Lbc	352	nos	LECO	7.67	7.59	0.0218	0.99
6	11kV	F	Sectionalizer	Faulty Sectionalizer	26	nos	LECO	5.00	4.71	0.1923	0.94
7	11kV	F	transformer	Faulty transformers	3,488	nos	LECO	9.67	13.54	0.0028	1.40
8	11kV	F	Line-inherent	failures	1,030	km	LECO	218.00	366.44	0.2117	1.68
	11kV	F	Line-interfered	failures	1,030	km	LECO	2,176.14	1,768.99	2.1128	0.81
	11kV	F		load transfers	1,030	km	LECO	1,692.66	355.70	1.6434	0.21
	11kV	F		load shedding	1,030	km	LECO	201.00	387.37	0.1951	1.93
	11kV	F		Wayleave	1,030	km	LECO	283.67	442.52	0.2754	1.45
	11kV	F		CEB & Other	1,030	km	LECO	157.67	296.01	0.1531	1.88
9	11kV	F	Surge Arrestors	Burnt Lightning Arrester	10,464	nos	LECO	27.67	51.37	0.0026	1.86
10	11kV	F	DDLO		10,464	nos	LECO	24.67	23.14	0.0024	0.94
11	LV	F	transformer		3,488	nos	LECO	38.00	293.54	0.0109	7.72
12	LV	F	transformer-accessories		3,488	nos	LECO	183.67	167.71	0.0527	0.91
13	LV	F	Line-inherent-ABC		2,647	km	LECO	71.67	145.54	0.0271	2.03
	LV	F	Line-inherent-bare		841	km	LECO	2.00	2.14	0.0024	1.07
	LV	F	Line-inherent-Common		3,114	km	LECO	57.33	186.60	0.0184	3.25
	LV	F	Line-interfered-bare		841	km	LECO	454.00	446.75	0.5398	0.98
	LV	F	Line-interfered-Common		3,114	km	LECO	1,119.50	1,974.22	0.3595	1.76
								9,674.97	8,026.24	97.31	
	33kV	P	Planned		32	nos	CEB	207.00	1,043.00	6.47	5.04
	11kV	P	line-Planned		1,030	km	LECO	600.33	3,819.69	0.58	6.36
	LV	P	Line-interfered-Common	Load Shedding	3,114	km	LECO	41.00	414.98	0.01	10.12
	LV	P	Line-interfered-Common	Rehabilitation Work	3,114	km	LECO	9.67	67.20	0.00	6.95
	LV	P	Line-interfered-Common	Interrupted For Ceb Work	3,114	km	LECO	21.00	145.14	0.01	6.91
								672.00	4,447.01	0.61	
	11kV	F	Line	Load Transfer	1,030	km	LECO	870.33	173.54	0.84	0.20
	11kV	P	Line	Load Transfer	1,030	km	LECO	822.33	182.16	0.80	0.22
	11kV	F	Line-inherent-ABC	failures	15	km	LECO	8.00	374.36	0.53	46.79
	11kV	F	Extreme	Flood	1,030	km	LECO	7.00	114.35	0.01	16.34

