Analysis on Losses Reduction with Series Capacitor Compensation Application in Distribution Network

by

Muhammad Azizi bin Mohd Wahidi

Dissertation submitted in partial fulfillment of
the requirements for the
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(Electrical and Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

____

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PROJECT SUPERVISOR

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD AZIZI BIN MOHD WAHIDI

ABSTRACT

The capacitor compensations have been widely used all over the world in order to improve the quality of power transmission. There are lot of capacitor compensations been applied in order to achieve that objective. Two common type of capacitor compensations widely used are series capacitor and shunt capacitor. The different between those compensations is the installation configuration of capacitor in the network. The difference in configuration might produce different effect on the network. Usually shunt capacitor compensation used to improve the voltage level at the receiving area while the series capacitor compensation used to reduce power losses and increase loadability. In this study, series capacitor compensation has been focused in order to find out what is the effect if this type of compensation been installed in distribution network. The element that would be interested for this study will be the losses reduction in the particular network. Theoretically, the existence of capacitor will result the power losses reduction in the network. By comparing a network without capacitor compensation and a network with series capacitor compensation, all the result will be recorded and discussed. Next, in order to prove the theory, a program will be used to analyze the power losses. In conclusion, the effect of the existence of capacitor compensation can be determined.

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CHAPTER 1
INTRODUCTION

1.1 Background of study

The main focus of this report is to present the result of research done in two semesters on series capacitor compensation application in distribution line. Specifically, the main interest in this study is to find out the effect of losses reduction in a network with this application. By using a simulation program some result will be obtained to prove all the theories mentioned in the literature review.

In the data collection, the main element is how the existence of capacitor compensation will affect the losses reduction in distribution network. The expected result to be produced by the simulation program is the reduction of power losses. Several cases have been simulated in order to analyze every single factor affecting the losses reduction.

1.2 Problem statement

In the distribution network, the main interest is to supply the power to the customer which called load. Basically, the generation side will generate power according to the load but usually the distance between the generation and load is far. Along the distribution line, some of the power transfer will be lost and it is considered as power losses. Every loss needs to be considered because it involves money since more power needs to be generated.

The length of distribution line will influence the losses since the impedance will increase proportional to the length of the line. Theoretically, the longer the line, more power loss will be recorded.

1.3 Objective and scope of study

1.3.1 Objective

The main objective of this study is to prove that the theory on the application of capacitor compensation can affect the losses reduction is true. The study will be conducted through a software simulation. By, the end of this study the result of simulation will be used to prove the theory behind it.

1.3.2 Scope of study

The scope of the study will cover only the software simulation where different parameters will be set in order to examine the effect of capacitor compensation application.

There are several cases to be investigated in order to discuss the effect of series capacitor compensation application in the distribution network. The cases are varied in term of capacitor compensation location, compensation value, loading, load power factor, voltage level, cable size and network configuration.

Generally, the longest length of distribution cable will be 100 km. Then, for the cases of voltage level and cable size, 11 kV and 33 kV voltages level are chosen while cable with 185 mm^2 size is compared with another cable with 240 mm^2 size.

At the end of the study, brief economic studies will be carried out in order to justify whether this application is worth to be installed or not.

CHAPTER 2
LITERATURE REVIEW

2.1 Considerations for the Application of Series Capacitors to Radial Power Distribution Circuits [1]

This paper described the effect of series capacitor application in distribution network. The author compared a network without series capacitor application with a network with the application of series capacitor in order to consider the usage of this application.

The author clearly emphasized that series capacitor compensation can improve the performance of transmission as well as distribution line network. Specifically, the implementation of this compensation will improve the voltage profile, reduced voltage fluctuations, higher network capacity and reduced demand for reactive power from the power system. Actually, this type of compensation is widely used all over the world with approximately 200 distribution series capacitor in-service.

$$\begin{aligned}\Delta V &= V_S - V_R = R_L I_L \cos \varphi_R + X I_L \sin \varphi_R \\ &= R_L I_L \cos \varphi_R + (X_L - X_C)\, I_L \sin \varphi_R\end{aligned} \tag{1}$$

$$\Delta V = \frac{P_R R_L + Q_R X}{V_R} = \frac{P_R R_L + Q_R (X_L - X_C)}{V_R} \tag{2}$$

The equation (1) and (2) show the present of series capacitor compensation will reduce the total reactance. It is predicted that the voltage regulation will be improved where the voltage at the receiving end is improved since the total reactance is reduced.

$$S_R = \overline{V_R} * \overline{I_L} \qquad (3)$$

$$P_{loss} = R_L (I_L)^2 \qquad (4)$$

When the total reactance is reduced, it will cause a lower line current. So, from the equation (4) it shows that power losses are reduced due to the reduction of line current.

Figure 1 shown below is a single line network with a series capacitor application installed in the network. The cable is represented by resistance and inductance.

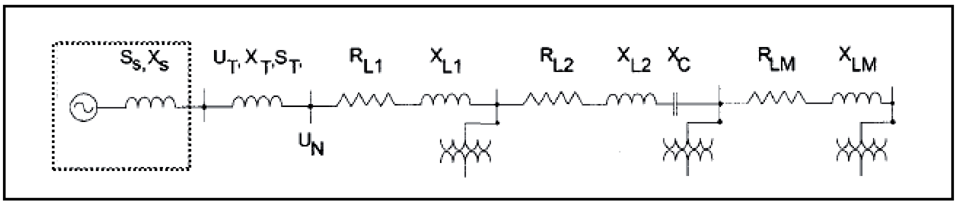

Figure 1 : Equivalent single-line diagram of a series compensated network with several taps along the line.

2.2 Application and Evaluation of a New Concept for Compact Series Compensation for Distribution Networks [2]

The author summarized that the series capacitor compensation application is suitable and cost efficient to improve voltage and loadability of the system. This application has been used since November 1990.

In the introduction part, the author stated that by reducing the reactance, the line becomes electrically shorter. The positive effects are improvement of voltage profile and reduction of losses.

Case study

A substation called Ballefors has a total peak load of 3.5 MW and the line voltage is 12 kV. But, in conjunction of increasing of demand, the load become higher which is 4.5 MW in the future. The increasing of load will cause the voltage supplied is lower than the limit set by the service provider.

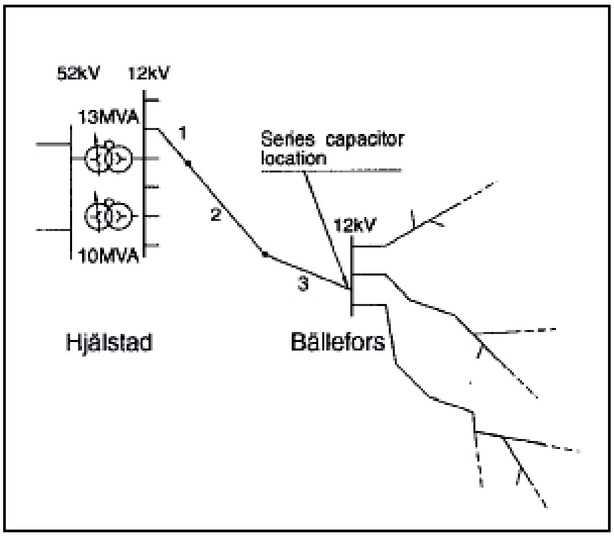

Figure 2 : Ballefors substation distribution network

Solutions

There are two possible solutions proposed by the engineers worked for the service provider. First, the problem can be solved by increase of system voltage. Instead of using 12 kV line systems, the system is upgraded to 52 kV and there are also transformers needed in order to step down the voltage at certain places. By implementing this method, the line losses would be very low and the voltage supplied is sufficient to the end user.

Next, the other solution is reactive power compensation. Since the increase of the load is not very much this method should be the better solution since the cost of installation is greatly lower compared to the first solution. Two types of compensation namely shunt and series capacitor compensations can be used to overcome this problem.

2.3 Distribution Series Capacitor Application for Improved Motor Start and Flicker Mitigation [3]

The basic theory introduced in this paper is the application of series capacitor is best explained by using the figure below.

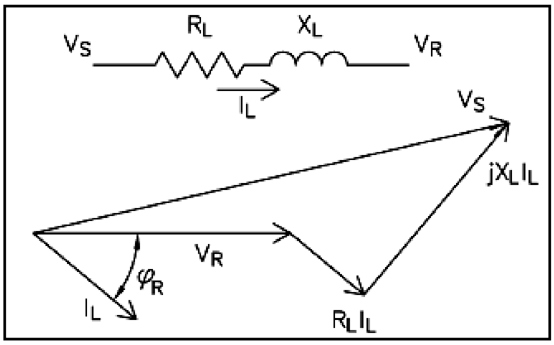

Figure 3: Distribution line segment without series capacitor and related phasor diagram

Then, when the series capacitor is installed there will be slightly different on the network and phasor diagram. The figure below is illustrated to give better explanation.

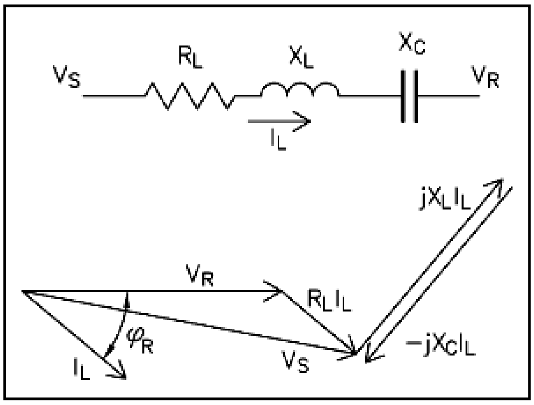

Figure 4: Distribution line segment with series capacitor and related phasor diagram

The series capacitor application will improve the voltage at the receiving end and directly it will reduce the line current. Consequently, the power losses will reduce due to the lower line current.

Next, in applying the series capacitor, the users should avoid overcompensation since it will cause the phenomenon called ferroresonance. But, it is clearly stated that higher degree of compensation will give better result in term of voltage at receiving end.

2.4 Series Compensation for a Hydro-Quebec Long Distribution Line [4]

In this paper, it is stated the existence of series capacitor compensation will cause the voltage drop per phase is decreased. This is due to the reduction of total net reactance since the capacitor will contribute the negative value of reactance as shown in **Figure 5**.

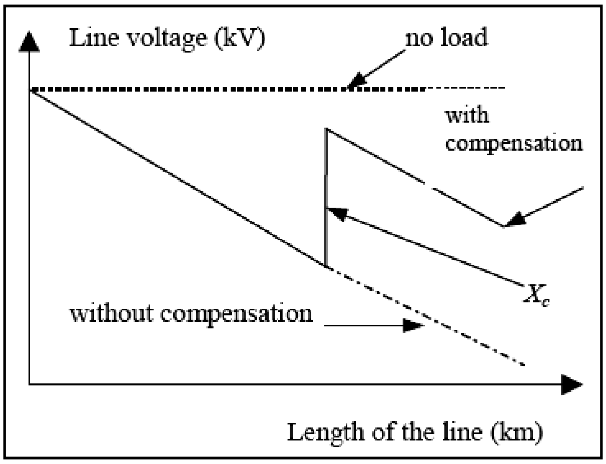

Figure 5: Voltage profile for a radial circuit with series capacitor

2.5 Reactive Compensation Techniques for Increasing Loadability of Long Primary Distribution Lines [6]

In this paper, 20 kV line voltages are used to supply remote consumer such as small village through a 150 km line.

The long distribution line will cause a huge voltage drop due to high impedance in the network. Hence, the loadability will be lower since the line current is increasing. In order to solve that problem, various compensators are applied such as voltage regulating transformers and series/shunt capacitors.

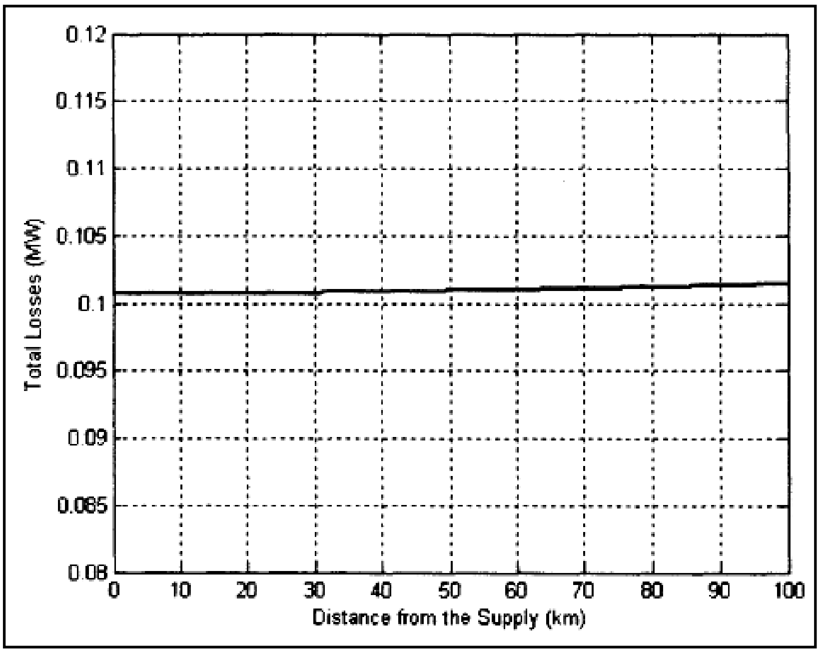

Figure 6: Line losses for different locations of the series capacitor

In series capacitor compensation, the compensation value is limited up to 100 % to avoid overcompensation situation. Besides that, it is concluded the best location for compensation in distribution network is at the receiving end while for the transmission line is at the middle. But, the system power loss is almost independent of the series capacitor location across the radial line.

2.6 Ferroresonance in a 13.8 kV Distribution Line [7]

A phenomenon where the nonlinear magnetizing reactance of a grounded and unloaded or lightly loaded transformer resonates with the distributed capacitances in lines or cables connected the transformer is called ferroresonance. When the situation occurs, the voltage is said to be distorted and produce a unstable voltage with 5 per unit high.

