Reconfiguration and Capacitor Placement in Najaf Distribution Networks Sector (design study)

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ABSTRACT

As a result of the urban expansion in cities and the increase in demand for electric power, as well as the significant expansion that occurred in the power distribution systems, therefore, the redesign of power distribution systems and networks is considered one of the important matters to keep pace with developments.

Designing for distribution systems simulates and analyzes how electrical distribution systems behave under various operation scenarios. The analysis offers insight into the current system and helps to create a short-term or long-term growth strategy that will direct system expansion & future investments required for greater network performance.

This study's target is to design the Al Jamiea distribution system (11 kV) in Najaf in Iraq using the effective and powerful CYM_Dist. software as a simulation and analysis tool.

By sequentially reconfiguring the network and inserting capacitors in the right places and at the right sizes, the planning strategy put forth in this thesis aims to achieve the network's ideal working conditions. Decreasing losses, enhancing voltage profile, and reducing overload for equipment of the networks like transformers and cables all contribute to the network's peak performance. Designing a distribution system, using CYM_Dist program, reconfiguring a network, placing capacitors, and minimizing losses are some of the related terms.

1. PREFACE

The target of distribution system designing is to optimize voltage profile, decrease line losses, account for yearly load increases throughout the designing period, and promote network dependability. Due to larger currents and lower voltage levels, distribution systems experience a substantial amount of power loss; nevertheless, this loss can be mitigate rather than abolished, according to Satish (2021). The method of reconfiguring the network and the method of adding shunt capacitors are the two main ways to reduce losses in the network. Network reconfiguration is the process of changing the open/closed condition of switches that are typically close (for sectionalizing) and ordinarily open (for tying) in distribution systems. Distribution network performance may be considerably enhance by installing shunt capacitors in the proper location and size.

Literature Review:

Pradeep Kumar et al. (2011) [Pradeep Kumar, Asheesh K. Singh and Nitin Singh 2011], provided a comparison of the loss sensitivity technique (method-1) and the bus sensitivity method as two sensitivity-based solutions to the optimal capacitor positioning snag (method-2). Utilizing particle swarm optimization, capacitor sizing (PSO). The efficacy of these two approach evaluated based on the value of active losses & voltage profile of a bus network following proper capacitor position.

Cristinel and Rajesh (2017) [Cristinel Ababei and Rajesh Kavasseri 2017**]**, designed an effective heuristic technique to address the loss reduction issue with distribution system reconfiguration. Minimum Cost Maximum Flow (MCMF) problem is use to formulate the issue of locating additional branch exchanges.

Pradeep Kumar (2011) [Pradeep Kumar, Asheesh K. Singh and Nitin Singh 2011**]**, provided a comparison of the loss sensitivity technique (method-1) and the bus sensitivity method as two sensitivity-based solutions to the optimal capacitor position snag (method-2). Utilizing particle swarm optimization, capacitor sizing (PSO). On the basic of the active losses and voltage profile of the bus systems following appropriate capacitor positioning, the effectiveness of these two strategies compared

Zidan and El-Saadany (2018) [E. F. El-Saadany and Aboelsood Zidan], There is a useful method for reconfiguring the balanced and unbalanced radial distribution networks connected to the DG units. Al-Saadany and Zidan published it.The suggested method begins with mesh networks by turning off all tie switches. By opening one key per loop within the operating limits of the system, after which the radial system of the system restored.

Khodr et al. (2016) [H. M. Khodr, Zita A. Vale and Carlos Ramos 2016**]**, developed a method for figuring out where and how big switching and fixed shunt capacitors should be in radial distribution systems.

Neelima and Subramanyam (2015) [Neelima, P. S. Subramanyam 2015**]**, provided a comparison of the loss sensitivity technique (method-1) and the bus sensitivity method as two sensitivity-based solutions to the optimal capacitor placement problem (method-2). Capacitor sizing using particle swarm optimization (PSO).

2. The Suggestion techniques

The suggested designing approach consists of three main parts included demand growth and installation of new consumers as follow:

Load allocation, optimal network reconfiguration and Reactive power adjustment for potential bus candidates to stop violating operational constraints and we can explain the above:

➢ This work makes use of the linked kVA load allocation approach offered by the CYM-Dist. software, that divides the substation load requirements (supplied in amps every phase by users) for the feeder in accordance with the transformers connection of the distribution (the value of KVA).
➢ Networks reconfiguration: Switched statuses serve as the control variables in the systems reconfiguration problems. The statuses of switches are change between two magnitude, such as 1 and 0 for close, open represently, to achieve a variety of topologies. The network reconfiguration issue's objective is to reduce energy losses that has the following mathematical expression: 2012, Manju et al.

The above topic is subject to several important criteria or restrictions, which are as follows:

✦ **Radial network (restriction):** According to this, distribution systems cannot include loops but every load bus must be served by a separate substation.

✦ **Power source capacity (restriction):** The maximum capacity of the related power source cannot be exceeds by the combined loads of a particular partial network where the value of P and Q to the load should be less than the maximum and minimum value of power source.

✦ **Voltage restriction**: the value of the voltage for each bus in the system is about in the range not less the minimum value or greater than the maximum value of the voltage to ensure sustaining the power quality level of the system.

2.1 The reconfiguration technique:

The switches are then open one at a time to close the loops. The power-flow software in CYM_Dist used to calculate the opening condition, which predicated on the smallest overall power loss rise. In Flavio et al., 2005, the two steps of this approach shown.

2.2 The ideal spot for a capacitor and its size

In order to find the ideal shunt capacitor value and position in a radial distribution system, the issue is set up to minimize ohmic losses while accounting for the capacitor's costs. Simultaneously time, limitations on the electricity system limit the options. According to Hector (2013), the values of capacitor banks determined by standard value that causes the set of solutions to be separate. For the sake of simplification, the capacitor installed in the distributed system's operating & repair costs not taken into account.

The CYM_Dist program contains a technique for placing capacitors that conducts single-topic optimization (either P_{loss} or V).

The Limitations are the additional aspect of the optimization issue that need definition along with the objective function. The dedicate distribution load flow software that estimates losses is responsible for maintaining the line flow restrictions. These limitations are take into account in this research:

1. Bus Voltage Limitation: During the optimization phase, the value of the bus voltage must be keep within allowable operating boundaries, where the rms magnitude of bus voltage (i_{th})load should be less than from maximum value and greater than from minimum magnitude of bus voltage.

2. Power-Conservation Limits: Over the entire distribution network, the algebraic total of (incoming & exiting) power, within it line losses, should equal zero.

$P_G - \sum_{i=1}^{n} P_D - P_L = 0$……………………………………………………………………………1

P_G: generated power P_D: Power demand P_L: overall power losses

3. The magnitude of line current where the magnitude of the current should be less than the magnitude of the line current (rated).

4. The restriction on the No. & size of acceptable shunt capacitors **:** The number of added capacitors expressing the formula must be specified, where the value of kvar is getting by the capacitor bank in the network should less than the magnitude of total reactive power are needed from the selected network as shown follow:

$\sum_{i=1}^{m} Q_c \leq Q_t$ ……………………………………………………………………………2

The best capacitor sizes and locations for this method are those that min. the target function, satisfies limitations, & satisfy equation for a single capacitor positioned at the correct bus.

3. Sweep load flow (Forward/Backward)

Load flow in a distribution system is subject to physical rules including Kirchhoff laws and Ohms laws, which were incorporate into the design process' restrictions. The backward-forward sweep technique, which consists of two stages, it is used in radial distribution systems where it operates in a repetitive system to solve load flow equations. The forward sweep, that updates the value of voltage using calculations of voltage drop & the reverse swept, that updates the value of currents using Kirchhoff's Current Law (KCL). The current injected into each branch is calculate using the backward sweep as a function of the end bus voltages. The voltages are update while a current summation is carrying out in the network. [Milad Askari Hashemabadi , , Marjan Tavakoli, Farzaneh Ostovar and Mahdi Mozaffari Legha, journal].

4. Energy losses cost

Using CYM-Dist. built-in loss factor algorithm, the annual cost of system losses is determined (equation 2.23). The loss factor expresses the actual power loss over a certain time and under a specified loading situation. The load factor affects the loss factor (LDF)

$Loss\ Factor = A \times LDF + (1 - A) \times LDF$……………………………………………3

Where: In the eq. (2.23) a constant A =0.15 is given occasionally & use for the distribution system [Meghana Mukerji 2016].

After a load flow simulation, the yearly cost of active power losses is calculate using the empirical formula shown below [Zainul A. Jaffery, Anwar Shahzad Siddiqui, Md Sarwar and Imran Ahmad Quadri 2018].

$\text{Cost} = P_{\text{loss max.}} \times L_{\text{fls}} \times T \times CF$ ……………………………………………4

Where:

$P_{loss\ max}$	Loss of power at max. demand power (kW)
L_{fls}	Factor of loss power -Time Separator (h)
T	Time lapse (h)
CF	Tariff cost ($)

The yearly cost formula will be [G. V. Siva Krishna Rao and P. Divya 2018]:

$$Cost = P_{loss\ max.} \times L_{fls} \times T \times CF + \sum_{c=1}^{j} K_c Q_c \quad \text{.....5}$$

Where:

Q_c	size of capacitor (kvar)
k	Capacitor cost according ($/kvar)
c	1, 2… j is the selected buses.

5. CYM_DIS PROGRAM

5.1 Loads in CYM_Dist program

1-Distributed loads, which are frequently represented by the size of the distribution transformers, are the normal demand loads in the system. In most cases, distributed load in a model describes an accurate average of system loads.