Included as failures  
excluded  
excluded  
excluded

**Appendix 5: Contribution to the PCC outage due to individual component for a typical distribution feeder**

**CONTRIBUTIONS TO THE PCC OUTAGE DUE TO INDIVIDUAL COMPONENTS FOR A TYPICAL DISTRIBUTION FEEDER**

**Excluding planned outages**

Component no	System voltage	Outage type	Class of Fault	Component type	(failures/year/unit)	Component nos	Unit	$\lambda$ (failures/year)	r(duration-hours per outage)	$\lambda$ .r.(forced hours of downtime per year)	Availability
1	33kV	F	Source		91.2813	1	nos	91.2813	0.35	31.98	0.99635
2	11kV	F	OCB	Faulty Ocb.	0.1068	1	nos	0.1068	4.50	0.48	0.99995
3	11kV	F	Auto Recloser	Faulty A.R.	0.0833		nos	0.0000	12.22	0.00	1.00000
4	11kV	F	Load Break Switch	Faulty Lbs	0.0177	3	nos	0.0531	1.59	0.08	0.99999
5	11kV	F	Load Break Cutouts	Faulty Lbc	0.0218		nos	0.0218	0.99	0.02	1.00000
6	11kV	F	Sectionalizer	Faulty Sectionaliser	0.1923		nos	0.0000	0.94	0.00	1.00000
7	11kV	F	transformer	Faulty transformers	0.0028	5	nos	0.0139	1.40	0.02	1.00000
8	11kV	F	Line-inherent-interfered	failures	4.5914	8	km	36.7311	0.76	27.86	0.99682
9	11kV	F	Surge Arrestors	Burnt Lightning Arresters	0.0026	9	nos	0.0238	1.86	0.04	0.99999
10	11kV	F	DDL0		0.0024	9	nos	0.0212	0.94	0.02	1.00000
11	LV	F	transformer		0.0109	1	nos	0.0109	7.72	0.08	0.99999
12	LV	F	transformer-accessories		0.0527	1	nos	0.0527	0.91	0.05	0.99999
13	LV	F	Line-inherent-ABC		0.9472	0.75	km	0.7104	1.62	1.15	0.99987

61.79

0.99296

Non Availability- Hrs/annum

61.67

## Appendix 6: Calculation of non availability of electricity due to component failures in Aluthgama CSC area

### CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES

LOCATION: ALUTHGAMA CSC

PSS : BENTOTA  
BENTOTA-

FEEDER: ALUTHGAMA

SECTION: BETWEEN PSS-BT 910-BT436

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	Transformer ID nos												
						4002	4003	4011	4004	4005	8498	4100	4101	8500	8502	4001	4010	4006
1	33kV	F	Source-Bentota	24.0000	1.15	1	1	1	1	1	1	1	1	1	1	1	1	
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1	1	
3	11kV	F	Auto Recloser	0.0833	12.22													
4	11kV	F	Load Break Switch	0.0177	1.59	3	3	3	3	3	3	3	3	3	3	3	3	
5	11kV	F	Load Break Cutouts	0.0218	0.99	2	2	2	2	2	2	2	2	2	2	2	2	
6	11kV	F	Sectionalizer	0.1923	0.94													
7	11kV	F	transformer	0.0028	1.40	13	13	13	13	13	13	13	13	13	13	13	13	
8	11kV	F	11kV Line- failures	4.5914	0.76	4.5	5	5	5	5	5	5	5	5	5	5	5	
9	11kV	F	Surge Arrestors	0.0026	1.86	39	39	39	39	39	39	39	39	39	39	39	39	
10	11kV	F	DDLO	0.0024	0.94	39	39	39	39	39	39	39	39	39	39	39	39	
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1	1	
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1	1	
13	LV	F	LV line- failures	0.9472	1.62	0.48	0.45	0.29	0.87	0.68	0.00	1.77	0.82	0.00	0.00	0.77	0.75	0.03
Outage hrs./year						45.1	45.1	44.8	45.7	45.4	44.4	47.1	45.6	44.4	44.4	45.6	45.5	44.4
- failures/year						45.6	45.6	45.4	46.0	45.8	45.2	46.8	45.9	45.2	45.2	45.9	45.9	45.2
Consumer hrs. lost				108,838		8,392	7,752	4,304	12,754	10,447	44	22,125	13,096	44	44	17,495	10,607	1,733
Consumer interruptions				109,452		8,484	7,841	4,362	12,829	10,535	45	22,011	13,183	45	45	17,622	10,687	1,762
Consumers				2,379														
LV-km						0.959	0.9	0.587	1.741	1.363		3.531	1.634			1.543	1.495	0.059
LV-bare-km						0	0	0	0.268	0.218		0.05	0			0.517	0	0
Consumers						186	172	96	279	230	1	470	287	1	1	384	233	39

