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DESIGN AND ANALYSIS OF 33 KV AND 11 KV ELECTRICAL NETWORKS FOR DISTRIBUTION SYSTEMS

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MAHER HUSSEIN MOSSA MOSSA

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By Maher Hussein Mossa MOSSA

January 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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ABSTRACT

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January 2023

Due to the massive growth in electrical energy consumption and the expansions put on distribution systems because of the enormous and rapid urban development, designing electrical distribution systems is currently; regarded as of the utmost importance in Iraq. The electrical system performs best when losses are minimized, the voltage profile is improved, and system component overload is reduced. This technique ensures redundancy and energy recovery in the electricity systems. This study suggests a design to attain the best network operating status by integrating network reconfiguration in synchronism with the insertion of capacitors of optimal sizing and locations. Because of the size of the separate non-linear configure problem, the vast number of variables, and the existence of objectives and conditions, this approach classify as such. The backward/forward load flow approach is used to get all scenarios' power dissipation and voltages on buses. The powerful and sophisticated CYM_Dist program is used to model distribution systems and conduct the necessary analysis in the proposed design of distribution systems. Many electrical enterprises worldwide, including the Iraqi Ministry of Electricity, employ the practical and effective analytical program CYM Dist. Using IEEE 33-bus and IEEE 34-bus test networks, respectively, the most effective ways for reconfiguring the network and placing capacitors are put to the test. Compared to earlier research referenced in the literature, the results exhibit great agreement. The project is being carried out on a real section of the Al-Jamiea 11kV, 145 bus, 4 feeders system in the Najaf city distribution system. The results have been obtained with minimal active power losses and an improved voltage profile.

2022, 100 pages

Keywords: Capacitor posting, CYM dist program, Distribution network designing, Reconfiguration of the network.

ÖZET

DAĞITIM SİSTEMLER İÇİN 33 KV VE 11 KV ELETRİK ŞEBEKELERİNİN TASARIM VE ANALİZİ

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Elektrik enerjisi tüketimindeki büyük artış ve muazzam ve hızlı kentsel gelişme nedeniyle dağıtım sistemlerinde yapılan genişlemeler nedeniyle, elektrik dağıtım sistemlerinin tasarımı şu anda Irak'ta en büyük öneme sahip olarak kabul edilmektedir. Elektrik sistemi, kayıplar en aza indirildiğinde, voltaj profili iyileştirildiğinde ve sistem bileşenlerinin aşırı yüklenmesi azaltıldığında en iyi performansı gösterir. Bu teknik, elektrik sistemlerinde fazlalık ve enerji geri kazanımı sağlar. Bu çalışmada, ağın yeniden yapılandırılmasını optimum boyutlandırma ve konumlardaki kapasitörlerin eklenmesiyle birleştirerek ağın optimum çalışma koşullarını elde etmek için bir planlama yöntemi önerilmiştir. Bu yöntem, kısıtlamaların ve hedeflerin varlığı ile birlikte çok sayıda değişken nedeniyle büyük bir ayrık doğrusal olmayan optimizasyon problemi olarak sınıflandırılır. Tüm durumlar için baralardaki güç kayıpları ve gerilimler, geriye/ileriye doğru yük akışı yöntemiyle elde edilmiştir. Güçlü ve sofistike CYM_Dist programı, dağıtım sistemlerinin modellenmesi ve dağıtım sistemlerinin önerilen tasarımında gerekli analizlerin yapılması için bir araç olarak kullanılır. Irak Elektrik Bakanlığı da dahil olmak üzere dünya çapındaki birçok elektrik işletmesi, pratik ve etkili analitik program CYM Dist. Sırasıyla IEEE 33-bus ve IEEE 34-bus test ağları kullanılarak, ağı yeniden yapılandırmanın ve kapasitörleri yerleştirmenin en etkili yolları test edilir. Literatürde atıfta bulunulan daha önceki araştırmalarla karşılaştırıldığında, sonuçlar büyük bir uyum sergiliyor. Proje, Necef şehir dağıtım sisteminde Al Jameia 11kV, 145 otobüs, 4 fider sisteminin gerçek bir bölümünde yürütülmektedir. Sonuçların, minimum aktif güç kayıpları ve geliştirilmiş bir voltaj profili ile elde edildiği gösterilmiştir.

2022, 100 sayfa

Anahtar Kelimeler: Kondansatör kaydı, CYM dist programı, Dağıtım şebekesi tasarımı, Şebekenin yeniden yapılandırılması.

PREFACE AND ACKNOWLEDGEMENTS

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Maher Hussein Mossa MOSSA
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CONTENTS

LIST OF SYMBOLS

$\|Vi\|$	RMS magnitude for ith (bus voltage)
A	Accidents matrix of Bus
$C\ (s,ph)$	No. of consumers on phase ph.segment
CF	Cost of traffic
Di	Branch switching
I_{rated}	Current of line (rated)
I_{ai}	Branch current (active)
I_{ri}	Branch current (reactive)
K_c	Cost of capacitor (candidate bus)
$Lfls$	Lossing factor
m	capacitor banks (total number)
n	Total number of branches
P_D	Demand of power
P_G	Generated power
pi	Branch active power (i)
P_L	Losses of power (total)
$P_{loss(q)}$	Before placement of capacitor (power losses)
$P_{loss(q+1)}$	After placement of capacitor (power losses)
P_{smax}	Max. value of active source (power)
P_t	Active power (total value)
Q	Reactive of power
Qc	Value of kvar from the capacitor bank
Qi	The value of reactive power (branch i)
Q_{smax}	Max. value of reactive of power source
Qt	Reactive power (total value)
Ri	The value of resistance (branch i)
Sn	Apparent power
T	Intervaling time
U	Factor of utilization
$Vmax$	Limiting value of voltage (maximum)
$Vmin$	Limiting value of voltage (lower)
Vs	Magnitude of the voltage source
Z	Impedance
ΔV, dV	Voltage Deviation
$p.u.$	Per Unit

LIST OF ABBREVIATIONS

BW/FW	Backward/forward sweeping (load flow)
COCF	Constraints objective cost function
COM	Component object model
CYME	Chang yvan micro electronics
DE	Differential evolution
DGs	Distribution generators
DRDLFA	Dimension reducing distribution load flow algorithm
EDNs	Electric distribution networks
GIS	Geographic ınformation system
GMD	Geometric mean distance
GMR	Geometric mean radius
GPS	Global positioning system
IAGA	Improved adaptive genetic algorithm
KCL	Kirchhoff current law
KVL	Kirchhoff voltage law
LDF	Load factor
LF	Load flow
MCMF	Minimum cost maximum flow
P.F.	Power factor
OPCAs	Optimal placement of capacitors
PSO	Particle swarm optimization
PSS/E	Power system simulator for engineering
REA	Rural electric associated
SL	Switch list
SLFA	Shuffled frog leaping algorithm
SOM	Switching optimization module
TS	Tabu search

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1 INTRODUCTION

Distribution networks start from distribution substations to the service entrance of the electricity consumers, including distribution substations, primary feeders, distribution transformers, and secondary systems . The existing distribution networks can only serve the requirements and standards of past decades and cannot meet renewed duties and upcoming challenges (Vahidinasab *et al.* 2020).

The process of designing electrical networks in the distribution sectors of the electrical systems includes several conditions that must be taken into consideration, namely, the voltage profile and the process of decreasing the losses in the network lines, in addition to the increased demand for electrical energy (the annual rate of increase), whereas this leads to an increase in reliability in the performance of the networks, which precedes:

The design of networks in the distribution sector is subject to two important options: designing new networks above; or redesigning existing networks, considering the increase in loads and considering the conditions mentioned. (Fletcher and Strunz 2007).

It has always been necessary for power distribution networks to adapt to variations in load demand, which has led to voltage oscillations beyond the permissible variation range at various buses and power losses (Ntombela *et al.* 2022).

Network capacity must be increased over time to handle the escalating demand brought on by population and economic expansion. Upgrades are required for feeders, transformers, and other network appliances to handle load increases and max load. Transformer and feeder upgrades may need to be more cost-effective. Other assistance can bring the strained systems to normal operation through economically sound improvement, avoiding the need for more enhancements.These methods consist of the following:

a) Area designing without constructing a new feeder or transferring load from nearby, lightly loaded feeders to nearby, fully loaded feeders.
b) Shunt capacitor installation (fixed or switched).
c) The installation of renewable and distributed energy sources.
d) Using a larger capacity conductor in place of the current one.
e) New feeder addition, shifting some of the demands on the current feeder.

1.1 The Losses of Power

When compared to transmission systems, distribution networks have much larger power losses due to their higher currents and lower voltage levels. According to studies, the distribution industry consumes up to 13% of the total power generated due to (I^2R losses). This substantial number of losses has a direct financial impact and lowers the power system's overall effectiveness. These losses cannot be stopped, but they can be minimized. (Chowdhury *et al.* 2009)

1.2 Methods for Minimizing Losses in The Distribution System

There are several ways to decrease energy loss in the distribution networks, the most important of which is reconfiguring the system in the selected network, adding capacitors to the network to compensate for the lost interactive energy, and adding generating units in the network in the selected places to enhance the voltage profile. Loads in the network. And through the experiments conducted on the networks, it was found that the best ways to improve the level of optimal operation in the networks are reshaping the network and adding capacitors. (Chang 2008). The capacitor allocation can be done from various methods, and today the optimization algorithms are one of the most well-known applied techniques (Babanezhad *et al.* 2022).

1.2.1 Network reconfiguration

Network reconfiguration is a method that may be utilized in designing studies to determine the optimal network configuration for a certain stage of the designing process. Reconfiguration is a process for modifying the topological structure of distribution feeders by changing the open/close status of sectional switches and feeder sections to find the minimum loss topology, maintaining voltages between their low and high limits simultaneously, and its radial structure, that is, there is only one path between two points in the same feeder (Tovar Ramírez *et al.* 2022). Manual or automatic switching methods can be used to alter the configurations of the conductors and other components depending on the number of loads, the size, and the length of the conductor.

1.2.1.1 Effects of reconfiguration of the network

Improving the optimal operating conditions of the networks by switching the feeders to adjust the loads between the feeders in the system may lead to changing the type of connection between the feeders and canceling the radial connection between them, and it has benefits that can be mentioned. (Kashem *et al.* 1998, Baran Mesut and Wu Felix 1989).

- Optimize the voltage profile
- Controlling loads and the possibility of transferring them between feeders
- It raises the level of reliability on networks by reducing sudden loads
- Operating networks within the permissible limits of loads to protect them from damage
- Optimal reduction of energy lost in the network, which has a direct impact on system capacity and saves wasted energy
- Through it, it is possible to control the separation and connection of loads that directly affect the operation process, the continuity of the electric current, and the energy dissipation. (Hosseinzadeh *et al.* 2009).

1.2.2 Capacitor positioning

Among the important things in the design of networks and their continuous expansion as a result of the growth of loads and ensuring the operation of the distribution networks under optimal conditions, capacitors installed in selected places on the feeders were used to make up for the reactive energy being squandered across the network. Optimal capacitor placement is a well-known method to minimize losses, enhance reliability, and improve the voltage profile of electric distribution networks (EDNs). Optimal capacitor placement consists of the optimal placement of capacitors (OPCAs) involves sizing and finding the optimal location of capacitor banks within the distribution network for reactive power control (Gallego *et al.* 2022). Installing a shunt capacitor allows for the injection of the necessary quantity of reactive-capacitive power at large loads to meet the need for reactive power (s). The set's over kvar capacity grew when individual capacitor units were connected in parallel. (Chang *et al.* 1990)

Shunt capacitors may considerably enhance the performance of distribution circuits, provided they be used correctly and under control (specify the size and location of the capacitor). However, the reactive power from capacitor banks can result in losses and excessive voltages if it is not used effectively. (Iyer *et al.* 1984).

It is possible to put distribution capacitors on a pole or a pad. From an installation standpoint, pole-mounted capacitors are the least costly method of supplying reactive power. When the power distribution circuit is buried, pad-mounted capacitors are employed. This type of capacitor’s downside might be its large size. (Salama and Chikhani 1993). The addition of compensating bank capacitors to the distributing network can boost the capacity of the generator and substation to handle an additional load by at least 30% and the voltage regulation capacity of each circuit by around 30% to 100%. Furthermore, the load on these kilovolt ampere-limited apparatuses is reduced by the reduction in current in transformers, distribution equipment, and lines. (Mendes *et la.* 2005).

1.2.2.1 Fixed and switched capacitor

BanksReactive power also fluctuates substantially when the loads are subject to large swings. In light of this, fixed capacitor banks frequently result in either overcompensation or under-compensation. Switched capacitors are used to produce variable var compensation. Timers, reactive power needing; or voltage requirements can manage automatic switching (Mekhamer *et la.* 2002).

1.2.2.2 Capacitor bank advantages

In the electric grid, capacitor banks support (voltage and kvar), To increase capacity and reduce losses in the system.

1) Voltage supporting: The voltage in the network can be increased by adding capacitors to the system.
2) Kvar supporting: This paragraph shows the ability of the capacitor to add reactive energy to the network and the process of supporting this energy to the network and its capabilities. Decreased system losses, the need for reactive power at generators, and Improved control of the voltage, as well as the power factor.
3) Capacity of System: Capacitor banks free up ability that may be utilized if the system's capacity has to be raised. They accomplish this by lowering the flow of reactive current.
4) Losses of power: Capacitor banks minimize the inductive current, which lowers the system's overall current flow. The losses in lines caused by conduction include thereby minimized. The current decrease has a bigger impact on losses Considering that power loss is proportional to the square of the current,. The system's effectiveness is then raised.

However, when the capacitors are connected to the network, there are some drawbacks to connecting them, which are:

1) Production of higher-order harmonics.
2) The raising in voltage over a long time.
3) An electrical current is cut off, which generates a relative voltage surge
4) A sudden increase in voltage occurs because of switching capacitors in the network, so protecting the network from high currents is very important.
5) It causes a decrease in the supply voltage and increases losses, affecting the network equipment.
6) Non-linear loads are affect by the process of connecting capacitors and the energy emitted from them in the network.

Adding the capacitive value [cvar] to the network as a result of adding the capacitors and changing the interactive value of the system from [kvar1]to [kvar2] to expand the system capacity and its carrying capacity, as shown in Figure 1.1.

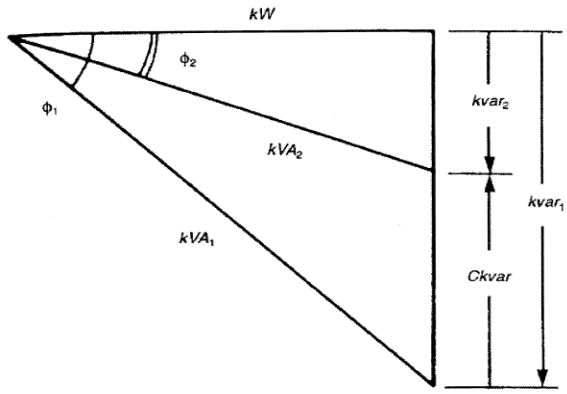

Figure 1.1 The triangle of reactive ability and its effect with actual ability

1.3 Literature Review

Civanlar *et al.* (1985), presented a branch-exchange-based network reconfiguration technique for load balancing between feeds and loss reduction. Two approximate load flow methods for radial systems, each with a different level of accuracy, can aid in the hunt. These are the basic backward/forward and dist. Flow techniques.

Zimmerman (1996), demonstrated a feeder reconfiguration technique that simultaneously reduces losses and balances loads. The suggested approach uses a back propagation neural network, limited fuzzy operation, and a heuristic-based fuzzy strategy. In addition, by eliminating repeated load flow computations, using neural networks in conjunction with fuzzy operations speeds up the process of getting results.

Cristinel and Rajesh (2017), Ababei and Kavasseri (2010), designed an effective heuristic technique to address the loss reduction issue with distribution system reconfiguration. The minimum Cost Maximum Flow (MCMF) problem is used to formulate the issue of locating additional branch exchanges.

Goldberg *et al.* (1989), Made suggested a productive meta-heuristic technique to reorganize the distribution systems. To achieve this, the active power losses associated with turning sectionalizing switches on and off are reduced using the Tabu Search (TS) method.

Mekhamer *et al.* (2008) rearranged the distribution networks using an effective meta-heuristic method. The Tabu Search (TS) approach decreases the active power losses by turning sectionalizing switches on and off. The (TS) technique has been modified in many ways, including using of a tabu list whose size varies depending on the size of the system, which should result in a resilient algorithm and prevent cycling. This method evaluates the radially of the selected system based on the (A) determinant value of the bus incidence matrix. During the search phase, It uses a random multiplying step to expand the search space to include previously unsearched areas.

Asakura *et al.* (2003), developed a strategy for planning the extension of a distribution network that involved reconfiguring the network and creating building plans that took into account the installation of new major customers and the natural rise of electric demands. The approach aims to reconfigure the objective network by altering the switch state minimize losses before using contingency analysis to assess the target network's security work.

Qin Zhou *et la.* (1997) , this reference preview reconfiguration method for balanced and unbalanced radial distribution networks influenced by DG units in 2012 [21]. The suggested method begins with mesh network by turning off all tie switches. Restoring the radial configuration is as simple as opening a single switch in each loop within the constraints of the system's operation. The switching index takes considers into computation the time-varying type of loads utilizing the daily load pattern to reduce loss during normal operating conditions and restore service during emergencies.

Pete and Ohki (2020) Loss minimizing in large-scale distribution networks via automated switching operation was suggested using an improved simulated annealing technique. Utilizing the polynomial-time cooling schedule enhances the simulation performance in the annealing algorithm, as this method revolves around the statistical number of iterations in the search process.

Huang (2002) combined optimization strategy merging network reconfiguration and capacitor control has suggested reducing losses in distribution systems. The optimal network architecture for each genetic instance is discovered by a simplified branches exchange technique produced for every repetition of the capacitor optimization technique, and a new algorithm (adaptive genetic) is formed to enhance capacitor switching. These improvements were made to the suggested algorithm to increase its performance and efficiency**.**

Eusuff and Lansey (2003) enhance the voltage profile and decrease power losses, a practical approach for figuring out the appropriate spot and size for capacitors in radial distribution systems was presented. There are two components to the answer. Potential locations for capacitor installation are selected in part one using loss sensitivity parameters. Part two of this post will calculate the ideal capacitor size for the buses chosen in Part 1 using a novel approach that collects the Shuffled Frog Leaping Algorithm (SFLA) with Particle Swarm Optimization (PSO).

Abdel-Salam *et al.* (1994) developed a method for figuring out where and how big switching and fixed shunt capacitors should be in radial distribution networks. The objective is to increase global savings via decreased energy losses and capacity release during network expansion.

Khodr *et la.* (2008), illstreted a quick and effective heuristic technique was proposed to assess the optimal numbers, positions, & sizes of capacitor banks in the radial distribution networks under various load situations. A novel Constraint Objective Cost Function (COCF) has been developed to optimize net yearly savings by reducing actual power losses, improving the system bus voltage profile, and optimizing the annual cost of capacitors.

Bala *et al.* (1995) The optimal network architecture for each genetic instance is discovered by a simplified branches exchange technique produced for every repetition of the capacitor optimization technique, and a new algorithm (adaptive genetic) is formed to enhance capacitor switching. Utilizing particle swarm optimization; and capacitor sizing (PSO). The efficiency of these two approaches is evaluated based on the actual losses and voltage profile of the bus networks after proper positioning of capacitors.

Storn and Schwarz (1996) The optimal capacitor placement problem has several sensitivity-based solutions, and this article compares and contrasts the loss sensitivity methodology (method 1) and the bus sensitivity method (method 2). Particle swarm optimization for capacitor sizing (PSO). The ideal determinant for the techniques above techniques is the difference between the values of network losses and the values of voltages in the conductors after adding capacitors.

1.4 Target of The Work

This study’s objective is to research the design of electrical systems for to the part of the Najaf network that ıts cıty in Iraq so that it may be to keep up with the sharp rise in electrical demand. A program called CYM_Dist use for a part of the network of the city of Najaf in Iraq (the Al_Jamiea network) to analyze it and identify the defects in it from

1) The voltage drop
2) Focus the loads on feeders without others in the same area and simulate it and extract solutions from the program
3) Try to implement it in reality to show its impact on the stability of the system
4) reduce losses in the Al_Jamiea network
5) optimization of energy. A period of 5 years take for the growth of the loads at the base of the program.

