THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

INSTITUE OF SCIENCE AND TECHNOLOGY

POWER SYSTEM RELIABILITY INVESTIGATION BY LOAD BALANCING TECHNOLOGY ACROSS THE DISTRIBUTION FEEDERS

MASTER THESIS

AYAD T. ABDULHAFEDH

1406030007

THE DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

THE PROGRAM OF ELECTRICAL POWER

DECEMBER 2017

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Türk Hava Kurumu Üniversitesi Fen Bilimleri Enstitüsü'nün 1406030007 numarlı Yüksek Lisans öğrencisi ''Ayad T. Abdulhafedh'' ilgili yönetmeliklerin belirlediği gerekli tüm şartları yerine getirdikten sonra hazırladığı "POWER SYSTEM RELIABILITY INVESTIGATION BY LOAD BALANCING TECHNOLOGY ACROSS THE DISTRIBUTION FEEDERS'' başlıklı tezini aşağıda imzaları bulunan jüri önünde başarı ile sunmuştur.

Tez Danışmanı : Prof. Dr. Doğan ÇALIKOĞLU.
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Tez Savunma Tarihi: 13/12/2017

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10/11/2017

Ayad. T Abdulhafedh

ACKNOWLEDGMENTS

I would like to express my deepest thanks to almighty GOD for helping me to finish this study.

I would like to express my special thanks to **Prof.Dr. DOĞAN ÇALIKOĞLU** For their direct supervision, encouragement, sharing of experiences and guide me through my research period.

Besides my supervisor, I would like to thank the rest of my research committee; **Assist. Prof. Dr.Ibrahim Mahariq** and **Assist. Prof. Dr. Ahmet Karaaslan** for their encouragement, insight full comments and questions.

I would like to express my special thanks to my father, mother, wife, sisters, and brothers for their support and encouragement to finish my research.

At the end my special thanks to my best friends who help me to finish my research.

10/11/2017

Ayad. T. Abdulhafedh

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LIST OF ABBREVIATIONS

ABCA	Artificial Bee Colony Algorithm
ANN	Artificial Neural Network
BFO	Bacterial Foraging Optimization
BFOA	Bacterial Foraging Optimization Algorithm
BFS	Backward-Forward Sweep
BIA	Biological Inspired Algorithms
DFA	Dragon Fly Algorithm
DFR	Distribution Feeder Reconfiguration
DG	Distribution Generator
DGs	Distribution Generators
DNR	Distribution Network Reconfiguration
DPA	Dynamic Program Algorithm
ETAP	Electrical Transient Analyzer Program

GA	Genetic Algorithm
GIS	Geographical Information System
GSA	Gravitational Search Algorithm
HAS	Harmony Search Algorithm
MSE	Mean square error
PGS	Plant Growth Simulation
PSAT	Power Train System Analysis Toolkit
PSO	Particle Swarm Optimization
RDS	Radial Distribution System
RGA	Revised Genetic Algorithm
SIGA	Selection Improvement of Genetic Algorithm
SPSO	Selective Partical Swarm Optimization
URDS	Unbalanced Radial Distribution Systems

Abstract

Power System Reliability Investigation by Load Balancing Technology Across The Distribution Feeders

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December - 2017

Pages: 91

Losses are considered as an essential threat to power system reliability and worthiness. The power losses take place in the distribution system. The power losses can be due to physical parameters of the elements used in distribution system such as material of cables and bus-bars or even the insulators which in whole constitute the distribution system. In this thesis, power loss due to load variation is studied. In a radial distribution system, load distributes among feed-forward bus-bars and hence losses may be developed due to overload in any particular node/bus-bar. In a radial system, three main feeders are designed to maintain the required power in order to run the branches connected to it so that three branches are implemented. In undesired situation such as fault at any node, current consumption will be extremely high and so this node will be subjected to trip off until the fault is cleared. As radial system involves a feed forward fashion, it is important to maintain the branch that fed from this faulty node during the trip off period. However, a new feeder may take over instead the faulty node. One more assumption is proven by previous studies: changing the network topology is yielded a noticeable improvement on reliability. For those two cases, network can be switched into another topology by changing the feeder of different bus bars. Switching (off/on) a particular node is produced a new topology and repetition of this procedure is provided many cases where reliability curve can be drawn.

System is implemented by using sixteen bus-bar distribution grid that is radially structured using Matlab software. Results are shown that optimum reliability is achieved by using artificial neural network when nodes (two, four and fifteen) are opened and so, the power losses is minimized and voltage profile is improved over seven iterations of different topologies.

Keyword: Distribution Feeder Reconfiguration, Radial Network, BackwardForward Load Flow, Artificial Neural Network.

özet

Dağıtım Besleyicileri Boyunca Yük Dengeleme Teknolojisi ile Güç Sistemi Güvenilirlik Araştırması

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Aralık - 2017

Sayfa sayısı: 91

Üretim santrallerinden nihai kullanıcılara kadar meydana gelen kayıplar, güç sisteminin güvenilirliği ve değerliliği için temel tehdit olarak değerlendirilmektedir. Göz ardı edilemeyecek miktarda elektrik kaybı dağıtım sisteminde meydana gelmekte olup bu kayıplar kablo, bara malzemeleri ve hatta dağıtım sisteminin tamamını oluşturan yalıtıcılar gibi dağıtım kalemlerinin fiziksel parametrelerinden kaynaklanabilmektedir. Bu tezde, yük değişimi nedeniyle meydana gelen güç kayıpları incelenmiştir. Radyal dağıtım sisteminde yük, ileri besleme baraları arasında sınıflandırılmakta ve dolayısıyla herhangi bir düğümdeki/baradaki aşırı yük nedeniyle kayıplar oluşabilmektedir. Radyal sistemde üç ana besleyici, sisteme bağlı branşları çalıştırmak amacıyla üç branşın da uygulanması için gerekli olan gücü muhafaza etmek üzere tasarlanmıştır. Herhangi bir düğümde arıza meydana gelmesi gibi istenmeyen durumlarda, akım tüketimi son derece yüksek olacak ve bu düğüm arıza giderilene kadar devre dışı kalacaktır. Radyal sistem ileri besleme şeklinde dahil oldukça, devre dışı kaldığı süre boyunca bu hatalı düğümden beslenen branşı muhafaza etmek önemlidir, ancak hatalı düğüm yerine yeni bir besleyici devreye alınabilir. Daha önceki çalışmalarda kanıtlanan bir diğer varsayım şöyledir; ağ topolojisini değiştirmek, güvenilirlik üzerine gözle görülür bir gelişme sağlamaktadır. Bu iki durumda ağ, farklı baraların besleyicilerini değiştirerek başka bir topolojiye dönüştürülebilir. Belli düğümlerin kapatılması/açılması, yeni bir topoloji üretmekte ve

bu işlemin tekrarlanması ile güvenilirlik eğrisinin çizilebileceği birçok durum temin edilmektedir.

Sistem, Matlab yazılımı kullanılarak radyal olarak yapılandırılan on altı adet bara dağıtım şebekesi kullanılarak uygulanmıştır. ANN kullanılmış ve sonuçlar, düğümlerin (iki, dört ve on beş) açılması ile optimum güvenilirliğin sağlandığı, böylece güç kayıplarının en aza indirgendiği, voltaj profilinin farklı topolojilerin yedi kez yinelemesi üzerine iyileştiğini göstermiştir.

Anahtar Kelimeler: Dağıtım Besleyici Yeniden Yapılandırması, Radyal Şebeke, Geriøleri Yönlü Yük Akışı, Yapay Sinir Ağı, ANN.

CHAPTER ONE

INTRODUCTION

1.1 Presentation of work

In this thesis, the reliability and economic are studied and achieved by reconfiguring a radial distribution system that described by S. Civanlar et al with sixteen bus-bars, 100 MVA and 23 KV is selected to study under various assumptions and operation criteria [2]. This work applies in the electrical power system especially in the distribution system. The distribution networks are consisted of two types of structures. The network is configured either radially structure or loop structure (Ring main). In this work, the radial configuration is used because it is simple system. The number of switches of radial network is small but the ring main system is complex. The ring main network has a large number of switches. The distribution networks are operated radially because of simpler protection and lower short circuit currents. Distribution systems consist of groups of interconnected radial circuits. The configuration may be varied via switching operations to transfer loads among the feeders through normally closed switches (sectionalizing switches) or normally open switches (tie switches). Distribution losses vary by changing configuration under same loading condition. Therefore, under normal operating conditions, distribution engineers periodically reconfigure distribution feeders by opening and closing of switches in order to increase the reliability and reduce line loss. The resulting feeders must remain radial and meet all the load condition requirements.

There are numerous numbers of switches in the distribution system and the number of possible switching operations is tremendous. The distribution feeder reconfiguration (DFR) is a process that consists of changing the status of the network switches in order to resupply the non-energized areas after a fault occurrence or optimize given criteria. DFR problem of radial power distribution systems may be stated as follows: given a load profile for a distribution network with a number of tie lines and switching points, find a radial configuration for the network which minimizes the network losses, supply the critical loads at acceptable voltage levels. DFR is a complex combinatorial optimization problem which yields the best distribution network configuration with minimal losses by optimizing an appropriate objective function and at the same time, maintaining the constraints imposed upon the network. These constraints are voltage limits at nodes, the radial topology of network and supply of power to all loads. In recent past, considerable research has been conducted for loss minimization in the area of DFR. DFR for loss reduction was first proposed by Merlin and Back [1].

There are many solutions for these problems such as (the equivalent resistance reduction, the placement of compensated capacitor, the distribution generator, the network reconfiguration). The network reconfiguration is motivated me due to many things such as:

- Power Loss Reduction: Power Loss reduction is a main objective of DFR because the reduction in system losses brings down the unnecessary operational cost to the profit-driven utilities. System losses are affected by many aspects, such as load imbalance, low voltages, and long distribution lines.
- Load Balancing: DFR for load balancing determines an optimum radial distribution system configuration to balance loads among distribution feeders. The optimal load balancing switching operation enables appropriate transfer of loads from heavy-loaded feeders to light loaded feeders, in order to maintain sufficient load transfer margin and consequently enhance operational efficiency. Load balancing can mitigate equipment overloading to avoid unnecessary system losses and faster equipment aging that will cause even more losses.

- Mitigation of Voltage sags: Distribution feeder emanates radially from the substation to supply the loads and thereby the voltage drops along the distribution lines from the substation. To maintain the node voltage profiles within operating limits, various control strategies have been implemented such as voltage regulators and reactive power support. In order to achieve a better voltage profile, DFR alters the network topology and therefore power flow magnitudes and directs to avoid over-loads and long distribution paths that will cause a significant voltage drop.

- Service Restoration: The goals described above are commonly targeted for normal conditions of a distribution system. Service restoration is a group of objectives in emergency conditions such as fault when switches are opened to isolate part of the system. The isolation can lead to loss of loads and/or distributed generators (DGs). DFR for service restoration redirects the power flow to regain the service to loads and DG connections to the network while considering the objectives for normal conditions and special requirements such as minimum restoration time, maximum restored load and minimum switching operations.

  Loss and reliability are two significant points among several factors in distribution network. Hence feeder reconfiguration helps to transfer the loads from heavily loaded feeders to lightly loaded feeders. These alterations not only reduce the real power losses of the network but also balance the loads among feeders and significantly improve the voltage profiles.

The results of this work are depended on the method that will be found the best solution of feeder reconfiguration. The network reconfiguration is tested on (16 bus system) [2]. This work is accomplished by the artificial neural network to make the best decision so that any configuration gets the best results.

The results demonstrated the reconfiguration number (5) is the best solution because it gets the minimum power losses and the best value of voltage profile.

1.2 Main component of work

This work is involved some things to make reconfiguration in electric distribution network.

- The reconfiguration is accomplished by using switches (tie switches and sectionalizing switches) and this will achieve by selecting the switches and changing the situation of these switches.
- The load flow algorithm (Backward-Forward load flow).
- The (ANN)is used to get the best reconfiguration of network.

1.2.1 The importance of component and the aim of work

The distribution network is existing with losses due to multiple reason occurrences. The proposed system to distribute the load within the network is expected to deliver the power from the generating end to the consumer end. This dissertation aims to implement a system that fulfils the following goals:

1- To implement an economic study to find the switches that should participate in a switch upgrade plan based on the results of reconfiguration.

2- The system may cope with the load variation during the operation time in order to set the optimum values that participating the performance and hence minimizing the losses.

3- An intelligent system for network reconfiguration and feeders upgrading will be implemented by using artificial neural network.

4- The ANN will take the call to find the switches (branches) that participating the upgrading plan. The ANN will make the better decision to assign the network reconfiguration to the required feeders.

5-A power system with 16 buses will be employed to determine the losses and monitor the performance prior and post adding the ANN model.

6- Economical consideration will be followed by minimizing loses and enhancing the voltage profile.

7- System will be modeled and simulated with Matlab and accordingly result with recommendations will be made.

In order to specify the optimum performance in the distribution network, the concept of feeder reconfiguration is arrived with big advantage to keep the load balanced across the network. It is obvious that load imbalance and losses occurring within the network is caused unfortunate events including economical worth degradation. The distribution network is usually designed with very high number of branches to deliver the electricity to the consumer‟s locations. The power flow from the generation point to the used end is happened throughout huge network routes. Generally, the propagation of the power through these routs is facing a resistance due to many considerations such as heat losses.

The losses within power grid are not identical for all routs and some routes can have lesser amount of losses as compared to others. Another fact about the power grid that load is not constant through particular path. The load is varied in daily and hourly times so the optimum conditions of the network are difficult to predict.

The problem of distributed network reconfiguration is to find best configuration of radial network having minimum power losses and meet all operating constraints which are voltage profile of the network, current capacity of the feeder and radial structure of the distribution network. Since many switching combinations are possible in a distribution network. The best configuration is a complex, non-linear, combinatorial, and non-differentiable constrained optimization problem. The differences in power losses, and voltage drops can be measured from the simulation of the network using power flow before and after the network reconfiguration. Conventional Gauss-Seidel and Newton-Raphson methods of load flow gives unreliable solutions in distribution network due to radial structure of the network, and have high R/X ratio.

1.3 Literature survey

1.3.1 Overview

This section is contained the studies which conducted by many researchers for developing the concept of network reconfiguration. This approach is reported a quite good results which are reflected into the overall performance. According to the following sections, several technologies were used to enhance the efficiency of network reconfiguration such as Genetic algorithm, Selective particle swarm optimization, Gravitational Search Algorithm, Bacterial foraging optimization algorithm and extra. The each is performing the required steps to keep the network stable and robust.

1.3.2 Network Reconfiguration

This concept involves the upgrading the status of network feeders and switches such as open/close operation, in order to balance the load across the system and hence improving the performance and reducing the losses. The great impact has reported by using a various technologies such as Genetic algorithm and artificial inelegancy to support the operation of network reconfiguration. The following is about the most relevant approaches that conducted in this regard:

In 1988, S. Civanlar et al**.** They presented strategy for network reconfiguration in the simplest way to make loss reduction. They are the first to conduct research on the subject of restructuring the electrical network. The method is depended on guessing and approximation the losses by changing the place of line to the other lines. They made the exchanging of branch and put method for power loss minimization[2].

In 1989, D. Shirmohammadi and H. W. Hong. They presented a heuristic method to reduce the line resistance losses by reconfiguration in normal operation condition. The convergence is used to reach the optimum or near optimal solution and without depending of final solution from initial status of the network switches. The method uses mathematically reliable and efficient for planning and operation studies [3].

In 1992, S. K. Goswami and S. K. Basu. This study presents loss-reduction on radial electrical distribution system by reconfiguration based on optimum power flow pattern. A new configuration is sought heuristically in order to minimize the interference on the optimum flow pattern. The reconfiguration method is utilized in this study to reduce resistive losses of distribution system that starts with analyzing the load flow of the meshed system by closing all the switches in the network. According to the Kirchhoff's laws, current favors to flow through the path with minimum losses.

Whereas the system is operated as a meshed network, the resistive losses would be small and opening a line carrying high amount of current would force the current to flow through paths with higher losses. The acceptance of opening the minimum current carrying switch would interfere the optimum flow least. The increase in losses by opening switches would be minimized. This switch opening step is repeated, in order to achieve a low loss configuration. Existing configuration and the meshed configuration with all switches closed are analyzed according to load flow calculations. A new network configuration satisfying the voltage and current limitations of the system with reduced losses is proposed for the system. The load flow analyzing is performed by calculating the admittance matrix of the network and using Newton-

Rhapson method. P and Q values of each bus are regarding to voltage magnitude and angles. The new voltage and current values of the network elements are calculated iteratively [4].

In 1997, Song et al. They put the fuzzy control for reconfiguration. This change or boom is a key change to modulate the rate of the boom in simulating evolutionary operation. The binary method is represented the situation of switches, whether they are open (0) or close (1). Optimization process increased it speed by chain-table and with merge depthfirst and breadth-first strategies [6].

In 2003, Y. Y. Hong and S. Y. Ho. They maintained that many criteria depending on the performance of the system for an operator to determine the switch statuses in the distribution systems such a minimization of losses and minimizing the voltage drop. For the successful operation of any radial distribution system, the configuration of the feeder with statuses of switch must be determined. Minimizing losses during normal condition and voltage drop during fault is important. The Genetic Algorithms (GAS) provides a useful tool for this purpose and (GA) has the capability of encoding the chromosomes with integers. The statuses of the switches were considered as genes (binary bits) in GAS. The bit with a value of “zero” (“one”) implies that the corresponding switch is open (close). After the genetic operations are applied, the structure of the distribution system may not be radial. An extra “mesh check” algorithm will be incorporated with GAS to discard the infeasible mesh (loop) structures [7].

In 2003, B. Venkatesh and Rakesh Ranjan. They presented the evolution program (multi -objective) to find feeder reconfiguration in real network. The multi objective consists of reducing energy loss, service reliability, enhancing voltage stability, decreasing the number of switching.

In this paper, the previous objective function is achieved by fuzzy algorithm to find the best solution. The work is implemented and simulated by C++ program and tested by Tai power 102bus system [8].

In 2006, N. C. Sahoo and K. Prasad. They made a test for two bus system 33bus and 69bus radial distribution system. They are used the fuzzy genetic algorithm to re-planned the radial distribution system to enhance the voltage stability for the network by using some loads. The methodology of solving had two approaches first one, they are taken the average of voltage stability in all buses. The second approach is reduced the losses in a previous two buses and make optimization for these two buses to get voltage stability improvement. After this work is achieved, they realized that the voltage stability enhancement for the network when the losses are reduced and this is achieved by system reconfiguration [9].

In 2007, A. Abuja. S. Das and A. Pahwa. They presented the development method for loss reduction calculation by finding the optimum trees of the network. The distribution network is consisted from a group of branches and nodes. The graph theory for distribution system is represented. Here, the problem is characterized as problem of specified the optimum tree of graph for radial distribution system and applying on each structure. This algorithm is reduced the switching combinations to minimum number and reduces the number of load flow. The implemented simulation is achieved by PSAT and MATLAB programs on (33-bus) test system [10].

In 2008, R. Srinivasa Rao, S.V.L. Narasimham, M. Ramalingaraju. They mentioned in distribution system that the feeder restructuring is achieved by altering the situation of sectionalizing switches to get the power losses reduction. This work is accomplished by modern method which is called an artificial bee colony algorithm (ABC). This algorithm is used to obtain the sectionalizing switches that will be operated to make solution for the power losses minimization problem. The (ABC) is modern form and derivative from the meta-heuristic algorithm. The (ABC) is taken from smart foraging manner of honey bee group. The benefit of (ABC) algorithm does not need external factors like the crossover or the mutation as the same in the genetic algorithm. It is complex to find these parameters in the beginning. The other benefit is ability to research in the algorithm and this is achieved by putting in the nearness exporter in production mechanism and that is similar to mutation operation. This work is tested on (69, 33, 14 buses) system to demonstrate the rightness of (ABC) algorithm and make comparison with other works to satisfy that. This method is best than the other methods by the solution quality and efficiency of computation. For all these systems, the substation voltage is considered as 1.0 p.u. and all tie and sectionalizing switches are considered as candidate switches for reconfiguration problem. The algorithm of this method was programmed in Matlab [11].

In 2009, Ganesh. Vulasala, Sivanagaraju, Sirigiri and Ramana Thiruveedula. They have presented an efficient approach to feeder reconfiguration for power loss reduction and voltage profile improvement in unbalanced radial distribution systems (URDS). In this paper Genetic Algorithm (GA) is used to obtain solution for reconfiguration of radial distribution systems to minimize the losses. A forward and backward algorithm is used to calculate load flows in unbalanced distribution systems by simulating the survival of the fittest among the strings. The optimum string is searched by randomized information exchange between strings by performing crossover and mutation. Results have shown that proposed algorithm has advantages over previous algorithms. The proposed method is effectively tested on 19 node and 25 node unbalanced radial distribution systems [13].

In 2010, P. V. V. Rama Rao and S. Sivanagraju. They mentioned in this study that the feeder reconfiguration is problem of merge optimization. The feeder reconfiguration is calculated the different constraints that operated in electrical distribution system.

The Plant Growth simulation is applied in this work and has a good formulation for optimization parameters that used to solve the nonlinear problems. The Plant Growth Simulation (PGS) algorithm is proposed with formulation to make the network more reliability and increase the speed. This method is used successfully to solve the standard mathematical problems. The work has a guide search that is related with configuration to reduce the losses in the network. The load balancing problem has objective function such as the index of load balancing of branch of the system. This method does not need to external parameters to complete its work and this is considered as distinguishes from the other methods. The study is applied and tested on radial configuration system (69bus) to reduce losses and balancing load is achieved [14].

In 2011, Suman Nath and Somnath Rana. They said that the civilization has many requirements. The development of industry need to expand and increasing in development of power network, with best efficiency and improved the voltage stability.

The goal of this work is to make the transmission system and the distribution system are worked with best efficiency, voltage stability and that will share to make reduction in the operational cost. The network reconfiguration is used in this work and the work is applied on (14bus) system. This study is implemented by (Matlab). The Newton Raphson method is used to make the load flow. The artificial neural network is applied to get the best switches reconfiguration. The standard IEEE-14 bus system has been modified with the addition of power lines which connect various buses in the power system by connection/disconnection switches. The results obtained from the load flow analysis corresponding to the various load conditions. Sensor with inbuilt artificial neural network may incorporate in electric system shall continue the monitoring of load variation to give a command to series and parallel combinations of load selection. The tie switches are selected to operate the optimum switches [15].

In 2012, Tamer M. Khalil. In this study, the goal of the work is to introduce a new algorithm to correct the network reconfiguration system. The new algorithm is coming after make modification for the partical swarm optimization (PSO) and the new one is called selective partical swarm optimization (SPSO). This work is applied by making the switches of network normally closed then another time normally opened. This work is tested on (69bus) and (33bus) system. The result is compared with another studying to make the new algorithm to demonstrate [16].

In 2012, Wardiah Mohd Dahalan and Hazlie Mokhlis. They presented an effective method based on Particle Swarm Optimization (PSO) to identify the switching operation plan for feeder reconfiguration and optimum value of DG size simultaneously. The main objective is to reduce the real power losses and improve the bus voltage profile in the system while satisfying all the distribution constraints. A method based on PSO algorithm to determine the minimum losses and their impact on the network. Real power losses and voltage profiles are investigated. For demonstrating the validity of the proposed algorithm, computer simulations are carried out on 33 bus system. The results are presented and compare with the Genetic Algorithm (GA) method [17].