In distribution line, when the single-phase isolation occurs, the distribution transformer may be lightly loaded. Under this situation, an overvoltage due to ferroresonance is possible. In overhead line, the distributed capacitance alone is too small to cause ferroresonance in most cases.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

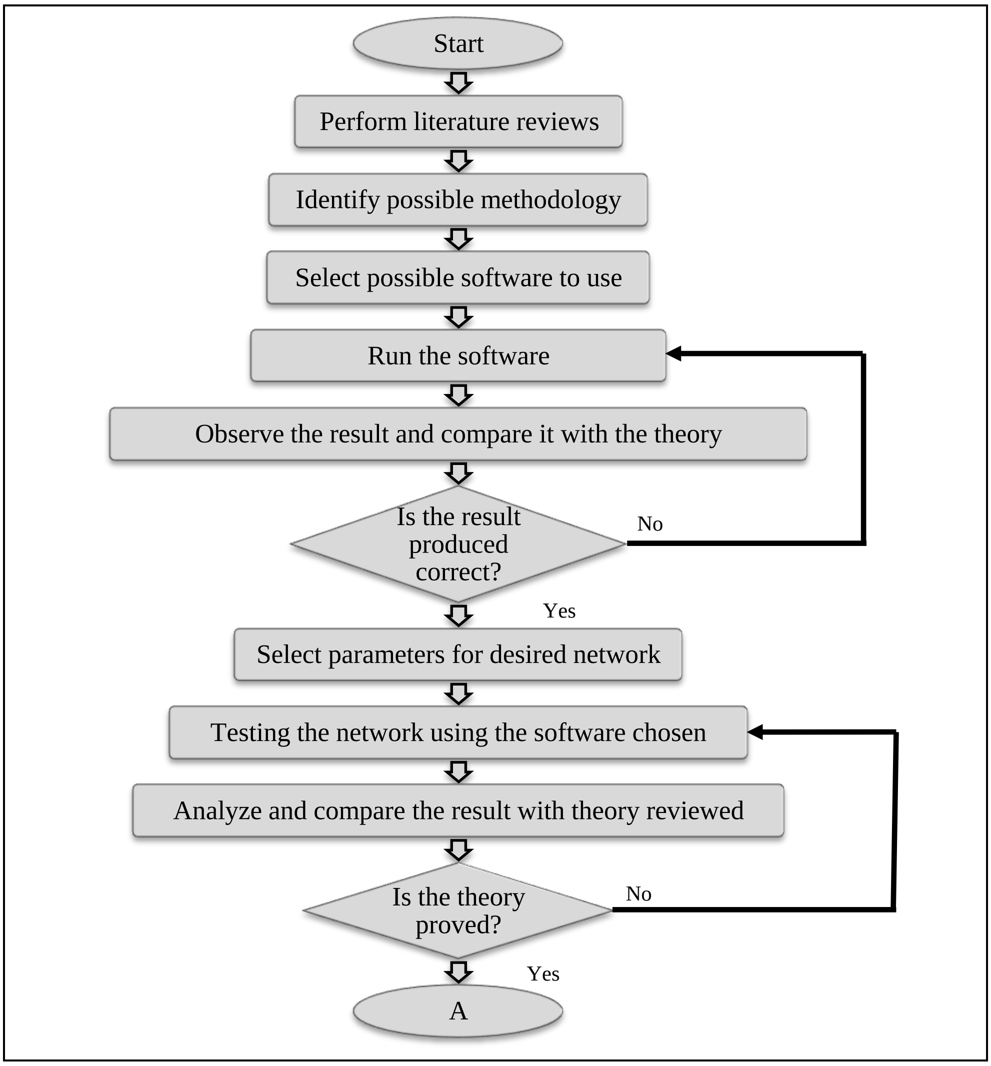

Figure 7: Flow chart for FYP I

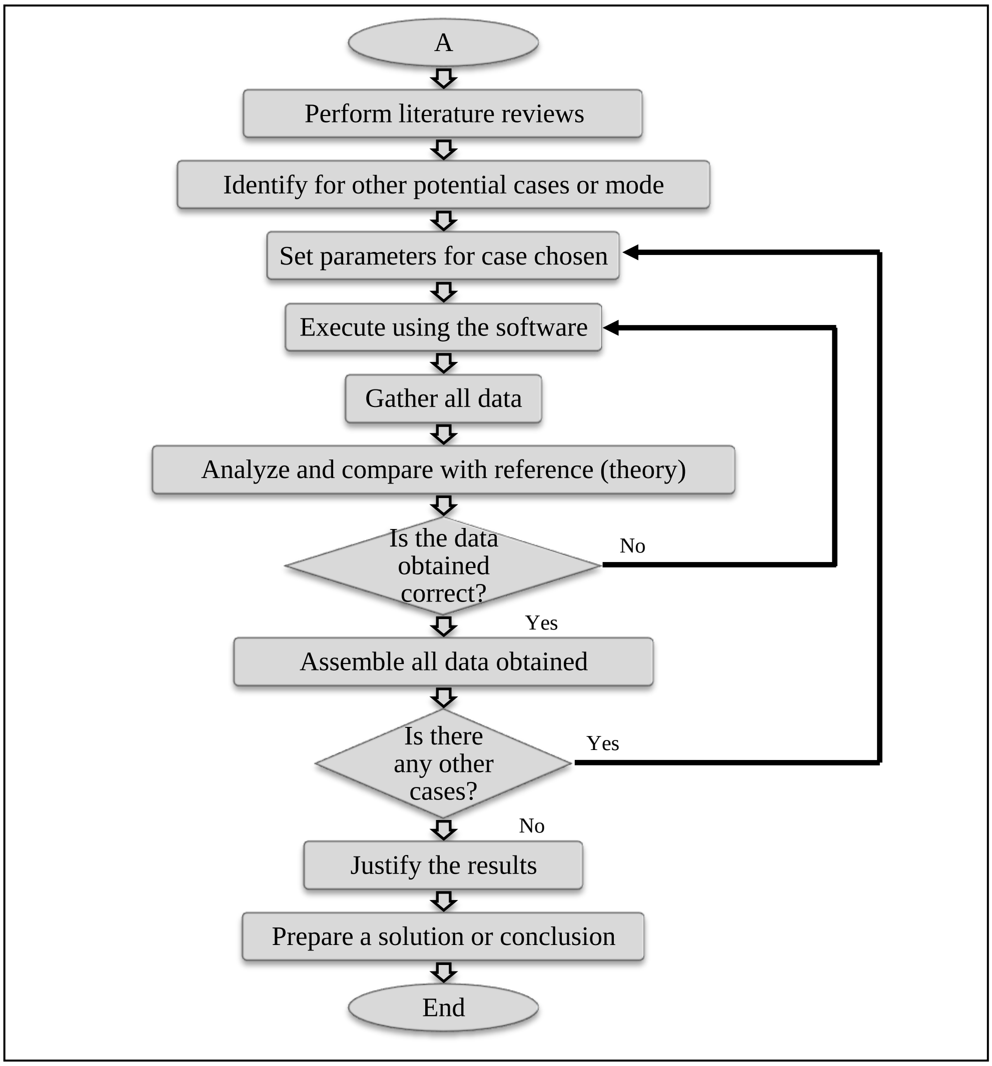

Figure 8: Flow chart for FYP II

3.2 Project Description

As mentioned in the scope of study, this study will focus on software simulation in order to produce result. The study will begin with the literature review where the related theories will be covered as reference.

Next, software code modification need to be carried out since the original MATLAB source code taken from the Power System Analysis text book by Hadi Saadat [5] is not suitable for the distribution network studied in this project. After several modifications, the source code is tested with parameters representing real distribution line. In the source code, the users are free to choose which type of calculation to be used such as Newton-Raphson method or Gauss-Seidal method. Hence, for this study, Newton Raphson method has been chosen due to the calculation accuracy and speed.

Then, all the data obtained are recorded in the table to be compiled in the result part. The power losses along the distribution line during each case are of interest. Graphs have been plotted according to give better view of the data.

Lastly, the discussion, conclusion and recommendation are derived from the data obtained.

3.3 MATLAB Software

Source code provided in one of power system text book will be used as a reference. In the source code, the user is free to choose which method to be used in the calculation of power flow.

In order to a get better result, software simulation will be used to compare the result expected as stated in the theory part. MATLAB will be used as a simulation program for this study. By using simulation program, a network can be created with multiple parameter depending on the user interest.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Basic parameters related

Firstly, all the parameters are set before any simulation start. The parameters are voltage, load, cable length, cable size and so on. For the calculation, per-unit system will be used to make it less complex. Besides that, the cable specification used is based on the real value obtained from the cable manufacturer.

Parameters involve,

Standard specification for the distribution cable for 240 mm^2 ,

$R = 0.161$ *ohm/km* ; $X = 0.0924$ *ohm/km* ; $B = 0.35$ *uF/km*

and 185 mm^2 size [8];

$R = 0.211$ *ohm/km* ; $X = 0.0962$ *ohm/km* ; $B = 0.31$ *uF/km*

Base value used,

$S_{base} = 1$ *MVA* ; $V_{base} = 11$ *kV* ; $Z_{base} = 121$ *ohm*

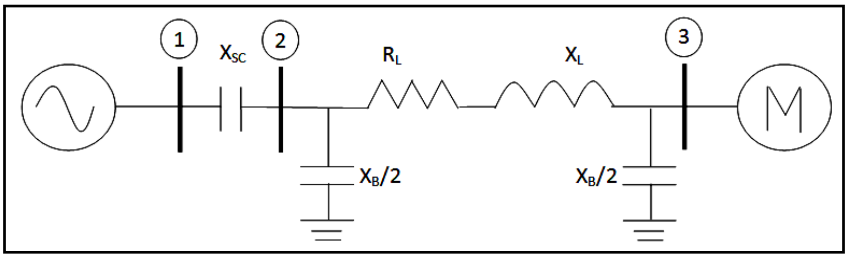

Figure 9: Circuit diagram for the series capacitor compensation at 0 % position value of 100 km long distribution line

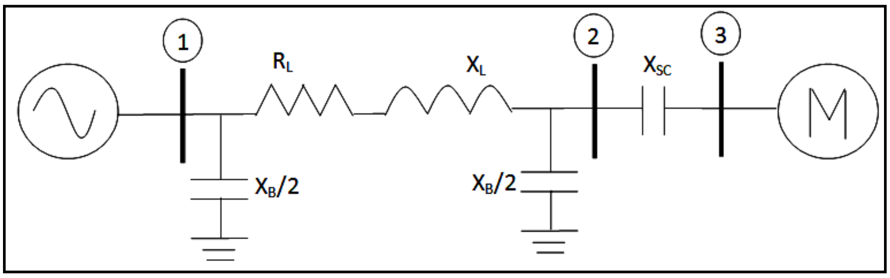

Figure 10: Circuit diagram for the series capacitor compensation at 100 % position value of 100 km long distribution line

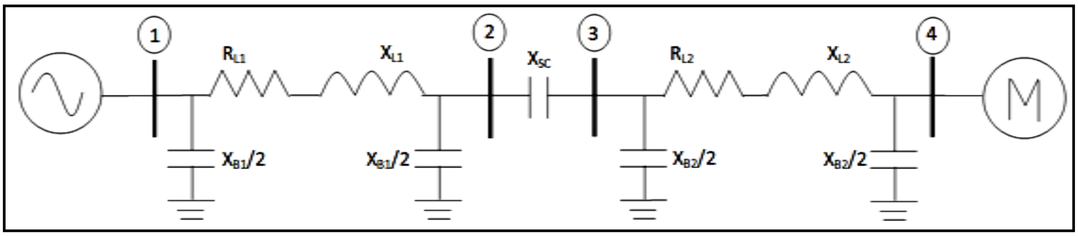

Figure 11: Circuit diagram for the series capacitor compensation at others position along 100 km long distribution line

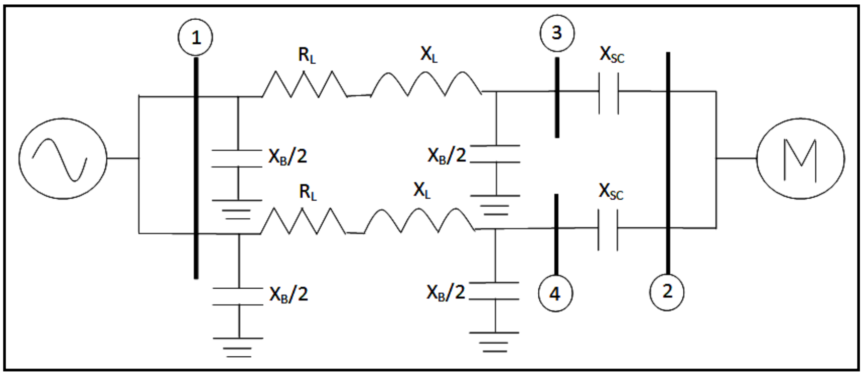

Figure 12: Circuit diagram for the series capacitor compensation at 100 % position value of 100 km long distribution line in parallel network configuration

Other parameters,

Rated load = 1 MVA ; Power factor = 0.9 lagging

$P_{motor} = 0.9\ MW$; $Q_{motor} = 0.436\ MVAR$

Value of compensation (%) = X_{SC} / X_L x 100 %

Simulations have been carried out to analyze the power losses from the network discussed. Newton-Raphson method is chosen in power flow analysis calculation. The source code information can be referred to appendices.

4.2 Losses Analysis

4.2.1 Case 1: Different in series capacitor compensation location

For the first case, a single line network with 11 kV voltage level and 100 km long cable is used. The capacitor compensation is fixed at 100 % value. Then, the location of series capacitor compensation is varied from 0 % (sending end) distance up to 100 % (receiving end) distance. The networks constructed are based on **Figure 9**, **Figure 10** and **Figure 11** configuration.

The power losses and voltage profile are observed and recorded for every loacation. **Table 1** and **Table 2** below show the simulated results using Newton-Raphson method in MATLAB program.

Table 1: Power losses and voltage magnitude for different series compensation location and 100 % compensation value

Compensation Position	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude at Load, pu
0%	0.14	0.00	0.976
10%	0.14	0.00	0.976
20%	0.14	0.00	0.976
30%	0.14	0.00	0.976
40%	0.14	0.00	0.976
50%	0.14	0.00	0.976
60%	0.14	0.00	0.976
70%	0.14	0.00	0.976
80%	0.14	0.00	0.976
90%	0.14	0.00	0.976
100%	0.14	0.00	0.976

Table 2: Power losses and voltage magnitude for different series compensation location and 50 % compensation value

Compensation Position	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude at Load, pu
0%	0.145	0.42	0.957
10%	0.145	0.42	0.957
20%	0.145	0.42	0.957
30%	0.145	0.42	0.957
40%	0.145	0.42	0.957
50%	0.145	0.42	0.957
60%	0.145	0.42	0.957
70%	0.145	0.42	0.957
80%	0.145	0.42	0.957
90%	0.145	0.42	0.957
100%	0.145	0.42	0.957

From the tables above, it is clearly seen that the location of capacitor compensation will not affect the power losses. The data are plotted in **Figure 13.**

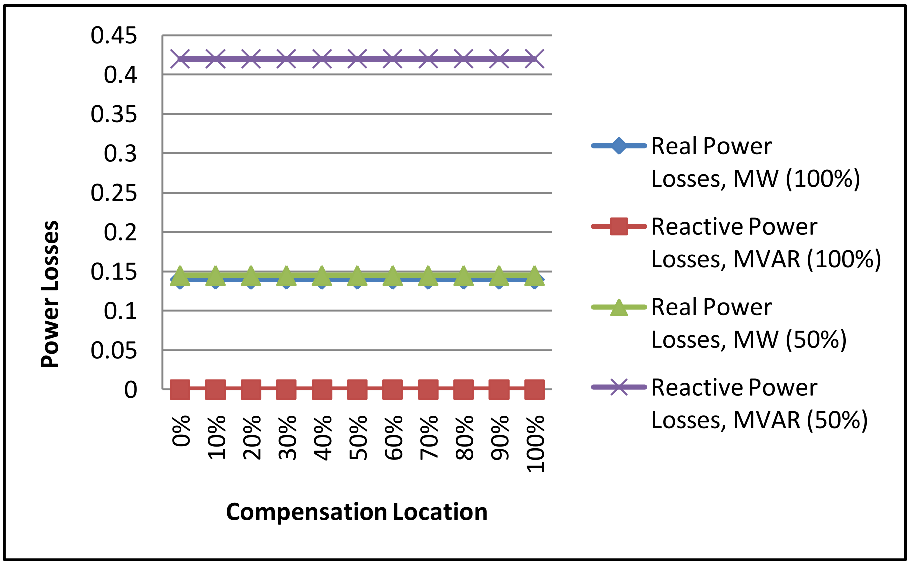

Figure 13: Graph of power losses for the network with capacitor compensation value of 100 % and 50 %

4.2.2 Case 2: Different in capacitor compensation value

In this case, a radial network with a fix location of series capacitor compensation and different compensation value is tested. Therefore, for this case it is decided to locate the series capacitor compensation at the 100 % location (receiving end). Then, the series capacitor compensation value will be varied from 0 % to 100 %. Basically, for the 0 % of compensation value means a network without any capacitor compensation.

Similar with the previous case, all the parameters will be the same except for the compensation value. **Table 3** shows the simulated results at 10 % interval of compensation value.

Table 3: Power losses and voltage magnitude for the different in compensation value and compensation location of 100 %

Compensation Value	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude at Load, pu
0%	0.152	0.087	0.937
10%	0.150	0.078	0.941
20%	0.149	0.068	0.945
30%	0.148	0.059	0.949
40%	0.146	0.050	0.953
50%	0.145	0.042	0.957
60%	0.144	0.033	0.961
70%	0.143	0.024	0.965
80%	0.142	0.016	0.969
90%	0.141	0.008	0.972
100%	0.140	0.000	0.976

Based on data recorded in **Table 3**, when the value of compensation is increasing, the power losses are reducing. So, the higher value of compensation will cause the reduction of power losses. Besides that, to compare a network without compensation with a network with series capacitor compensation installed, the real power losses reduction is almost 8 %.

For the reactive power losses, at 100 % compensation value the result is zero. This is because of at the first place the max value of compensation is assume to be equal with line reactance. Hence, at 100 % compensation value the reactive power will cancel each other and give zero value as the reactive power losses. **Figure 14** shows the trend of power losses with regard to different compensation value.

