DISTRIBUTION LOSS REDUCTION THROUGH ENERGY MANAGEMENT FOR RURAL ELECTRIFICATION

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Degree of Master of Science

Department of Electrical Engineering

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The above candidate has carried out research for the Masters thesis/Dissertation under our supervision.

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Signature of the supervisor Date
(Dr. H.M. Wijekoon)

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Signature of the supervisor Date
(Dr. WDAS Rodrigo)

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ABSTRACT

The Ministry of Power & Energy has taken initiative to electrify rural areas to uplift the living standard of the people in rural areas by providing the electricity, which is a basic need of people. Ceylon Electricity Board gives special concessions to in line with this by initiating number of rural electrification Projects Island wide. This increases the distribution losses by increasing the line lengths and by adding number of under loaded transformers to the power system. In this study, three main factors; selection of proper transformer capacity, effect of high tension line reconductoring, and effect of reactive power compensation are discussed in concerned to reduce the line losses in rural areas. The analysis was done as a case study for the Monaragala consumer service area. It was required to initially determine the load growth rate and the load factor for the area of concern. Load factor was obtained from the daily load curve of the passara feeder which feeds to the Monaragalaarea. The tabulated value was 0.395. The load growth rate of the area was analyzed by collecting the historical data of 167 numbers of identified transformers located in three consumer centers in the Monaragala area from year 2010. The resulted load growth rate of 0.48 was used in the analysis for data forecasting for next twenty years. The total cost of a transformer includes the initial purchase costs, maintenance cost and the cost due to losses of the transformer throughout the lifetime. The cost due to losses will be a cost for the country as a whole since this will affect to the total generation capacity to meet the country's demand. Therefore the proper selection of transformers is vital for any electrical installation. Transformer losses were forecasted for next twenty years, for different transformer capacity ratings and total costs were analyzed. If the initial peak load of the transformer is less than 30 kVA, the most economical transformer is 63 kVA. In rural distribution systems, its large number of low load consumers is distributed over a large geographical area lengthening the network and this has created more problems to the energy management. The results of the case study done for the Monaragala area clearly shows that the HT reconductoing is not economically viable, with respect to the line loss reduction in the RE network is very low. This study is focused to analyze the effect of loss reduction by reactive power compensation too. The results of this case study for Monaragala area shows that it is more feasible to install a one 1200 kvar fixed type capacitor for Passara feeder of the Badulla Grid Substation (GSS). More generalizing the outcome of this research, it can be concluded that for rural areas, which are having the load growth rate around 40% or below than that capacitor installation is economically viable and the ratings to be determined by a cost benefit analysis.

TABLE OF CONTENTS

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATIONS

Abbreviation	Description
CSC	Consumer Service Center
CEB	Ceylon Electricity Board
DD3	Distribution Division 3
GIS	Geographic Information System
GPS	Geographic Positioning System
GSS	Grid Substation
HT	High Tension
HV	High Voltage
IEC	International Electro technical Commission
km	kilo meter
kWh	kilo Watt hour
kvar	kilo var
LKR	Lanka Rupees
LV	Low Voltage
MV	Medium Voltage
Mn	Million
MSCADA	Micro SCADA
MV	Medium Voltage
O&M	Operation & maintenance
RE	Rural Electrification
TOC	Transformer Owning Cost
WPS II	Western Province South II

Chapter 1

Introduction

1.1 Background

The government of Sri Lanka attaches great importance to rural electrification (RE) with a vision to accelerate the work in order to achieve an electrification level goal of 100% by year 2016. Sri Lanka has reached the national electrification level of 94% which is substantial improvement in the power sector compared with electrification level of 70% by end of 2005. A separate project for each provinces such as Lighting Sri Lanka Uva province, Lighting Sri Lanka Hambantota, UthuruWasanthaya etc, were established with financial assistance from international lending organizations and with Government of Sri Lanka (GOSL) funds focusing to reach the target.

Ceylon Electricity Board (CEB) distribution network consists with 24,370 km Medium Voltage (MV) line length by year 2010. Among them 2680.29km were belongs to the Uva Province. During the last four years number of new rural electrification schemes and extensions had been completed island wide and 115 new rural electrification schemes and 562 extensions have been completed in Monaragala area. This results increase of Medium Voltage (MV) line lengths enormously and add huge number of under loaded distribution transformers to the power system. Thus increases the distribution power losses.100 kVA is the lowest capacity used in distribution sector in CEB for many years. The transformer peak load data reveals that the many substations were under loaded and majority of them loaded less than the 20% of the transformer rated capacity, while a transformer could be loaded more than 10% - 20% of its rated capacity [1]

Lynx and Raccoon are more commonly used conductors in Sri Lanka and it has been practiced to convert weasel line to raccoon for upgrading the system. Monaragala distribution network consists with both weasel and raccoon types conductors.

Power loss is a crucial factor which is more concerned in last few years to be minimized and it is around 10.7 % in Sri Lanka. Transmission loss is 3% while 11% loss taken place in distribution network. Uva provincial loss percentage is around 12.3% and this has been targeted to reduce for 5%by 2025.

1.2 Objectives

This analysis was focused on identifying the effect of following three scenarios for loss reduction in REs.

1. Selection of an economical transformer capacity for REs
2. Effect of High Tension (HT) line reconductoring
3. Effect of Reactive Power Compensation

1.3 Methodology

1.3.1 Selection of an economical transformer capacity for REs

It was required to analyze and identify the existing network conditions and practices available in distribution sector. 100 kVA is the lowest capacity used in distribution sector in Ceylon Electricity Board (CEB) for many years. One hundred and sixty seven numbers (167 nos.) of rurally electrified transformers were selected for the analysis and historical load data from year 2010 to 2014 were used for the analysis. The transformer peak load data reveals that the many substations were under loaded and majority of them loaded less than the 20% of the transformer rated capacity, while a transformer could be loaded more than 10% - 20% of its rated capacity [1]. Several transformer capacities available in the market, having the capacity less than the 100 kVA, were identified and studied the transformer losses at the different loading levels. Transformer life cycle cost includes the initial purchase price of the transformer and all costs associated with the operation of the transformer over its lifetime [2]. Cost of losses depends on tariff, load curve and load growth over the life of the transformer. The cost due to losses will be a cost for the country as a whole since this will affect to the total generation capacity to meet the country's demand. The transformer rating selection was done basis on the results of TOC evaluation.[3]

1.3.2 Effect of High Tension (HT) line Reconductoring

The size of conductor in a distribution system is an important parameter as it determines the current density and the resistance of the line. A lower conductor size can cause high I^2R losses and high voltage drop which causes a loss of revenue. Hence reconductoring is currently practicing to reduce the line losses and upgrading the system. This analysis focuses to study the economic viability of practicing reconductoring for rural areas which flows light loads along the lengthy liens. Reconductoring process includes a large amount of labour cost for cable removing and line rehabilitation. Hence the utility has to be considered on the benefit of the investment and to be conducted a comparison of investment and capitalized cost of energy loss.

1.3.3 Effect of Reactive Power Compensation

One of the main benefits of capacitor installation is that they can reduce distribution line losses. Losses come from current flow against the resistance of conductors. Some of that current transmits real power, but some flows to supply reactive power. Reactive power provides magnetizing for motors and other inductive loads. Reactive power does not spin kWh meters and performs no useful work, but it must be supplied. Capacitors which are installed to supply reactive power reduce the amount of current in the line. Since line losses are a function of the current squared, I^2R, reducing reactive power flow on lines significantly reduces losses. In this study different capacitor rating combinations were examined for the amount of loss reduction by load flow analysis in Synergee simulation software and performed cost benefit analysis for each case to determine the best suit capacitor size. Capacitor placement was done in the way of obtaining the maximum loss reduction.

1.4 Literature Review

Three main literature surveys have been conducted for the purpose of this research thesis. The first literature survey aimed at finding an economical transformer capacity for the rural areas and second for the analysis on the reconductoring effect and third for analyzing the effect of reactive power compensation for the system.

In the[4] paper presented by A. A. Chowdhury, L. Bertling, D. E. Custer, described a novel reliability cost-benefit model to compare different transformer loading philosophies while simultaneously taking into account varying levels of transformer emergency capability. It has been illustrated that using the developed value-based model, standards for loading in-service transformers can be established. Also, the developed value-based model can be utilized to establish standard emergency rating criteria for purchasing new transformers that would optimize reliability performance Versus cost. The applications of the model have been illustrated using practical system examples.

In [5] the paper aims to investigate geo-electrical options to improve distribution efficiency of electrical network. Distribution efficiencies corresponding to several possible electrical network options are assessed using Geographical Information System (GIS) integrated electrical theory. Information related to characteristics of loads, features of conductors and transformers of the existing network are used for this investigation. The line losses of the three existing transformers are estimated as about 36%, 20% and 3% of their respective connected loads. Longer distribution lines associated with higher loads are the causes of higher line losses. Using basic electrical theory and GIS tools it is found that line losses can be reduced in the existing distribution system through management of distribution transformer and reconductoring. Similarly, five different types of commercially available conductors are identified for possible reconductoring to reduce line loss. The economic viability of reconductoring of distribution lines are also assessed through an economic analysis. Net present values of total expenditure comprising purchase prices of conductor and cost attributed to line losses are estimated considering 30 years of useful life. The existing conductor has the worst economic merit, though it is the cheapest amongst all. A net saving of about US$24084 is possible through the best choice of distribution conductor for the village.

The work by Andrija Volkanovski, Marko Cepin, BorutMavko ,Jozef Stefan Institute[18] present a new approach for optimal compensation of the reactive power in the distribution network. The optimized function is defined as a difference between the yearly savings resulting from the decreased losses and peak power, and the yearly cost for installation and maintenance of the capacitors. The combination and allocation of the capacitors resulting in maximum yearly savings are integrated in to the optimization. The results confirm the need for application and optimization of the reactive power compensation in the distribution network. The decrease in energy losses and peak load in the distribution network results in substantial yearly savings.

In [15], it has been discussed on optimal placement of capacitors of widely used method of the “2/3’s” rule for sizing and placing capacitors to optimally reduce losses. Neagle and Samson (1956) developed a capacitor placement approach developed for uniformly distributed lines and showed that the optimal capacitor location is the point on the circuit where the reactive power flow equals half of the capacitor VAR rating. From this, the developed the “2/3’s rule” for selecting and placing capacitors. For a uniformly distributed load, the optimal size capacitor is 2/3 of the VAR requirements of the circuit. The optimal placement of this capacitor is 2/3 of the distance from the substation to the end of the line. For this optimal placement for a uniformly distributed load, the substation source provides VARs for the first 1/3 of the circuit, and the capacitor provides VARs for the last 2/3 of the circuit.

S.Salamat Sharif, Jame H Taylor and Eugene F.Hill, “On line reactive power flow by energy loss minimization “ [18] presented a method of on-line optimal reactive power flow by energy loss minimization. The three objectives are included in this method; the first objective is to maintain the voltage profile of the network into acceptable range; the second objective is to minimize the total system losses while satisfying the first one; Third objective is to avoid the excessive adjustments of the system configurations. During the steady state conditions total power loss can be minimized by the finding optimal reactive power dispatch for the year.

Chapter 2

Selecting an Economical Transformer Capacity

2.1 Selection of an Economical Transformer Capacity

“Transformer Efficiency “is not much considered in the distribution divisions in CEB and this had created many problems.

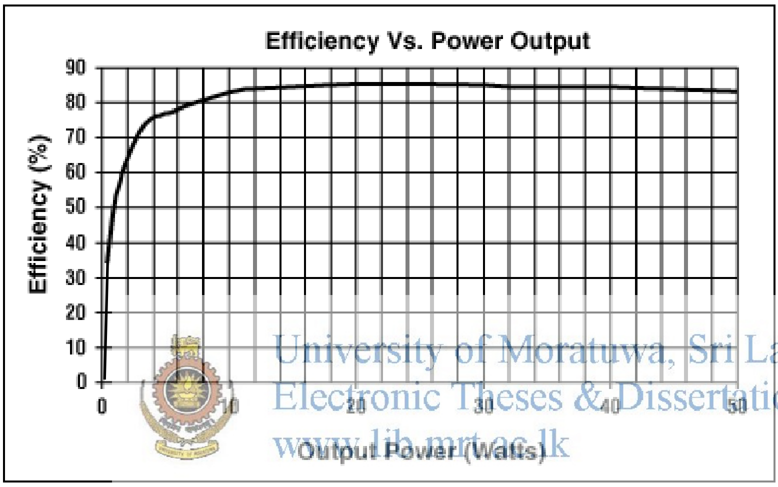

Figure 2.1: Transformer Efficiency Curve

When the transformer output power is zero, the efficiency is zero; when the output power increases, the efficiency is also increased; when the efficiency reaches its maximum, if it continues to increase the output power of the transformer,

efficiency will decline. This is because in a certain voltage, the transformer iron loss is a constant, when the output power is small, due to iron loss does not vary with load changes, the transformer efficiency is reduced. Because the transformer copper loss and the load current is proportional to the quadratic, when the load current increases to a certain extent, the increase in copper loss faster. Mathematical analysis can be shown that the copper loss and iron loss is equal to the highest efficiency of the transformer.[5]

Transformer no-load operation is required reactive power, supplied by the power supply system. If the capacity of the transformer selected too large, not only to increase the initial investment it leads to more losses. If the capacity of the transformer selected too small, the transformer will be long-term overload, and easy to damage the device. If the load rate is too high, the loss is significantly increased; therefore, the rated capacity of the transformer must be reasonably selected.

2.2 Study on Transformer Loading Level in Monaragala Area

2.2.1 Transformer loading level of Rurally Electrified (RE) Areas

Monaragala is one of the rural areas in Sri Lanka, which is being electrifying under rural electrification projects. It consists with four consumer service centers (CSCs); Monaragala, Bibila, Wellawaya, and Thanamalwila. It was selected 167 numbers of RE schemes (rural transformers) for the analysis. Recently commissioned 167 numbers of transformer peak load data from year 2010 to year 2014 were used for the analysis.

2.2.2 Transformer Loading Data Collection

Uva provincial planning unit measures transformer peak load data for the preparation of MV plan once in two years' time. In this analysis transformer peak load data from year 2010 to 2014 were obtained from the provincial planning units to carry out the analysis.

2.3 Transformer Losses

As electric power distribution systems continue to grow in size and complexity. Reducing losses can result in substantial savings for utility. Other benefits from loss reduction include released system capacity, and possible deferral of capital expenditures for system improvements and expansion. Transformer losses occur due to both copper and core losses. The energy used by distribution transformers is characterized by two types of losses.

1. No Load Losses
2. Load Loses

The first type is no-load losses that arise primarily from the switching of the magnetic field in the transformer core material. No-load losses are roughly constant and exist whenever the transformer is energized (i.e., connected to live power lines). No-load losses are, vary with the size (kVA) of the transformer, and the core steel selected; hence the emphasis on proper sizing. Since the no-load loss is a function of the kVA capacity of the transformer, careful selection of the transformer capacity closer to the intended task will ensure lowest core loss.

The second type of losses is load losses which are also known as resistance or I^2R losses. Load losses vary with the load on the transformer and at any point in time are proportional to the load squared plus a relatively small (<15% for loads less than rated load) temperature correction. An increase in loading will result in an increase of current flow and correspondingly greater amount of loss in the transformer. Moreover, an unbalance in the system load will increase transformer losses. Distribution transformers can be more efficient and economical when the right technology is considered. [5]

Transformer losses can be expressed as follows,

Total Loss = No Load Loss + Load Loss

= Core Loss + I^2R (Assuming the eddy current loss is negligible)

In this analysis transformer full load loss value and no load loss value for different transformer capacities were obtained by a loading standard of ‘Outdoor Type Three-Phase 33 kV/433-250 V Distribution Transformers up to and including 100 kVA’ [6] Transformer resistance was derived from the full load loss. Load loss was calculated using the equation I^2R at different loading levels.

2.4 Economic Evaluation

In a utility-based system, economy would not be achieved simply minimizing investment. As the system subject to various changes and the demand grows, the economic is achieved by optimizing initial investment, system losses and commitment for future investments.

A typical demand curve of a MV feeder is shown below.It should be noted that the shape of the demand curve varies according to type of loads, area etc.

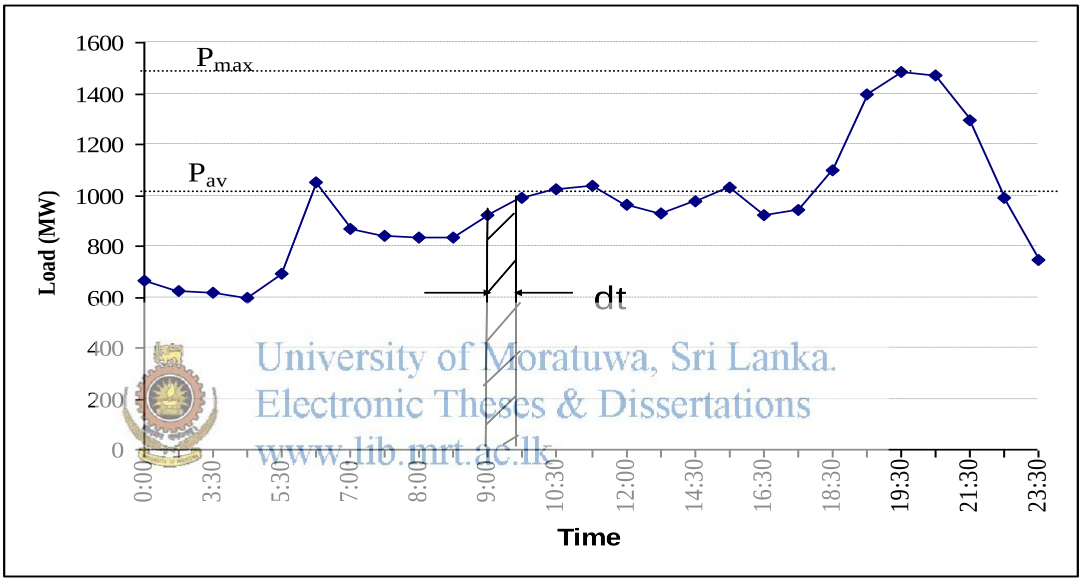

Figure 2.2: A Typical Demand Curve

2.4.1 The average power, load factor and Energy demand

From the demand curve the average power

$$P_{av} = \frac{1}{T}\int_{0}^{T} P(t)\,dt$$

The load factor $e = \frac{P_{av}}{P_{max}}$

Then Energy delivered $E_{del} = \int_{0}^{T} P\,dh = \text{Area under Demand curve}$

$$\mathbf{E_{del} = P_{max} \times e \times T} \qquad \text{kWh}$$

Electrical circuits have to be designed to provide the peak power although it actually occurs for a small duration of time. Hence during off peak time the capacity of the electricity network is not fully utilized. Therefore the load factor can be considered as a measure of utilization of the electricity Network.

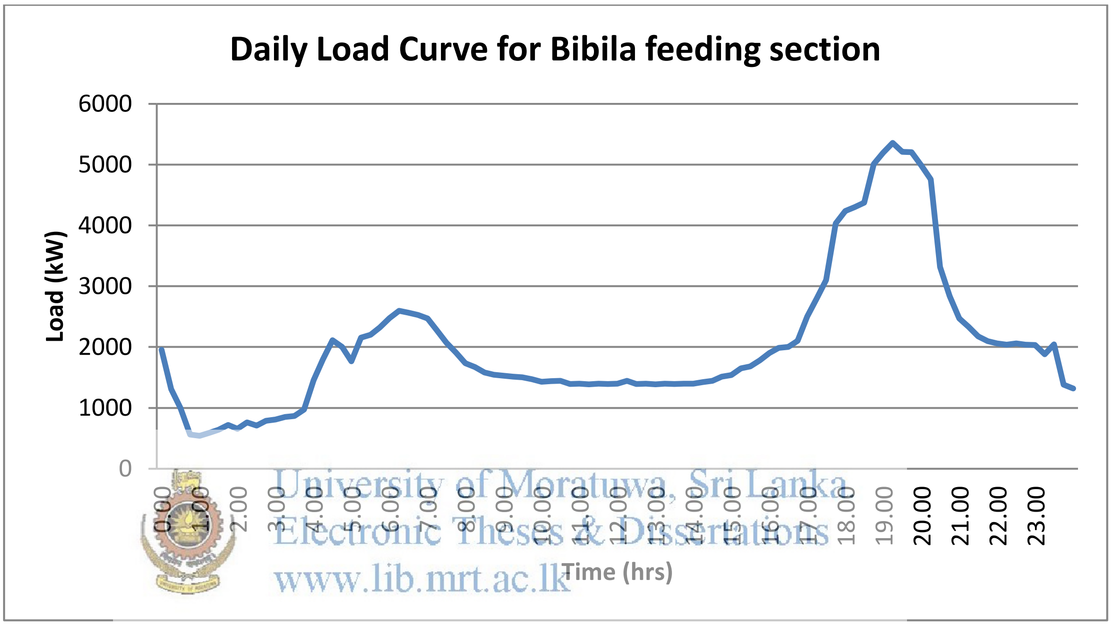

Figure 2.3: Daily load curve for Bibila feeding section

2.4.2 `Deriving load factor for Manaragala Area

Average Load = Area Under the Load Curve / 24

= 50784.4 / 24

= 2116.02 kW

Peak Load = 5357 kW

Load Factor = $\frac{\text{Average load}}{\text{Peak Load}}$

= $\frac{2116.02}{5357}$

= 0.395

2.4.3 The loss curve

From theoretical calculation it is possible to evaluate losses for a given load. Since losses are proportional to square of current, loss curve is usually steeper than its respective demand curve. A typical loss curve is shown below. [7]

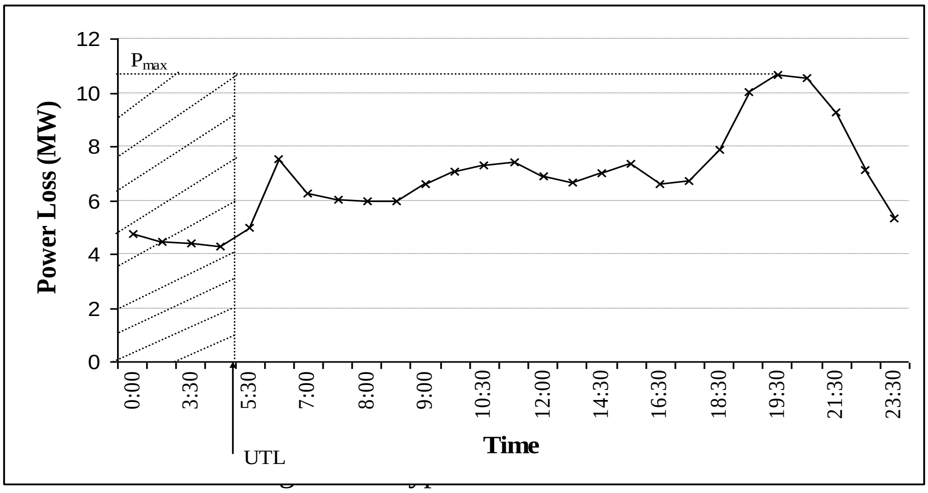

Figure 2.5: A typical loss curve

2.4.4 Utilization Time of Losses (UTL)

The UTL is defined as the time required dissipating same amount of energy losses if peak power loss is maintained instead of actual demand curve. [7]

An empirical formula (Jung's Formula) for UTL in terms of load factor (e) is as follows:

$$\text{UTL} = \frac{e^2(2+e^2)}{(1+2e)} * 8760 \qquad \text{Hrs/Year.}$$

2.4.5 Evaluation of energy loss

By definition of UTL we have

Energy loss = (Peak power loss) x (UTL) kWh.

This is usually used to evaluate energy losses from peak power loss.

2.4.6 Cost of losses

The cost of losses can be written as

Cost of losses = (Capacity cost + Energy cost)

Capacity cost: This is the investment per year through generation to distribution required for supplying an incremental 1kW at the point of distribution (Rs./kW/Yr.)

Energy Cost: This is the operation and maintenance cost of generation, transmission and distribution of 1kWh at distribution point.

The present figures for capacity and energy cost are given below.[7]

Capacity Cost	=	18,679.00	Rs./kW/Yr
Energy Cost	=	24.66	Rs./kWh/Yr

The above equations stipulated in this section were used to calculate the Transformer losses and the results were tabulated in table 2.1 to table 2.5.