2-Spot loads frequently reflect big, predictable loads, such as those from industrial clients, who have correct information and would not be representing by scattered loads. Spot load types are typically used in Iraq to describe loads.

5.2 CYM_DIST database

The primary part in the modeling process is to gather inter data required. Once the data have been aggregate and process, they are then loaded into or imported from program package into CYM_Dist to produce the distribution network model, with an single line diagram created by automated mothed.

The distribution network design processing requires several different types of simulation study, but only one model has to be create [Owen Schelenz and Kathleen O'Brien 2019].

5.3 Analysis feature types in CYM_Dist

The iterative software employs the backward-forward sweep technique, sometimes referred to as the ladders approach. Instead of calculating the load flow, CYM_Dist, which calculates the branch currents. Numerous load flow techniques based on the backward/forward sweep method exist. Power flow ladder associative approach is use by the program to analysis the system [Shah M. Mehryoon 2009].

5.3.1 Allocation techniques of loads

The four load allocation techniques in CYM_Dist in this thesis.

5.3.2 Power flow and CYM_Dist

The user can find both unbalanced & balanced circuit solution methods in the CYME Load Flow module. The user can select from the following the calculation techniques for balanced systems:

I.Voltage Drop that Require apply application CYM_Dist.

Ii.Fast Decoupled that Require apply application CYMFLOW.

Iii.Full Newton-Raphson that Require apply application CYMFLOW.

Iv.Gauss-Seidel that Require apply application CYMFLOW.

5.3.3 Feature switching optimization in CYM_Dist_SOM

The CYME Power Engineering Analysis Software now includes a Switching Optimization module to help distribution engineers to find the best network structures. By recommending new places or new switching plans for existing devices, the modules can decide where the tie points should be place in order to accomplish one of the following aims, [http://www.cyme.com/software/cymdistsom/B1170-13013-Switching Optimization.pdf].

6. The SUGGESTED DESIGNING METHODOLOGY

The flowchart in fig. (6.1) Serves as an illustration of the suggested planning process in this thesis.

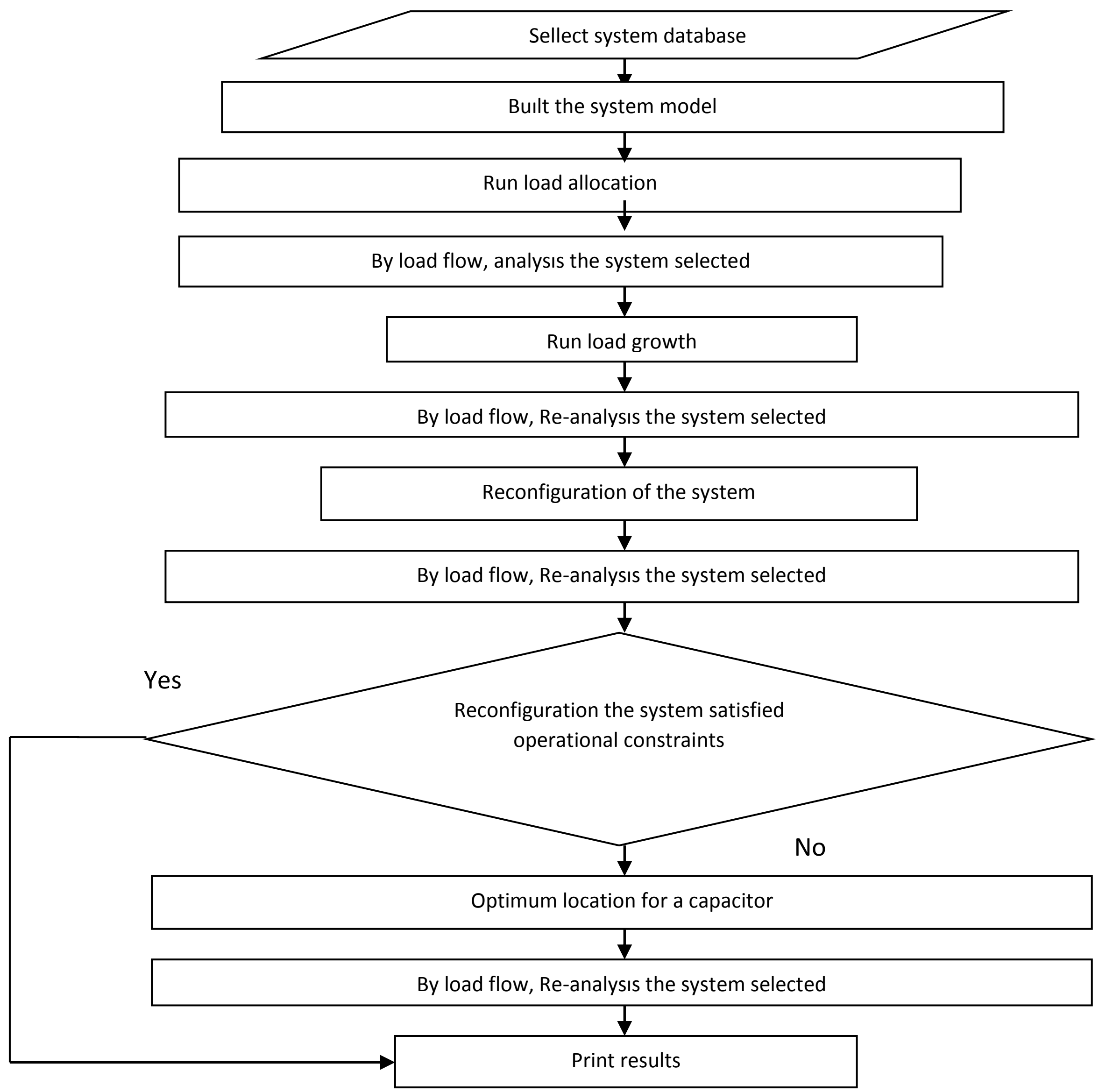

Fig. 6.1 Flowchart representing the suggesting designing network by CYM_Dist program

7. STADY AND DISSCUSION OF THE CASSES

Al Jamiea distribution system was select as the distribution system to use to implement the suggested strategy in Najaf city, where feed from two 33kV feeders that are the Al-North-Najaf and Al-kufa power stations (132/33 kV), which have a combined capacity of (2*31.5 MVA), supply the Al- Jamiea (33/11 kV) substation. A broad area with a mixture of residential, commercial, industrial, and trading loads is served by fourteen (11 kV) feeders that leave the Al- Jamiea substation. Due to the impossibility to acquire further information, only four feeders are take into consideration in this work.

7.1 Third case: Al_ Jamiea station feed Al_Jamiea distribution network

Al_Jamiea distribution network is a part of the power systems in Najaf network, that is the rated voltage is 11 kV, base MVA = 100, & frequency of 50 Hz including (150) line sections, (146) buses, & six tie switches. Figure (7.1) depicts the Al Jamiea system's schematic diagram created by CYM_Dist (Initial configuration). Approximately 94% of the demand for the Al Jamiea feeders is residential, while 6% is commercial.

According to the table 7.1, the load duration curve is separate into three loading rates (high, medium, & low) during the years of the planned period.

Table 7.1 Load duration curve (Al_ Jamiea substation)

Percentage load (%)	Yearly time load (%)	Annual period (h)
100	33	2886
70	52	4549
40	15	1315

Al_ Jamiea system modeling based on the precise locations of each bus. In accordance with the Worldwide Positioning System, these dimensions obtained from the Iraqi Ministry of Electricity (GPS). The process of building the model in the program and giving an accurate description of the lengths used is done by entering the dimensions x and y in the program

A useful system from Najaf's distribution network was using to put the suggested strategy into practice. Four 11kV distribution feeders make up the system, which originates at Al-Jamiea station. The data of the systems is obtain from the Iraqi Ministry of Electricity (MOE).

In this study, various presumptions are taking before beginning:

1. When using the balance voltage iterative drop technique, the load flow iterations are limited to a maximum of 40, As for the amount of convergence error in the voltage value, it is adjusted by specifying it 0.01% as a maximum.

2. Cost of electrical energy according to the Iraqi Ministry of Electricity which is 0.1 USD/kWh (tariff cost).

3. The bus voltages (rms value) will be adjust beyond suitable tolerance border (5%) after employing both optimal system reconfiguration & capacitor location.

4. Decreasing losses (KW) for the peak demand load (average) and for the last year of designing horizon are the aim functions of the optimum system reconfiguration & capacitor location.

5. Harmonics' impact is disregards and the stability ignored in this thesis.

6. The power factor of each load is the same.

The load factor for the Al Najaf distribution network is 100%, while it is 65% used of the selected feeders in this work.the distribution of loads at each phase for all sectors is based on the value of the current as well as the power factor at the end of the feeder. In addition to the sizes of the transformers in the feeder (down distribution transformers with a conversion ratio of 11/0.4 and the type of delta-star).