The simulated data are in the pattern of decreasing for power losses. Basically, when the series capacitor is installed in a network, the total reactance of the network will be reduced and it causes the line current to be lower. The lower of line current will cause the power losses to be reduced.

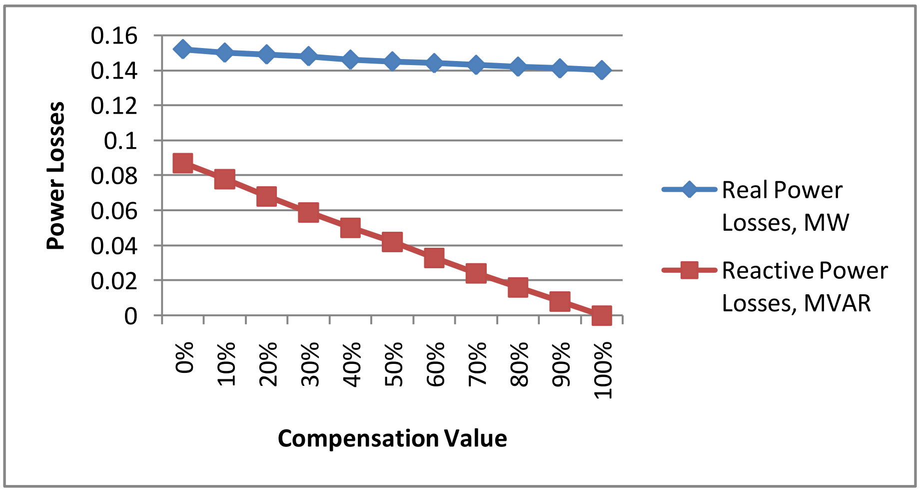

Figure 14: Graph of power losses for the network with different capacitor compensation and at location of 100 km

4.2.3 Case 3: Different in loading

By varying the loading, the power losses are analyzed. The location and value of series capacitor compensation is set to be unchanged in this case. But, the loading is varied from a range of 50 % to 170 % where the 100 % load is set to be 1 MVA. On the other hand, a network without any compensation is also analyzed in order to see the difference between those two network.

Table 4 and **Table 5** show the simulated data for a compensated network and uncompensated network respectively. From the data in the table, power losses and voltage magnitude are changing when the loading is varied.

Table 4: Power losses and voltage magnitude for the different loading when compensation location and value are 100 %

Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude at Load, pu
50%	0.031	0.00	1.042
70%	0.063	0.00	1.017
100%	0.140	0.00	0.976
120%	0.214	0.00	0.946
150%	0.374	0.00	0.895
170%	0.525	0.00	0.856

Figure 15 and **Figure 16** are plotted based on simulated data recorded in **Table 4**.

Table 5: Power losses and voltage magnitude for the different loading where compensation value of 0 % (uncompensated)

Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude at Load, pu
50%	0.032	0.018	1.025
70%	0.066	0.038	0.992
100%	0.152	0.087	0.937
120%	0.239	0.137	0.895
150%	0.446	0.256	0.820
170%	0.674	0.387	0.755

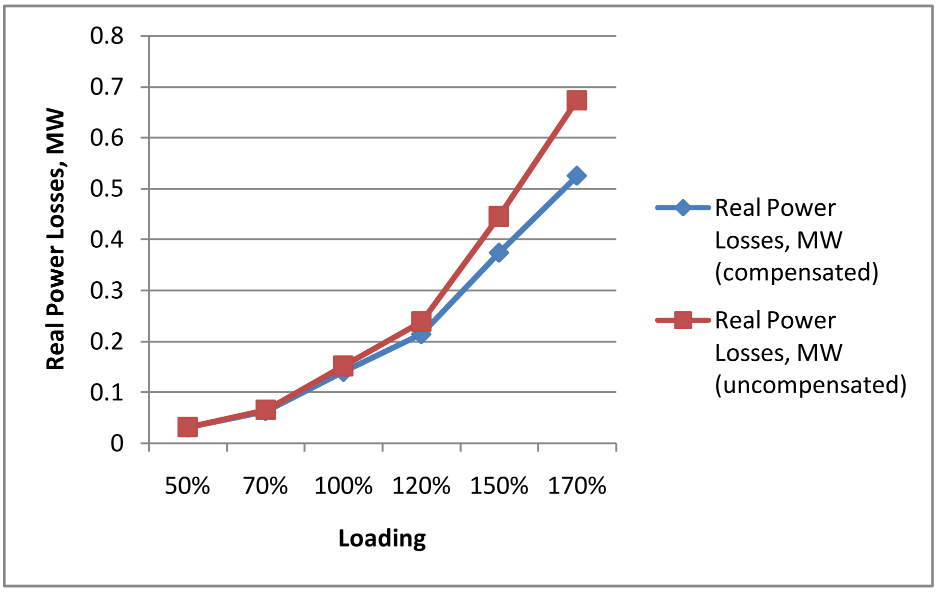

Figure 15: Graph of real power losses to compare a network with capacitor compensation and uncompensated network under different loading

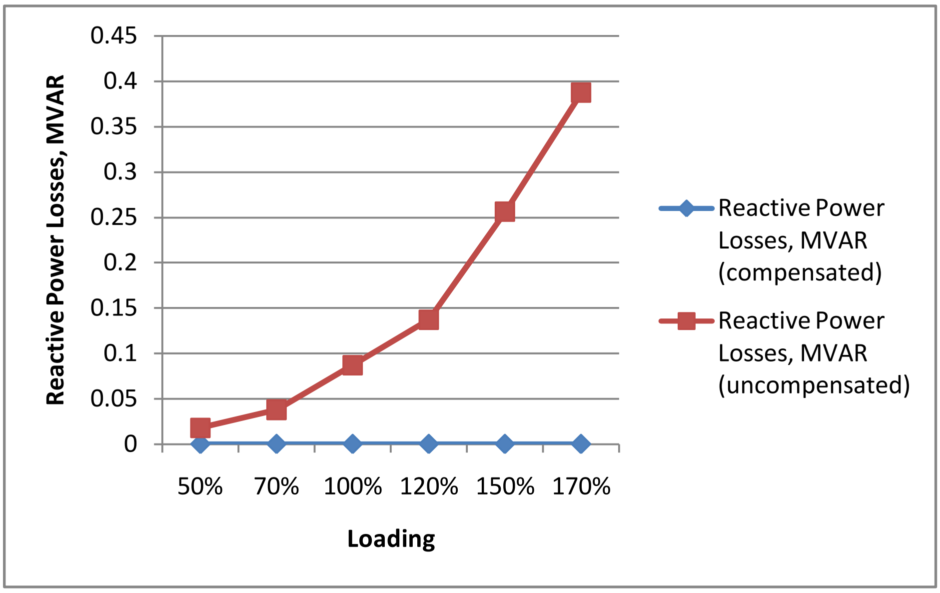

Figure 16: Graph of reactive power losses to compare a network with capacitor compensation and uncompensated network under different loading

Obviously, when the loading is increased power losses will be increased as well. But, to compare a network with compensation and a network without any compensation, the power losses are higher in the latter. In comparison, **Table 6** below shows the difference between a network without any compensation and a network with series capacitor compensation installed.

Table 6: Power losses and voltage magnitude different between a network without compensation and a network with series capacitor compensation under different loading

Loading	MW losses difference,%	MVAR losses difference,%	Voltage Magnitude Difference, %
50%	3.13	100.00	1.66
70%	4.55	100.00	2.52
100%	7.89	100.00	4.16
120%	10.46	100.00	5.70
150%	16.14	100.00	9.15
170%	22.11	100.00	13.38

Data in **Table 6** shows that the higher loading value will give better power losses reduction. But, for the value of loading at 200 % and above, the simulation did not converging. This is because of the source is now incapable to supply the load.

To explain on the reactive power (MVAR) losses difference, the values are shown 100 % since the compensated network tested for a compensation value of 100 % that resulting zero reactive power losses. The graph below plots the simulated data in **Table 6**.

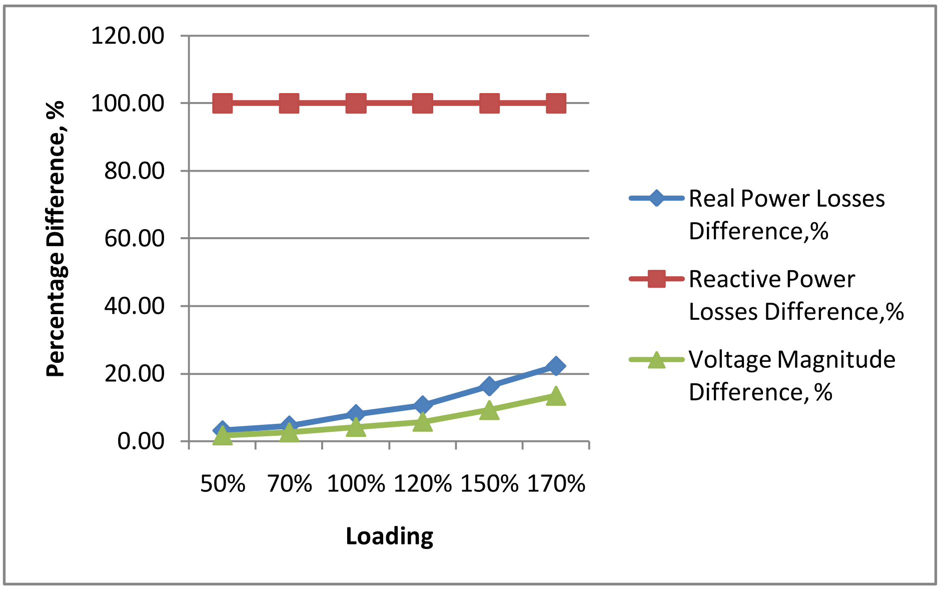

Figure 17: Graph of percentage difference to compare a network with capacitor compensation and uncompensated network under different loading

4.2.4 Case 4: Different in load power factor

Different in load power factor illustrated by changing the value of load power factor while the other parameters are remain the same such as the line length, loading, voltage level and so on. The previous cases, the load power factor is set to be 0.9 power factor lagging while for this case the value of power factor is changing from lagging 0.7 to 1.0 power factor. **Table 7** below shows the simulated data after simulations are done.

Table 7: Power losses and voltage magnitude for different power factor between a network without compensation and a network with series capacitor compensation

1 MVA Load			
Power Factor	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
0.70	0.132	0.00	1.003
0.75	0.141	0.00	0.996
0.80	0.136	0.00	0.989
0.85	0.138	0.00	0.983
0.90	0.140	0.00	0.976
0.95	0.142	0.00	0.969
1.00	0.144	0.00	0.962
1 MVA Load with no compensation			
Power Factor	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
0.70	0.150	0.086	0.942
0.75	0.160	0.092	0.936
0.80	0.151	0.087	0.937
0.85	0.152	0.087	0.936
0.90	0.152	0.087	0.937
0.95	0.151	0.086	0.940
1.00	0.145	0.083	0.958

In order to analyze the result in **Table 7**, two graphs are plotted in **Figure 18** and **Figure 19**.

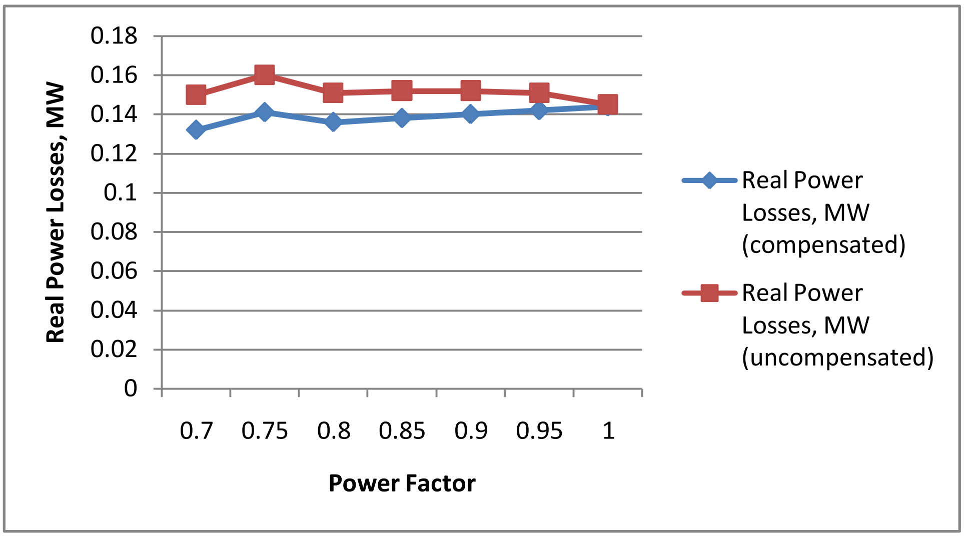

Figure 18: Graph of real power losses to compare a network with capacitor compensation and uncompensated network under different power factor

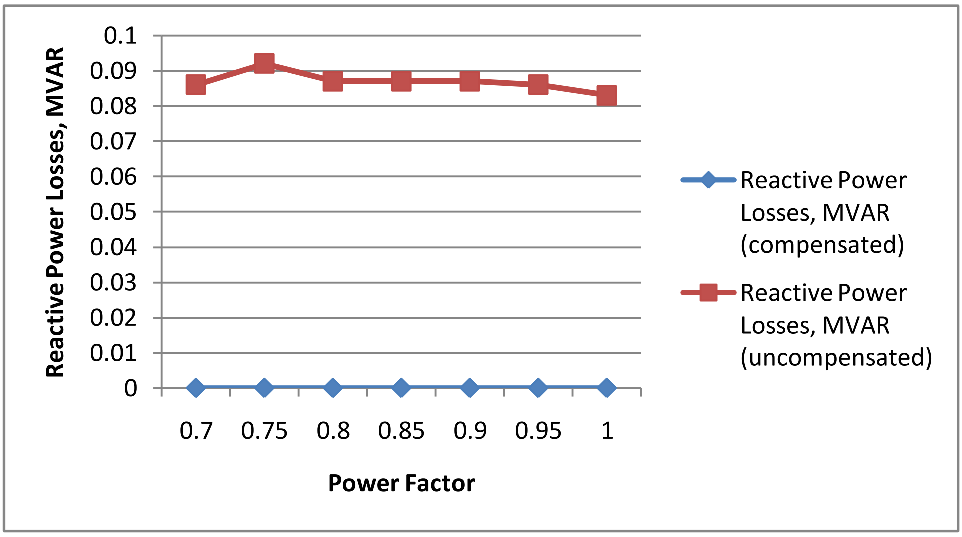

Figure 19: Graph of reactive power losses to compare a network with capacitor compensation and uncompensated network under different power factor

From the graphs plotted, it is obvious that a network with series capacitor compensation will reduce the power losses. The power losses are better in a compensated network for all power factor values except for 1.0 power factor where the power losses are the same. This is due to not reactive load during unity power factor.

Table 8 below shows the difference in percentage of power losses and voltage magnitude in those two networks.

Table 8: Power losses and voltage magnitude different between a network without compensation and a network with series capacitor compensation under different power factor

Power Factor	MW losses difference,%	MVAR losses difference,%	Voltage Magnitude Difference, %
0.70	12.00	100.00	6.48
0.75	11.88	100.00	6.41
0.80	9.93	100.00	5.55
0.85	9.21	100.00	5.02
0.90	7.89	100.00	4.16
0.95	5.96	100.00	3.09
1.00	0.69	100.00	0.42

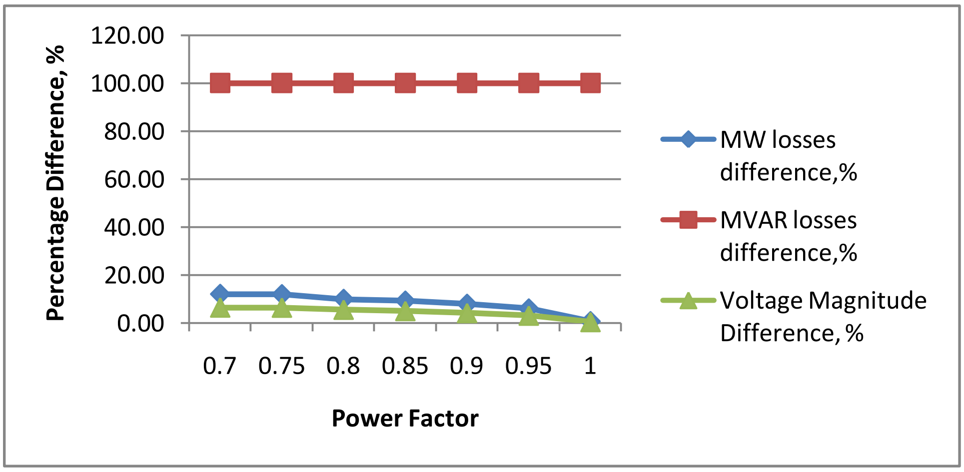

Figure 20: Graph of percentage difference to compare a network with capacitor compensation and uncompensated network under different power factor

4.2.5 Case 5: Overcompensation

Overcompensation happens where the value of series capacitor compensation is very high and the data calculated is no longer significant. Theoretically, the higher value of compensation will give better power losses reduction but it is valid up to some value of compensation only. After that, the network probably will expose to a phenomenon called ferroresonance which the voltage magnitude at the load is 4 or 5 times higher than the normal value. The procedures in Case 2 are repeated but the value of compensation is extended instead of 100 %. **Table 9** shows the simulated data obtained.