Year	Tr Loading Level /(kVA)	I /A	Load Loss/ W	No Load Loss/ W	Total Loss /W	Capacity Cost /Rs	Cost of Energy / Rs	Total Cost / Rs	Present Value of Total Cost / Rs
2012	15.00	21.65	246.58	100	346.58	6,473.71	3,812.35	10,286.06	10,286.06
2013	15.72	22.69	270.82	100	370.82	6,926.48	4,078.98	11,005.46	12,106.01
2014	16.47	23.78	297.44	100	397.44	7,423.76	4,371.83	11,795.59	14,272.66
2015	17.27	24.92	326.68	100	426.68	7,969.92	4,693.46	12,663.38	16,854.96
2016	18.09	26.12	358.79	100	458.79	8,569.78	5,046.71	13,616.49	19,935.90
2017	18.96	27.37	394.06	100	494.06	9,228.60	5,434.69	14,663.29	23,615.37
2018	19.87	28.68	432.80	100	532.80	9,952.18	5,860.81	15,812.99	28,013.68
2019	20.83	30.06	475.35	100	575.35	10,746.90	6,328.81	17,075.71	33,275.74
2020	21.83	31.50	522.08	100	622.08	11,619.74	6,842.83	18,462.57	39,576.16
2021	22.87	33.02	573.40	100	673.40	12,578.39	7,407.37	19,985.76	47,125.37
2022	23.97	34.60	629.76	100	729.76	13,631.27	8,027.41	21,658.68	56,177.04
2023	25.12	36.26	691.67	100	791.67	14,787.66	8,708.40	23,496.06	67,037.00
2024	26.33	38.00	759.67	100	859.67	16,057.72	9,456.34	25,514.06	80,074.04
2025	27.59	39.83	834.35	100	934.35	17,452.64	10,277.80	27,730.44	95,732.99
2026	28.92	41.74	916.36	100	1,016.36	18,984.68	11,180.01	30,164.69	114,550.37
2027	30.30	43.74	1,006.45	100	1,106.45	20,667.33	12,170.92	32,838.25	137,173.50
2028	31.76	45.84	1,105.38	100	1,205.38	22,515.39	13,259.23	35,774.62	164,383.41
2029	33.28	48.04	1,214.05	100	1,314.05	24,545.12	14,454.54	38,999.65	197,122.58
2030	34.88	50.35	1,333.39	100	1,433.39	26,774.38	15,767.34	42,541.72	236,528.43
2031	36.56	52.77	1,464.47	100	1,564.47	29,222.78	17,209.20	46,431.98	283,973.78
								470,517.43	1,677,815.03

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2018	19.87	28.68	432.80	100	532.80	9,952.18	5,860.81	15,812.99	28,013.68
2019	20.83	30.06	475.35	100	575.35	10,746.90	6,328.81	17,075.71	33,275.74
2020	21.83	31.50	522.08	100	622.08	11,619.74	6,842.83	18,462.57	39,576.16
2021	22.87	33.02	573.40	100	673.40	12,578.39	7,407.37	19,985.76	47,125.37
2022	23.97	34.60	629.76	100	729.76	13,631.27	8,027.41	21,658.68	56,177.04
2023	25.12	36.26	691.67	100	791.67	14,787.66	8,708.40	23,496.06	67,037.00
2024	26.33	38.00	759.67	100	859.67	16,057.72	9,456.34	25,514.06	80,074.04
2025	27.59	39.83	834.35	100	934.35	17,452.64	10,277.80	27,730.44	95,732.99
2026	28.92	41.74	916.36	100	1,016.36	18,984.68	11,180.01	30,164.69	114,550.37
2027	30.30	43.74	1,006.45	100	1,106.45	20,667.33	12,170.92	32,838.25	137,173.50
2028	31.76	45.84	1,105.38	100	1,205.38	22,515.39	13,259.23	35,774.62	164,383.41
2029	33.28	48.04	1,214.05	100	1,314.05	24,545.12	14,454.54	38,999.65	197,122.58
2030	34.88	50.35	1,333.39	100	1,433.39	26,774.38	15,767.34	42,541.72	236,528.43
2031	36.56	52.77	1,464.47	100	1,564.47	29,222.78	17,209.20	46,431.98	283,973.78
								470,517.43	1,677,815.03

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Year	Tr Loading Level /(kVA)	I /A	Load Loss/ W	No Load Loss/ W	Total Loss /W	Capacity Cost /Rs	Cost of Energy / Rs	Total Cost / Rs	Present Value of Total Cost / Rs
2012	15.00	21.65	246.58	100	346.58	6,473.71	3,812.35	10,286.06	10,286.06
2013	15.72	22.69	270.82	100	370.82	6,926.48	4,078.98	11,005.46	12,106.01
2014	16.47	23.78	297.44	100	397.44	7,423.76	4,371.83	11,795.59	14,272.66
2015	17.27	24.92	326.68	100	426.68	7,969.92	4,693.46	12,663.38	16,854.96
2016	18.09	26.12	358.79	100	458.79	8,569.78	5,046.71	13,616.49	19,935.90
2017	18.96	27.37	394.06	100	494.06	9,228.60	5,434.69	14,663.29	23,615.37
2018	19.87	28.68	432.80	100	532.80	9,952.18	5,860.81	15,812.99	28,013.68
2019	20.83	30.06	475.35	100	575.35	10,746.90	6,328.81	17,075.71	33,275.74
2020	21.83	31.50	522.08	100	622.08	11,619.74	6,842.83	18,462.57	39,576.16
2021	22.87	33.02	573.40	100	673.40	12,578.39	7,407.37	19,985.76	47,125.37
2022	23.97	34.60	629.76	100	729.76	13,631.27	8,027.41	21,658.68	56,177.04
2023	25.12	36.26	691.67	100	791.67	14,787.66	8,708.40	23,496.06	67,037.00
2024	26.33	38.00	759.67	100	859.67	16,057.72	9,456.34	25,514.06	80,074.04
2025	27.59	39.83	834.35	100	934.35	17,452.64	10,277.80	27,730.44	95,732.99
2026	28.92	41.74	916.36	100	1,016.36	18,984.68	11,180.01	30,164.69	114,550.37
2027	30.30	43.74	1,006.45	100	1,106.45	20,667.33	12,170.92	32,838.25	137,173.50
2028	31.76	45.84	1,105.38	100	1,205.38	22,515.39	13,259.23	35,774.62	164,383.41
2029	33.28	48.04	1,214.05	100	1,314.05	24,545.12	14,454.54	38,999.65	197,122.58
2030	34.88	50.35	1,333.39	100	1,433.39	26,774.38	15,767.34	42,541.72	236,528.43
2031	36.56	52.77	1,464.47	100	1,564.47	29,222.78	17,209.20	46,431.98	283,973.78
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Year	Tr Loading Level /(kVA)	I /A	Load Loss/ W	No Load Loss/ W	Total Loss /W	Capacity Cost /Rs	Cost of Energy / Rs	Total Cost / Rs	Present Value of Total Cost / Rs
2012	15.00	21.65	246.58	100	346.58	6,473.71	3,812.35	10,286.06	10,286.06
2013	15.72	22.69	270.82	100	370.82	6,926.48	4,078.98	11,005.46	12,106.01
2014	16.47	23.78	297.44	100	397.44	7,423.76	4,371.83	11,795.59	14,272.66
2015	17.27	24.92	326.68	100	426.68	7,969.92	4,693.46	12,663.38	16,854.96
2016	18.09	26.12	358.79	100	458.79	8,569.78	5,046.71	13,616.49	19,935.90
2017	18.96	27.37	394.06	100	494.06	9,228.60	5,434.69	14,663.29	23,615.37
2018	19.87	28.68	432.80	100	532.80	9,952.18	5,860.81	15,812.99	28,013.68
2019	20.83	30.06	475.35	100	575.35	10,746.90	6,328.81	17,075.71	33,275.74
2020	21.83	31.50	522.08	100	622.08	11,619.74	6,842.83	18,462.57	39,576.16
2021	22.87	33.02	573.40	100	673.40	12,578.39	7,407.37	19,985.76	47,125.37
2022	23.97	34.60	629.76	100	729.76	13,631.27	8,027.41	21,658.68	56,177.04
2023	25.12	36.26	691.67	100	791.67	14,787.66	8,708.40	23,496.06	67,037.00
2024	26.33	38.00	759.67	100	859.67	16,057.72	9,456.34	25,514.06	80,074.04
2025	27.59	39.83	834.35	100	934.35	17,452.64	10,277.80	27,730.44	95,732.99
2026	28.92	41.74	916.36	100	1,016.36	18,984.68	11,180.01	30,164.69	114,550.37
2027	30.30	43.74	1,006.45	100	1,106.45	20,667.33	12,170.92	32,838.25	137,173.50
2028	31.76	45.84	1,105.38	100	1,205.38	22,515.39	13,259.23	35,774.62	164,383.41
2029	33.28	48.04	1,214.05	100	1,314.05	24,545.12	14,454.54	38,999.65	197,122.58
2030	34.88	50.35	1,333.39	100	1,433.39	26,774.38	15,767.34	42,541.72	236,528.43
2031	36.56	52.77	1,464.47	100	1,564.47	29,222.78	17,209.20	46,431.98	283,973.78
								470,517.43	1,677,815.03

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Table 2.6 Losses for 20 years

Year	Total Loss / W				
	25 kVA	50 kVA	63kVA	75 kVA	100 kVA
2010	346.58	234.07	250.63	283.97	304.31
2011	370.82	242.82	257.08	289.47	308.28
2012	397.44	252.44	264.17	295.52	312.63
2013	426.68	263.00	271.95	302.15	317.41
2014	458.79	274.60	280.50	309.44	322.66
2015	494.06	287.34	289.88	317.45	328.43
2016	532.80	301.33	300.19	326.24	334.76
2017	575.35	316.70	311.52	335.90	341.72
2018	622.08	333.58	323.96	346.51	349.36
2019	673.40	352.12	337.62	358.16	357.75
2020	729.76	372.48	352.62	370.95	366.97
2021	791.67	394.84	369.10	385.01	377.09
2022	859.67	419.40	387.19	400.44	388.20
2023	934.35	446.38	407.07	417.39	400.41
2024	1,016.36	476.01	428.90	436.01	413.82
2025	1,106.45	508.55	452.88	456.46	428.55
2026	1,205.38	544.28	479.21	478.92	444.73
2027	1,314.05	583.53	508.13	503.58	462.49
2028	1,433.39	626.64	539.90	530.68	482.01
2029	1,564.47	673.99	574.78	560.43	503.44

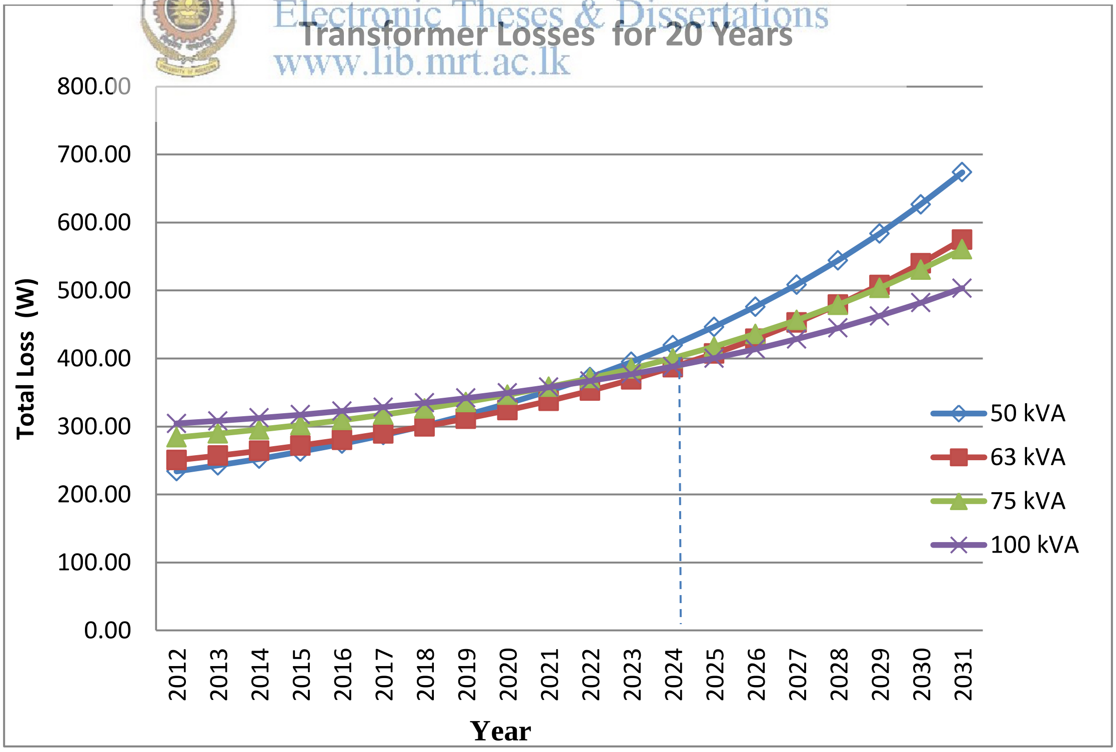


Figure 2.6: Transformers Losses for different transformer ratings for 20 years

2.5 Transformer Life Cycle Cost

Transformers typically can be expected to operate around 20 years or more, so buying a unit based only on its initial cost is uneconomical. Transformer life-cycle cost (also called "total owning cost") takes into account not only the initial transformer cost, but also the cost to operate and maintain the transformer over its life. This requires that the total owning cost (TOC) be calculated over the life span of the transformer. With this method, it is now possible to calculate the real economic choice between competing models.[8] This same method can be used to calculate the most economical total owning cost of any transformer and to compare competing models on the same basis.

Electrical utilities could use the total owning cost method to make transformer purchasing decisions. This method allows the total losses over the whole life cycle to be taken into account. [8]

Formula for TOC:

TOC = Transformer Purchase Price + Cost of Losses

= Transformer Purchase Price + Energy Cost + Capacity Cost

Transformer purchase prices were calculated using the following equation [8] and the results obtained were compared with the available market price in the Lanka Transformers Ltd.(LTL) . Price for the 100 kVA transformer was obtained from the CEB price List for 2015.[9]

$$C2=C1 \; {\frac{Rated\ power\ of\ transformer\ 2}{Rated\ power\ of\ transformer\ 1}}^{0.4}$$

Table 2.7 Transformer Owning Cost

Transformer Rating / kVA	Price /Rs	Cost of Losses/ Rs	(Tr Price + Cost of Losses (TOC))/ Rs
25	439,894.04	1,545,951.70	1,985,845.73
50	580,443.66	791,133.2	1,371,576.94
63	636,661.06	715,798.16	1,341,259.16
75	682,647.61	729,840.50	1,412,488.11
100	765,900.00	1,329,278.87	2,095,178.87

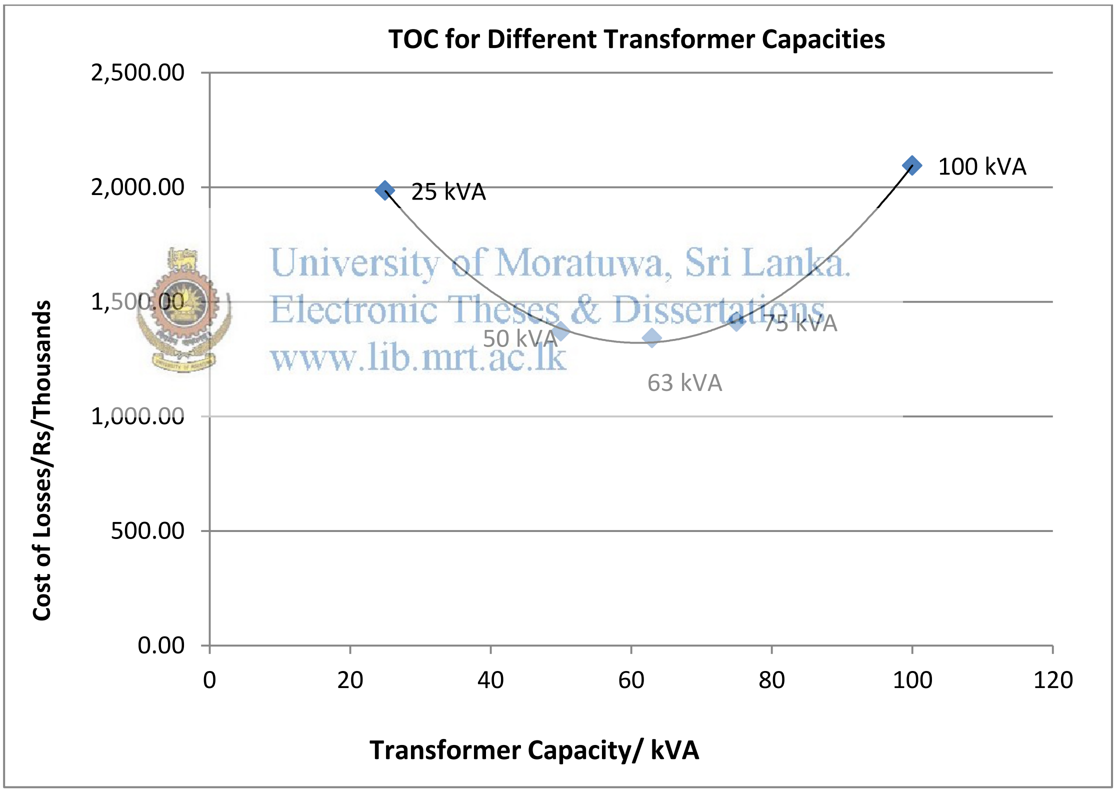


Figure 2.7: TOC for different transformer ratings for 20 years period

The figure 2.6 shows that the least transformer owning cost will be given by the 63 kVA ratings.

Chapter 3

HT Reconductoring

3.1 Reconductoring Effect

Second part of the research is to find out the impact of reconductoring for loss reduction in rural areas.

In the process of reconductoring, the cable will be upgraded to a higher current capacity cable and most probably the line to be rehabilitated to increase the line span and tension of the poles to withstand the increased weight. This process would be more likely to construct a new HT line, with additional work content of removal of the existing cable and replacing the poles and increasing the line span where needed.

With all these knowledge about the nature of conductor resistance, electric utilities innovatively include this idea as a method for line loss reduction for distribution system. Reconductoring of distribution lines have been a widely accepted practice for line loss reduction. [11]

Conductor size selection for optimum objective will most likely be based on loss considerations for distribution lines which are heavily loaded or for rural feeders.

Besides reducing the distribution line losses, reconductoring of distribution lines usually to a higher conductor size becomes also beneficial for increasing the current-carrying capabilities of the system. By upgrading the distribution lines, electric utilities are not only able to minimize the line loss but also increase the line capacity as well. Reconductoring is done when percentage loading of the conductor exceeds economic loading or to replace the deteriorated/off size conductor. Studies of different conductor sizes have indicated that in many cases, it is more economical to use conductors of higher cross sectional area. Replacement of existing line conductors by bigger sized conductors will result in reduction of technical losses in direct proportion to the ratio between the resistance of the new and existing conductor. The cost of reconductoring must be compared with the saving due to reduction in losses, increase in revenue and relief of distribution system capacity.

Like any other methods for distribution line loss reduction, economic considerations should always be studied. Line reconductoring projects involve monetary value. If the whole purpose of the line reconductoring is for loss reduction, it should always be look into whether the loss savings obtained from this project can justify the cost involve in upgrading the line in the long run.

3.2 Study on Existing conductors in Monaragala MV network

Distribution network of Monaragala area consists with Raccoons and Weasel type conductors. Weasel conductor was used from mid of eighties. It has a current carrying capacity of 95A. Raccoon (7/4.09mm) is the most commonly used ACSR conductor in distribution sector in Sri Lanka and It has a current carrying capacity of 220 A. Monaragala consumer area consists with 1109.55 km of total HT line length. One hundred and six kilometers (106 km) out of the total line length is weasel. Urban areas have already been upgraded to Raccoon type considering the higher loading levels. Following figure 3.1 shows the availability of two types of conductors in Monaragala distribution network.

Figure 3.1: Availability of weasel and Raccoon conductors in Monaragala area

Table 3.1 Raccoon and Weasel availability in Monaragala area.

Conductor type	Details	Current carrying capacity
ACSR (Weasel)	7/2.59 mm	95 A
ACSR (Raccoon)	7/4.09mm	220 A

3.3 Collection of Conductor Data

Type of the conductor was more crucial and it was required to obtain conductor type, more accurately. Otherwise the load flow results would not be much accurate and it will lead for faulty decision. Hence conductor data was collected throughout the Monaragala area in connection with a parallel running project of GPS data collection for formulation of a Geographic Information System (GIS) of the MV network in DD3. The points of references as per the distribution circuit are recorded from the field visit using handheld GPS system. These points are then transferred into appropriately digitized and georeferenced Arc map. Lengths of all the required sections of conductor are determined from the map using GIS software ArcGIS 9.3 (ESRI®).

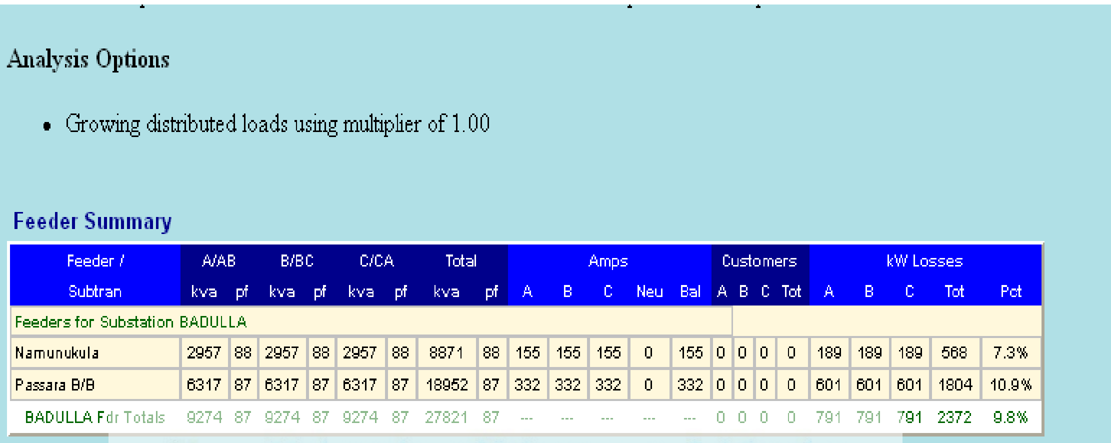
3.4 Analyze the Reconductoring Effect

Load flow analysis is conducted to determine the feeder losses with peak loads and conditions likely to be encountered during the normal operation of the system. The result of load flow analysis is utilized to determine the energy losses. Network modeling and results analysis was done in Synergee 3.8.

Monaragala area is fed from the Passara back bone line in Badulla grid substation. Initially feeder losses were obtained both in peak load and off-peak load condition for the existing network scenario. Then Weasel conductors were modeled to ACSR Raccoon type in Synergee and run the load flow to obtain the loss results for peak and off peak load conditions to analyze the loss reduction in the presence of reconductoring effect.

Table 3.2 and Table 3.3 show the load flow results at the peak load condition for the existing network and after reconductoring the existing Weasel lines to Racoon respectively.