Table 7.2a The Feeders current of Al_ Jamiea network

Feeder	Current at every phase(A)	Power factor per. (%)
Al_Jamiea_1	245	80
Al_Jamiea_2	205	80
Al_Jamiea_3	225	80
Al_Jamiea_4	175	80

Table 7.2b Al_ Jamiea network (Secondary transformer sizes)

Number of Spot load	Transformers sizes
2, 3, 6, 11, 26, 27, 30, 31, 32, 34, 36, 37, 40, 41, 43, 46, 48, 49, 50, 56, 59, 63, 64, 68, 69, 71, 78, 82, 85, 88, 89, 91, 94, 95, 96, 97, 107, 111, 112, 113, 115, 117, 118, 120, 121, 125, 128, 130, 132, 134, 149.	250 KVA
4, 7, 8, 9, 12, 13, 14, 18, 19, 20, 21, 22, 23, 25, 29, 35, 38, 54, 58, 60, 67, 73, 84, 87, 90, 92, 98, 101, 102, 105, 109, 110, 123, 126, 138, 142, 144, 150.	400KVA

From what mention above regarding the selected electrical network (Al_Jamiea) in the city of Najaf, initially we would describe the initial configuration of the network in the CYM_Dist. program, as shown in Figure (7.1).

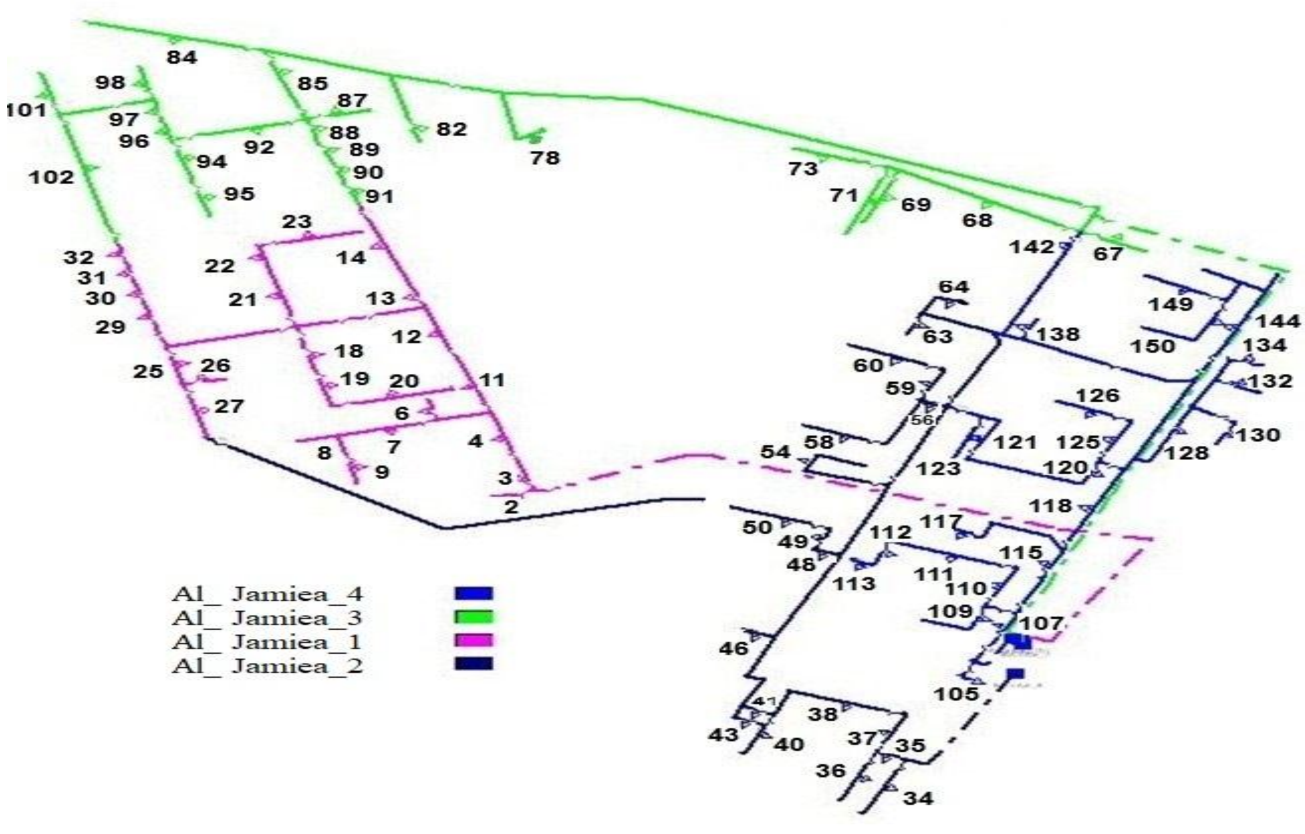

Fig. 7.1 Al_Jamiea network indicate no. of transformers (Initial configuration)

It is necessary to examine the load flow of the current network before implementing the short-term designing to it. Applying load growth study to the network allows for the examination of its resilience and effectiveness in the face of yearly load growth. Figure 7.2 illustrates how the network is evaluated using the percentage yearly load increase rate solely (household and commercial loads) over the upcoming 5 years (2021-2025).

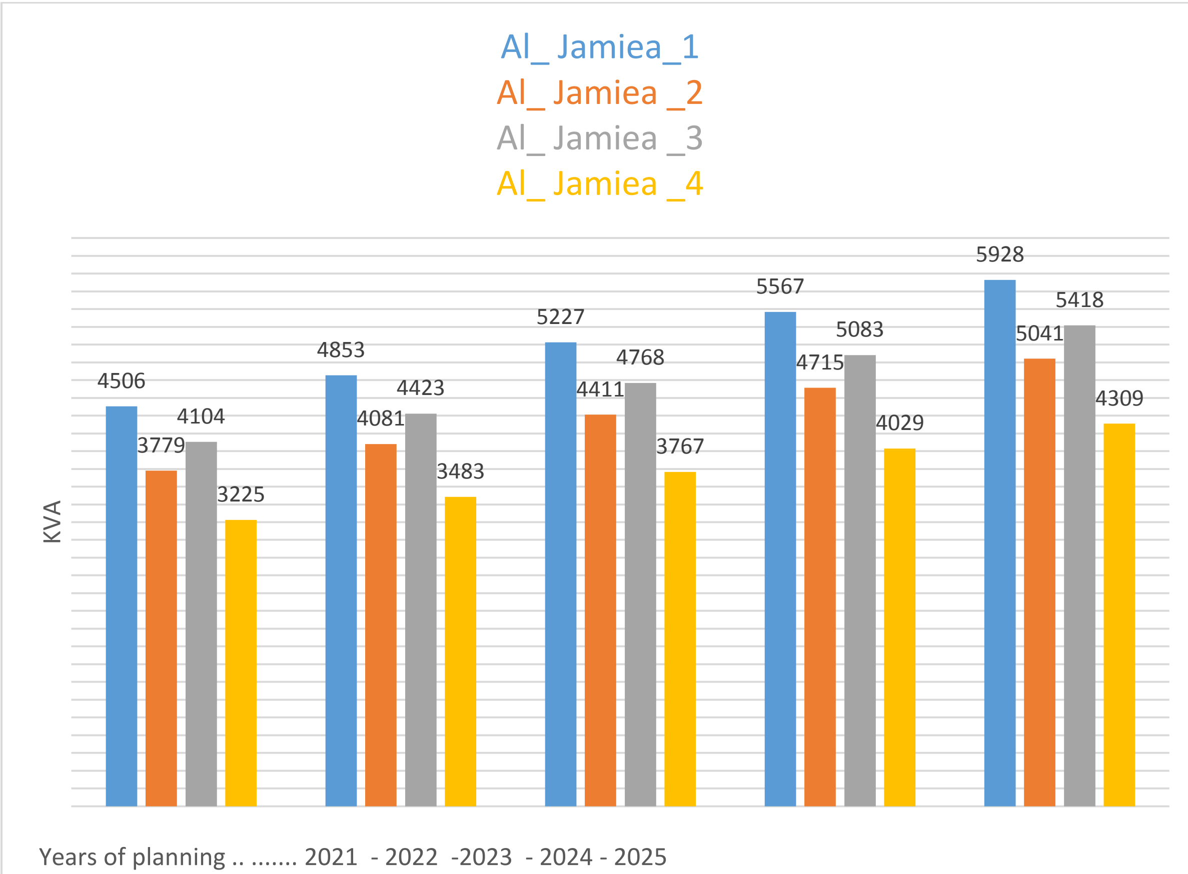

Fig. 7.2 Al_ Jamiea network (Load growthing feeders)

As seen in fig. (7.3), there are five portions that are operating under overload conditions (All estimates are for peak demand only and done for the last year of the planned period.)

Energy losses after load growth in the specified network and for all sources in 2021 were 271.04 kW, as demonstrated by the modeling results in table (7.4). The final power loss after reconfiguring the network to reduce losses and evenly distribute loads between feeders was 228.26 kW, and the overall decrease in power losses after reconfiguring the network was 42.78 kW (15.78% of its initial value). In fig. (7.3), the ideal setup displayed. As example for changing progress of switches in the feeder is that the action of the ID switch (S55) is open and for switch S142 is close.