In 2013, Manju Mam et al. The researchers are proposed in this study the radial system reconfiguration and the efficiency of this method is found on the testing system to remove the overload of the system and reduced the power losses .This is achieved by restrict the electrical network and this method is used to decrease the load of calculation. The results of this work are demonstrated that this method is more efficient to solve the problem of the power losses reduction in radial distribution system. The (CYME) simulation is used to accomplish all the constraints. In the proposed system, an 11 KV, 16 node bus system has been considered with base reconfiguration based on 1 MVA [18].

In 2014, N. H. Shamsudin et al. They said that in distribution system, the losses of the electrical power are continued for this last years in a huge desired of the electrical energy and that happen in the modern countries. Therefore, the feeder distribution system of the radial structure is used in wide field to ensure the flowing electrical energy continuous even the fault is occurred.

This approach is used a new algorithm called the selection improvement of genetic algorithm(SIGA) and it is same the genetic algorithm but it is made the modification of switching by gradation probability of the genetic operator and all the constraints are satisfaction in distribution system reconfiguration. This algorithm (SIGA) is applied and tested on (33bus) distribution system but the work is done by chosen just (5) tie switches. The losses of power are classified in the stratification to the minimum values and voltage profile is enhanced by using this algorithm. The results are demonstrated that this algorithm is best than the genetic algorithm in comparing the results of the power losses. The proposed algorithm with improved selection operator is tested to the initial 33-bus distribution system with 28 closed switches and 5 opened switches. The analysis involved the determination of power losses and voltage profile before and after DNR while maintaining the radially of the original network [19].

In 2014, Zeinab Ghofrani-Jahromi, Mostafa Kazemi, and Mehdi Ehsan. They presented an economic study to find the participate switches in electrical network that depend on the results of reconfiguration. The traditional reconfiguration problem tends to be considered an electric load condition (mostly maximum demand), in order to get the optimal reconfiguration. However, there are variations in distribution loading condition such as hourly and daily variations. There is a constant changing in optimal reconfiguration. Consequently, considering only one loading condition might lead to inefficiency of the results. In this work, daily load curves of different types of distribution consumers during various types of days (weekdays and holidays) and seasons (summer and winter) are used to find the best reconfiguration hours during a day. They used the genetic algorithm (GA) to find the optimal reconfiguration in each time interval. The objective function applied to GA consists of loss and energy not supplied. The switches that contribute to reconfiguration should be remotely controlled in order to have the capability of immediate mode alteration. For evaluation feasibility of automated switch installation; the benefit-to-cost ratio is calculated. The entire procedure is applied to test distribution system, and the results are discussed also [20].

In 2014, K. Sathish Kumar, K. Rajalakshmi and S. Prabhakar Karthikeyan. They presented the best reconfiguration of radial distribution system. They reconfigure the primary feeder to loss reduction by using feeder reconfiguration as planning and control of real time. The considered mathematical solution is applied. The optimal reconfiguration is applied by using artificial neural network for radial distribution system. They worked to reduce the peak load demand, enhance the voltage. This work is used (16 bus) network [21].

In2015, Laximi. M. Kottal and Dr. R Prakash. Network reconfiguration process may help to rectify many distribution system problems such as planning, energy restoration and loss minimization. This research describes loss reduction in a radial distribution system by network reconfiguration using a new algorithm. Gravitational Search Algorithm [GSA] considers all the objectives in order to meet the reliability requirements. The processing time can be reduced and the quality of solution can be improved. The proposed approach has been applied to test system including IEEE 33 system. The heuristic algorithm is based on the law of gravity and mass interactions.

The algorithm is comprised of collection of searcher agents that interact with each other through the gravity force. The agents are considered as objects and their performance is measured by their masses. The gravity force causes a global movement where all objects move towards other objects with heavier masses. The essential achievements of this study were gained with 33bus-test system before make network reconfiguration is 79KW and after make reconfiguration losses becomes 60KW. So after network reconfiguration is implemented the losses were reduced up to 23.6% for half load conditioned [22].

In 2015, Su Mon Myint and Soe Win Naing. In this work, there are two kinds of power losses in distribution system are called (technical and non technical) methods for power losses. Power flow in electrical distribution system must have exact reduction of losses and the stability of voltage must improve. There are many methods to get reduction of losses and make the voltage improvement. These two parameters will achieve when the reconfiguration of the network is done. The (ETAP) software program is used to make the power flowing. The reconfiguration of distribution network under 10 MVA, 33/11 kV transformer is presented. The base voltage is 11kV and 74 buses are studied in detail for reconfiguration. After reconfiguration has processed, voltage regulation and efficiency of distribution system is better since operating voltage exists between 95% and 105% and line losses also reduced. There are some things are very important in system feeder reconfiguration such as (reduction of losses, capacity of the power losses and voltage improvement).

The work is accomplished by testing the distribution system (74 nodes). This grid is taken as case of study in this research because the grid has a great number of the industrial loads that make the efficiency of the system is reduced. This work is achieved by using partical swarm optimization to get optimal switches technique and this is implemented by Matlab. The results are demonstrated from this work is shown a great enhancement in voltage profile and the losses are reduced. This mean, the stability of voltage is improvement and losses reduction are achieved when the result is compared with the other model [23].

In 2016, A. V. sudhakara and M. Damodar Reddy. They are presented a new method that illustrates the feeder reconfiguration to balance the network and to make optimization for radial network system. The new method is demonstrated the efficient for optimizing the radial network. The feeder reconfiguration is a great method to make the power flow changing through the branches of the network. This work is introduced a modern method to get solution for network reconfiguration problem with satisfying all the constraints such as (active power losses, enhancing the voltage in the radial network system). The load flow algorithm is worked and then the objective function is satisfied to put the solution for the problem of radial distribution system (RDS). The Meta -heuristic Dragon Fly algorithm (DFA) is used to make reconfiguration and to obtain the optimal switches in the network and reducing the power losses in the distribution network. The strategy has been tested with final configuration of the 100MVA, 23kV, IEEE 16-bus test system with 16 branches, 13 sectionalizing switches and 3 tie switches. The results demonstrate that a significant reduction in real power losses and improvement of voltage profiles [24].

In 2016, Manju Mam, Leen G, N. S. Saxena .An approach was proposed to introduce a new algorithm to solve system feeder reconfiguration and this algorithm is called Bacterial Foraging Optimization (BFO). The load flow in this work is achieved by using the backward-forward sweep method (BFS) and geographical information system

(GIS). The distribution feeder reconfiguration is characterized by (non linearity, the combinatorial problem, hard and non differentiable). The goal of distribution system reconfiguration is to find radial structure that getting minimal power losses with all constraints are satisfied. The algorithm (BFOA) is used to get the optimum switches structure with power losses minimization. The (BFOA) is utilized to make optimization to the deviation at the node voltage. The (GIS) is utilized for good planning and analyzing. The work is tested to the (33bus) system. The results are compared to another researches and the result is demonstrated that this method is efficient and it is the best in convergence parameter. The algorithms which are inspired from the natural biological behavior are called Biological Inspired Algorithms (BIA). The BIA inspired from the foraging behavior of b a c t e r i a is called Bacterial Foraging Optimization Algorithm (BFOA), proposed by Passino. Since its inception BFOA has been widely accepted as global optimization algorithm for real world problems such as transmission loss reduction, learning of artificial neural networks, active power filters, optimal controller design, and harmonic estimation [25].

In 2016, J. Nosratain Ahour, M.rostami, V. Taheri Majad, M. Rashidbeygi and H.Moazen. They presented the optimal placement of switching that implemented by genetic algorithm without any correction. The costs and structure of the distribution network depend on the number of chosen switches and the location of these switches. They talked about the reliability of distribution system and related with controllable switches. The location and the number of switches are depended on changing the load, time of faults, frequency, kinds of customers, investment and the maintenance work.
In this work, the revised genetic algorithm (RGA) is utilized for nonlinear objective function to reduce the cost and the optimal structure by choosing the optimum number of switches and location in radial distribution system [26].

1.4 The main aspects of this work and its importance

The main aspects of this work are the feeder reconfiguration of radial network, the load flow method for each successfully configuration, the optimization method to get best result for loss reduction and best voltage, selection of switches that makes the work able to yield the best results. In this work, it was mentioned in the previous section S. Civanlar et al [2], Sathish Kumar et al [21] and A.V Suhakara and M. Damodar Reddy [24] that They worked on (16 bus system), also studied the same network but they are used another way to make reconfiguration system by using different topologies from them. In other word, this work used and tried another switches for reconfiguring. This work achieved by using the backward-forward load flow and the optimization method carried out by artificial neural network to get minimum losses and best voltage. In [2], they presented strategy for the feeder reconfiguration in simple way to minimize power losses. They got results for loss reduction by guessing and approximating the losses and this achieved by changing the place of line to other lines. They made an equation to get results. They none mentioned the load flow method or optimization method and they utilized another status of switches. In [21], the work implemented by artificial neural network for optimization but with used different parameters. The load flow none mentioned in this work and they used different switches operation. In [24], they used a new way for optimization and its name is Dragon Fly Algorithm. Bus injection bus current utilized for load flow calculation and the status of switches were different. None of all the three papers mentioned reliability and economic gain.

1.5 Thesis Organization

This thesis has seven chapters to describe the entire procedure of employing concept of artificial intelligence to support the power distribution network by selecting the optimum switches that are participating the network reconfiguration to minimize the losses. Chapter one “**Presentation of work**” is entitled to describe the main concept of distribution network and the feeder reconfiguration with their impact on the power system.

Chapter two “**Methodology**” is entitled to describe the proposed algorithm and its impact on the network.

Chapter three “**ANN Module**” is entitled to describe the details of artificial neural network and the infrastructure of the employed model.

Chapter four “**Practical Module**” involves a complete simulation and design of our proposed model and the results with the design specifications in ideal outcomes resulting from the calculations.

Chapter five “**Conclusion and Recommendations**”, where the interpretation
of the gained results will carry out and accordingly the recommendations will be set.

Chapter six “**References and Publications**”, that illustrating the references list and the project participation in the other journals.

CHAPTER TWO

METHODOLOGY

2.1 Outline

Power systems in general are attributed by generating the required energy and successfully delivering of that energy to the consumers. The means that adopted by such systems to carry out the power across diversity of lands are known as distribution systems. This section of power system is quite essential in terms of efficient delivery of power to the consumers. Effective distribution system is termed by loss less system where same energy that was generated is ensured to the consumers with zero losses; such assumption seems non logical as impedance lies on each distributor and hence power cannot transport without losses. Actually, the losses minimization is very interested argument in power engineering so that a plenty of approaches are invented to reduce the power losses. [11] Present of generated power is faded away in distribution system. Attention was given in this project to the methods that in turn minimizing the power losses in distribution system. This chapter is providing the main technical information that required for implementing of distributors with lesser possible losses. The radial and ring distribution systems are explained and efforts are paid to employ a radial system to build up an efficient distribution network with possible immunity of losses.

2.2 Distribution systems

Distribution of electrical power is usually taking place under the said "distribution systems"; the same is considered as final level of power processing that ensures a safe delivery of the said electricity to the consumers. Loads or consumers are interfaced on the terminals of power distribution system and can be

- Residential places such as apartments, row-houses and residential premises.
- Commercial places such as hotels, restaurants, companies or schools.
- Industrial consumers such as factories and manufacturing premises.

Above categories are made under the fact of consumption of electrical unites (unites systems). Moreover, it can be used to study of power system behaviors from the consumer prospective. In other word, residential places are seem to operate at all times (24 X 24) whereas the companies and schools are remained operational during working hours of that particulars organization. It can be said that bus bar where the residential loads are connected in higher portion of its load are expected to be in high demand, similarly this fact can be applied for the rest categories of consumers.

The distribution systems in general can be described as set of nodes which can carry of electricity from generation ends/sub stations and delivery it to the consumers. Transformers and protection devices are integrated with distribution systems in order to ensure the quality of power. Different optimization schemes are on table and each is having its own contribution and impacts on the network.

Distribution transformers are in turn brought the voltage from medium limits that sent from sub-station to low limits that supposed to be consumed in the loads. Generally, two types of distribution systems are found and described below.

2.2.1 Ring distribution System

As shown in figure 2.1, the name of ring distribution system is indicated as the closed shape (the power distributed in closed cycle) where the energy from generation unites is participated by many feeders. Usually, it is utilized for connecting the main feeders of high voltage together. The cost of ring system is higher than radial system because the structure of ring system has many switches, nodes and the protection devices are involved.

It is not good when the generation voltage is low and the construction is high as more conductors and switches are used. The distribution system uses a radial system due to above reasons.

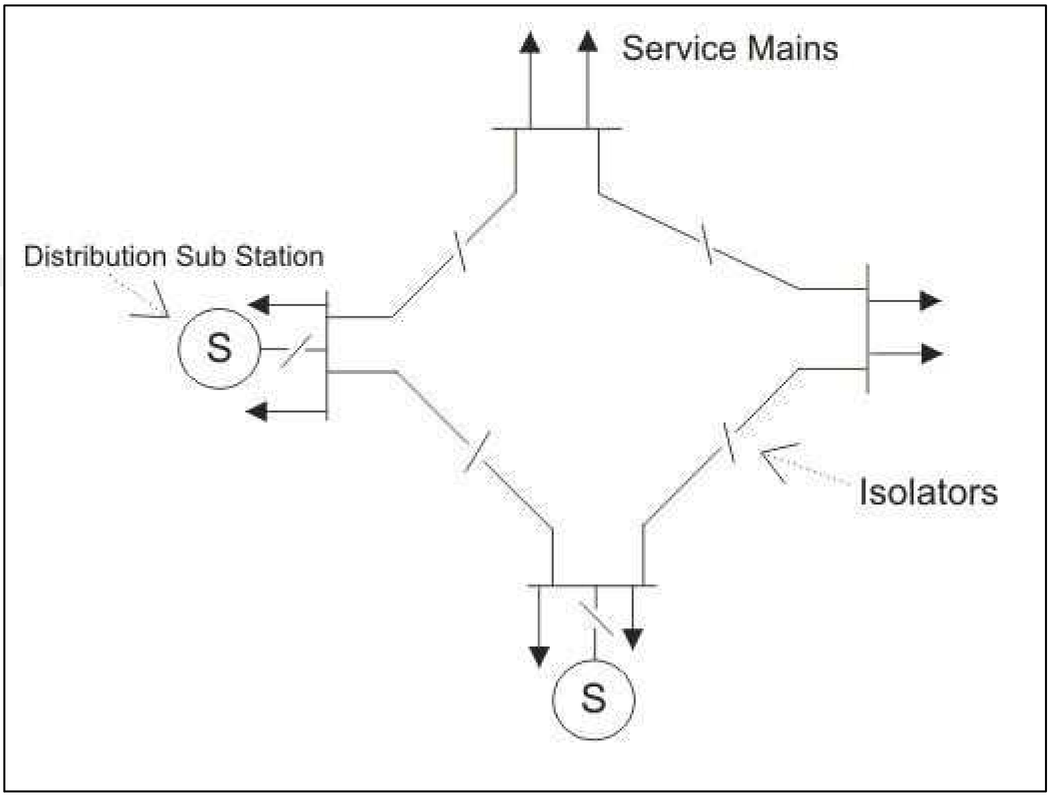


Figure 2.1: Ring distribution system.

2.2.2 Radial distribution system

Unlike ring distribution system, radial system is another form of distribution that connecting multiple nodes with sub-station where each node is supplied with power from single feeder. Figure 2.2 is depicting of this system and it is cleared that a central node is entitled with root node. It radiates power from upper unites (generation/substations) to lower nodes. Every node is connected to serve particular geographical area with electricity and at the same time it is connecting the coming nodes. In such form of distribution system, each node gets supplied by another node in the network and nodes in turn serve the loads connected on their terminals (consumers). For radial network, it is important to maintain the following constrains:

1. No loop is developed when network is on operational mode: each bus bar is provided with power from one end (input), bus bar should divert of received power into the load connected on same bus bar and the rest portion of power must be provided to the next bus bar so that power is ensured to not propagate in backward.
2. Each bus bar is provided with power from single feeder: node is generated for one time from one feeder. In case of multiple feeders are serving of this particular node then one of them should be tripped off.
3. The power delivered to any bus bar should be limited to consumption budget: power fed to this node must be enough to serve loads on bus bar terminals as well as load of next bus bar if any.
4. As figure 2.2 is depicting; it is mandatory for assuring the radial structure that one or more node does not feed any other node in the system.

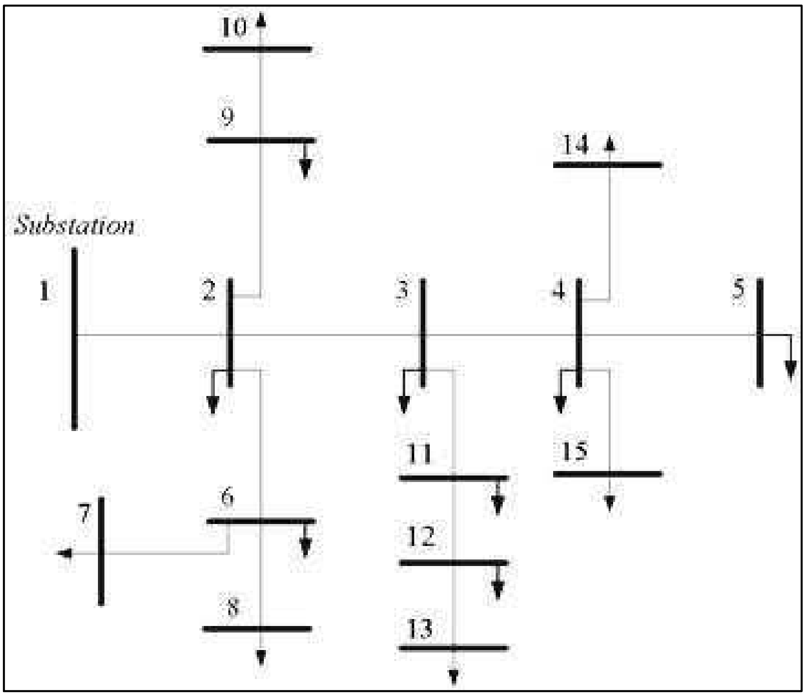


Figure 2.2: Radial structure of distribution system.

This structure is adopted by service provider to serve the loss population areas such as remote geographical locations and rural places. The cost of installation for such kind of distribution network is relatively cheaper than ring system. The advantages of such distribution systems can be summarized as:

1. Low cost of construction.
2. Relatively simple structure.
3. Very useful if low voltage generation is existed.
4. And useful when the main generation unit is locating at the mid of grid.

2.3 Network reconfiguration

Power system distributed from generation ends to consumers ends throughout radial or ring distribution system. Many researchers have shown that an effective portion of losses which exists on entire power system is attributed to the distribution losses. Around [9] presents of total power losses are happened in distribution system so that power companies are keen on controlling of such disorders that leads for losses.

Many approaches are proposed to put down the real power losses to the minimum level and network reconfiguration is one of those studies. Reconfiguration can be interpreted as changing of network switches conditions so new form of network can be obtained. Basically, any distribution system contains two types of switches which are:

- Tie switch: for isolation or conduction of feeder with other feeder in radial distribution system.
- Sectionalisation switch: since the main feeders of radial structure are segregated to many load feeder (load bus bars). The sectionalizing switch is responsible to connect or isolate the load bus bars from each other within the same feeder in radial structure.

Usually, large number of switches can be found in any distribution system with different switching status i.e. “normally close switch” or “normally opened switch”. Reconfiguration is conducting by altering the feeder status by opening or closing of the switch that isolate or conduct the input of this feeder. Reconfiguration is resulted another network topology which might develop of new parameters in terms of losses and voltage profile. Figure 2.3 is highlighting of radial structure switches.

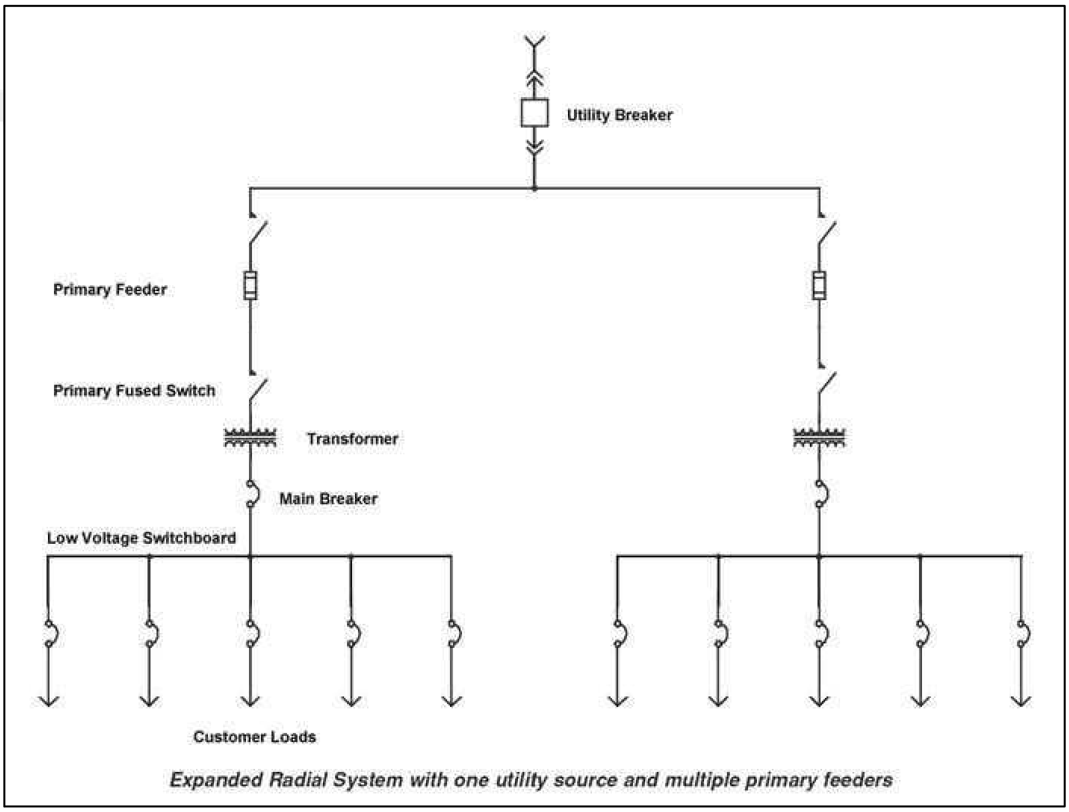


Figure 2.3: Tie and sectionalizing switches in radial distribution system.

2.4 Constrains of reconfiguration

As stated above, network reconfiguration is proposed for optimizing the bus voltage and hence minimizing the real power losses. In order to apply such proposal on the grid of bus bars in radial distribution system, we need to consider many limitations.

2.4.1 Network representation

A new configuration is achieved by opening and closing the switches in original network layout (as a case of ON and OFF switches) so that, grid is represented with new topology. This approach is carried out by integration of software programs due to computational complexity in such calculations.