Table 3.2: Load flow results for peak load condition for the existing network



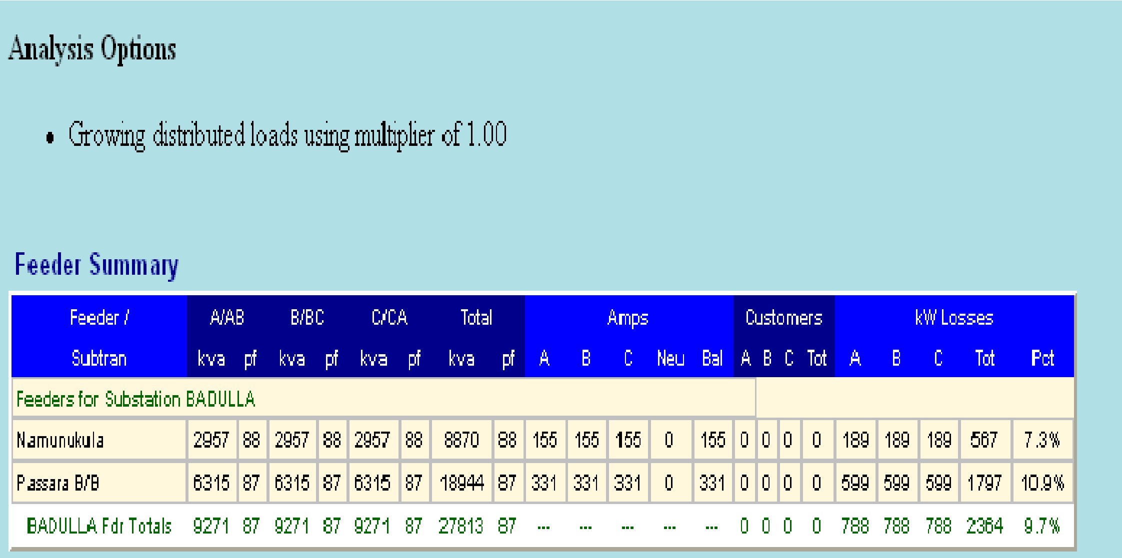
Analysis Options

- Growing distributed loads using multiplier of 1.00

Feeder Summary

Feeder /	A/AB		B/BC		C/CA		Total		Amps					Customers				kW Losses				
Subtran	kva	pf	kva	pf	kva	pf	kva	pf	A	B	C	Neu	Bal	A	B	C	Tot	A	B	C	Tot	Pct
Feeders for Substation BADULLA																						
Namunukula	2957	88	2957	88	2957	88	8871	88	155	155	155	0	155	0	0	0	0	189	189	189	568	7.3%
Passara B/B	6317	87	6317	87	6317	87	18952	87	332	332	332	0	332	0	0	0	0	601	601	601	1804	10.9%
BADULLA Fdr Totals	9274	87	9274	87	9274	87	27821	87	---	---	---	---	---	0	0	0	0	791	791	791	2372	9.8%

Table 3.3: Load flow results for peak load condition after reconductoring existing Weasel cables to Raccoon cables



Analysis Options

- Growing distributed loads using multiplier of 1.00

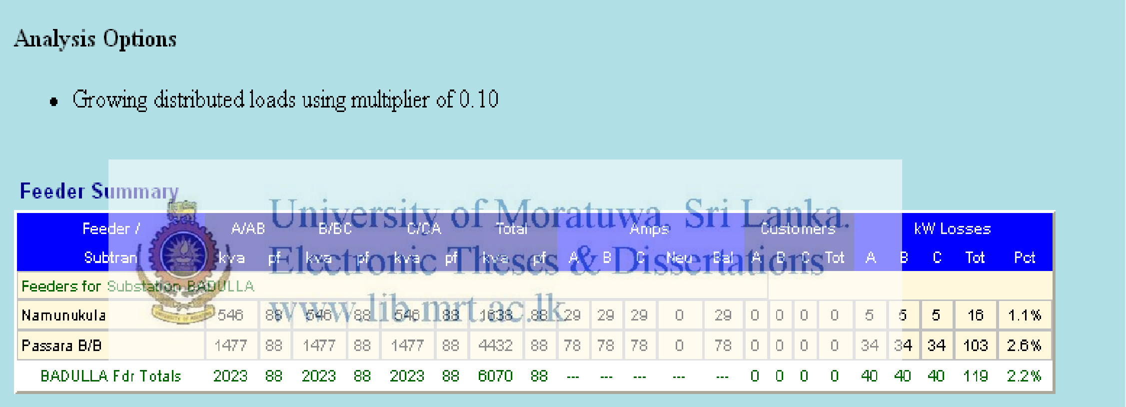
Feeder Summary

Feeder /	A/AB		B/BC		C/CA		Total		Amps					Customers				kW Losses				
Subtran	kva	pf	kva	pf	kva	pf	kva	pf	A	B	C	Neu	Bal	A	B	C	Tot	A	B	C	Tot	Pct
Feeders for Substation BADULLA																						
Namunukula	2957	88	2957	88	2957	88	8870	88	155	155	155	0	155	0	0	0	0	189	189	189	567	7.3%
Passara B/B	6315	87	6315	87	6315	87	18944	87	331	331	331	0	331	0	0	0	0	599	599	599	1797	10.9%
BADULLA Fdr Totals	9271	87	9271	87	9271	87	27813	87	---	---	---	---	---	0	0	0	0	788	788	788	2364	9.7%

The results show the losses being reduced by 7kw at the peak load condition, after reconductoring the network. Load flow analysis done for the peak load condition by applying the distributed load growth rate to (1). It has to be noted that the peak loading lasts only for very few hours throughout the day (nearly1.5 hours – 2 hours) during day peak and night peak. Further this would be much lesser in rural areas than the normal scenario.

Table 3.4 and Table 3.5 show the load flow results at the off-peak load condition for the existing network and after reconductoring the existing Weasel lines to Raccoon respectively.

Table 3.4: Load flow results for off - peak load condition for the existing network



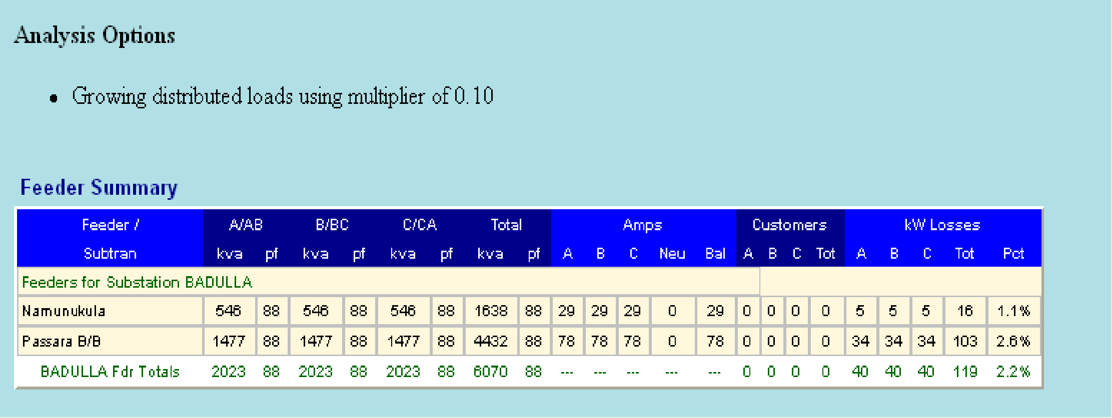
Analysis Options

- Growing distributed loads using multiplier of 0.10

Feeder Summary

Feeder /	A/AB		B/BC		C/CA		Total		Amps					Customers				kW Losses				
Subtran	kva	pf	kva	pf	kva	pf	kva	pf	A	B	C	Neu	Bal	A	B	C	Tot	A	B	C	Tot	Pct
Feeders for Substation BADULLA																						
Namunukula	546	88	546	88	546	88	1638	88	29	29	29	0	29	0	0	0	0	5	5	5	16	1.1%
Passara B/B	1477	88	1477	88	1477	88	4432	88	78	78	78	0	78	0	0	0	0	34	34	34	103	2.6%
BADULLA Fdr Totals	2023	88	2023	88	2023	88	6070	88	---	---	---	---	---	0	0	0	0	40	40	40	119	2.2%

Table 3.5: Load flow results for off - peak load condition after reconductoring existing Weasel cables to Raccoon cables



Analysis Options

- Growing distributed loads using multiplier of 0.10

Feeder Summary

Feeder /	A/AB		B/BC		C/CA		Total		Amps					Customers				kW Losses				
Subtran	kva	pf	kva	pf	kva	pf	kva	pf	A	B	C	Neu	Bal	A	B	C	Tot	A	B	C	Tot	Pct
Feeders for Substation BADULLA																						
Namunukula	546	88	546	88	546	88	1638	88	29	29	29	0	29	0	0	0	0	5	5	5	16	1.1%
Passara B/B	1477	88	1477	88	1477	88	4432	88	78	78	78	0	78	0	0	0	0	34	34	34	103	2.6%
BADULLA Fdr Totals	2023	88	2023	88	2023	88	6070	88	---	---	---	---	---	0	0	0	0	40	40	40	119	2.2%

Load flow analysis was done for the off peak load condition by applying the distributed load growth rate to (0.1).The results show the losses are not being reduced at the off peak load condition, after reconductoring the network. Further analysis carried out for two more levels of light load conditions by applying load growth rate to 0.25 and 0.5 respectively. The load flow results were shown in next page. It was decided to carry out the cost – benefit analysis using the loss reduction on peak load condition.

3.5 Economic Evaluation

3.5.1 Cost Analysis

Line reconductoring involves the costs of labour and cost of material. In CEB these works are done by private contractors at the rates approved for island wide. Labour rates for Construction & Rehabilitation of LV & MV Overhead Distribution Lines & Substation by Private Contractors – 2015 was referred to calculate the cost incurred for reconductoring of 106 kilometers from weasel to Raccoon [13]. Further reconductoring will lead some amount of line rehabilitation works, when and where required to bear the increased loading level due to higher weight of the Raccoon conductor.

Following rates were used to determine the cost.

Rates for Conductor Removing : 30 Man hours per kilometer (Mhrs/km)
: 315 Rs per Mhr

Rates for Cost of Stringing : 27 Man hours per kilometer (Mhrs/km)
: 302 Rs per Mhr

It was assumed the line rehabilitation rate is Rs.75 000 per kilometer

Cost of Conductor Removing =106.869 x 30 x 315
= Rs.1,009,912.05

Cost of Conductor Stringing =106.869 x 27 x 302
= Rs.871,409.83

Cost of Labour = Cost of Conductor Removing + Cost of Stringing

= Rs.1,009,912.05 + Rs.871,409.83

= Rs. 1,881,321.88

Cost of Materials (Raccoon) = 370 Rs/kg * 319 kg /km * 106.869

= Rs. 12,613,748.07

Cost of Line Rehabilitation = 75,000 * 106.869

= Rs 8,015, 175

Total Cost of Reconductoring = Cost of Labour + Cost of Materials + Cost of line Rehabilitation

Total Cost of Reconductoring = Rs. 22,510,244.95

3.5.2 Cost of Energy Saving

In a utility-based system, economy would not be achieved simply minimizing the investment. As the system subject to various changes and the demand grows, the economic is achieved by optimizing initial investment, system losses and commitment for future investments. From theoretical calculation it is possible to evaluate losses for a given load.

During off peak time the capacity of the electricity network is not fully utilized. Therefore the load factor can be considered as a measure of utilization of the electricity Network.

Present figures for capacity and energy cost in CEB are given below. [7]

Capacity cost (Rs./(kW, Yr) : Rs. 18,679.00

Energy cost (Rs./(kWh,Yr) : Rs. 11.00

It was required to obtain the load factor for the Passara feeder to calculate the energy saving due to reconductoring. The UTL is defined as the time required to dissipate same amount of energy losses if peak power loss is maintained instead of actual demand curve.

Load Factor (e) = $\frac{P_{av}}{P_{max}}$

= 0.395 (Tabulated in Chapter 2)

3.5.3 Utilization time of losses (UTL)

As described in chapter 2, empirical formula (Jung’s Formula) for UTL in terms of load factor (e) is as follows:

$$\text{UTL} = \frac{e^2(2+e^2)}{(1+2e)} * 8760 \quad \text{Hrs/Year.}$$

Energy Saving = Peak Power Loss Reduction x UTL kWh

Annual Energy Saving = Peak Power Loss Reduction x UTL x 8760 kWh

Cost of Energy Saving = Peak Power Loss Reduction x UTL x 8760 x 11 Rs.

= 7 x 0.184 x 8760 x 11

= Rs.124,014.44

Capacity Cost = Peak Power Loss x Capacity Cost

= 7 X 18679.00

= Rs. 130,753.00

The cost of savings can be written as,

Annual Cost of Savings = Capacity Cost Saving + Energy Cost Saving

= Rs. (130,753.00 + 124,014.44)

= Rs 254, 794.35

Annual cost saving is Rs 254, 794.35 by reconductoring around 106km line length. It has to be evaluated the economic viability of the reconductoring of existing weasel to raccoon in Monaragala area. In this analysis cost of savings through the line losses compared with respect to the total cost incurred to the reconductoring process and values obtained are as follows,

Annual Cost of Savings = Rs. 254, 794.35
Total Cost of Reconductoring = Rs. 22,510,244.95

Simple payback period = Rs. 22,510,244.95 / Rs. 254, 794.35 per yr
= 88.35 yrs.

Simple payback period is more than the life time of the HT line. Hence line reconductoring is not feasible in the aspect of loss reduction.

Chapter 4

Reactive power compensation for loss reduction

4.1 Effect of reactive power compensation

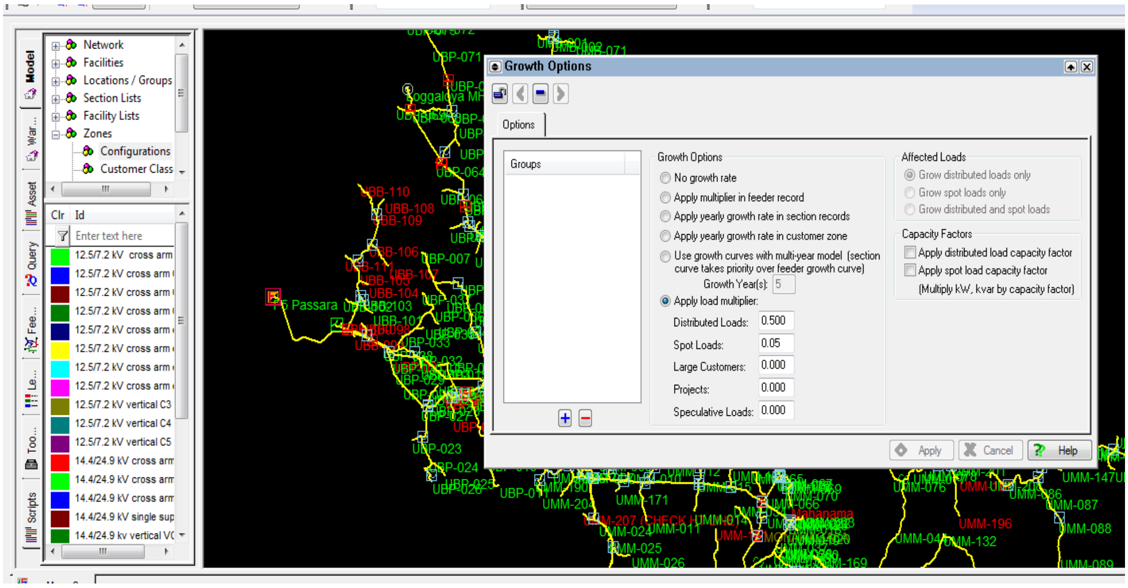
One of the main benefits of capacitor installation is that they can reduce distribution line losses. Losses come from current flow against the resistance of conductors. Some of that current transmits real power, but some flows to supply reactive power. Reactive power provides magnetizing for motors and other inductive loads. Reactive power does not spin kWh meters and performs no useful work, but it must be supplied. Capacitors which are installed to supply reactive power reduce the amount of current in the line. Since line losses are a function of the current squared, I^2R, reducing reactive power flow on lines significantly reduces losses.

4.2 Selecting the size of capacitors and the placement

It is widely used the “2/3’s” rule for sizing and placing capacitors to optimally reduce losses. Neagle and Samson (1956) developed a capacitor placement approach developed for uniformly distributed lines and showed that the optimal capacitor location is the point on the circuit where the reactive power flow equals half of the capacitor var rating. From this, they developed the “2/3’s rule” for selecting and placing capacitors. For a uniformly distributed load, the optimal size capacitor is 2/3 of the var requirements of the circuit. The optimal placement of this capacitor is 2/3 of the distance from the substation to the end of the line. For this optimal placement for a uniformly distributed loads, the substation source provide vars for the first 1/3of the circuit, and the capacitor provides vars for the last 2/3 of the circuit.[17]

In this analysis var requirement of F5 (Passara feeder) was obtained by a load flow run in Synergee simulation software. Further Synergee simulation software was used to do the capacitor placement and to analyze the effect.

Following figures illustrate the feeder demand of the Passara feeder at different loading levels.



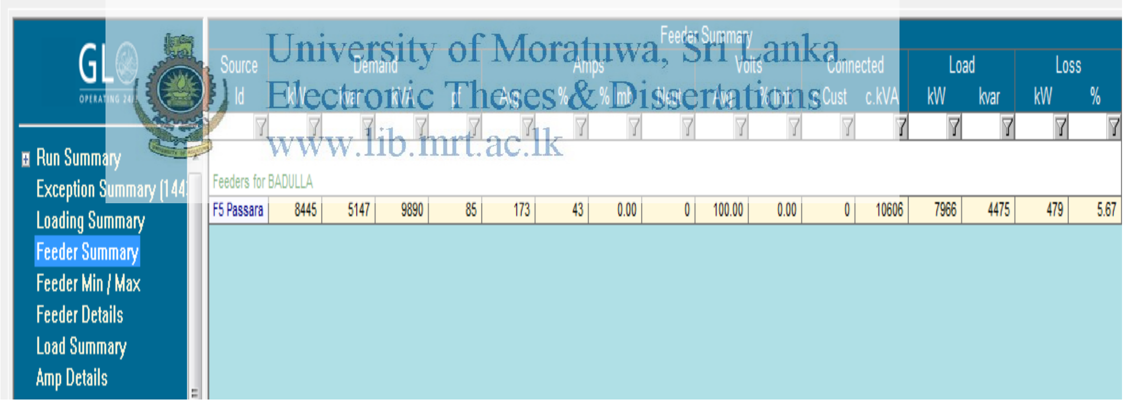
Growth Options

Growth Options
- ○ No growth rate
- ○ Apply multiplier in feeder record
- ○ Apply yearly growth rate in section records
- ○ Apply yearly growth rate in customer zone
- ○ Use growth curves with multi-year model (section curve takes priority over feeder growth curve)
  Growth Year(s): 5
- ● Apply load multiplier:
  Distributed Loads: 0.500
  Spot Loads: 0.05
  Large Customers: 0.000
  Projects: 0.000
  Speculative Loads: 0.000

Affected Loads
- ● Grow distributed loads only
- ○ Grow spot loads only
- ○ Grow distributed and spot loads

Capacity Factors
- ☐ Apply distributed load capacity factor
- ☐ Apply spot load capacity factor
  (Multiply kW, kvar by capacity factor)

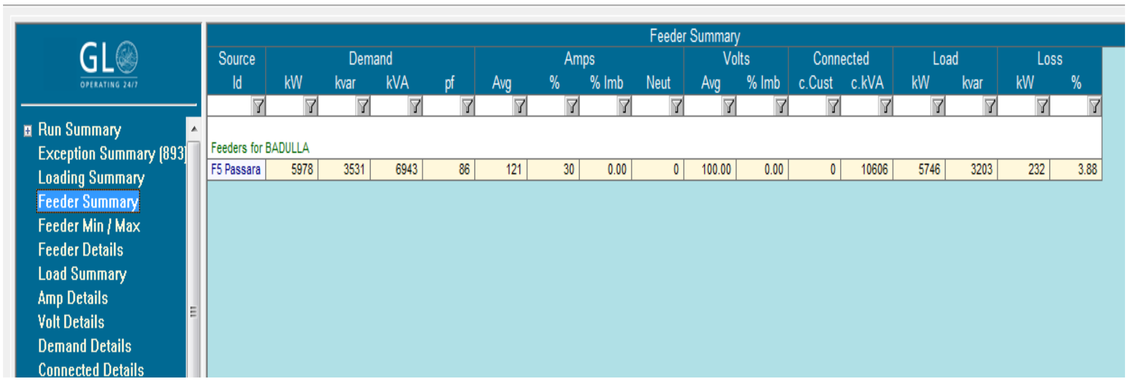
Figure 4.1 : Applying loading multiplier in Synergee



Feeder Summary

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8445	5147	9890	85	173	43	0.00	0	100.00	0.00	0	10606	7966	4475	479	5.67

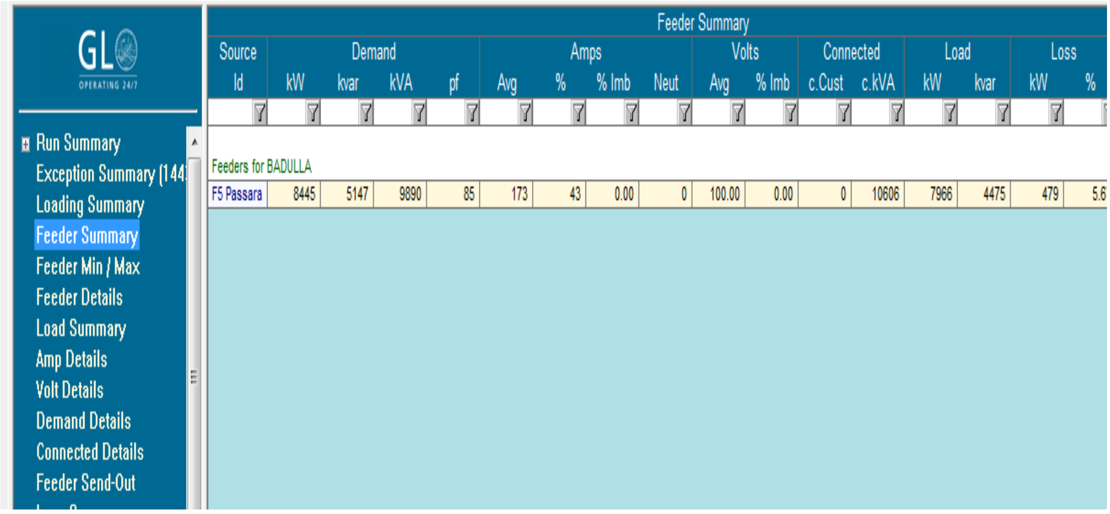
Figure 4.2 : Load flow results at 0.25 % loading level



Feeder Summary

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	5978	3531	6943	86	121	30	0.00	0	100.00	0.00	0	10606	5746	3203	232	3.88

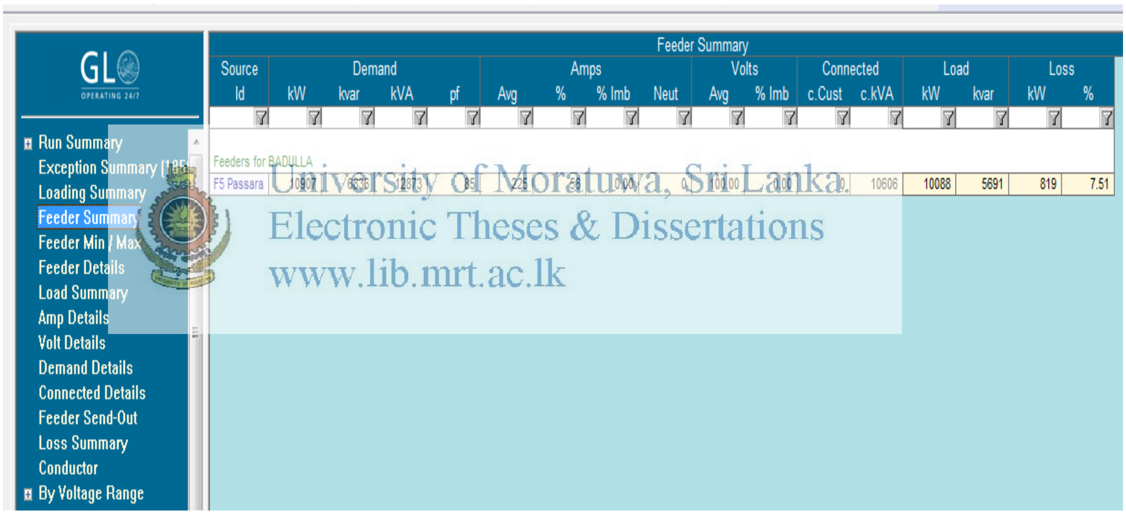
Figure 4.3 : Load flow results at 0.5 % loading level



Feeder Summary

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8445	5147	9890	85	173	43	0.00	0	100.00	0.00	0	10606	7966	4475	479	5.6

Figure 4.4 : Load flow results at 0.75 % loading level



Feeder Summary

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	10907	6836	12873	85	225	56	0.00	0	100.00	0.00	0	10606	10088	5691	819	7.51

Figure 4.5 : Load flow results at 1 % loading level

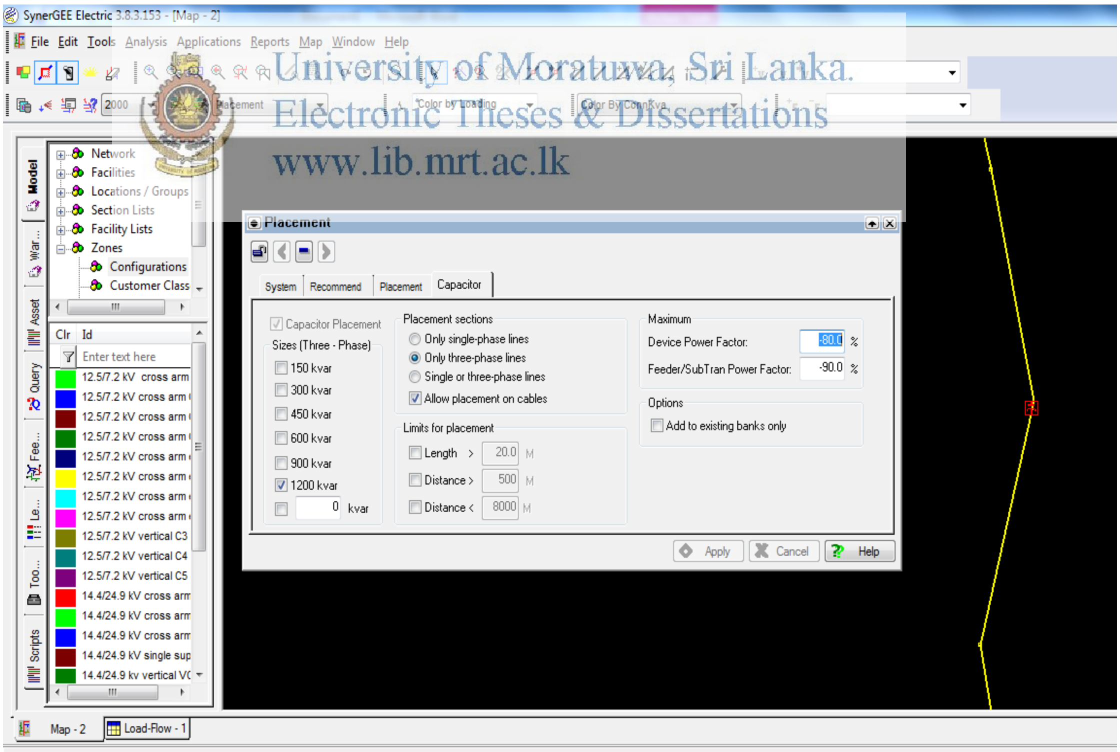
Table 4.1: Feeder demand of the Passara feeder (F5) at different loading levels

Loading Level	Feeder Demand				Power Loss /(kW)	Loss percentage (%)
	kW	kvar	kVA	Pf(%)		
0.25 %	3501	1982	4023	87	75	2.15
0.5%	5978	3531	6943	86	232	3.88
0.75 %	8445	5147	9890	85	479	5.67
1% (Peak)	10907	6836	12873	85	819	7.51

4.3 Load flow analysis with different capacitor placement combinations

Capacitor rating was decided basis on the off – peak level var demand and initially 2/3 rule was applied to determine the range of capacitor ratings. The off peak var demand is 1982 kvar and it is required to inject around 1200 kvar as per the rule. Most commonly150, 300, 450, 600, 900, and 1200(kvar) of sizes are commercially available. Those ratings were used in the load flow analysis by modeling them in Synergee(3.8) simulation software .