Table 7.4 Al_ Jamiea network maximum demand load overview before and after load increase, after network reconfiguration, and after kvar adjustment

Jamiea _1		loading System	Total (adjusted value capacitor + capacitances of conductor	Network loosing	Power supply
Before loading growth	k.W.	3599.96	-----	50.98	3650.94
	kvar	2697.53	0+5.69	45.99	2737.83

2021	kVA	4499.28	----	69.54	4568.82
	Power Factor	0.801	----	0.702	0.801
After loading growth 2025	k.W.	4745.11	----	91.01	4836.22
	kvar	3554.48	0+5.66	80.97	3635.45
	kVA	5927.55	----	121.55	6049.1
	Power Factor	0.801	----	0.74	0.8
After reconfiguration of Network	k.W.	4290.98	-----	69.48	4360.46
	kvar	3216.07	0+5.48	62.01	3272.6
	kVA	5361.98	----	94.01	5455.99
	Power Factor	0.801	----	0.74	0.8
After compensation kvar	k.W.	4290.98	----	44.8	4335.78
	kvar	3215.07	3086.01+5.49	39.9	163.47
	kVA	5361.97	----	60.87	4339.53
	Power Factor	0.801	----	0.74	0.99

Jamiea _2		**loading System**	**Total (adjusted value capacitor + capacitances of conductor**	**Network loosing**	**Power supply**
Before loading growth 2021	k.W.	3024.88	-----	23.58	3048.46
	kvar	2264.79	0 + 2.69	22.96	2287.75
	kVA	3778.80	-----	33.23	3812.03
	Power Factor	0.8	-----	0.68	0.8
After loading growth 2025	kW	4036.02	-----	41.91	4077.93
	kvar	3019.98	0 + 2.68	42.93	3062.91
	kVA	5042.02	-----	61.02	5103.04
	Power Factor	0.8	-----	0.69	0.8
After reconfiguration of Network	kW	4118.01	-----	51.91	4169.92
	kvar	3082.85	0 + 2.64	55.01	3137.86
	kVA	5142.97	-----	76.01	5218.98
	Power Factor	0.8	-----	0.69	0.8
After compensation kvar	kW	4118.01	-----	33.94	4152.97
	kvar	3083.56	2204.31 + 2.65	35.54	911.84
	kVA	5144.10	-----	48.99	4249.87
	Power Factor	0.8	-----	0.691	0.96

Jamiea _3		Loading System	Total (adjusted value capacitor + capacitances of conductor	Network loosing	Power supply
Before loading growth 2021	k.W.	3286.64	----	65.93	3352.57
	kvar	2457.61	0 ±6.45	63.81	2514.96
	kVA	4105.02	----	93.01	4198.03
	Power Factor	0.801	----	0.722	0.802
After loading growth 2025	kW	4338.9	----	118.01	4456.91
	kvar	3245.02	0 ±6.43	112.55	3350.9
	kVA	5418.91	---	163.1	5582.01
	Power Factor	0.801	----	0.721	0.802
After reconfiguration of Network	kW	4123.01	----	75.82	4198.83
	kvar	3084.02	0 ± 6.62	69.30	3145.89
	kVA	5148.95	----	103.01	5251.96
	Power Factor	0.801	----	0.731	0.802
After compensation kvar	kW	4124.94	----	49.91	4174.85
	kvar	3086.01	2635.49 + 6.66	45.76	489.38
	kVA	5151.79	----	67.801	4204.02
	Power Factor	0.801	----	0.73	0.989

Jamiea _4		Loading System	Total (adjusted value capacitor + capacitances of conductor	Network loosing	Power supply
Before loading growth 2021	k.W.	2581.01	----	10.8	2591.81
	kvar	1934.28	0 + 2.33	11.43	1944.02
	kVA	3225.11	----	15.721	3240.82
	Power Factor	0.801	----	0.68	0.802
After loading growth 2025	k.W.	3446.97	----	20.01	3466.98
	kvar	2584.43	0 + 2.32	20.5	2602.61
	kVA	4309.03	----	29.02	4338.05
	Power Factor	0.801	-----	0.68	0.802
After reconfiguration of Network	k.W.	4039.01	----	31.05	4070.06
	kvar	3026.58	0 + 2.4	32.7	3056.87
	kVA	5047.03	----	45.04	5092.07
	Power Factor	0.801	----	0.68	0.802

After compensation kvar	k.W.	4044.06	----	21.06	4065.12
	kvar	3030.32	2224.38 + 2.41	22.12	825.64
	kVA	5053.10	----	30.40	4147.39
	Power Factor	0.8	----	0.68	0.981

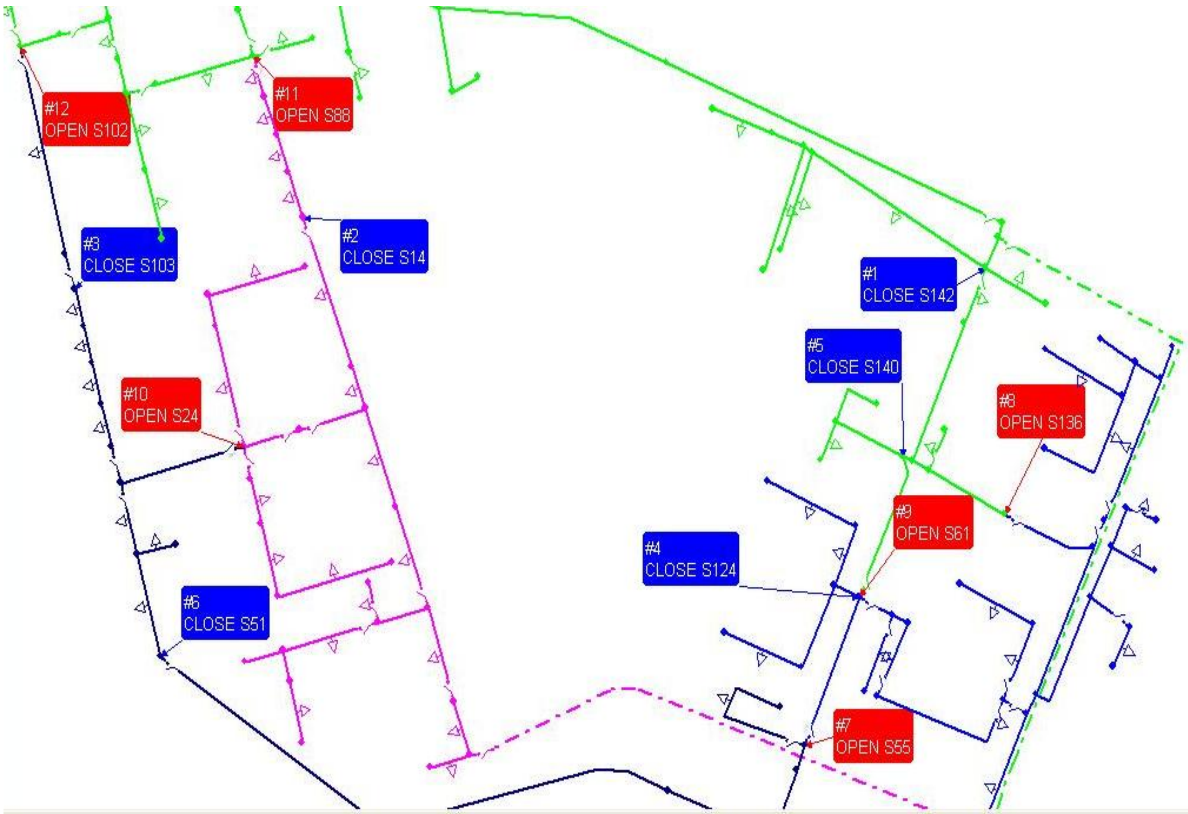

Fig. (7.3) Al_ Jamiea network (Optimal configuration)

Clearly that the system is still working in abnormal conditions after implementing the load flow (five parts are working under overloaded conditions, as illustrated in figure (7.4). Reactive power compensation may therefore be use to address this issue by boosting the sizes of these feeders. Figure (7.5) depicts the ideal capacitor installation sites, while table (7.6) lists the ideal capacitor placement and dimensions. The loading summary of load growth (before and after), network reconfiguration, and the value of kvar correction is shown in Table (7.4). The overall summary of data is show in Table (7.7) for feeders in the network. Figure (7.6) displays the overall network losses for feeders (KW).

Table (7.6) Al_ Jamiea Network's ideal capacitor placement and sizing for cases of maximum load (100 percent loading)

Al_ Jamiea_1: P.F 0.989 (corrected) ,capacitor voltage 11 kv

Node	Total magnitude of kvar	Decreased of Loosing (kilowatt)
14	950	7.65
16	950	11.41
4	1360	4.85
Total	3250	23.91

Al_ Jamiea_2: P.F 0.969(corrected) , capacitor voltage 11 kv

Node	Total magnitude of kvar	Decreased of Loosing (kilowatt)
39	925	3.12
49	465	4.2
29	925	10.88
Total	2315	18.2

Al_ Jamiea_3: P.F 0.988 (corrected) , capacitor voltage 11 kv

Node	Total magnitude of kvar	Decreased of Loosing (kilowatt)
66	1375	5.75
96	475	9.6
85	850	10.4
Total	2800	25.75

Al_ Jamiea_4: P.F 0.979(corrected) , capacitor voltage 11 kv

Node	Total magnitude of kvar	Decreased of Loosing (kilowatt)
115	925	1.85
56	925	5.54
119	425	2.47
Total	2275	9.86