- The probabilities of resulting new topology are huge: for a network Containing of n bus bar, 2^n of results can be achieved. That implies a very large networks will be gained from n bus bar network after applying the reconfiguration.
- From the results in previous point, most of the new networks are subjected for negligence, due to unwanted type of results. A radial configuration is only required after applying the reconfiguration.
- Furnishing through of new resulted networks, each bus bar must be supplied with power from only one feeder.
- The power supplied to that bus bar must be enough to run the load connected on that bus bar, otherwise, real power losses will be developed.

  It is obvious that bus bar voltage is required to as large as the limit of voltage in the network permit. For example, if the designated voltage on every node was 32 KV as maximum and 29 KV as minimum then the voltage of that node after reconfiguration should be 32 KV. Per unit values are referred always while analyzing the network.
- Talking about expensive computational involves the budget of load flow calculations for every reconfiguration. The number of switches in the distribution system required losses calculation within each line separating two consecutive switches so that more switches lead to more calculations.

In this project, optimum load flow method is used for selecting a best configuration of distribution network.

2.5 Problem formulation

Since the feeders are segregated into sections of load which are controlled by sectionalisation switches and the feeder within radial distribution system are tied with each other by tie switches. The reconfiguration program is up to change of those switches status. However, the normally opened switch will be subjected for closing and normally close switch will be subjected for opening. The target of those processes is to obtain the power losses of distribution with the minimum level so that the following constrains will be satisfied.

$$\sum \; 1 \quad \square \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (1)$$

The branches count is represented by “NB”; each branch of distribution network is represented by “J” and finally the losses occurred within each branch is PLOSS. This function entitled with “F” is considered to be the objective function or target of processing in the search algorithm in hereafter. The minimum f is obtained after initializing of load flow program where the power and voltage are calculated in each part of the network. The obtained topology is restricted to the following constrains:

Power (min.) < pow r o bus < pow r (ax.) ggggggg..g..gg. (2)

Voltage (min.) < voltage in bus bar < volta (ax.) ggggggggg.(3)

2.6 Load flow calculations

In radial distribution system, load flow analysis is essential for applying reconfiguration method on the network. The major of this section of processing is to determine the power in each point of the grid as below:

a) Power (S in VA or equivalent per units) is obtained in all buses of the system. Assuming of radial system implies some nodes are main feeders and serving of particular part of load bus bars. The power in those nodes should be the summation of entire nodes (load bus bars) that connected under this feeder. However, in this project the main feeders are assumed with null/blank value in load flow table and their value will be updated continuously after each configuration/switching.

b) Line power is obtained to update the load flow table. The line power means the amount of energy consumed by transmission lines connecting the feeders to each other in the grid system.

c) In this approach, three phases, multiple bus bar and balanced load system is implemented. Balanced system means that loads connected on each phase are identical. However, single phase calculations will be achieved and apply to the other phases by considering 120^0 and 180^0 of phase shifting at consecutive phases.

d) Current summation method is used to identify of load flow in this system as will be discussed in further sections.

2.6.1 Backward-Forward method

This method is presented to perform load flow analysis in power system, current summation scheme is selected due to it easies the calculations by using V and I information instead of power components (P and Q).

Basically, this method involves a couple sweeps (backward and forward). It begins by determining the network currents from end to start. In other word, nodes and branches currents are determined from last node though first node (main feeders). Upon the evaluation of those currents, voltages in nodes and branches are obtained in forward direction (from first node to last node).

These steps (backward and forward) are repeated for “K” times till the reaching of optimum convergence of results.

2.6.2 Mathematical representation

For the sample network of figure (3.4); three bus bars are representing the feeder and load busses. By applying of Backward-Forward method, the current and voltage in every bus and branch are determined to be obtained.

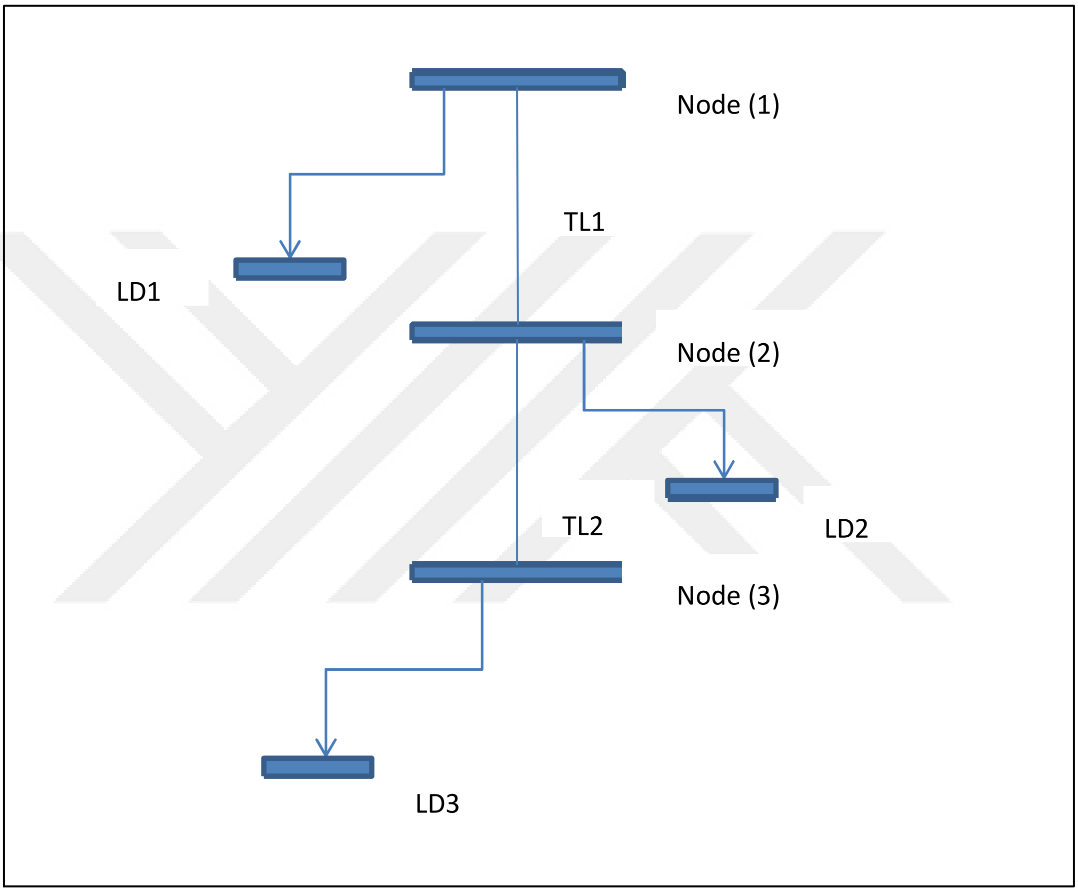


Figure 2.4: Simple load flow example.

Backward sweep: Using of KCL:

$$[illegible] = [illegible]_{([illegible])}$$

$$[illegible]_{([illegible])} = \frac{[illegible]_{([illegible])}}{[illegible]_{([illegible])}} \quad => \quad [illegible] = \frac{[illegible]_{([illegible])}}{[illegible]_{([illegible])}}$$

[illegible] = [illegible]( ) + [illegible]

[illegible] = [illegible]( ) + [illegible] / [illegible]

For above [illegible] and [illegible] is achieved by considering the initial voltage in each bus bar with unity value. By the end of this, the backward sweep is over.

Forward sweep: in this section of analysis, the voltage in each node is updated with by help of calculated currents from backward sweep.

[illegible]

In general form:

[illegible]

Where n= [1, 2, 3 ….. k]

[illegible]

PL: Real power line losses
QL: Reactive power line losses
R: real part of line impendence
X: imaginary part of line impedance

Finally, the losses can be estimated in whole by mathematical summation of all lines losses in the distribution system so we can write the following formula:

QLT [illegible] ∑ [illegible] and PLT=∑ [illegible]

Where, “k” stands for the maximum number of lines separating the bus-bars (nodes) in radial system. The load flow algorithm is implemented by software using Matlab to perform the analysis in quick and flexible fashion. The figure 2.5 is depicting the steps of coding the above method in software.

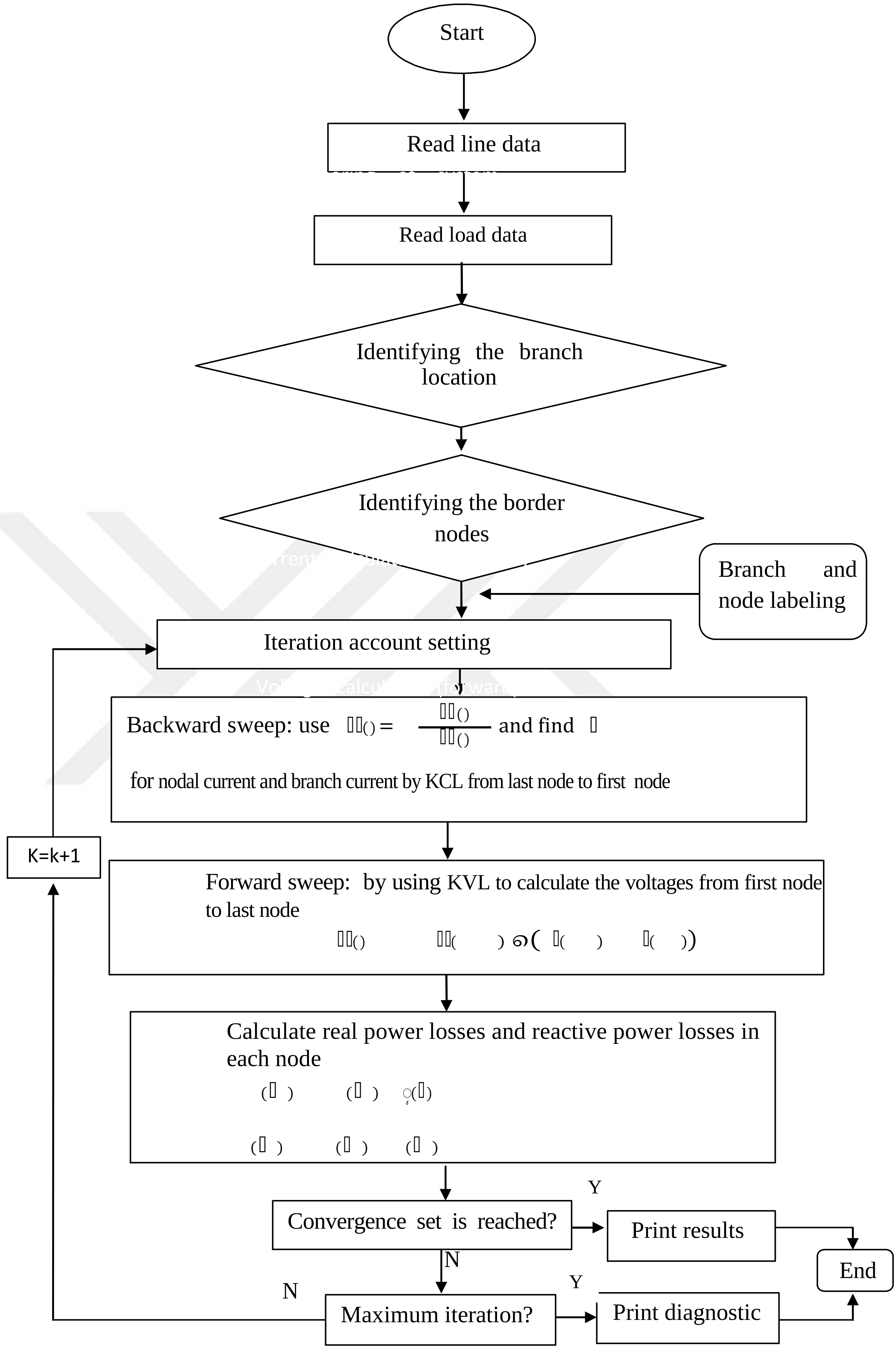


Figure 2.5: load flow calculation program.

The above mentioned steps are used for identifying the system losses using backward and forward sweep method. This procedure is repeated for all possible topologies of the network.

The process may begin with reliability assessment of network in ordinary configuration without applying of any switching operations. Similarly, program will work side to side with reconfiguration algorithm to assess the performance.

Performance will be evaluated base on reliability parameters. In this project, the term reliability is attributed to the minimum losses in optimum node voltage. Ultimately, the program will suggest the results of lower losses configuration (topology) that yield maximum bus voltage amongst available networks. The networks to be judged are produced by the artificial neural network program.

CHAPTER THREE

ARTIFICIAL NEURAL NETWORK

3.1 Outline

The principle of neural networks are similar to the human brain working by implementing the right connections and this is achieved by silicon and wire such as dendrites and neurons. There are 86 billion of nerve cells in a human brain called (neurons) and these neurons are connected to hug number of cells by axons as shown in the figure(3.1).The dendrites are accepted the inputs from sensory organs or from external environment. The electric impulses are created by these inputs that transported fast in the neural network. The message is sent by neuron to other neuron to complete the some issues [5].

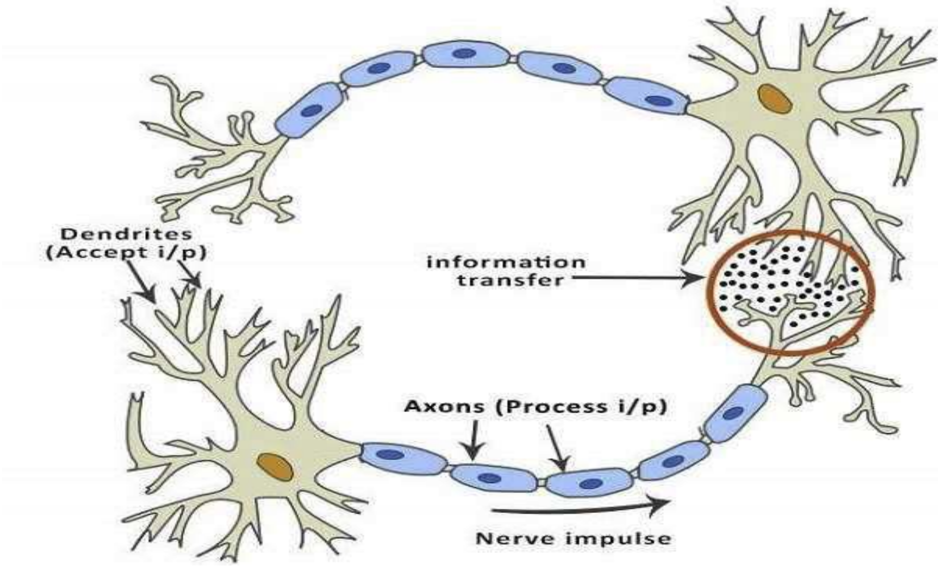


Figure 3.1: Human neuron system.

3.2 Structure of ANN

The ANNs are consisted from a higher number of nodes that is similar in its work to the biological neurons of the human brain. The links are used to make connection between neurons that the neurons are interacted to each other as shown in figure (3.2). The nodes are accepted data and can make simple processes to this data. The outputs of these operations are gone to other neuron. The output of each node is named as its activation or the value of node. The weight is related by link. ANNs has ability to learn that is taken the place by changing the value of the weight [27].

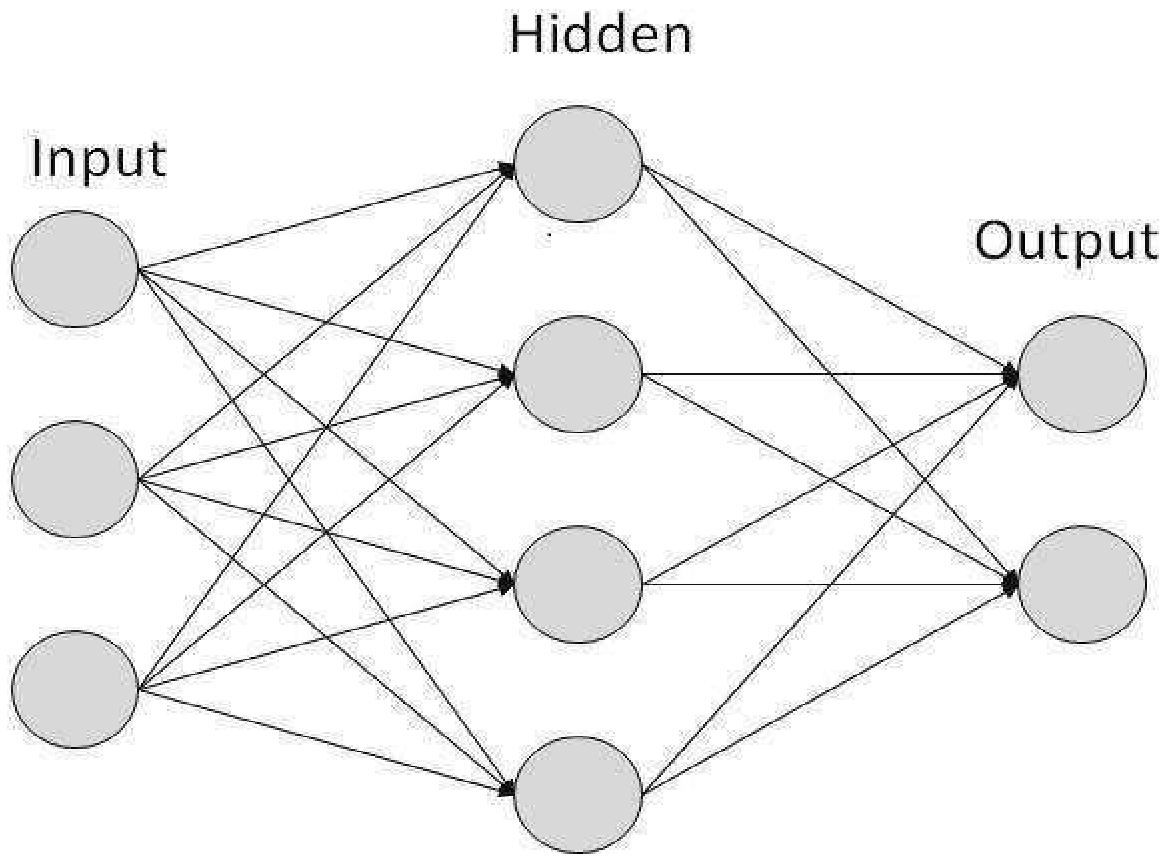


Figure 3.2: Artificial neural network structure.

3.3 ANN categories

The ANNs are composed from two topologies- Feed-forward and the feedback.

- **Feed-Forward:** the data flow is in one direction. Any node is sent data to another from which it does not accept any data. It is characterized that no feedback (no loops) as shown in figure (3.3).
  This kind of ANN is used for (generation/ recognition /classification). They have repaired the inputs and outputs.

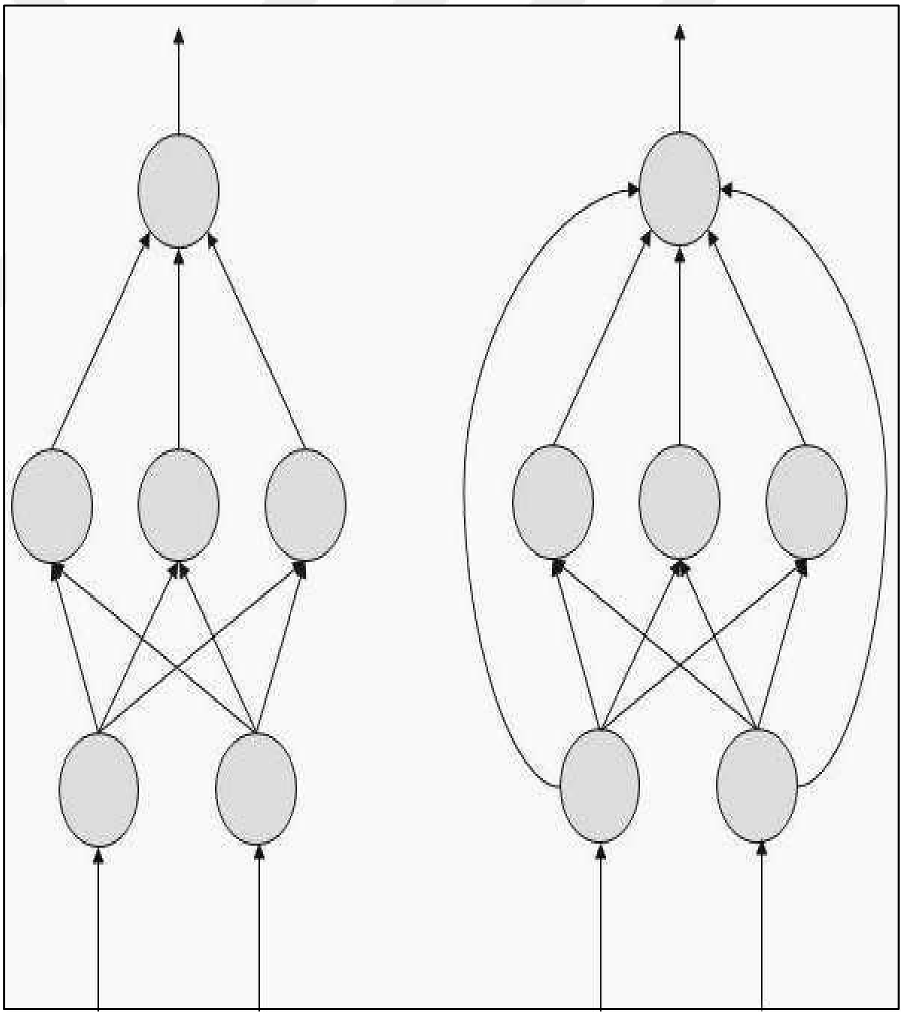


Figure 3.3: The feed forward artificial neural network.

- **Feed-Back:** Here, feedback loops are permissible as shown in figure (3.4). They are used in title-based content memories.

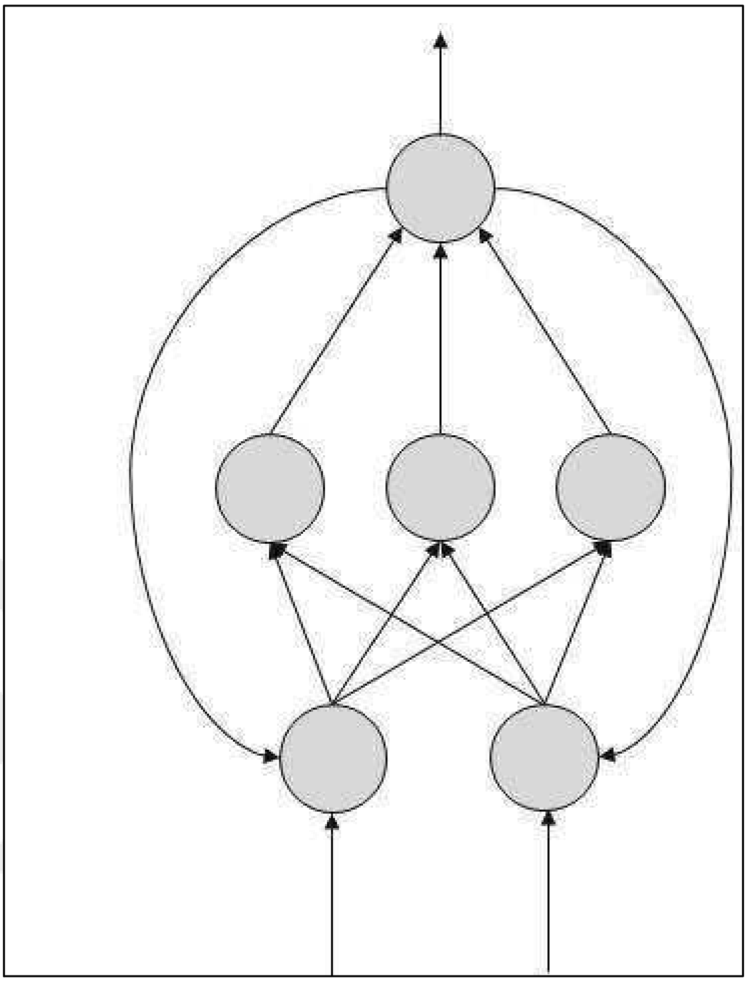


Figure 3.4: The feed-back artificial neural network.