1.5 Organization of The Thesis

This thesis contains five chapters, the following being one of them:

Chapter two you will learn about the distribution system's feeder reconfiguration and the reactive power compensation, the problem analysis, the basics, and a review of forward/backward sweep load flow. Along with the construction of the cost function that will be minimized.

Chapter three the design and analysis of power distribution networks are Carrie out by the Iraqi Ministry of Electricity (MOE) using the optimization tool CYM-Dist.

Chapter four provides two basic distribution network IEEE test systems. Finally, in the principal Al-Jamiea network in Najaf city, 4 feeders, were modeled and planned to function for the next 5 years without exceeding any overloaded restrictions or constraints.

Chapter five derivation and proposals for future projects.

2 PROBLEM ANALYSIS

2.1 Introduction

The analysis of the design issue for the distribution network is covered in this chapter. To satisfy power supply requirements under virtually all conditions, This is done through the process of design analysis of the distribution networks and within the requirements of the quantity of demand for loads (peak load) as well as the operational status of the annular networks, taking into account the distance of the network.

Sections of the distribution networks operate under conditions of high loads (above the level of network tolerance), i.e., in conditions of peak loads, which leads to an increase in the possibility of interruption on the feeders, which causes a shortening of the life of the equipment and perhaps the loss of some of them.

2.2 Suggestion Methods

The design process for networks in power distribution systems, because of the continuous demand for electric power and the addition of new consumers to the network, goes through three stages:

- The first step is to determine the loads; according to the sizes of the transformers in the feeder.
- In addition to the distribution of loads in the above paragraphs, the network was re-optimized by using the state of the switch and its changes to reduce energy losses and ensure a state of balance in loads.
- Reactive power adjustment for potential bus candidates to stop violating operational constraints.

The application of the algorithm for reconfiguring networks and the algorithm for adding capacitors to networks is to reduce losses and costs to the lowest possible level through this, it is not possible to reach optimal results. Here, reconfiguration is an employee tactic to change the distribution network's fundamental design to arrange the capacitors more effectively while reducing power losses (Abdelaziz *et al.* 2009).

2.2.1 Load distribution method

To meet the metered demand, the connected load will be adjusted using the load allocation mechanism. This work uses 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 feeder following distribution transformers.

Summary of method (connection load-kVA) as follow in Equation (2.1), Equation (2.2) and Equation (2.3)

$$kVA_{total(ph)} = \sum_s connected\_kVA(s,ph) \times LDF \tag{2.1}$$

$$kW_{alloc(s,ph)} = kW_{dem(ph)} \times \left[\frac{connected\_kVA(s,ph) \times LDF}{kVA_{total(ph)}}\right] \tag{2.2}$$

$$kVar_{alloc(s,ph)} = kW_{alloc(s,ph)} \times \left(\left(\frac{1}{P.F(ph)}\right)^2 - 1\right)^{0.5} \tag{2.3}$$

Where : *s* denote the section and *ph.* Denote the phase and *dem* is the demand in kilowatt.

In addition, the other methods; and the summary are listed in (Appendx 1)

2.2.2 Allocation grid reconfiguration method

Finding the appropriate switching sequences during typical distribution operations is the target of network reconfiguration to obtain real power losses reduction and feeder load balancing.

2.2.2.1 Concept of grid reconfiguration

The two most common kinds of switches in distribution networks are typically closed (sectionalizing) and ordinarily open (tie) switches.

However, the configuration may be altered by changing the states of these switches while they are active. Since the system can change by first shutting an open branch, as shown by branch 21 in Figure 2.1, a branch in the loop carrying a switch, say branch 7, must be opened to restore the system to its original radial configuration (made up of branches 8, 9, 10, 11, 15, 21, 1, 2, and 3). This switching will allow for a smooth shift of loads between feeders serving Branches 7 and 11. CYM-Dist. The software describes the fundamental network switching procedure between nodes 21 and 7.

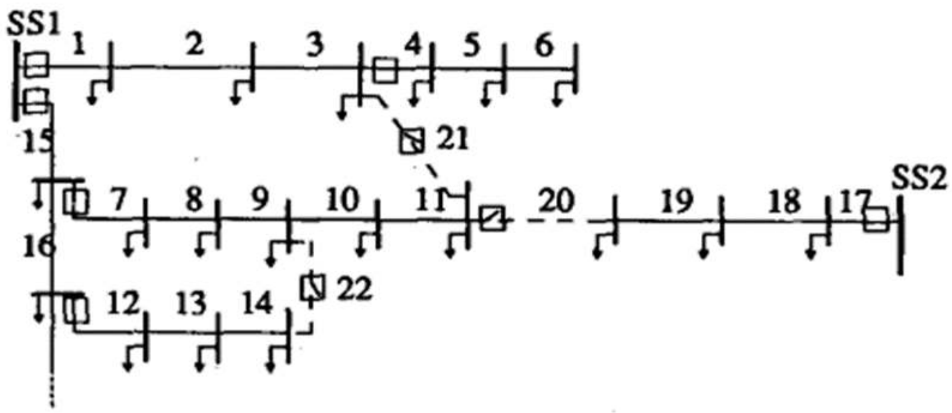

Figure 2.1 Buses in the dis. Network (single line diagram) (Civanlar *et al.* 1985).

2.2.2.2 Reconfiguration problem analysis

The reduction of power loss and, thus, the reduction of costs; is the primary mission of the network reconfiguration issues. States switching of different switches acts as the control variables in the system reconfiguration challenge. The switching statuses alternate randomly between two magnitudes, like one for closed and zero for opening, to create a diversity of topology. The loss minimization in the network reconfiguration issue may be stated mathematically as follows (Abur 1996).

$$min. f = \sum_{i=1}^{n} D_i R_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad (2.4)$$

Where: *f* primary function, *n* Branches no. *Ri* Branch resistance i, *Qi* Branch reactive power *Pi* Branch active power i, *Vi* Branch voltage on sending bus i, *Di* Switch on branch i, code 1 for close state, code 0 for open state.

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

Radial network restriction: Ring networks are the most used type in power distribution systems by about 80%. [Zlatko Zmijarevi et al. 2020]. This indicates that no loops are permitted in the distribution system. Therefore, power supplied to each load carrier in the network is done through a single station. As a result, supplying a load from two distinct substations creates a network loop that is not permitted. Because of its clear design, typical cheap cost, and help save it, the radial distribution network is commonly employed (Sirisumrannukul 2010).

Voltage restriction: To ensure sustaining the power quality level, the amount of the voltage for every bus must be implicit in the permitted range

$$V_{min.} \leq V_{load} \leq V_{max.} \quad (2.5)$$

$$P_t \leq P_s^{max.} \tag{2.6}$$

$$Q_t \leq Q_s^{max.} \tag{2.7}$$

Where: *V min.* minimum voltage limiting, *V max.* maximum voltage limiting and power source capacity restriction. The maximum capacity of the related power source cannot be exceeded by the combined loads of a particular partial network.

Harmonics, voltage angle, and power factor constraints were not considered in an effort to simplify the issue.

2.2.2.3 Optimal network reconfiguration by the proposed algorithm

Determining the status of switches opened and closed, which determine the state of fragmentation and interconnection in the network, will reduce energy losses, which is at the heart of the goal of this thesis. The losses in the network can be calculated through the difference between the results that appear by applying the two load; tests (as they are the system installation) before and after the system reconfiguration of the system structure. The suggested approach begins with a meshed distribution system that is created by assuming that all switches are closed. The switches are then opened one at a time to close the loops. The flowchart in the figure illustrates how the opening criterion, which is anchored on the smallest overall increase of power losses, is derived using a power flow algorithm as shown in Figure 2.2. The next two steps will better clarify the flowchart:

- **Procedure 1**

A switch list (SL) is initially put up; all of the system's (r) switches that should be considered throughout the optimization process must be included in this list. Then, (r) network configurations are created so that just one switch (e≤ r) is open for each of them while the status of all the other switches are closed. The number of the associated switch is used to identify the setups. When the switch (e) is open, any configuration (e) is checked and established, and a BW/FW power flow is computed. The total value of power losses is computed for each linked network configuration and recorded on the losses categorization list. After closing switch (e), the previous procedures are repeated until all (r) settings have been treated. Using the resulting loss-rating list, the configuration with the smallest rise in losses is identified; this configuration is considered consideration (w). Then, the pair of switches closest to the area around (w) and generated the least increases in losses is chosen to remain in the open state permanently closest to the area around (w) and generated the least increases in losses is chosen to remain in the open state permanently remain in the open state. This pair is stored in a neighbor list to collect data for the second technique, which will be discussed in the following section.

The swap list must be updated update (r) as soon as a specific key is opened to delete the key and any other keys that were broken because of being separated from the other loops from the above procedure, which leads to unconnected networks. To ensure the list of keys is empty, the procedure mentioned above is used in succession with the updated SLs, as this indicates that all loops are broken; and the system is radial.

- **Procedure 2**

A better configuration could be acquired in certain instances by running a second operation to enhance the first procedure result. Making exchanges between each switch (w) and its associated pair of neighbors, which is found in the initial method, forms the second step of the algorithm. The exchange process is described as opening closed switches and closing open switches in the selected loop to maintain communication in the network and ensure that the network is radial.Then, two exchange procedures, including the neighbors, were carried out for each swap. The total losses for each configuration so acquired are calculated and contrasted with the losses from the initial configuration operation. One of the configurations was chosen to replace configuration (w) if it results in fewer systemic losses than configuration (w).

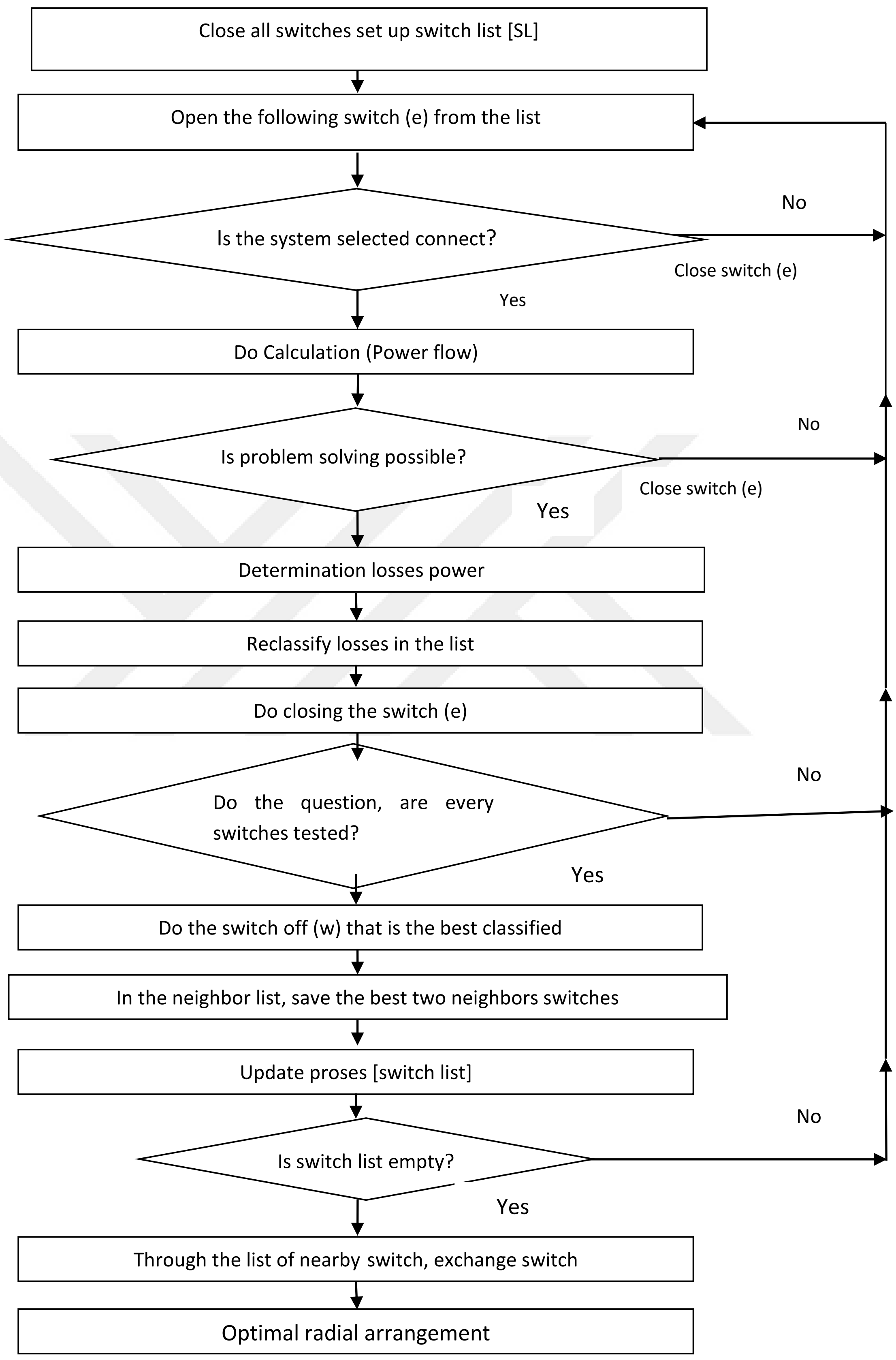

Figure 2.2 Distribution system reconfiguration (Proposed algorithm).

2.2.3 Optimum positioning and size of capacitors method

The problem is posed to minimize ohmic losses while considering the cost of the capacitor and calculating the optimal size and placement of the shunt capacitor in any distribution network (radial). At the same time, limitations on the electric network limit the options. Standard sizes define the capacitor banks, producing a distinct set of solutions. This makes us classify the issue as a "discrete optimization problem.

The cost of operating and maintaining the capacitor installed in the distribution system will not be included for simplicity's sake.

The CYM-Dist. the Module contains a procedure for placing capacitors that conducts the first target optimization (either power losses or voltage profile).

2.2.3.1 Real power losses(total value)

If you have n nodes in your distribution network, you may calculate the total power losses, or I2R, by solving for n:

$$P_L = \sum_{i=1}^{n} I_i^2 R_i \tag{2.8}$$

Where : R_i is the branch resistance *ith* and *Ii* is the current of branch.

The load flow solution may be used to determine the branch current. The real element (Ia) and the reactive component (Ra) make up the two halves of the branch current (Ir). The loss connected to the reactive and active parts of branch currents is expressed as follows:

$$P_{La} = \sum_{i=1}^{n} I_{ai}^2 R_i \tag{2.9}$$

$$P_{Lr} = \sum_{i=1}^{n} I_{ri}^2 R_i \tag{2.10}$$

Reducing the damage Since all branch currents should begin from the root bus, PLa is connected to the active component of branch currents. The reactive element of branch currents has a loss, denoted by PLr, which can be mitigated by supplying part of the reactive power locally. [Ali A. Abdullah Albakry and Ghaith Ali Abdul-Rahim 2019].

2.2.3.2 Limitations

The Limitations are the additional aspect of the optimization issue that needs definition the objective function. The dedicated distribution load flow software that estimates losses is responsible for maintaining the line flow restrictions.

These limitations are taken into account in this research:

1) Bus Voltage Limitation:

   While optimizing, the bus voltage must be maintained within safe working ranges.

$$V_{min.} \leq |V_i| \leq V_{max.} \qquad (2.11)$$

Where : $V_{min.}$ Lower bounded bus voltage boundaries, $V_{max.}$ Upper bounded bus voltage boundaries and $|V_i|$ rms magnitude the ith bus voltage.

The power loss function rises if the voltage magnitude exceeds the predetermined limitations. Since installation capacitors at any bus in the distribution network raise voltage value, voltage value must be modeled as restraints in the math formula to optimize (Sundhararajan 1994).

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

$$P_G - \sum_{i=1}^{n} P_D - P_L = 0 \qquad (2.12)$$

Where: PG generated power, PD demand of Power and PL overall power losses.

3) The current of a line (I) must be lower than the line-rated.

$$I \leq I_{rated} \tag{2.13}$$

4) The restriction on the No. and size of acceptable shunt capacitor banks:

The number of capacitor banks required to meet the following equation can be set explicitly:

$$\sum_{i=1}^{m} Q_c \leq Q_t \tag{2.14}$$

Where: Capacıtor Reactıve power is the Qc, Kvar is needed (total) is the Qt and Cpa is numbers is the m.

2.2.3.3 Suggested algorithm for the best position capacitors

The bests position sizes and locations for this method are those that min. The target function; satisfies limitations, & satisfies the equation for a single capacitor positioned at the correct bus Equation (2.15).

$$P_{loss(q+1)} \leq P_{loss(q)} \tag{2.15}$$

Where :
$P_{loss(q+1)}$ Power loss with the installation of the capacitor and $P_{loss(q)}$ Power losses before the insertion of the capacitor.

So following is a summary of the solution algorithm for this method:

Operation 1: To gather the sector (sectional) losses and other important data, do the load flow analysis for the source.

Operation 2: Start by setting “Qc” from the substation at the far end bus (bus number =N) equal to the least value listed in (Appendix1), Table A1.1, and then carry out the “load flow: process.

Operation 3: Make a comparison between the segment losses in every feeder branch that followed operation 2 with those that followed operation 1.

Operation 4: Execute operation 3-load flow and comparison of sectional losses, but this time compares them to the sectional losses generated when the previous value of “Qc” was set. Try the next magnitude of “Qc” from the table (A1.1standard) magnitudes of “Qc” if each branch's sectional losses are less than or equal to those in the previous case.

Operation 5: Up Until you find the ideal value of Qc, repeat Operation 4 with various magnitudes of (Qc) positioned at this bus.

Operation 6: If any feeder branch's sectional losses exceed those in the preceding scenario, the current value of “Qc” should be replaced with the previous value of “Qc”.

Operation 7: Execute the load flow & examine the voltage profile with the “Qc” optimally positioned at the far end. Stop if 0.95 V bus 1.05; if not, continue with bus number (N-1) until V min 0.95.

A flowchart depicting the proposed process for capacitor allocation in radial distribution networks is demonstrated in Figure 2.3.

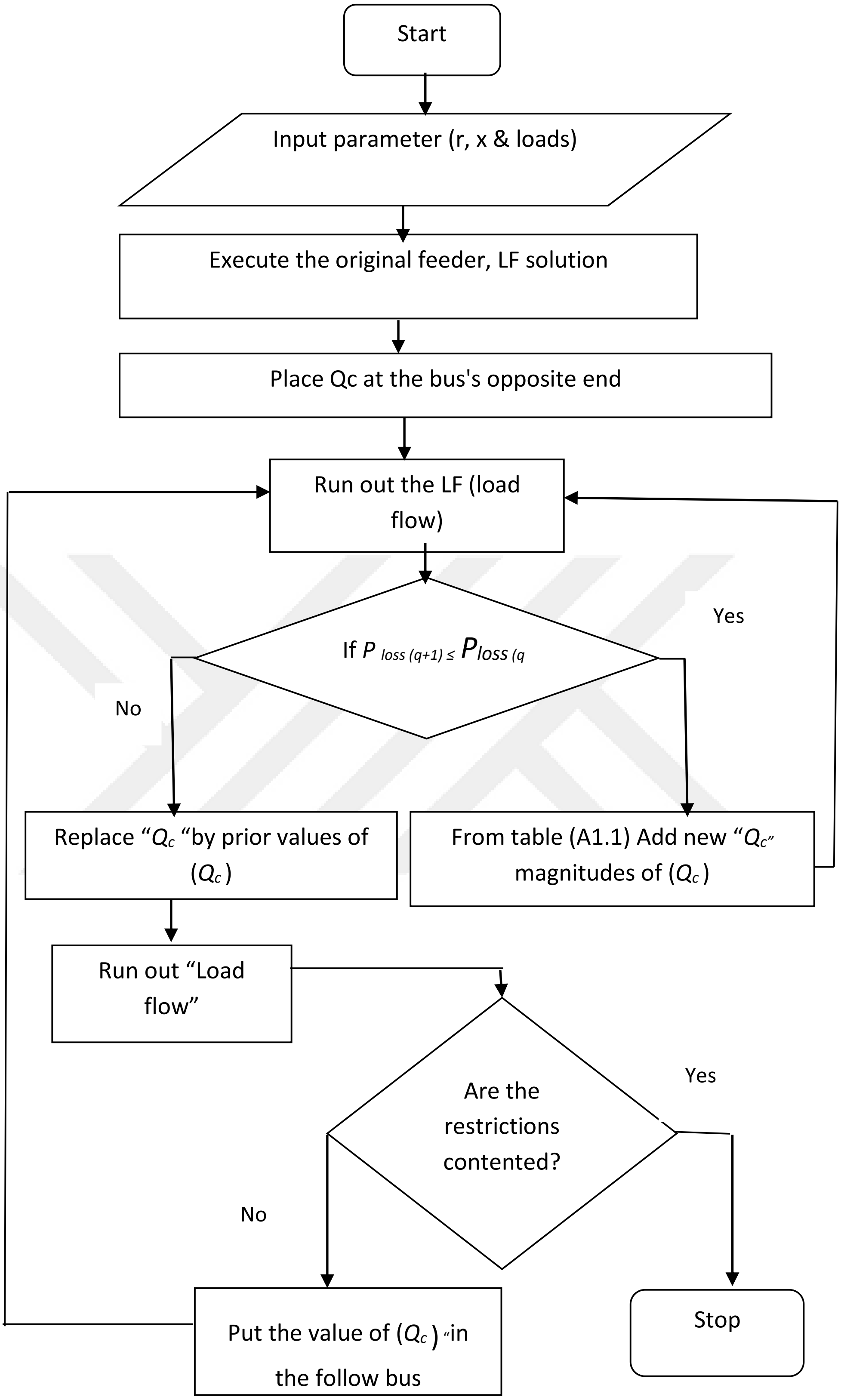

Figure 2.3 Flow-chart of the suggested technique for capacitor position in the feeders in the network (type radial).