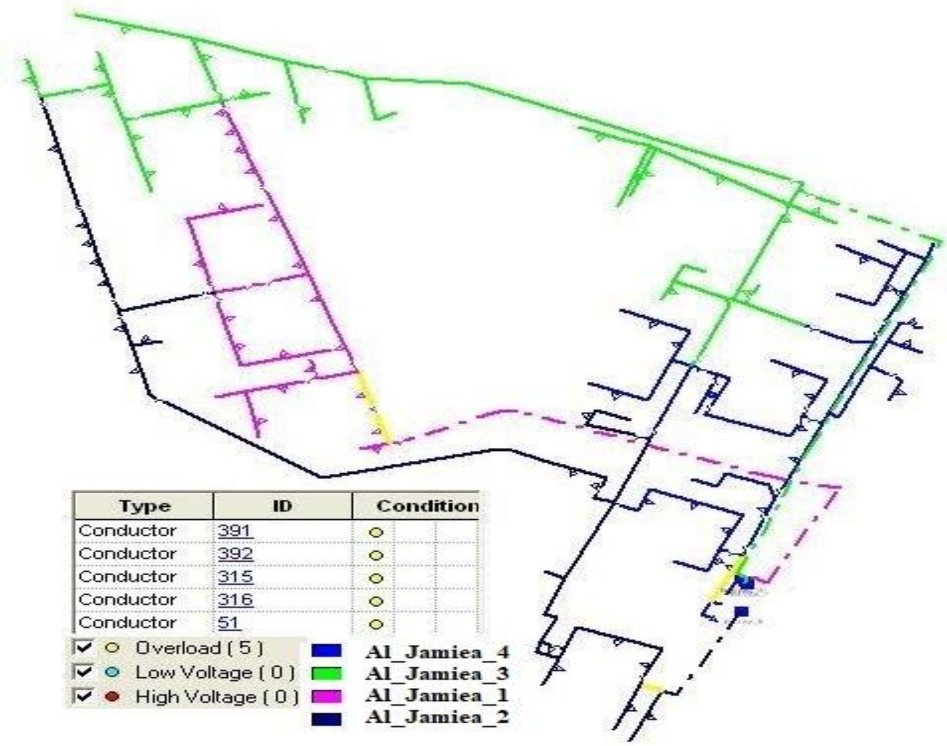

Fig. 7.4 Al_ Jamiea Network after application (reconfiguration system method) (with abnormal conditions)

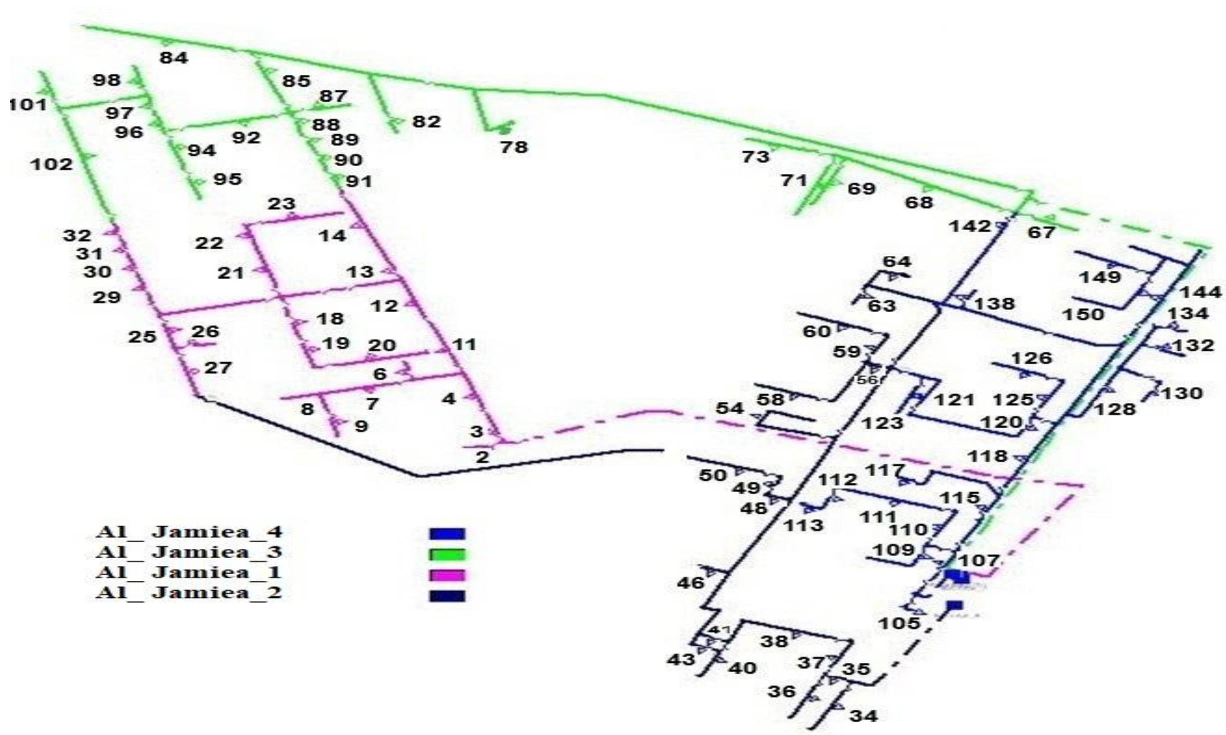

Fig. 7.5 Al_ Jamiea network (Optimal capacitor placement)

Table 7.7 Al_ Jamiea network (Summary of results by CYM_Dist)

Jamiea _1	Before growthing of load at 2021	After growthing of load at 2025	After System reconfiguration	After Compensation kvar
Voltage value (max.) per unit	1.0	1.0	1.0	1.0
Voltage value (min.) per unit	0.983	0.974	0.985	0.986
kW per unit phase (total active power)	17.28	30.23	23.3	14.97
Total Reactive power loss (kvar) per phase	15.6	27.23	20.59	13.29
power load per phase (Total kW)	1203	1582.5	1431	1431
load per phase (Total kvar)	900	1179	1071	1071
Total apparent power kVA load per phase (total value)	1501	1975	1788	1786

Table 7.7 continued

Jamiea _2	Before growthing of load at 2021	After growthing of load at 2025	After System reconfiguration	After Compensation kvar
Voltage value (max.) per unit	1.0	1.0	1.0	1.0
Voltage value (min.) per unit	0.988	0.982	0.974	0.986
Total Power loss (kW) per unit phase (active)	7.72	14.02	17.51	11.42
Total reactive power loss (kvar) per phase	7.92	14.42	18.20	11.79
power load per phase (Total kW)	1012.0	1351.2	1371.9	1371.9
load per phase (Total kvar)	758	1010	1027.8	1027.9
Total apparent power kVA load per phase (total value)	1265	1690	1714.9	1714.8

Table 7.7 continued

Jamiea _3	Before growthing of load at 2021	After growthing of load at 2025	After System reconfiguration	After Compensation kvar
Voltage value (max.) per unit	1.0	1.0	1.0	1.0
Voltage value (min.) per unit	0.973	0.964	0.973	0.982
Total Power loss (kW) per unit phase (active)	22.14	39.07	25.37	16.67
Total reactive power loss (kvar /phase)	21.30	37.49	23.11	15.30
power load per phase (Total kW)	1095.9	1448.01	1376.9	1376.8
load per phase (Total kvar)	820	1082	1030	1030
Total apparent power kVA load per phase (total value)	1369	1807	1720	1720

Table 7.7 continued

Jamiea _4	Before growthing of load at 2021	After growthing of load at 2025	After System reconfiguration	After Compensation kvar
Voltage value (max.) per unit	1.0	1.0	1.0	1.0
Voltage value (min.) per unit	0.994	0.992	0.988	0.994
Total Power loss (kW) per unit phase (active)	3.6	6.46	10.26	6.93
Total reactive power loss (kvar)per phase	3.81	6.84	10.92	7.40
power load per phase (Total kW)	862.2	1151.2	1351.1	1351.01
load per phase (Total kvar)	647	864	1013	1011
Total apparent power kVA load per phase (total value)	1075.8	1440	1687	1686.5