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMMOR

SECTION: BETWEEN BT430-BT414

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	Transformer ID nos												
						8667	8668	8492	8489	8490	3912	8487	8485	8484	8483	8482	3908	8184
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22													
4	11kV	F	Load Break Switch	0.0177	1.59	2	2	2	2	2	2	2	2	2	2	2	2	2
5	11kV	F	Load Break Cutouts	0.0218	0.99	4	4	4	4	4	4	4	4	4	4	4	4	4
6	11kV	F	Sectionalizer	0.1923	0.94													
7	11kV	F	transformer	0.0028	1.40	22	22	22	22	22	22	22	22	22	22	22	22	22
8	11kV	F	11kV Line- failures	4.5914	0.76	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04
9	11kV	F	Surge Arrestors	0.0026	1.86	66	66	66	66	66	66	66	66	66	66	66	66	66
10	11kV	F	DDLO	0.0024	0.94	66	66	66	66	66	66	66	66	66	66	66	66	66
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.00	0.00	0.00	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00	2.00	0.00
Outage hrs./year						47.8	47.8	47.8	47.8	47.8	49.4	47.8	47.8	47.8	47.8	47.8	50.9	47.8
- failures/year						65.4	65.4	65.4	65.4	65.4	66.4	65.4	65.4	65.4	65.4	65.4	67.3	65.4
Consumer hrs. lost				28,942		47.8	47.8	47.8	47.8	47.8	1117	47.8	47.8	47.8	47.8	1724	47.8	
Consumer interruptions				38,550		2	2	2	2	2	1	2	2	2	2	5	2	
Consumers				576		65.4	65.4	65.4	65.4	65.4	1501	65.4	65.4	65.4	65.4	2282	65.4	
						2	2	2	2	2	1	2	2	2	2	0	2	
LV-km						8667	8668	8492	8489	8490	3912	8487	8485	8484	8483	8482	3908	8184
LV-bare-km						0	0	0	0	0	2.118	0	0	0	0	0	4.009	0
Consumer s											0.99					0.048		
						1	1	1	1	1	226	1	1	1	1	339	1	

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMMOR  
 SECTION: BETWEEN BT430-BT414

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	Transformer ID nos								
						8480	3821	3909	8486	8651	8466	8465	8476	8494
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22									
4	11kV	F	Load Break Switch	0.0177	1.59	2	2	2	2	2	2	2	2	2
5	11kV	F	Load Break Cutouts	0.0218	0.99	4	4	4	4	4	4	4	4	4
6	11kV	F	Sectionalizer	0.1925	0.94									
7	11kV	F	transformer	0.0028	1.40	22	22	22	22	22	22	22	22	22
8	11kV	F	11kV Line- failures	4.5914	0.76	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04
9	11kV	F	Surge Arrestors	0.0026	1.86	66	66	66	66	66	66	66	66	66
10	11kV	F	DDLO	0.0024	0.94	66	66	66	66	66	66	66	66	66
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.00	1.07	1.26	0.00	0.00	0.00	0.00	0.00	0.00
Outage hrs./year						47.8	49.4	49.7	47.8	47.8	47.8	47.8	47.8	47.8
- failures/year						65.4	66.4	66.6	65.4	65.4	65.4	65.4	65.4	65.4
Consumer hrs. lost				28,993		47.82	15476	13182	47.82	47.82	47.82	47.82	47.82	47.82
Consumer interruptions				38,903		65.42	20792	17653	65.42	65.42	65.42	65.42	65.42	65.42
Consumers				585										
LV-km						8480	3821	3909	8486	8651	8466	8465	8476	8494
LV-bare-km						0	2.138	2.529	0	0	0	0	0	0
Consumers						1	313	265	1	1	1	1	1	1