In the topology diagrams shown, each arrow represents a connection between two neurons and indicates the pathway for the flow of information. Each connection has a weight, it is an integer number that controls the signal between the two neurons.

If the network generates a “good or desired” output, there is no need to adjust the weights. However, if the network generates a “poor or undesired” output or an error, then the system alters the weights in order to improve subsequent results.

3.4 The ANNs learning of machine

The ANNs have ability to learn and continuously trained. ANNs have many kinds of learning machine [12].

- **The supervised Learning** − It contains a teacher who has more knowledge than the same ANNs. For example, The teacher gives some examples of data that the teacher knows immediately answers. For example, pattern recognizing. The ANN comes up with guesses while recognizing. Then the teacher provides the ANN with the answers. The network then compares it guesses with the teacher"s "correct" answers and makes adjustments according to errors.
- **Unsupervised Learning** - This type is required when the example data is not existed but the answers are known.

For example, look for a hidden style. In this case, clustering i.e. separating a set of elements into groups according to some unknown pattern is implemented depended on the existing data sets present.

- Reinforcement Learning − This strategy is based on observation. The ANN takes a decision by observing their environment. If the note is negative, the network adjusts its weights to be able to make a different solution next time.

3.5 The ANN development for network reconfiguration

The ANN has ability for mapping very puzzling nonlinear relationship between best optimum configurations and the levels of load or the variation of load which is required for distribution feeder reconfiguration and to find the most suitable topology according to the pattern of load based on training knowledge in training set, instead of the repetitive operation of transport the load [15]. ANNs have robustness for disturbance and massive parallelism for hardware implementation.

For above reasons artificial neural networks are applied in power system. In this work a multi- layer feed-forward artificial neural network is trained with the error back propagation algorithm is used for loss reduction and voltage improvement.

3.6 Model description

In Matlab, ANN application can be started by "newff" command to create "supervised learning model". This model is expected to find the possible topology of radial distribution system. The possible inputs are formed as matrix of (16 by 8) dimension which stands for the power limits in each node. The artificial neural network model is trained to make the proper path for such input where the same can form the distribution system with predefined constrains.

3.6.1 Input Layer

The suitable chosen of input variables is worked for successfully (ANN) application**.** Usually the guide knowledge is required to select the input variables. The load variation (P and Q) real and reactive power in each node is considered the inputs in ANN. The input load (P and Q) is controlled the losses of power and the voltage profile in any system chosen.

3.6.2 Hidden Layer

The computing power in ANN can be improved by increasing the hidden layers. However, there are no guidelines to find the number of the hidden layers. Usually used single hidden layer for many applications of the ANN to get the complex relationship between the output and the input. In my work, there are two hidden layers with sixteen neurons (nodes) gives the good performance to improve the voltage and getting the minimum losses.

3.6.3 Output Layer

For determining the minimum losses and best voltage, the output of ANN is depended on the status of switches to give the output for best voltages and minimum losses. The figure (3.5) below is explained the ANN input and output.

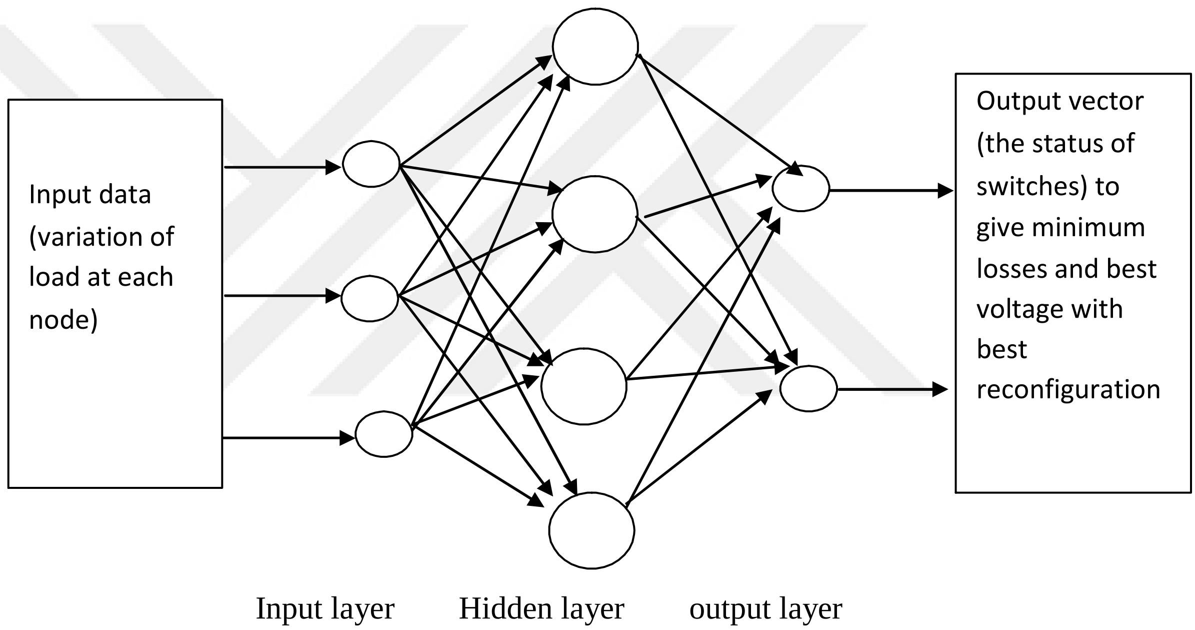


Figure 3.5: The input and the output of the ANN

System is created with sixteen nodes so that artificial neural network has implemented with sixteen nodes of input layer and sixteen nodes for output layer. The approximation function that used while constructing of this model is selected as "minmax". Model parameters can be described as follow:

1) Layers creation: two layers were made, each of sixteen nodes where every node is connected with each other by neuron. The proper decision of this model can be achieved by exact diversion of data from input layer to output layer through the middle layer of hidden nodes. The hidden layer performs the required approximation to achieve the desired output.
2) Approximation function: for successfully responding to the data on input layer, approximation was done by using "minmax" function. However, the input matrix is divided in columns fashions and then approximation takes place using the above function.
3) Inter layer processing (first): data is manipulated within each layer i.e. input layer and output layer. Hence another two types of processing are applied. During the data residence in first layer, it got approximation by "tansig" function where tangent transfer function is returned the data in form of -1 and +1 only as in figure below:

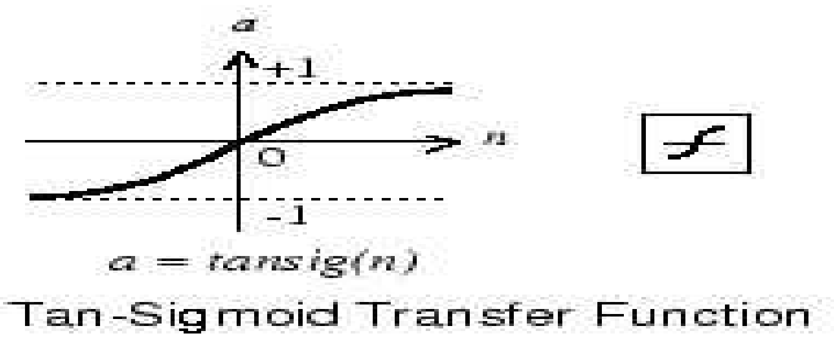


Figure 3.6: Tansig transfer function.

4) Inter layer processing (second): on the output layer, the data was converted into -1,+1 form and pre-approximated by minmax transfer function so that finally the output layer another transfer function is applied to linearate the data in the best possible accuracy, however “purelin” transfer function is used.

5) Training: input is trained with the right target to act so while next processing “Trainlm” was used for this purpose.

6) Final result: the implemented neural network is become ready to give the expected results. So the command “sim” can be used to call the input into network. The process is required a proper definition of some parameters as in table (3.1) like the error rate or learning rate that is responsible to

Table 3.1: ANN optimum settings.

Parameters	Values
Error rate	5 e (-3)
Maximum epochs	1 e (3)
Training iterations	50
Training goal	0

correct the weights in ANN. If we put the large value of error rate then the algorithm becomes instable but if we put it in small value then we reached the convergence after long time. The second is maximum epochs mean the maximum epochs for training the algorithm. The third is training iteration that responsible to display the training status. The goal is responsible to stop the training when the performance of algorithm drops down the goal. These parameters are setting and defined in the algorithm.

3.7 Statistical validation

After implementing the ANN model and getting the highly accurate results, it is necessary to high light the internal statistical of ANN model. However, the performance of results is depicted in figure 3.7.

The performance of algorithm is checked by (MSE) and the value of it must be low for good training and close to zero at minimum gradient reached that means the output of training set is become very close to each other at number of epoch (11).

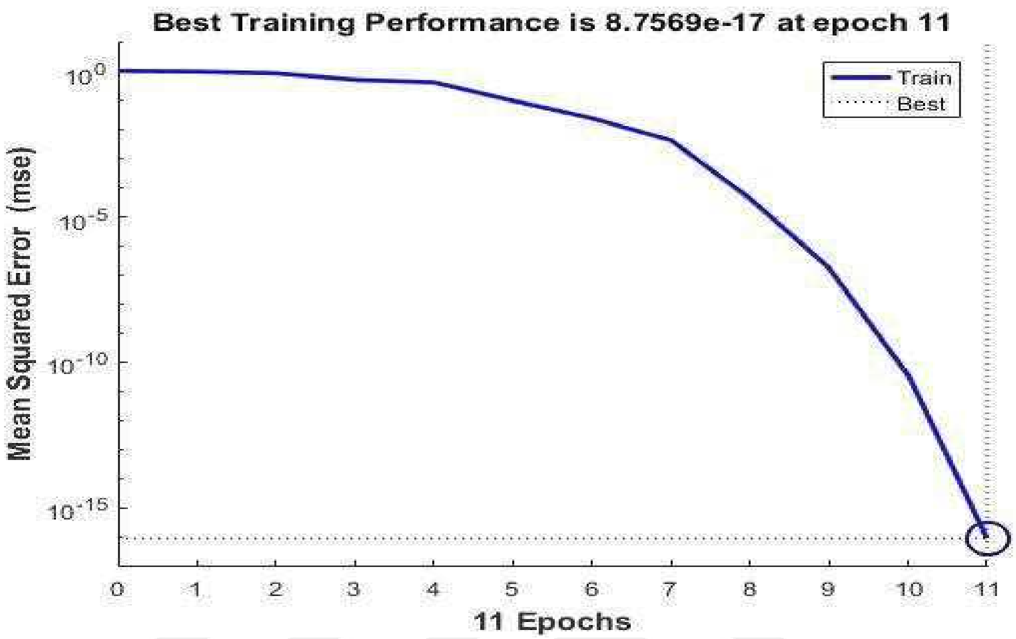


Figure 3.7: The outcomes performance measure.

The training status is given in the below figure:

Gradient: - The gradient is used to stop the training when the magnitude of gradient drop below (<ꟹ) and this is happened at epoch (11) that give us the desired outputs.

MU: - It is responsible to control the parameter of algorithm and the magnitude of (mu) is directly affecting the error of convergence.

Validation fail: - It is used to stop the training early if the network performance on validation vectors fails to improve number of validation failures. The validation number when reaches (6) the training is stop.

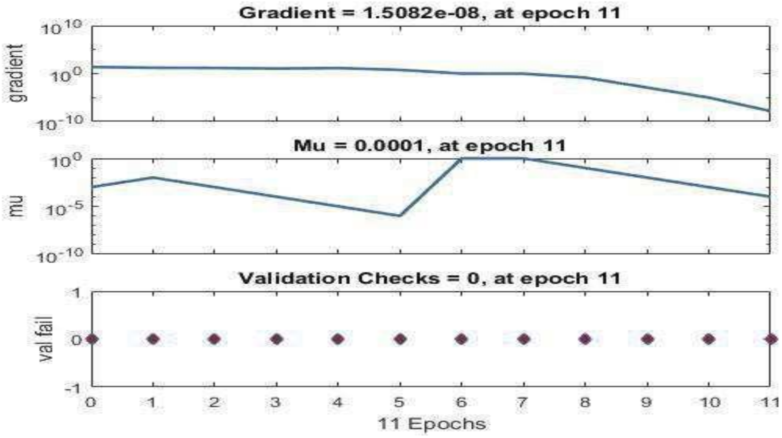


Figure 3.8: The training status of ANN program.

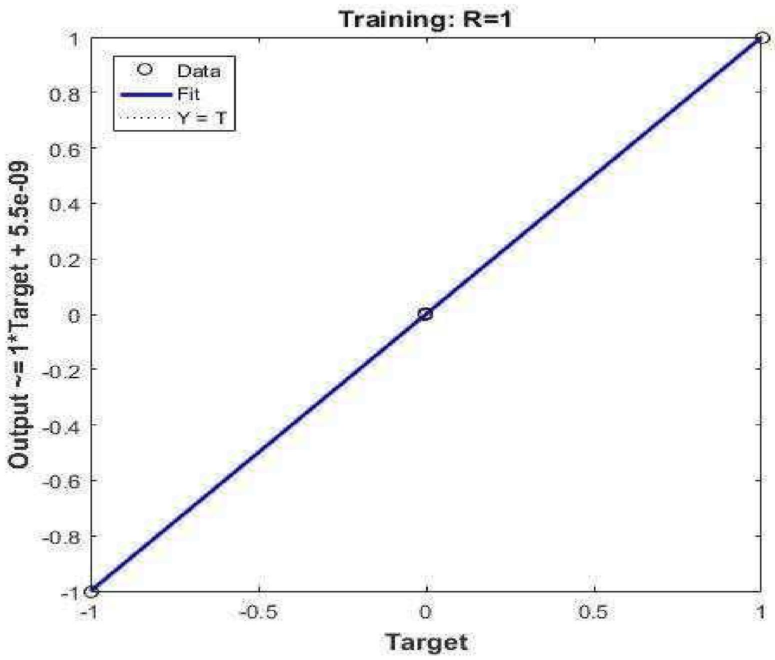


Figure 3.9: The regression of ANN program

Finally the regression process is given in below figure: that responsible about the linear relationship between the targets and the output. If (R=1) then the exact linear relationship is happened and best results are gotten.

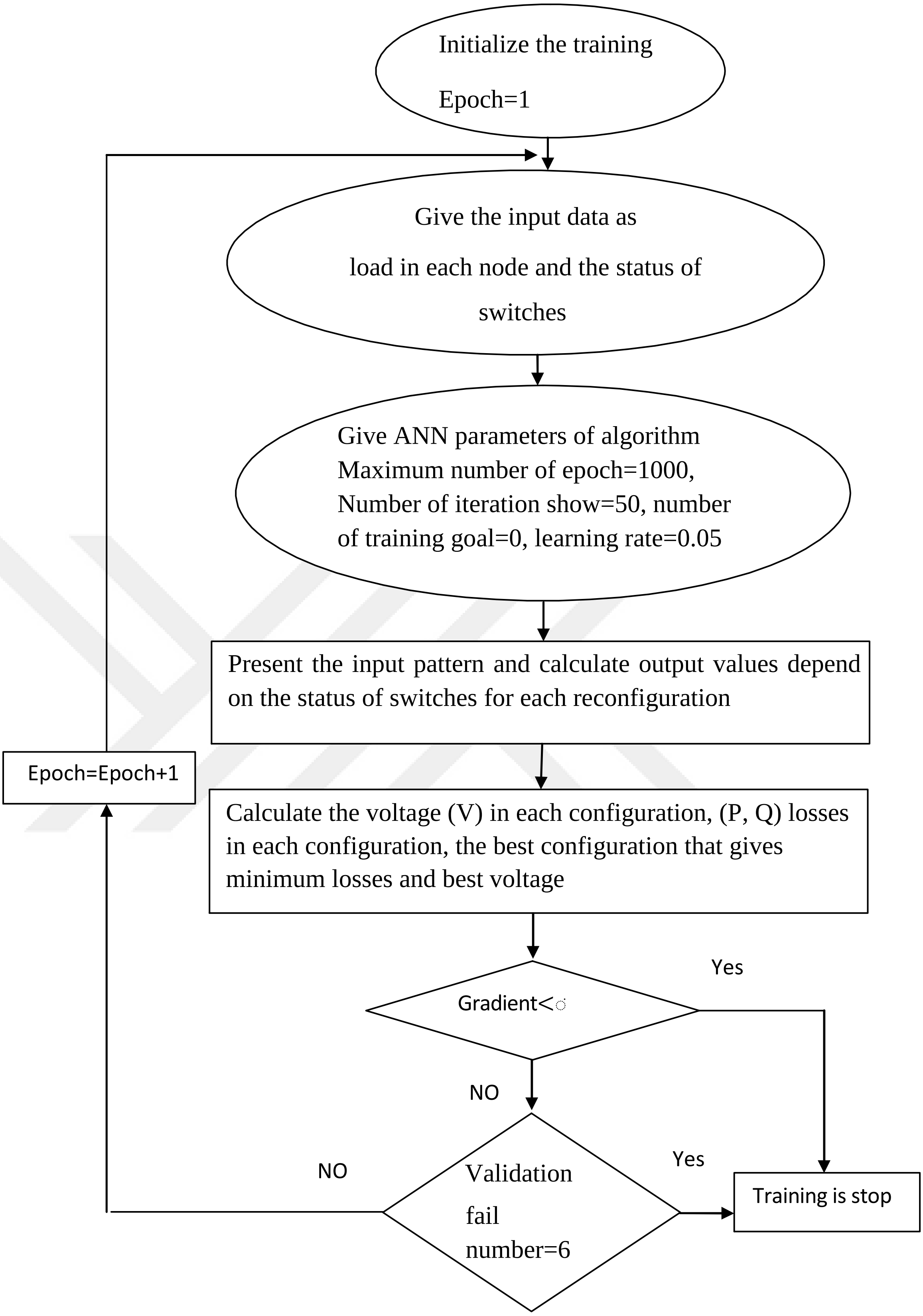


Figure 3.10: The ANN testing and training algorithm

3.8 The ANN testing and training

The ANN is trained by back-propagation algorithm. Each input consists of the load variation at each node in the distribution network and the switching status that form the target of output. These combinations of switches are utilized for ANN training. Error is monitored during the operation of training which usually reduces when the number of iteration is growing. The validation error is tended to increase when the overtraining is happened and this situation is useful to make training stop after validation error has increased for a few successive number of iterations to save the time. The network will be tested with new inputs which were not utilized to train the ANN and the results are compared with actual simulation results that determined for these new test input. The operation is achieved as follow:

1- Give the input data that containing the load at each node that gets from load flow method.
2- Present set of parameters for training the ANN network such as number of epochs, learning rate or error rate, number of iteration show and the number of goal.
3- The load (P and Q) at each node and status of switching are used for input-target training pair to train the ANN.
4- The ANN training is finished, ANN is used to estimate the optimal configuration that will lead to get the best voltage profile with minimum losses. The ANN is training as shown in the figure (3.10).

CHAPTER FOUR

SOFT COMPUTING AND OUTCOMES

4.1 Outline

As stated in Chapter (2), radial system with multiple nodes is chosen for power quality analysis so that solutions and methods are worked side to side for improving the reliability. Two factors which determine the reliability in distribution systems which are power losses and voltage profile. However, we complied with this particular system criterion and applied the possible tools for optimizing the reliability. It was clearly detailed in Chapter (2) that after selecting the desired system and preparing of its data for analysis that we must end with the optimum reliability by changing the system configurations in terms of switching the bus-bars and forming a new topologies every time. Power flow and decision makers are also explained. In this section we are performed a continuation of methodologies and constructing the codes that capable to yield the designated targets. In coming sections, system data will be discussed and for sake of reliability. The designated distribution system will be examined under several barriers such as faults and beak loading time. At the end of this chapter, the results shall be displayed.

Matlab software is used to group all conditions and cases of this project. This analysis is seem impossible with traditional solution methods, huge calculations and parameters are yielded very costly computations so that software programs and artificial intelligence schemes are used to construct of two corners of solutions; the data representation and scanning by computer to create load flow; and reconfiguration solution corner to provide the path where load flow program can work. Ultimately, the best configuration will be selected and results will be sketched.

4.2 System architecture

The radial distribution system is described in work of S.Civanlar et al with sixteen bus-bars, 100 MVA and 23 KV is selected to study under various assumptions and operation criteria [2]. Table 4.1 shows the system configuration in basic form.

Table 4.1: Data of sixteen nodes system [2].

Serial Number	Receiving Bus-Bar	Sending Bus-Bar	Line Resistance	Line Reactance	Switch Number
1	16	7	0.0900	0.12000	16
2	14	10	0.0400	0.04000	15
3	11	5	0.0400	0.04000	14
4	16	15	0.0400	0.04000	13
5	15	13	0.0800	0.11000	12
6	14	13	0.0900	0.12000	11
7	13	3	0.1100	0.11000	10
8	12	9	0.0800	0.11000	09
9	11	9	0.1100	0.11000	08
10	10	8	0.1100	0.11000	07
11	9	8	0.0800	0.11000	06
12	8	2	0.1100	0.11000	05
13	7	6	0.0400	0.04000	04
14	6	4	0.0900	0.18000	03
15	5	4	0.0800	0.11000	02
16	4	1	0.07500	0.10000	01

In this system, radial structure should be assured for completion of further process so that an array of single dimensional implying of switches status must be developed in Matlab.

The system of table 4.1 can be plotted in figure 4.1b; it is important to mention that switches as in table above can be divides into three groups [14].

- Permanent closed switch: such type is remained close and do not participate in reconfiguration program as those switches are responsible to close and open of main feeders and since we need such feeders to be always operational to comply radial system criteria.

- Normally open switch: such switches are kept opened in ordinary system and can be participated the reconfiguration plan by changing of their status from the opening to the closing status.

- Normally closed switch: this group of switches are kept closed during the design of system (ordinary system) and can be participated the reconfiguration plan by changing of their status from closing to opening. However, looking to the ordinary structure of this selected system i.e. 16 buses radial distribution system, the table of above mentioned switches can be implemented and so it carries the initial status of each switch in the system.