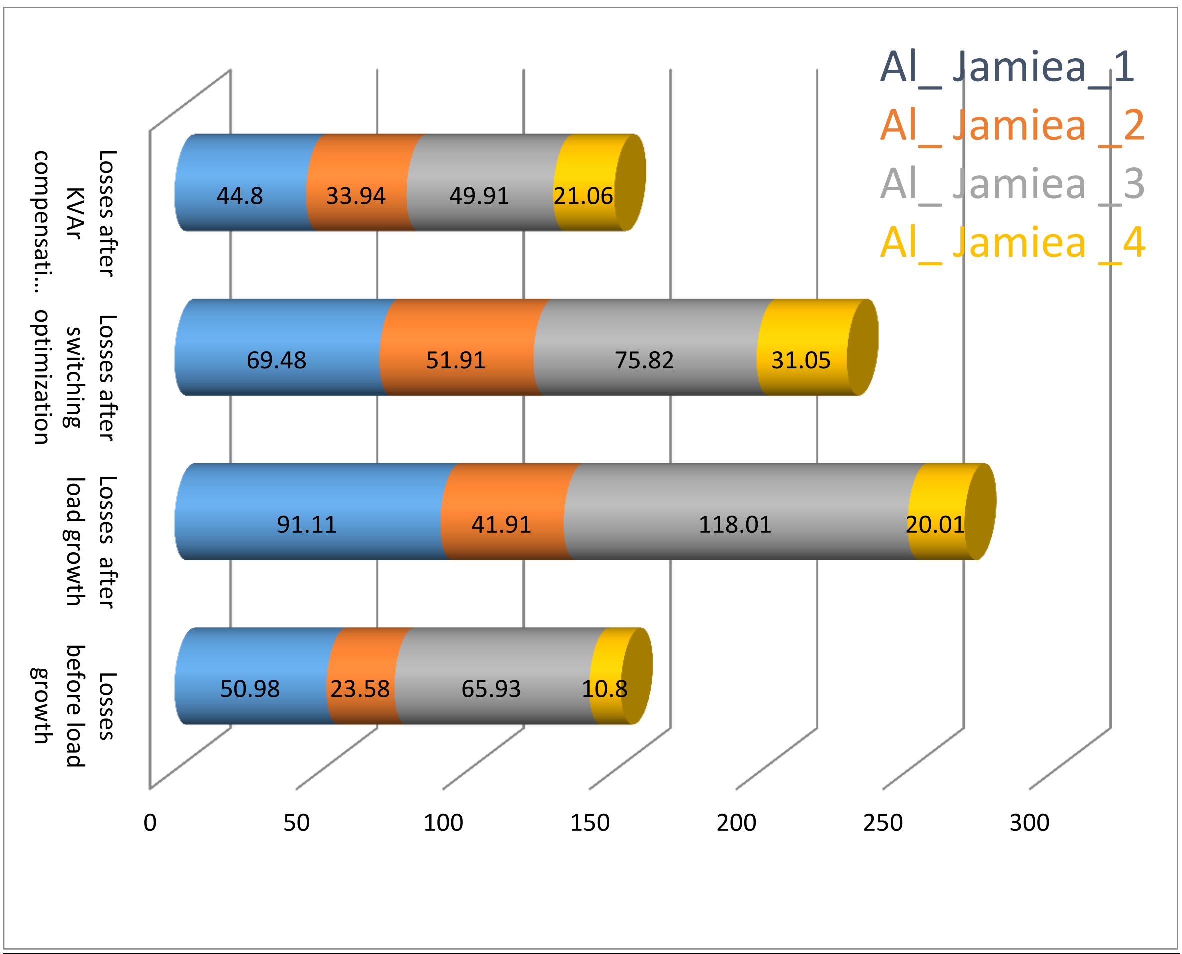

Fig. 7.6 Al_ Jamiea system kW losses

According to table (7.4), the total network power losses are 151.29, 269.36, 229.29, and 149.97 kW, respectively, before, after load rise, after system reconfiguration, and after kvar correction. Thus, 118.07 kW are save between the case with load increase and the case with kvar correction.

Table 7.8 shows the yearly costs of losses using equations (4) and (5); the overall net saving cost of the maximum demand is 32.45*10^3 $/year.

Table 7.8 Yearly cost of losses (Al_ Jamiea system) ($/year)

Feeder name	Feeder load factor (%)	Before growthing of load at 2021	After growthing of load at 2025	After System reconfiguration	After Compensation kvar
Jamiea _1	65	6.73	12.04	9.175	6.53
Jamiea _2	65	3.12	5.53	6.848	4.92
Jamiea _3	65	8.71	15.57	10.01	7.153
Jamiea _4	65	1.43	2.64	4.101	3.23
Total loss cost ($)		19.99	35.78	30.134	21.833

Fig. (7.7 a, b, c, and d) depict the bus voltage profiles of selected feeders of Al Jamiea's network.

1. before growthing of load
2. after growthing of load
3. after reconfiguration of the system.
4. 4. after capacitor positioning.

It is demonstrate that the total voltage values would drastically decrease within the defined limits after implementing load increase. By using the network reconfiguration approach, these values were improved, and they further improve after allocating capacitors to these feeds, bringing them closer to one p.u.

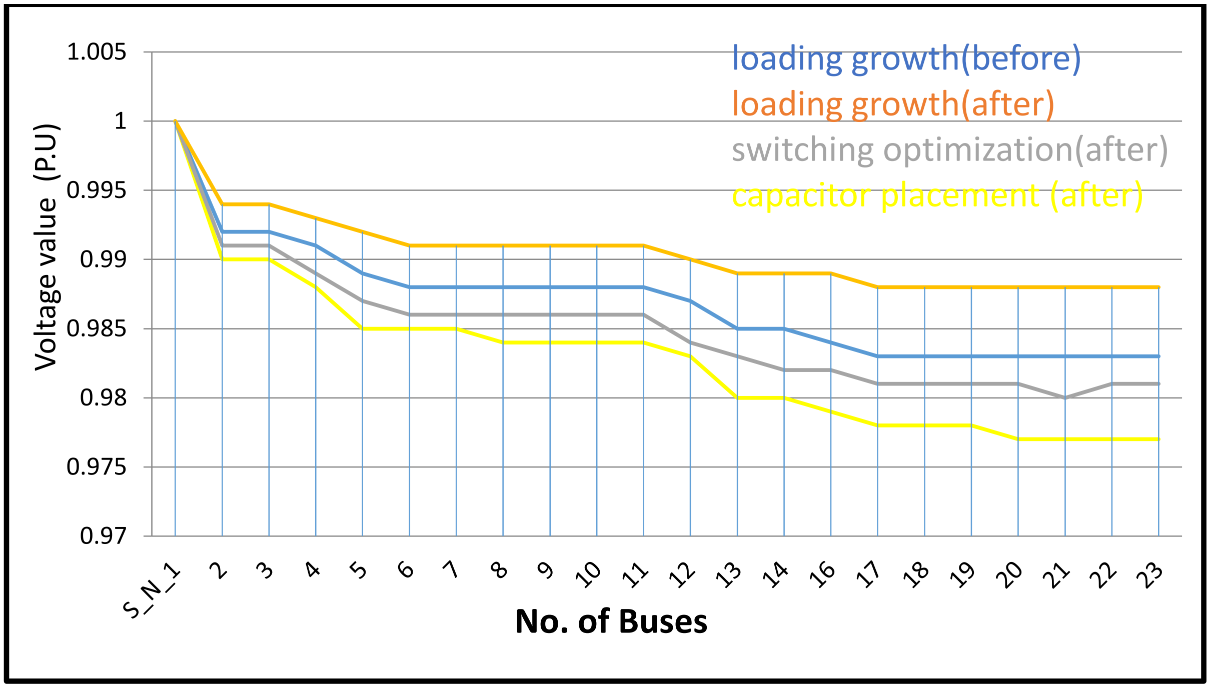

Fig. 7.7a Feeder Al_ Jamiea _1 (Voltage profile)

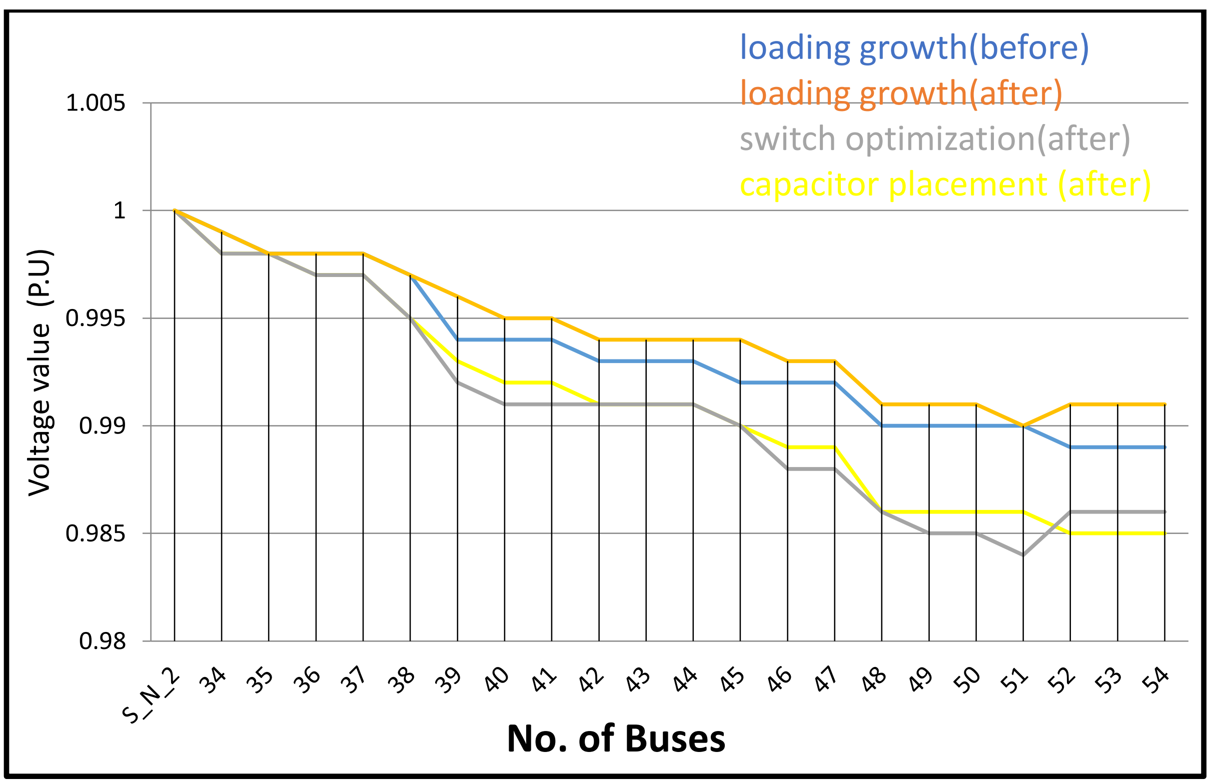

Fig. 7.7b Feeder Al_ Jamiea_2 (Voltage profile)