Load flow analysis was conducted to determine the different feeder losses with placement of capacitors to inject reactive power. In this case most probable capacitor rating combinations were examined and results were tabulated. The result of load flow analysis is used to determine the energy losses. Capacitor modeling and load flow analysis was done in Synergee(3.8) simulation software.



☑ Capacitor Placement

Sizes (Three - Phase)
☐ 150 kvar
☐ 300 kvar
☐ 450 kvar
☐ 600 kvar
☐ 900 kvar
☑ 1200 kvar
☐ 0 kvar

Placement sections
○ Only single-phase lines
● Only three-phase lines
○ Single or three-phase lines
☑ Allow placement on cables

Limits for placement
☐ Length > 20.0 M
☐ Distance > 500 M
☐ Distance < 8000 M

Maximum
Device Power Factor: -80.0 %
Feeder/SubTran Power Factor: -90.0 %

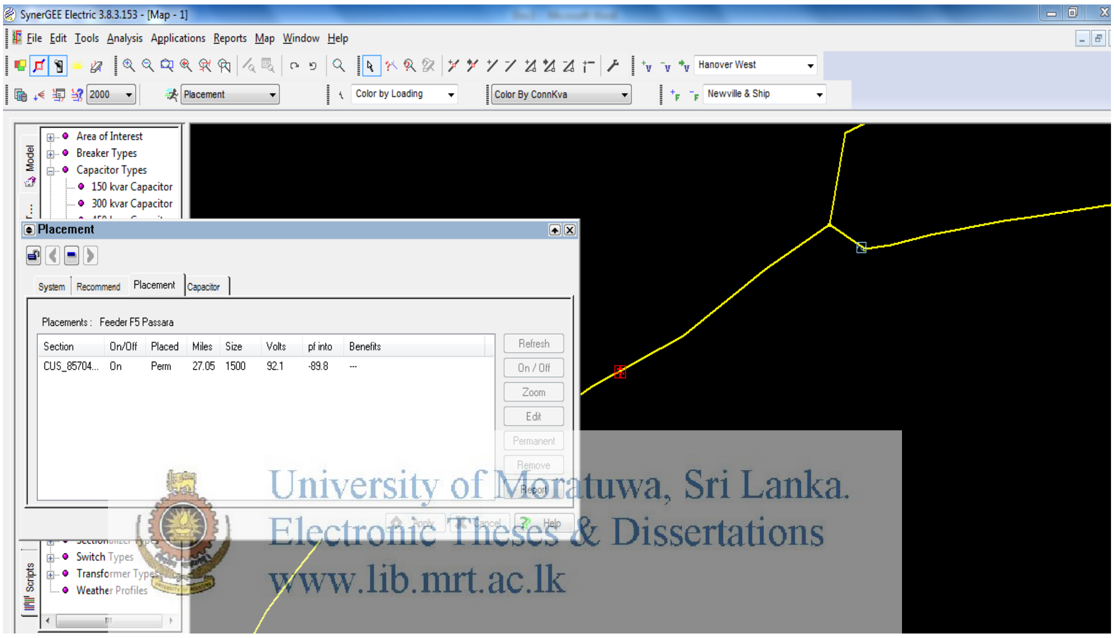
Options
☐ Add to existing banks only

Figure 4.6 : Modeling capacitors in Synergee

4.4 Load flow analysis

4.4.1 Placement of one 1500 kvar capacitor in Passara feeder

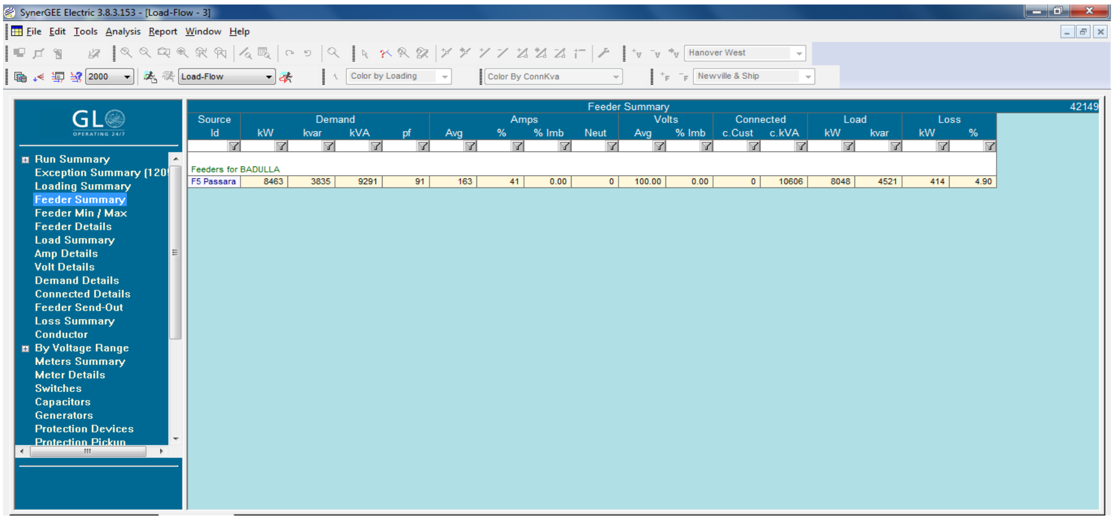
Figure 4.7 and figure 4.8 show the best suit location for placement of the first 1500 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of 1500 kvar capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85704...	On	Perm	27.05	1500	92.1	-89.8	---

Figure 4.7 : Placement of capacitor 1500 kvar (1 no.)



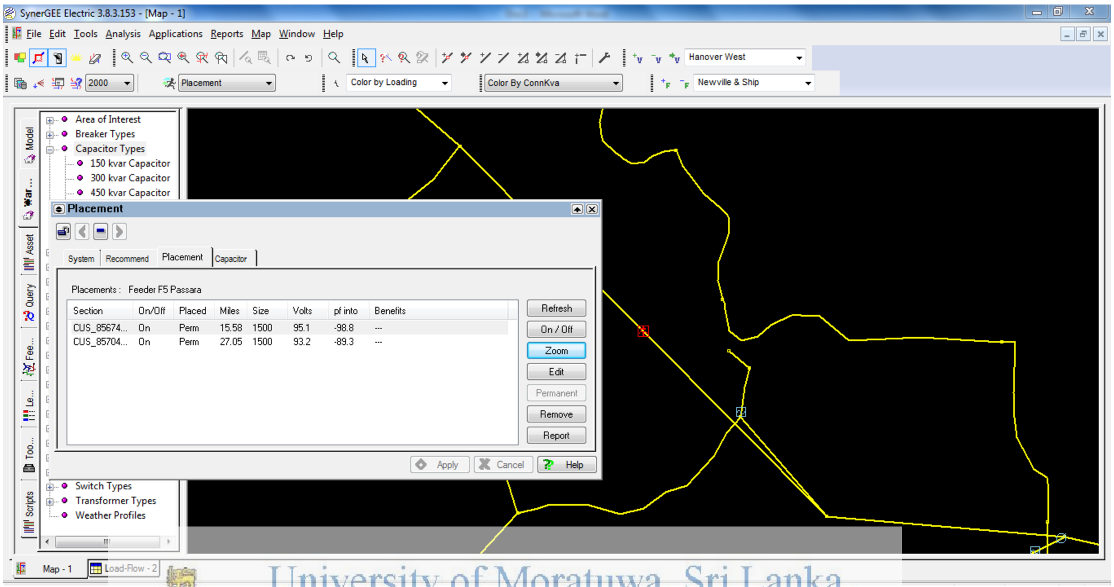
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8463	3835	9291	91	163	41	0.00	0	100.00	0.00	0	10606	8048	4521	414	4.90

Figure 4.8 : Load Flow results - Placement of Capacitor (1500 kvar x 1 no)

4.4.2 Placement of two 1500 kvar capacitors in Passara feeder

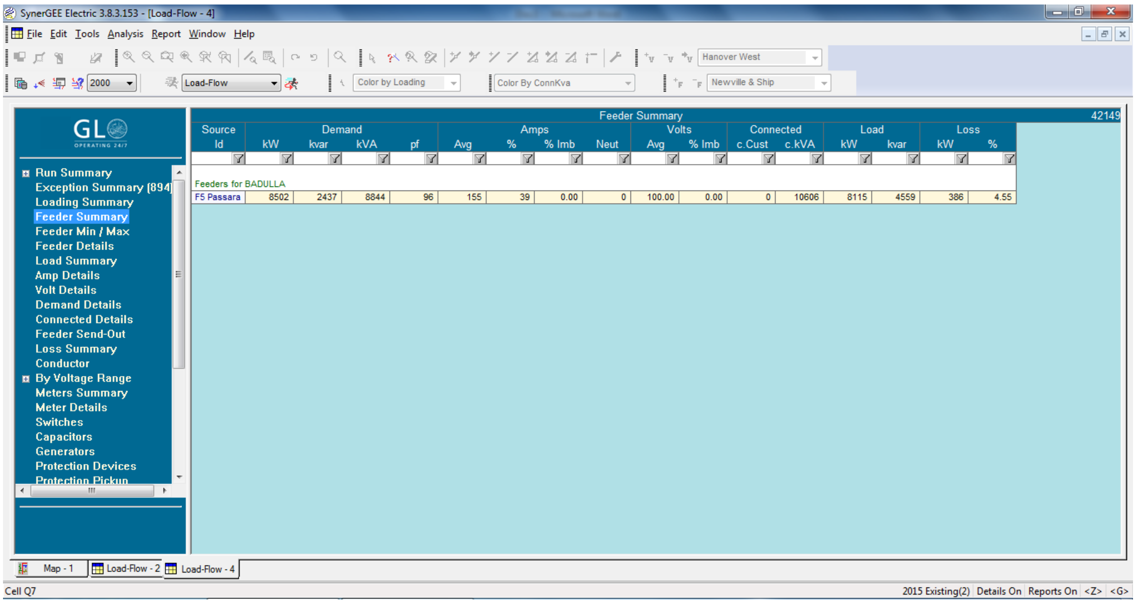
Figure 4.9 and figure 4.10 show the best suit location for placement of the second 1500 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of two 1500 kvar capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85674...	On	Perm	15.58	1500	95.1	-98.8	---
CUS_85704...	On	Perm	27.05	1500	93.2	-89.3	---

Figure 4.9 : Placement of capacitor 1500 kvar (2 nos.)



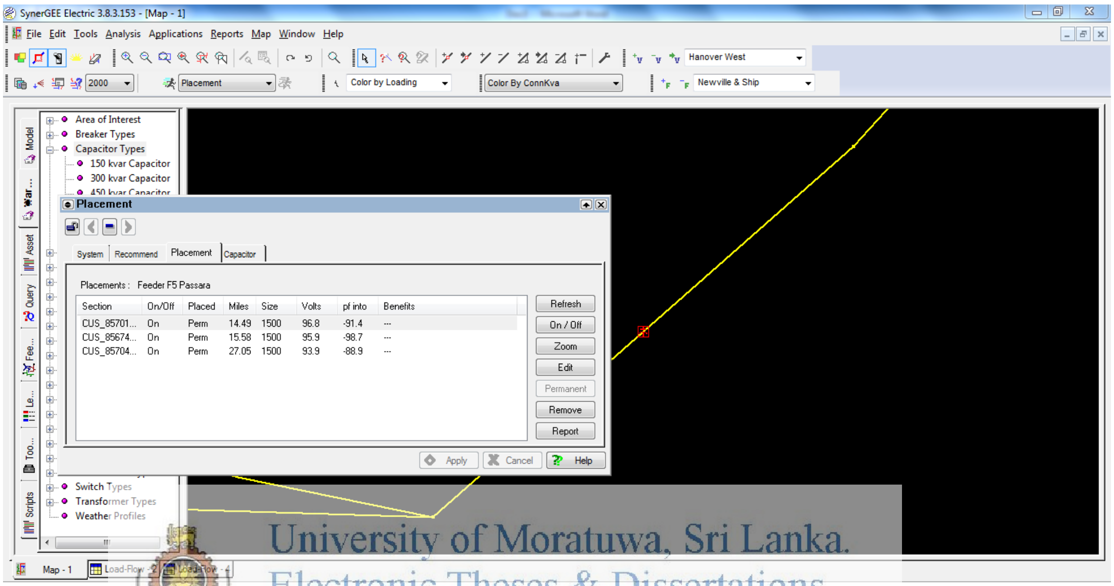
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8502	2437	8844	96	155	39	0.00	0	100.00	0.00	0	10606	8115	4559	386	4.55

Figure 4.10 : Load Flow results - Placement of Capacitor (1500 kvar x 2nos)

4.4.3 Placement of three 1500 kvar capacitors in Passara feeder

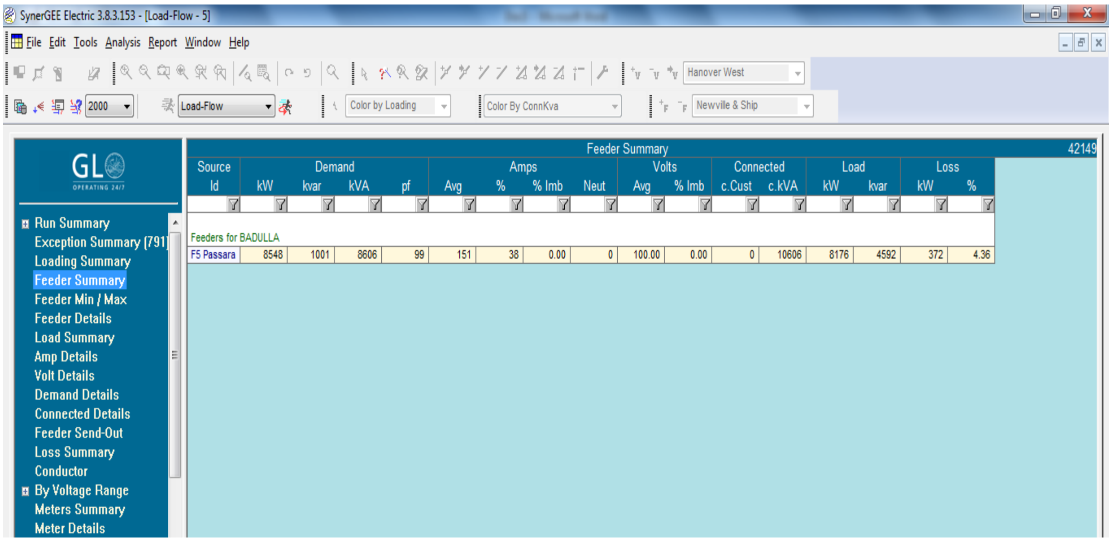
Figure 4.11 and figure 4.12 show the best suit location for placement of the third 1500 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of third 1500 kvar capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85701...	On	Perm	14.49	1500	96.8	-91.4	---
CUS_85674...	On	Perm	15.58	1500	95.9	-98.7	---
CUS_85704...	On	Perm	27.05	1500	93.9	-88.9	---

Figure 4.11 : Placement of capacitor 1500 kvar (3 nos.)



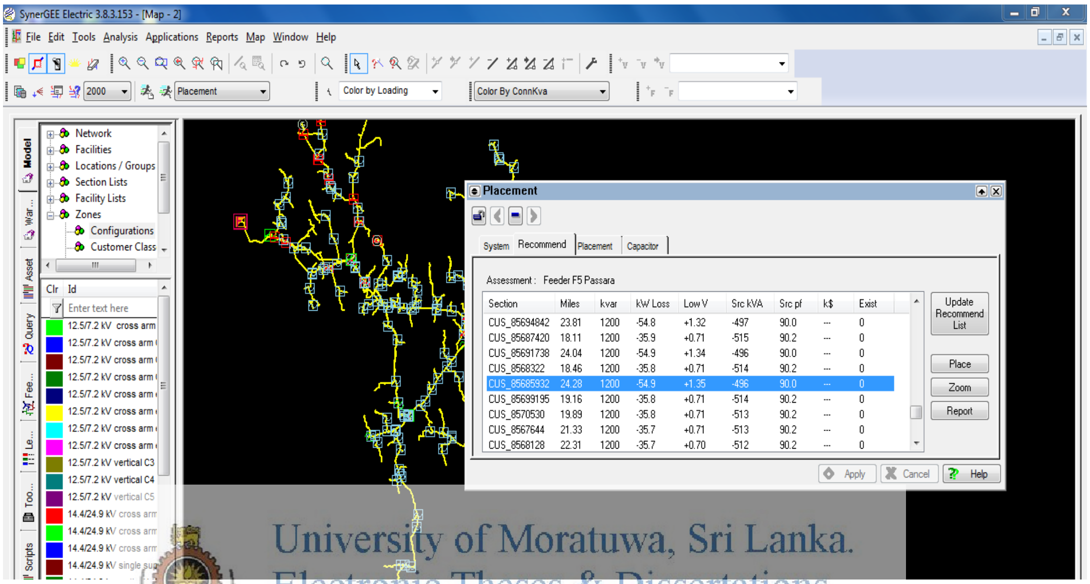
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8548	1001	8606	99	151	38	0.00	0	100.00	0.00	0	10606	8176	4592	372	4.36

Figure 4.12 : Load Flow results - Placement of Capacitor (1500 kvar x 3 nos)

4.4.4 Placement of one 1200 kvar capacitor in Passara feeder

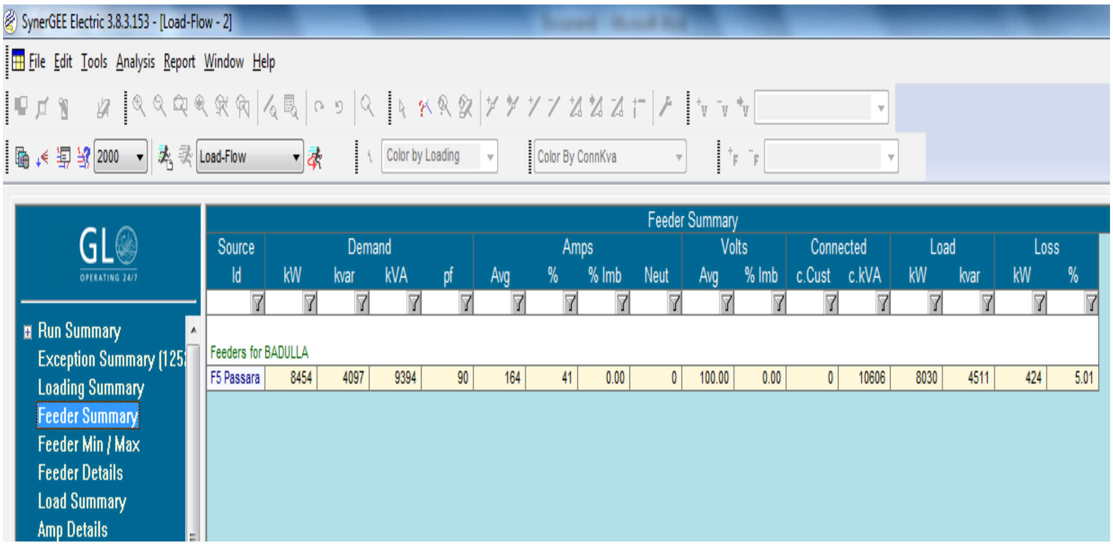
Figure 4.13 and figure 4.14 show the best suit location for placement of the 1200 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of one1200 kvar capacitor.