Table 4.2: Switching status in radial groups as per the ordinary structure

Switch Number	Status	Working switches
01	Permanently closed	-
02	Normally closed	-1
03	Permanently closed	-
04	Normally closed	-1
05	Permanently closed	-
06	Permanently closed	-
07	Normally closed	-1
08	Normally closed	-1
09	Permanently closed	-
10	Permanently closed	-
11	Normally closed	-1
12	Permanently closed	-
13	Normally closed	-1
14	Normally open	0
15	Normally open	0
16	Normally open	0

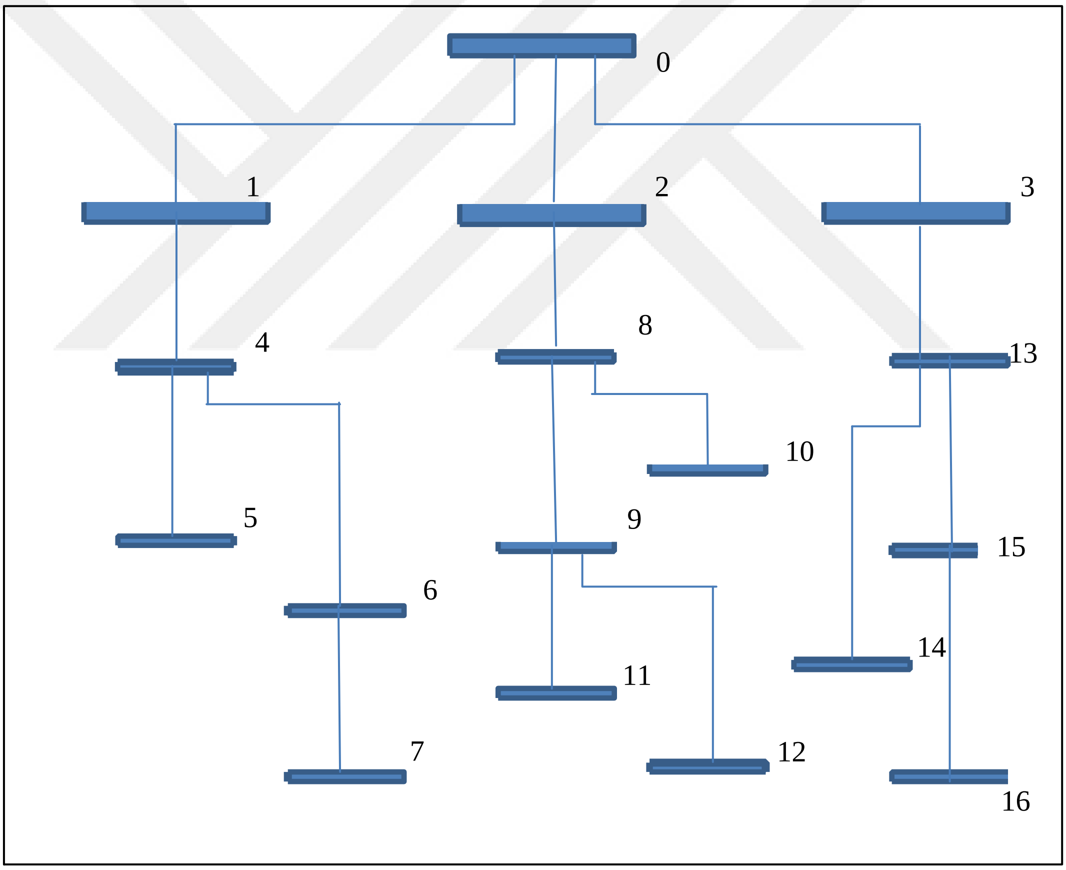


Figure 4.1a: The initial structure of radial system[2].

The location of each switch that tabulated in table 4.2, figure 4.1b was mentioned earlier in table 4.1; for example, switch number 5 is located between node 8 and node 2 and switch number 4 lies between node 7 and 6.

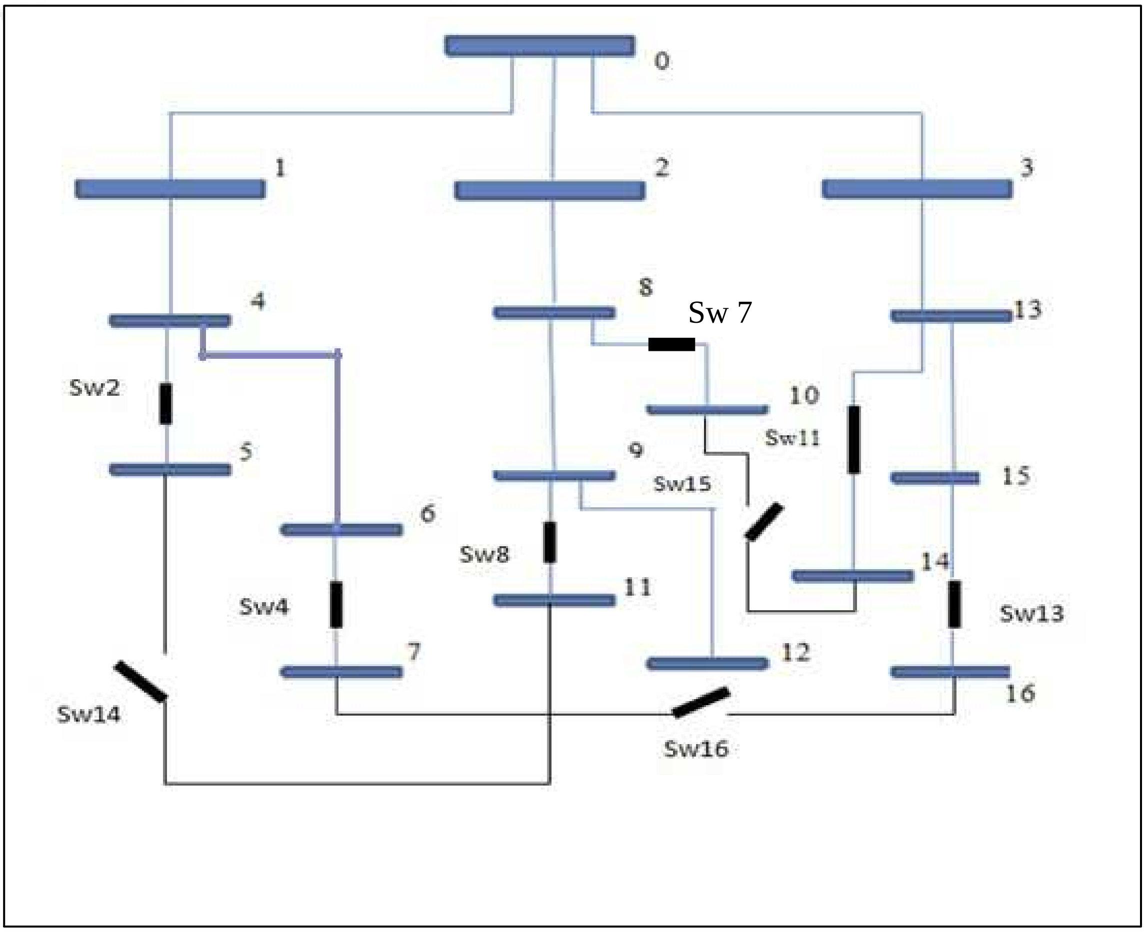


Figure 4.1b: The initial structure of radial system with working switches.

Recalling the load flow program, the current of branches (switches) can be determined, voltage can be determined as well. For system in figure 4.1, the following results are obtained.

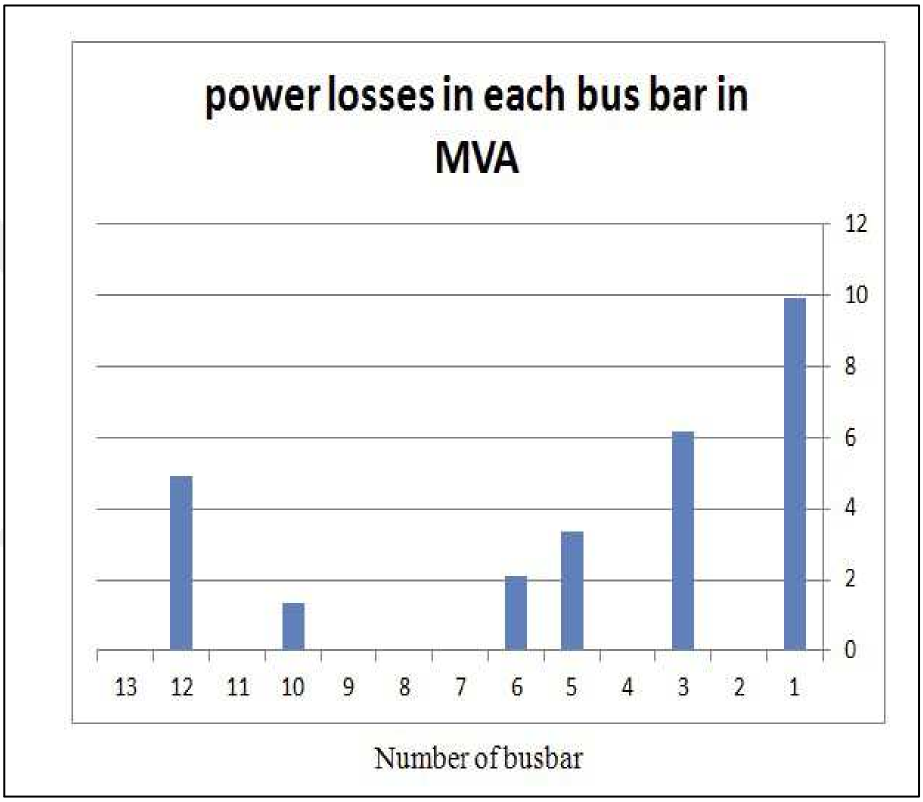


Figure 4.2: Power losses in each node during standard configuration of the radial distribution system in MVA.

Voltage profile in each node

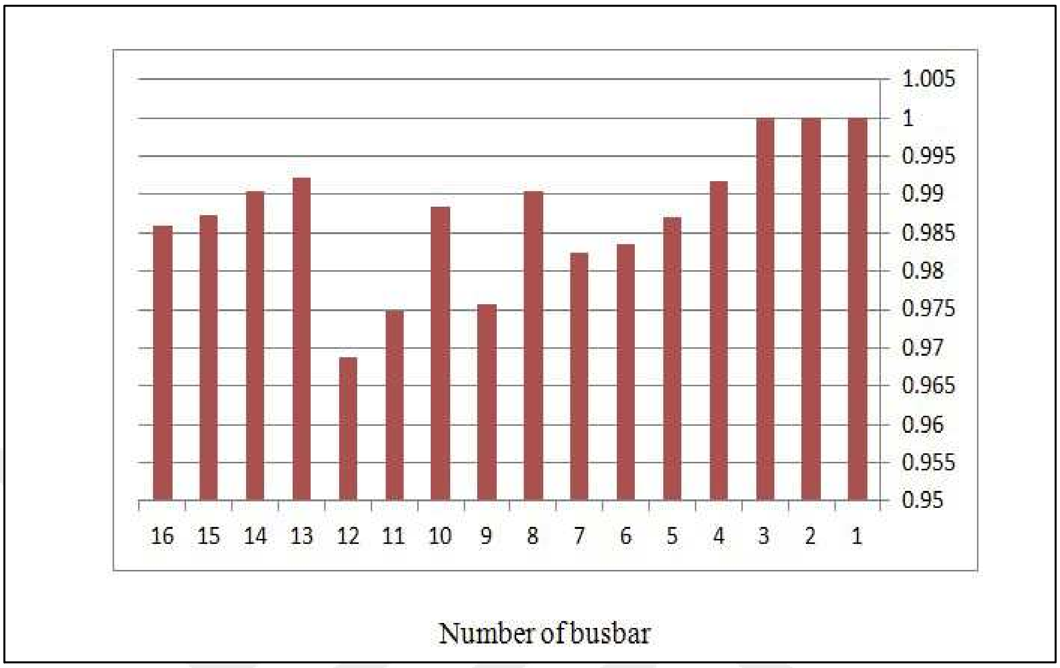


Figure 4.3: Voltage profile in each node during standard configuration of the radial distribution system in p.u.

4.3 Reconfiguration method

Redial system is targeted so that all resulted topologies shall comply this constrain. In order to generate radial topologies, we must recall the conditions in chapter two and remember the most important criterion which each node is feed by single feeder so that loops are prevented. System in figure 4.3 (a) is comprised from three switches SW1, SW2 and SW3; if all switches is closed as figure reveals then loop is produced and analysis will be considered incorrect.

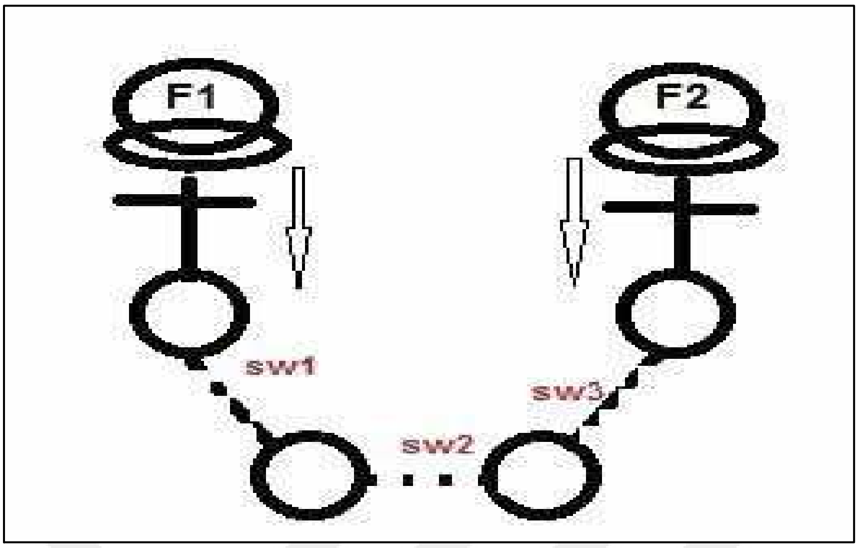


Figure 4.3 (a): Three buses configuration of distribution system that considered inappropriate for the study.

This topology is reconfigured to obey for radial criterion so that system in figure 4.3 (b) is produced. Majority of challenges in reconfiguration algorithm lie on feeder distribution among available load bus-bars where each feeder is bursting of power into the bus-bar of its own area so that each bus-bar will be allotted to a unique feeder. Topology of figure 4.3(b) implements the condition of interest. However, SW1 is opened and SW2 and SW3 are supplied with power from feeder 2; in other word, among three switches, one should be opened to implement radial distribution form.

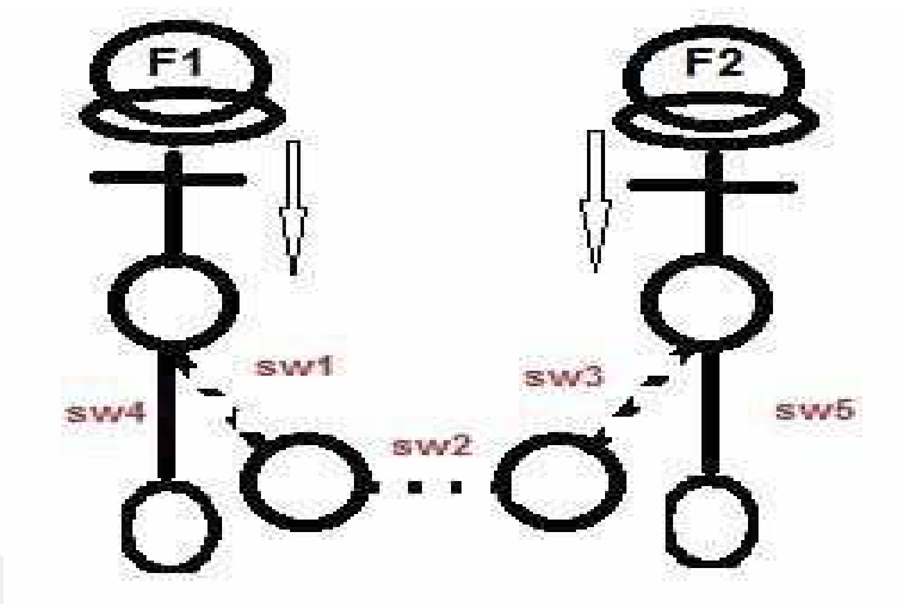


Figure 4.3 (b): Five buses configuration of distribution system that considered appropriate for the study.

4.4 Case study

According to the target of ANN program and sticking on the criteria of section 4.3 of radial system assurance, seven cases are selected for study where each is about new topology derived from figure 4.1 and representing a particular event which may exist within distribution system.

i. Case one: the standard system has reconfigured by applying ON and OFF Techniques using ANN and radial algorithm. However, system of figure 4.4 is implemented by making switches (7, 8 and 16) open.

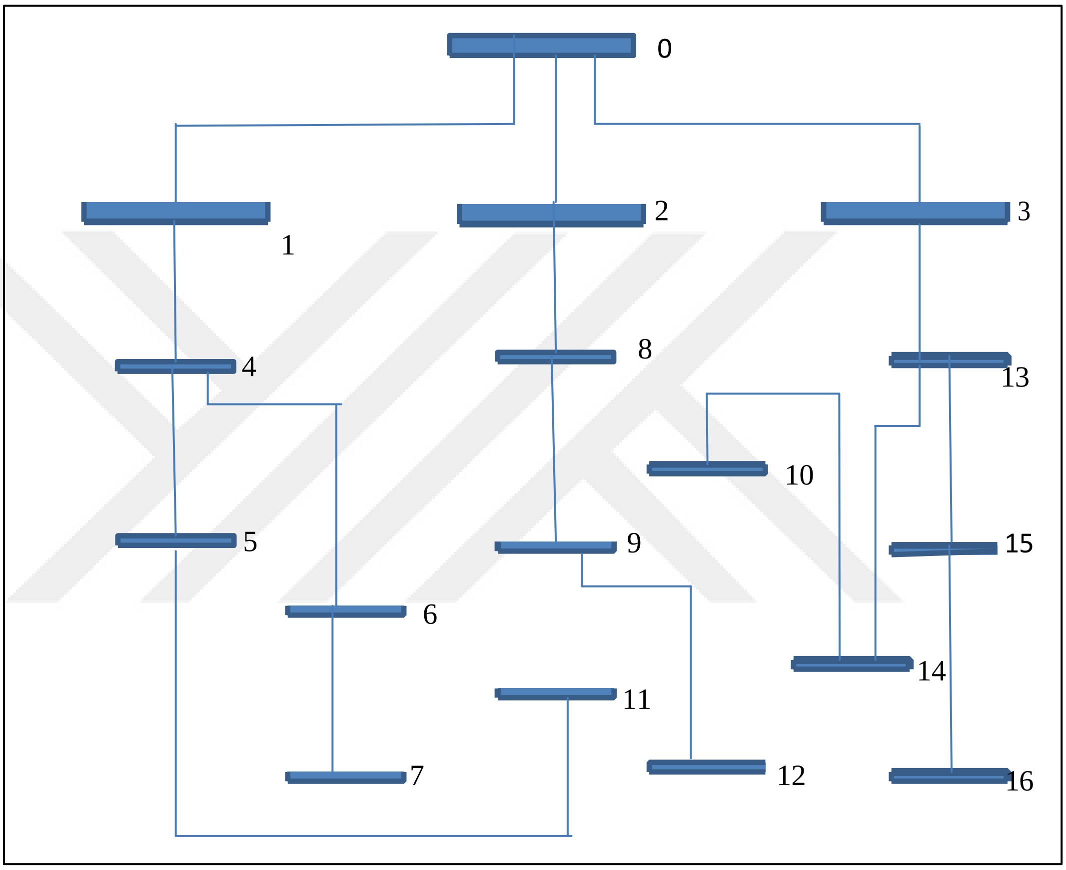
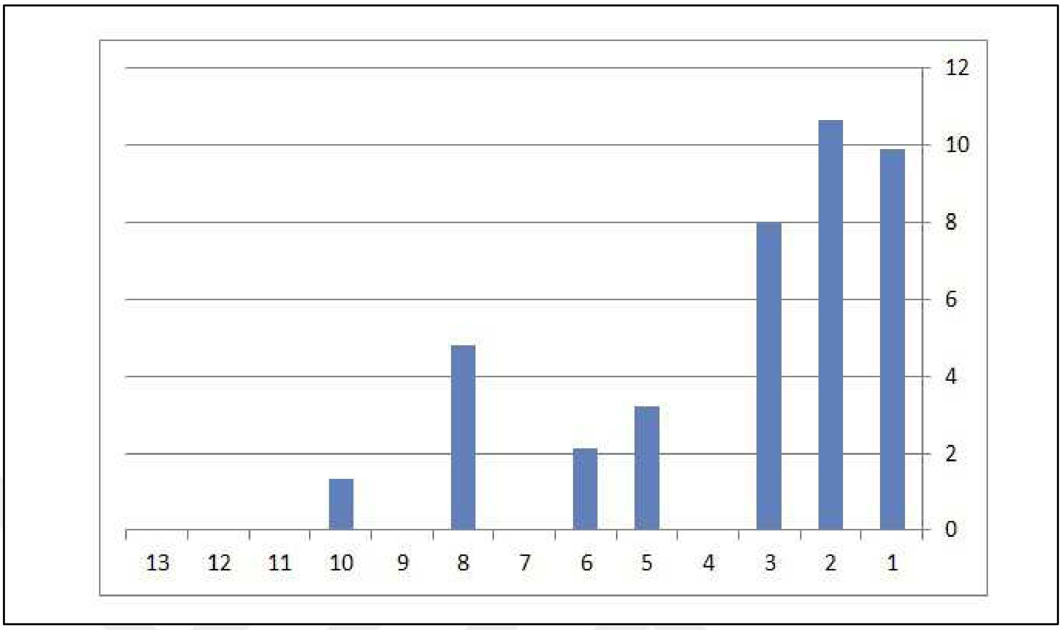


Figure 4.4: First topology of system.

The resulted power losses in each node along with voltage profile are plotted in figures 4.6 and 4.7.

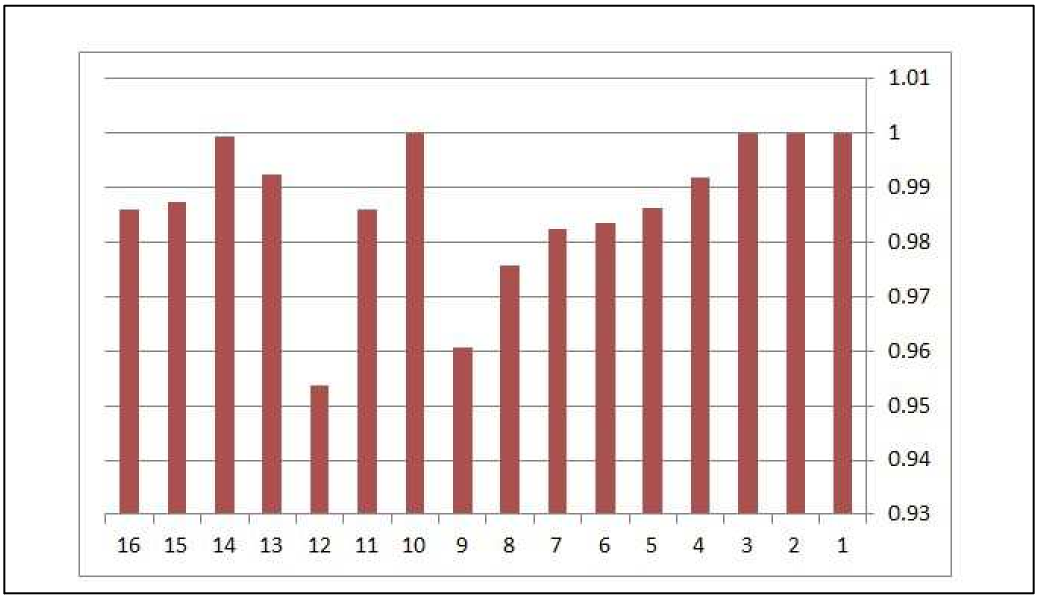
Power losses in each busbar



Number of busbar

Figure 4.6: Power losses after first reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.7: Voltage profile after the first configuration in p.u.

ii. Case two: system is reconfigured according the norms coded in algorithm and new radial topology has been yielded as in figure 4.8; however switches (4, 7 and 14) are kept opened.