Table 9: Power losses and voltage magnitude for a network with series capacitor compensation at 100 km position under overcompensation condition

Compensation Value	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
100%	0.140	0.000	0.976
200%	0.131	-0.075	1.007
300%	0.125	-0.144	1.032
400%	0.120	-0.207	1.052
500%	0.117	-0.268	1.067
600%	0.114	-0.328	1.078
700%	0.113	-0.390	1.085
800%	0.113	-0.453	1.086
900%	0.114	-0.523	1.081

From the result shown in **Table 9**, when the value of compensation is increased, the power losses are reduced. Therefore, this is the advantage of installing this application in a distribution network which is to reduce power losses. But, for the value of compensation 600 % and higher, the power losses reduction is slowing down. For the value after 800 %, the real power losses are increased back to 0.114 MW. **Figure 21** below shows the pattern of changes for this case.

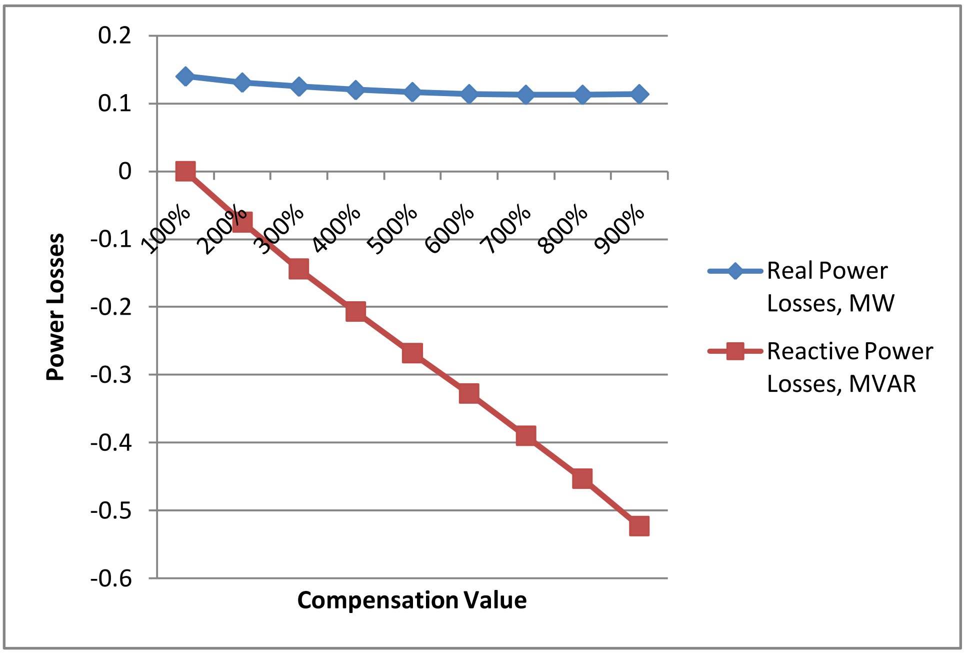

Figure 21: Graph of power losses for the different value of compensation

If the user wishes to maximize their reduction of power losses, overcompensation test need to be considered to avoid a problem such as ferroresonance. For this case, the compensation value suggested is not more than 800 % since the value more than that will result the power losses to be higher.

Other than that, from the value of voltage magnitude recorded, there is no sign of ferroresonance since the value is not 4 or 5 times higher than usual. But, it is assume that after the value of 800 %, the network might experience some problem such as ferroresonance as discussed in literature review part.

4.2.6 Case 6: Network with 33 kV level

In this case, a network with a voltage level of 33 kV will be tested to examine whether the series capacitor compensation can affected the power losses in the network. Previously, the voltage level used is 11 kV and the others parameters are the same as stated earlier.

For this case, the main procedure is to compare a network with capacitor compensation and a network without any compensation installed. The other parameters are the same such as loading, power factor and so on. Then, a few potential factors that can affect the power losses are analyze such as the location of the compensation installed, value of compensation and variation of loading.

After several simulations have been carried out, tables below show the simulated data of the power losses and voltage magnitude at the load.

Table 10: Power losses and voltage magnitude for a 33 kV network with series capacitor compensation value of 100 %

Compensation Location	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
0%	0.015	0.00	0.986
10%	0.015	0.00	0.986
20%	0.015	0.00	0.986
30%	0.015	0.00	0.986
40%	0.015	0.00	0.986
50%	0.015	0.00	0.986
60%	0.015	0.00	0.986
70%	0.015	0.00	0.986
80%	0.015	0.00	0.986
90%	0.015	0.00	0.986
100%	0.015	0.00	0.986

Table 11: Power losses and voltage magnitude for a 33 kV network with series capacitor compensation location at 100 km

Compensation Value	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
0%	0.015	0.010	0.982
10%	0.015	0.009	0.983
20%	0.015	0.008	0.983
30%	0.015	0.007	0.983
40%	0.015	0.006	0.984
50%	0.015	0.005	0.984
60%	0.015	0.004	0.985
70%	0.015	0.003	0.985
80%	0.015	0.002	0.986
90%	0.015	0.001	0.986
100%	0.015	0.000	0.986

Based on **Table 10** and **Table 11**, there are no changes on the power losses for the range 0 % to 100 %. In other word, the change in compensation location and value will not affect the power losses for the range of 0 % to 100 %.

The value of loading is change from 100 % up to 1200 % to observe if there are any changes in power losses. **Table 12** shows the simulated data after simulations are done. From the table, in can be seen that the power losses reduction only occur for the loading value greater than 170 %. Besides that, a few graphs have been plotted to show the pattern of changes.

Table 12: Power losses and voltage magnitude for a 33 kV network with series capacitor compensation location at 100 km and 100 % compensation value

1 MVA Load			
Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
100%	0.015	0.00	0.986
120%	0.022	0.00	0.984
150%	0.035	0.00	0.980
170%	0.045	0.00	0.977
200%	0.063	0.00	0.973
300%	0.145	0.00	0.958
400%	0.266	0.00	0.943
500%	0.429	0.00	0.928
600%	0.640	0.00	0.912
700%	0.905	0.00	0.895
800%	1.230	0.00	0.877
900%	1.626	0.00	0.858
1000%	2.103	0.00	0.838
1200%	3.374	0.00	0.794
1 MVA Load with no compensation			
Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
100%	0.015	0.010	0.982
120%	0.022	0.014	0.979
150%	0.035	0.023	0.973
170%	0.045	0.030	0.969
200%	0.064	0.042	0.964
300%	0.149	0.097	0.944
400%	0.277	0.181	0.924
500%	0.453	0.296	0.903
600%	0.686	0.448	0.881
700%	0.987	0.643	0.857
800%	1.369	0.893	0.831
900%	1.854	1.209	0.804
1000%	2.473	1.613	0.773
1200%	4.362	2.845	0.699

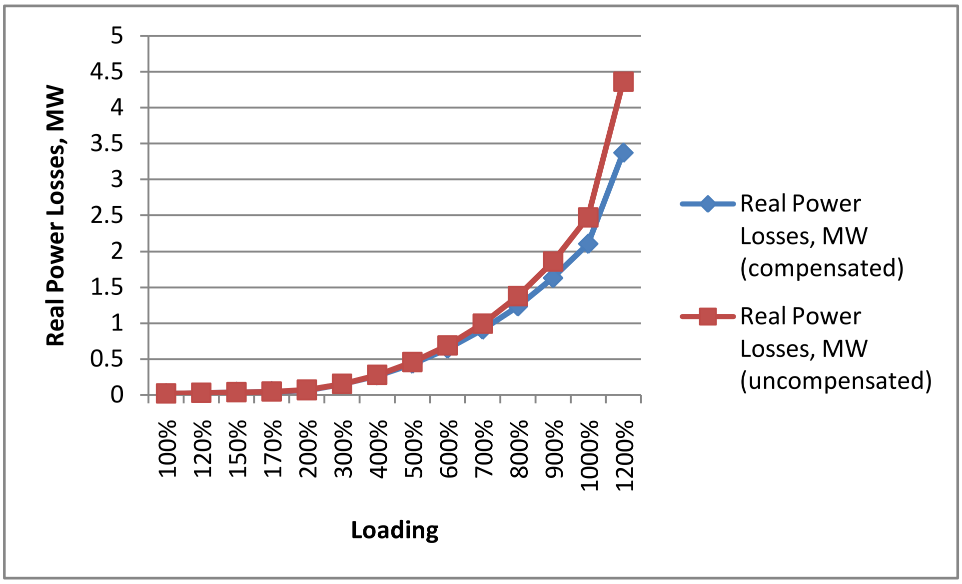

Figure 22: Graph of real power losses for a 33 kV network with and without compensation installed

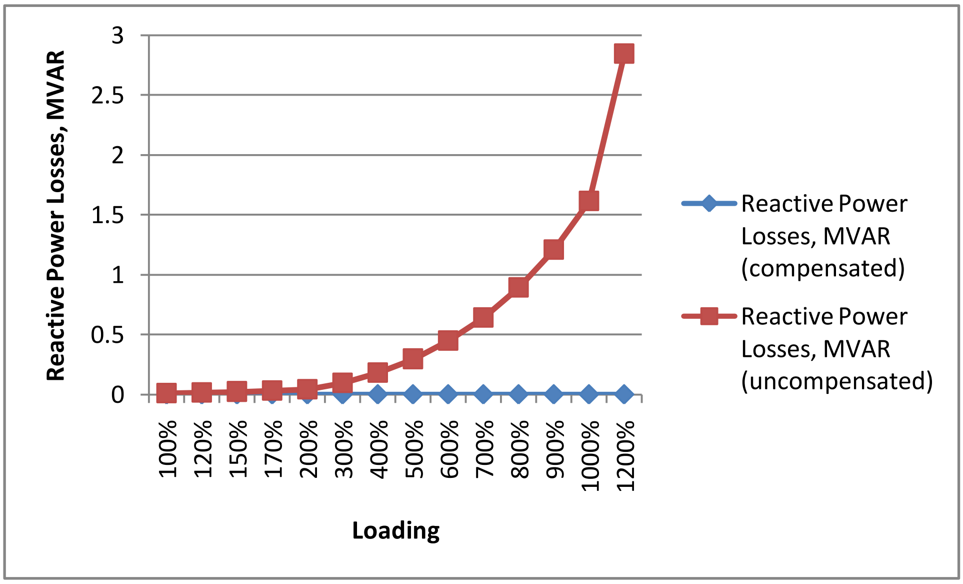

Figure 23: Graph of reactive power losses for a 33 kV network with and without compensation installed

For the changes in the network with and without compensation installed, a table is provided to show the difference in percentage.

Table 13: Power losses and voltage magnitude difference between a 33 kV network with and without series capacitor compensation installed

Loading	MW losses difference,%	MVAR losses difference,%	Voltage Magnitude Difference, %
100%	0.00	100.00	0.41
200%	1.56	100.00	1.56
300%	2.68	100.00	2.68
400%	3.97	100.00	3.97
500%	5.30	100.00	5.30
600%	6.71	100.00	6.71
700%	8.31	100.00	8.31
800%	10.15	100.00	10.15
900%	12.30	100.00	12.30
1000%	14.96	100.00	14.96
1200%	22.65	100.00	22.65

4.2.7 *Case 7: Network with 185 mm^2 size of cable*

By using the different size of cable, a network with and without series capacitor compensation are analyzed. Previously, a cable with 240 mm^2 size is used but for this time the cable size is reduced to 185 mm^2. Basically, the smaller size of cable will cause the impedance of the cable to be increased.

For this case, only loading and overcompensation conditions have been discussed since compensation location will not affect power losses. Meaning that at every location the power losses will be the same.

The table below shows the simulated data for different loading. Theoretically, a network with series capacitor compensation will have a losses reduction compared with a network without any compensation installed.

Table 14: Power losses and voltage magnitude for networks with 185 mm^2 cable size and 100 km long

1 MVA Load			
Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
50%	0.042	0.00	1.023
70%	0.088	0.00	0.987
100%	0.203	0.00	0.928
120%	0.323	0.00	0.881
150%	0.622	0.00	0.794
1 MVA Load with no compensation			
Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
50%	0.043	0.020	1.005
70%	0.093	0.042	0.96
100%	0.224	0.102	0.883
120%	0.374	0.170	0.819
150%	0.867	0.395	0.673

Based on the data, a network with a compensation installed is obviously better in term of power losses compared with a network without any compensation. Graphs are plotted to show the pattern of changes while a table showing the differences between those two networks is provided as well.

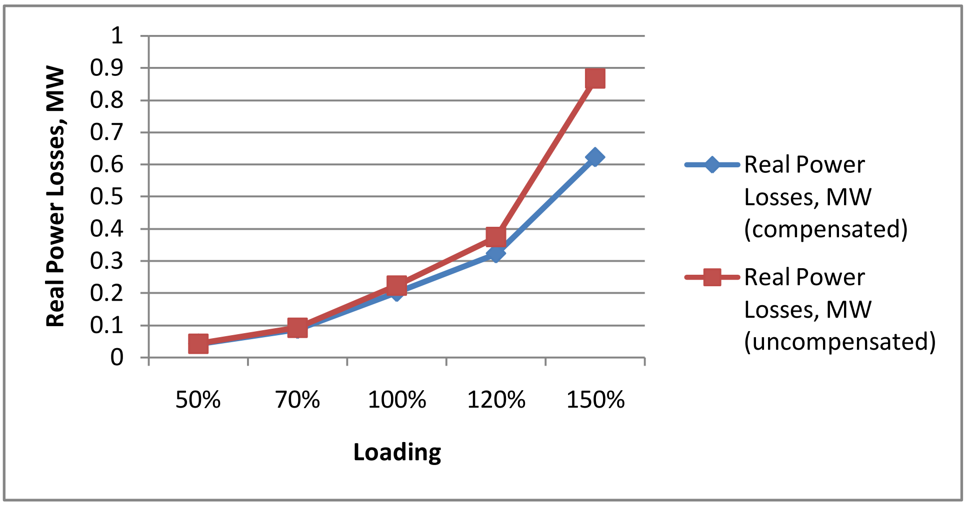

Figure 24: Graph of real power losses for a network with and without compensation installed with 185 mm^2 cable size

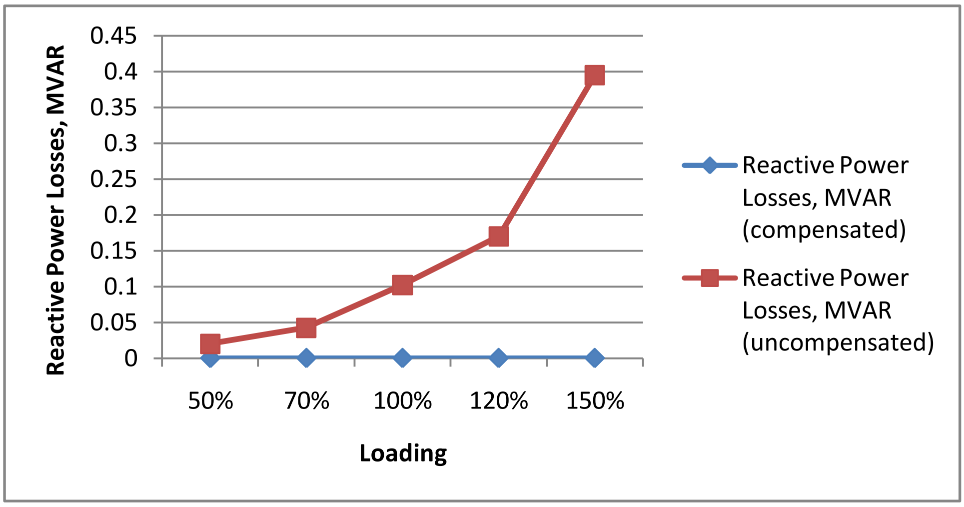

Figure 25: Graph of reactive power losses for a network with and without compensation installed with 185 mm^2 cable size

Table 15: Power losses and voltage magnitude difference between a network with and without series capacitor compensation installed with 185 mm^2 cable size

Loading	MW losses difference,%	MVAR losses difference,%	Voltage Magnitude Difference, %
50%	2.33	100.00	1.79
70%	5.38	100.00	2.81
100%	9.38	100.00	5.10
120%	13.64	100.00	7.57
150%	28.26	100.00	17.98

From the data show in **Table 15**, the real power losses differences are better in the higher loading. Similarly the voltage magnitude difference is almost 20 %.