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC

PSS : KALUWAMODARA

FEEDER: KMBE

SECTION: BETWEEN BT435-BT414-BT411

Bev BU-621

Transformer ID nos

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	3918	3911	3915	3910	3824	8467	3817	3823	8468	3809	3840
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22											
4	11kV	F	Load Break Switch	0.0177	1.59	6	6	6	6	6	6	6	6	6	6	6
5	11kV	F	Load Break Cutouts	0.0218	0.99	11	11	11	11	11	11	11	11	11	11	11
6	11kV	F	Sectionalizer	0.1923	0.94	1	1	1	1	1	1	1	1	1	1	1
7	11kV	F	transformer	0.0028	1.40	61	61	61	61	61	61	61	61	61	61	61
8	11kV	F	11kV Line- failures	4.5914	0.76	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55
9	11kV	F	Surge Arrestors	0.0026	1.86	183	183	183	183	183	183	183	183	183	183	183
10	11kV	F	DDLO	0.0024	0.94	183	183	183	183	183	183	183	183	183	183	183
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.87	1.40	1.68	0.36	0.87	0.00	0.38	0.63	0.00	1.26	1.47
Outage hrs./year						107.9	108.7	109.1	107.1	107.9	106.6	107.1	107.5	106.6	108.5	108.8
- failures/year						143.2	143.7	143.9	142.7	143.1	142.3	142.7	142.9	142.3	143.5	143.7
Consumer hrs. lost				195,985		1434	2401									
Consumer interruptions				259,650		6	5	25856	11674	23514	107	16926	15265	107	37634	26542
Consumers				1,811		1903	3174	34110	15551	31207	142	22545	20295	142	49802	35069
LV-km						3918	3911	3915	3910	3824	8467	3817	3823	8468	3809	3840
LV-bare-km						1.738	2.798	3.365	0.729	1.734	0	0.759	1.257	0	2.519	2.947
Consumers						0	0.414	0.911	0	0.743	0	0	0.558	0	0.321	0.11
						133	221	237	109	218	1	158	142	1	347	244

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMBE  
 SECTION: Bey BU-601

						BETWEEN BU601-BU600-BU606												
						Transformer ID nos												
Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration - hours per outage)	3822	3820	3827	3818	3816	3832	3813	8652	3812	8470	8493	8459	8474
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22													
4	11kV	F	Load Break Switch	0.0177	1.59	6	6	6	6	6	6	6	6	6	6	6	6	6
5	11kV	F	Load Break Cutouts	0.0218	0.99	11	11	11	11	11	11	11	11	11	11	11	11	11
6	11kV	F	Sectionalizer	0.1923	0.94	1	1	1	1	1	1	1	1	1	1	1	1	1
7	11kV	F	transformer	0.0028	1.40	61	61	61	61	61	61	61	61	61	61	61	61	61
8	11kV	F	11kV Line- failures	4.5914	0.76	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55
9	11kV	F	Surge Arrestors	0.0026	1.86	183	183	183	183	183	183	183	183	183	183	183	183	183
10	11kV	F	DDLO	0.0024	0.94	183	183	183	183	183	183	183	183	183	183	183	183	183
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.69	1.07	0.47	1.00	0.90	0.83	1.06	0.00	0.99	0.00	0.00	0.00	0.00
			Outage hrs./year			107.6	108.2	107.3	108.1	107.9	107.8	108.1	106.6	108.1	106.6	106.6	106.6	106.6
			- failures/year			143.0	143.3	142.8	143.3	143.2	143.1	143.3	142.3	143.3	142.3	142.3	142.3	142.3
			Consumer hrs. lost	258,612		22810	43159	18127	44735	36798	31800	35257	107	25393	107	107	107	107
			Consumer interruptions	343,097		30312	57193	24129	59314	48825	42217	46725	142	33668	142	142	142	142
			Consumers	2,396														
			LV-km			1	2	1	2	2	2	2	0	2	0	0	0	0
			LV-bare-km			0	0	0	1	1	0	1	0	0	0	0	0	0
			Consumers			212	399	169	414	341	295	326	1	235	1	1	1	1