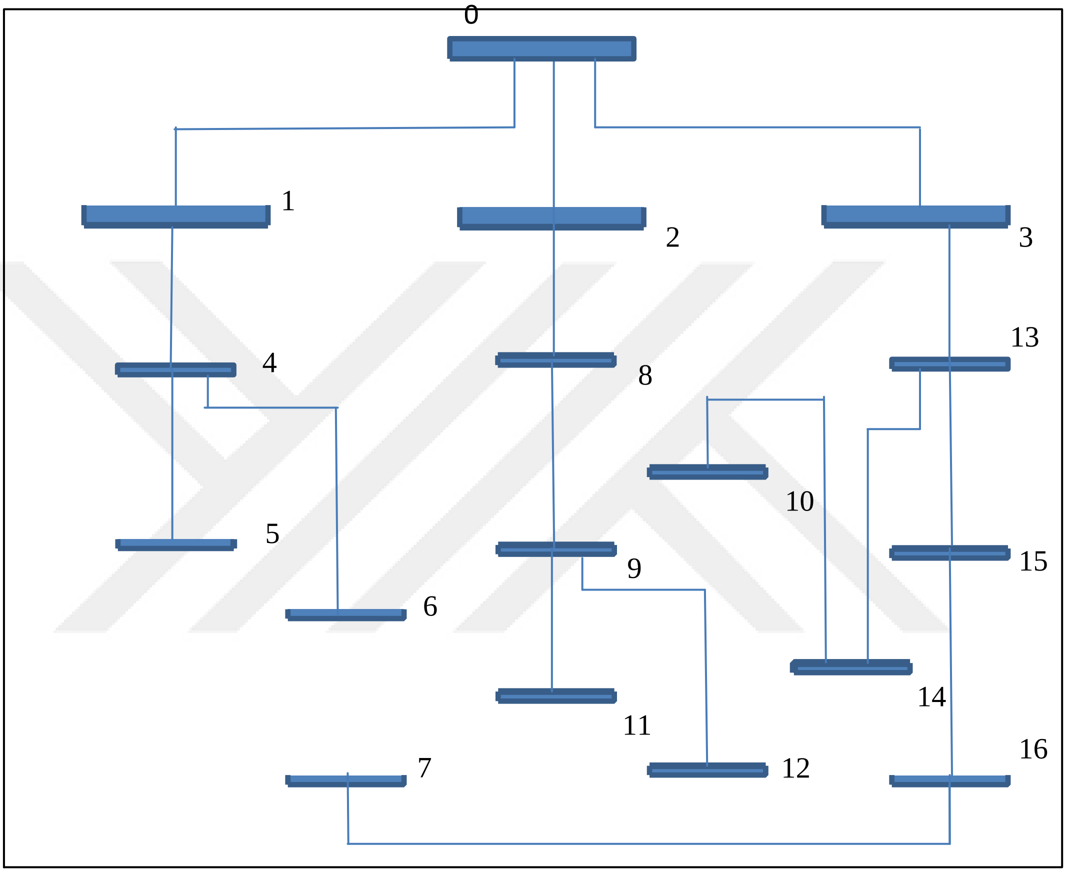
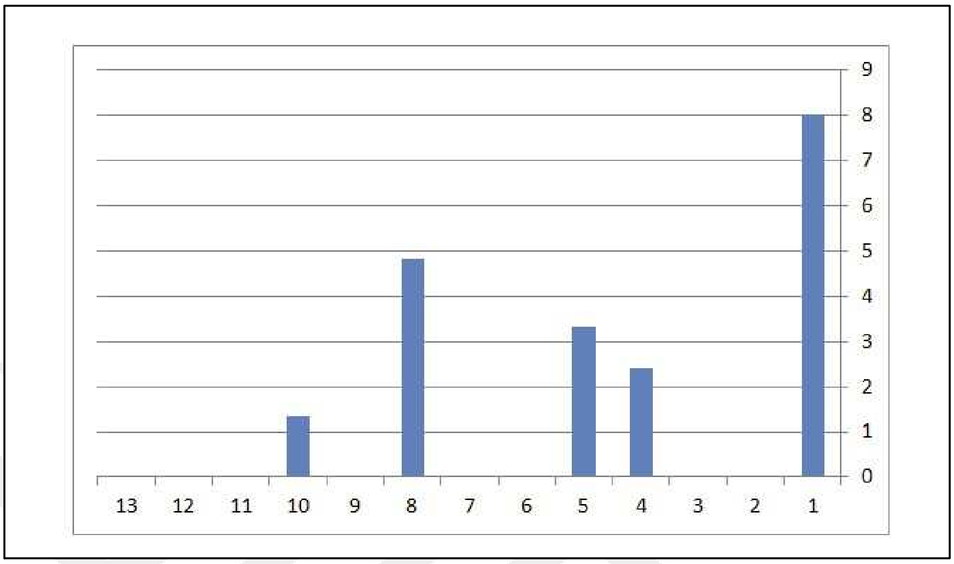


Figure 4.8: Second topology of system.

The resulted voltage profile and losses are plotted in figures 4.9 and 4.10.

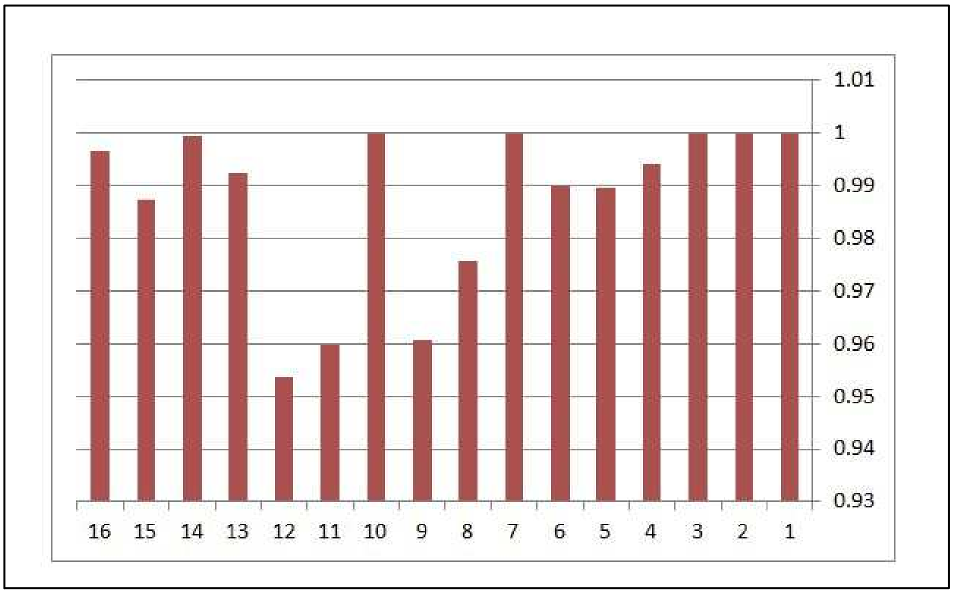
Power losses in each busbar



Number of busbar

Figure 4.9: Power losses after second reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.10: Voltage profile after second reconfiguration in p.u.

iii. Case three: another attempt of reconfiguration has taken place by opening the switches (8, 11 and 16).

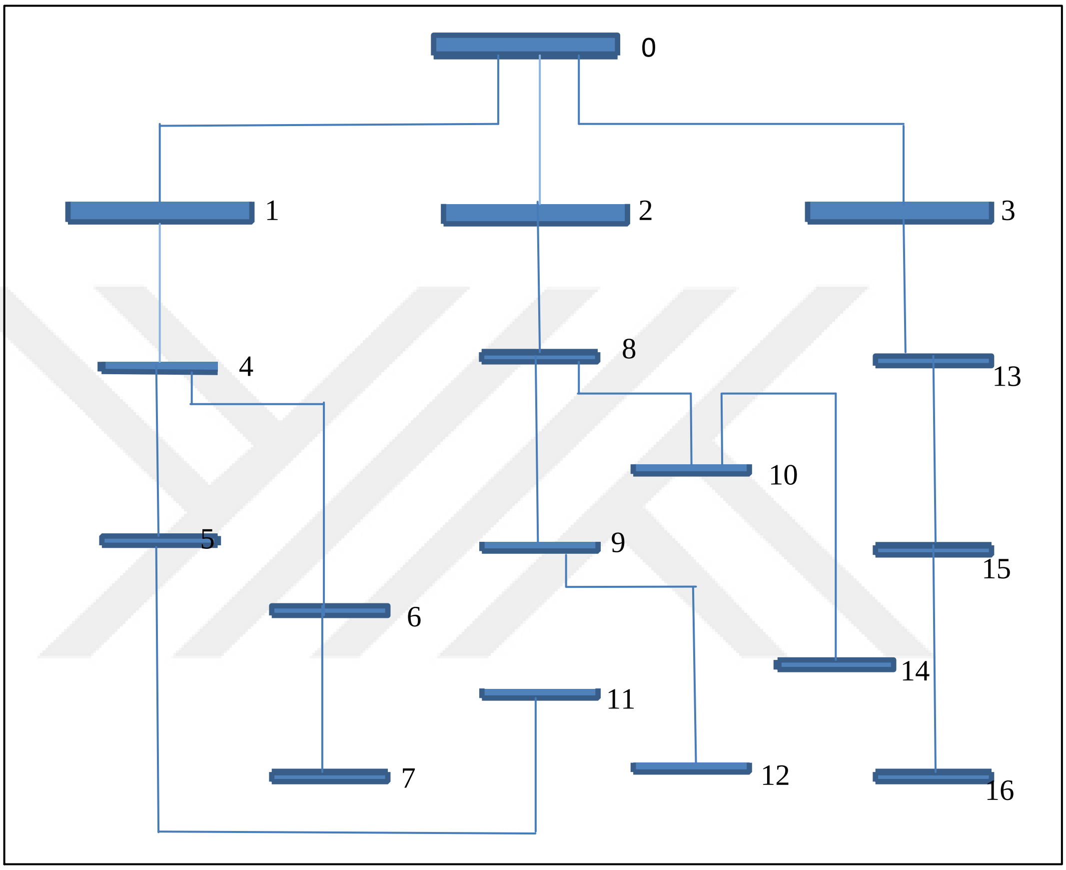
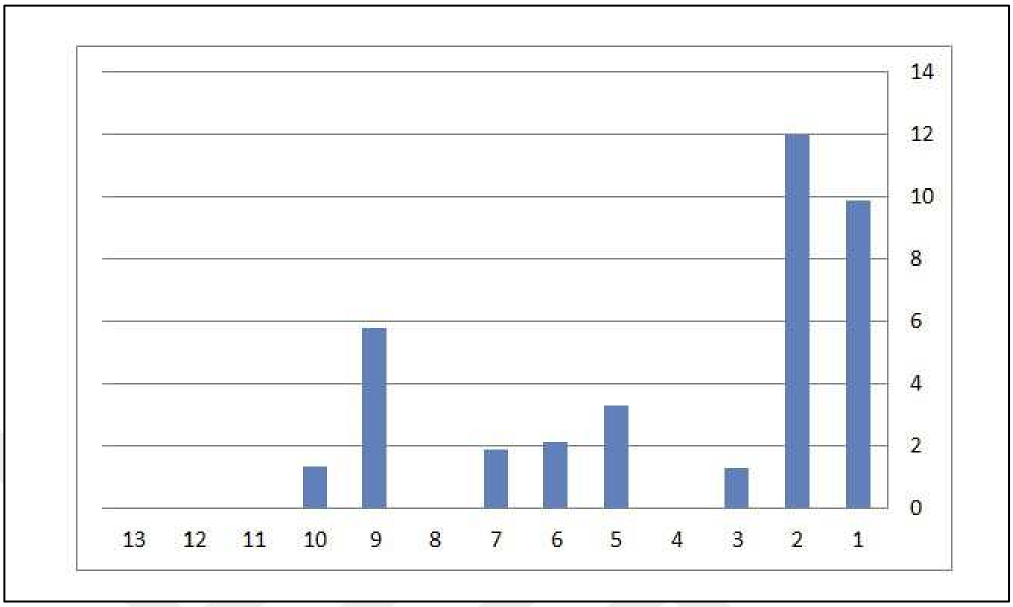


Figure 4.11: Third topology of system.

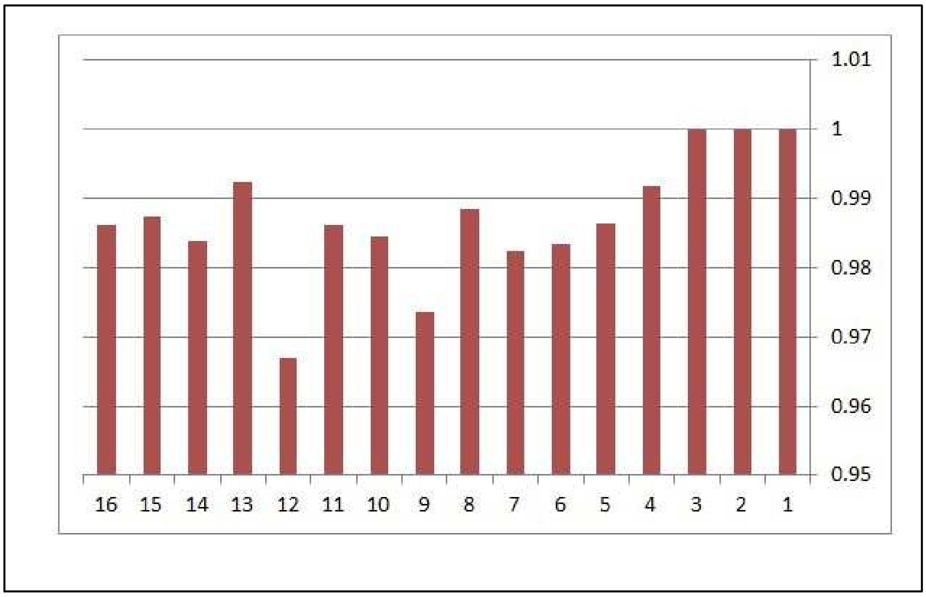
Power losses in each busbar



Number of busbar

Figure 4.12: Power losses after third reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.13: Voltage profile after third reconfiguration in p.u.

iv. Case four: another attempt to reconfigure the radial system is done by opening the switches (2, 4 and 15) and closing all others.

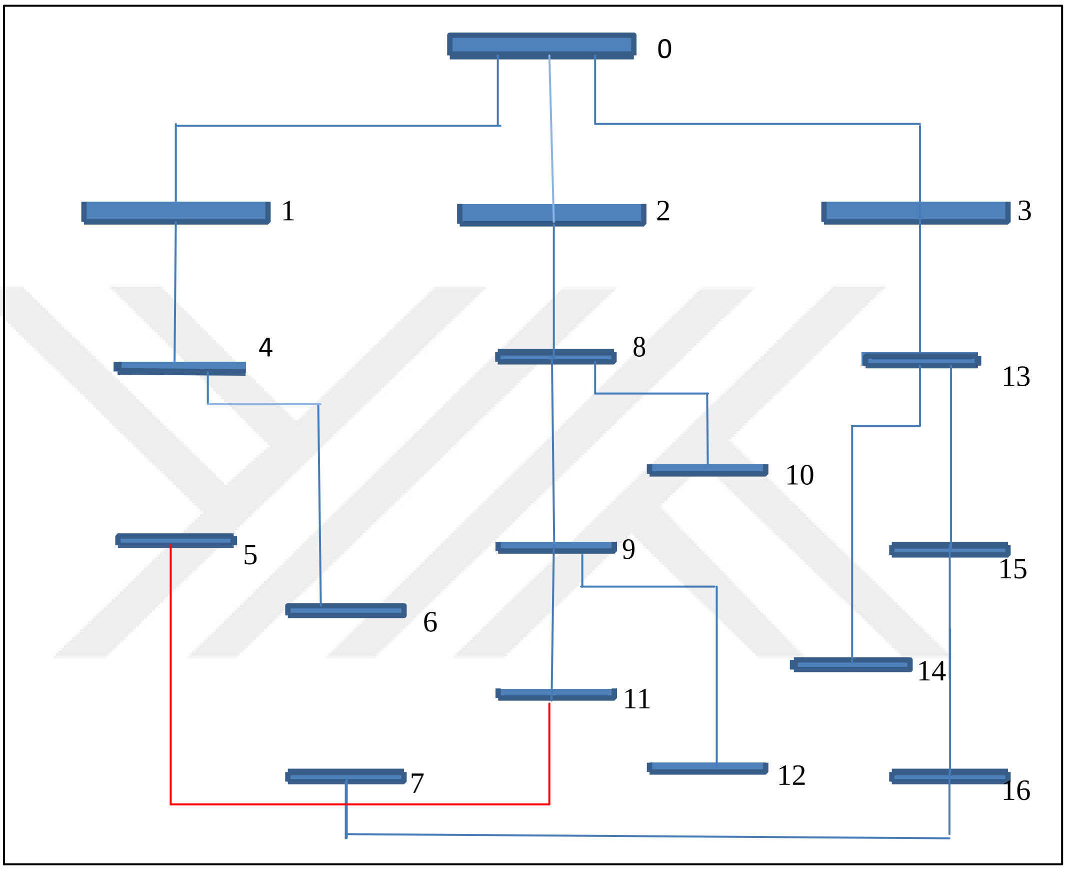
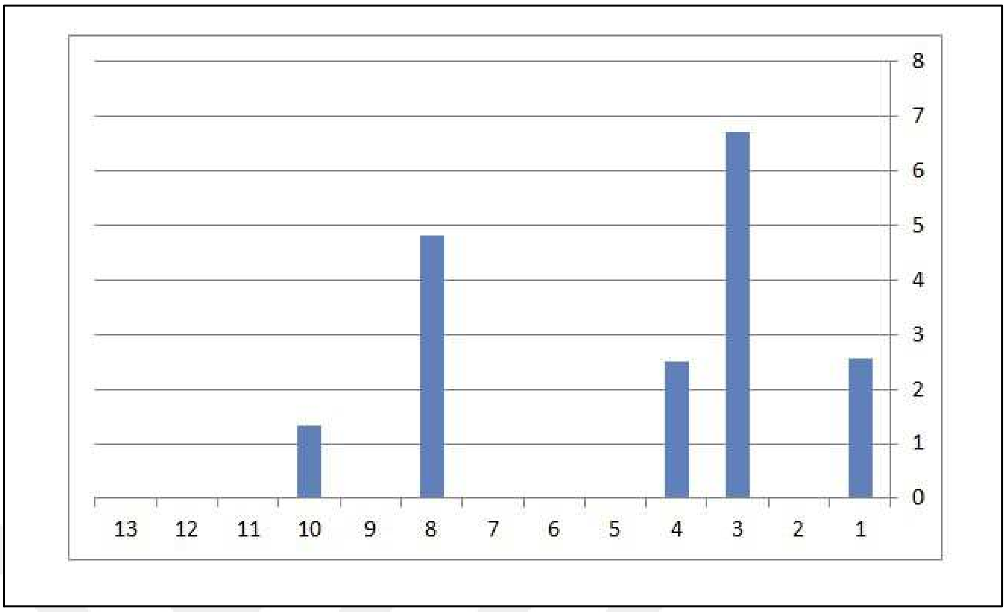


Figure 4.14: Forth topology of system.

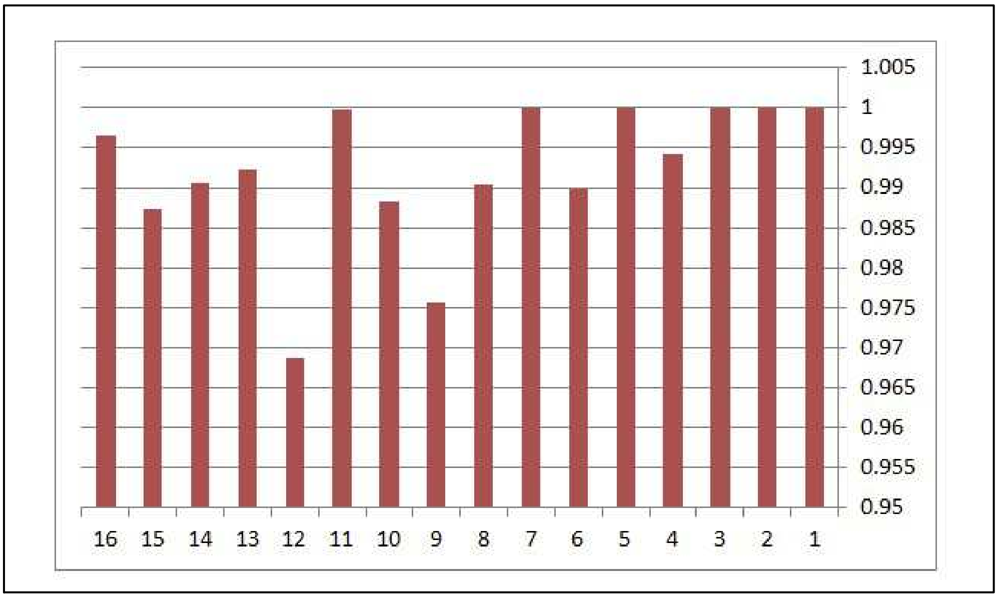
Power losses in each busbar



Number of busbar

Figure 4.15: Power losses after fourth reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.16: Voltage profile after forth reconfiguration p.u.

v. Case five: in this case the switches (4, 14 and 15) are opened and all other are closed so the network in figure below is produced.