The overcompensation is being simulated to observe the effect on power losses if the value of compensation is changed. The table below shows the simulated data obtained from the simulations.

Table 16: Power losses and voltage magnitude for a network with series capacitor compensation at 100 km position and 185 mm^2 cable size

Compensation Value	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
100%	0.203	0.000	0.928
200%	0.188	-0.086	0.962
300%	0.178	-0.163	0.989
400%	0.171	-0.234	1.009
500%	0.166	-0.304	1.024
600%	0.164	-0.373	1.032

The value of compensation allowed is not more than 600 %. Graphs have been plotted to show the pattern of changes as shown in **Table 16**.

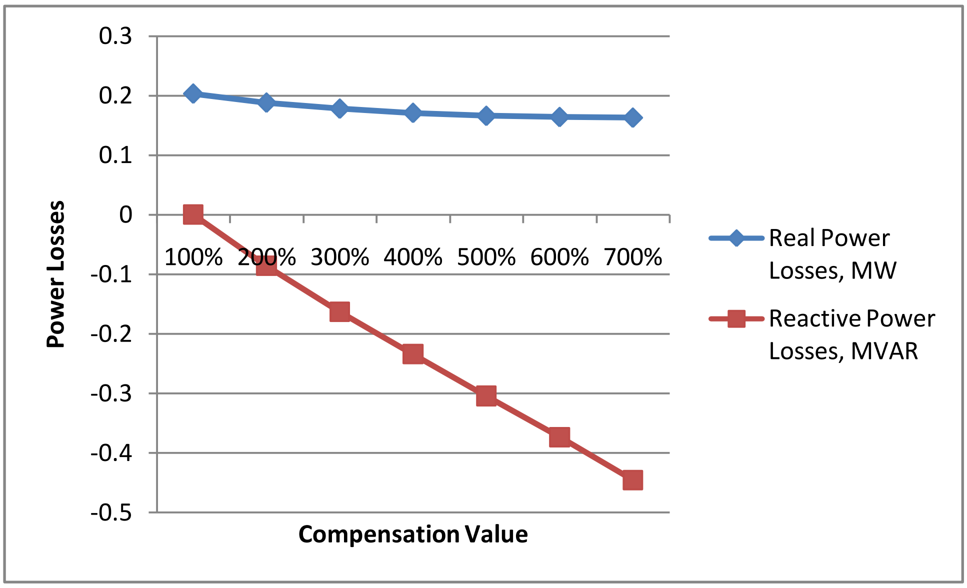

Figure 26: Graph of power losses for the difference value of compensation in a network with 185 mm^2 cable size

4.2.8 Case 8: Parallel configuration network

In previous cases, the configuration used is called radial or spur system. It is of interest to investigate what happen when the network is cable. This network will have 11 kV source, 100 km long cables and a 1 MVA load at the end of the cable.

The position of compensation location will not affect the losses reduction. Only the value of series capacitor compensation will affect the losses reduction. For this case, there will be two series capacitor compensation at each cable. So, a loading test and overcompensation simulation is done to analyze the losses reduction.

Table 17 below shows the simulated data under different loading where a network with series capacitor compensation is compared with a network without any compensation installed. Then, the value of loading is varied from 50 % to 300 %.

From the data in **Table 17**, the network with compensation installed will give better losses reduction. To show the pattern of changes, **Figure 27** and **Figure 28** are drawn.

Then, **Table 18** shows the differences in losses reduction and voltage magnitude in percentage. Obviously, the higher value of loading will give higher percentage difference.

Table 17: Power losses and voltage magnitude for networks with parallel configuration and 100 % compensation value

1 MVA Load			
Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
50%	0.014	0.00	1.072
70%	0.029	0.00	1.060
100%	0.061	0.00	1.042
120%	0.090	0.00	1.030
150%	0.147	0.00	1.010
170%	0.194	0.00	0.997
200%	0.280	0.00	0.976
300%	0.748	0.00	0.895
1 MVA Load with no compensation			
Loading	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
50%	0.015	0.008	1.064
70%	0.030	0.017	1.049
100%	0.063	0.036	1.025
120%	0.094	0.054	1.009
150%	0.155	0.089	0.983
170%	0.206	0.118	0.965
200%	0.303	0.174	0.937
300%	0.891	0.511	0.820

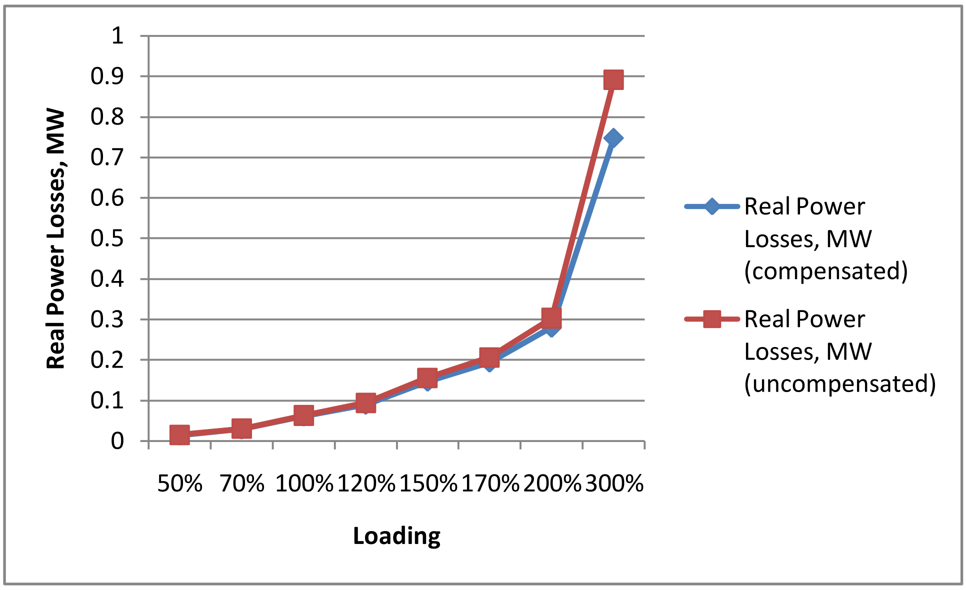

Figure 27: Graph of real power losses for a network with and without compensation installed with parallel configuration

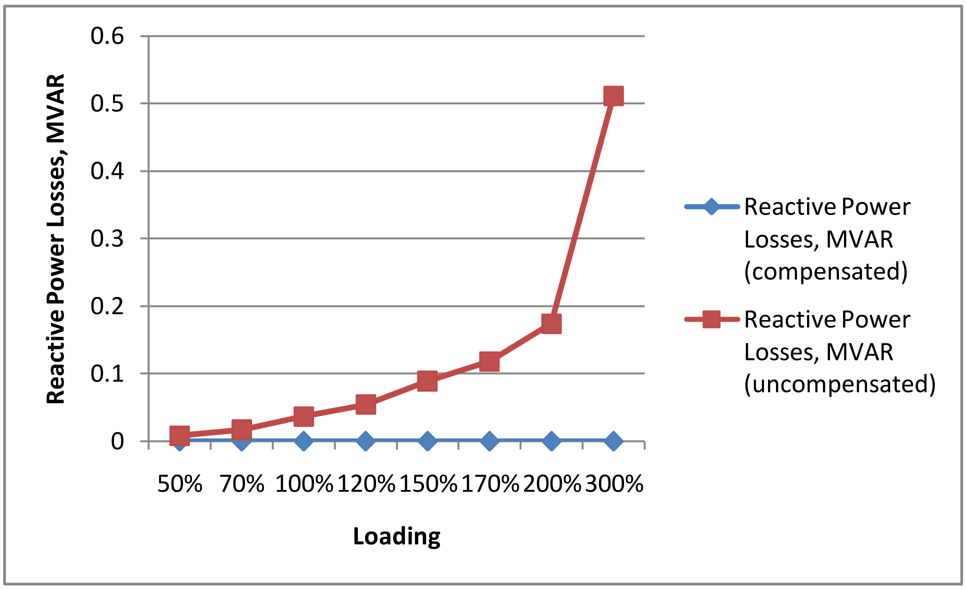

Figure 28: Graph of reactive power losses for a network with and without compensation installed with parallel configuration

Table 18: Power losses and voltage magnitude difference between a network with and without series capacitor compensation installed with parallel configuration

Loading	MW losses difference,%	MVAR losses difference,%	Voltage Magnitude Difference, %
50%	6.67	100.00	0.75
70%	3.33	100.00	1.05
100%	3.17	100.00	1.66
120%	4.26	100.00	2.08
150%	5.16	100.00	2.75
170%	5.83	100.00	3.32
200%	7.59	100.00	4.16
300%	16.05	100.00	9.15

Next, **Table 19** shows the simulated data after overcompensation condition has been performed. Similarly, overcompensation test will be stopped after the simulation is not converged. **Figure 29** shows a graph based on the data in **Table 19**.

From the result obtained, it can be seen that the changes in losses reduction is not very much compared with the previous cases. But, the network is said to be better in term of losses reduction if a higher value of series capacitor compensation is installed.

Table 19: Power losses and voltage magnitude for a network with series capacitor compensation at 100 km position and with parallel configuration

Compensation Value	Real Power Losses, MW	Reactive Power Losses, MVAR	Voltage Magnitude
100%	0.061	0.000	1.042
200%	0.059	-0.034	1.057
300%	0.058	-0.067	1.071
400%	0.057	-0.098	1.084
500%	0.055	-0.127	1.096
600%	0.054	-0.156	1.106
700%	0.053	-0.184	1.115
800%	0.053	-0.212	1.124
900%	0.052	-0.239	1.131
1000%	0.051	-0.266	1.138
1200%	0.050	-0.319	1.149

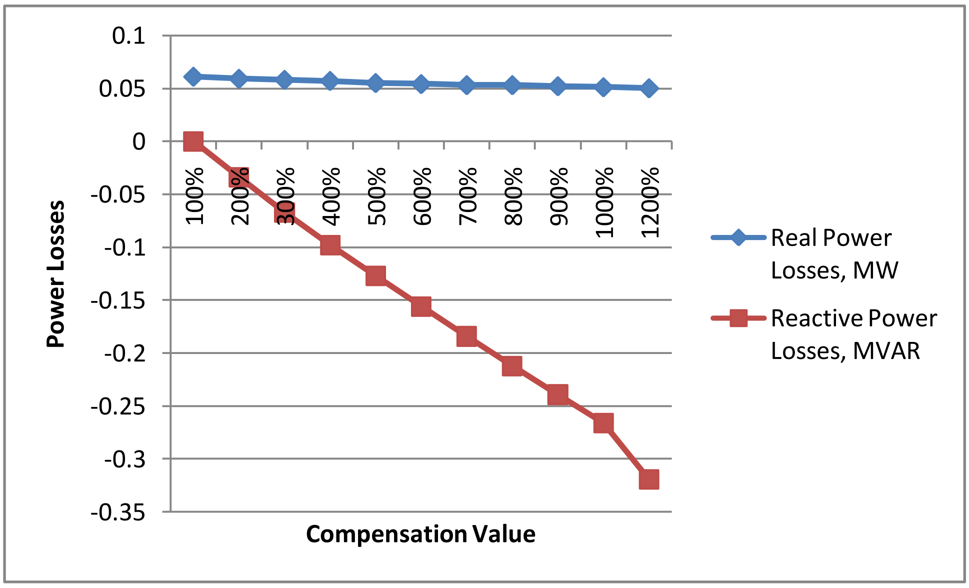

Figure 29: Graph of power losses for the difference value of compensation in a network with 185 mm^2 cable size

4.3 Voltage Analysis

4.3.1 Case 1: Different in series capacitor compensation location

For a network with series capacitor compensation installed, the location of compensation will not change the voltage magnitude at the load. To prove the statement, **Figure 30** shows the voltage magnitude when the series capacitor compensation location is set to be at 100 km and 50 km.

The results obtained are due to the voltage magnitude depends on the voltage source and total impedances where for this case although the location of compensation is changing but the voltage source and total impedance are the same.

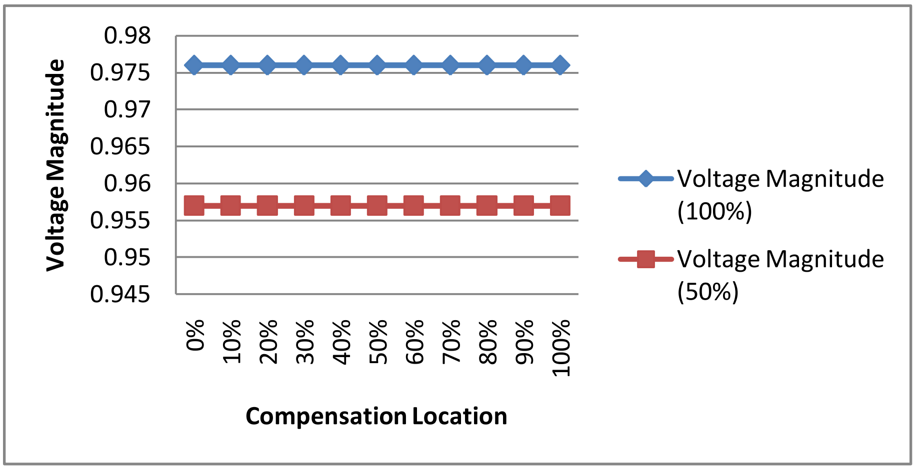

Figure 30: Graph of voltage magnitude for the network with capacitor compensation value of 100 % and 50 %

4.3.2 Case 2: Different in capacitor compensation value

Base on Case 2 in previous part, the value of series capacitor compensation is changed and the data is collected from the simulation. Then, **Figure 31** shows the effect on voltage magnitude at the load after the simulation is done.

When the value of series capacitor is increased, the voltage magnitude at the load is increased as well. In other word, the higher value of capacitor compensation will result the voltage magnitude to be increased.

The increasing of voltage magnitude is due to the total impedance has been reduced. Therefore, the reduction of total impedance will cause the voltage at the load to be improved.

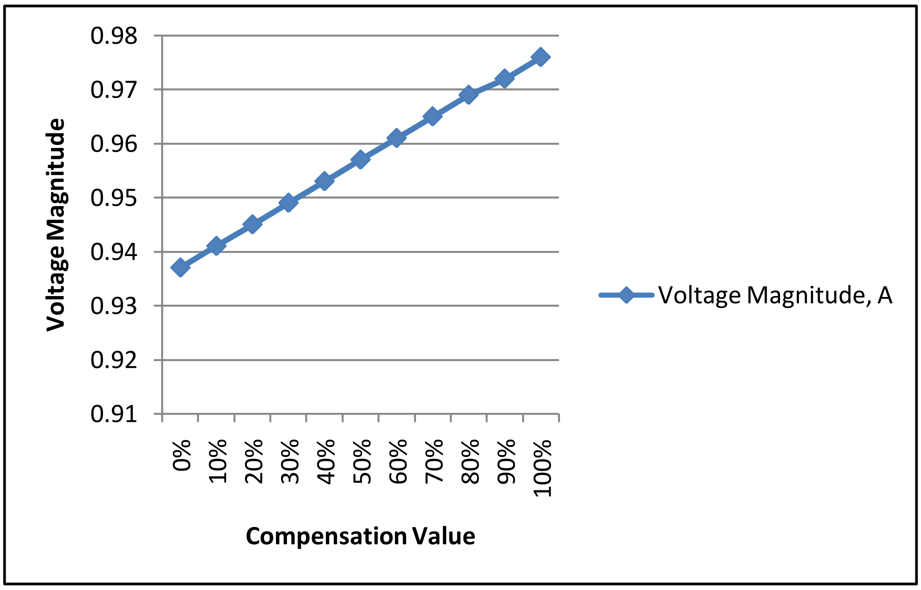

Figure 31: Graph of voltage magnitude for the network with capacitor compensation location at 100 %

4.3.3 *Case 3: Different in loading*

For this case, when the loading is changing the voltage magnitude at the load will decreasing. Meaning to say, the increase of loading will cause the voltage at the load to be lower.