Design switched capacitors: Switched capacitors to decrease network loss in distribution feeders because the high load variability. A similar method may be used to pinpoint switching capacitors in the power grid. The distinction is that only during periods of peak traffic was moved to the network. Capacitors will be considered switched when they are added to the constant capacitors at higher load levels, but they will remain constant for the minimal load level (Ng *et al.* 2000).

2.3 Sweep Load Flow (Forward/Backward)

To the present feeders, plan, and construct future systems, distribution networks' load flow studies are a crucial instrument. In distribution network planning, load-flow analysis is primarily used to evaluate how various modifications, such as load increase and configuration changes, would affect the system's performance. Information on the potential system states may be derived by doing the load-flow analysiz repeatedly for various loading circumstances. The steady-state operation of an electric power system under varied operating circumstances is ascertained through load-flow studies. It computes power flow, power losses, and voltage magnitudes and angles at all feeder buses and all branches and feeder circuits. Additionally, it displays the feeder's capacity status when overloaded (Macqueen 1989).

The load flow algorithm's effectiveness in solving the optimization problem depends on how often the solution must execute. It must thus be strong and quick. The study of balanced and unbalanced radial distribution networks may be done using various techniques that fall into two categories. By appropriately modifying existing techniques like the Newton Raphson and Gauss Seidel procedures, The first is used. Another group of methods relies on Kirchhoff's laws and backward and forward sweep processes. Some details about the structural structure of the distribution networks; affect the method chosen for analyzing these systems, such as the radial type of the network, unbalanced loads, or the ratio value. Therefore, Newton Raphson and Gauss Seidel have become ineffective in solving problems in distribution networks. Algorithms that depend on back and front scanning have become the most preferred in analyzing loads in distribution systems; due to the capabilities of computers, the low need for memory used and the stable characteristics of the algorithm. Among the basic things that must provide are the voltage angle, the voltage used in the network, and knowledge of the load values on every bus and along the feeder. (Carpaneto and Chicco 2008).

2.3.1 Designing of the load-flow issue (using the ladder reiteration method)

Load flow in a distribution network is subject to physical rules, including Kirchhoff laws and Ohms laws that were incorporated into the design process restrictions. The backward-forward sweep technique, which consists of two stages, is an iterative approach solving for solutions of the load flow equations of radial type distribution systems. The forward sweep; updates the value of voltage by calculating of voltage drop & the reverse sweep updates the value of currents by Kirchhoff's Current Law (KCL). The current injected into every branch is calculated using the backward sweep as a function of the end bus voltages. The voltages are updated while a current summation is carried. For the initial iteration, the end buses' bus voltages are initialized. Every branch is passed toward the source bus starting at the end buses while the voltage is being updated and the calculated current injection at each bus, so computed currents are registered & utilized in the next forward sweep computations. By contrasting it with the stated source voltage, the computed source voltage is utilized for the termination criteria's mismatch computation. The bus voltages are set by the forward sweep based on the currents that are input into every bus. The forward sweep is a voltage drop determination with the restriction, which the voltage source utilized at starting each forward sweep, is the stated nominal voltage. Using the currents computed in the prior backward sweep, the value of voltage computed at every bus, starting from the bus (source) and moving out to the bus (end) (Karaboga and Basturk 2006).

2.3.2 Mathematic equations (feeder flow)

As illustrated in the figure, a balanced three-phase system with a single feeder Figure 2.4. It is assumed for the ladder network that the source voltage and all line and load impedances are known (Vs).

Assuming a voltage at the furthest load (V5), the solution for this network is to calculate the loading current at every bus as follows:

$$I_n = \left(\frac{S_n}{V_n}\right)^* \tag{2.16}$$

The load current is :

$$I_5 = \left(\frac{S_5}{V_5}\right)^* \tag{2.17}$$

By applying Kirchhoff's law (KVL), then, the magnitude of the voltage at the bus (V_4) as in Equation (2.18).

$$V_4 = V_5 + Z_{45}.I_{45} \tag{2.18}$$

Then by Kirchhoff's current law (KCL), we can find the current (I_4) as in Equation (2.19).

$$I_{34} = I_{45} + I_4 \tag{2.19}$$

The bus voltage V_3 can find by Kirchhoff's voltage law (KVL) in Figure 2.4, and we can find V_1 by the same procedure:

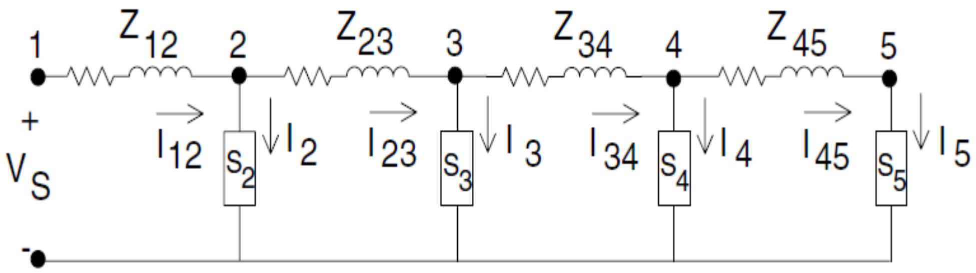

Figure 2.4 Network type: ladder

The error in voltage in this network as shown in Equation (2.20) and the proportion between the determined voltage and specified voltage as shown in Equation (2.21).

$$Error = \left||V_s| - |V_1|\right| \quad (2.20)$$

$$Ratio = \frac{V_s}{V_1} \quad (2.21)$$

The voltage generated in this initial iteration will not match the given source voltage (Vs). Since the network is nonlinear, the solution cannot be found by multiplying voltages and currents by proportionating the wanted value voltage to the calculated voltage. A forward sweep is a change to the ladder system theory that is the most obvious. The backward sweep's line currents and the preset source voltage initiate the forward sweep. The voltage at the bus (2) is calculated using Kirchhoff's voltage law

$$V_2 = V_s - Z_{12}.I_{12} \quad (2.22)$$

Each line segment must undergo this process again until bus 5 determines a new voltage. A second backward sweep is initiated using the updated voltage at bus 5, resulting in an updated calculated voltage at the exporter. Therefore, the forward and backward scanning process continues until the difference between the calculated voltage and the voltage at the source reaches certain limits.

2.3.3 Main feeder

The major main, sub-laterals tapped off the laterals, laterals tapped off the primary main, sub-laterals tapped off the laterals, etc., make up a typical distribution feeder. For the typical feeder seen in Figure 2.5, the ladder iterative method would go as follows:

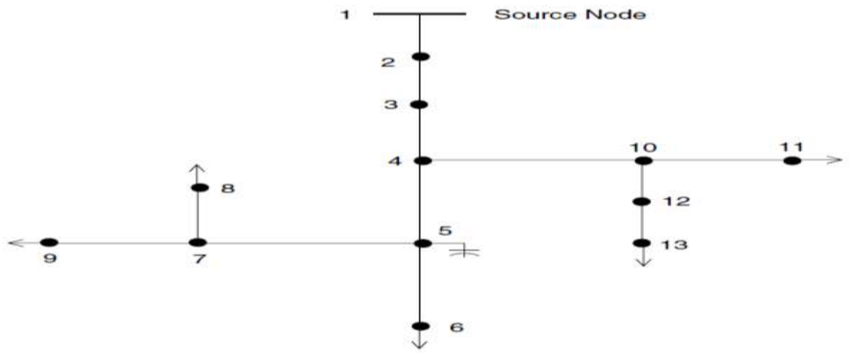

Figure 2.5 Typical feeder

Assume that the end buses have three-phase voltages (6, 8, 9, 11, and 13). Usual practice dictates that nominal voltages be used. Calculate the bus current (load current + any existing capacitor current) starting at the bus (13). Using this current, get the bus voltages at (12) and (10) by using Kirchhoff's voltage law (KVL).

The fact that laterals branch off of Bus (10) in two separate directions gives rise to the term "junction bus." Determine the bus current at the bus (11) serving this feeder. To determine the voltage at the bus (10), use that current. The phrase "the most recent voltage at bus (10) “describes this. The (newest voltage) reading at the bus (10) uses to calculate the current at the bus (10) (if any). Calculate the current flowing from the bus (4) to bus (10) using Kirchhoff's current law (KCL).

Using this current, apply KVL to determine the value of voltages at buses (12) and (10). (KVL). Because its laterals split; off in two different directions, bus (10) is known as a "junction" bus. Calculate the bus current of that feeder at the bus stop (11) by going there. Utilize that current to determine the bus voltage (10). The phrase "the most recent voltage at the bus (10)" will describe this. The most recent voltage values at bus 10 are used to determine the current at bus 10 (If any).

Using Kirchhoff's law, calculate the value of the current running from bus No. 4 to bus 10, and then check the value of the current in bus No. 4. At bus (4), determine the magnitude of the voltage and then Determine the current at the same bus. The current passing from bus No. 3 to bus No. 4 must be calculated; using KCL at bus 4. Make a voltage calculation for the bus (3). Determine bus 3's bus current.

To calculate the current flowing from the bus (2) to the bus (3), apply KCL to the bus (3). Make a voltage calculation for the bus (2). Calculate bus 2's current on the bus. Use KCL on the bus (2). For bus (1), make a voltage calculation. Make a compensation of the computed value at bus 1 to the designated source voltage in the paragraph. Once; at the source, the computed voltage is within a certain tolerance of the voltage of the source, keep doing the backward and forward sweeps. At this stage, all buses have known voltages, and all line segments have known currents (Kersting 2002).

2.4 Energy Losses Cost

Electrical power losses increase the price of power. A constant effort is made in distribution networks to lower the cost of power transmission and distribution. After completing the 3-phase load flow analysis and using the suggested techniques to solve the planning strategy, the cost of power loss was calculated. Energy costs for the yearly peak loading are represented by the cost of losses.

Using CYM-Dist. Built-in loss factor algorithm, the annual cost of system losses as follow in 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)

$$Loss\ Factor = A \times LDF + (1 - A) \times LDF \qquad (2.23)$$

Where the load factor (LDF) is the average demandation for customer or group of customers divided by the highest demandation at the same moment.

In the Equation (2.23) a constant A =0.15 is given occasionally and use for the distribution system (Parizad *et al.* 2010).

The load factor (LDF), which used commonly to characterize loads. LDF always ≤ to unity (the ideal LDF), and it serves as a gauge for the distribution system's load (Houssem 2011).

After a load flow simulation, the yearly cost of active power losses is calculated using the empirical formula shown below (Amaresh *et al.* 2006).

$$Cost = P_{loss\,max.} \times L_{fls} \times T \times CF \tag{2.24}$$

Where : $P_{loss\,max.}$ losses of power at max. Demand active power (kW), L_{fls} The factor of loss power -Time Separator (*h*), Time-laps Time lapse (*h*) and *CF* Tariff cost (*$*).

The price of power loss and the capital expenditure required to install capacitors are included in the cost of reactive power compensation. The price per kvar varies according to the size. Larger capacitor sizes are often less expensive than smaller ones. The overall reactive loads should be at most the maximum capacitor size Qmax. Standard capacitor sizes are limited, as stated in (Appendix 1), Table A1.1, and their related (cost/kvar). The yearly cost formula will be:

$$\mathrm{Cost} = \mathrm{P_{loss\,max.}} \times \mathrm{L_{fls}} \times \mathrm{T} \times \mathrm{CF} + \sum_{c=1}^{j} \mathrm{K_c Q_c} \tag{2.25}$$

where: Q_c value of the capacitor (kvar), *k* Capacitor constant according ($/kvar) and *c* selected buses 1, 2… j.

3 CYM-DIST PROGRAM & NETWORK RECONFIGURATION

3.1 Cym-Dist Software

Distribution analysis program called CYM_Dist. CYM_Dist is a cutting-edge engineering tool used to design the research and simulate how electrical distribution systems would behave in existing ones or the future under various operative situations and variables. The CYME software's;" analytical capabilities completely support all simulation types, and the graphical acting of network elements may be shown either conceptually or geographically. (CYME 2000).

3.1.1 Loads in cym_dist

1-Distributed loads, 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 the correct information and would not be represented as scattered loads. Spot load types are typically used in Iraq to describe loads.

3.1.2 Cym-dist database

The network and equipment data are saved by CYM_Dist using adaptable databases. Studies are not kept in the database but rather in individual files (*.xst). Users are free to make several copies of these databases to segregate projects. Also, studies and databases can be stored in the same file (*.sxst). Following is a quick description of the databases.

i) Tools Database

All devices and equipment accessible for network connection (including conductors) have their electrical characteristics stored in the database of the tool. The only time this data has to be updated is when new equipment becomes ready because it is comparatively static.

ii) Database of network

The data system contains information on the connection of the components, the types of conductors and types of equipment used, the settings of certain types of equipment, the loads and capacitor banks connected to each segment, and the connection between systems. The database networks are meant to depict the situation as it stands up to a particular period (usually the present). Versions of these networks serve as the foundation for investigations. (CYME 2000).

3.1.3 Build the database tools

The CYM_Dist equipment database's unique equipment ID must be utilize to identify and model each of the many device subtypes and kinds that are employee in the distribution system. Feeders made up of subsurface cables and above wires. Construction of overhead and underground line libraries comes after that of conductor and spacing libraries.

When conductor placements for overhead lines specify in the spacing database, CYM_Dist may generate the Geometric Mean Displacement (GMD) parameters for the phases & neutral.

By selecting the phase & contactor & spacing kinds for each kind of overhead line, an overhead line library can be create, and the impedance of the overhead power lines may be calculated using built-in CYM_Dist equations.

The types of conductors, the circular conductor lines, the type of dielectric, and the thickness over dielectric may all be customize to design an underground line library (CYME 2022).

3.2 Modelation of Network

The primary part of the modeling process is to gather all necessary input information. Once the data have been aggregated and processed, the distribution network model is created by loading or importing them into CYM_Dist, where an automatic one-line diagram is constructed.

The distribution network design processing requires several different types of the simulation study, but only one model has to be created (CYME 2020).

3.3 Cym-Dist Consequences Submit

The CYM_Dist user interface allows for the following:

1. Choose a network segment and then access the study's findings to use the results box that may be set up to show any accessible electrical parameters.
2. Color-coding the network by its properties (such as overloads, under/over voltages, feeder type, etc.).
3. Tags shown next to system components provide specific user-defined characteristics of the component.
4. Create tabular summaries and graphics for the chosen portion or trace the source of the current selection (Alistair and David 2013).

When we design and edit on the screen:

- Edit and zoom buses & branches online.

- Quickly dragging and dropping the shapes with alignment & automatic snap (Raja 2012).

3.4 Analysis Feature Types in Cym-Dist

In truth, this program requires particular and thorough data based on the intricacy of the connection methods, kinds of equipment, and devices utilized in a network.

Although CYM-Dist has two basic analytical functions, the first is analyzing the network according to voltage drop & the second is a system-analyzing system according to short circuit. The program uses the power flow ladder associative approach to analyze the system.

3.4.1 Cym-dist analytical skills and characteristics

1) Analyze the secondary & primary distribution systems, which is suitable for unbalanced & balanced analysis, that is, voltage drop analysis (looped, radial, or meshed).
2) Choosing the right capacitor position and size to reduce losses and/or enhance voltage level, load balancing to reduce losses, and load distribution.
3) For load transfer simulations, we should study the growing load over several years & connect the feeder.
4) Analysis of short-circuiting and fault over the whole network while accounting for pre-fault loading circumstances.
5) Verify protection devices coordinate using user-defined standards loading & clearance for devices.
6) Estimate generator impedance, model of the distributed generation, and the features of the protection & control for the grid side.
7) Multiple chosen parts are automatically re-conducted and rephrased.
8) Flexible load model for spot loads and evenly distributed loads with separate load mixes for every segment of the circuit.

9) Optimization of switching (tie-points); network planning modelization; analysis of substations and subnetworks; reliability analysis (historical & forecast); examination of potential outcomes when restoring service; Analysis of harmonics.

3.4.2 Distribution techniques of loads

The four load allocation techniques that CYM_Dist offers are as follows:

- Connecting KVA that distributes the need amongst the loads according to each *one's;"* transformer ability.
- KWh connects and distributes the demands among the loads according to how much energy each consumes.
- The demands are divided among the loads by Rural Electric Associated (REA), taking into account the KWh & the no. of customers that every load kind represents.
- Real KVA that proportionally shares the demand across the loads based on the kVA specified for every load. This thesis uses the linked (kVA) load allocation approach.

3.4.3 Power flow and cym-dist

The iterative software employs the backward-forward sweep technique, sometimes called the ladders approach. Instead of calculating the load flow, CYM_Dist calculates the branch currents. Numerous load flow techniques based on the backward/forward sweep technique exist. They may be divided into two categories: current summation techniques and power summation techniques. The current summation strategy used in this thesis is fast and practical, the power collection technique, since it just uses "V" & "I" instead of "P" and "Q." (Hong and Ho 2005).

The typical method for performing a load flow estimate assumes that the system is balanced. As a result, calculations are performed for a single phase assuming that the other steps are similar but vary by 120 degrees in phase. In network planning activities, load flow estimations are required for the following reasons:

- Calculate the voltage at each bus (the phase angle and magnitude) and the power (both kvar and kW) going through each line.
- Verify that the network complies with the operating requirements.
- Identify power losses for the network's specific condition.

3.4.3.1 Load flow analysis procedures in cyme

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:

- Voltage Drop that Require apply application CYM_Dist.
- Fast Decoupled that Require apply application CYMFLOW.
- Full Newton-Raphson that Require apply application CYMFLOW.
- Gauss-Seidel that Require apply application CYMFLOW.

With regard to weakly or radial meshed networks, the voltage drop determined approaching is an iterative method that has been specially create and enhanced for them. Within 10 rounds or fewer, the repeated voltage drop calculation approached will calculate the voltages & power flows at each sector. When no computed voltage on any of the specified networks varies by more than the calculations tolerance from one repetition to the next, the computation provides the results.

3.4.3.2 Consensus criteria

1. Tolerances: The load flow will announce network convergence if the difference between two subsequent repetitions is within the set tolerance. The convergence criterion of voltage drop techniques is the percent voltage deviance, which is (dV). The power mismatch serves as the convergence criterion for the other approaches.

2. Repetitions puts a cap on the overall number of repetitions at a certain amount. If the program does not converge, the number of repetitions can be raise. For instance, the Fast-Decoupled approach often converges after 10–20 rounds. Gauss-Seidel could need a lot more retries [http://cyme.com].

3.4.4 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 placed in order to accomplish one of the following aims [Cooper Power System, CYM_Dist Summary]:

1. To find out how loads may be transferred from a substation or feeder that is severely loaded to another through tie-points, do load transfer analyses.
2. Reduce voltage deviations as much as possible to lower the amount of voltage transgression.
3. Do decrease overloaded portions to decrease the No. Of overloaded devices in the network.
4. Decrease operating costs through reducing losses (KW) in the system.

In addition, there is other software created especially for engineers (distribution power system), including:

- (CYMCAP) cable ampacity calculations.
- Analysis & design of grounding grid.
- (CYMTCC) protective device coordination.