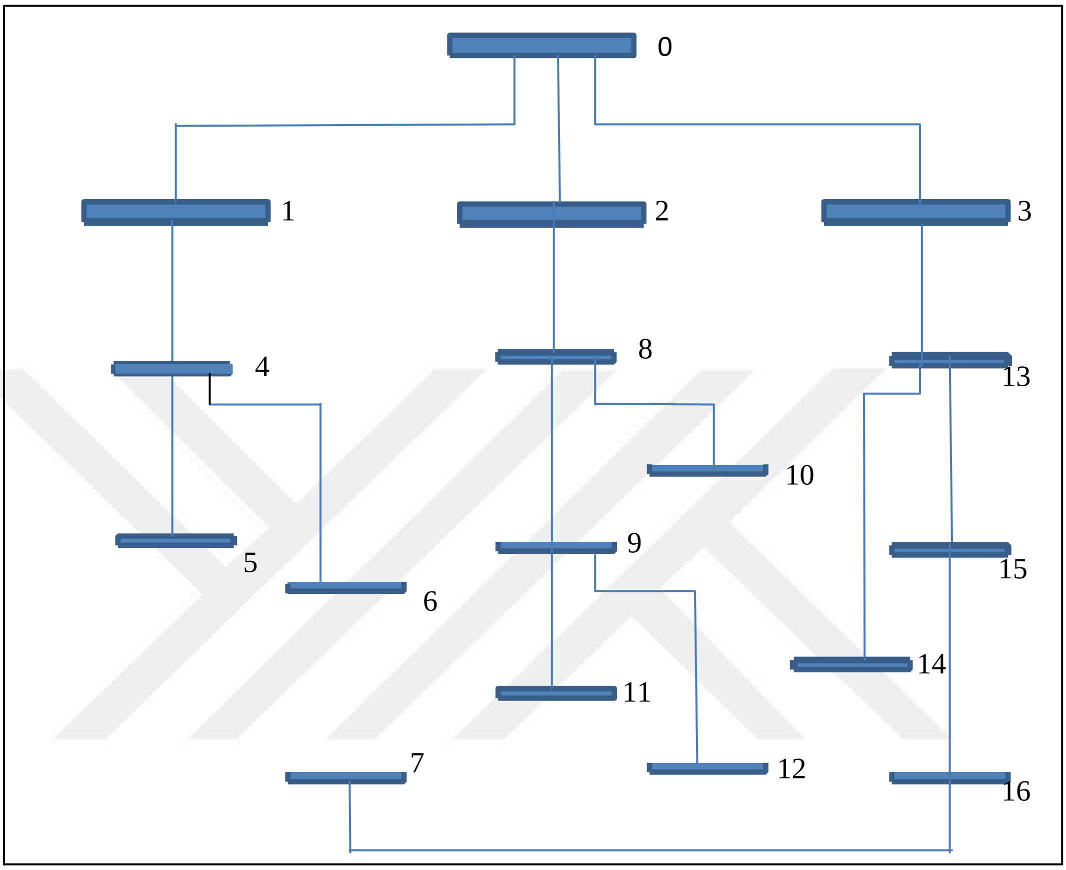
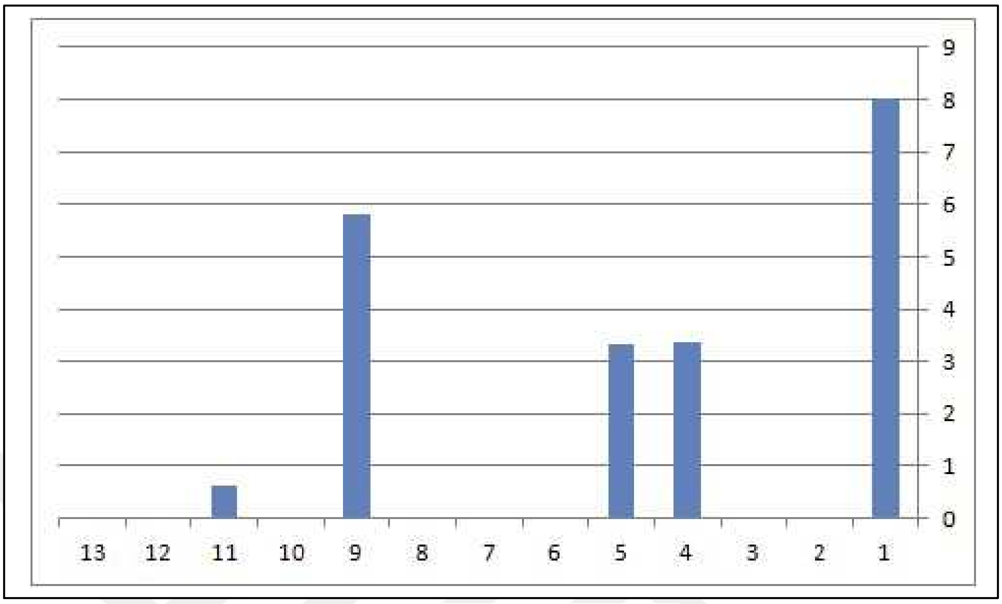


Figure 4.17: Fifth topology of system.

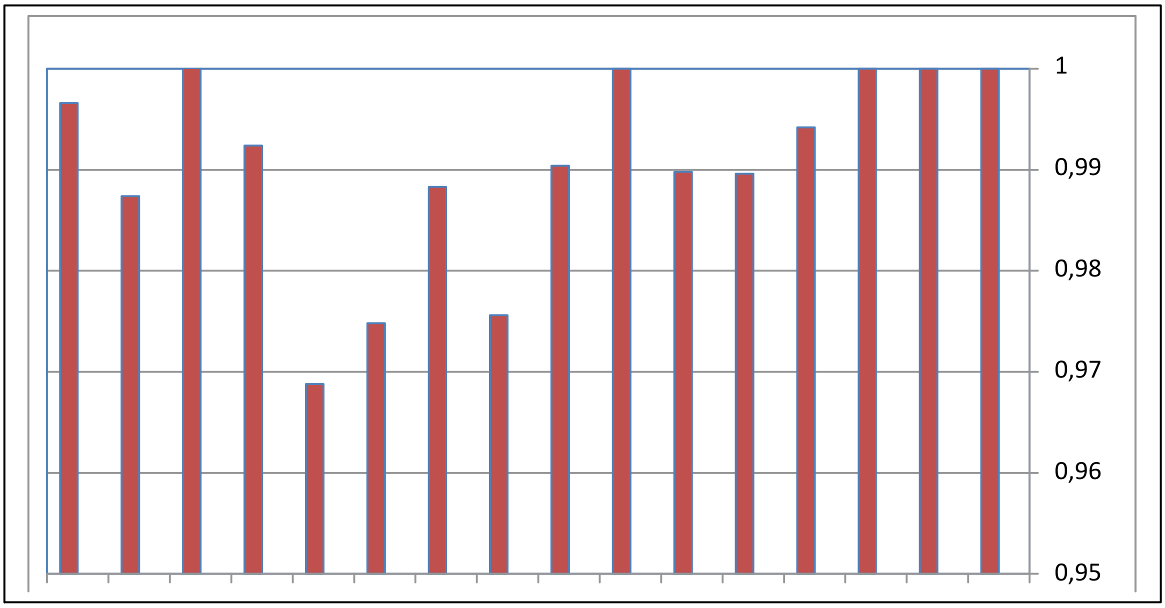
Power losses in each busbar



Number of busbar

Figure4.18: Power losses after fifth reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.19: voltage profile after fifth reconfiguration in p.u.

vi. Case six: switches of (2, 4 and 11) are kept opened and all others are closed to form the following topology.

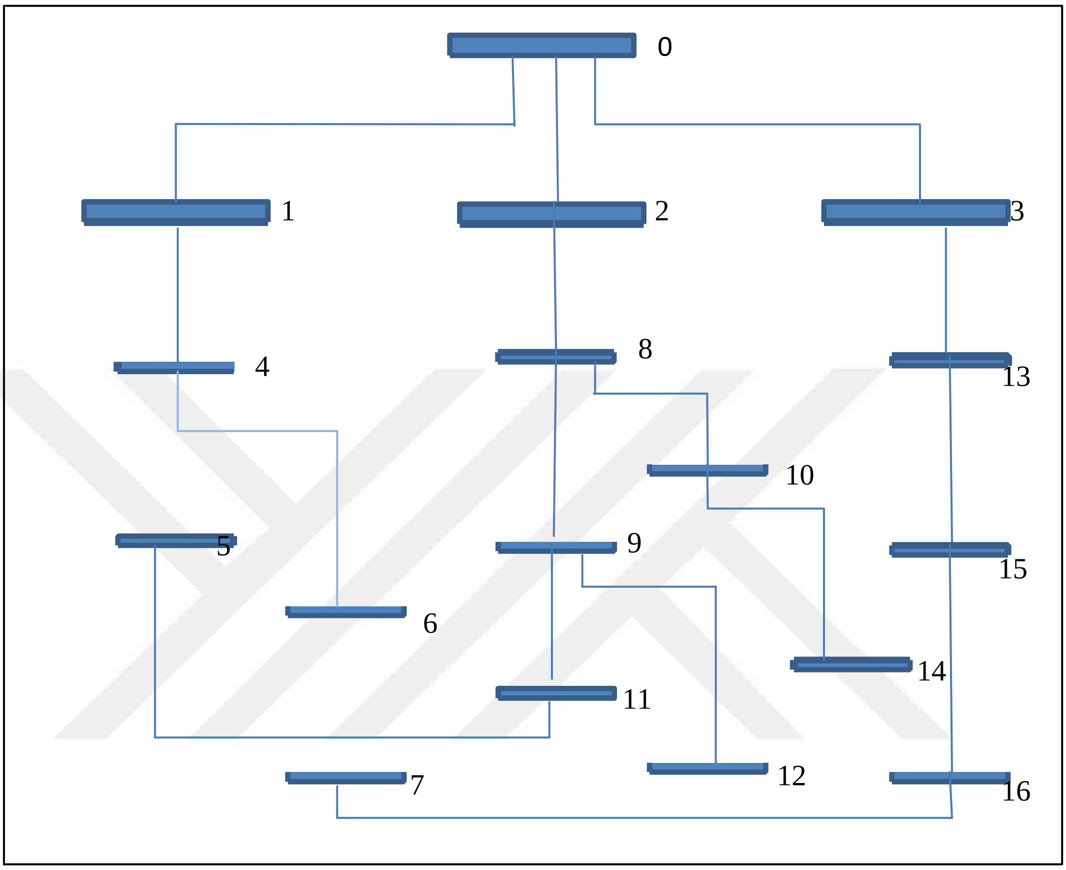
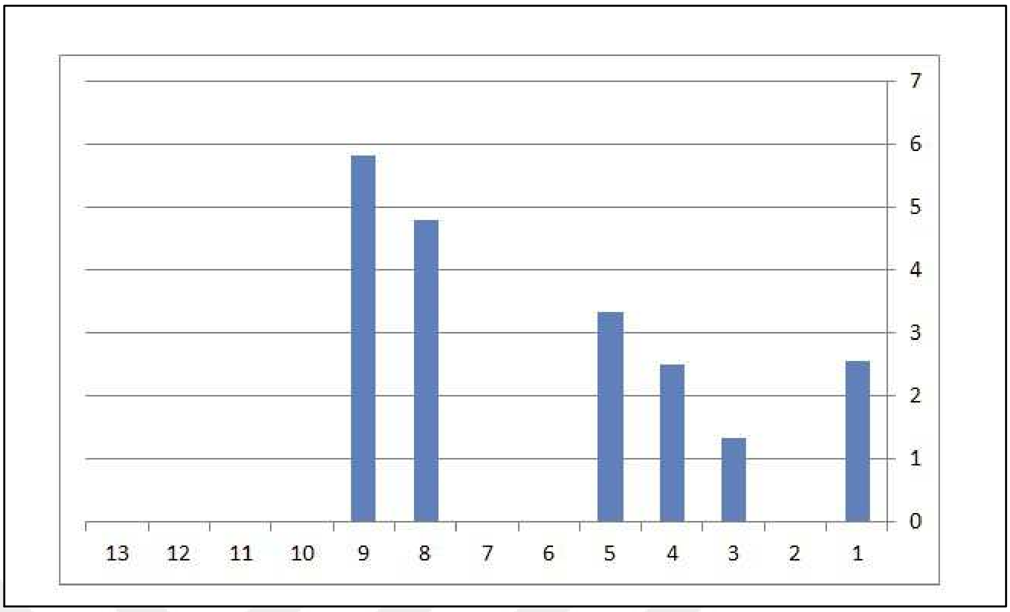


Figure 4.20: Sixth topology of system.

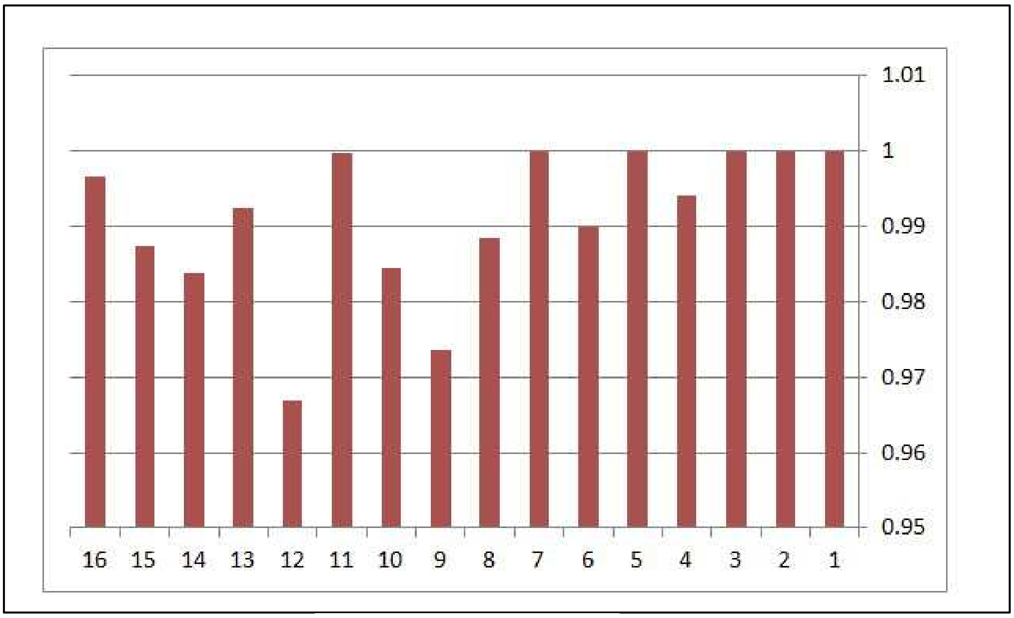
Power losses in each busbar



Number of busbar

Figure 4.21: Power losses after sixth reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.22: Voltage profile after sixth reconfiguration in p.u.

vii. Case seven: switches of (11, 13 and 14) are opened in this case and all rest is closed to form the below topology.

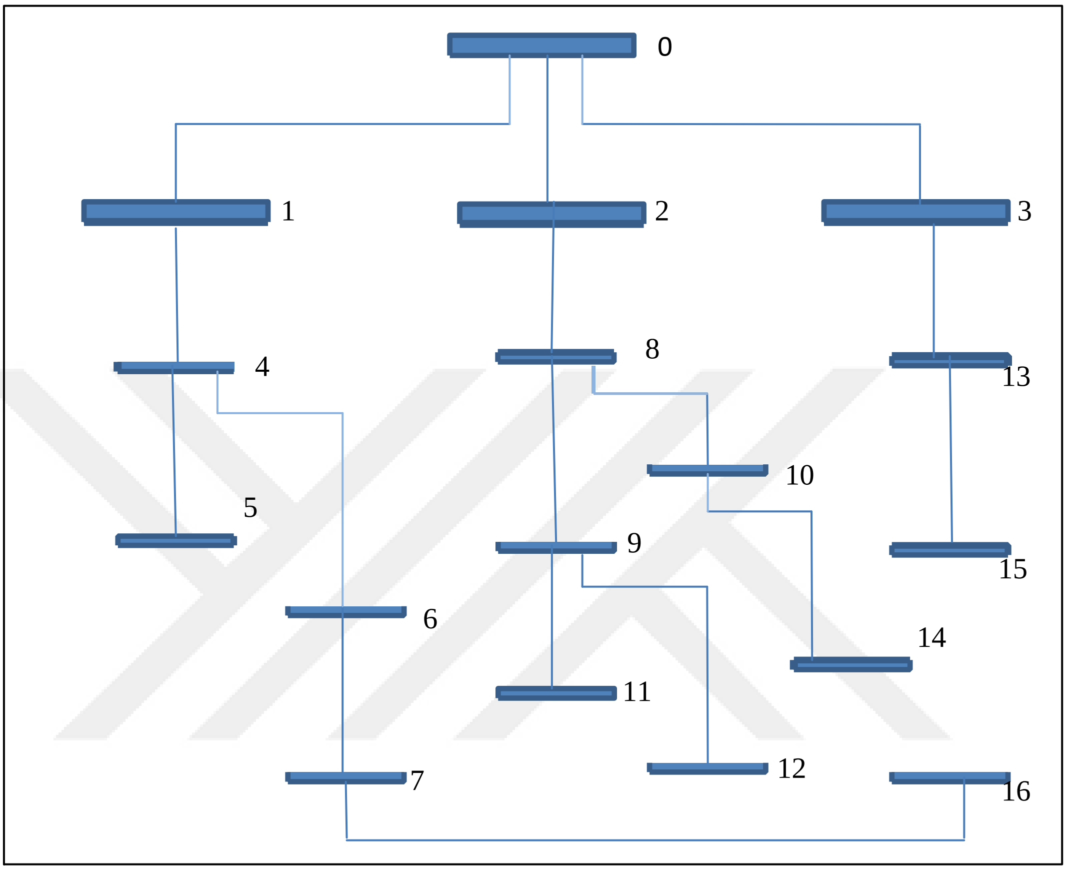
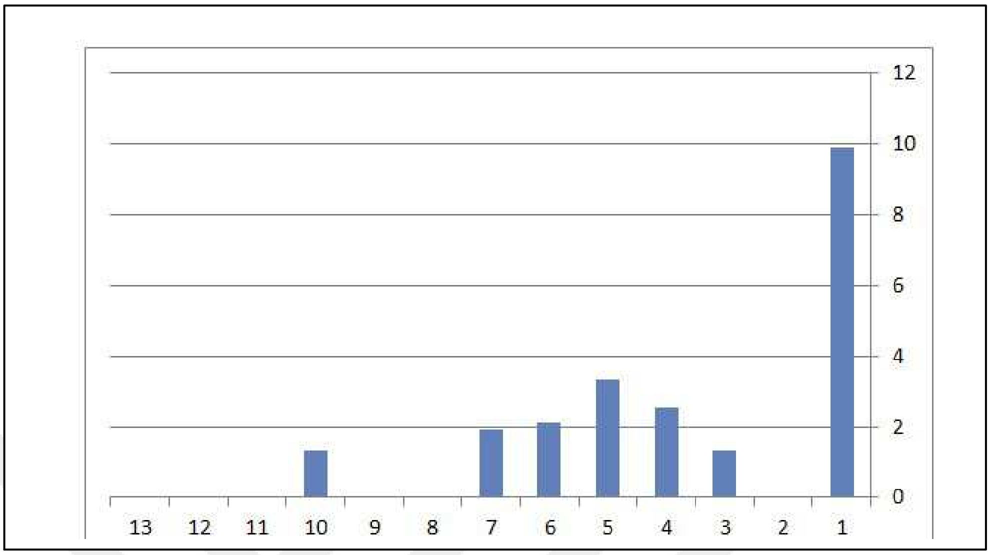


Figure 4.23: Seventh topology of system.

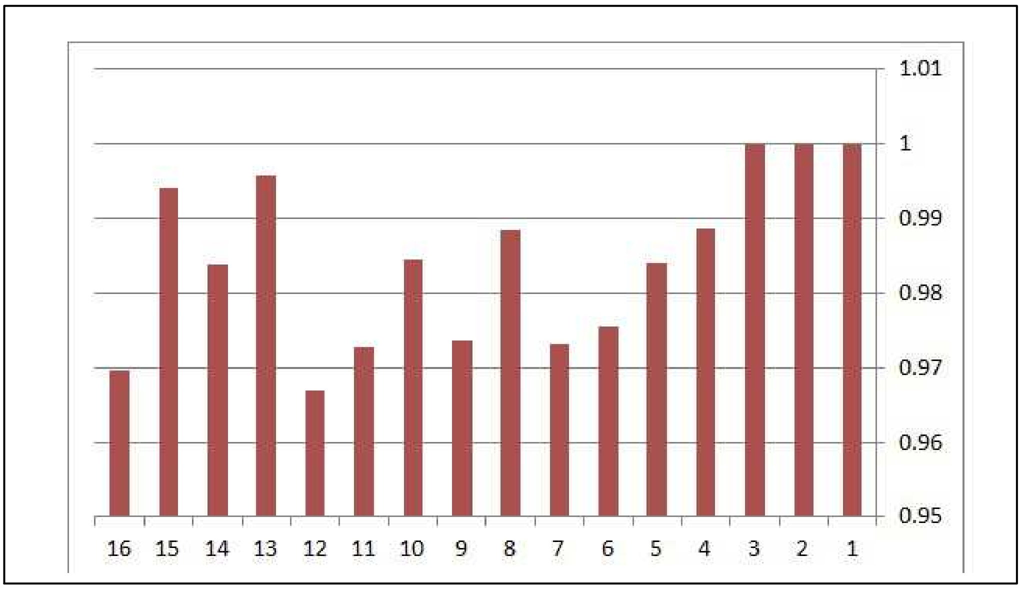
Power losses in each busbar



Number of busbar

Figure 4.24: Power losses after seventh reconfiguration in MVA.

Voltage profile in each node



Number of busbar

Figure 4.25: Voltage profile after sixth reconfiguration in p.u.

4.5 Technical observations

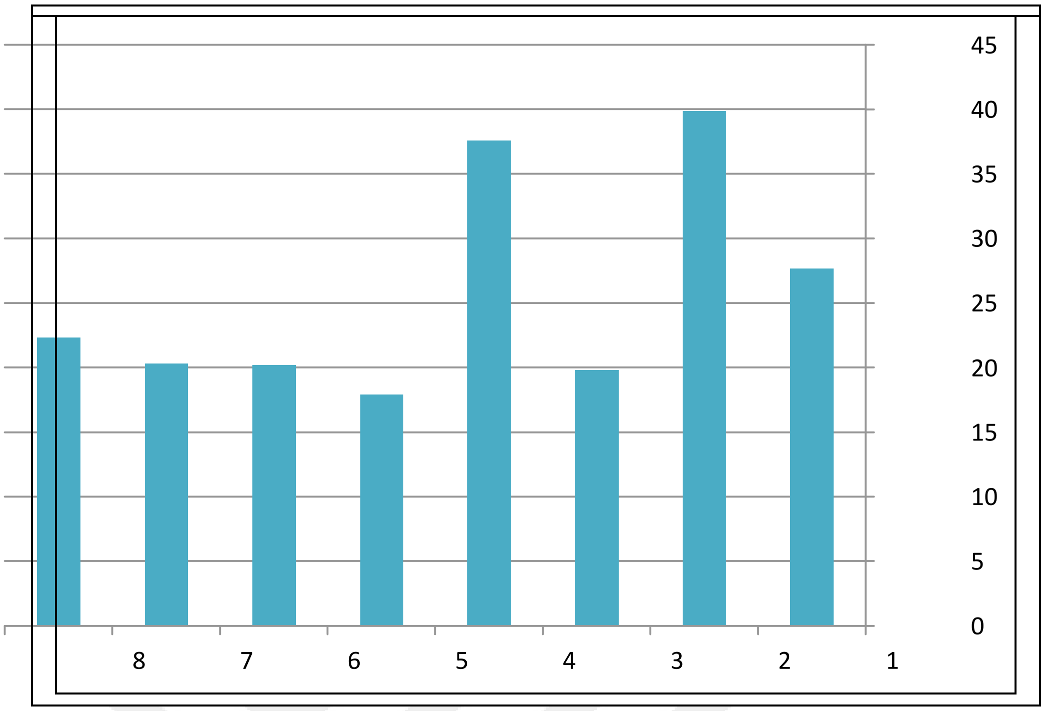
Reasons behind this reconfiguration can be either unwanted occurrence such as fault at any bus-bar or it can be done to distribute the network load from loaded bus to light loaded bus. Network criteria should be obeyed and that can be seen in all topologies resulted from reconfiguration program; radial system is assured for each case.

Losses mitigation is achieved by conducting different reconfigurations and optimum results are noticed at case number “five “ (if the standard configuration is considered as first iteration otherwise, the same case is holding number “four” of previous section).