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA

FEEDER: KMBE  
 SECTION: Bey BU-601

						BEY BU606									
						Transformer ID nos									
Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	8473	3829	3839	8475	3814	3828	3815	3819	3825	3826
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22										
4	11kV	F	Load Break Switch	0.0177	1.59	6	6	6	6	6	6	6	6	6	6
5	11kV	F	Load Break Cutouts	0.0218	0.99	11	11	11	11	11	11	11	11	11	11
6	11kV	F	Sectionalizer	0.1923	0.94	1	1	1	1	1	1	1	1	1	1
7	11kV	F	transformer	0.0028	1.40	61	61	61	61	61	61	61	61	61	61
8	11kV	F	11kV Line- failures	4.6914	0.76	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55
9	11kV	F	Surge Arrestors	0.0026	1.86	183	183	183	183	183	183	183	183	183	183
10	11kV	F	DDLO	0.0024	0.94	183	183	183	183	183	183	183	183	183	183
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.00	0.36	0.60	0.00	0.39	0.48	0.83	0.62	0.56	0.68
Outage hrs./year						106.6	107.1	107.5	106.6	107.1	107.3	107.8	107.5	107.4	107.6
- failures/year						142.3	142.7	142.9	142.3	142.7	142.8	143.1	142.9	142.9	143.0
Consumer hrs. lost						106.6	5355	21600	106.6	13178	28213	35682	23434	28459	13231
Consumer interruptions						142.3	7134	28723	142.3	17552	37552	47370	31156	37857	17585
Consumers						1,576									
LV-km						8473	3829	3839	8475	3814	3828	3815	3819	3825	3826
LV-bare-km						0	0.726	1.209	0	0.775	0.959	1.655	1.248	1.115	1.35
Consumers						0	0	0.115	0	0.042	0	0.177	0.28	0	0.056
						1	50	201	1	123	263	331	218	265	123



**SUMMARY OF COMPONENT FAILURE RATES AND DOWNTIME OF LECO DISTRIBUTION SYSTEM**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMBE

SECTION:						BT411-BT412-BU617		BEY BU619		BET BT412-BU933-BU618-BU603-BU605										
Component no	System voltage	Outage type	Component	(failures/year/unit)	duration- hours per outage)	3801	8477	3830	3810	3831	3803	3835	3804	3833	3805	3806	8472	3808	3903	3902
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22															
4	11kV	F	Load Break Switch	0.0177	1.59	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
5	11kV	F	Load Break Cutouts	0.0218	0.99	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
6	11kV	F	Sectionalizer	0.1923	0.94	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	11kV	F	transformer	0.0028	1.40	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
8	11kV	F	11kV Line- failures	4.5914	0.76	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55
9	11kV	F	Surge Arrestors	0.0026	1.86	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183
10	11kV	F	DDLO	0.0024	0.94	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.88	0.00	0.56	1.02	0.77	0.56	0.32	0.61	0.38	0.81	1.51	0.00	0.55	1.35	2.17
Outage hrs./year						107.9	106.6	107.4	108.1	107.7	107.4	107.0	107.5	107.1	107.8	108.8	106.6	107.4	108.6	109.8
- failures/year						143.2	142.3	142.9	143.3	143.1	142.9	142.6	142.9	142.7	143.1	143.8	142.3	142.9	143.6	144.4
Consumer hrs. lost				243,870		27727	106.6	1492	3167	2725	1514	1059	1547	2292	2521	3983	106.6	1288	2899	3218
Consumer interruptions				323,734		36794	142.3	1985	4198	3619	2014	1412	2057	3053	3348	5261	142.3	1714	3834	4230
Consumers				2,822				8	5	4	3	1	8	5	4	7	3	2	3	4
LV-km						3801	8477	3830	3810	3831	3803	3835	3804	3833	3805	3806	8472	3808	3903	3902
LV-bare-km						1.767	0	1.124	2.037	1.539	1.121	0.641	1.213	0.755	1.614	3.028	0	1.104	2.698	4.338
Consumers						0	0	0.498	0	0	0	0	0	0	0.755	0	0	0.599	0.145	1.318
						257	1	139	293	253	141	99	144	214	234	366	1	120	267	293

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMBE  
 SECTION: BETWEEN BT435-BT414-BT411