Assessment : Feeder F5 Passara

Section	Miles	kvar	kW Loss	Low V	Src kVA	Src pf	k$	Exist
CUS_85694842	23.81	1200	-54.8	+1.32	-497	90.0	---	0
CUS_85687420	18.11	1200	-35.9	+0.71	-515	90.2	---	0
CUS_85691738	24.04	1200	-54.9	+1.34	-496	90.0	---	0
CUS_8568322	18.46	1200	-35.8	+0.71	-514	90.2	---	0
CUS_85685932	24.28	1200	-54.9	+1.35	-496	90.0	---	0
CUS_85699195	19.16	1200	-35.8	+0.71	-514	90.2	---	0
CUS_8570530	19.89	1200	-35.8	+0.71	-513	90.2	---	0
CUS_8567644	21.33	1200	-35.7	+0.71	-513	90.2	---	0
CUS_8568128	22.31	1200	-35.7	+0.70	-512	90.2	---	0

Figure 4.13: Selection of capacitor location by maximizing the loss reduction



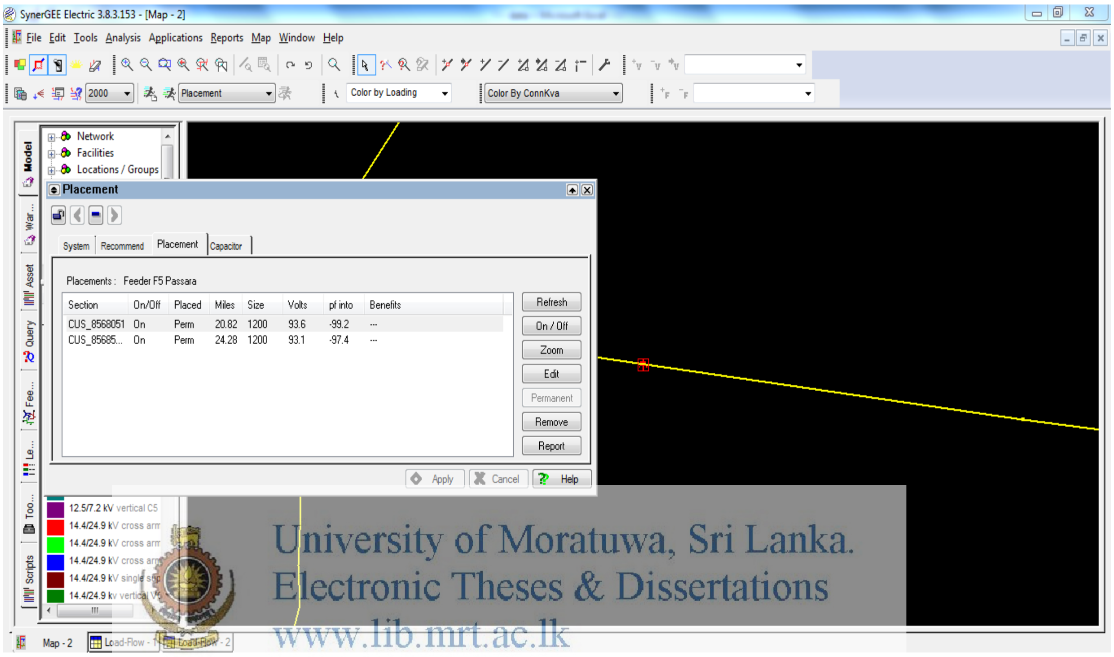
Feeder Summary

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8454	4097	9394	90	164	41	0.00	0	100.00	0.00	0	10606	8030	4511	424	5.01

Figure 4.14 : Load Flow results - Placement of Capacitor (1200 kvar x 1 no)

4.4.5 Placement of two 1200 kvar capacitors in Passara feeder

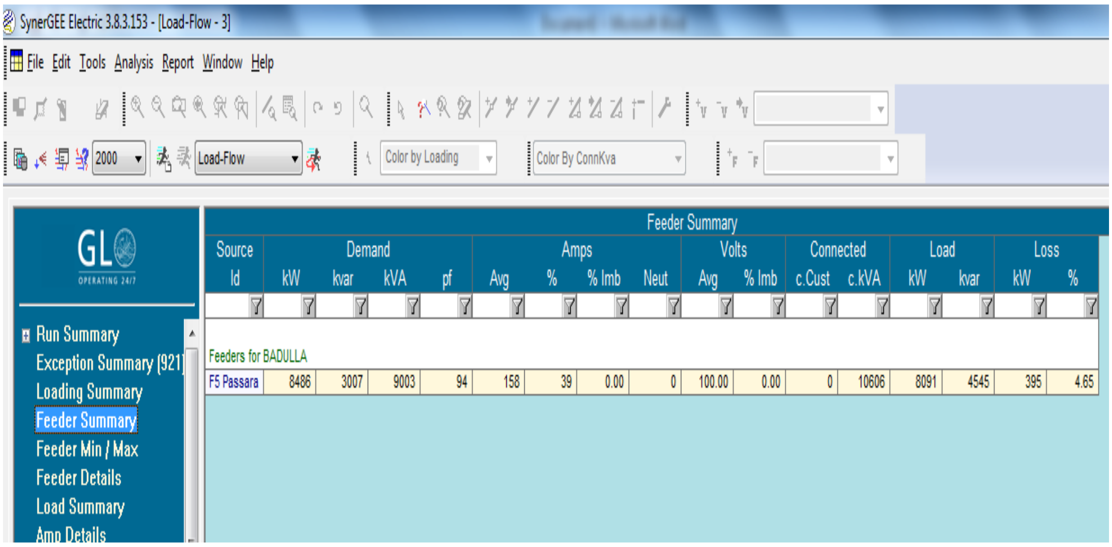
Figure 4.15 and figure 4.16 show the best suit location for placement of the second 1200 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of second 1200 kvar capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_8568051	On	Perm	20.82	1200	93.6	-99.2	---
CUS_85685...	On	Perm	24.28	1200	93.1	-97.4	---

Figure 4.15 : Placement of capacitor 1200 kvar (2 nos.)



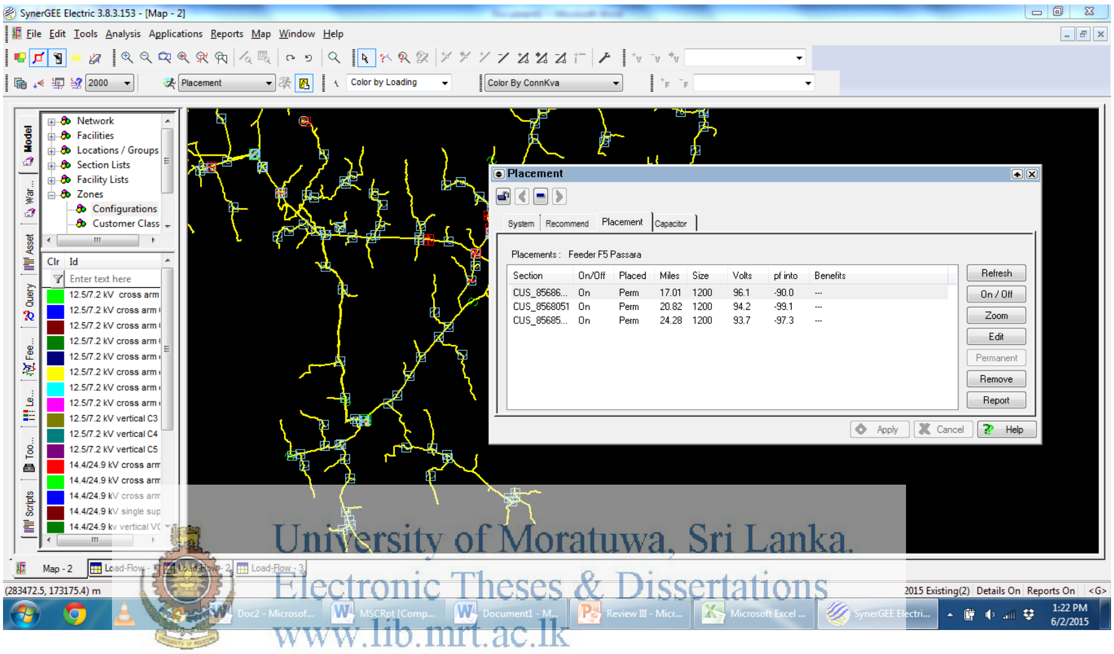
Feeder Summary

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8486	3007	9003	94	158	39	0.00	0	100.00	0.00	0	10606	8091	4545	395	4.65

Figure 4.16 : Load Flow results - Placement of Capacitor (1200 kvar x 2 nos)

4.4.6 Placement of three 1200 kvar capacitors for Passara feeder

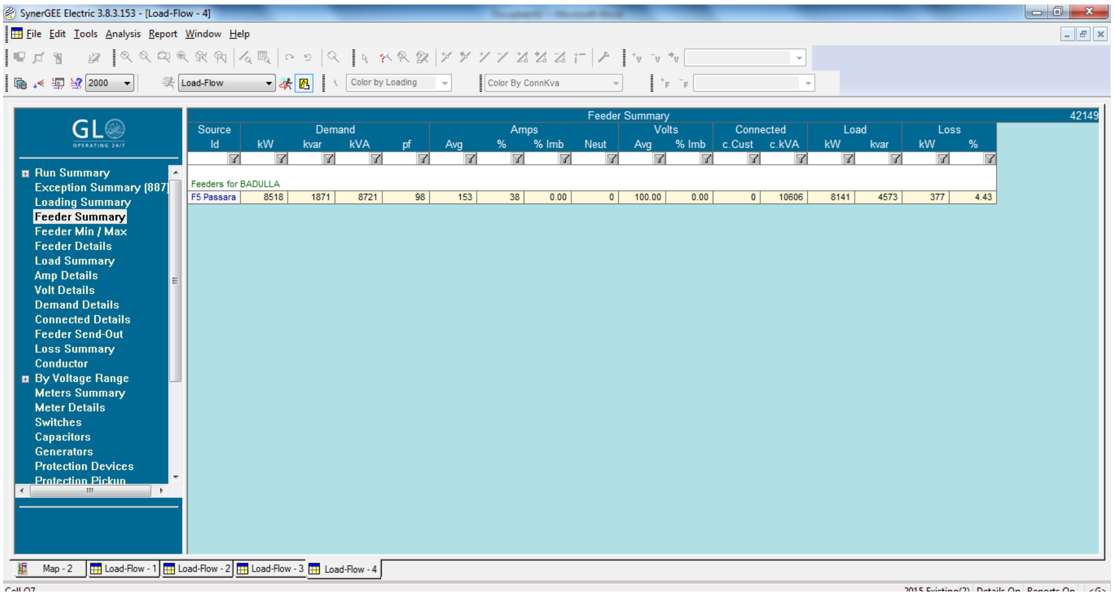
Figure 4.17 and figure 4.18 show the best suit location for placement of the third 1200kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of third 1200 kvar capacitor.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85686...	On	Perm	17.01	1200	96.1	-90.0	---
CUS_8568051	On	Perm	20.82	1200	94.2	-99.1	---
CUS_85685...	On	Perm	24.28	1200	93.7	-97.3	---

Figure 4.17 : Placement of capacitor 1200 kvar (3 nos.)



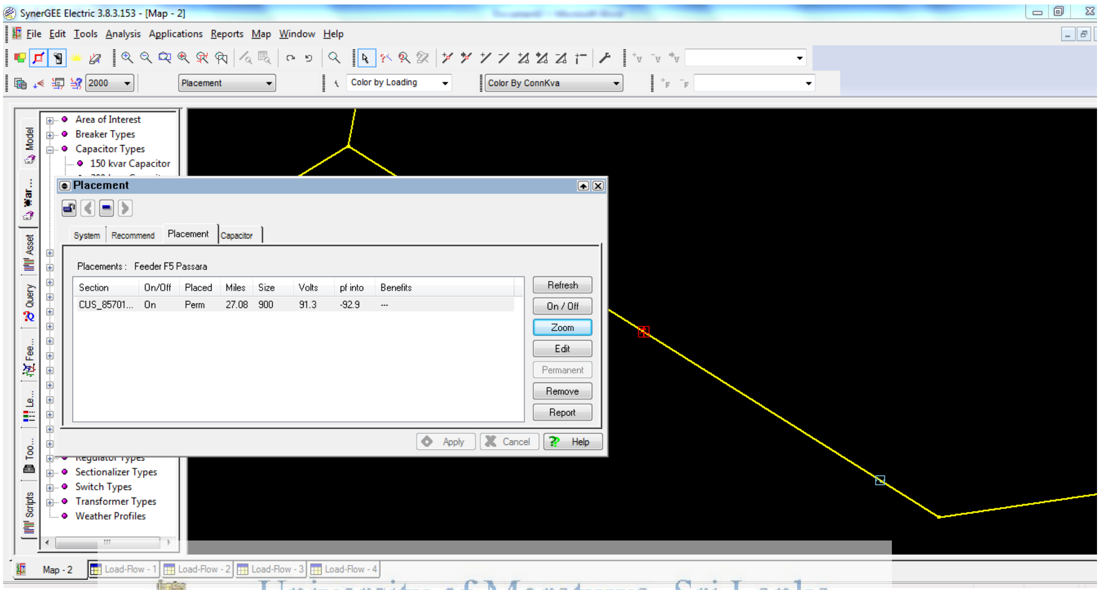
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8518	1871	8721	98	153	38	0.00	0	100.00	0.00	0	10606	8141	4573	377	4.43

Figure 4.18 : Load Flow results - Placement of Capacitor (1200 kvar x 3 nos)

4.4.7 Placement of one 900kvar capacitor for Passara feeder

Figure 4.19 and figure 4.20 show the best suit location for placement of 900 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of 900kvar capacitor.



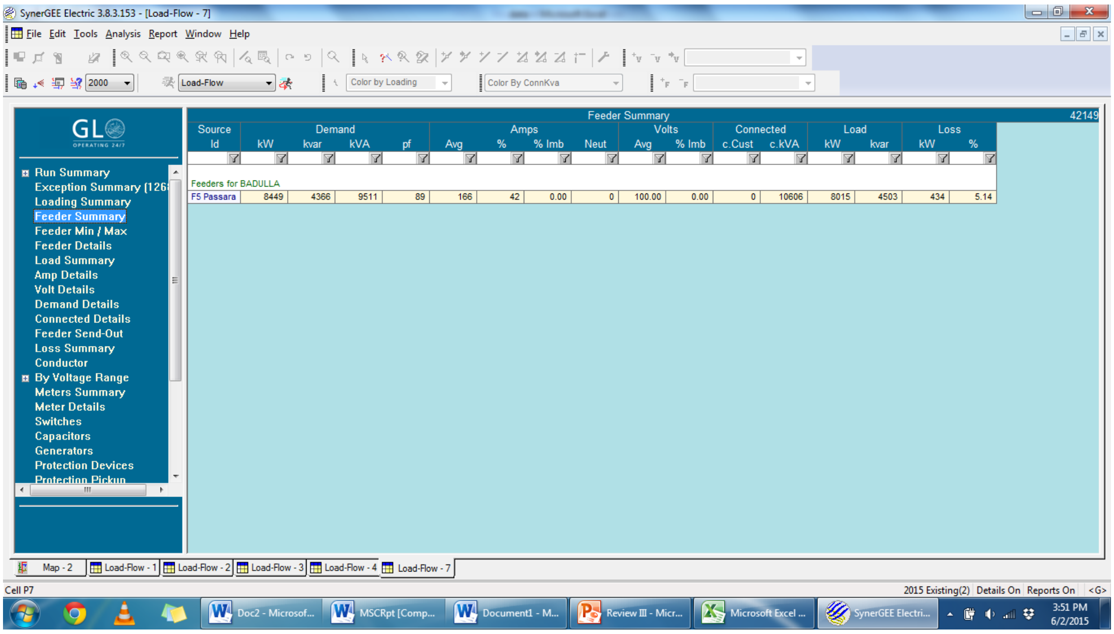
Placement

System | Recommend | Placement | Capacitor

Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85701...	On	Perm	27.08	900	91.3	-92.9	---

Figure 4.19: Placement of capacitor 900 kvar (1 no.)



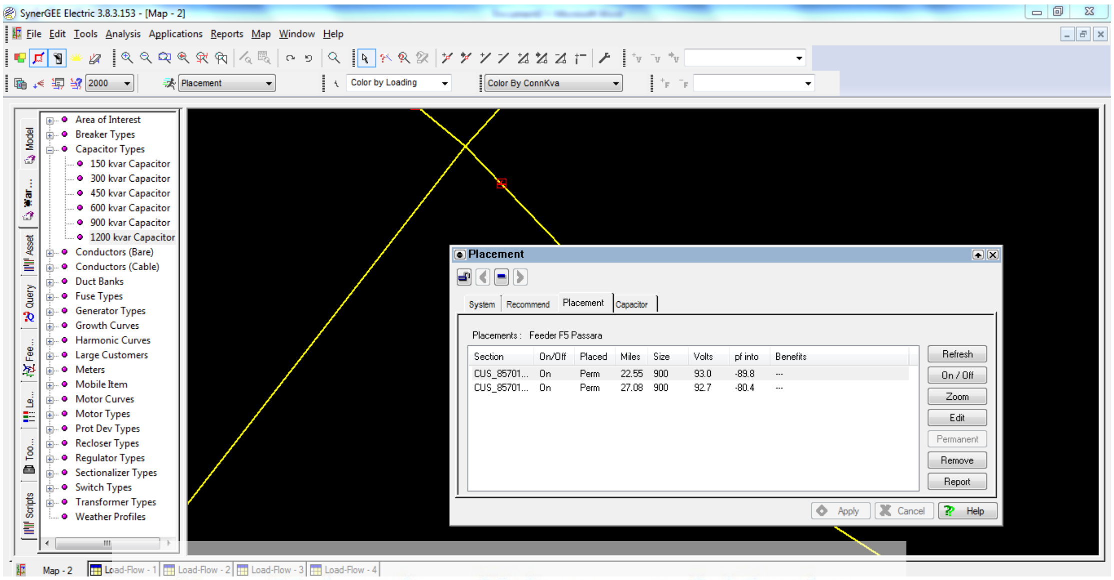
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8449	4366	9511	89	166	42	0.00	0	100.00	0.00	0	10606	8015	4503	434	5.14

Figure 4.20 : Load Flow results - Placement of Capacitor (900 kvar x 1 no.)

4.4.8 Placement of two 900 kvar capacitors for Passara feeder

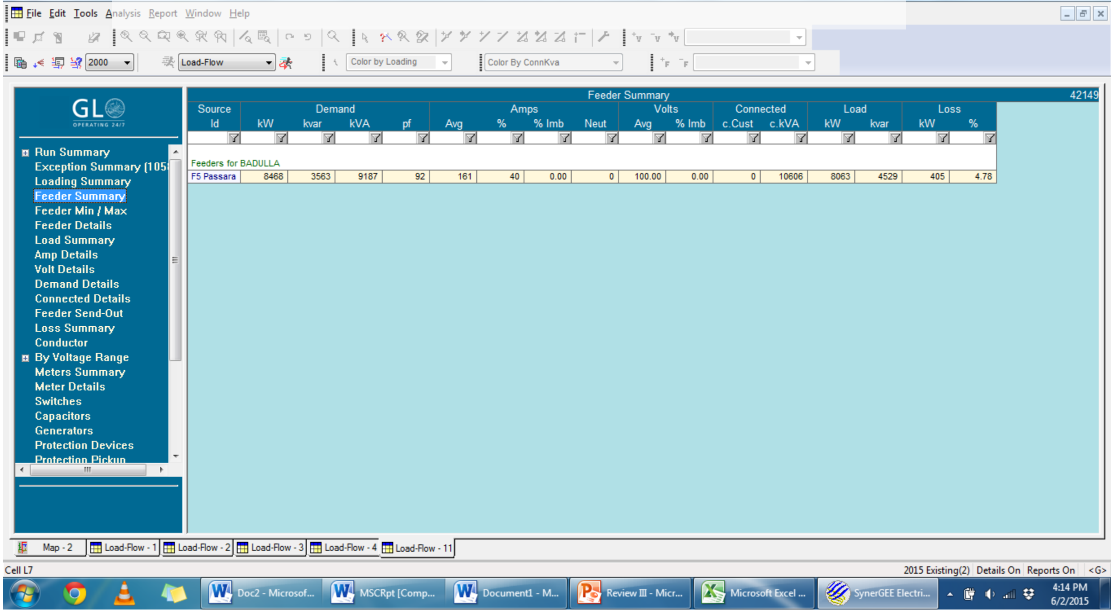
Figure 4.21 and figure 4.22 show the best suit location for placement of second 900 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of second 900 kvar capacitor.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85701...	On	Perm	22.55	900	93.0	-89.8	---
CUS_85701...	On	Perm	27.08	900	92.7	-80.4	---

Figure 4.21 : Placement of capacitor 900 kvar (2 nos.)



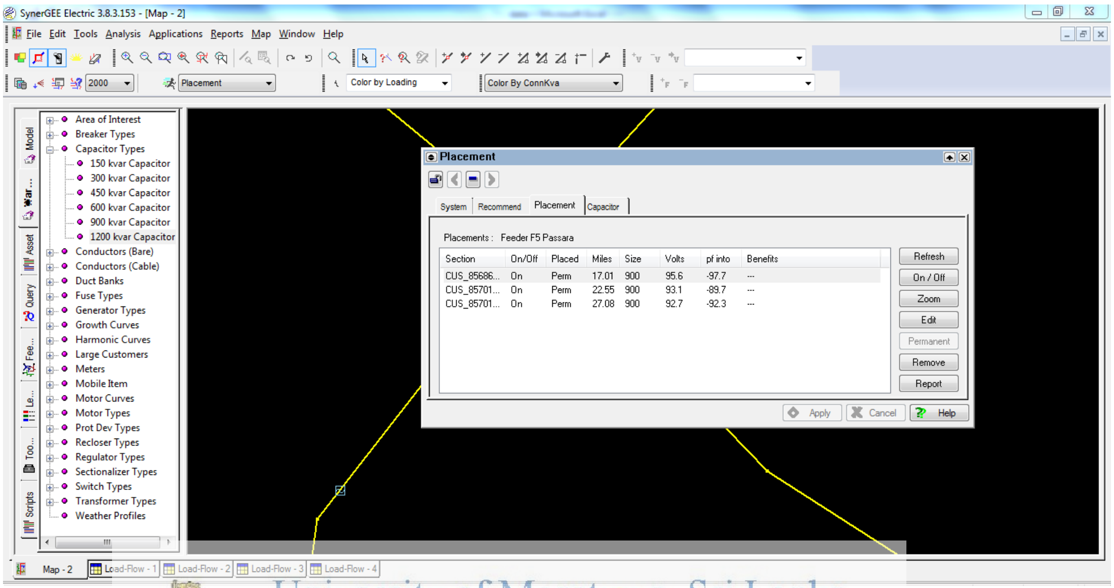
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8468	3563	9187	92	161	40	0.00	0	100.00	0.00	0	10606	8063	4529	405	4.78

Figure 4.22 : Load Flow results - Placement of Capacitor (900 kvar x 2 nos.)

4.4.9 Placement of three 900 kvar capacitors for Passara feeder

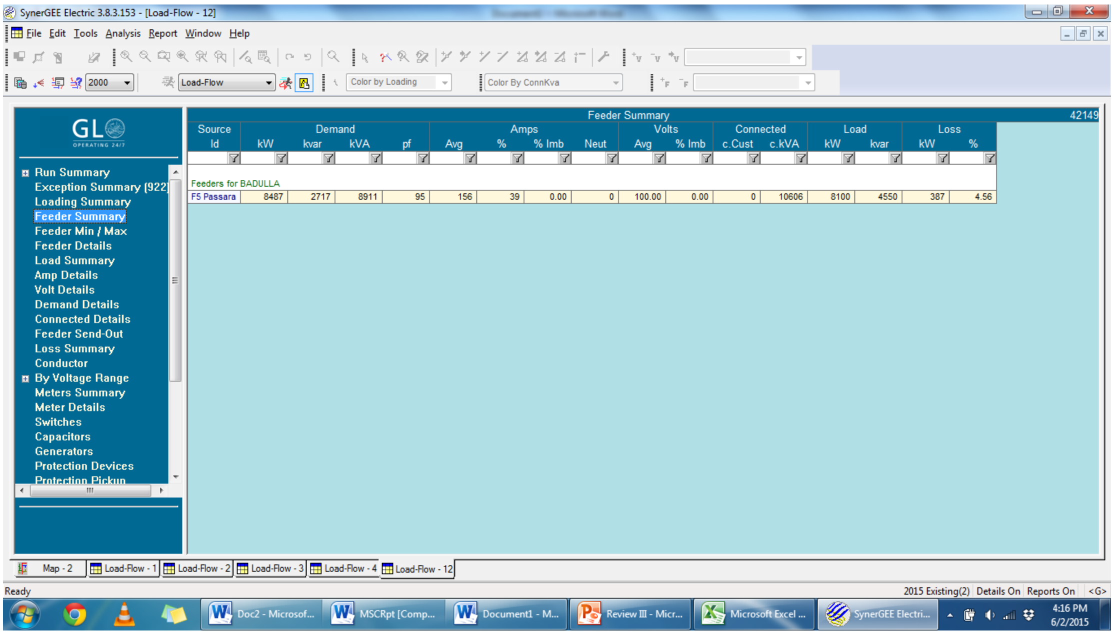
Figure 4.23 and figure 4.24 show the best suit location for placement of third 900 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of third 900 kvar capacitor.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85686...	On	Perm	17.01	900	95.6	-97.7	---
CUS_85701...	On	Perm	22.55	900	93.1	-89.7	---
CUS_85701...	On	Perm	27.08	900	92.7	-92.3	---

Figure 4.23: Placement of capacitor 900 kvar (3 nos.)



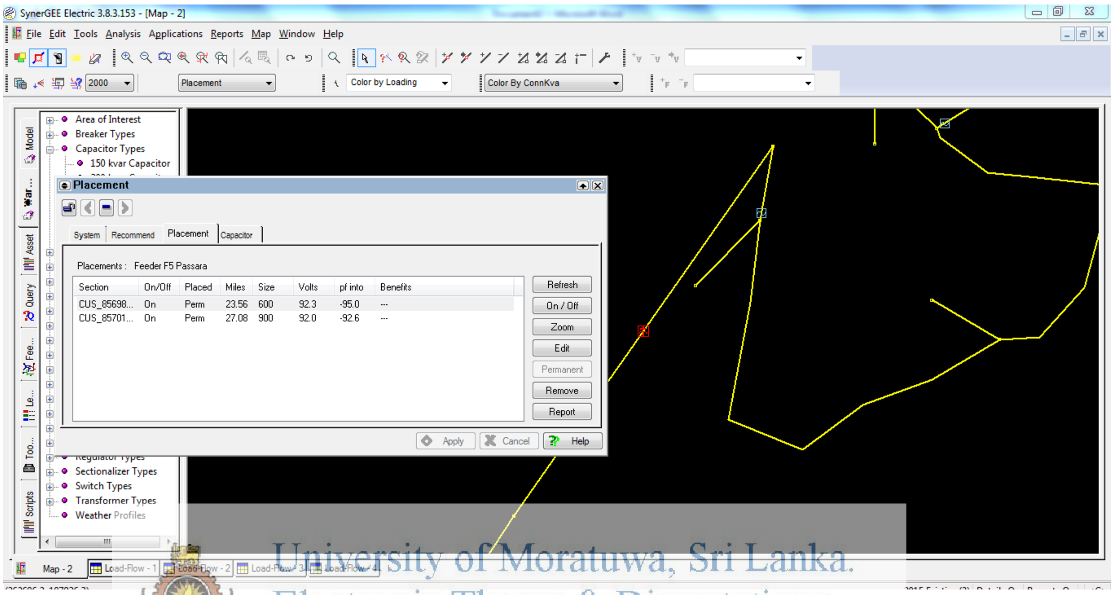
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8487	2717	8911	95	156	39	0.00	0	100.00	0.00	0	10606	8100	4550	387	4.56

Figure 4.24 : Load Flow results - Placement of Capacitor (900 kvar x 3 nos.)