Distribution network model including (creation/maintenance) (CYME 2000). However, other software applications, particularly the Component Object Model (COM) module, are needed for specialized analytics. The COM module enables access to simulated results

& feeders type attributes kept in the back-end databases of CYMDIST by external systems (like MATLAB) (Parizad *et al.* 2010).

3.5 Suggested Designing Methodology

The flowchart in fig. (3.1) illustrates the suggested planning process in this thesis. The following details are provided for every step in this flowchart:

Step 1: Gather information about the distribution system, such as:

- Voltage level.
- Conductor properties.
- Power demand.
- Switch state (open/closed).
- Parts lengths.
- Connecting status within parts.

Step 2: Use the CYM_Dist program to build the system model.

Step 3: Utilizing the load distribution technique in CYM_Dist, distribute load demand for each load point per the data gathered.

Step 4: Do load flow to compute real power losses, voltage quantity & angles at every bus, operational limitations, and power dissipation to ensure the system runs normally. Finally, determine the yearly cost of real power loss.

Step 5: Determine the value of (load growth) for the selected design period (from 2021 to 2025) by using the load demand (peak value) for the last design period's year (at the year 2022).

Step 6: Repeating step (4).

Step 7: The targeted network is reconfigured in the first step of the planning approach by conducting loss reduction and imbalanced loading repair by moving loads from feeders that are heavily loaded to feeders that are connected but relatively less loaded.

Step 8: Repeating step 4.

Step 9: Step 10 should be followed if no feasible network configurations thatfulfill the operational limitations. Else, step 12 should be taken.

Step 10: To meet operational requirements and accommodate rising demand, capacitor banks are positioned as efficiently as possible to avoid additional expenditures associated with network reinforcement and strengthening.

Step 11: Repeating step 4.

Step 12: Print results.

Other remedies, Like increasing the current substations' capacity with the corresponding new feeder needs and adding new building plans (new sub-station or feeders), etc., can be an if the solutions above cannot remedy the breaches of the operational restrictions

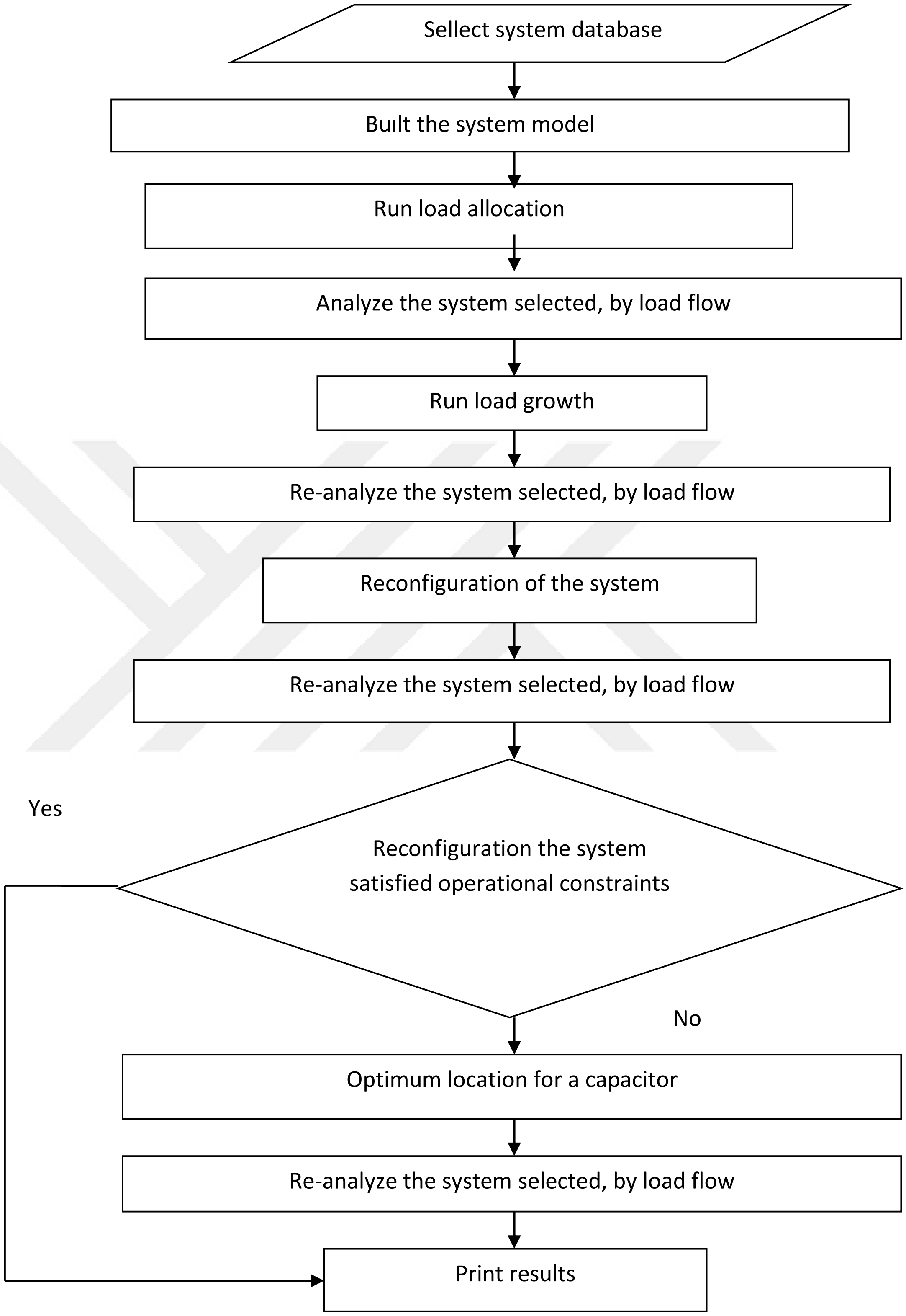

Figure 3.1 Flowchart representing the suggesting designing network by CYM-Dist program.

4 STUDY AND DISCUSSION OF THE CASES

4.1 Introduction

Within that chapter, many instances have been investigate. For every case, the problem is describe, and the program CYM-Dist is use to accomplish network reconfiguration & capacitors location.

The purpose of the first case study was to confirm the CYM_Dist program's applicability on a standard distribution system, which reconfiguration outcomes have been extensively examine in the literature. The IEEE-33 bus radial distribution system was the standard system under consideration (Civanlar *et al.* 1985).

The second case involves an IEEE-34 bus radial distribution system, and the best possible capacitor arrangement has been implemented for this architecture. (Taylor and Lubkeman 1990).

Finally, 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 systems' data is obtained from the Iraqi Ministry of Electricity (MOE).

In this study, various presumptions are taking before beginning:

When using the balance voltage iterative drop technique, the load flow iterations are limited to 40, and a maximum converging error of 0.01% for voltage magnitude is established.

1. By the Iraqi Ministry of Electricity, the price of electricity is 0.1 USD/kWh (tariff cost).
2. The magnitude of buses voltages (rms) will be adjust beyond suitable tolerance limits (5%) after employing both optimal system reconfiguration & capacitor location.
3. 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. The Al Najaf distribution network load factor is 100%, while it is 65% for the IEEE-33 and 34 bus test systems.
4. Harmonics' impact is disregards.
5. The power factor of each load is the same.

4.2 Results

The CYM-Dist 4.5 (Rev.6) program is used to carry out the suggested analysis, and the following results are provided for the three examples that were taken into consideration:

4.2.1 First case: optimal network reconfiguration for test system the (IEEE) that continent 33-bus

The testing system includes feeder distribution network and is 23 miles long (Baran Mesut and Wu Felix 1989). The system has a 12.66 kV (L-L) operational voltage and is a 33-bus radial distribution system. The reconfiguration of the system depends on a frequency of 50 Hz and a 10 MVA. (Appendix 2) contains the sections' length, loads, and impedances Table A2.1

The voltage loads on the 33 buses are provided by step-down transformers, similar to the 32-load buses. Figure 4.1 depicts the schematic layout of the test system, which includes five tie switches that are normally open (S1, S2, S32) and 32 sectionalizing switches that are normally closed (S33 - S37). The total load is shown in Table (4.1) before and after the implementation of distribution network reconfiguration.

The CYM-Dist software has validated that the initial system's actual power loss was 197.22 kW, as stated in reference [34] (198.32 kW). The ultimate power loss after network reconfiguration will be 139.45 kW (savings are 58.87 kW), as stated in the Table 4.1. The simulation results are provided in the Table 4.2 demonstrate that the power losses upon reconfiguration are decreased by 29.7% of its starting value. Those results are the same as those attained utilizing various ways according to the procedures suggested in [Flávio Vanderson Gomes et al. 2017]. In the Figure 4.2, the ideal setup is displayed. The outcomes of 33 bus and switching processes during network reconfiguration are shown in Tables 4.3 and Table 4.4, respectively.

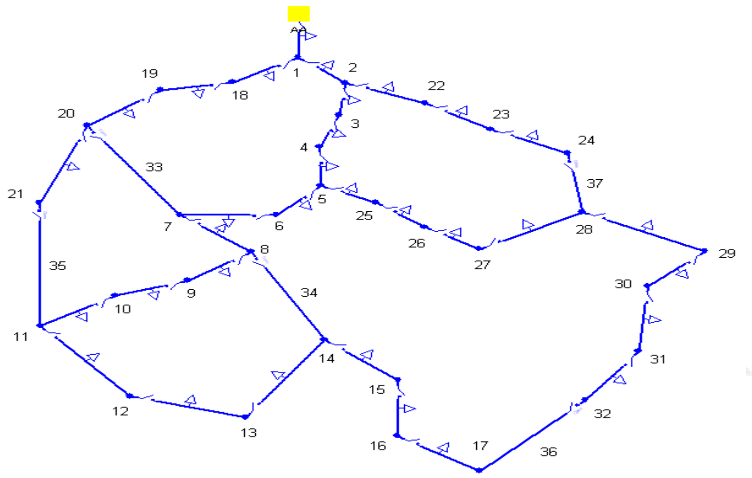

Figure 4.1 Test international system 33-bus (Initial configuration)

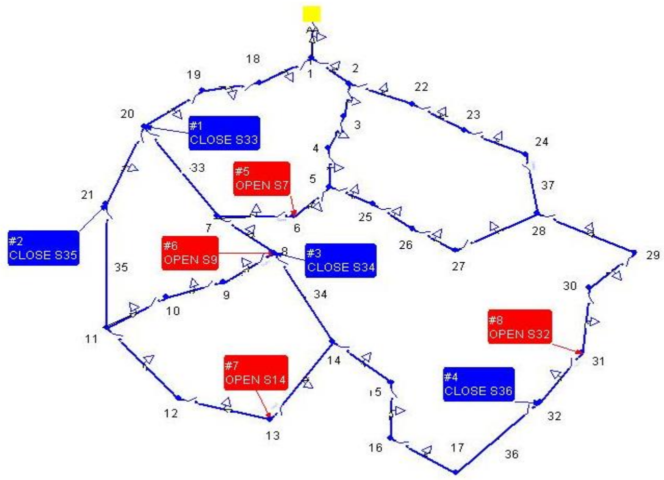

Figure 4.2 Test international system 33-bus (Optimal configuration)

Table 4.1 Test international system 33-bus (Load summary)

Power	**Distribution network (before reconfiguration)**				**Distribution network (after reconfiguration)**			
	Real power kw	Reactive power kvar	Parent power kva	Power factor	Active power kw	Reactive power kvar	Parent power kva	Power factor
Loading	3714.86	2300.01	4370.02	0.851	37114.86	2300.01	4370.02	0.851
Loss	198.32	118.03	230.04	0.851	139.45	88.1	163.02	0.83
Supplying	3911.99	2416.97	4599.06	0.85	3851.97	2386.88	4533.01	0.851

Table 4.2 The 33-bus test international system (CYM_Dist program and the other methods) Reconfiguration result

System reconfiguration	**Losses (kW)**	**Saving (%) power**	**Tie switches State is open**
without reconfiguration	198.32	**----**	S(33,34,35,36,37)
by CYM_Dist program	139.45	29.7	S(7,9,14,32,37)
by heuristic strategy method	135.98	32.5	S(7,9,14,32,37)
by Shirmohammadi method	135.99	33.4	S(7,10,14,32,37)

Table 4.3 The 33-bus test international system (Summary results of reconfiguration)

Description	**Reconfiguration(Before)**	**Reconfiguration(After)**
Max. Volt. Per unit	1	1
Min. volt. Per unit	0.914	0.939
Total load (KW) per phase	1238.2	1238.2
Total load (Kvar) per phase	766.44	766.44
Total system losses (KW) per phase	65.61	45.52
Total system losses (kvar) per phase	39.16	29.17
Total load KVA per phase	1455.45	1455.46

Table 4.4 The 33-bus test international system (Switching operations)

ID (segment)	status	ID (Switch)
7	Opened	S7
9	Opened	S9
14	Opened	S14
32	Opened	S32
33	Closed	S33
35	Closed	S35
34	Closed	S34
36	Closed	S36

As per equation (2.24), the yearly cost of the distribution network both before and after system reconfiguration for 8760 hours is $79.01*10^3$ \$/year and $55.02*10^3$ \$/year, respectively. Therefore, the annual cost of saving is $23.9*10^3$ \$/year.

4.2.1.1 Test system ieee-33 bus (discussion the result)

To quantify the loss of reconfiguration (before and after), the distribution system network has been constructed.

The load flow findings from (Appendix 2), Table A2.2 compare the amplitudes for all of the system's buses before and after using the network reconfiguration procedure. Given that all load needs will be the same across all system configurations, the overall electrical energy losses will be lowered considerably (from 198.32 kW to 139.45 kW), enhancing system dependability overall and the caliber of power provided to customers. The suggested feeder reconfiguration algorithm's improved voltage profile is depict in Figure 4.3. the min. voltage in each phase has increased from 0.91 to 0.94 per unit, as seen Figure 4.3.

A close look at Figure 4.3 reveals that the system's reconfiguration greatly increased the voltage at bus 17. Additionally, there has been no discernible improvements for bus 18.

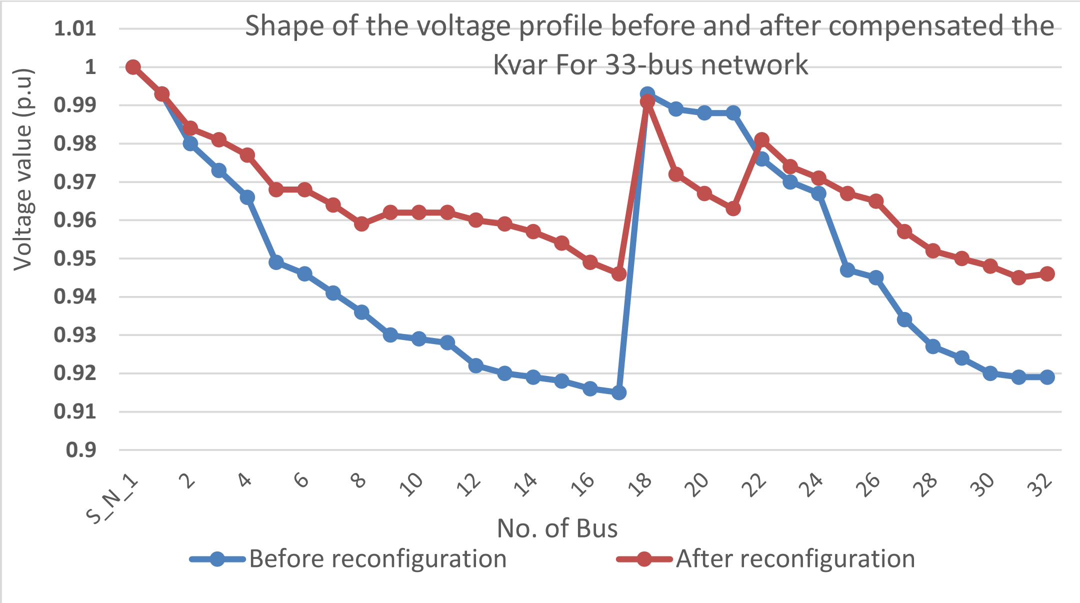

Figure 4.3 The 33-bus test international system (Voltage profile every phase)

4.2.2 Second case: the ieee- 34 bus test system (optimal capacitor placement)

According to Figure 4.4 [M. Chis, S. Jayaram and M. M. A. Salama 1998], the next test program is the 13.4 km long, three-phase, 34 bus radial feeder with four lateral branches. The first reconfiguration depends on a system voltage of 11 kV (L-L), a power output of 100 MVA, and a frequency of 60 Hz. (Appendix3) provides information on the feeder & load properties Table A3.1. The average power factor is 0.85 as well as the installed peak power is 5.4 MVA overall.

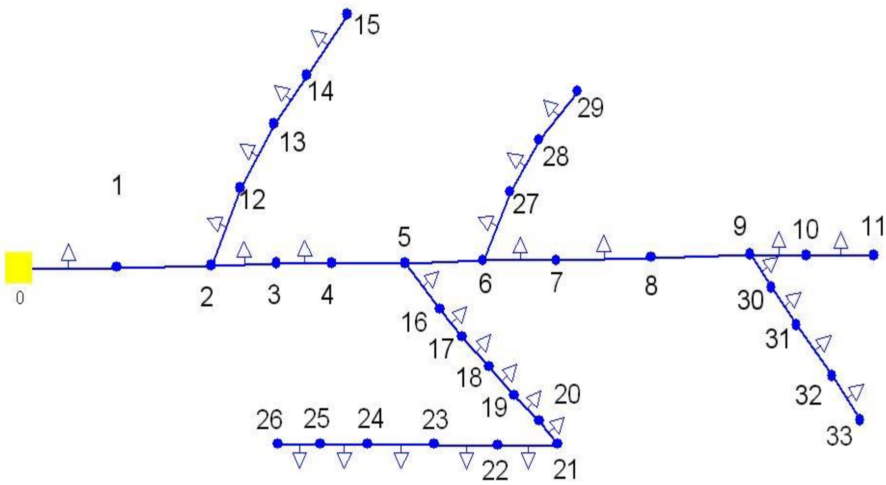

Figure 4.4 The 34 bus test system (Distribution network configuration)

According to Table 4.5 [H.N. Ng, M.M.A.Salama, and A.Y.Chikhani, 2000], the load distribution curve is separated into three different loads (high, mid, & low) in a year.

Table 4.5 The 34-bus test international system (Load distribution curve)

Loading (%)	Yearly time of loading (%)	Yearly distribution (h)
100	42	3679
80	48	4205
60	10	876

It can be seen that this feeder runs abnormally with six parts at under voltage after implementing the load flow for the original design, as illustrated in Figure 4.5 .All bus pre- and post-capacitor-installation voltages are listed in Appendix (3) Table A3.2. Reactive power (kvar) adjustments are summarized in Table, along with the total load before and after the changes made. The distribution of the capacitors at the reception buses is shown in Figure. 4.6.