Then, a network with compensation installed is compared with a network without any compensation installed. The series capacitor compensation application has improved the voltage magnitude. It is proven by the graph in **Figure 32**. Similar with the previous cases, the present of series capacitor compensation will reduce the total impedance and cause the voltage magnitude to be improved.

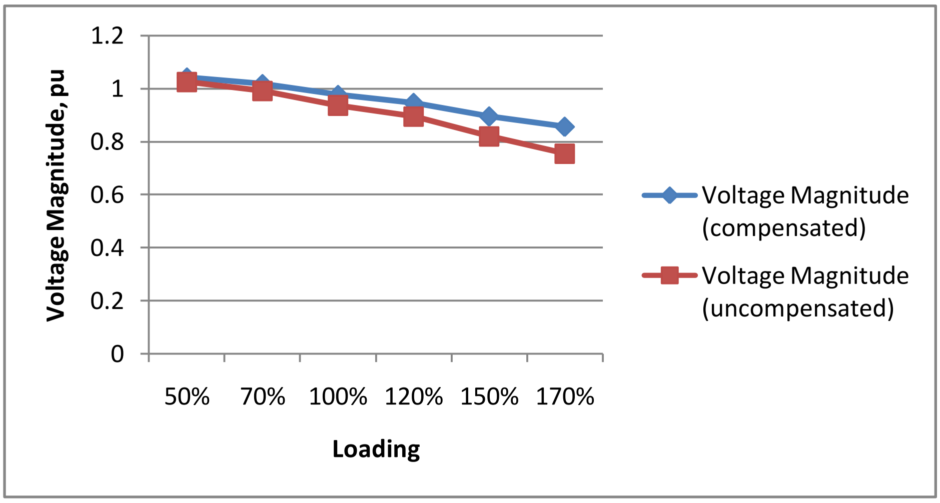

Figure 32: Graph of voltage magnitude to compare a network with capacitor compensation and uncompensated network

4.3.4 *Case 4: Different in load power factor*

From the graph drawn below, the present of series capacitor compensation has improved the voltage magnitude. As an example, at 0.9 power factor value, the voltage magnitude in the compensated network is higher compared with the voltage magnitude in the uncompensated network.

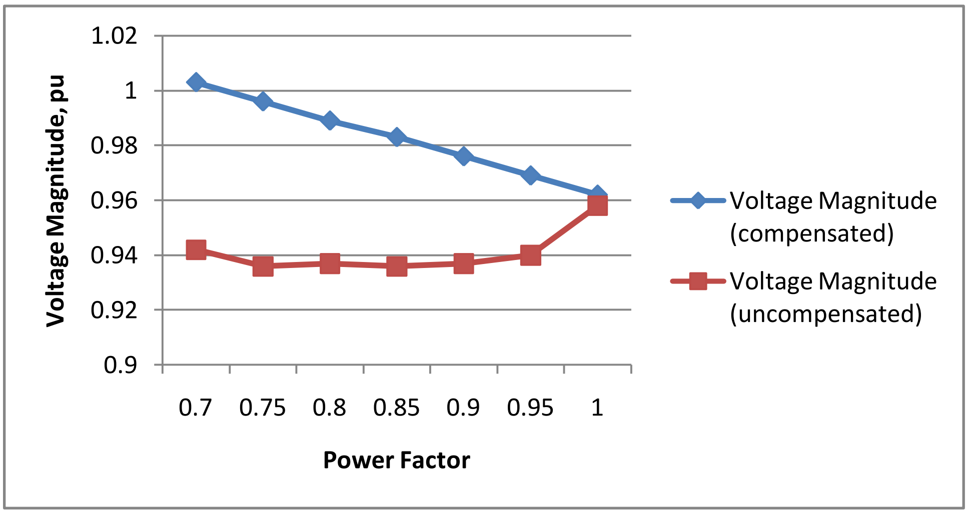

Figure 33: Graph of voltage magnitude to compare a network with capacitor compensation and uncompensated network

4.3.5 Case 5: Overcompensation

To extend the analysis on compensation value affecting the voltage magnitude, overcompensation simulation has been done. A compensated network is tested with the value of series capacitor compensation is ranging from 100 % to 900 %.

From the graph drawn, the voltage magnitude at the load in the increasing trend and after certain level which is at 700 % the voltage magnitude is decreasing.

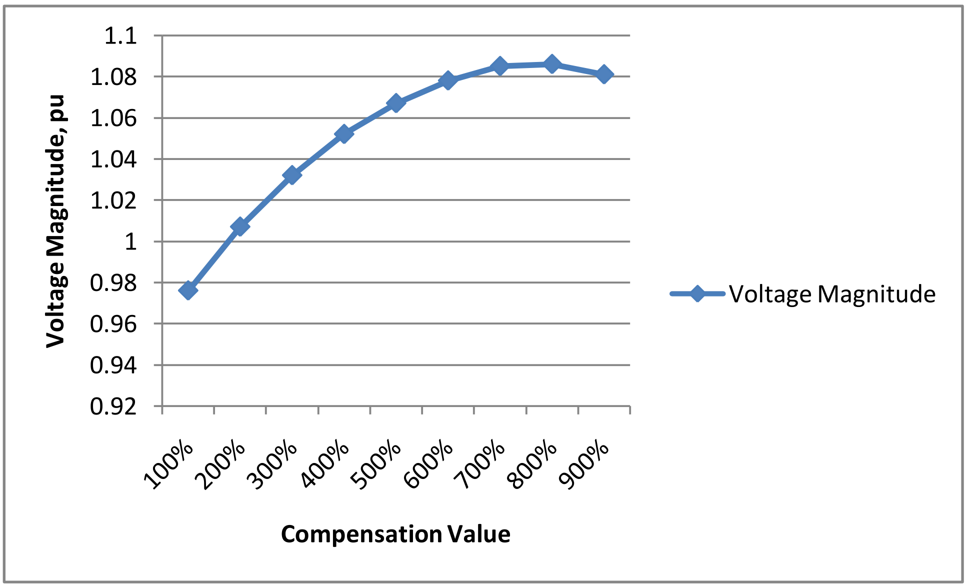

Figure 34: Graph of voltage magnitude at the load for the different value of compensation

4.3.6 *Case 6: Network with 33 kV level*

By using a 33 kV voltage source, a compensated network is compared with uncompensated network whether the loading different will affect the voltage magnitude or not.

Based on the graph drawn below, the compensated network give better voltage magnitude at the load compared with the uncompensated network. But, comparing the 11 kV network and 33 kV network, the voltage magnitude different are greater for the 11 kV network.

As an example, in 11 kV network, the voltage magnitude percentage different between compensated network and uncompensated network at 100 % loading is 4.16 % while in 33 kV the percentage difference is about 0.41 %.

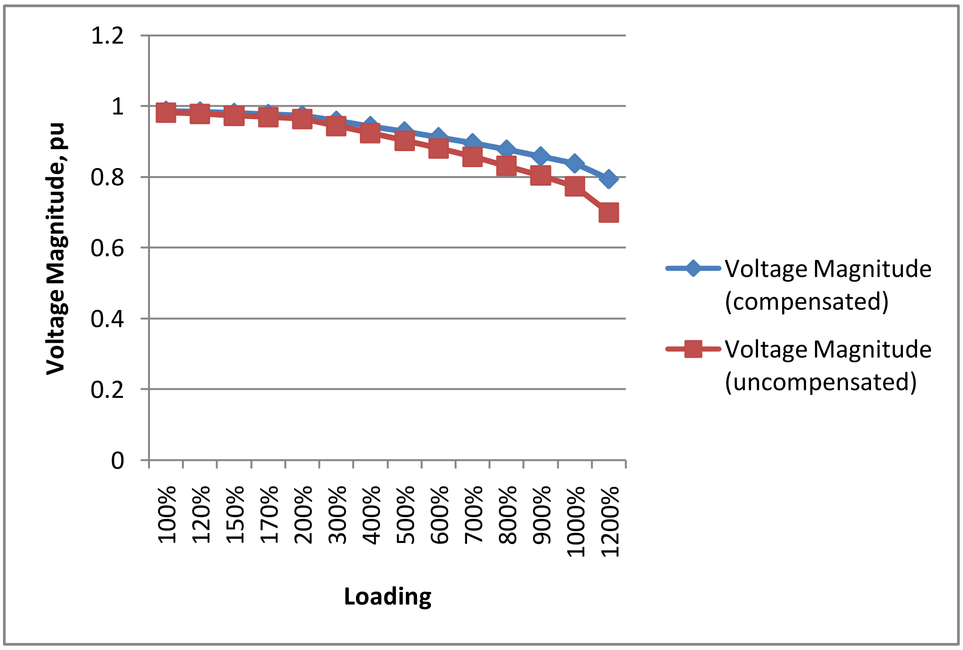

Figure 35: Graph of voltage magnitude at the load for a 33 kV network with and without compensation installed

4.3.7 Case 7: Network with 185 mm^2 size of cable

Previously, the cable of 240 mm^2 sizes is used as the cable but for this case the 185 mm^2 sizes of cable will be used. Basically, from the data collected and graph drawn below, the present of series capacitor compensation has improved the voltage magnitude at the load.

But, the difference can be explained where the smaller size of cable will increase the total impedance of the network. For example, the voltage magnitude percentage difference for this case is about 5.1 % at 100 % loading while for the network with 240 mm^2 the percentage difference is about 4.16 %.

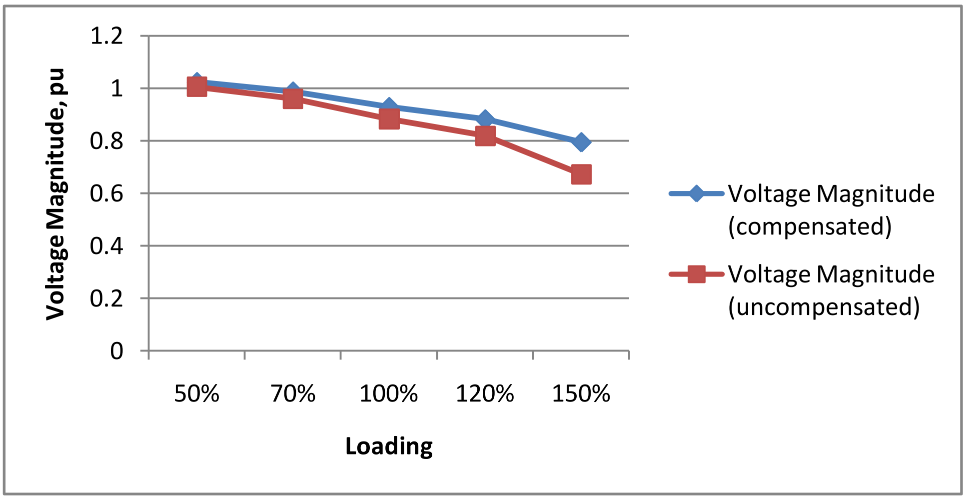

Figure 36: Graph of voltage magnitude at the load for a network with and without compensation installed with 185 mm^2 cable size

4.3.8 Case 8: Parallel configuration network

The network with 100 km long, 1 MVA loading and 11 kV voltage level is taken into consideration. But for this time around, the network configuration is set to be parallel which means there will be 2 cable of 100 km long cable.

By varying the loading, the voltage magnitude at the load is analyzed. At 100 % loading in parallel configuration network, the voltage magnitude configuration percentage difference is around 1.66 % while for the similar parameters in radial configuration the percentage difference is about 4.16 %.

Obviously, from the graph shows below the present of this series capacitor compensation will improve the voltage magnitude at the load.

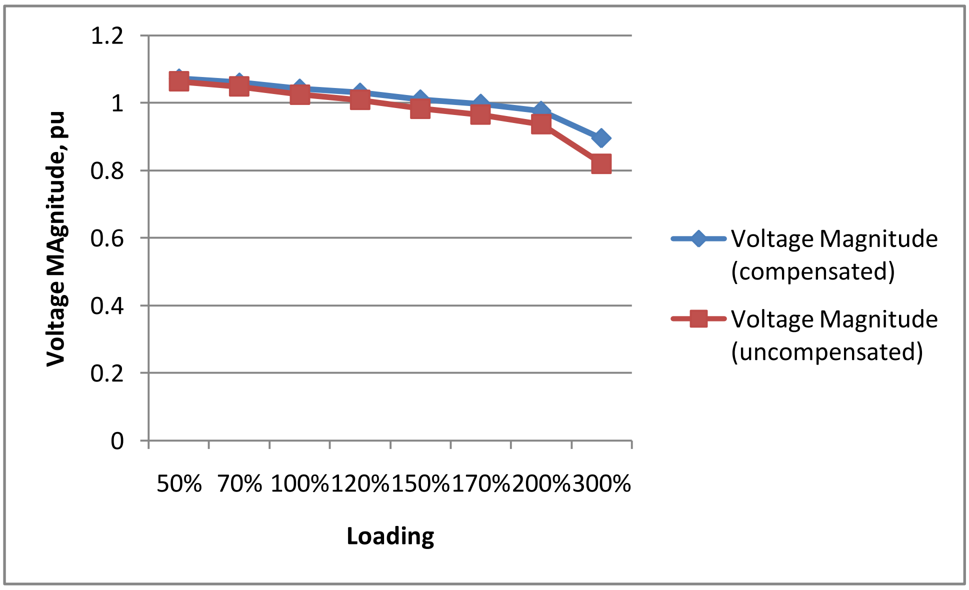

Figure 37: Graph of voltage magnitude at the load for a network with and without compensation installed with parallel configuration

4.4 Economic Analysis

Apart of analysis on losses reduction, the economic analysis is also taken into consideration in order to decide whether this series capacitor compensation is worth to be installed or not. But, to be able to analyze this application economically, certain elements or factors need to be determined such as the estimation cost involved to install this application and amount of losses can be reduced in term of money.

The estimation cost to install this series capacitor compensation involves the cost to buy the equipment such as the capacitor, circuit breaker protection system and some other equipment. The cost estimated is around RM 200,000.00 and extra RM 50,000.00 for the maintenance in 20 years time.

Next, to calculate the amount of money that the user can save taking into account the amount of power losses reduction, tariff rate and load factor. The information mentioned is;

Tariff rate (for C1, 11 kV)	:	28.8 cent/kWh
Load factor (assumption)	:	0.6

Table 20: Real power losses according to the compensation value in a network with 11 kV level, 1 MVA load, 100 km long and 0.9 lagging power factor

Compensation Value	Real Power Losses, MW
0%	0.152
50%	0.145
100%	0.140
300%	0.125
600%	0.114

Based on the data in **Table 20**, the real power losses in a network without any compensation is 152 kW but for a network with 100 % compensation value which is a recommended value of compensation give 140 kW real power losses. But, as mentioned earlier, at 600 % value of compensation the network still working properly and the user might considering to go up to this value.

As the result, a payback period can be calculated by setting the total cost to be RM 250,000.00.