4.4.10 Placement of one 900 kvar and one 600kvar capacitors for Passara feeder

Figure 4.25 and figure 4.26 show the best suit location for placement of one 900 kvar capacitor and one 600 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85698...	On	Perm	23.56	600	92.3	-95.0	---
CUS_85701...	On	Perm	27.08	900	92.0	-92.6	---

Figure 4.25: Placement of capacitor 900 kvar x 1 & capacitor 600 kvar x 1

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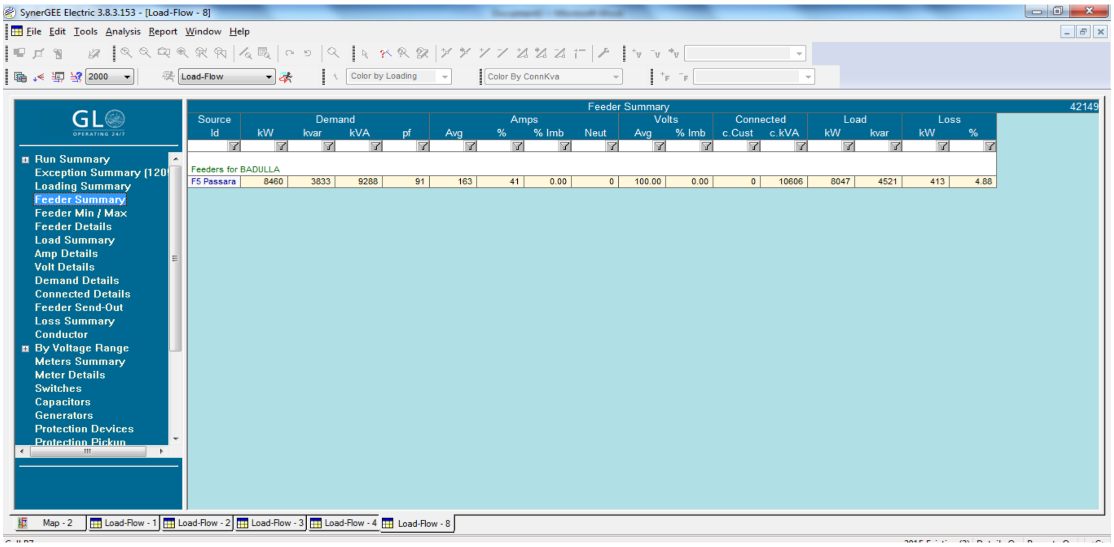


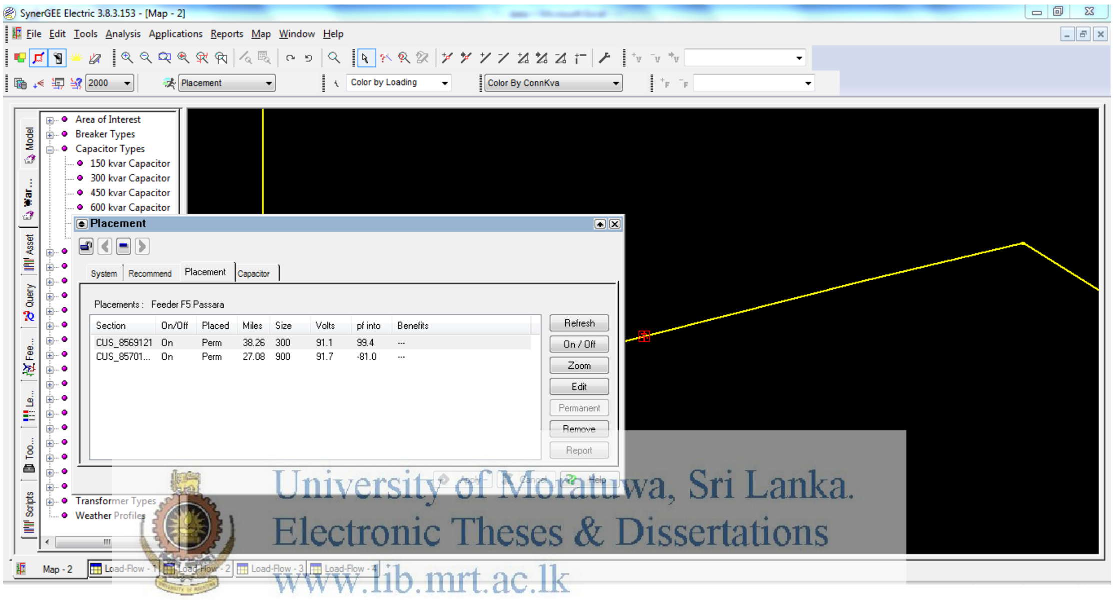
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8460	3833	9288	91	163	41	0.00	0	100.00	0.00	0	10606	8047	4521	413	4.88

Figure 4.26 : Load Flow results - Placement of Capacitors (900 kvar x 1 & 600 kvar x1)

4.4.11 Placement of one 900 kvar and one 300 kvar capacitors for Passara feeder

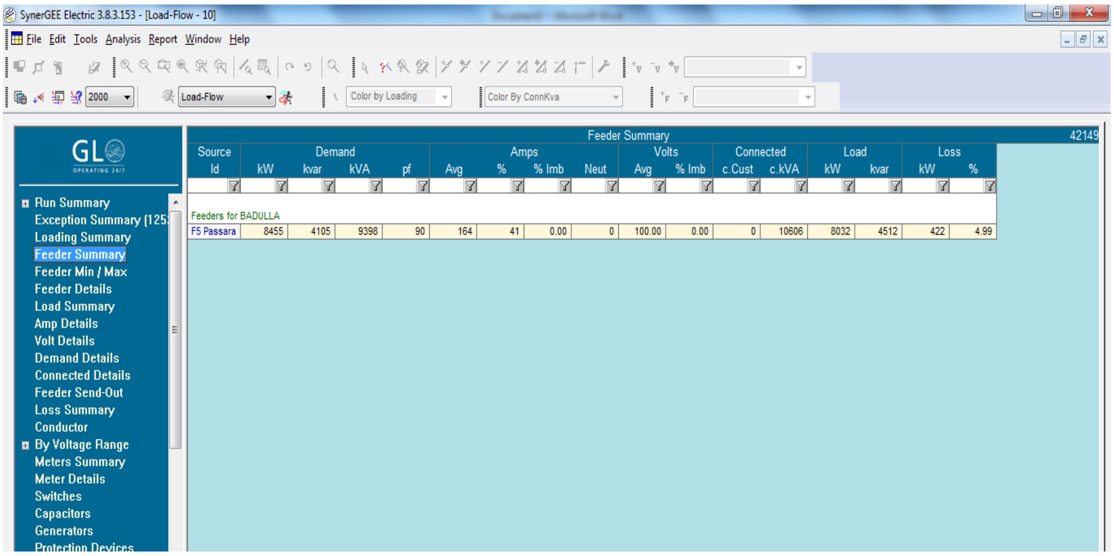
Figure 4.27 and figure 4.28 show the best suit location for placement of one 900 kvar capacitor and one 300 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_8569121	On	Perm	38.26	300	91.1	99.4	---
CUS_85701...	On	Perm	27.08	900	91.7	-81.0	---

Figure 4.27: Placement of capacitor 900 kvar x 1 & capacitor 300 kvar x 1



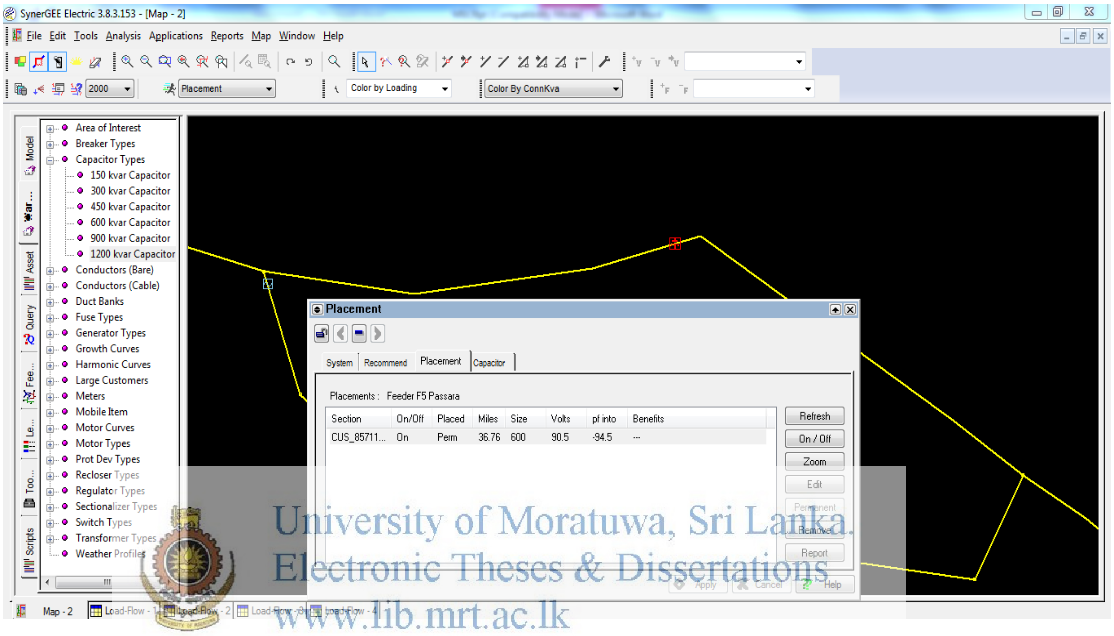
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8455	4105	9398	90	164	41	0.00	0	100.00	0.00	0	10606	8032	4512	422	4.99

Figure 4.28 : Load Flow results : Placement of Capacitors (900 kvar x 1 & 300 kvar x1)

4.4.12 Placement of one 600 kvar capacitor for Passara feeder

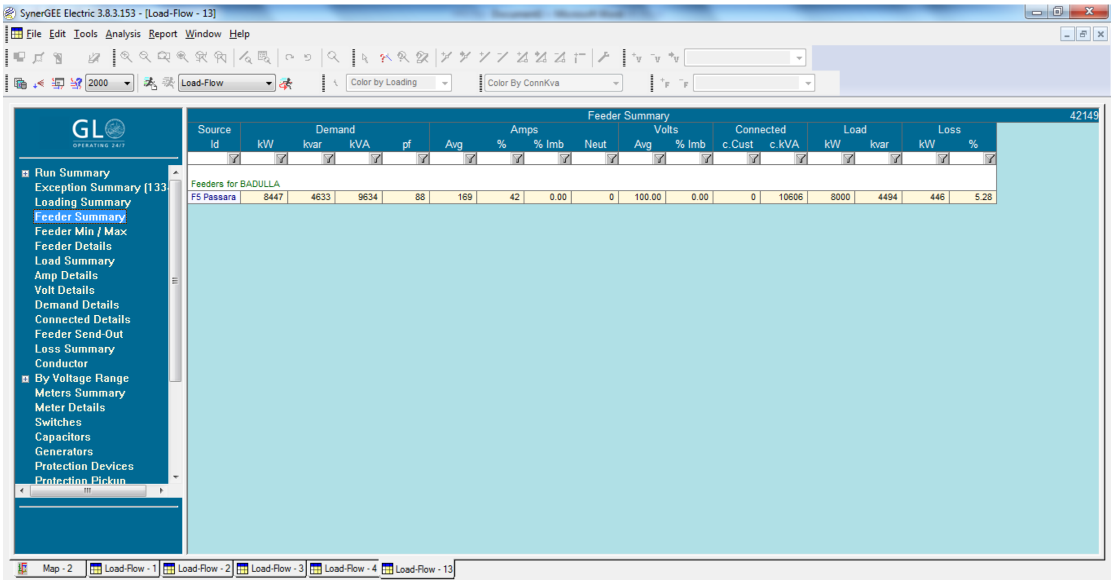
Figure 4.29 and figure 4.30 show the best suit location for placement of one 600 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitor respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85711...	On	Perm	36.76	600	90.5	-94.5	---

Figure 4.29 : Placement of capacitor 600 kvar x 1



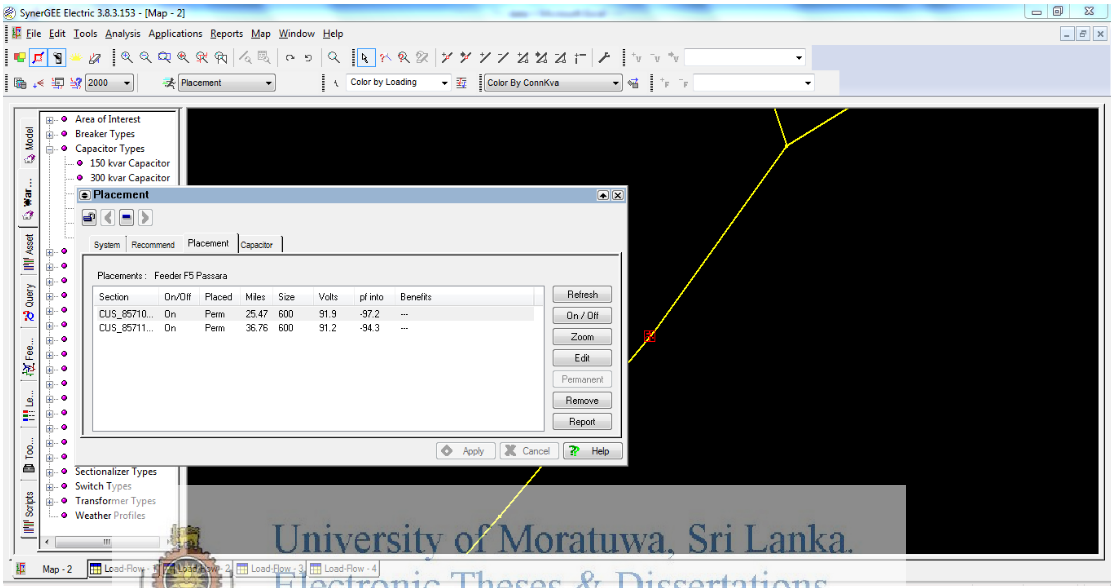
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8447	4633	9634	88	169	42	0.00	0	100.00	0.00	0	10606	8000	4494	446	5.28

Figure 4.30 : Load Flow results : Placement of Capacitor (600 kvar x 1)

4.4.13 Placement of two 600 kvar capacitors for Passara feeder

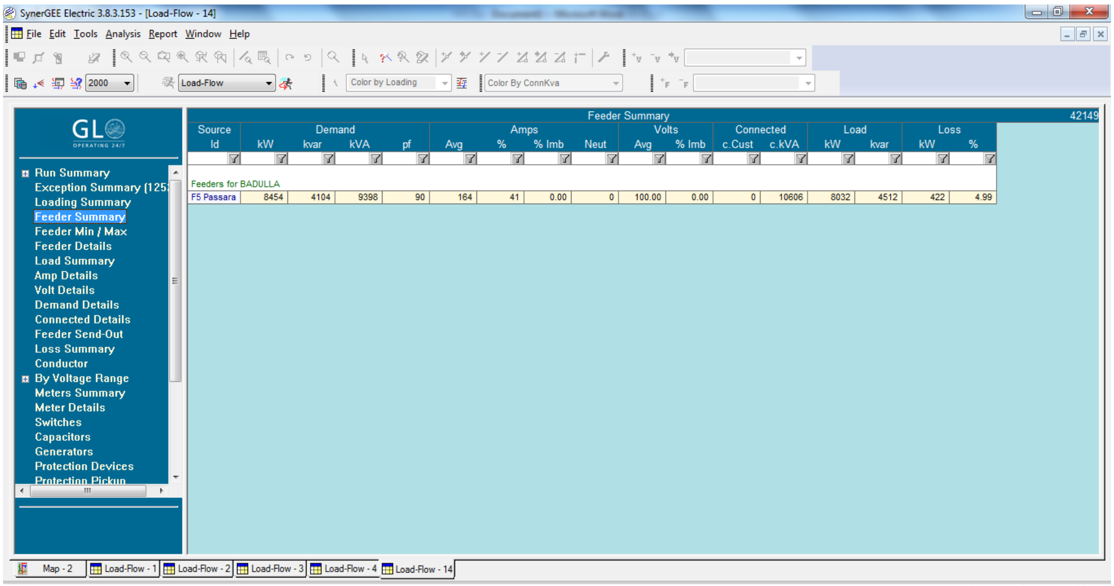
Figure 4.31 and figure 4.32 show the best suit location for placement of second 600 kvar capacitors in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85710...	On	Perm	25.47	600	91.9	-97.2	---
CUS_85711...	On	Perm	36.76	600	91.2	-94.3	---

Figure 4.31 : Placement of capacitors 600 kvar x 2



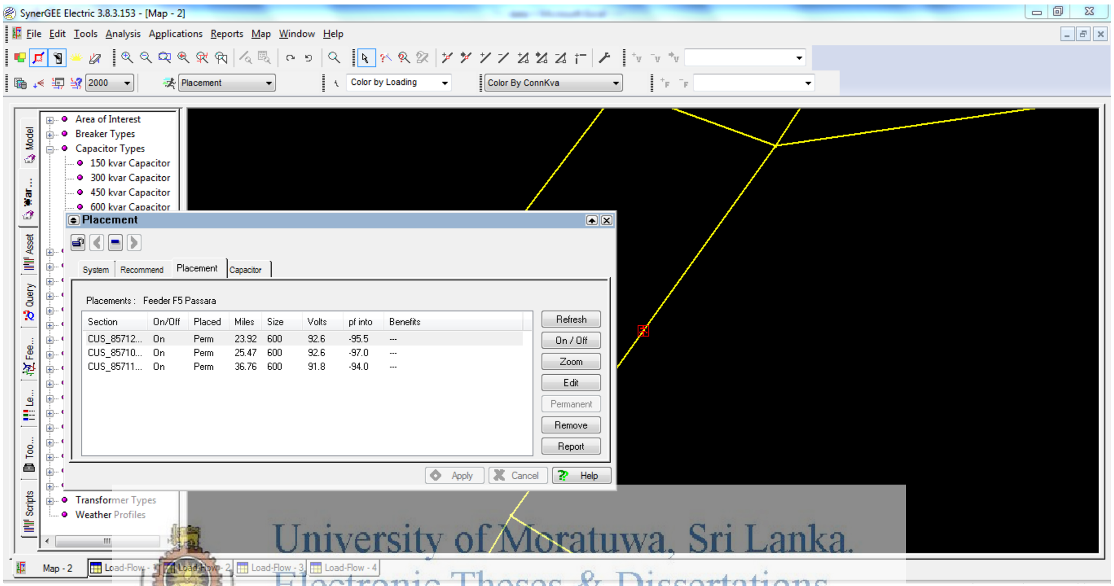
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8454	4104	9398	90	164	41	0.00	0	100.00	0.00	0	10606	8032	4512	422	4.99

Figure 4.32 : Load Flow results : Placement of Capacitors (600kvar x 2)

4.4.14 Placement of three 600 kvar capacitors for Passara feeder

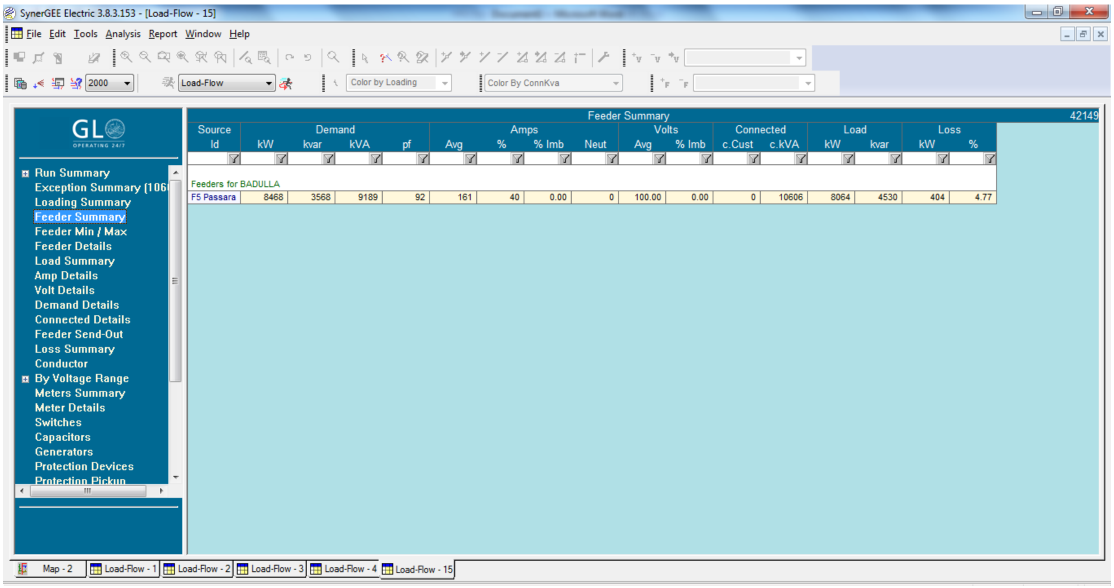
Figure 4.33 and figure 4.34 show the best suit location for placement of third 600 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85712...	On	Perm	23.92	600	92.6	-95.5	---
CUS_85710...	On	Perm	25.47	600	92.6	-97.0	---
CUS_85711...	On	Perm	36.76	600	91.8	-94.0	---

Figure 4.33 : Placement of capacitors 600 kvar x 3



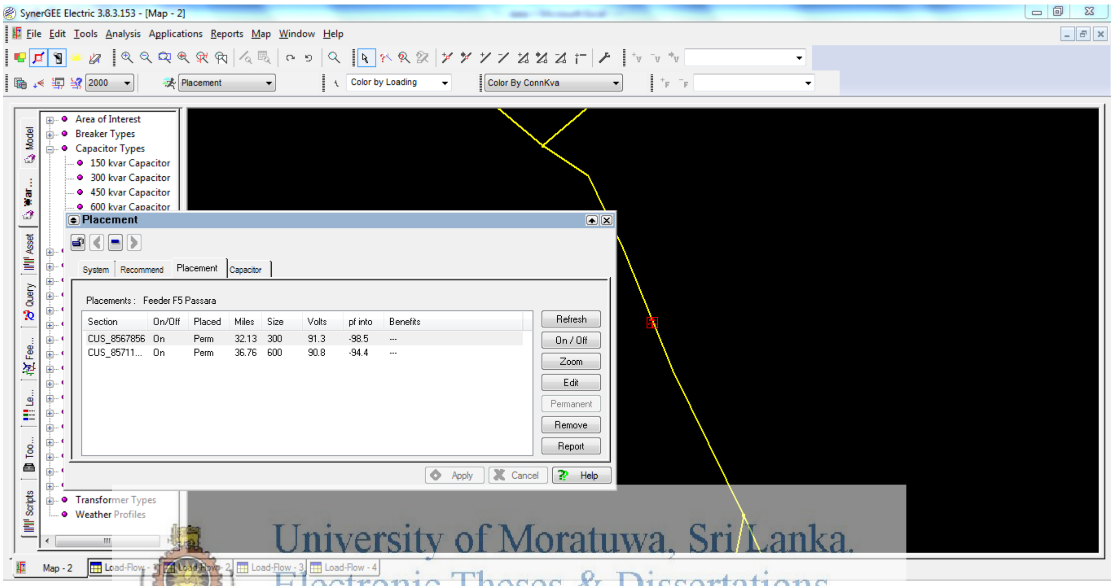
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8468	3568	9189	92	161	40	0.00	0	100.00	0.00	0	10606	8064	4530	404	4.77

Figure 4.34 : Load Flow results : Placement of Capacitors (600 kvar x 3)