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration - hours per outage)	BEY BU605					BEY BU603			BEY BU617			
						3920	3901	3900	3905	3904	3834	3802	8471	3800	3729	3836	3837
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22												
4	11kV	F	Load Break Switch	0.0177	1.59	6	6	6	6	6	6	6	6	6	6	6	6
5	11kV	F	Load Break Cutouts	0.0218	0.99	11	11	11	11	11	11	11	11	11	11	11	11
6	11kV	F	Sectionalizer	0.1923	0.94	1	1	1	1	1	1	1	1	1	1	1	1
7	11kV	F	transformer	0.0028	1.40	61	61	61	61	61	61	61	61	61	61	61	61
8	11kV	F	11kV Line failures	4.5914	0.76	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55	22.55
9	11kV	F	Surge Arresters	0.0026	1.86	183	183	183	183	183	183	183	183	183	183	183	183
10	11kV	F	DDLO	0.0024	0.94	183	183	183	183	183	183	183	183	183	183	183	183
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.87	1.34	1.76	0.70	1.12	1.27	0.78	0.00	1.09	0.90	1.06	1.26
Outage hrs./year						107.9	108.6	109.2	107.6	108.2	108.5	107.7	106.6	108.2	107.9	108.2	108.5
- failures/year						143.1	143.6	144.0	143.0	143.4	143.5	143.1	142.3	143.4	143.2	143.3	143.5
Consumer hrs. lost						22435	22475	36150	4089	9742	2321	1314	2694	1953	2390	1496	
Consumer interruptions						286,908	29725	47663	5434	12905	3071	1745	3569	2591	3167	1980	
Consumers						2,000					6	4	142.3	6	6	7	6
LV-km						3920	3901	3900	3905	3904	3834	3802	8471	3800	3729	3836	3837
LV-bare-km						1.73	2.679	3.522	1.396	2.24	2.538	1.561	0	2.171	1.806	2.127	2.514
Consumer s						0.263	0.715	1.868	0	0.38	0	0.666	0	0.678	0	0.426	0
						208	207	331	38	90	214	122	1	249	181	221	138

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMAG  
 SECTION: BETWEEN BT431-BT436-BT439

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	Transformer ID nos								
						3917	3907	8497	8499	4007	4008	4000	4009	8496
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22									
4	11kV	F	Load Break Switch	0.0177	1.59	3	3	3	3	3	3	3	3	3
5	11kV	F	Load Break Cutouts	0.0218	0.99									
6	11kV	F	Sectionalizer	0.1923	0.94									
7	11kV	F	transformer	0.0028	1.40	9	9	9	9	9	9	9	9	9
8	11kV	F	11kV Line- failures	4.5914	2.76	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
9	11kV	F	Surge Arrestors	0.0026	1.86	27	27	27	27	27	27	27	27	27
10	11kV	F	DDLO	0.0024	0.94	27	27	27	27	27	27	27	27	27
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.75	1.72	0.00	0.00	1.09	0.78	1.38	0.42	0.00
Outage hrs./year						34.7	36.1	33.5	33.5	35.2	34.7	35.6	34.2	33.5
- failures/year						47.4	48.4	46.7	46.7	47.8	47.5	48.0	47.1	46.7
Consumer hrs. lost						5617	6000	33.53	33.53	10205	7014	11082	6286	33.53
Consumer interruptions						7685	8026	46.73	46.73	13850	9589	14939	8670	46.73
Consumers						1,318								
LV-km						3917	3907	8497	8499	4007	4008	4000	4009	8496
LV-bare-km						1.5	3.43	0	0	2.178	1.565	2.762	0.833	0
Consumers						162	166	1	1	290	202	311	184	1

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMDT  
 SECTION: BETWEEN BT432-BT910