Payback Period, T_{year}

$$P_{loss} * R_{tariff} * T_{hour/day} * T_{day/year} * T_{year} * F_{load} = C_{total}$$

Where,		
	P_{loss}	, in kW
	R_{tariff}	, 0.288 RM/kWh
	$T_{hour/day}$	, $24_{hour/day}$
	$T_{day/year}$	, $365_{day/year}$
	C_{total}	, RM 250, 000.00
	F_{load}	, 0.6

Table 21: Real power losses, losses reduction and payback period according to the compensation value

Compensation Value	Real Power Losses, MW	Losses Reduction, kW	Payback Period, years
0%	0.152		
50%	0.145	7	24
100%	0.140	12	14
300%	0.125	27	7
600%	0.114	38	5

After calculating the payback period, the user can decide whether to install this series capacitor compensation or not. Based on several assumptions been made, the best compensation value to be chosen is at 300 % where it takes 7 years for the user to cover back all the installation cost. Usually, this series capacitor compensation can be used up to 20 years and for the balance of 13 years the user can collect the profit.

To compare the result calculated in **Table 21**, the user can compare how much is the losses in term of money if this series capacitor compensation is not been installed. By using the same values and assumptions, the losses per day are about RM 111.97.

4.5 Loadability Analysis

Loadability analysis focuses on the current supplying the load. Therefore, this analysis is carried out by comparing a network with capacitor compensation with network without any compensation installed. From the data assembled in previous cases, the loadability analysis can be performed.

Basically, by knowing the power losses and resistance of the network, the line current can be calculated. The equation (5) is obtained from the equation (4) in the literature review part. Similarly, to calculate the line current, equation (6) can be used.

$$(I_L)^2 = \frac{P_{loss}}{R_L} \tag{5}$$

$$I_L = \frac{V_S - V_R}{R_L \cos \varphi_R + (X_L - X_C) \sin \varphi_R} \tag{6}$$

Next, before start calculating the line current, there are several parameters that need to be clarified. The parameters are;

R = 0.161 ohm/km ; X = 0.0924 ohm/km ; B = 0.35 uF/km

S_{base} *= 1 MVA ;* V_{base} *= 11 kV ;* Z_{base} *= 121 ohm ;* I_{base} *= 90.91 A*

Power factor = 0.9 lagging

Table 22: Real power losses, voltage regulation and total impedance according to the compensation value

Compensation Value	Real Power Losses, MW	Voltage Regulation, ΔV	Total Impedance, R+jX
0%	0.152	0.163∟0.596	16.1 + j9.240
50%	0.145	0.143∟-1.287	16.1 + j4.620
100%	0.140	0.124∟-3.098	16.1 + j0.000
300%	0.125	0.063∟-9.914	16.1 - j18.48
600%	0.114	0.022∟-19.791	16.1 - j46.20

From the data collected in **Table 22**, the value of line current can be calculated. The line currents are as follow;

Table 23: Value of line current according to compensation value

Compensation Value	Line Current, A
0%	97.16
50%	94.90
100%	93.25
300%	88.11
600%	84.15

From the value of line current calculated in **Table 23**, the reduction of line current is almost 10 %. Therefore, the loadability is said to be improved by 10 % if the user use compensation value of 300 %.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The main reason why capacitor compensations have been installed in the network is to improve the power transmission in distribution line. By having the series capacitor compensation, the voltage regulation and power losses can be controlled and limited. From the result obtained, it is proven that the application of series capacitor compensation can improve the power transmission in term of voltage improvement and power losses. The changes in power factor and loading can affect the network with series capacitor compensation where the voltage is improved and power losses reduced as well.

Voltage improvement is important in distribution network because service provider is required to supply quality power to the customer. The supply is said to be out of tolerance if the voltage regulation is not within the interval of ±5 % at 11 kV. The service provider can easily step up the voltage at the sending end to improve the voltage regulation but it would involve a very high cost.

After considering all the cases, series capacitor compensation is capable to reduce the losses and improve loadability. Besides that, with series capacitor compensation installed the voltage at receiving end can be improved as well. As a conclusion, although the losses reduction is not very significant but by having this application the service provider can solve a few other problems such as loadability and voltage regulation.

5.2 Recommendations

After completing this study, there are advantages and disadvantages of installing the series capacitor compensation in distribution line. The advantages are losses are reduced along the network, voltage at the receiving end is improved and improve the loadability. In economic point of view, installing series capacitor compensation will need only 7-10 years of payback period over 20 years life span.

On the other hand, there are a few disadvantages of this application. The disadvantages are special protection system is required to avoid any damage to the system and the system might exposed to some side effect such as ferroresonance or overcurrent conditions.

To conclude, it is depending on the service provider whether to consider series capacitor compensation to be installed in distribution line or not. Economically, this application can reduce the losses that lead to saving the money. However, there are several disadvantages need to be considered such as ferroresonance and spending on new protection system or new cables.

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APPENDICES

APPENDIX I

Source code for compensation location at 100 km

and 100 % compensation value

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW     Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0       0    0   0    0    0    0
         2   0    1       0.0      0       0    0   0    0    0    0
         3   0    1       0.0     0.90   0.436  0   0    0    0    0];


%                                            Line code
%          Bus bus   R       X       1/2 B    = 1 for lines
%          nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.13306  0.07636  0.00005   1
          2   3   0.00000 -0.07636  0.00000   1];


lfybus                     % Forms the bus admittance matrix
%lfgauss       % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX II

Simulation for compensation location at 100 km
and 100 % compensation value

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 4.51584e-008
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.040	0.436	0.000
2	0.944	-1.180	0.000	0.000	0.000	0.000	0.000
3	0.976	3.098	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	1.040	0.436	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		1.040	0.436	1.127			
	2	1.040	0.436	1.127	0.140	0.080	
2		0.000	0.000	0.000			
	1	-0.900	-0.356	0.968	0.140	0.080	
	3	0.900	0.356	0.968	0.000	-0.080	
3		-0.900	-0.436	1.000			
	2	-0.900	-0.436	1.000	0.000	-0.080	
Total loss					0.140	-0.000	

APPENDIX III

Source code for compensation location at 50 km

and 50 % compensation value

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 50 km

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 50% , Distance = 100km , PF = 0.9 lagging

basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0       0    0   0     0    0    0
         2   0    1       0.0      0       0    0   0     0    0    0
         3   0    1       0.0      0       0    0   0     0    0    0
         4   0    1       0.0    0.90  0.436    0   0     0    0    0];


%                                             Line code
%          Bus bus   R        X        1/2 B    = 1 for lines
%          nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.06653  0.03818  0.000023   1
          2   3   0.00000 -0.03818  0.000000   1
          3   4   0.06653  0.03818  0.000023   1];


lfybus                    % Forms the bus admittance matrix
%lfgauss       % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow    % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX IV

Simulation for compensation location at 50 km
and 50 % compensation value

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 4.01889e-008
No. of Iterations = 4

Bus	Voltage	Angle	------Load------		---Generation---		Injected
No.	Mag.	Degree	MW	Mvar	MW	Mvar	Mvar
1	1.100	0.000	0.000	0.000	1.045	0.478	0.000
2	1.020	-0.415	0.000	0.000	0.000	0.000	0.000
3	1.037	1.596	0.000	0.000	0.000	0.000	0.000
4	0.957	1.287	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	1.045	0.478	0.000

Line Flow and Losses

--Line--		Power at bus & line flow			--Line loss--		Transformer
from	to	MW	Mvar	MVA	MW	Mvar	tap
1		1.045	0.478	1.149			
	2	1.045	0.478	1.149	0.073	0.042	
2		0.000	0.000	0.000			
	1	-0.973	-0.436	1.066	0.073	0.042	
	3	0.973	0.436	1.066	-0.000	-0.042	
3		0.000	0.000	0.000			
	2	-0.973	-0.478	1.084	-0.000	-0.042	
	4	0.973	0.478	1.084	0.073	0.042	
4		-0.900	-0.436	1.000			
	3	-0.900	-0.436	1.000	0.073	0.042	
Total loss					0.145	0.042	

APPENDIX V

Source code for compensation location at 100 km

and 70 % compensation value

```
%clear
%        Name     : Muhammad Azizi bin Mohd Wahidi
%        Title    : Analysis on Losses Reduction with Series Capacitor
%                   Compensation in Distribution Network
%        SV       : IR Mohd Faris bin Abdullah
%        Case     : Compensation's location at 100 km
%                   Value of compensation is 70%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1    1    1.1     0.0      0      0    0   0    0    0    0
         2    0    1       0.0      0      0    0   0    0    0    0
         3    0    1       0.0    0.90  0.436   0   0    0    0    0];


%                                              Line code
%          Bus bus   R        X       1/2 B    = 1 for lines
%          nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1    2   0.13306  0.07636  0.00005   1
          2    3   0.00000 -0.05346  0.00000   1];


lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX VI

Simulation for compensation location at 100 km
and 70 % compensation value

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 8.69795e-009
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.043	0.460	0.000
2	0.942	-1.015	0.000	0.000	0.000	0.000	0.000
3	0.965	2.019	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	1.043	0.460	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		1.043	0.460	1.140			
	2	1.043	0.460	1.140	0.143	0.082	
2		0.000	0.000	0.000			
	1	-0.900	-0.379	0.976	0.143	0.082	
	3	0.900	0.379	0.976	-0.000	-0.057	
3		-0.900	-0.436	1.000			
	2	-0.900	-0.436	1.000	-0.000	-0.057	
Total loss					0.143	0.024	

APPENDIX VII

Source code for the 150 % loading

and compensation location and value are 100%

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%
%                 Load : 150% (1 MVA)

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW     Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0       0       0    0  0     0    0    0
         2   0    1       0.0       0       0    0  0     0    0    0
         3   0    1       0.0    1.35   0.654    0  0     0    0    0];


%                                            Line code
%         Bus bus   R        X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.13306  0.07636  0.00005   1
          2   3   0.00000 -0.07636  0.00000   1];


lfybus                   % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow    % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX VIII

Simulation for the 150 % loading

and compensation location and value are 100%

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 8.4903e-006
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.724	0.654	0.000
2	0.847	-2.744	0.000	0.000	0.000	0.000	0.000
3	0.895	5.071	1.350	0.654	0.000	0.000	0.000
Total			1.350	0.654	1.724	0.654	0.000

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		1.724	0.654	1.844			
	2	1.724	0.654	1.844	0.374	0.214	
2		0.000	0.000	0.000			
	1	-1.350	-0.439	1.420	0.374	0.214	
	3	1.350	0.439	1.420	0.000	-0.215	
3		-1.350	-0.654	1.500			
	2	-1.350	-0.654	1.500	0.000	-0.215	
Total loss					0.374	-0.000	

APPENDIX IX

Source code for the 150 % loading

and compensation location and value are 100% and 0 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 0%
%                 Load : 150% (1 MVA)

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0      0    0   0     0    0    0
         2   0    1       0.0    1.35  0.654   0   0     0    0    0];


%                                            Line code
%         Bus bus   R       X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.13306  0.07636  0.00005   1];



lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX X

Simulation for the 150 % loading

and compensation location and value are 100% and 0 % respectively

Power Flow Solution by Newton-Raphson Method

Maximum Power Mismatch = 2.73751e-005

No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.795	0.910	0.000
2	0.820	-1.021	1.350	0.654	0.000	0.000	0.000
Total			1.350	0.654	1.795	0.910	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		1.795	0.910	2.013			
	2	1.796	0.910	2.013	0.446	0.256	
2		-1.350	-0.654	1.500			
	1	-1.350	-0.654	1.500	0.446	0.256	
Total loss					0.446	0.256	

APPENDIX XI

Source code for the 0.8 lagging power factor load

and compensation location and value are 100%

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%
%                 Power Factor : 0.8 lagging

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1    1    1.1     0.0      0      0    0   0     0    0    0
         2    0    1       0.0      0      0    0   0     0    0    0
         3    0    1       0.0    0.80  0.600   0   0     0    0    0];


%                                           Line code
%         Bus bus   R        X       1/2 B     = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.13306  0.07636  0.00005   1
          2   3   0.00000 -0.07636  0.00000   1];


lfybus                     % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple    % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XII

Simulation for the 0.8 lagging power factor load
and compensation location and value are 100%

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 2.93958e-008
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	0.936	0.600	0.000
2	0.945	0.461	0.000	0.000	0.000	0.000	0.000
3	0.989	4.206	0.800	0.600	0.000	0.000	0.000
Total			0.800	0.600	0.936	0.600	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		0.936	0.600	1.112			
	2	0.936	0.600	1.112	0.136	0.078	
2		0.000	0.000	0.000			
	1	-0.800	-0.522	0.955	0.136	0.078	
	3	0.800	0.522	0.955	0.000	-0.078	
3		-0.800	-0.600	1.000			
	2	-0.800	-0.600	1.000	0.000	-0.078	
Total loss					0.136	-0.000	

APPENDIX XIII

Source code for the 0.8 lagging power factor load

and compensation location and value are 100% and 0 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 0%
%                 Power Factor : 0.8 lagging

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0      0    0   0    0    0    0
         2   0    1       0.0    0.80  0.600   0   0    0    0    0];


%                                            Line code
%         Bus bus   R       X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.13306  0.07636  0.00005   1];



lfybus                     % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple    % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XIV

Simulation for the 0.8 lagging power factor load

and compensation location and value are 100% and 0 % respectively

Power Flow Solution by Newton-Raphson Method

Maximum Power Mismatch = 3.68961e-009

No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	-------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	0.951	0.687	0.000
2	0.937	1.041	0.800	0.600	0.000	0.000	0.000
Total			0.800	0.600	0.951	0.687	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		0.951	0.687	1.173			
	2	0.951	0.687	1.173	0.151	0.087	
2		-0.800	-0.600	1.000			
	1	-0.800	-0.600	1.000	0.151	0.087	
Total loss					0.151	0.087	

APPENDIX XV

Source code for the overcompensation condition

and compensation location and value are 100% and 300 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 300%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW     Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0      0     0   0    0    0    0
         2   0    1       0.0      0      0     0   0    0    0    0
         3   0    1       0.0    0.90   0.436   0   0    0    0    0];


%                                            Line code
%         Bus bus   R       X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.13306  0.07636  0.00005   1
          2   3   0.00000 -0.22908  0.00000   1];


lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow    % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XVI

Simulation for the overcompensation condition
and compensation location and value are 100% and 300 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 1.82588e-006
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.025	0.292	0.000
2	0.956	-2.143	0.000	0.000	0.000	0.000	0.000
3	1.032	9.914	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	1.025	0.292	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		1.025	0.292	1.066			
	2	1.025	0.292	1.066	0.125	0.072	
2		0.000	0.000	0.000			
	1	-0.900	-0.221	0.927	0.125	0.072	
	3	0.900	0.221	0.927	0.000	-0.215	
3		-0.900	-0.436	1.000			
	2	-0.900	-0.436	1.000	0.000	-0.215	
Total loss					0.125	-0.144	

APPENDIX XVII

Source code for the network with 33 kV voltage level

and compensation location and value are 0% and 100 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 0 km
%                 Value of compensation is 100%

%Base power = 1 MVA , Base voltage = 33 kV , Base impedance = 1089 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.105 ohm/km , Line capacitance = 0.22 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1       0.0      0       0    0   0     0    0    0
         2   0    1       0.0      0       0    0   0     0    0    0
         3   0    1       0.0   0.90   0.436    0   0     0    0    0];


%                                            Line code
%          Bus bus   R        X       1/2 B     = 1 for lines
%          nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.00000 -0.00964  0.0000000   1
          2   3   0.01478  0.00964  0.0000032   1];


lfybus                   % Forms the bus admittance matrix
%lfgauss       % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XVIII

Simulation for the network with 33 kV voltage level
and compensation location and value are 0% and 100 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 2.4564e-006
No. of Iterations = 3

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.000	0.000	0.000	0.000	0.915	0.436	0.000
2	1.004	0.503	0.000	0.000	0.000	0.000	0.000
3	0.986	0.374	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	0.915	0.436	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		0.915	0.436	1.014			
	2	0.915	0.436	1.014	0.000	-0.010	
2		0.000	0.000	0.000			
	1	-0.915	-0.446	1.018	0.000	-0.010	
	3	0.915	0.446	1.018	0.015	0.010	
3		-0.900	-0.436	1.000			
	2	-0.900	-0.436	1.000	0.015	0.010	
Total loss					0.015	-0.000	

APPENDIX XIX

Source code for the network with 33 kV voltage level

and compensation location and value are 100% and 80 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 80%

%Base power = 1 MVA , Base voltage = 33 kV , Base impedance = 1089 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.105 ohm/km , Line capacitance = 0.22 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1       0.0      0      0    0   0     0    0    0
         2   0    1       0.0      0      0    0   0     0    0    0
         3   0    1       0.0   0.90  0.436    0   0     0    0    0];


%                                             Line code
%         Bus bus   R        X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.01478  0.00964  0.0000032   1
          2   3   0.00000 -0.00771  0.0000000   1];


lfybus                   % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple    % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XX

Simulation for the network with 33 kV voltage level
and compensation location and value are 100% and 80 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 1.33387e-005
No. of Iterations = 3

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.000	0.000	0.000	0.000	0.915	0.438	0.000
2	0.982	-0.137	0.000	0.000	0.000	0.000	0.000
3	0.986	0.274	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	0.915	0.438	0.000

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		0.915	0.438	1.015			
	2	0.915	0.438	1.015	0.015	0.010	
2		0.000	0.000	0.000			
	1	-0.900	-0.428	0.997	0.015	0.010	
	3	0.900	0.428	0.997	0.000	-0.008	
3		-0.900	-0.436	1.000			
	2	-0.900	-0.436	1.000	0.000	-0.008	
Total loss					0.015	0.002	

APPENDIX XXI

Source code for the network with 33 kV voltage level and 500 % loading and compensation location and value are 100%

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%

%Base power = 1 MVA , Base voltage = 33 kV , Base impedance = 1089 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.105 ohm/km , Line capacitance = 0.22 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1       0.0      0      0    0   0     0    0    0
         2   0    1       0.0      0      0    0   0     0    0    0
         3   0    1       0.0   4.50  2.180    0   0     0    0    0];


%                                            Line code
%         Bus bus   R        X        1/2 B     = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.      >1 or<1 tr. tap at bus nl
linedata=[1   2   0.00000 -0.00964  0.0000000   1
          2   3   0.01478  0.00964  0.0000032   1];


lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXII

Simulation for the network with 33 kV voltage level and 500 % loading and compensation location and value are 100%

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 8.60752e-008
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.000	0.000	0.000	0.000	4.929	2.180	0.000
2	1.022	2.665	0.000	0.000	0.000	0.000	0.000
3	0.928	1.990	4.500	2.180	0.000	0.000	0.000
Total			4.500	2.180	4.929	2.180	0.000

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		4.929	2.180	5.390			
	2	4.929	2.180	5.390	0.000	-0.280	
2		0.000	0.000	0.000			
	1	-4.929	-2.460	5.509	0.000	-0.280	
	3	4.929	2.460	5.509	0.429	0.280	
3		-4.500	-2.180	5.000			
	2	-4.500	-2.180	5.000	0.429	0.280	
Total loss					0.429	-0.000	

APPENDIX XXIII

Source code for the network with 33 kV voltage level and 500 % loading and compensation location and value are 100% and 0 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 0%

%Base power = 1 MVA , Base voltage = 33 kV , Base impedance = 1089 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.105 ohm/km , Line capacitance = 0.22 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1       0.0      0      0    0   0     0    0    0
         2   0    1       0.0    4.50   2.180  0   0     0    0    0];


%                                            Line code
%         Bus bus   R        X        1/2 B     = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.      >1 or<1 tr. tap at bus nl
linedata=[1   2   0.01478  0.00964  0.0000032   1];



lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXIV

Simulation for the network with 33 kV voltage level and 500 % loading and compensation location and value are 100% and 0 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 6.21229e-007
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.000	0.000	0.000	0.000	4.953	2.476	0.000
2	0.903	-0.708	4.500	2.180	0.000	0.000	0.000
Total			4.500	2.180	4.953	2.476	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		4.953	2.476	5.537			
	2	4.953	2.476	5.537	0.453	0.296	
2		-4.500	-2.180	5.000			
	1	-4.500	-2.180	5.000	0.453	0.296	
Total loss					0.453	0.296	

APPENDIX XXV

Source code for the network with 185 mm^2 cable size and 150 % loading and compensation location and value are 100%

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.211 ohm/km, Line reactance = i0.0962 ohm/km , Line capacitance = 0.31 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging

basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW     Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0       0    0   0    0    0    0
         2   0    1       0.0      0       0    0   0    0    0    0
         3   0    1       0.0    1.35  0.654    0   0    0    0    0];


%                                            Line code
%         Bus bus   R        X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   2   0.17438  0.07950  0.000040  1
          2   3   0.00000 -0.07950  0.000000  1];


lfybus                  % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXVI

Simulation for the network with 185 mm^2 cable size and 150 % loading and compensation location and value are 100%

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 6.81791e-008
No. of Iterations = 5

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.972	0.654	0.000
2	0.741	-3.006	0.000	0.000	0.000	0.000	0.000
3	0.794	7.501	1.350	0.654	0.000	0.000	0.000
Total			1.350	0.654	1.972	0.654	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		1.972	0.654	2.078			
	2	1.972	0.654	2.078	0.622	0.284	
2		0.000	0.000	0.000			
	1	-1.350	-0.370	1.400	0.622	0.284	
	3	1.350	0.370	1.400	0.000	-0.284	
3		-1.350	-0.654	1.500			
	2	-1.350	-0.654	1.500	0.000	-0.284	
Total loss					0.622	-0.000	

APPENDIX XXVII

Source code for the network with 185 mm^2 cable size and 150 % loading and compensation location and value are 100% and 0 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 0%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.211 ohm/km, Line reactance = i0.0962 ohm/km , Line capacitance = 0.31 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1    1    1.1     0.0      0      0    0   0    0    0    0
         2    0    1       0.0    1.35  0.654   0   0    0    0    0];


%                                             Line code
%          Bus bus   R        X       1/2 B     = 1 for lines
%          nl  nr  p.u.     p.u.     p.u.      >1 or<1 tr. tap at bus nl
linedata=[1   2   0.17438  0.07950  0.000040  1];



lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow    % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXVIII

Simulation for the network with 185 mm^2 cable size and 150 % loading and compensation location and value are 100% and 0 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 3.666e-005
No. of Iterations = 5

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	2.217	1.049	0.000
2	0.673	0.520	1.350	0.654	0.000	0.000	0.000
Total			1.350	0.654	2.217	1.049	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		2.217	1.049	2.453			
	2	2.217	1.049	2.453	0.867	0.395	
2		-1.350	-0.654	1.500			
	1	-1.350	-0.654	1.500	0.867	0.395	
Total loss					0.867	0.395	

APPENDIX XXIX

Source code for the network with 185 mm^2 cable size

and compensation location and value are 100% and 400 % respectively