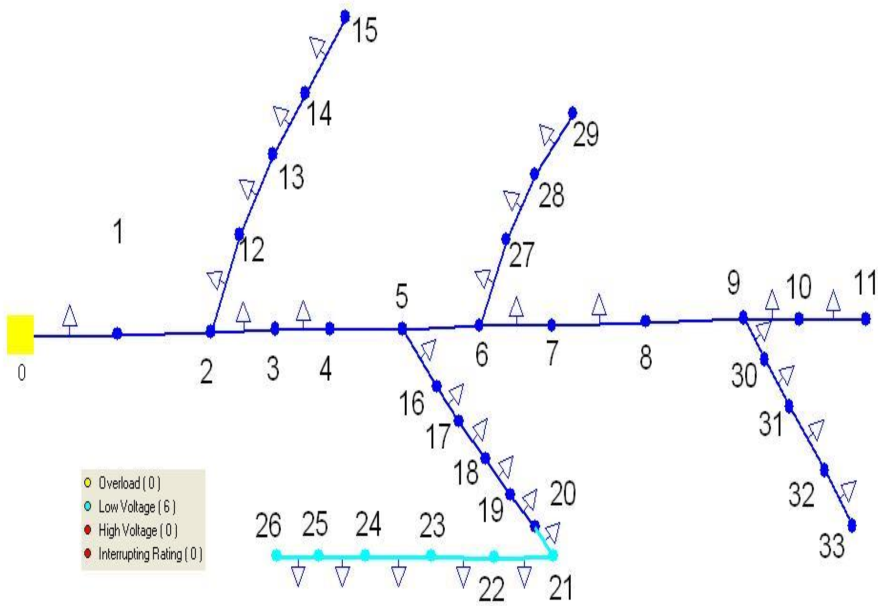

Figure 4.5 System international test 34-bus (abnormal conditions)

Table 4.6 System international test 34-bus

System	before compensating(Total load)				after compensating (Total load)			
	Active power kw	Reactive power kvar	Parent power kva	Power factor	Active power kw	Reactive power kvar	Parent power kva	Power factor
The load	4635.7	2871.47	5453.81	0.85	4636.58	2873.6	5454.77	0.85
Adjusted capacitor						2500.99		
Power loss	223.02	64.99	232.21	0.951	162.09	46.97	167.39	0.961
Supplying Power	4857.39	2937.7	5676.88	0.85	4798.02	418.99	4816.02	0.99

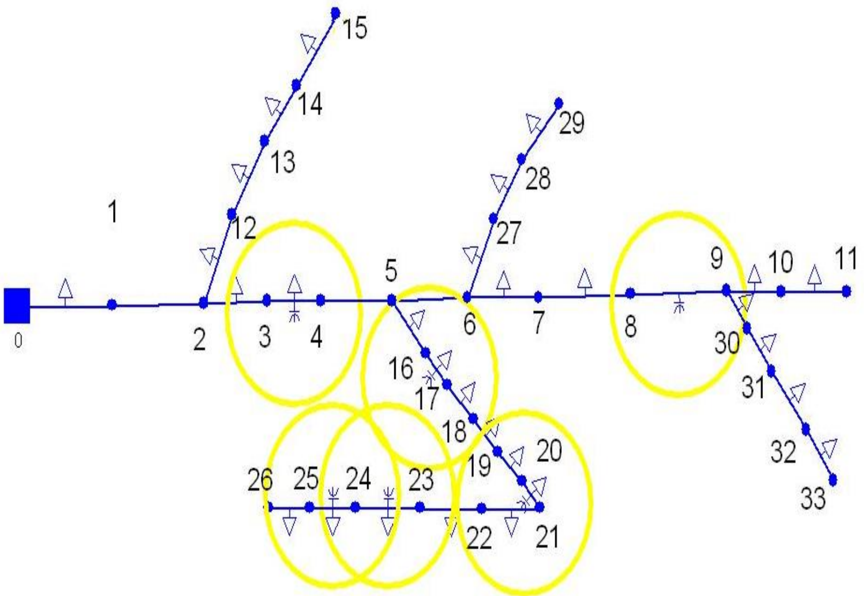

Figure 4.6 The 34-bus test system (The distribution of capacitors at the receive nodes)

The CYM-Dist program has validated that the initial network real power losses were 221.67 kW, as stated in reference (Wang *et al.* 2008) (221.75 kW). The ultimate power loss after compensating for reactive power is 160.68 kW (61.06 kW is savings) using the optimal capacitor location method, as shown in Table 4.7. The positioning of the best capacitors is shown in Table 4.8.

Table 4.7 The (34-bus) test international system (Simulation results at Max. Load)

	Units	Uncom- - Pensated	Network compensated			
			suggested	Heuristic based. (Wang *et al.* 2008)	PSO (Kennedy and Eberhart 1995)	Fuzzy (Kennedy and Eberhart 1995)
Total network loss	K.W.	221.75	161.01	169.11	169.1	166.2
Loss decreasing	K.W.	---	60.88	52.89	53	56
Max. Volt.	Per unit	1	1	1	1	1
Min. volt.	Per unit	0.943	0.955	0.949	0.949	0.950
yearly cost	$/year	37,242	26,995	33,183	29,937	28,251
Net saving	$/year	---	10,263	4,071	7,318	9,005

Table 4.8 The 34-bus test international system max. load (full load) (better position and value of capacitors)

CYM_Dist program							**Heuristic based**		**PSO**		**Fuzzy reasoning**	
Bus Id	**Loading for capacitors operation**	**Cap. kV(L-L)**	**Cap. kvar/phase**	**Total kvar**	**Loss reduction (kW)**	**Total adjusted kvar**	**Bus Id**	**Cap. kvar**	**Bus Id**	**Cap. kvar**	**Bus Id**	**Cap. kvar**
9	≤ 60%	11	150	450	11.12	416.88	4	250	19	781	4	250
17	≤ 60%	11	150	450	6.82	416.88	11	750	20	479	10	750
21	≤ 60 %	11	150	450	14.72	416.88	17	300	22	803	16	300
24	≤ 60 %	11	150	450	22.41	416.88	26	1400	---	---	26	1400
4	= 100 %	11	150	450	2.72	416.88	---	---	---	---	---	---
25	> 80 %	11	150	450	4	416.88	---	---	---	---	---	---
Total kvar				2700	62.6	2501.28	---	2700	---	2063	---	2700

According to Equations (2.24) and (2.25), respectively, the yearly saving cost of the power loss capacitor insertion (before and after) is 37251 ($/year), depending on the period in the table for the peak demand load Figure 4.5. Thus, the yearly net saving is $9579.

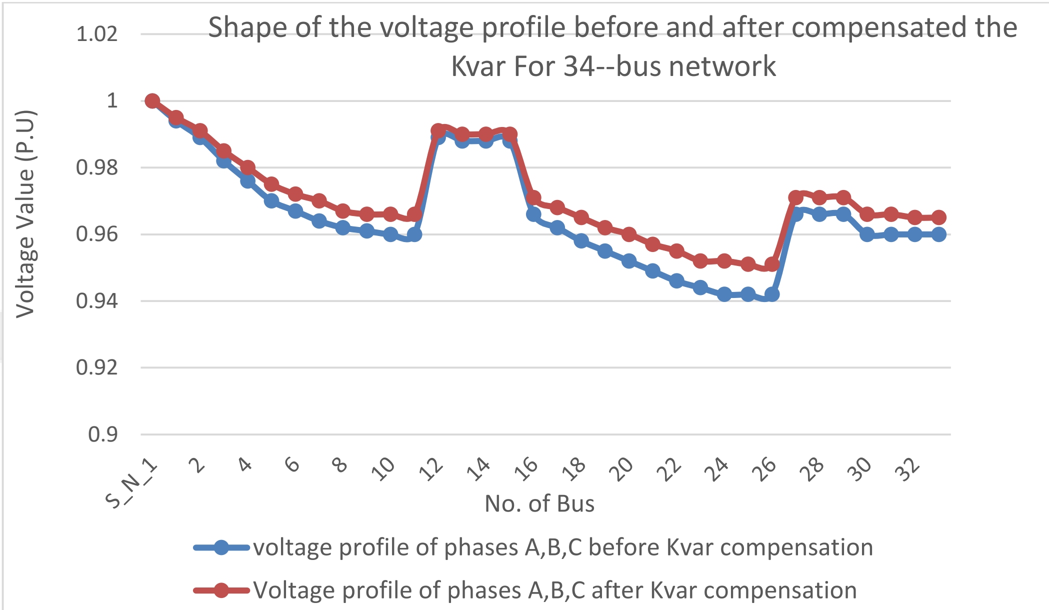

Figure 4.7 The 34-bus IEEE international network- Voltage profile-Kvar compensating (before and after)

When testing the global system bus 34 and for the longest side of the bus in their feeders in that system, i.e., bus 26, the figure shows the reaction to the total downstream reactive power profile (kvar) for the lengths of each. Figures (4.8a) and (4.8b) depict the behavior before and following the insertion of capacitors, respectively. The maximum demands plus reactive power losses, shown in (Appendix 3), are included in the overall reactive power characteristics in these Figures and Table A3.3.Where the Figure 4.8 shows the effect of the total value of reactive energy for the longest side of the 34 test feeds on bus 26 and for the distances of each segment and downstream.

Figure 4.8a and Figure 4.8b depict the behavior before and following the insertion of capacitors, respectively. The maximum demands plus reactive power losses, shown in Appendix (3), are included in the overall reactive power characteristics in these figures Table A3.3.

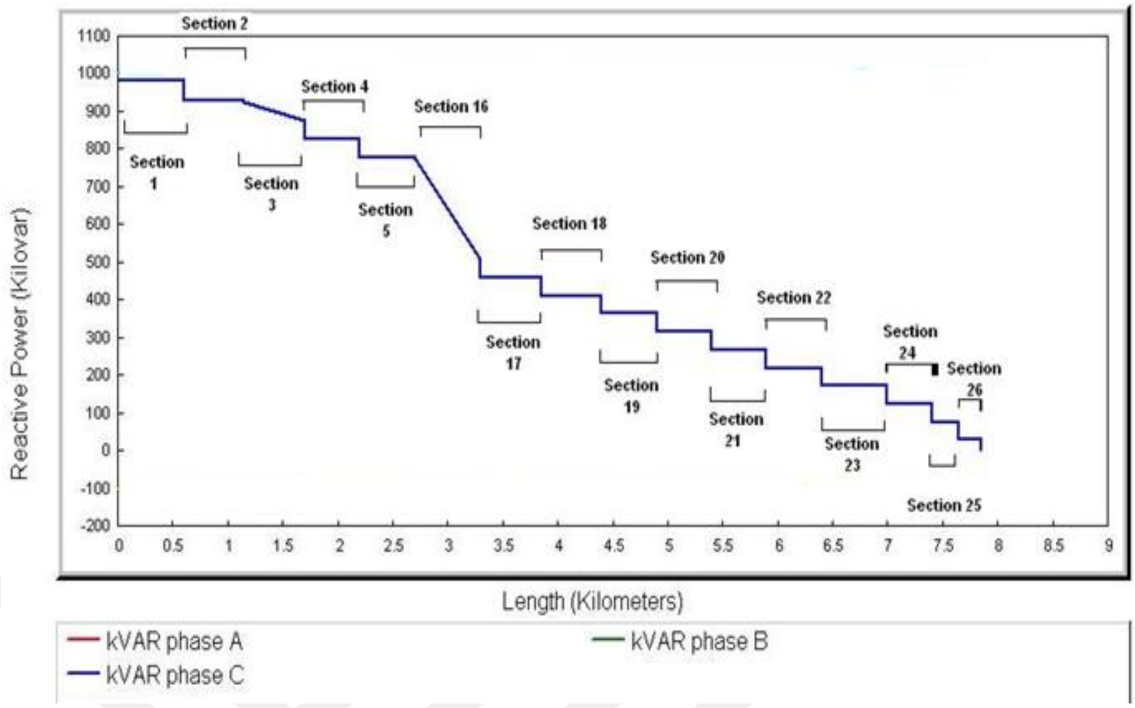

Figure 4.8a The 34 bus test international system kvar profile (before Compensating)

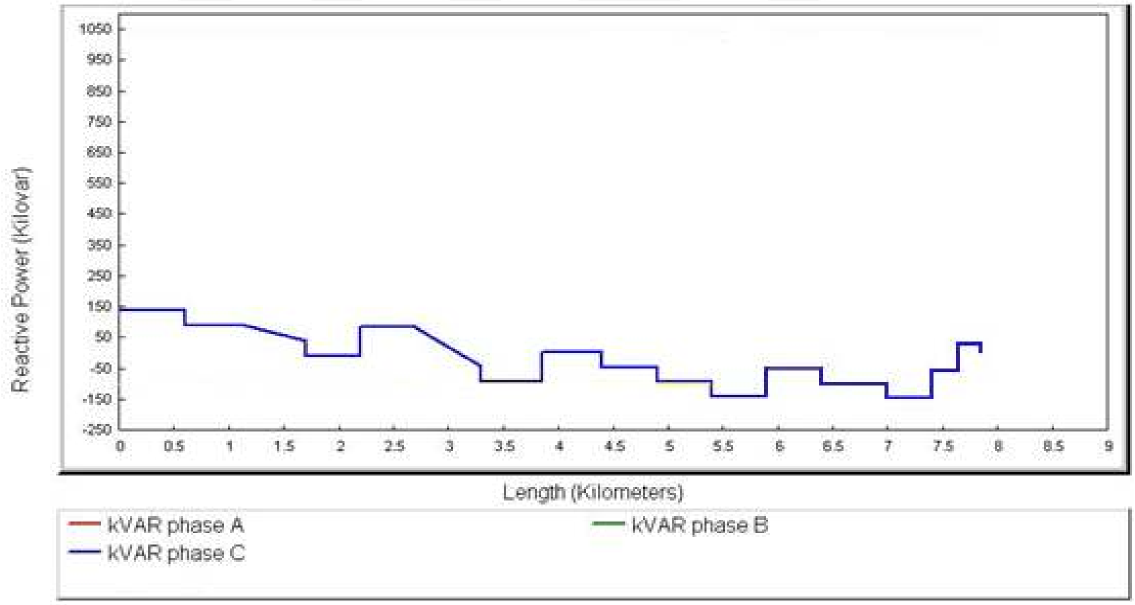

Figure 4.8b The 34 bus test international system kvar profile (after compensating)

4.3 Al-Jamiea Substation

Al Jamiea distribution system was selected as the distribution system to use to implement the suggested strategy in Najaf city. Appendix (4) Table A4.1 provides a brief overview of the power source, substation, and distribution systems in Najaf city.

There are two 33kV feeders from the Al-North-Najaf and Al-Kufa expansion 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 of acquiring further information, only four feeders are considered in this work.

4.3.1 Third case: al- Jamiea distribution network

This 11 kV, 100 MVA, 50 Hz network is part of Najaf's electrical system and has 151 line sections, 145 buses, and six tie switches Figure 4.9. Appendix (5) contains the system information Table A5.1. Figure 4.10 depicts the Al Jamiea system's schematic diagram created by CYM-Dist. Approximately 94% of the demand for the Al Jamiea feeders is residential, while 6% is commercial.

According to Table 4.9, the load period curve is separated into 3 levels of loading (low, medium and high) during the years of the planned duration according to Table 4.9.

Table 4.9 Substation (Al-Jamiea) load time.

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

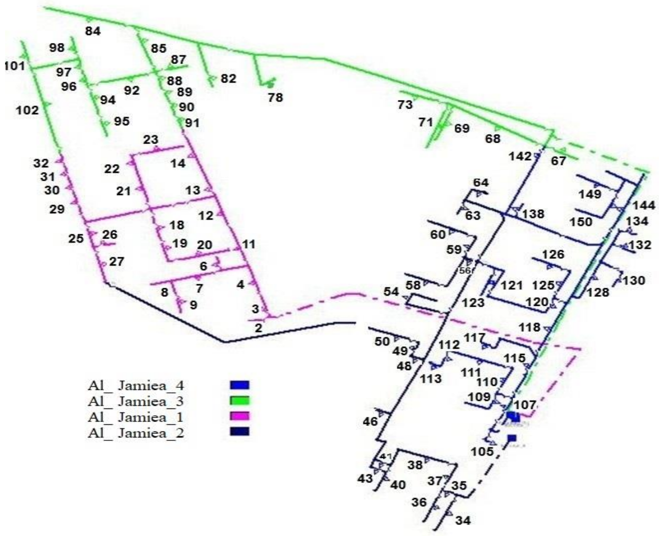

Figure 4.9 Transformers in the selected Al-Jamiea network (Initial configuration).

For each feeder unit, depending on the current. The value of the power factor at the end of the bus and using the connected kvar technology with a margin of accuracy of 0.01%. According to the sizes of the distribution transformers (11/0.4d), the loads are spread uniformly throughout each phase, as indicated in the Figure 4.9 and the Table. 4.10a and b.

Table 4.10a Currents of Al-Jamiea feeders

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 4.10b 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

To examine the load flow of the current network before implementing the short-term design. Applying load growth study to the network allows for examining its resilience and effectiveness in the face of yearly load growth. Figure 4.10 illustrates how the network is evaluated using the percentage yearly load increase rate given in the (Appendix 5). Table A5.2 for solely household and commercial loads over the upcoming 5 years (2021-2025).

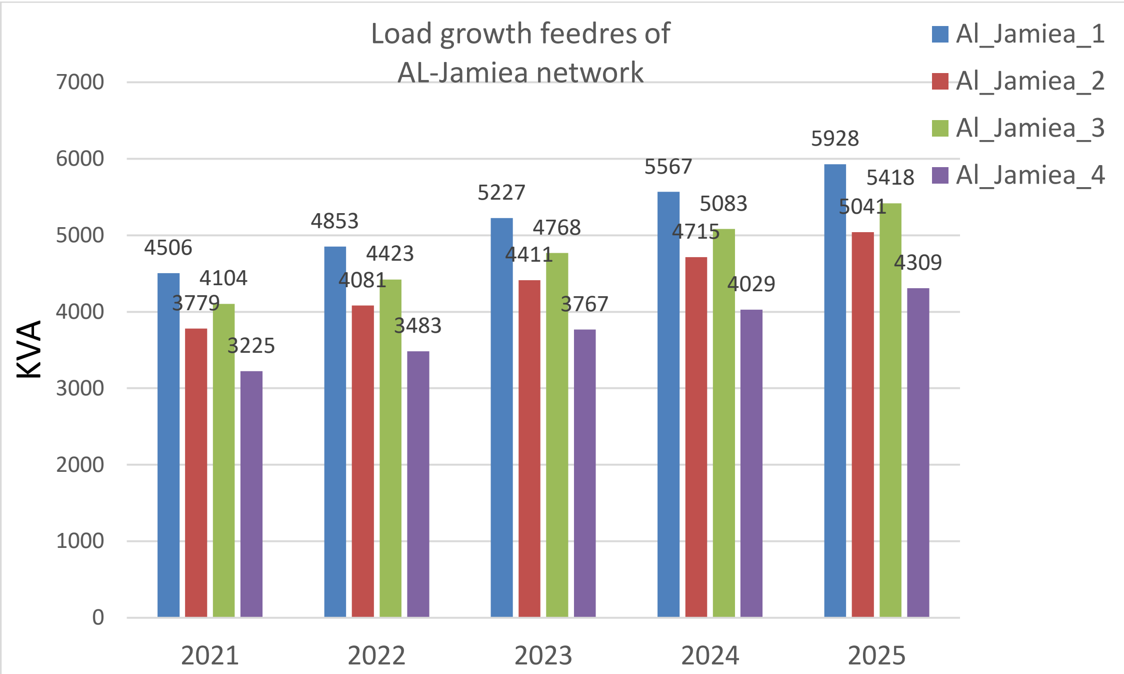

Figure 4.10 Al-Jamiea network (Load grow thing feeders)

As seen in Figure 4.11, 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.)

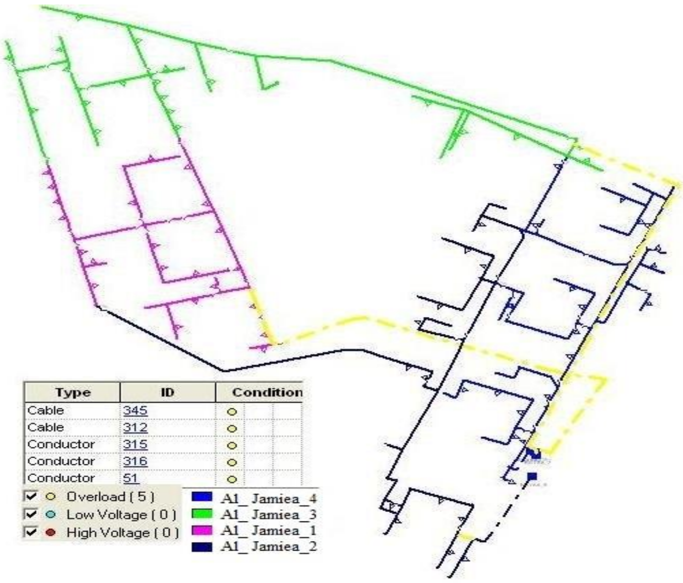

Figure 4.11 Al-Jamiea Network after load growth (Abnormal conditions)

The first system's actual power loss following load growth for all sources in 2021 was 271.04 kW, as demonstrated by the modeling results in a Table 4.13. 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).

The changing progress modes during system reconfiguration are shown in Table 4.11and figure 4.12. Clearly that the system is still working in abnormal conditions after implementing the load flow (five parts are working under conditions (overloaded), as illustrated in Figure 4.13a. Reactive power (kvar) compensation may use to solve this problem by increasing the size of those feeders. Figure 4.13b depicts the ideal capacitor installation sites, while Table 4.12 lists the ideal capacitor placement and dimensions. The loading summary load growth (before and after), network reconfiguration, and (kvar) correction is shown in Table 4.13. The overall data summary is shown in Table 4.14 for feeders in the network. Figure 4.14 displays the overall network losses for feeders (KW).