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	Transformer ID nos											
						3906	8666	3916	3913	3914	4113	4103	4114	4104	8691	4106	8513
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22												
4	11kV	F	Load Break Switch	0.0175	2.59	2	2	2	2	2	2	2	2	2	2	2	2
5	11kV	F	Load Break Cutouts	0.0218	0.99	5	5	5	5	5	5	5	5	5	5	5	5
6	11kV	F	Sectionalizer	0.1923	0.94												
7	11kV	F	transformer	0.0028	1.40	21	21	21	21	21	21	21	21	21	21	21	21
8	11kV	F	11kV Line- failures	4.5914	9.76	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71
9	11kV	F	Surge Arrestors	0.0026	1.86	63	63	63	63	63	63	63	63	63	63	63	63
10	11kV	F	DDLO	0.0024	0.94	63	63	63	63	63	63	63	63	63	63	63	63
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	1.61	0.00	0.62	0.65	0.51	0.68	1.42	0.25	1.37	0.00	1.46	0.00
Outage hrs./year						56.1	53.6	54.5	54.6	54.4	54.6	55.8	54.0	55.7	53.6	55.8	53.6
- failures/year						74.6	73.1	73.7	73.7	73.6	73.7	74.4	73.3	74.4	73.1	74.5	73.1
Consumer hrs. lost						14857	53.61	3873	7425	5439	10492	16788	1674	22889	53.61	16748	53.61
Consumer interruptions						19773	73.09	5231	10023	7357	14156	22404	2273	30571	73.09	22340	73.09
Consumers						1,810											
LV-km						3906	8666	3916	3913	3914	4113	4103	4114	4104	8691	4106	8513
LV-bare-km						3.223	0	1.232	1.294	1.026	1.359	2.84	0.503	2.733	0	2.911	0
Consumers						0.794	0	0.349	0.054	0.611	0	0.54	0	0	0	0	0
						265	1	71	136	100	192	301	31	411	1	300	1

**CALCULATION OF NON AVAILABILITY OF ELECTRICITY DUE TO COMPONENT FAILURES**

LOCATION: ALUTHGAMA CSC  
 PSS : KALUWAMODARA  
 FEEDER: KMDT  
 SECTION: BETWEEN BT432-BT910

Component no	System voltage	Outage type	Component	(failures/year/unit)	r(duration-hours per outage)	BEY BU649								
						Transformer ID nos								
						4112	4111	8510	4105	4107	8512	4108	4109	8511
1	33kV	F	Source-Kaluwamodara	37.0000	0.69	1	1	1	1	1	1	1	1	1
2	11kV	F	OCB	0.1068	4.50	1	1	1	1	1	1	1	1	1
3	11kV	F	Auto Recloser	0.0833	12.22									
4	11kV	F	Load Break Switch	0.0177	0.59	2	2	2	2	2	2	2	2	2
5	11kV	F	Load Break Cutouts	0.0218	0.99	5	5	5	5	5	5	5	5	5
6	11kV	F	Sectionalizer	0.11928	0.94									
7	11kV	F	transformer	0.0028	1.40	21	21	21	21	21	21	21	21	21
8	11kV	F	11kV Line- failures	4.5914	9.76	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71
9	11kV	F	Surge Arrestors	0.0026	1.86	63	63	63	63	63	63	63	63	63
10	11kV	F	DDLO	0.0024	0.94	63	63	63	63	63	63	63	63	63
11	LV	F	transformer	0.0109	7.72	1	1	1	1	1	1	1	1	1
12	LV	F	transformer-accessories	0.0527	0.91	1	1	1	1	1	1	1	1	1
13	LV	F	LV line- failures	0.9472	1.62	0.68	0.93	0.00	0.74	1.47	0.00	1.33	0.65	0.00
Outage hrs./year						54.7	55.0	53.6	54.7	55.8	53.6	55.6	54.6	53.6
- failures/year						73.7	74.0	73.1	73.8	74.5	73.1	74.3	73.7	73.1
Consumer hrs. lost				82,308		8799	19481	53.61	11439	17200	53.61	17802	7426	53.61
Consumer interruptions				110,450		11871	26186	73.09	15421	22939	73.09	23790	10024	73.09
Consumers				1,491										
LV-km						4112	4111	8510	4105	4107	8512	4108	4109	8511
LV-bare-km						1.367	1.865	0	1.475	2.935	0	2.652	1.302	0
Consumers						0.574	0.273	0	0	0	0	0.171	1.025	0
						161	354	1	209	308	1	320	136	1