```
%clear
%       Name     : Muhammad Azizi bin Mohd Wahidi
%       Title    : Analysis on Losses Reduction with Series Capacitor
%                  Compensation in Distribution Network
%       SV       : IR Mohd Faris bin Abdullah
%       Case     : Compensation's location at 100 km
%                  Value of compensation is 400%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.211 ohm/km, Line reactance = i0.0962 ohm/km , Line capacitance = 0.31 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging

basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1    1    1.1     0.0      0       0    0   0    0    0    0
         2    0    1       0.0      0       0    0   0    0    0    0
         3    0    1       0.0    0.90  0.436    0   0    0    0    0];


%                                             Line code
%          Bus bus    R        X        1/2 B     = 1 for lines
%          nl  nr   p.u.     p.u.     p.u.      >1 or<1 tr. tap at bus nl
linedata=[1    2    0.17438  0.07950  0.000040  1
          2    3    0.00000 -0.31802  0.000000  1];


lfybus                     % Forms the bus admittance matrix
%lfgauss        % Power flow solution by Newton-Raphson method
lfnewton      % Power flow solution by Newton-Raphson method
%decouple      % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow    % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXX

Simulation for the network with 185 mm^2 cable size and
and compensation location and value are 100% and 400 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 1.97344e-005
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	1.071	0.202	0.000
2	0.917	-2.841	0.000	0.000	0.000	0.000	0.000
3	1.009	15.181	0.900	0.436	0.000	0.000	0.000
Total			0.900	0.436	1.071	0.202	0.000

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		1.071	0.202	1.090			
	2	1.071	0.202	1.090	0.171	0.078	
2		0.000	0.000	0.000			
	1	-0.900	-0.124	0.908	0.171	0.078	
	3	0.900	0.124	0.908	0.000	-0.312	
3		-0.900	-0.436	1.000			
	2	-0.900	-0.436	1.000	0.000	-0.312	
Total loss					0.171	-0.234	

APPENDIX XXXI

Source code for the network with parallel configuration and 300 % loading and compensation location and value are 100% and 100 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging

basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0     0      0    0   0     0    0    0
         2   0    1       0.0   2.70  1.308   0   0     0    0    0
         3   0    1       0.0     0      0    0   0     0    0    0
         4   0    1       0.0     0      0    0   0     0    0    0];

%                                            Line code
%         Bus bus   R       X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   3   0.13306  0.07636  0.000045  1
          3   2   0.00000 -0.07636  0.000000  1
          1   4   0.13306  0.07636  0.000045  1
          4   2   0.00000 -0.07636  0.000000  1];

lfybus                     % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout       % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXXII

Simulation for the network with parallel configuration and 300 % loading and compensation location and value are 100% and 100 % respectively

Maximum Power Mismatch = 8.58733e-006
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	3.448	1.308	0.000
2	0.895	5.071	2.700	1.308	0.000	0.000	0.000
3	0.847	-2.744	0.000	0.000	0.000	0.000	0.000
4	0.847	-2.744	0.000	0.000	0.000	0.000	0.000
Total			2.700	1.308	3.448	1.308	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		3.448	1.308	3.687			
	3	1.724	0.654	1.844	0.374	0.214	
	4	1.724	0.654	1.844	0.374	0.214	
2		-2.700	-1.308	3.000			
	3	-1.350	-0.654	1.500	0.000	-0.215	
	4	-1.350	-0.654	1.500	0.000	-0.215	
3		0.000	0.000	0.000			
	1	-1.350	-0.439	1.420	0.374	0.214	
	2	1.350	0.439	1.420	0.000	-0.215	
4		0.000	0.000	0.000			
	1	-1.350	-0.439	1.420	0.374	0.214	
	2	1.350	0.439	1.420	0.000	-0.215	
Total loss					0.748	-0.000	

APPENDIX XXXIII

Source code for the network with parallel configuration and 300 % loading and compensation location and value are 100% and 0 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 0%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging


basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%         Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%         No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1    1    1.1     0.0      0      0    0   0     0    0    0
         2    0    1       0.0    2.70   1.308  0   0     0    0    0];


%                                            Line code
%          Bus bus   R       X       1/2 B    = 1 for lines
%          nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1    2   0.13306  0.07636  0.000045  1
          1    2   0.13306  0.07636  0.000045  1];


lfybus                    % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton    % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow    % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXXIV

Simulation for the network with parallel configuration and 300 % loading and compensation location and value are 100% and 0 % respectively

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 5.47511e-005
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	3.591	1.819	0.000
2	0.820	-1.021	2.700	1.308	0.000	0.000	0.000
Total			2.700	1.308	3.591	1.819	0.000

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		3.591	1.819	4.025			
	2	1.796	0.910	2.013	0.446	0.256	
	2	1.796	0.910	2.013	0.446	0.256	
2		-2.700	-1.308	3.000			
	1	-1.350	-0.654	1.500	0.446	0.256	
	1	-1.350	-0.654	1.500	0.446	0.256	
Total loss					0.891	0.511	

APPENDIX XXXV

Source code for the network with parallel configuration

and compensation location and value are 100% and 1000 % respectively

```
%clear
%       Name    : Muhammad Azizi bin Mohd Wahidi
%       Title   : Analysis on Losses Reduction with Series Capacitor
%                 Compensation in Distribution Network
%       SV      : IR Mohd Faris bin Abdullah
%       Case    : Compensation's location at 100 km
%                 Value of compensation is 100%

%Base power = 1 MVA , Base voltage = 11 kV , Base impedance = 121 ohm
%Line resistance = 0.161 ohm/km, Line reactance = i0.0924 ohm/km , Line capacitance = 0.35 uF/km
%Capacitor compensation = 100% , Distance = 100km , PF = 0.9 lagging

basemva = 1;  accuracy = 0.0001; accel = 1.6;  maxiter = 60;

%        Bus Bus  Voltage Angle   ---Load---- -----Generator-----Injected
%        No  code Mag.    Degree  MW    Mvar  MW  Mvar Qmin Qmax Mvar
busdata=[1   1    1.1     0.0      0      0    0   0    0    0    0
         2   0    1       0.0    0.90  0.436   0   0    0    0    0
         3   0    1       0.0      0      0    0   0    0    0    0
         4   0    1       0.0      0      0    0   0    0    0    0];


%                                            Line code
%         Bus bus   R       X       1/2 B    = 1 for lines
%         nl  nr  p.u.     p.u.     p.u.     >1 or<1 tr. tap at bus nl
linedata=[1   3   0.13306  0.07636  0.000045  1
          3   2   0.00000 -0.76360  0.000000  1
          1   4   0.13306  0.07636  0.000045  1
          4   2   0.00000 -0.76360  0.000000  1];

lfybus                  % Forms the bus admittance matrix
%lfgauss      % Power flow solution by Newton-Raphson method
lfnewton     % Power flow solution by Newton-Raphson method
%decouple     % Power flow solution by Newton-Raphson method
busout        % Prints the power flow solution on the screen
lineflow   % Computes and displays the line flow and losses
% (b) Comment lfgauss and uncomment lfnewton
% (c) Comment lfgauss and lfnewton and uncomment decouple
```

APPENDIX XXXVI

Simulation for the network with parallel configuration
and compensation location and value are 100% and 1000 % respectively

Maximum Power Mismatch = 3.63061e-005
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.100	0.000	0.000	0.000	0.951	0.171	0.000
2	1.138	15.676	0.900	0.436	0.000	0.000	0.000
3	1.037	-1.255	0.000	0.000	0.000	0.000	0.000
4	1.037	-1.255	0.000	0.000	0.000	0.000	0.000
Total			0.900	0.436	0.951	0.171	0.000

Line Flow and Losses

--Line-- from	to	Power at bus & line flow MW	Mvar	MVA	--Line loss-- MW	Mvar	Transformer tap
1		0.951	0.171	0.967			
	3	0.476	0.085	0.483	0.026	0.015	
	4	0.476	0.085	0.483	0.026	0.015	
2		-0.900	-0.436	1.000			
	3	-0.450	-0.218	0.500	0.000	-0.147	
	4	-0.450	-0.218	0.500	0.000	-0.147	
3		0.000	0.000	0.000			
	1	-0.450	-0.071	0.456	0.026	0.015	
	2	0.450	0.071	0.456	0.000	-0.147	
4		0.000	0.000	0.000			
	1	-0.450	-0.071	0.456	0.026	0.015	
	2	0.450	0.071	0.456	0.000	-0.147	
Total loss					0.051	-0.266	

APPENDIX XXXVII

Gantt chart of the project (Final Year Project 1)

SECTION	DESCRIPTION	WEEK NUMBER													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
STUDY	Literature review on the title														
DOCUMENTATION	Preliminary report														
SOFTWARE	Identify the software														
HARDWARE	Identify the lab modeling														
DOCUMENTATION	Progress Report														
SOFTWARE	Run some examples and design a circuit														
SOFTWARE	Find the result (simulation)														
PRESENTATION	Prepare for seminar														
DOCUMENTATION	Prepare a draft report														
DOCUMENTATION	Compile all works (final report)														

APPENDIX XXXVIII

Gantt chart of the project (Final Year Project 2)

SECTION	DESCRIPTION	WEEK NUMBER													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
STUDY	Literature review on the title	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SOFTWARE	New result on previous cases	■	■	■											
DOCUMENTATION	Prepare the progress report 1		■	■	■										
SOFTWARE	Add more cases for testing			■	■	■	■	■							
DOCUMENTATION	Prepare the progress report 2						■	■	■						
SOFTWARE	Identify the solution							■	■	■	■	■			
STUDY	Problem in the application									■	■	■			
DOCUMENTATION	Prepare a poster for ElectEx											■	■		
DOCUMENTATION	Prepare a draft report										■	■	■		
DOCUMENTATION	Prepare a technical report												■	■	
PRESENTATION	Oral presentation										■	■			■
DOCUMENTATION	Prepare the final report								■	■			■		■