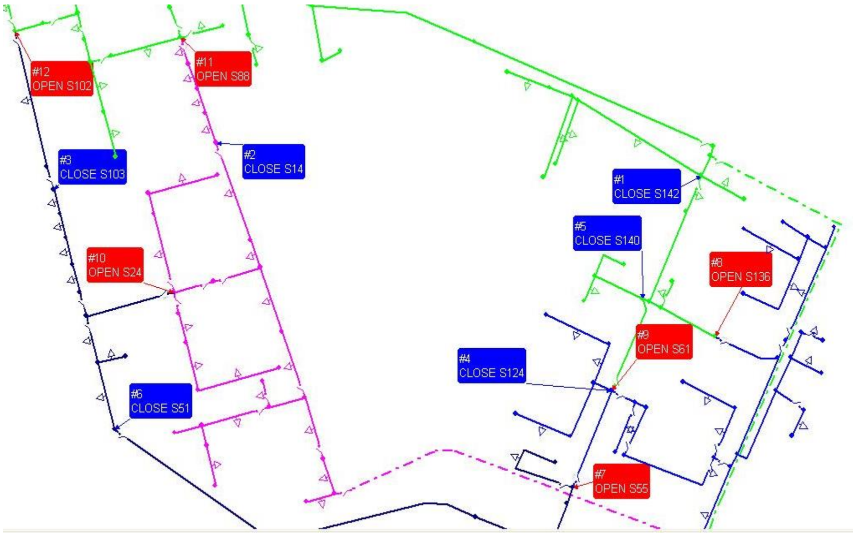

Figure 4.12 Al-Jamiea network (Optimal configuration)

Table 4.11 Networks of Al_ Jamiea are switching operations

Segment Id	Status of switch	Switch Id
55	Opened	S55
136	Opened	S136
61	Opened	S61
24	Opened	S24
88	Opened	S88
102	Opened	S102
142	Closed	S142
14	Closed	S14
103	Closed	S103
124	Closed	S124
140	Closed	S140
51	Closed	S51

Table 4.12 Al-Jamiea Network's ideal capacitor placement and sizing for cases of maximum load (100 percent loading)

Table 4.12a 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

Table 4.12b 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

Table 4.12c 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

Table 4.12d 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

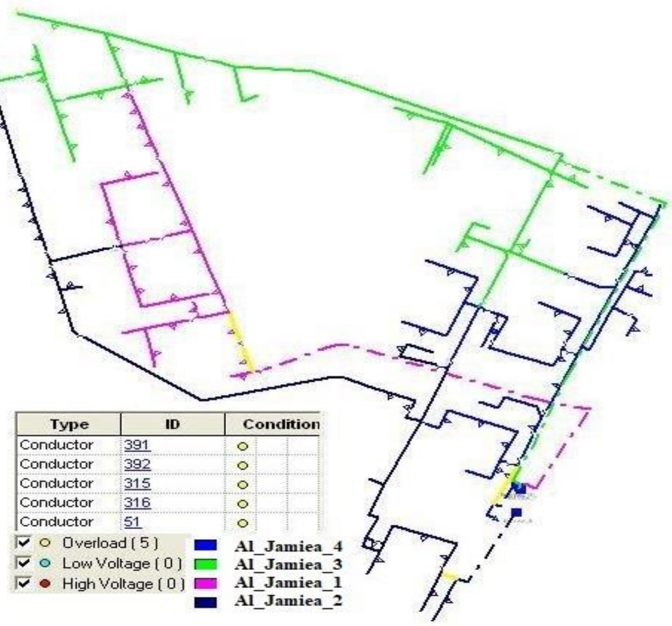

Figure 4.13a Al-Jamiea Network after application (reconfiguration system method) (with abnormal conditions)

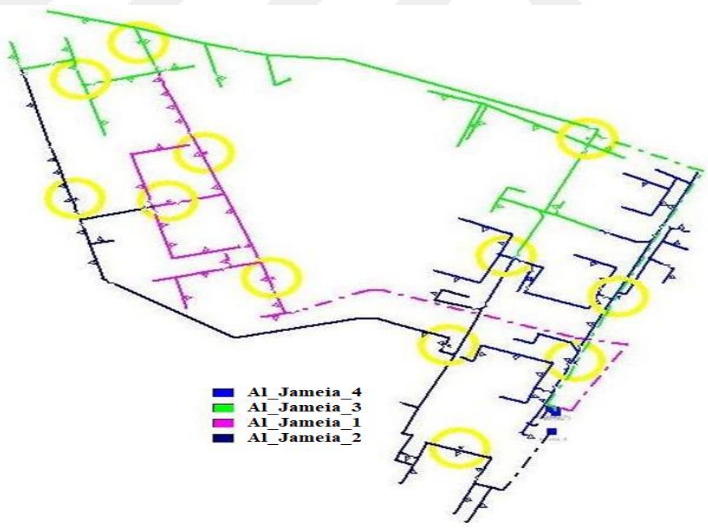

Figure 4.13b Optimal capacitor allocations for Al_ Al-Jamiea network

Table 4.13 Al-Jamiea-1 network maximum demand load overview increasing load, network reconfiguration, and reactive power adjustment (before and after)

Jamiea-1		**loading System**	**Total (adjusted value capacitor + capacitances of conductor**	**Network loosing**	**Power supply**
Before loading growth 2021	k.W.	3599.96	-----	50.98	3650.94
	kvar	2697.53	0+5.69	45.99	2737.83
	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

Table 4.14 Al-Jamiea-2 network maximum demand load overview increasing load, network reconfiguration, and reactive power adjustment (before and after)

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

Table 4.14 Al-Jamiea-2 network maximum demand load overview increasing load, network reconfiguration, and reactive power adjustment (before and after) (Continued)

Jamiea-2		**loading System**	**Total (adjusted value capacitor + capacitances of conductor**	**Network loosing**	**Power supply**
After compensation kvar	kW	4118.01	-----	33.94	4152.97
	kvar	3083.56	2204.31 + 2.65	35.54	911.84
	kVA	5142.60	-----	49.29	4251.01
	Power factor	0.80		0.690	0.970

Table 4.15 Al-Jamiea-3 network maximum demand load overview increasing load, network reconfiguration, and reactive power adjustment (before and after).

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	----	0.719	0.802
After reconfiguration of Network	kW	4123.01	----	75.82	4198.83
	kvar	3084.02	0 ± 6.630	69.30	3147.01
	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

Table 4.16 Al-Jamiea-4 network maximum demand load overview increasing load, network reconfiguration, and reactive power adjustment (before and after)

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	1935.02	0 + 2.320	11.50	1944.02
	kVA	3225.11	----	15.71	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	5052.99	----	30.40	4148.03
	Power factor	0.80		0.680	0.981

Table 4.17 Al-Jamiea-1 network (report by CYM_Dist for result)

Jamiea-1	**Before loading growth (at 2021)**	**After loading growth (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
Total Power loss (kW) per unit phase (active)	17.28	30.23	23.3	14.97
Reactive power losses (total kvar) per phase	15.6	27.22	20.70	13.29
power loading 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 4.18 Al-Jamiea-2 network (report by CYM_Dist for result)

Jamiea-2	**Before loading growth (at 2021)**	**After loading growth (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
Reactive power losses (total kvar) per phase	7.89	14.39	18.20	11.79
power loading 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 4.19 Al-Jamiea-3 network (report by CYM_Dist for result)

Jamiea-3	**Before loading growth (at 2021)**	**After loading growth (at 2025)**	**After System reconfiguration**	**After Compensatio n 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
Reactive power losses (total kvar) per phase	21.30	37.48	23.10	15.19
power loading 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 4.20 Al-Jamiea-4 network (report by CYM_Dist for result)

Jamiea-4	Before loading growth (at 2021)	After loading growth (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
Reactive power losses (total kvar) per phase	3.79	6.78	10.89	7.40
power loading 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

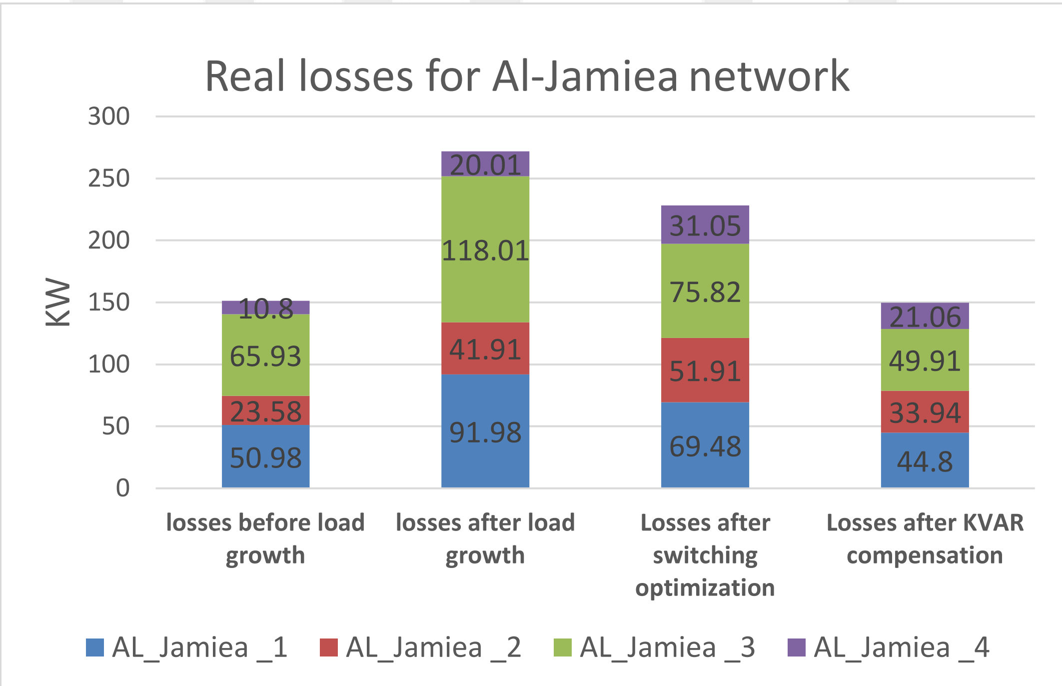

Figure 4.14 Al-Jamiea real losses network

According to the Table 4.13, Overall network losses are 149.81, 270.61, 228.67, and 152.15 kW, respectively, before, after load rise, after system reconfiguration, and after kvar correction. Thus, 118.46 kW is saved between the case with load increase and the case with kvar correction.

Table 4.15 shows the yearly costs of losses using Equation (2.24) and Equation (2.25). The overall network saving the cost of the maximum demand is 32.44*103 $/year. In Appendix (5), those computations are displayed.

Table 4.21 Yearly cost of losses (Al_ Jamiea network) ($/year)

Feeder name	Feeder load factor (%)	Before loading growth (at 2021)	After loading growth (at 2025)	After System reconfiguration	After Compensation kvar
Jamiea _1	100	$14.74*10^3$	$26.34*10^3$	$20.09*10^3$	$13.58*10^3$
Jamiea _2	100	$6.82*10^3$	$12.12*10^3$	$15*10^3$	$10.27*10^3$
Jamiea _3	100	$19.06*10^3$	$34.11*10^3$	$21.92*10^3$	$15.007*10^3$
Jamiea _4	100	$3.122*10^3$	$5.784*10^3$	$8.98*10^3$	$6.534*10^3$
Total loss cost ($)		$43.74*10^3$	$78.354*10^3$	$65.99*10^3$	$45.391*10^3$

4.3.1.1 Analysis of Al-Jamiea distribution system findings

Figure 4.15a, Figure 4.15b, Figure 4.15c, and Figure 4.15d shows the values of the buses voltages in the two feeders of the Al-Jamiea network within the network of the city of Najaf

1.before loading growth
2.after loading growth
3.after a system reconfiguration
4.After inserting the capacitor into the network .

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

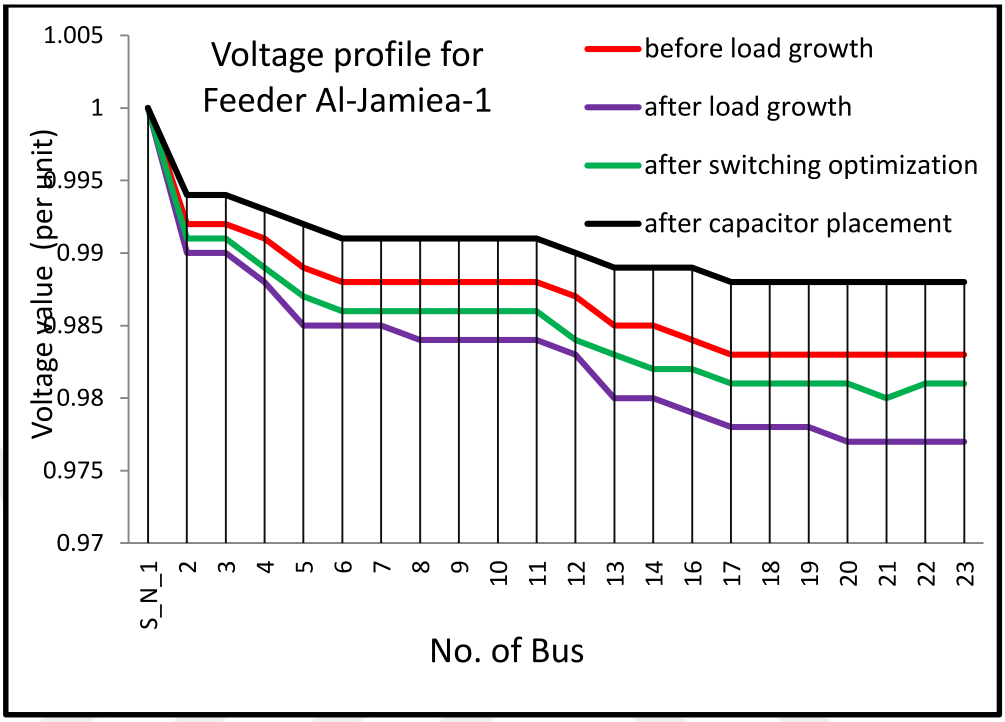

Figure 4.15a Feeder Al-Jamiea-1 (Voltage profile)

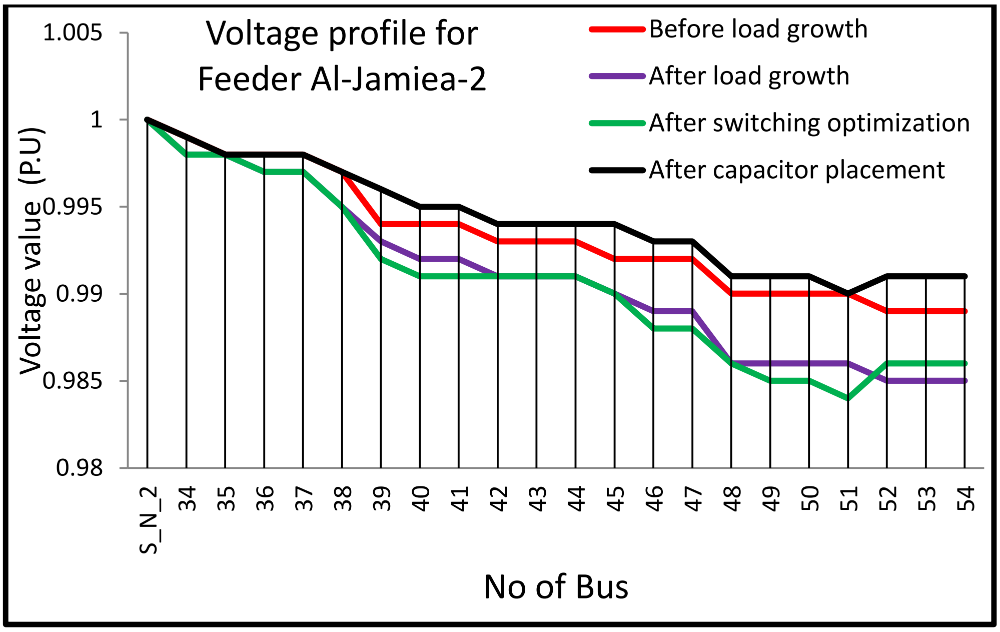

Figure 4.15b Feeder Al_ Jamiea_2 (Voltage profile)

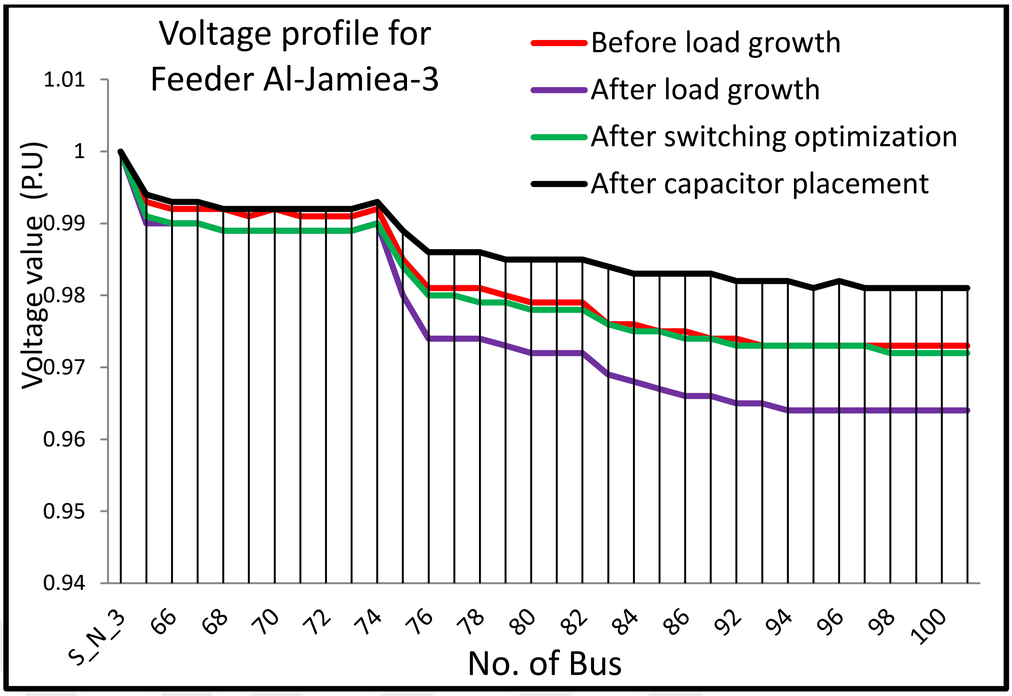

Figure 4.15c Feeder Al_ Jamiea_3 (Voltage profile)

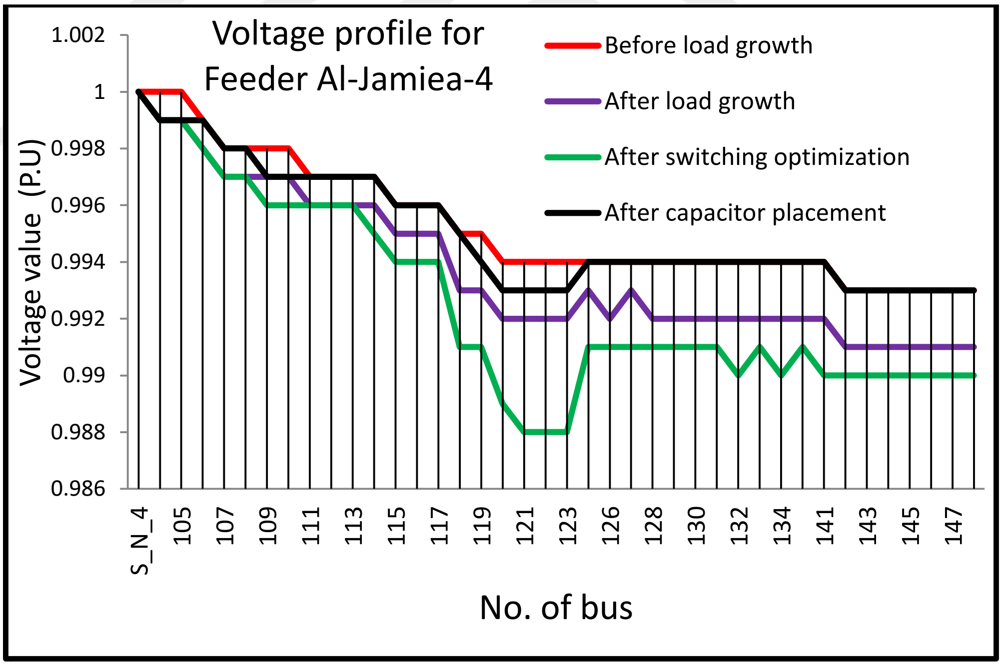

Figure 4.15d Feeder Al_ Jamiea_4 (Voltage profile)

With regard to the Al_Jamiea network feeders, Figure 4.16 shows the effect of the downstream reactive power profile (Kvar) and its relationship to the distances to the feeders. This shows that the longest path from the substation to bus 21 is one feeder that feeds each part. Figure 4.16a shows the behavior of the reactive power before the load growth. Figure 4.17b shows its behavior after the loads' increase. Finally, Figure 4.16 c and Figure 4.16 d show the behavior of the interactive power after reconfiguring the network and adding capacitors to the network, and correcting them respectively.