**Appendix 7: Map of the 11kV distribution network in Aluthgama CSC area**



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

**Appendix 8: 11kV single line diagram of the Aluthgama CSC area**



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## Appendix 9 : Summary of the results derived from step restoration method

### CALCULATION OF SAIDI USING STEP RESTORATION MEDEL FOR 11kV NETWORK

11kV Feeder	Connected consumers	State Probability at convergence	Interrupted Consumers	11kV Outage minutes per minute	11kV System-Consumer hrs lost per year	11kV-Feeder wise consumer hrs. lost per year	33kV-Consumer hrs lost per year	LV-Consumer hrs lost per year	Total-Consumer hrs lost per year
BTAG	2,379	0.9983	0	0	-	34,508	65,660	3576	103,745
		0	2379	0.0463	406				
		0.0001	280	0.0236	207				
		0.0016	2379	3.8694	33,896				
KMMOR	1,161	0.9975	0	0	-	19,036	29,640	2586	51,263
		0	1161	0.0304	266				
		0.0001	2	0.0002	2				
		0	1161	0.0353	309				
		0.0001	2	0.0003	3				
		0.0001	1161	0.0749	656				
		0.0003	341	0.0943	826				
		0.0001	1161	0.1058	927				
		0.0004	582	0.2283	2,000				
		0.0014	1161	1.6036	14,048				
KMBE	10,605	0.9891	0	0	-	388,733	270,746	15733	675,212
		0.0002	10605	2.1918	19,200				
		0.0009	1323	1.145	10,030				
		0.0003	10605	2.818	24,586				
		0.0012	2645	3.1394	27,501				
		0.0004	10605	0.9393	8,228				
		0.0004	591	0.2192	1,920				
		0.0002	10605	2.3484	20,572				
		0.0009	874	0.8104	7,099				
		0.0002	10605	1.8787	16,457				
		0.0007	337	0.25	2,190				
		0	10605	0.4697	4,115				
		0.0002	2	0.0004	4				
		0.0001	10605	0.7828	6,857				
		0.0003	342	0.1057	926				
		0.0002	10605	1.8787	16,457				
		0.0007	789	0.5853	5,127				
		0.0009	10605	9.0907	79,635				
		0.0004	10605	3.7574	32,915				
		0.0016	3343	5.2904	46,344				
		0.0001	10605	1.5656	13,715				
		0.0006	1168	0.722	6,325				
		0.0001	10605	1.5656	13,715				
0.0006	4564	2.8214	24,715						
KMAG	1,318	0.999	0	0	-	9,371	33,649	2297	45,317
		0.0001	1318	0.0671	588				
		0.0002	167	0.0363	318				
		0.0007	1318	0.9664	8,466				



11kV Feeder	Connected consumers	State Probability at convergence	Interrupted Consumers	11kV Outage minutes per minute	11kV System-Consumer hrs lost per year	11kV-Feeder wise consumer hrs. lost per year	33kV-Consumer hrs lost per year	LV-Consumer hrs lost per year	Total-Consumer hrs lost per year
KMDT	3,301	0.9968	0	0	-	58,219	84,275	6152	148,645
		0.0001	3301	0.3164	2,772				
		0.0004	457	0.1875	1,643				
		0.0001	3301	0.2317	2,030				
		0.0003	515	0.1546	1,354				
		0.0001	3301	0.2093	1,833				
		0.0003	308	0.0833	730				
		0	3301	0.1401	1,227				
		0.0002	71	0.0129	113				
		0	3301	0.1401	1,227				
		0.0002	265	0.0481	421				
0.0016	3301	5.122	44,869						
Total	18764					509,868	483,969	30,344	1,024,181
SAIDI- Consumer hrs lost per year per consumer									54.58



University of Moratuwa, Sri Lanka.  
 Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)