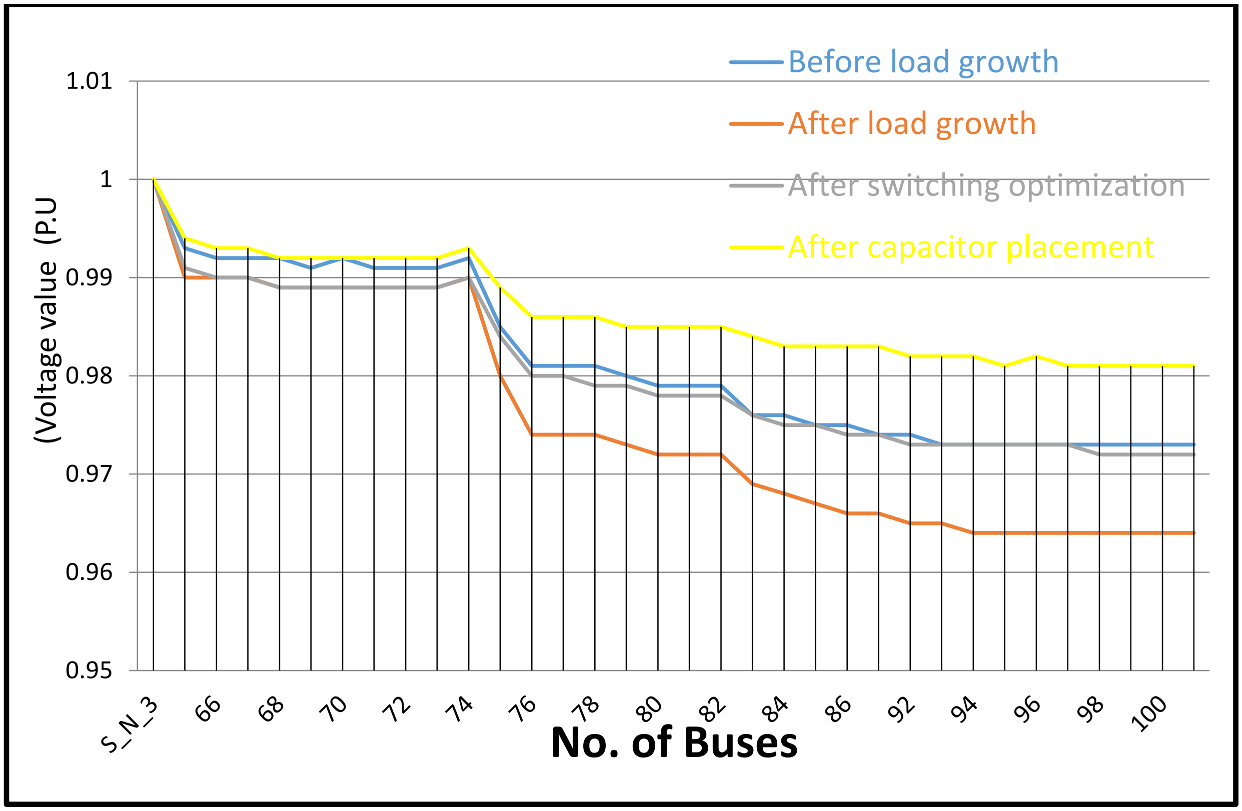

Fig. 7.7c Feeder Al_ Jamiea_3 (Voltage profile)

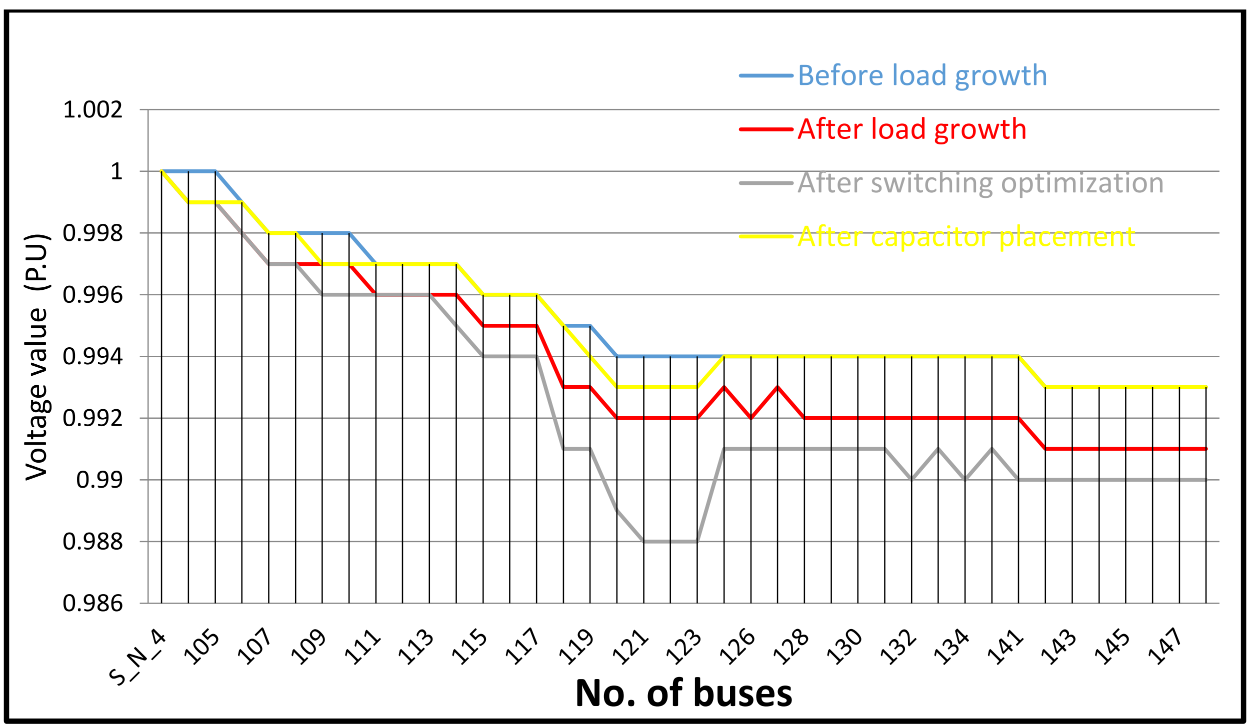

Fig. 7.7d Feeder Al_ Jamiea_4 (Voltage profile)

For Al_ Jamiea, Fig. (7.8) depicts the influence of the completely downstream kvar profile in relation to lengths. The longest route from the substation that feeds this system to bus 21 is 1 feeder of each segment. Figure (7.8a) considers the behavior before load increase.. Considered in Figure 7.8b is the behavior following load increase. Figures 7.8c and 7.8d depict the behavior following network reconfiguration & kvar correction, respectively.

At Section 1 (1319 m in length) has 914.3 downstream kvar per phase before adjusting; when load increases, this value increases to 1210 kvar/phase (above the max. value).After implementing system reconfiguration, the kVar/phase is then decrease to 1091. The kVar/phase increased to 54.5 at the end of the design process when the capacitors were install, and so on for the remaining portions. The total active & reactive power losses will be decrease since the capacitor-equipped parts serve as a source of reactive power. Each feeder's total P.F. has increased, as seen in table (7.4).

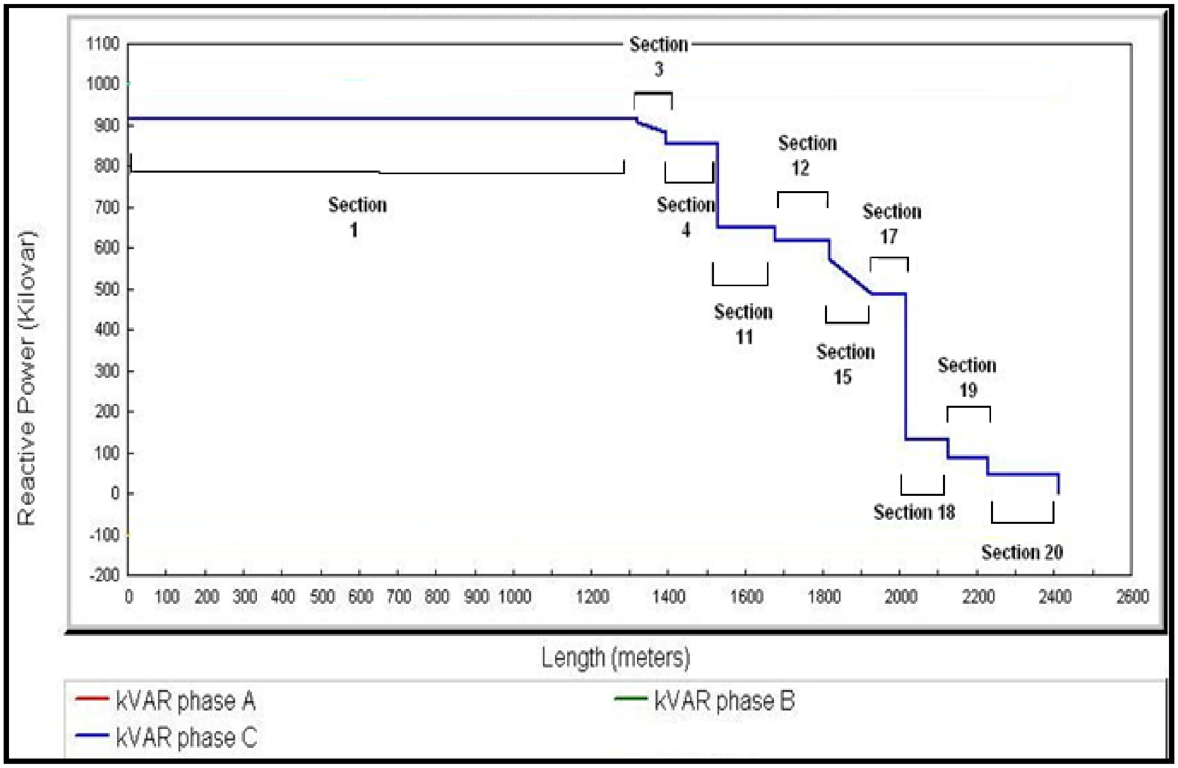

Fig. 7.8a Al_ Jamiea_1 before load growth (kvar profile)