4.4.15 Placement of one 600 kvar & one 300 kvar capacitors for Passara feeder

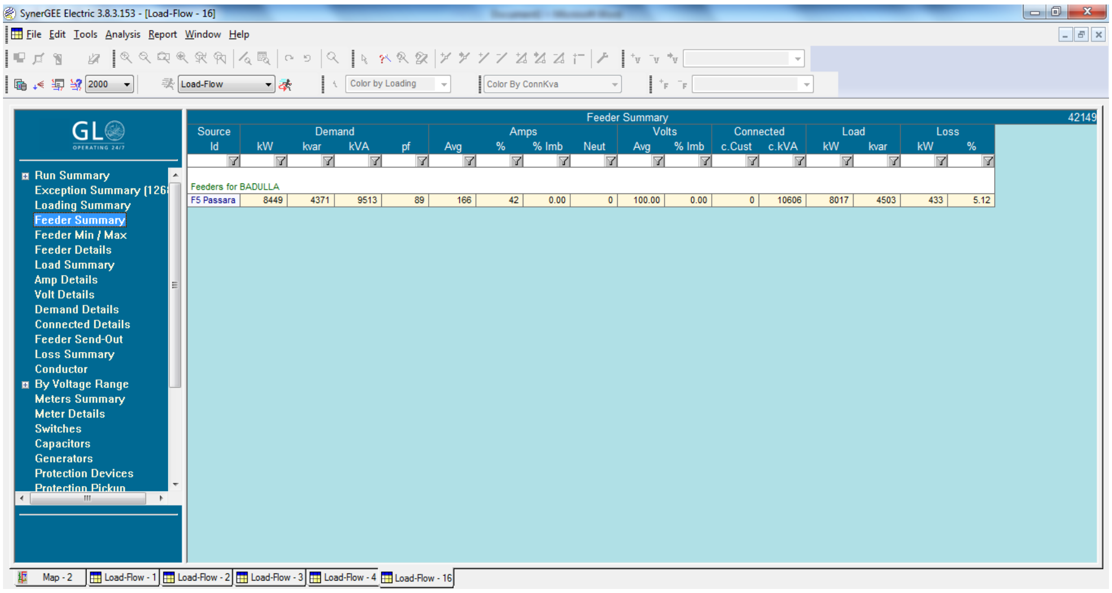
Figure 4.35 and figure 4.36 show the best suit location for placement of 600 kvar capacitor and 300 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_8567856	On	Perm	32.13	300	91.3	-98.5	---
CUS_85711...	On	Perm	36.76	600	90.8	-94.4	---

Figure 4.35: Placement of capacitor 600 kvar x 1 & capacitor 300 kvar x 1



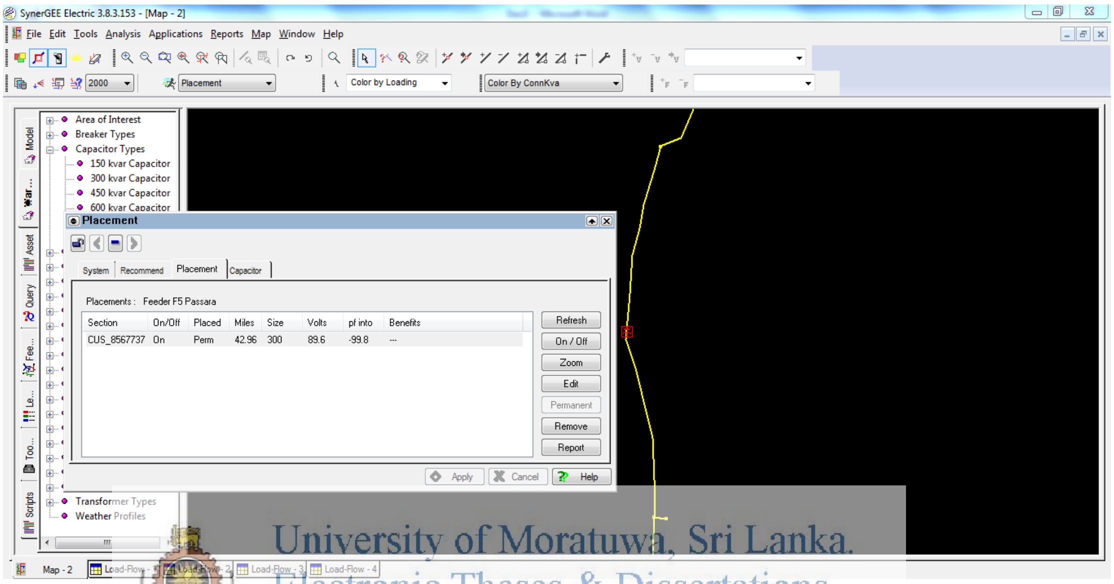
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8449	4371	9513	89	166	42	0.00	0	100.00	0.00	0	10606	8017	4503	433	5.12

Figure 4.36 : Load Flow Results : Placement of Capacitors (600 x1)& capacitor (300 x 1)

4.4.16 Placement of one 300 kvar capacitor for Passara feeder

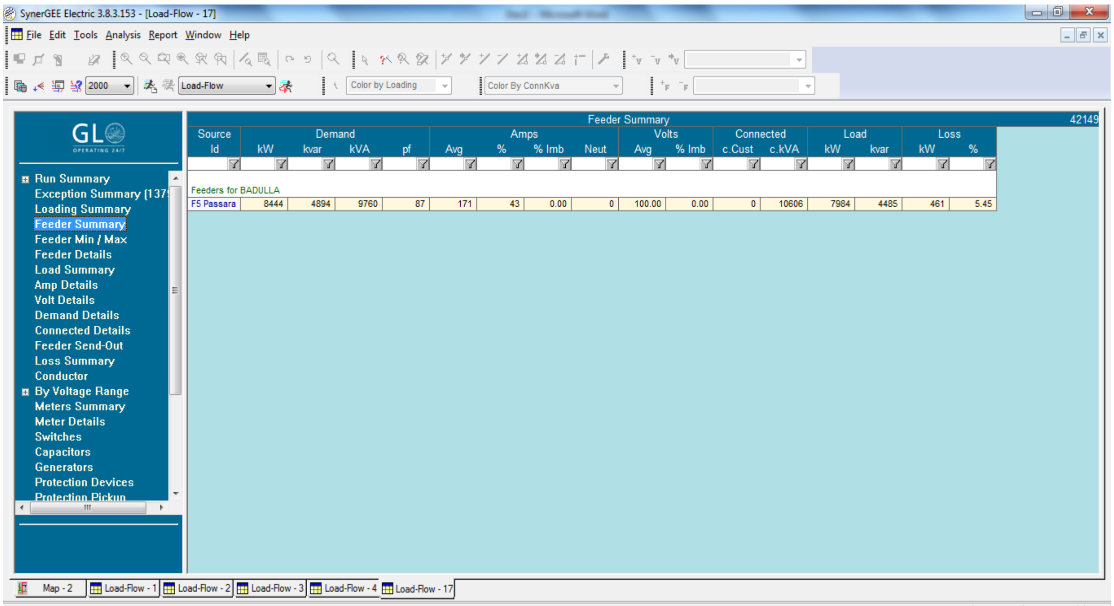
Figure 4.37 and figure 4.38 show the best suit location for placement of first 300 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitor respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_8567737	On	Perm	42.96	300	89.6	-99.8	---

Figure 4.37: Placement of capacitor 300 kvar x 1



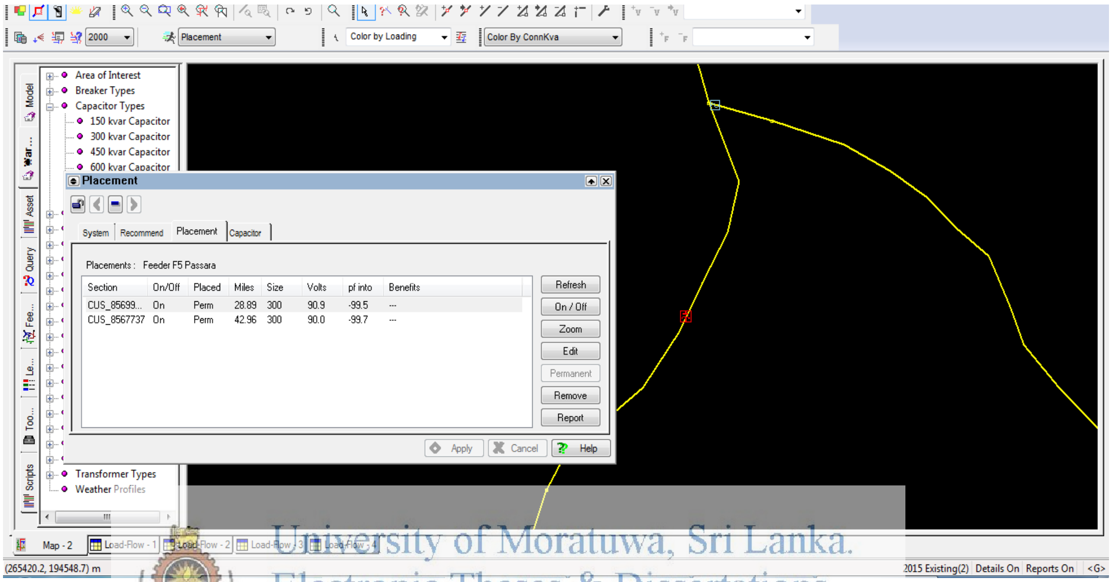
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8444	4894	9760	87	171	43	0.00	0	100.00	0.00	0	10606	7984	4485	461	5.45

Figure 4.38 : Load Flow Results : Placement of Capacitors (300 kvar x 1)

4.4.17 Placement of two 300 kvar capacitors for Passara feeder

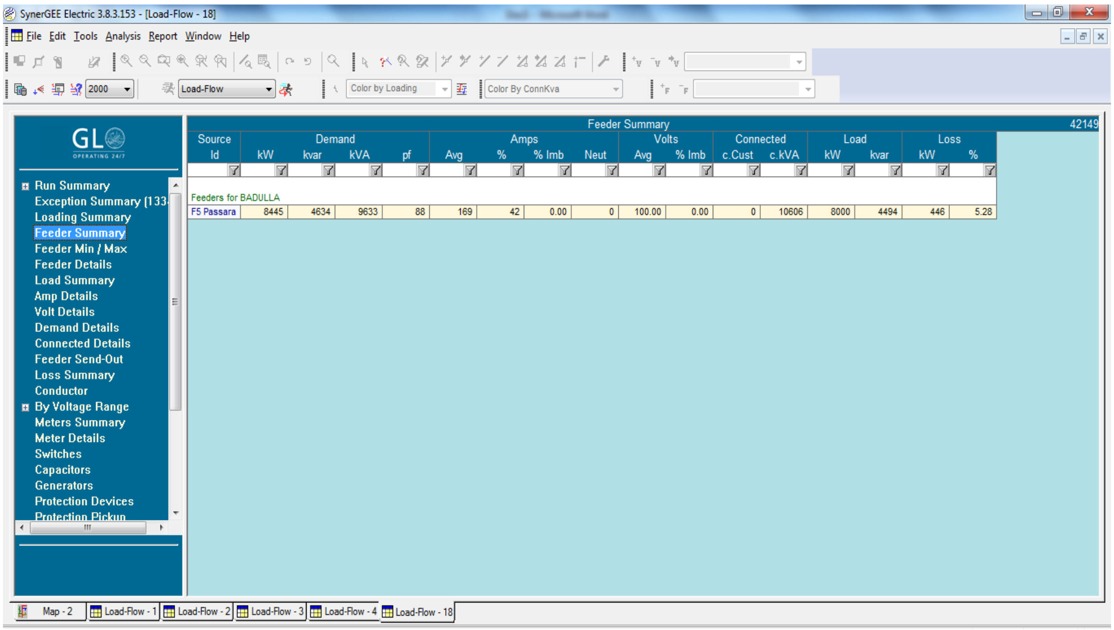
Figure 4.39 and figure 4.40 show the best suit location for placement of second 300 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85699...	On	Perm	28.89	300	90.9	-99.5	---
CUS_8567737	On	Perm	42.96	300	90.0	-99.7	---

Figure 4.39 : Placement of capacitors 300 kvar x 2



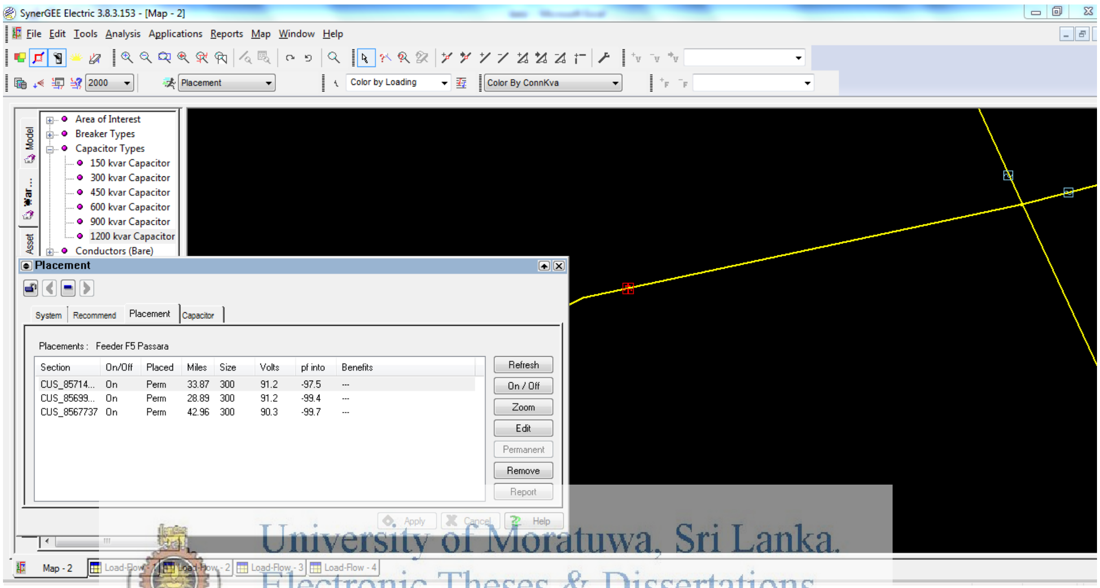
Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8445	4634	9633	88	169	42	0.00	0	100.00	0.00	0	10606	8000	4494	446	5.28

Figure 4.40 : Load Flow Results : Placement of Capacitors (300 kvar x 2)

4.4.18 Placement of three 300 kvar capacitors for Passara feeder

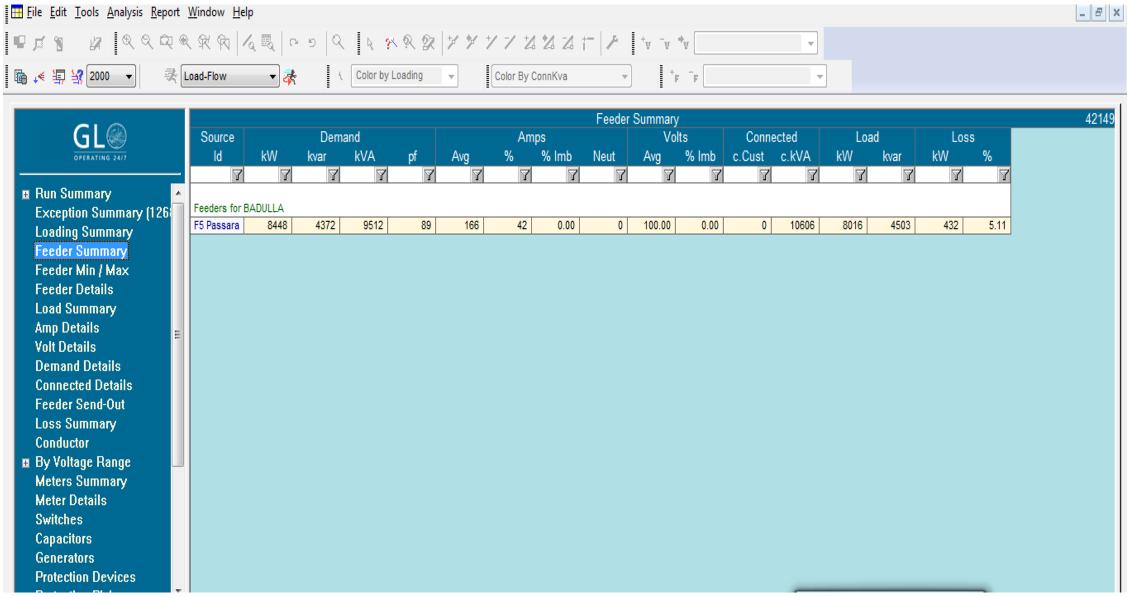
Figure 4.41 and figure 4.42 show the best suit location for placement of third 300 kvar capacitor in the manner of maximizing the loss reduction in the feeder and the load flow results after placement of above capacitors respectively.



Placements : Feeder F5 Passara

Section	On/Off	Placed	Miles	Size	Volts	pf into	Benefits
CUS_85714...	On	Perm	33.87	300	91.2	-97.5	---
CUS_85699...	On	Perm	28.89	300	91.2	-99.4	---
CUS_8567737	On	Perm	42.96	300	90.3	-99.7	---

Figure 4.41: Placement of capacitors 300 kvar x 3



Feeder Summary 42149

Source	Demand				Amps				Volts		Connected		Load		Loss	
Id	kW	kvar	kVA	pf	Avg	%	% Imb	Neut	Avg	% Imb	c.Cust	c.kVA	kW	kvar	kW	%
Feeders for BADULLA																
F5 Passara	8448	4372	9512	89	166	42	0.00	0	100.00	0.00	0	10606	8016	4503	432	5.11

Figure 4.42 : Load Flow Results : Placement of Capacitors (300kvar x3)

4.5 Economic Analysis

4.5.1 Placement of one 1500 kvar capacitor in Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	60.00	kW
Annual Energy Saving	=	210,240.00	kWh
Cost of Annual Energy Savings	=	2,417,760.00	Rs
Capacity Cost Saving	=	1,120,740.00	Rs
Total Cost Savings	=	3,538,500.00	Rs
Cost of Capacitor bank/banks	=	2,982,500.00	Rs
Cost of Installation	=	60,000.00	
	=	3,042,500.00	
For Ten Years Period			
Operation & Maintenance Cost	=	400,000.00	Rs
Total Cost for 10 years	=	7,042,500.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	24,006,122.96	Rs
Benefit / Cost Ratio	**=**	**3.41**	

1500 kvar x 1

Power Saving : 60 kW

Benefit / Cost Ratio : 3.41

4.5.2 Placement of two 1500 kvar capacitors in Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	93.00	kW
Annual Energy Saving	=	325,872.00	kWh
Cost of Annual Energy Savings	=	3,747,528.00	Rs
Capacity Cost Saving	=	1,737,147.00	Rs
Total Cost Savings	=	5,484,675.00	Rs
Cost of Capacitor bank/banks	=	5,965,000.00	Rs
Cost of Installation	=	120,000.00	
	=	6,085,000.00	
For Ten Years Period			
Operation & Maintenance Cost	=	800,000.00	Rs
Total Cost for 10 years	=	14,085,000.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	37,209,490.58	Rs
Benefit / Cost Ratio	=	**2.64**	

1500 kvar x 2

Power Saving : 93 kW

Benefit / Cost Ratio : 2.64

4.5.3 Placement of three 1500 kvar capacitors in Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	107.00	kW
Annual Energy Saving	=	374,928.00	kWh
Cost of Annual Energy Savings	=	4,311,672.00	Rs
Capacity Cost Saving	=	1,998,653.00	Rs
Total Cost Savings	=	6,310,325.00	Rs
Cost of Capacitor bank/banks	=	8,946,750.00	Rs
Cost of Installation	=	180,000.00	
	=	9,126,750.00	
For Ten Years Period			
Operation & Maintenance Cost	=	1,200,000.00	Rs
Total Cost for 10 years	=	21,126,750.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	42,810,919.27	Rs
Benefit / Cost Ratio	**=**	**2.03**	

1500 kvar x 3

Power Saving : 107 kW

Benefit / Cost Ratio : 2.03

4.5.4 Placement of one 1200 kvar capacitor in Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor = 0.40
Peak Power loss saving = 55.00 kW
Annual Energy Saving = 192,720.00 kWh

Cost of Annual Energy Savings = 2,216,280.00 Rs
Capacity Cost Saving = 1,027,345.00 Rs
Total Cost Savings = 3,243,625.00 Rs

Cost of Capacitor bank/banks = 2,305,800.00 Rs
Cost of Installation = 60,000.00
= 2,365,800.00

For Ten Years Period

Operation & Maintenance Cost = 400,000.00 Rs
Total Cost for 10 years = 6,365,800.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 22,005,612.71 Rs

Benefit / Cost Ratio = 3.46

1200 kvar x 1

Power Saving : 55 kW

Benefit / Cost Ratio : 3.46

4.5.5 Placement of two 1200 kvar capacitors in Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor = 0.40
Peak Power loss saving = 84.00 kW
Annual Energy Saving = 294,336.00 kWh

Cost of Annual Energy Savings = 3,384,864.00 Rs
Capacity Cost Saving = 1,569,036.00 Rs
Total Cost Savings = 4,953,900.00 Rs

Cost of Capacitor bank/banks = 4,611,600.00 Rs
Cost of Installation = 120,000.00 Rs
= 4,731,600.00 Rs

For Ten Years Period

Operation & Maintenance Cost = 800,000.00 Rs
Total Cost for 10 years = 12,731,600.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 33,608,572.14 Rs

Benefit / Cost Ratio = 2.64

1200 kvar x 2

Power Saving : 84 kW

Benefit / Cost Ratio : 2.64

4.5.6 Placement of three 1200 kvar capacitors in Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	102.00	kW
Annual Energy Saving	=	357,408.00	kWh
Cost of Annual Energy Savings	=	4,110,192.00	Rs
Capacity Cost Saving	=	1,905,258.00	Rs
Total Cost Savings	=	6,015,450.00	Rs
Cost of Capacitor bank/banks	=	6,917,400.00	Rs
Cost of Installation	=	180,000.00	Rs
	=	7,097,400.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	1,200,000.00	Rs
Total Cost for 10 years	=	19,097,400.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	40,810,409.03	Rs
Benefit / Cost Ratio	=	**2.14**	

1200 kvar x 3

Power Saving	:	**102 kW**
Benefit / Cost Ratio	:	**2.14**

4.5.7 Placement of one 900 kvar capacitor for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load actor = 0.40
Peak Power loss saving = 45.00 kW
Annual Energy Saving = 157,680.00 kWh

Cost of Annual Energy Savings = 1,813,320.00 Rs
Capacity Cost Saving = 840,555.00 Rs
Total Cost Savings = 2,653,875.00 Rs

Cost of Capacitor bank/banks = 1,829,350.00 Rs
Cost of Installation = 60,000.00 Rs
= 1,889,350.00 Rs

For Ten Years Period
Operation & Maintenance Cost = 400,000.00 Rs
Total Cost for 10 years = 5,889,350.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 18,004,592.22 Rs

Benefit / Cost Ratio = 3.06

900 kvar x 1

Power Saving : 45 kW

Benefit / Cost Ratio : 3.06

4.5.8 Placement of two 900 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	74.00	kW
Annual Energy Saving	=	259,296.00	kWh
Cost of Annual Energy Savings	=	2,981,904.00	Rs
Capacity Cost Saving	=	1,382,246.00	Rs
Total Cost Savings	=	4,364,150.00	Rs
Cost of Capacitor bank/banks	=	3,658,700.00	Rs
Cost of Installation	=	120,000.00	Rs
	=	3,778,700.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	800,000.00	Rs
Total Cost for 10 years	=	11,778,700.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	29,607,551.65	Rs
Benefit / Cost Ratio	=	2.51	

900 kvar x 2

Power Saving : 74 kW

Benefit / Cost Ratio : 2.51

4.5.9 Placement of three 900 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	92.00	kW
Annual Energy Saving	=	322,368.00	kWh
Cost of Annual Energy Savings	=	3,707,232.00	Rs
Capacity Cost Saving	=	1,718,468.00	Rs
Total Cost Savings	=	5,425,700.00	Rs
Cost of Capacitor bank/banks	=	5,488,050.00	Rs
Cost of Installation	=	180,000.00	Rs
	=	5,668,050.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	1,200,000.00	Rs
Total Cost for 10 years	=	17,668,050.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	36,809,388.53	Rs
Benefit / Cost Ratio	=	**2.08**	

900 kvar x 3

Power Saving : 92 kW

Benefit / Cost Ratio : 2.08

4.5.10 Placement of one 900 kvar and one 600 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	66	kW
Annual Energy Saving	=	231,264.00	kWh
Cost of Annual Energy Savings	=	2,659,536.00	Rs
Capacity Cost Saving	=	1,232,814.00	Rs
Total Cost Savings	=	3,892,350.00	Rs
Cost of Capacitor bank/banks	=	2,982,200.00	Rs
Cost of Installation	=	120,000.00	Rs
	=	3,102,200.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	800,000.00	Rs
Total Cost for 10 years	=	11,102,200.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	26,406,735.25	Rs
Benefit / Cost Ratio	**=**	**2.38**	

900 kvar x 1 & 600 kvar x 1

Power Saving : 66 kW

Benefit / Cost Ratio : 2.38

4.5.11 Placement of one 900 kvar and one 300 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	57.00	kW
Annual Energy Saving	=	199,728.00	kWh
Cost of Annual Energy Savings	=	2,296,872.00	Rs
Capacity Cost Saving	=	1,064,703.00	Rs
Total Cost Savings	=	3,361,575.00	Rs
Cost of Capacitor bank/banks	=	2,405,800.00	Rs
Cost of Installation	=	120,000.00	Rs
	=	2,525,800.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	800,000.00	Rs
Total Cost for 10 years	=	10,525,800.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	22,805,816.81	Rs
Benefit / Cost Ratio	=	**2.17**	

900 kvar x 1 & 300 kvar x 1

Power Saving : 57 kW

Benefit / Cost Ratio : 2.17

4.5.12 Placement of one 600 kvar capacitor for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor = 0.40
Peak Power loss saving = 33.00 kW
Annual Energy Saving = 115,632.00 kWh

Cost of Annual Energy Savings = 1,329,768.00 Rs
Capacity Cost Saving = 616,407.00 Rs
Total Cost Savings = 1,946,175.00 Rs

Cost of Capacitor bank/banks = 1,152,900.00 Rs
Cost of Installation = 60,000.00 Rs
= 1,212,900.00 Rs

For Ten Years Period

Operation & Maintenance Cost = 400,000.00 Rs
Total Cost for 10 years = 5,212,900.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 13,203,367.63 Rs

Benefit / Cost Ratio = 2.53

600 kvar x 1

Power Saving : 33 kW

Benefit / Cost Ratio : 2.53

4.5.13 Placement of two 600 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor = 0.40
Peak Power loss saving = 57.00 kW
Annual Energy Saving = 199,728.00 kWh

Cost of Annual Energy Savings = 2,296,872.00 Rs
Capacity Cost Saving = 1,064,703.00 Rs
Total Cost Savings = 3,361,575.00 Rs

Cost of Capacitor bank/banks = 2,305,800.00 Rs
Cost of Installation = 120,000.00 Rs
= 2,425,800.00 Rs

For Ten Years Period

Operation & Maintenance Cost = 800,000.00 Rs
Total Cost for 10 years = 10,425,800.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 22,805,816.81 Rs

Benefit / Cost Ratio = 2.19

600 kvar x 2

Power Saving : 57 kW

Benefit / Cost Ratio : 2.19

4.5.14 Placement of three 600 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained as from the commercially available rates.