Appendix (5) has the complete reactive power profiles for every one of these graphs, including the maximum load reactive and reactive power losses Table A5.3.

Part 1 (1320 m in the distance) has 914.5 downstream reactive power per phase before adjusting; when the load increases, this value increases to 1211 kvar/phase. After implementing system reconfiguration, the kvar/phase is then decreased to 1091. The kvar/phase increased to 54.5 at the end of the design process when the capacitors were installed, and so on for the remaining portions. The total kW& kvar losses will decrease since the capacitor-equipped parts serve as a source of kvar. Each feeder's total P.F. has increased, as seen in the Table 4.13.

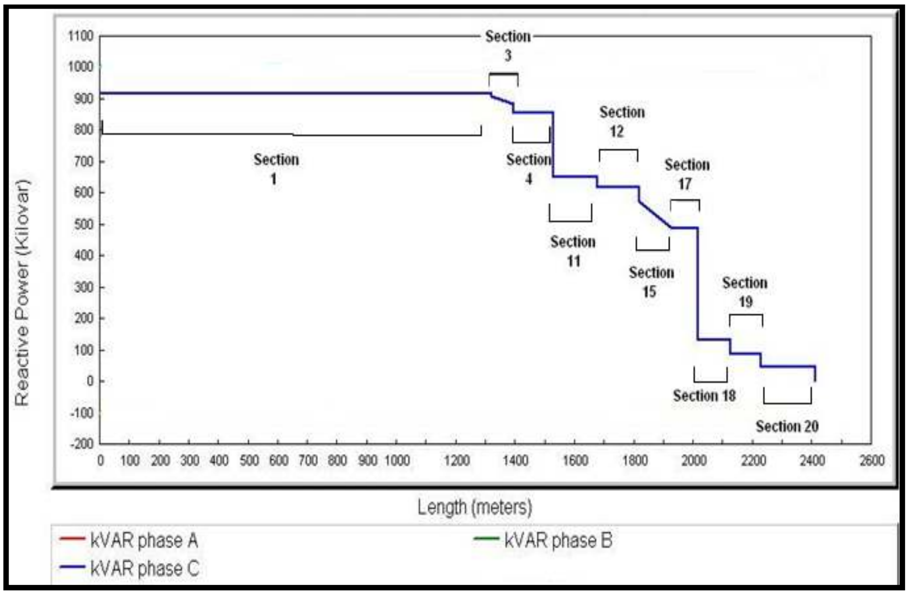

Figure 4.16a Al-Jamiea-1 before load growth (kvar profile)

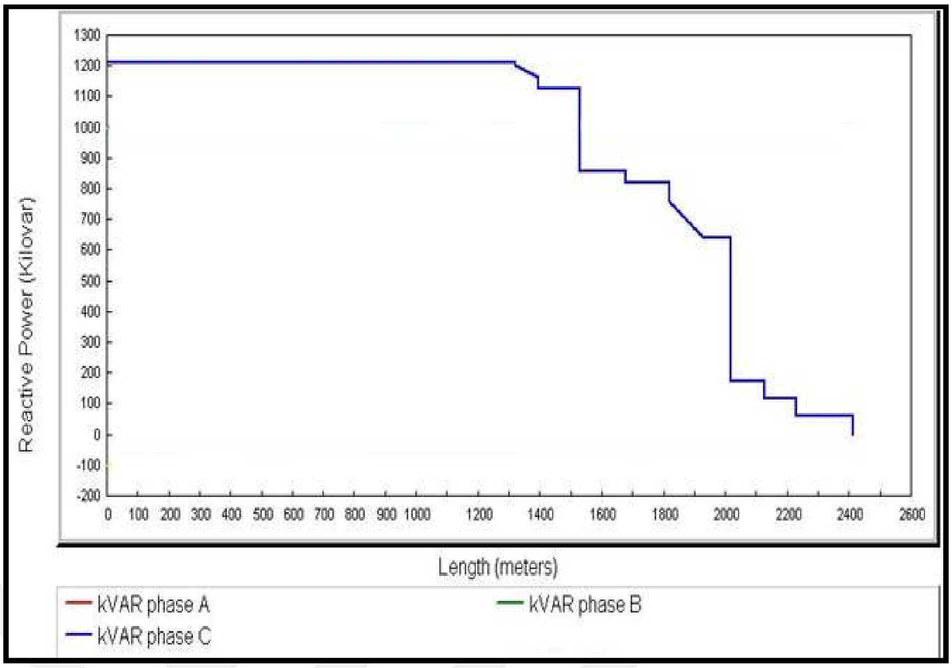

Figure 4.16b Al-Jamiea-1 after load growth (kvar profile).

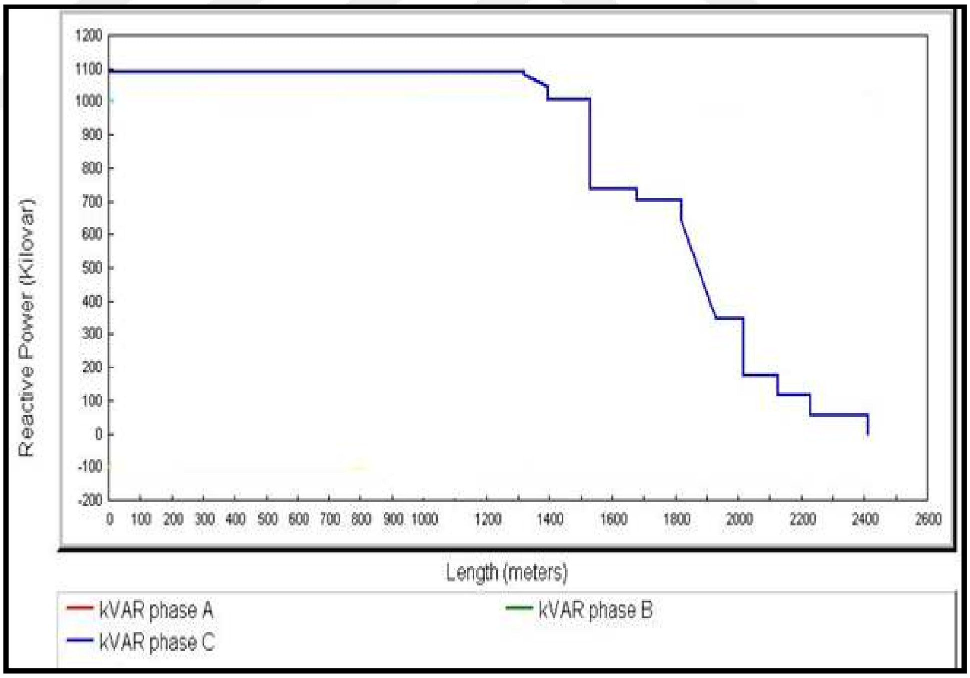

Figure 4.16c Al-Jamiea-1 after load growth (kvar profile)

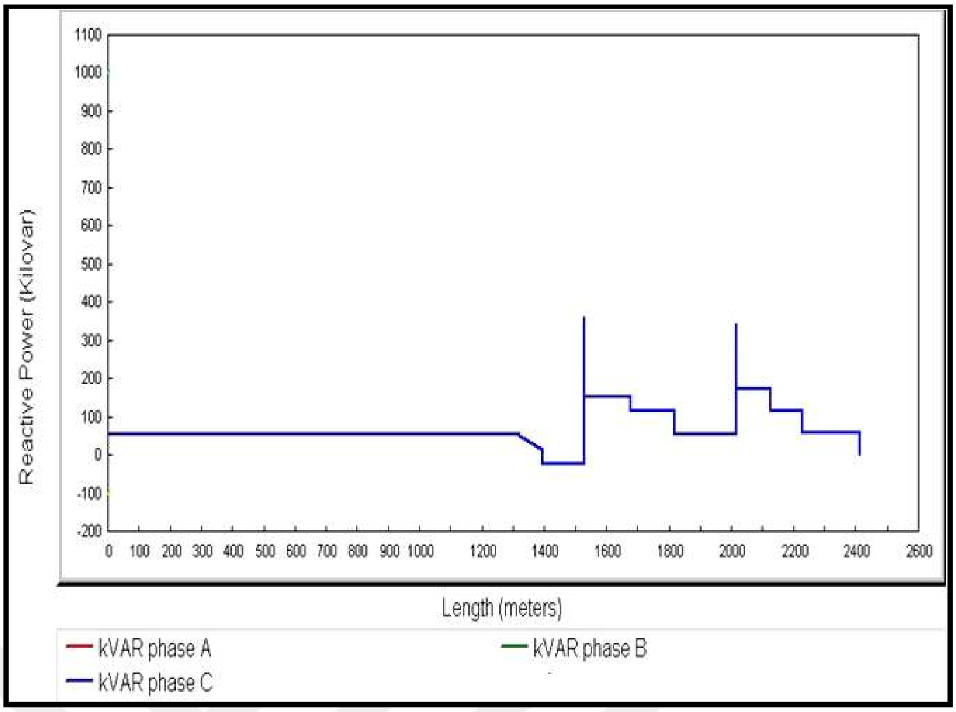

Figure 4.16d Al-Jamiea-1 after capacitor placement (kvar profile)

5 DERIVATION AND PROPOSALS FOR FUTURE PROJECT

5.1 Derivation

The design results obtained for the power distribution system through the application of the CYM _Dist program, 3 simulated works achieved, which are the process of load flow, reconfiguration of networks, and addition of capacitors to the network ideally, and it shows that the selected network is created once. Through this, this procedure is possible; it caters to different types of simulation analysis processes needed to design distribution networks.

The targeted method was implemented during the research and validated, and it appeared that the results were identical to those mentioned in the literature using the program functions (reconfiguration and addition of capacitors). The optimal network operating settings & loss reduction became substantially lower than in the scenario where reconfiguration is not considered, according to simulation and result comparison. Additionally, it is critical to properly arrange capacitors to minimize system energy losses and overall capacitor expenses.

The backward/forward sweep based on the load flow approach was employed for a faster power flow fix. Therefore, the total computation time is generally less, even for distributed network systems that are widely used, and this system is suitable for automation systems that exist over the Internet.

After applying for the CYM-Dist program on the selected network, which is part of the network of the city of Najaf, the results showed in the year 2025, after the short-term design, a decrease in energy losses by 40.07 kilowatts, amounting to 44.3% of the total losses in the selected system after the process Reconfigure the system. The value of losses decreased by 119.39 kilowatts, amounting to 44.3% of the total losses value, after adding capacitors to compensate for the reactive power in the system. In addition, the voltage file for all parts of the system was improved, and it was noted that the system works without violating any restrictions and under normal conditions.

This is what discusses was in a specific network, and a group of feeders was selected. When applying this to city networks, the results will appear in large and influential numbers on the electrical network to reduce losses and improve the voltage profile, which directly affects the costs of electric power distribution.

5.2 Suggestions for Future Work

The following proposals can be added to this project in the future:

1. With both the reconfiguration stage, voltage-controlled installation in radial distribution systems should be evaluated.
2. Adding generating units to the distribution networks, which are close to the loads and have a strong and direct impact on the performance of the networks by improving the voltage profile, so it is important to reconfigure the systems from this perspective and other considerations.
3. Reconsidering the conditions of high-frequency capacitors and pulses resulting from introducing the two capacitors into the network.

The power quality must be considered for the network operator to perform at its best. Optimal system operation requires consideration of load imbalance and harmonic distortion.

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APPENDICES

APPENDIX 1 Practically commercially capacitors sizes with cost (U.S. $/kVar) Methods

Table A1.1 Practically commercially capacitors sizes with cost (U.S. $/kVar)

J	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Q_c unit kVar	50	200	350	500	650	800	950	1100	1250
$ for every /kVar	0.6	0.4	0.35	0.27	0.32	0.20	0.25	0.19	0.24
J	10	11	12	13	14	15	16	17	18
$Q_{c\ for\ every}$ kVar	1400	1550	1700	1850	2000	2150	2300	2450	2600
$/kVar	0.23	0.22	0.21	0.232	0.195	0.213	0.19	0.21	0.209

APPENDIX 2. IEEE-33 Bus Test International Distribution System

Table A2.1 The 33-Bus test distribution international system (No. Of Bus and loading data)

Segment No.	Sending bus	Received bus	Segment R (Ω)	Segment X (Ω)	Real power (kW) Receive bus	Reactive power (kVar) Receive bus
1	Source 1	1	0.0933	0.0469	10	60
2	1	2	0.4932	0.2509	90	40
3	2	3	0.3662	0.1858	120	80
4	3	4	0.3814	0.1939	60	30
5	4	5	0.8188	0.7069	60	20
6	5	6	0.1869	0.6190	200	100
7	6	7	0.7110	0.2349	200	100
8	7	8	1.0304	0.7401	60	20
9	8	9	1.0439	0.7401	60	20
10	9	10	0.1958	0.0649	45	30
11	10	11	0.3739	0.1240	60	35
12	11	12	1.4679	1.1549	60	35
13	12	13	0.5409	0.7130	120	80
14	13	14	0.5908	0.5259	60	10
15	14	15	0.7459	0.5449	60	20
16	15	16	1.2889	1.7209	60	20
17	16	17	0.7319	0.5739	90	40
18	1	18	0.1639	0.1559	90	40
19	18	19	1.5037	1.3549	90	40

Table A2.1 The 33-Bus test distribution international system (the No. Of Bus and loading data) (Continued)

Segment No.	Send bus	Received bus	Segment R (Ω)	Segment X (Ω)	P (kW) Receive bus	Q (kVar) Receive bus
20	19	20	0.4089	0.4779	90	40
21	20	21	0.7091	0.9369	90	40
22	2	22	0.4509	0.3087	90	50
23	22	23	0.8978	0.7088	420	200
24	23	24	0.8958	0.7008	420	200
25	5	25	0.2029	0.1029	60	25
26	25	26	0.2842	0.1450	60	25
27	26	27	1.0586	0.9340	60	20
28	27	28	0.8039	0.7008	120	70
29	28	29	0.5080	0.2590	200	600
30	29	30	0.9739	0.9629	150	70
31	30	31	0.3110	0.3620	210	100
32	31	32	0.3408	0.5306	60	40
33	7	20	2.001	2.001	---	---
34	8	14	2.001	2.001	---	---
35	11	21	2.001	2.001	---	---
36	17	32	0.5001	0.5001	---	---
37	24	25	0.5002	0.5002	---	---

Table A2.2 The 33-Bus distribution international system

no. of bus	Voltage per unit (before -reconfiguration)	Voltage per unit (after-reconfiguration)
Source 1	1	1
1	0.994	0.994
2	0.981	0.985
3	0.974	0.982
4	0.967	0.978
5	0.950	0.969
6	0.947	0.969
7	0.942	0.965
8	0.937	0.960
9	0.931	0.963
10	0.930	0.963
11	0.929	0.963
12	0.923	0.961
13	0.921	0.960
14	0.920	0.958
15	0.919	0.956
16	0.918	0.950
17	0.916	0.947
18	0.994	0.990
19	0.990	0.973
20	0.989	0.968
21	0.989	0.964
22	0.977	0.982
23	0.971	0.975
24	0.968	0.972
25	0.948	0.968
26	0.946	0.966
27	0.935	0.958
28	0.928	0.953
29	0.925	0.951
30	0.921	0.949
31	0.920	0.946
32	0.920	0.947

APPENDIX 3. IEEE 34-Bus Test International Distribution Systems

Table A3.1 34-Bus IEEE test international systems (data of loading and data of line)

Send bus	Received bus	Section Id	Resistance (Ω/km)	reactance (Ω/km)	Length (km)	Received load	
						P (kW)	Q (kW)
S_N_1	1	1	0.196	0.081	0.61	231	142
1	2	2	0.196	0.081	0.56	0	0
2	3	3	0.300	0.084	0.56	231	142
3	4	4	0.300	0.084	0.51	231	142
4	5	5	0.300	0.084	0.51	0	0
5	6	6	0.525	0.091	0.61	0	0
6	7	7	0.525	0.091	0.41	231	142
7	8	8	0.525	0.091	0.61	231	142
8	9	9	0.525	0.091	0.41	0	0
9	10	10	0.525	0.091	0.26	231	142
10	11	11	0.525	0.091	0.21	138	84.5
2	12	12	0.525	0.091	0.31	73	45.5
12	13	13	0.525	0.091	0.41	73	45.5
13	14	14	0.525	0.091	0.21	73	45.5
14	15	15	0.525	0.091	0.11	13.6	7
5	16	16	0.300	0.084	0.61	231	142
16	17	17	0.300	0.084	0.56	231	142
17	18	18	0.379	0.087	0.56	231	142

Table A3.1 34-Bus IEEE test international systems (of loading and data of line) (Continued)

Send bus	**Receive bus**	**Section Id**	**Resistance (Ω/km)**	**reactance(Ω/km)**	**Length kilometer**	Receiving end load	
						P (kW)	Q (kW)
18	19	19	0.379	0.087	0.51	231	142
19	20	20	0.379	0.087	0.51	231	142
20	21	21	0.525	0.091	0.51	231	142
21	22	22	0.525	0.091	0.51	231	142
22	23	23	0.525	0.091	0.61	231	142
23	24	24	0.525	0.091	0.41	231	142
24	25	25	0.525	0.091	0.26	231	142
25	26	26	0.525	0.091	0.21	138	85.5
6	27	27	0.525	0.091	0.31	75.5	48.5
27	28	28	0.525	0.091	0.31	75.6	48.5
28	29	29	0.525	0.091	0.31	75.6	48.5
9	30	30	0.525	0.091	0.31	57.5	34
30	31	31	0.525	0.091	0.41	57.5	34
31	32	32	0.525	0.091	0.31	57.5	34
32	33	33	0.525	0.091	0.21	57.5	34

Table A3.2 34- Bus test international IEEE (compensating reactive power)

Bus no.	voltage (p.u.) before compensating	Voltage (p.u.) after compensating
Source 1	1	1
1	0.995	0.996
2	0.990	0.992
3	0.983	0.986
4	0.977	0.981
5	0.971	0.976
6	0.968	0.973
7	0.965	0.971
8	0.963	0.968
9	0.963	0.967
10	0.961	0.967
11	0.961	0.967
12	0.990	0.992
13	0.990	0.991
14	0.989	0.991
15	0.989	0.991
16	0.967	0.972
17	0.963	0.969
18	0.959	0.966
19	0.956	0.963
20	0.953	0.961
21	0.950	0.958
22	0.947	0.956
23	0.945	0.953
24	0.943	0.953
25	0.943	0.952
26	0.943	0.952
27	0.967	0.972
28	0.967	0.972
29	0.967	0.972
30	0.961	0.967
31	0.961	0.967
32	0.961	0.966
33	0.961	0.966

Table A3.3 The -34bus test international IEEE system compensating (Total downstream reactive power)

Segment No.	From the bus	To the bus	before compensating kVar per phase	after compensating kVar per phase
1	Source 1	1	979.6	139.9
2	1	2	927.9	89.3
3	2	3	876.8	39.3
4	3	4	826.0	-10.8
5	4	5	775.8	84.1
16	5	16	508.1	-42.9
17	16	17	459.4	-91.
18	17	18	411.0	1.4
19	18	19	362.7	-46.8
20	19	20	314.6	-94.7
21	20	21	266.7	-142.1
22	21	22	218.9	-52.9
23	22	23	171.2	-100.1
24	23	24	123.5	-149
25	24	25	75.9	-60.1
26	25	26	28.4	28.4

APPENDIX 4. Iraqi Najaf City (Distribution System)

- **The Iraqi Distribution Network**

The portion of the electrical company network that is located between the main power supply and the service breakers for the customer known as the distribution system. A sample one-line schematic of a section distribution network in the Iraqi grid shown in Fig. (A4.1). the distribution substation receives electricity from bulk power sources via sub-transmission networks at a sub-transmission voltage of 33kV.