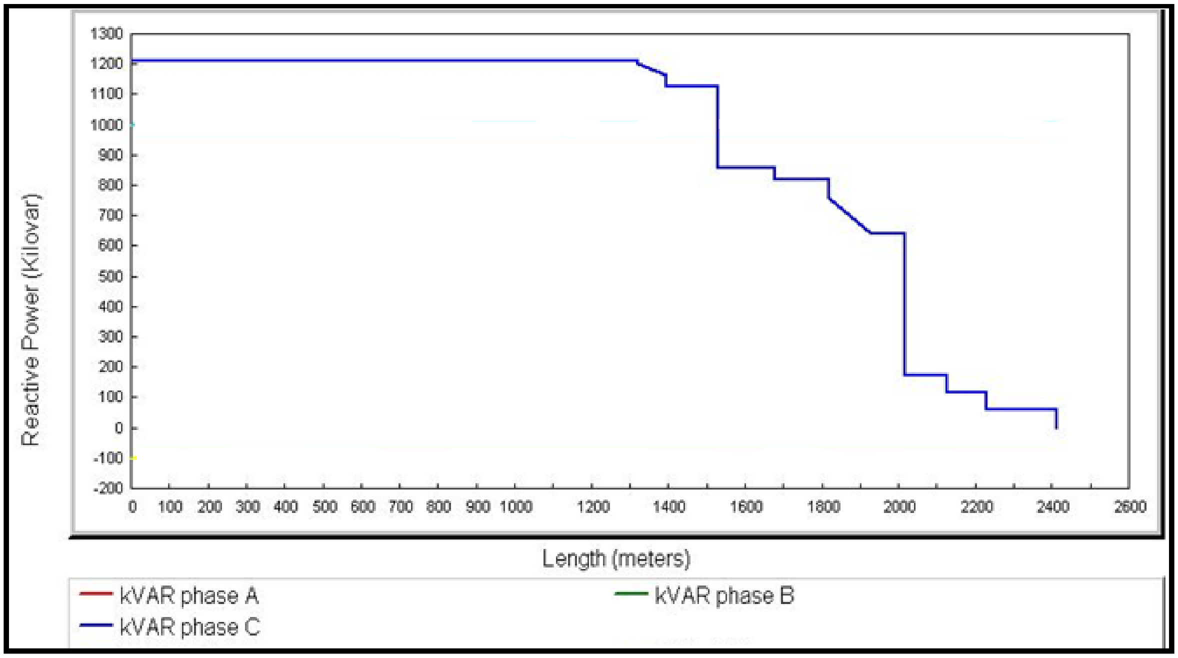

Fig. 7.8 b Al_ Jamiea_1 after load growth (kvar profile)

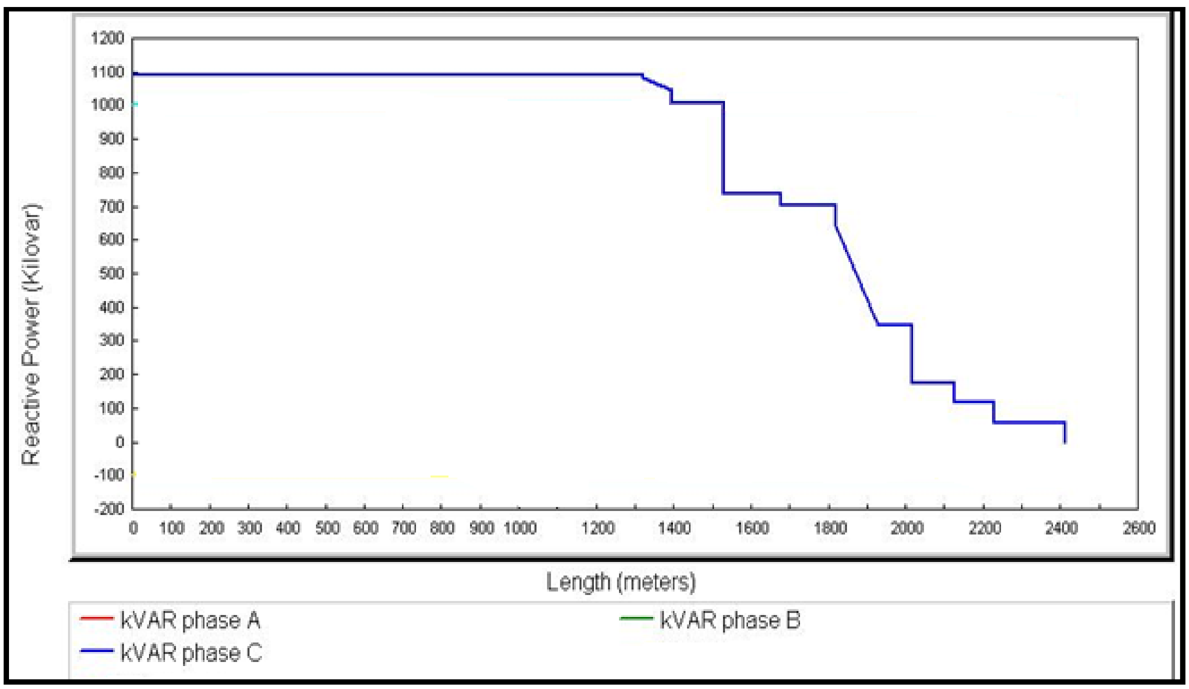

Fig. 7.8 b Al_ Jamiea_1 after load growth (kvar profile)

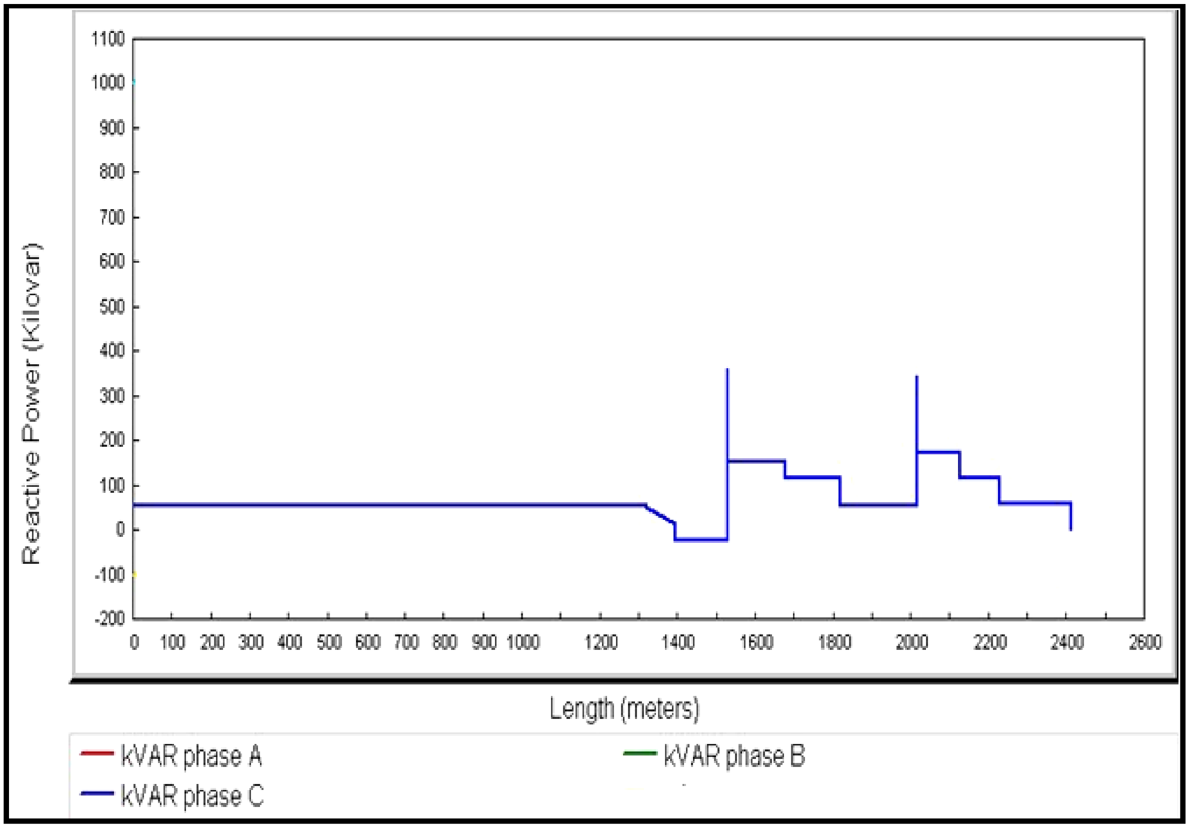

Fig 7.8 d Al_ Jamiea_1 after capacitor placement (kvar profile)

8. CONCLOSION OF WORK

The outcomes of 3 simulation processes performed when constructing distribution systems using the CYM_Dist program;

Load flow then network reconfiguration and capacitor optimal allocation.

The recommended method then verified and confirmed through application to typical distribution network with a perfect match of outcomes to those reported in the literature utilizing both optimum reconfiguration & capacitor positioning.

In addition, the results from designing in the Al_Jamiea distribution network in the Najaf city in Iraq by the CYM_Dist program show that the reduction in power losses after applying the proposed technique by use the reconfiguration of selected network in addition with optimal capacitor position.

The system's overall voltage profile has also enhanced, and it is now possible to see that the system is running normally with no restrictions being broken.

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