Load factor = 0.40
Peak Power loss saving = 75.00 kW
Annual Energy Saving = 262,800.00 kWh

Cost of Annual Energy Savings = 3,022,200.00 Rs
Capacity Cost Saving = 1,400,925.00 Rs
Total Cost Savings = 4,423,125.00 Rs

Cost of Capacitor bank/banks = 3,458,700.00 Rs
Cost of Installation = 180,000.00 Rs
= 3,638,700.00 Rs

For Ten Years Period
Operation & Maintenance Cost = 1,200,000.00 Rs
Total Cost for 10 years = 15,638,700.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 30,007,653.69 Rs

Benefit / Cost Ratio = 1.92

600 kvar x 3

Power Saving : 75 kW

Benefit / Cost Ratio : 1.92

4.5.15 Placement of one 600 kvar & one 300 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	46	kW
Annual Energy Saving	=	161,184.00	kWh
Cost of Annual Energy Savings	=	1,853,616.00	Rs
Capacity Cost Saving	=	859,234.00	Rs
Total Cost Savings	=	2,712,850.00	Rs
Cost of Capacitor bank/banks	=	1,729,350.00	Rs
Cost of Installation	=	120,000.00	Rs
	=	1,849,350.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	800,000.00	Rs
Total Cost for 10 years	=	9,849,350.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	18,404,694.27	Rs
Benefit / Cost Ratio	**=**	**1.87**	

600 kvar x 1 & 300 kvar x 1

Power Saving	**:**	**46 kW**
Benefit / Cost Ratio	**:**	**1.87**

4.4.16 Placement of one 300 kvar capacitor for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load actor	=	0.40	
Peak Power loss saving	=	18.00	kW
Annual Energy Saving	=	63,072.00	kWh
Cost of Annual Energy Savings	=	725,328.00	Rs
Capacity Cost Saving	=	336,222.00	Rs
Total Cost Savings	=	1,061,550.00	Rs
Cost of Capacitor bank/banks	=	576,450.00	Rs
Cost of Installation	=	60,000.00	Rs
	=	636,450.00	Rs
For Ten Years Period			
Operation & Maintenance Cost	=	400,000.00	Rs
Total Cost for 10 years	=	4,636,450.00	Rs
Cost of Energy saving at 10% discount rate for ten years	=	7,201,836.89	Rs
Benefit / Cost Ratio	**=**	**1.55**	

300 kvar x 1

Power Saving : 18 kW

Benefit / Cost Ratio : 1.55

4.5.17 Placement of two 300 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor = 0.40
Peak Power loss saving = 33.00 kW
Annual Energy Saving = 115,632.00 kWh

Cost of Annual Energy Savings = 1,329,768.00 Rs
Capacity Cost Saving = 616,407.00 Rs
Total Cost Savings = 1,946,175.00 Rs

Cost of Capacitor bank/banks = 1,152,900.00 Rs
Cost of Installation = 120,000.00 Rs
= 1,272,900.00 Rs

For Ten Years Period
Operation & Maintenance Cost = 800,000.00 Rs
Total Cost for 10 years = 9,272,900.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 13,203,367.63 Rs

Benefit / Cost Ratio = **1.42**

300 kvar x 2

Power Saving : **33 kW**

Benefit / Cost Ratio : **1.42**

4.5.18 Placement of three 300 kvar capacitors for Passara feeder

Economic analysis was done for the above different combinations for the load flow analysis were performed. Capacitor cost, installation cost and operation & maintenance cost were obtained from the commercially available rates.

Load factor	=	0.40	
Peak Power loss saving	=	47.00	kW
Annual Energy Saving	=	164,688.00	kWh

Cost of Annual Energy Savings	=	1,893,912.00	Rs
Capacity Cost Saving	=	877,913.00	Rs
Total Cost Savings	=	2,771,825.00	Rs

Cost of Capacitor bank/banks	=	1,729,350.00	Rs
Cost of Installation	=	180,000.00	Rs
	=	1,909,350.00	Rs

For Ten Years Period

Operation & Maintenance Cost	=	1,200,000.00	Rs
Total Cost for 10 years	=	13,909,350.00	Rs

Cost of Energy saving at 10% discount rate for ten years	=	18,804,796.32	Rs
Benefit / Cost Ratio	=	**1.35**	

300 kvar x 3

Power Saving	:	**47 kW**
Benefit / Cost Ratio	:	**1.35**

4.6 Benefit to cost Ratio

Table 4.2 : Benefit /cost ratio for different capacitor combinations

Selected capacitor rating combinations (kvar)	Benefit / Cost
1500 x 1	3.41
1500 x 2	2.64
1500 x 3	2.03
1200 x 1	3.46
1200 x 2	2.61
1200 x 3	2.14
900 x 1	3.06
900 x 2	2.51
900 x 3	2.08
900 + 600	2.38
900 + 300	2.17
600 + 300	1.87
600 x 1	2.53
600 x 2	2.19
600 x 3	1.92

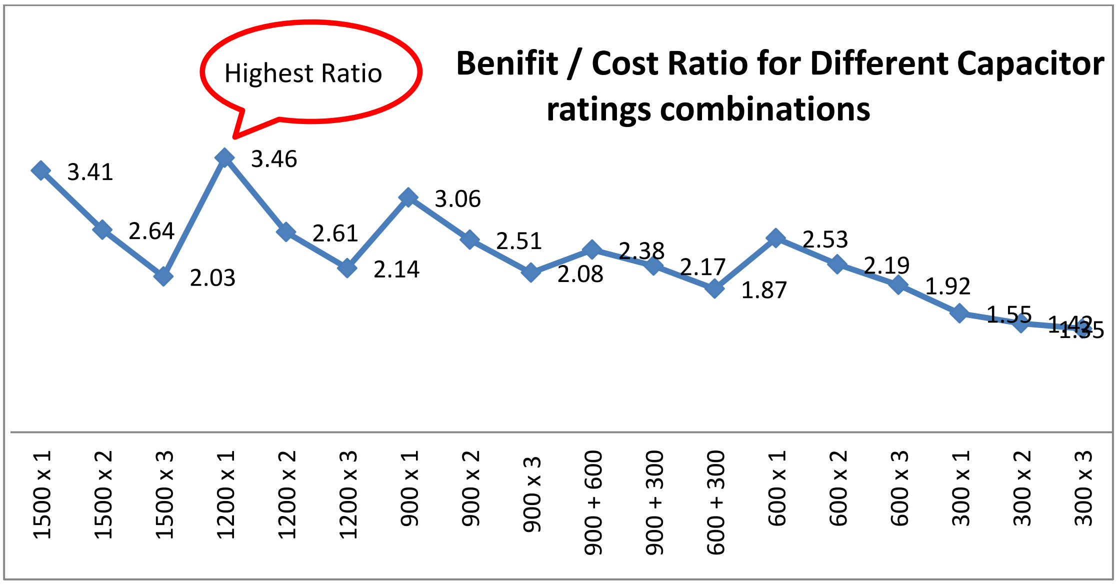


Figure 4.43: Benefit / Cost Ratio for Different Capacitor ratings combinations

4.7 Selection of switched type or fixed type

Capacitor size and the location have been decided and further it was required to determine whether to select switched or fixed type capacitors. Hence 1200 kvar switched type capacitor was model in the Synergee and analyzed. The automatic switching capacitors are assumed to be activated on var based or power factor based control law. The maximum numbers of switching steps were limited to three. For investment calculation purposes it is assumed that vacuum circuit breakers are used in switching capacitor banks. Switching capacitor banks are assumed to be installed on 13m double pole arrangement. For a switching capacitor bank, the installation cost is estimated as Rs. 145,000.00 per location. Total investment cost of capacitor installation had been calculated based on above figures and the annual maintenance cost was assumed to be Rs. 100,000.00.

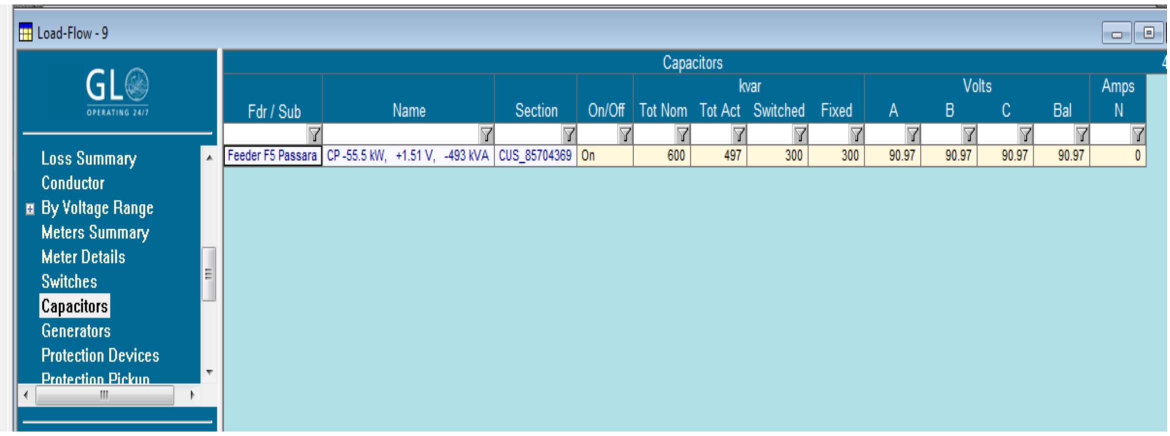
4.7.1 Modeling1200 kvar switched type in synergee (3.8)

Switched capacitor modeling is done in Synergee as per the operation rules in table. It was used the var control mode to model the 1200 kvar switched capacitor for the analysis.

Table 4.3 :Switched capacitor operation rules

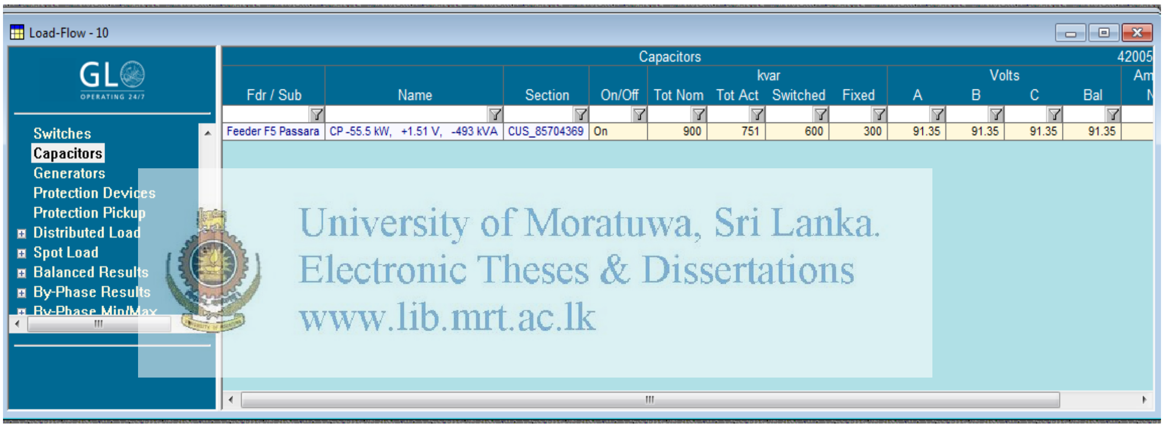
Switched capacitor operation rules					
(g = metered value; ts = trip setting; cs = close setting)					
Control	Metering	Verify	Close	No operation	Trip
kvar	g = kvar	cs>ts	g >cs	cs> g >ts	g <ts
amp	g = amps	cs>ts	g >cs	cs> g >ts	g <ts
voltage	g = volts	cs<ts	g <cs	cs< g <ts	g >ts
power factor	g = pf	cs<ts	g <cs	cs< g <ts	g >ts
Time	g = time	cs>ts	g >cs	cs> g	g >ts

4.7.2 Load flow results of switched type capacitor at different switching steps



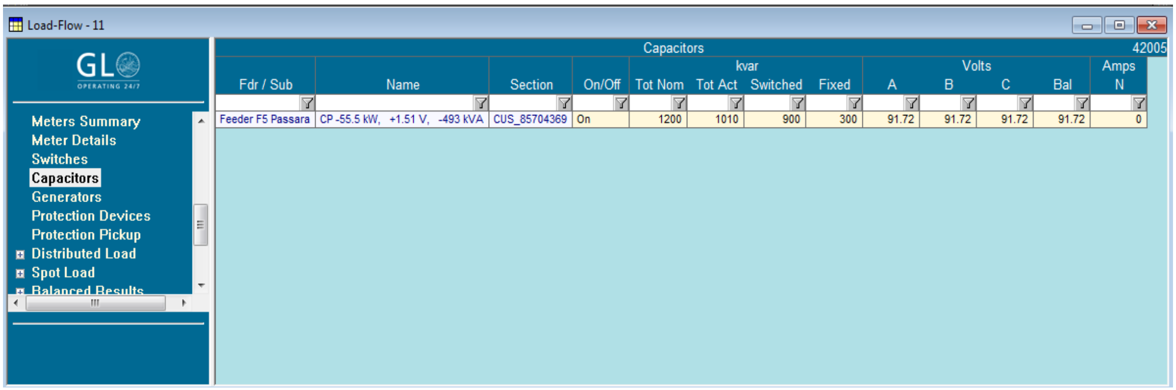
Capacitors												
				kvar				Volts				Amps
Fdr / Sub	Name	Section	On/Off	Tot Nom	Tot Act	Switched	Fixed	A	B	C	Bal	N
Feeder F5 Passara	CP -55.5 kW, +1.51 V, -493 kVA	CUS_85704369	On	600	497	300	300	90.97	90.97	90.97	90.97	0

Figure 4.44 : At first switching step



Capacitors												
				kvar				Volts				Am
Fdr / Sub	Name	Section	On/Off	Tot Nom	Tot Act	Switched	Fixed	A	B	C	Bal	N
Feeder F5 Passara	CP -55.5 kW, +1.51 V, -493 kVA	CUS_85704369	On	900	751	600	300	91.35	91.35	91.35	91.35	

Figure 4.45 : At second switching step



Capacitors												
				kvar				Volts				Amps
Fdr / Sub	Name	Section	On/Off	Tot Nom	Tot Act	Switched	Fixed	A	B	C	Bal	N
Feeder F5 Passara	CP -55.5 kW, +1.51 V, -493 kVA	CUS_85704369	On	1200	1010	900	300	91.72	91.72	91.72	91.72	0

Figure 4.46 : At third switching step

4.7.3 Economic analysis on switched capacitor installation

For investment calculation purposes it is assumed that vacuum circuit breakers are used in switching capacitor banks. Switching capacitor banks are assumed to be installed on 13m double pole arrangement. For a switching capacitor bank, the installation cost is estimated as Rs. 145,000.00 per location. Total investment cost of capacitor installation has been calculated based on above figures and the maintenance cost was assumed to be Rs. 80,000.00.

Load factor = 0.40
Peak Power loss saving = 56.00 kW
Annual Energy Saving = 196,224.00 kWh

Cost of Annual Energy Savings = 2,256,576.00 Rs
Capacity Cost Saving = 1,046,024.00 Rs
Total Cost Savings = 3,302,600.00 Rs

Cost of Capacitor bank/banks = 5,909,500.00 Rs
Cost of Installation = 100,000.00 Rs
6,009,500.00 Rs

For Ten Years Period

Operation & Maintenance Cost = 800,000.00 Rs
Total Cost for 10 years = 14,009,500.00 Rs

Cost of Energy saving at 10% discount rate for ten years = 22,405,714.76 Rs

Benefit / Cost Ratio = 1.60

Table 4.4 : comparing benefit / cost ratios on fixed & switched type capacitors

Capacitor Type	Benefit / Cost Ratio
1200 kvar Fixed type	3.46
1200 kvar Switched type	1.60

Benefit to cost ratio is highest for installing one 1200 kvar fixed type capacitor at the 24.2 km from the grid.

Chapter 5

Discussion

Ceylon Electricity Board, the power producer in Sri Lanka has to compete with the government goal of 100% electrification island wide and this was targeted to achieve through number of rural electrification projects. This analysis was focused to examine three main factors to reduce the power loss in rural areas.

1. Selection of an economical transformer capacity.
2. HT reconductoring
3. Reactive power compensation

5.1 Selection of an economical transformer capacity.

Study of 167 numbers, of transformer loading data reveals that more than 70% of transformer's loading level is less than 20kVA and transformer load growth rate was around 4.8%, for the Monaragala area while it was 6.67% for Uva province. Load forecasting for the next 20 years reveals that 50% of them were not get fully loaded to its full capacity throughout the transformer life time. Hence this is a totally waste of initial investment and has to be rectified. While transformer gets connect to the power system no load losses occurs continuously regardless of its loading level. This results the loss of energy in the system. No load losses and load losses were considered in total loss calculation in the transformer and Junge's empirical formula was used to perform the load losses. Load factor was calculated using the daily load curve for the Bibila feeding section. It was 0.395 and used in the analysis for loss calculation. Optimum capacity rating was decided by analyzing the transformer owning cost method and 63 kVA rating was selected, which resulted least TOC throughout the transformer life time.

5.2 Effect of HT Reconductoring

Reconductoring is currently practicing in power systems to reduce the losses and to upgrading the system. Besides reducing the distribution line losses, reconductoring of distribution lines usually to a higher conductor size becomes also beneficial for increasing the current-carrying capabilities of the system. By upgrading the distribution lines, electric utilities are not only able to minimize the line losses but also increase the line capacity as well. Reconductoring is done when percentage loading of the conductor exceeds economic loading levels or to replace the deteriorated or off size conductor. Studies of different conductor sizes have indicated that in many cases, it is more economical to use conductors of higher cross sectional area. These all above viable for heavy loading areas and this analysis has shown that light loading areas like Monaragala area reconductoring is not economically viable.

5.3 Effect of reactive power compensation

This study was done to analyze the effect of reactive power compensation with respect to the loss reduction for rural areas and a case study was done for the Monaragala consumer service area. The study was done applying the different possible capacitor rating combinations and the results of the case study shows that it is more feasible to install a one 1200 kvar fixed type capacitor for Passara feeder of the Badulla Grid Substation (GSS). Further it was analyzed whether to fix a switched or fixed type capacitor in the system and cost- benefit analysis reveals that installation of fixed type is more feasible.

Chapter 6

Conclusion and Recommendation

The main objective of this research was to analyze the loss reduction through energy management under following three aspects;

4. Selection of an economical transformer capacity.
5. HT Reconductoring
6. Reactive power compensation

6.1 Selection of an economical transformer capacity.

Considerable amount of energy being loosing due to under loaded transformers in the network due to the transformer no-load losses are dominant at light load conditions. This analysis reveals that more than 70% of transformers installed in rural areas were loaded less than 20% of the full load capacity at the commissioning stage. Further they were not get loaded around 50% of the full load throughout the transformer life time. This is not only the waste of investment but causes to increase the distribution losses since the no-load losses are constant and occur 24 hours a day, 365 days a year, while connects to the power system, regardless of the load.

Hence it can be concluded that the current practicing of installing 100 kVA transformer to the rural areas which are lying the load growth rate less than 4.8%
has no economic benefit but a loss.

Typically a transformer is a long-lived device that can be in service for decades. Hence transformer life-cycle cost “Total Owning Cost" to be taken into account to determine an economic transformer capacity for rural areas. With this method, it is currently possible to calculate the real economic choice between competing models. It can be concluded that 63 kVA rating is the most economical transformer capacity forMonaragala area by observing the results of the analysis. More generalizing it can be recommended for the rural areas which are having the load growth rate below the

4.8% and the initial loading level below the 30 kVA can install 63 kVA instead of the 100 kVA. This is allowed saving around 26,701.31 kWh from a single distribution sub and the cost saving would be around 753,919.71 LKR for 20 years.

6.2 Effect of HT Reconductoring

In rural distribution systems, its large number of low load consumers is distributed over a large geographical area lengthening the network and this has created more problems to the energy management. There were number of studies were done to analyze the total effect of reconductoring of distribution network and had proven that this was viable concerning the mutual benefits receiving the line upgrading parallel to the loss reduction.

The aim of this study was to analyze the effect of reconductoring in concern to the loss reduction in RE s and determine whether it is economically viable. The peak power loss reduction was only 7 kW after reconductoring around 106 km HT line length and the amount of financial benefit gained was negligible with compared to the cost incurred. The results of the case study done for the Monaragalaarea clearly shows that the HT reconductoing is not economically viable, concerning the line loss reduction in the RE network is very low.

Around 4% of the total cost to be spent on existing conductor removal and this has no value. Further this cost also higher than the cost of savings due to losses. When line rehabilitation cost accumulative to the conductor removal cost, it was very much higher than the cost of savings. Hence HT reconductoring is totally a waste investment and erection of new line is much better concerning the return in future with its upgraded capacity.

6.3 Effect of reactive power compensation

The aim of this study was to analyze the effect of reactive power compensation in concern to the loss reduction in RE s and determine whether it is economically viable.

The results of this case study for Monaragala area shows that it is more feasible to install a one 1200 kvar fixed type capacitor for Passara feeder of the Badulla Grid Substation (GSS). More generalizing the outcome of this research, it can be concluded that for rural areas, which are having the load growth rate around 40% or below than that capacitor installation is economically viable and the ratings to be determined by a cost benefit analysis.

It can be clearly seen in figure 4.36, installation of one 1200 kvar, has higher benefit to cost ratio than incorporating more than one capacitors in same size. The same results have been received in the other capacitor ratings of 1500 kvar, 900 kvar, 600 kvar and 300 kvar too. These results will emphasize that for a RE feeder, installation of one capacitor is more suitable than installing more capacitors in same size.
This analysis, it was identified that the reactive power compensation is economically viable and it is required to perform a cost – benefit analysis to determine the best suit capacitor ratings.

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