The incoming voltage in the transmission lines shall be reduce to a lower voltage to match the local voltage applied in the distribution stations. It made up of distribution transformer as well as the appropriate voltage-regulating equipment, buses, & switchgear. The substation's low-voltage buses is distributed to the load center by the three-phase main feeder, which normally operates at 11 kV which it branched into 3 ph. sub feeders with capacity ranging from 100 to 1000 KVA. Normally, every major feeder, sub-feeder, and lateral connected to one another.

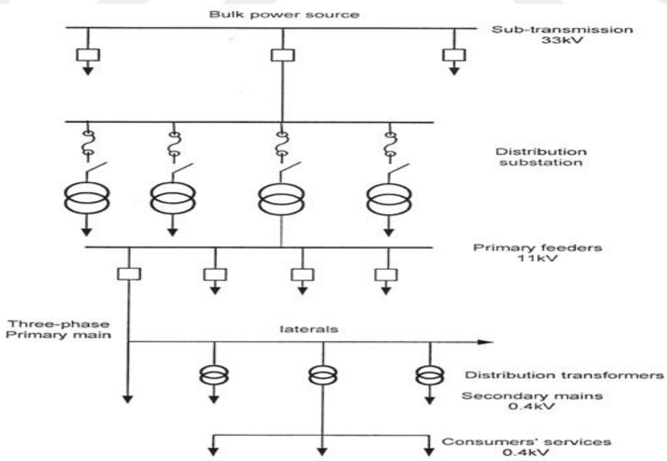

Figure A4.1 Typical distribution system (One line diagram).

- **Electrical System in Najaf City (distribution)**

The majority of the city of Najaf's power source comes from six major 400/132kV substations, that in turn serve several 132/33kV or 132/33/11kV substations that are geographically disperse around the city. The numbers of these substations and their details shown in Table (d.1). A huge number of 33/11kV substations supplied with electricity by these 132/33kV substations.

The majority of these 33/11kV power stations have transformers with a 31.5MVA capacity apiece; image shows a single line diagram for one such station (d.2). Every transformer provides an 11kV bus that linked to its (7) feeders and the assistant feeder is connect to one of the two buses to provide tiny "11/0.4kV" transformers for substation services and control. In addition, some of substations "33/11kV" that having two transformers with capacity "16MVA", each of it supplying bus bar "11kV". One of these bus bars is connected directly to its four feeders, while the others are connected to their three feeders through an auxiliary one. The low voltage bus bars of the two kinds of substations supply the 11 kV distribution feeders by subterranean cables or overhead power lines. A significant No. of 11/0.4kV transformers constructed using one of the following techniques receive power from each 11kV feeder:

1. Transformers installed on poles powered by 11 kV overhead cables through manually controlled fused switches. The majority of the transformers in this network have ratings of 250 KVA or 400 KVA; 100 KVA transformers is occasionally utilize in places with a low demand load density.

2. Compact type units often positioned on the pavement of streets. Those substations are equipped with three compartments: transformers, low voltage, and high voltage. 630KVA transformers are often use in this system, while occasionally 400KVA, 1000KVA, and 1600KVA transformers are again utilized. Numerous outgoing 0.4kV feeders in the low voltage compartments are available to give power to varied numbers of users.

3. Private property sub - station set up on the grounds of consumers in basements or power rooms of buildings. The capacities employed in this instance range from 100 to 1000 kVA and determined by the electrical load's energy.

Table A4.1 Najaf substations.

NO.	***Full Name***	***No. of Trans.***	***Trans. Voltage ratio(KV)***	***Capacity MVA***	**Earthling Tr.**	**Percentage impedance**		
						H-M	H-L	M-L
1	North Najaf	*3*	*132/33/11*	*63/63/63*	1	0.126	0.207	0.066
2	alataba	*3*	*132/33*	*90/90/90*	2	0.004	0.001	0.004
3	Old station	*3*	*132/33/11*	*63/63/63*	2	0.1085	0.234	0.341
4	alhasania	*2*	*132/33/11*	*63/63/63*	1	0.106	0.182	0.094
5	alkufa	*3*	*132/33*	*63/63/63*	0	0.126	0.207	0.06
5	Al jawaheri	*3*	*132/33*	*63/63/63*	0	0.103	0.118	0.061
6	West Najaf	*3*	*132/33/11*	*90/90/90*	1	0.1246	0.241	0.083
7	alnedaa	*3*	*132/33*	*90/90/90*	0	0.104	0.125	0.012

APPENDIX 5. Al-Najaf Distribution Network

Table A5.1 Al_Najaf distribution network (Line and load data)

segment no.	From the bus	To the bus	Type of Conductor	Segment distance (meter)	Loading bus (end)		
					Kilowatt per phase Actual power	Kvar per phase-reactive power	Type of load
1	Source 1	2	T2	1320	---	---	---
2	2	3	T1	64	37.43	28.4	Residention
3	2	4	T1	77	37.43	28.4	Residention
4	4	5	T1	135	59.29	44.69	Residention
5	5	6	T1	82	---	---	---
6	6	7	T1	56	37.43	28.4	Residention
7	6	8	T1	154	57.29	44.69	Residention
8	8	9	T1	45	57.29	44.69	Residention
9	9	10	T1	87	57.29	44.69	Residention
10	8	11	T1	63	---	---	---
11	5	12	T1	148	37.43	28.4	Residention
12	12	13	T1	143	59.29	44.69	Residention
13	13	14	T1	62	59.29	44.69	Residention
14	14	91	T1	218	59.29	44.69	Residention
15	13	16	T1	109	---	---	---
16	16	17	T1	91	---	---	Residention
17	17	18	T1	47	---	---	---
18	18	19	T1	64	59.29	44.69	Residention
19	19	20	T1	104	59.29	44.69	Residention
20	20	21	T1	19	59.29	44.69	Residention
21	17	22	T1	170	59.29	44.69	Residention
22	22	23	T1	46	59.29	44.69	Residention
23	23	24	T1	158	59.29	44.69	Residention
24	17	25	T1	200	---	---	---
25	25	26	T1	101	59.29	44.69	Residention
26	26	27	T1	64	37.43	28.4	Residention
27	26	28	T1	145	37.43	28.4	Residention
28	25	29	T1	53	---	---	---
29	29	30	T1	60	59.29	44.69	Residention
30	30	31	T1	60	37.43	28.4	Residention
31	31	32	T1	52	37.43	28.4	Residention
32	32	33	T1	54	37.43	28.4	Residention

Table A5.1 Al-Najaf distribution network (Line and load data) (continued)

Segment no.	From the bus	To the bus	Type of Conductor	Segment distance (meter)	Ending Bus		
					Real power of Loading(kW/phase)	Reactive power of loading (kvar/phase)	Type of load
33	Source 2	34	T2	300	---	---	---
34	34	35	T1	155	46.99	35.43	Residention
35	34	36	T1	49	74.57	56.05	Residention
36	36	37	T1	135	46.99	35.43	Residention
37	36	38	T1	111	46.99	35.43	Residention
38	38	39	T2	182	74.57	56.09	Residention
39	39	40	T1	64	---	---	---
40	40	41	T1	113	46.99	35.43	Residention
41	40	42	T1	51	46.99	35.43	Residention
42	42	43	T1	31	---	---	---
43	43	44	T1	46	46.99	35.43	Residention
44	42	45	T1	101	---	---	---
45	45	46	T1	107	---	---	---
46	46	47	T1	49	46.99	35.43	Residention
47	46	48	T1	233	---	---	---
48	48	49	T1	41	46.99	35.43	Residention
49	49	50	T1	59	46.99	35.43	Residention
50	50	51	T1	137	46.99	35.43	Residention
51	51	28	T1	882	---	---	---
52	48	52	T1	158	---	---	---
53	52	53	T1	36	---	---	---
54	53	54	T1	252	74.57	56.09	Residention
55	53	55	T1	221	---	---	---
56	55	56	T1	43	45.99	35.43	Residention
57	56	57	T1	124	---	---	---
58	57	58	T1	131	74.57	56.09	Residention
59	56	59	T1	89	46.99	35.43	Residention
60	59	60	T1	153	74.57	56.09	Residention
61	55	61	T1	211	---	---	---
62	61	62	T1	116	---	---	---
63	62	63	T1	59	46.99	35.43	Commercial
64	62	64	T1	99	46.99	35.43	Residention
65	Source 3	65	T1	1373	---	---	---
66	65	66	T1	47	---	---	---
67	66	67	T1	109	65.02	48.87	Commercial
68	66	68	T1	314	42	30.92	Residention
69	68	69	T1	143	42	30.92	Residention
70	68	70	T1	17	---	---	---

Table A5.1 Al-Najaf distribution network (Line and load data) (continued)

Segment no.	From the bus	To the bus	Type of Conductor	Segment distance (meter)	Real power of Loading(kW/phase)	Reactive power of loading (kvar/phase)	Type of load
71	70	71	T1	182	42	30.92	Residention
72	70	72	T1	54	---	---	---
73	72	73	T1	100	65.02	48.87	Residention
74	65	74	T1	22	---	---	---
75	74	75	T1	570	---	---	---
76	75	76	T1	372	---	---	---
77	76	77	T1	120	---	---	---
78	77	78	T1	46	42	30.92	Residention
79	76	79	T1	97	---	---	---
80	79	80	T1	75	---	---	---
81	80	81	T1	114	---	---	---
82	81	82	T1	66	41.01	30.92	Residention
83	80	83	T1	198	---	---	---
84	83	84	T1	271	65.02	48.87	Residention
85	83	85	T1	122	41.01	30.92	Residention
86	85	86	T1	67	---	---	---
87	86	87	T1	98	65.02	48.87	Residention
88	86	88	T1	60	41.01	30.92	Residention
89	88	89	T1	56	41.01	30.92	Residention
90	89	90	T1	55	65.01	48.87	Residention
91	90	91	T1	67	41.01	30.92	Residention
92	86	92	T1	158	65.02	48.87	Residention
93	92	93	T1	49	---	---	---
94	93	94	T1	109	41.01	30.92	Residention
95	94	95	T1	99	41.01	30.92	Residention
96	93	96	T1	49	41.01	30.92	Residention
97	96	97	T1	57	41.01	30.92	Residention
98	97	98	T1	91	65.02	48.87	Residention
99	97	99	T1	80	---	---	---
100	99	100	T1	66	---	---	---
101	100	101	T1	108	65.02	48.87	Residention
102	100	102	T1	292	65.02	48.87	Residention
103	33	103	T1	52	---	---	---
104	Source 4	104	T2	110	---	---	---
105	104	105	T2	43	---	---	---
105-1	105	162	---	---	47.88	36.14	Commercial
106	104	106	T1	62	---	---	---
107	106	107	T1	80	30.30	22.97	Residention
108	107	108	T1	51	---	---	---

Table A5.1 Al-Najaf distribution network (Line and load data) (continued)

segment no.	From the bus	To the bus	Type of Conductor	Real power of Loading(kW/phase)	Ending Bus		
					Real power of Loading(kW/phase)	Reactive power of loading (kvar/phase)	Type of load
109	108	109	T1	140	47.88	36.14	Residention
110	108	110	T1	109	47.88	36.14	Residention
111	110	111	T1	203	30.30	22.97	Residention
112	111	112	T1	66	30.30	22.97	Residention
113	112	113	T1	40.95	30.29	22.97	Residention
114	107	114	T1	97	---	---	---
115	114	115	T1	79	30.30	22.97	Residention
116	115	116	T1	133	---	---	---
117	116	117	T1	100	30.30	22.97	Residention
118	115	118	T1	230	30.30	22.97	Residention
119	118	119	T1	43	---	---	---
120	119	120	T1	245	30.30	22.97	Residention
121	120	121	T1	112	30.30	22.97	Commercial
122	121	122	T1	28	---	---	---
123	122	123	T1	114	47.88	36.14	Commercial
124	122	55	T1	59	---	---	---
125	119	125	T1	114	30.30	22.97	Residention
126	125	126	T1	127	47.88	36.14	Residention
127	118	127	T1	31	---	---	---
128	127	128	T1	179	30.30	22.97	Residention
129	128	129	T1	76	---	---	---
130	129	130	T1	61	30.30	22.97	Residention
131	128	131	T1	78	---	---	---
132	131	132	T1	77	30.30	22.97	Residention
133	131	133	T1	59	---	---	---
134	133	134	T1	52	30.30	22.97	Residention
135	127	135	T1	221	---	---	---
136	135	136	T1	150	---	---	---
137	136	137	T1	134	---	---	---
138	137	138	T1	61	47.88	36.14	Commercial
139	137	139	T1	31	---	---	---
140	61	140	T1	17	---	---	---
141	139	141	T1	205	---	---	---
142	66	140	T1	83	47.88	36.14	Commercial
143	135	141	T1	41	---	---	---
144	141	142	T1	215	47.88	36.14	Residention
145	142	143	T1	48	---	---	---
146	142	144	T1	47	---	---	---
147	144	145	T1	64	---	---	---

Table A5.1 Al-Najaf distribution network (Line and load data) (continued)

segment no.	From the bus	To the bus	Type of Conductor	Segment distance (meter)	Ending Bus		
					Real power of Loading(kW/phase)	Reactive power of loading (kvar/phase)	Type of load
148	144	146	T1	51	---	---	---
149	146	147	T1	137	30.30	22.97	Residention
150	146	148	T1	198	47.88	36.14	Residention

Where:

- Type number 1: T1

  Conductor type "11 kilovolt" Alloy Aluminum Conductor size (95) mm2_ D1250:

  Diameter of conductor = 1.26 cm

  GMR = 0.47376

  Resistance at temp.25º = 0.3150 Ω

  Resistance at temp.50º = 0.3460 Ω

  Nom. rating (summer) = 240 A.

  Nom. rating (winter) = 390 A.

  Spacing between conductors:

  Coordinates by meter

	X-axis	Y-axis
1	-	8.86
2	0.546	9.95
3	1.095	8.90
N	-	-

impedance1= 0.3150 +j 0.3450 (Ω per kilometer); B= 3.347 (μs/km)

impedance0= 0.4628+j 1.6073 ((Ω per kilometer); B= 1.30 (μs/km)

- Type number 2: T2

  Cable medium voltage 3*150mm2 11kv

  impedance1= 0.1265+j0.0933 ((Ω per kilometer)

impedance0= 0.6390+j0.3089 ((Ω per kilometer)

Table A5.2 Yearly Al-Jamiea network loading growth

Year	Domestic	Commercialive	Industrialive	Governmentive	Agriculturalive
2015	7.7	9.5	8.1	3.6	10.0
2016	6.5	8.3	7.7	3.6	9.7
2017	6.5	8.3	7.2	3.6	9.5
2018	6.5	7.9	6.9	3.6	9.2
2019	6.5	7.6	6.5	3.6	8.8
2020	6.5	7.3	6.5	3.6	8.3
2021	6.5	7.0	6.6	3.6	7.9
2022	6.5	6.7	6.6	3.6	7.5
2023	7.4	6.4	7.7	3.9	7.0
2024	7.2	6.1	7.5	3.8	6.6
2025	7.4	6.3	7.4	3.7	6.3
2026	7.9	7.0	7.1	3.7	5.5
2027	7.6	7.0	6.7	3.5	5.3
2028	7.3	7.0	6.4	3.5	5.1
2029	7.0	7.0	6.1	3.4	5.0
2030	6.8	7.0	5.8	3.3	5.0

Table A5.3 Feeder Al-Jamiea-1 total downstream reactive power

No. of segment	From the bus	To the (bus)	Before load growth (2021)	After load growth total 2025)	After network reconfiguration	After kVar compensating
1	Source 1	2	914.5	1211	1091.1	54.6
3	2	4	881.6	1165	1046.1	13.8
4	4	5	852.9	1126	1008.1	-23.6
11	5	12	648.5	855.2	739	15.1
12	12	13	619.8	816.7	701.1	114
15	13	16	487.4	642	345.6	52.4
16	16	17	486.8	640.9	345.3	52.2
17	17	18	131.2	172.6	172.6	172.6
18	18	19	132	172.5	172.5	172.5
19	19	20	87.4	115	115	115
20	20	21	43.8	57.6	57.6	57.6

APPENDIX 6. Calculation for the Cost to the System (Yearly)

Calculation for the cost to the system (yearly)

Before reconfiguration- Bef. Rec. / Aft. Rec. main after reconfiguration

Before kvar compensating-Bef. Kvar comp. / after kvar compensating-Aft. Kvar comp.

Before load growth-Bef. L. G. / after load growth-Aft. L. G. / after network reconfiguration- Aft. Net. Rec. / after capacitor placement- Aft. Cap. Pls.

Load Factor-LF

LF= $0.150*0.650 + (1-0.150)*(0.650)^2= 0.456626$

1. 33 bus test international IEEE system "Standard"

- Bef. Rec.

  Yearly cost losses system = $198.32*0.456626*0.1*8760 = 79.328*10^3$ "$per year"

- Aft. Rec

  Yearly cost losses system = $139.45*0.456626*0.1*8760= 55.728*10^3$ "$per year"

2. IEEE-34 bus test international system "Standard"

- Bef. Kvar comp.

  Yearly cost losses system = $223.02*0.456626*0.1*3679 = 37.465*10^3$ "$per year"

- Aft. Kvar comp.

  Yearly cost losses system=$162.09*0.456625*0.1*3679 + (6*450*0.253)$ $=27.792*10^3$ $per year

3. Al-Jamiea network: Loss factor = $0.15*1 + (1-0.15)*(1)^2 = 1$

➢ **Al-Jameia-1 feeder (max. load):**

- Bef. L. G. (at year 2021):

  Yearly costing= $51.84*1*0.1*2891 = 14.74*10^3$ "$ per year"

- Aft. L. G. (at year 2025):

  Yearly costing= $91.11*1*0.1*2891 = 26.34*10^3$ "$per year"

- Aft. Net. Rec.:

  Yearly costing= $69.48*1*0.1*2891 = 20.09*10^3$ "$ per year"

- Aft. Cap. Pls.:

Yearly costing= [44.8*1*0.1*2891+ (2*950*0.183+1360*0.207)]

= 13.58*10^3 "$per year"

➢ **Al_Jameia-2 feeder (max. load):**

- Bef. L. G (at year 2021):

Yearly cost losses system = 23.58*1*0.1*2891 = 6.82*10^3 "$per year"

- Aft. L. G. (at year 2025):

Yearly cost losses system = 41.91*1*0.1*2891 = 12.12*10^3 "$per year"

- Aft. Net. Rec:

Yearly cost of system losses = 51.91*1*0.1*2891 = 15*10^3 "$per year"

- Aft. Cap. Pls.:

Yearly cost losses system = [33.94*1*0.1*2891+ (2*925*0.183+465*0.253)]

= 10.27*10^3 "$per year"

➢ **Al_Jameia-3 feeder (max. load):**

- Bef. L. G (at year 2021):

Yearly cost losses system = 65.93*1*0.1*2891 = 19.06*10^3 "$per year"

- Aft. L. G. (at year 2025):

Yearly cost losses system = 118.01*1*0.1*2891 = 34.11*10^3 "$per per year"

- Aft. Net. Rec.:

Yearly cost losses system = 75.82*1*0.1*2891= 21.92*10^3 "$per year"

- Aft. Cap. Pls. :

Yearly cost losses system [49.91*1*0.1*2891+ (475*0.253+950*0.183+1375*0.207)]

= 15.007*10^3 "$per year"

➢ **Al_Jameia_4 feeder (max. load):**

- Bef. L. G (at year 2021):

  Yearly cost of system losses = 10.8*1*0.1*2891= 3.122*10^3 "$per year"

- Aft. L. G. (at year 2025):

  Yearly cost of system losses = 20.01*1*0.1*2891= 5.784*10^3 "$per year"

- Aft. Net. Rec.:

  Yearly cost of system losses = 31.05*1*0.1*2891= 8.98*10^3 "$per year"

- Aft. Cap. Pls.:

  Yearly cost of system losses = [21.06*1*0.1*2891+ (425*0.253+2*925*0.183)]

  = 6.534*10^3 "$per year"

CURRICULUM VITAE

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Academic Activities

1. Topaloğlu, İ. and MOSSA, M. H. 2022. Reconfiguration and capacitor placement in Najaf distribution networks sector (design study). International Research Journal of Engineering and Technology (IRJET), 9(12): 856-877.