However, losses of each node were calculated based on the subtraction of line losses (switches losses) from the total provided power of this node. As power burst from generation node to the coming node connected with it by particular line, losses is developed in that line and the magnitude of these losses are depended on transmission line length and other physical environmental parameters such as weather conditions and material used to fabricate the line. However, another issues such as load is also considered as reason behind losses development in transmission line. Load connected to any node is required power in sufficient value to prevent losses. The system reconfiguration was done randomly using ANN program to provide the possibilities that comply the conditions of predefined database and above cases have generated.

Mathematical summation of losses in each node within every case is yielded single value called total power losses. Figure 4.26 is depicting these values for total eight cases. It is clearly seen that case number five is represented the minimum losses, in this iteration the switches (2, 4 and 15) were opened and all other switches were closed.

Power losses in each configuration



Number of configuration

Figure 4.26: Total power losses in all iterations.

The maximum losses are laid on case one when switches 7, 8 and 16 were opened and all others were closed.

4.6 results discussion

Considering the first case of reconfiguration as peak losses and fourth case as minimum in losses; the loads and line status must be studied. At standard configuration, all nodes are supplied from feeders (1, 2 and 3) with power in MVA with standard configuration the feeder (1) provides nodes under its control with (5.1 MW and 8.5 MVAR) as in table 4.3.

Table 4.3: Power supplied by the feeders during standard, peak and minimum losses in MW, MVAR

Feeder 3	Feeder 2	Feeder 1	Feeder/iteration
Iteration 1	5.1+8.5i	8.7+15.1i	3.5+5.1i
4.3+ 6.7i	5.7+9i	5.1+ 8.5i	Iteration 2
Iteration 5	1.6+2i	8.7+15i	3.6+ 5.7i

From the above table it seems that system (generator) is required to produce the active power with 17.3 MW and reactive power of 28.7 MVAR at standard system configuration. These values are kept as reference for validation with system capacity (required power to run the load) at iteration two (first case of reconfiguration) and iteration five (fourth case study). However, system generator shall provide the load with 15.1 MW and 24.2 MVAR if topology in second iteration is deployed and 13.9 MW and 22.7 MVAR if the topology of fourth case is deployed. It is quite interested to make the generation capacity in minimum possible limit for running the same load. Ultimately, all nodes are supplied and every consumer is getting his requirement of power demand during all topologies (iterations) so, it is seen that iteration number five helps to reduce the load by reducing the losses to feasible break. Economically, the losses are reduced and so power generation is minimized as proved in previous points. The fuel required to generate the demand of case five is obviously lower than the same in rest cases so that economical gain is yielded by network reconfiguration. Table 4.4 is detailing the demanded and generation power in all nodes by assuming the node one through three as generation nodes.

Table 4.4 Demand levels of power for entire nodes in (MW, MVAR)

8	7	6	5	4	3	2	1	Configuration \ node
1	5.1+8.5i	5.1+8.5i	3.9 +7i	5.1+8.5i	1.6+2i	3.9 +7i	1.6+2i	5.1+8.5i
8.7+15.1i	8.7+15.1i	5.7+9i	8.7+15.1i	6.6+10i	5.7+9i	5.7+9i	8.7+15.1i	2
3	3.5+5.1i	4.3+6.7i	3.5+5.1i	0.9+1i	3.6+5.7i	3.5+5.1i	0.9+1i	0.9+1i
1.6+2i	1.6+2i	1.6+2i	1.6+2i	1.6+2i	1.6+2i	1.6+2i	1.6+2i	4
5	1.5+3i	1.5+3i	1.5+3i	1.5+3i	1.5+3i	1.5+3i	1.5+3i	1.5+3i
0.8+2i	0.8+2i	0.8+2i	0.8+2i	0.8+2i	0.8+2i	0.8+2i	0.8+2i	6
7	1.2+1.5i	1.2+1.5i	1.2+1.5i	1.2+1.5i	1.2+1.5i	1.2+1.5i	1.2+1.5i	1.2+1.5i
2.7+4i	2.7+4i	2.7+4i	2.7+4i	2.7+4i	2.7+4i	2.7+4i	2.7+4i	8
9	3+5i	3+5i	3+5i	3+5i	3+5i	3+5i	3+5i	3+5i
0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	10
11	0.1+0.6i	0.1+0.6i	0.1+0.6i	0.1+0.6i	0.1+0.6i	0.1+0.6i	0.1+0.6i	0.1+0.6i
2+4.5i	2+4.5i	2+4.5i	2+4.5i	2+4.5i	2+4.5i	2+4.5i	2+4.5i	12
13	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i
0.7+1i	0.7+1i	0.7+1i	0.7+1i	0.7+1i	0.7+1i	0.7+1i	0.7+1i	14
15	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i	0.9+1i
1+2.1i	1+2.1i	1+2.1i	1+2.1i	1+2.1i	1+2.1i	1+2.1i	1+2.1i	16

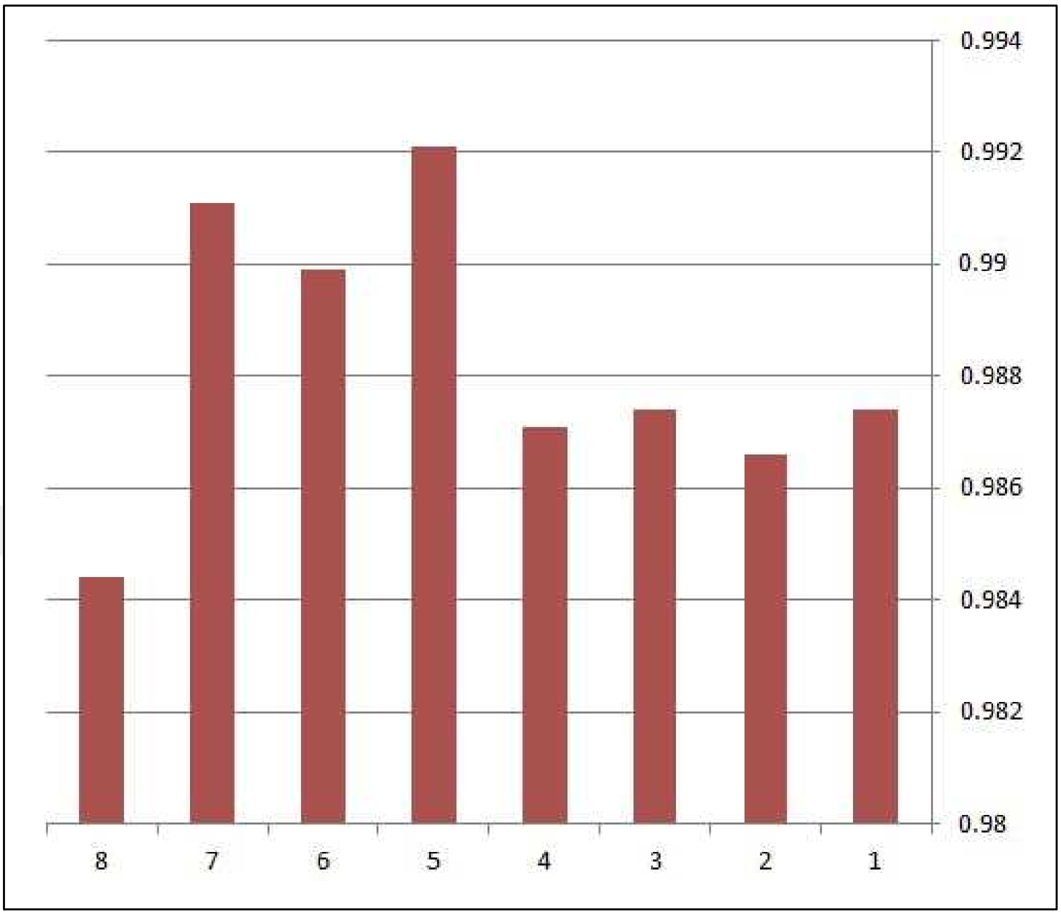
The losses were found minimum at iteration five (fourth case study) table 4.5 is depicted the losses occurrence in each reconfiguration and the average voltage in each reconfiguration.

Table 4.5 the losses and voltages in each reconfiguration

Number of reconfiguration	The total losses in each reconfiguration(MVA)	The voltage in each reconfiguration(p.u.)
1	27.528	0.987
2	39.88	0.9866
3	19.804	0.9874
4	37.6	0.9871
5	17.89	0.9921
6	20.196	0.9899
7	20.3	0.9911
8	22.32	0.9847

voltage profile recorded and represent the per unit voltage of node. However, in order to simplify the statistical presentation, the average value is calculated in each iteration as depicted in figure 4.27 and the table 4.5.

Voltage in each configuration



Number of configuration

Figure 4.27: Average voltage versus configuration number.

CHAPTER FIVE

CONCLUSION

5.1 Conclusion

Project was included detailed study that aiming to improve the reliability of distribution system. It was also cleared that power losses in distributors are considered as fundamental even that may threat the system reliably. In order to treat the problem, a reconfiguration protocol is one of feasible solutions, it simply implied, searching the lesser losses path from generation end to consumer end. System analysis was carried out on sixteen bus radial distribution system. Procedure is started by examining the standard topology of system without applying any change hence, power supplied to each node is identified and base of current summation load flow method (backward forward sweeps). Power losses are determined in each branch of network. The branches have been defined by two or more nodes coordination so that each couple of nodes is forming one branch, this can be considered as distribution line where power losses are developed. After the test of losses, voltage profile in every node is then calculated and by this reliability assessment study for standard topology of system is yielded.

Following procedure is devoted to implement a multiple topologies from the mother system, this idea is implemented to reconfigure the system in efforts to minimize the path losses and maximize it bus voltage. Artificial Neural Network is deployed to predict the possible paths which are obeying to this system constrains. Reliability assessment is also initiated for every possible topology and results were recorded. System is implemented in software using Matlab and results are found much consistence. Among of eight different topologies that called by program.

It was seen that iteration two yielded the worse result of performance and attempt of fifth iteration yielded the best result of performance.

System is examined under various topologies and it was found that in optimum reconfiguration the power required to be generated from the plant end is reduced. This topology can be considered as more economical worth that others including the standard system prior to apply any configuration.

The table (5.1) shows some comparisons with two paper that using the same network. However, the number of changing switches is different and the load flow method is different. The optimization method is different.

Table 5.1 comparison results with other 16- bus system

notes	The reduction of losses % of best reconfiguration	Best Voltage profile	References of paper
This work	0.9921 p.u	24.8	This work study the losses of the system and voltage profile to check the reliability of system and get the economic gain
They none mentioned the best voltage and they none worked for reliability and economic gain	6.432	--------	Sathish Kumar, K.Rajalakshim and S. Preabhakar Karthikeyan [21]
A.V Suhakara and M. Damodar Reddy [24]	0.9716 p.u	8.86	They mentioned the minimum voltage and they none worked for reliability and economic gain

5.2 Future work

There are several future visions on this subject network reconfiguration such as:

1- Try the same idea but apply a new way of optimization and load flow analysis algorithms for same network or another one.
2- Use the same algorithm of (ANN) with developed parameter for same network because the (ANN) implements the work quickly and take the best decision for optimization method.
3- Use the combination of feeder reconfiguration with distribution generation or with placement of capacitor to reduce losses by using the artificial neural network for same network.

CHAPTER SIX

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APPENDIX

Working program

1. Part one(testupF)

```
%%% program is applyied to the network and expected to shape the matrix
and
                             % prepare of intial load caluclations in
each node%%%


function [impup,loadup,SS] = testupF(SW, conf, conload)

%copy the configuration matrix into temp matrix
impup=conf;
loadup= conload;
% number of nodes
Nnn=impup(:,1);
Nn=max(Nnn);
% Branch impedence
R=impup(:,4);
X=impup(:,5);
Z=complex (R,X);
% switch status in the system
% in this wherever the switch is opened then remove the line data from
the
% matrix
SW;
%**********************************************************************
*******input
for  k=1:length  (impup(:,1))
    if SW(k)==0
        impup(k,:)=0;
    end
end
    impup;
    % removing all zeros arms in the matrix

    % identify the branches after reconfigureation like main feeders
are 1
    % 2 and 3 so all nodes connected to those feeders are needed to %
    evaluared
    ind1=[];
    ind2=[];
    ind3=[];
    F1=1;
    F2=2;
    F3=3;
            % Now finding the location of main feeders in the matrix for
            ji=1:16
                if impup(ji,2)==1
                    ki=impup(ji,7);
                end
```

```
            if impup(ji,2)==2
                ke=impup(ji,7);
            end

            if impup(ji,2)==3
                kz=impup(ji,7);
            end
        end
ki;
while (impup(ki,2)>=F1 && impup(ki,2)~=F2 && impup(ki,2)~=F3)
    ind1(ki)=impup(ki,3);
    ki=ki+1;
end

ke;
while (impup(ke,2)>=F2 && impup(ke,2)~=F1 && impup(ke,2)~=F3)
    ind2(ke)=impup(ke,3);
    ke=ke+1;
end

kz;
while (impup(kz,2)>=F3 && impup(kz,2)~=F1 && impup(kz,2)~=F2)
    ind3(kz)=impup(kz,3);
    kz=kz+1;
end
ind1(ind1==0)=[];
ind1;  % nodes connected to the feeder F1
ind2(ind2==0)=[];
ind2;  % nodes connected to the feeder F2
ind3(ind3==0)=[];
ind3;  % nodes connected to the feeder F3
% Now, load of F1 , F2 and F3 will be evaluated
ind1;
ind2;
ind3;
P1=0;
Q1=0;
for kj=1:length (ind1)
    P1=  loadup(ind1(kj),2)  +P1;
    Q1= loadup(ind1(kj),3)+Q1;
end
loadup(1,2)=P1;
loadup(1,3)=Q1;
P2=0;
Q2=0;
for ks=1:length (ind2)
    P2=  loadup(ind2(ks),2)  +P2;
    Q2= loadup(ind2(ks),3) +Q2;
end
loadup(2,2)=P2;
loadup(2,3)=Q2;
P3=0;
Q3=0;
for ka=1:length (ind3)
    P3=  loadup(ind3(ka),2)  +P3;
    Q3= loadup(ind3(ka),3) +Q3;
end
```

```
  loadup(3,2)=P3;
    loadup(3,3)=Q3;
    % now load matrix is ready according the new network configuration
    loadup(:,2);
    loadup(:,3);
    SS= loadup(:,2)+(i*loadup(:,3));
    % calcultion of load flow using BFA algo.

End
```

2- Part two (BFAF)

```
        %%% The Back ward-Forward Algo. to calculated the lossess and
evaluated voltage profile %%%
                                                        %%%%%%  $$$$
%%%%

function [v, ppp, LoN, PLOSS ]= BFAF(impup,loadup)


% configuration matrix where zeros are removed
impup;
impup( ~any(impup,2), : ) = [];
% load matrix
loadup;
% network pre known information
BMVA=100;  % base power
BKV=23;    % base potential
% number of nodes in the system
Ms=max (impup(:,2));
Mr=max  (impup(:,3));
Mn=max (Mr,Ms);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% number of branches in the grid
Br=impup(:,1);
MB=length (Br);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%v=ones(Mn,1);
%voltage  in bus  intailly
for kkv=1:Mn
    v(kkv)=1;  % in per unit
    v=v';
end
% currents in each branch intailly for
kzz=1:MB
    iB(kzz)=0;
    iB =iB';
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
p=loadup(:,2);
q=loadup(:,3);
s=p+(q*i);
r=impup(:,4);
x=impup(:,5);
z=r+(x*i);
```

```
% per unit power
s=s/BMVA;

for repeat=1:30

    I=conj(s./v);
    mbb=length(impup(:,1));
for k=mbb:-1:1
[xf1  xf2]=  find(impup(:,2:3)==impup(k,3));
xf=[xf1 xf2];
xr=length   (xf(:,1));
xc=length   (xf(1,:));
rc=xr*xc;
z=[];
z1=[];
zI=[];
zI1=[];

for jq=1:xr
   if xf(jq,2)==1
        z=xf(jq,1);  % branch  current  indicator
        z1=impup(z,1);
   end
   if xf(jq,2)==2
        zI=xf(jq,1);  % node  current  indicator
        zI1=impup(zI,3);
   end
end
if rc<=2
    iB(impup(k,1))=I(zI1);
else
    iB(impup(k,1))=I(zI1)+sum(iB(z1));


end
end

for ss=1: MB

     v(impup(ss,3))=(v(impup(ss,2))-
(iB(impup(ss,1))*(impup(ss,4)+(i*impup(ss,5)))));
end

end
% claculation on  losses per  line
for kf=1:length (impup(:,1))
    PLOSS(impup(kf,1))=  (abs  (iB(impup(kf,1))))^2  *(impup(kf,4));
end
% Power losses in each branch in terms of mega VA
PLOSS=PLOSS * BMVA;
% Power losses in each branch in terms of mega VA
PBL=PLOSS*(10^6);

% total losses of network branches branches in mega volt ampper
ppp=sum(PLOSS);
% losses claculation in each node (bus bar)

Snn=loadup(:,2)+(loadup(:,3)*i);
```

```
%impup( ~any(impup,2), : ) = [];
sdd=max(impup(:,2));
sbb=max(impup(:,3));
sar=max(sbb,sdd);
    for h=1:length (impup(:,1))
        det=find  (impup(h,3)==impup(:,2));
        if size(det)>=1
            LoN(h)= Snn(h)-  PLOSS(impup(h,1));
        else
           LoN(h)=0;
        end


    end

    % $$$$ ploting the results $$$$ %
    voltage per bus
    figure ()

    plot(abs(v),'bo');
    title ('Voltage profile for each node');
    legend('V (p.u.)');
    grid on
    ylabel ('Voltage in per unit');
    xlabel ('Bus Bar number');
    hold on
    plot(abs(v),  'r');
    hold off

    % power losses in each bus
    figure ()

    plot(abs(LoN),'bo');
    title ('Power losses in each node');
    legend('zero indicates that node is "OFF"');
    grid on
    ylabel ('MVA Losses');
    xlabel ('Bus Bar number');
    hold on
    plot(abs(LoN),  'r');
    hold off
end
```

2- Part three (final result)

```
        % Applying of topologies on the network in all predefined
conditions%

%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$%

%copy switch status from the configuration matrix
str=swstallup;
ktr=swstallup;


%configuration I
SW=str(:,1);

    %update the grid
    [impup, loadup,  SS ]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN , PLOSS]= BFAF(impup,loadup);
    v1=v;
    ppp1=ppp;
    LoN1=LoN;
    SS1=SS;

    PP1=PLOSS;
%configuration II
SW=str(:,2);

    %update the grid
    [impup, loadup, SS ]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN, PLOSS ]= BFAF(impup,loadup);
    v2=v;
    ppp2=ppp;
    LoN2=LoN;
    PP2=PLOSS;
     SS2=SS;
%configuration III
SW=str(:,3);

    %update the grid
    [impup, loadup,  SS]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN, PLOSS ]= BFAF(impup,loadup);
    v3=v;
    ppp3=ppp;
    LoN3=LoN;
    PP3=PLOSS;
     SS3=SS;
%configuration IV
SW=str(:,4);

    %update the grid
    [impup, loadup, SS ]=testupF(SW, conf, conload);
```

```
 %get the results
    [v, ppp, LoN , PLOSS]= BFAF(impup,loadup);
    v4=v;
    ppp4=ppp;
    LoN4=LoN;
    PP4=PLOSS;
     SS4=SS;
%configuration V
SW=str(:,5);

    %update the grid
    [impup, loadup, SS ]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN , PLOSS]= BFAF(impup,loadup);
    v5=v;
    ppp5=ppp;
    LoN5=LoN;
    PP5=PLOSS;
    SS5=SS;
%configuration VI
SW=str(:,6);

    %update the grid
    [impup, loadup,  SS]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN , PLOSS]= BFAF(impup,loadup);
    v6=v;
    ppp6=ppp;
    LoN6=LoN;
    PP6=PLOSS;
    SS6=SS;
%configuration VII
SW=str(:,7);

    %update the grid
    [impup, loadup, SS]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN, PLOSS ]= BFAF(impup,loadup);
    v7=v;
    ppp7=ppp;
    LoN7=LoN;
    PP7=PLOSS;
    SS7=SS;
%configuration VIII
SW=str(:,8);

    %update the grid
    [impup, loadup, SS ]=testupF(SW, conf, conload);
    %get the results
    [v, ppp, LoN , PLOSS]= BFAF(impup,loadup);
    v8=v;
    ppp8=ppp;
    LoN8=LoN;
    PP8=PLOSS;
    SS8=SS;
```

```
 % all outcomes concenation
LOON=[sum(LoN1), sum(LoN2), sum(LoN3), sum(LoN4), sum(LoN5), 
sum(LoN6), sum(LoN7), sum(LoN8)];
LoNL=length (LOON(1,:));
%for kki=1:LoNL
```

2- Part four (annt)

```
         %$$$$$$$$$$$$$ End To End %%%%%%%%%%%%%%%%%%%%%%%%%
                              % entire results are gaind and displayed 
here%%%%
PPT1=abs(SS1);
Tar1=str(:,1);


new1=newff(minmax(PPT1), [16,16 ] , {'tansig','purelin'},'trainlm');
new1.trainParam.show = 50;
new1.trainParam.lr = 0.005;
new1.trainParam.epochs  =1000;
new1.trainParam.goal = 0;

n1w= trainlm (new1 , PPT1 ,Tar1);
n1w= trainlm (new1 , PPT1 ,Tar1);
n1w= trainlm (new1 , PPT1 ,Tar1);

res1=sim(n1w, PPT1);
res1=round (res1);
%
PPT2=[abs(SS2)];
Tar2=[str(:,2)];


new2=newff(minmax(PPT2), [16,16 ] , {'tansig','purelin'},'trainlm');
new2.trainParam.show = 50;
new2.trainParam.lr = 0.005;
new2.trainParam.epochs  =1000;
new2.trainParam.goal = 0;

n2w= trainlm (new2 , PPT2 ,Tar2);
n2w= trainlm (new2 , PPT2 ,Tar2);
n2w= trainlm (new2 , PPT2 ,Tar2);

res2=sim(n2w, PPT2);
res2=round (res2);
%
PPT3=[abs(SS3)];
Tar3=[str(:,3)];
```

```
new3=newff(minmax(PPT3), [16,16 ] , {'tansig','purelin'},'trainlm');
new3.trainParam.show = 50;
new3.trainParam.lr = 0.005;
new3.trainParam.epochs  =1000;
new3.trainParam.goal = 0;

n3w= trainlm (new3 , PPT3 ,Tar3);
n3w= trainlm (new3 , PPT3 ,Tar3);
n3w= trainlm (new3 , PPT3 ,Tar3);

res3=sim(n3w, PPT3);
res3=round (res3);
%
PPT4=[abs(SS4)];
Tar4=[str(:,4)];



new4=newff(minmax(PPT4), [16,16 ] , {'tansig','purelin'},'trainlm');
new4.trainParam.show = 50;
new4.trainParam.lr = 0.005;
new4.trainParam.epochs  =1000;
new4.trainParam.goal = 0;

n4w= trainlm (new4 , PPT4 ,Tar4);
n4w= trainlm (new4 , PPT4 ,Tar4);
n4w= trainlm (new4 , PPT4 ,Tar4);

res4=sim(n4w, PPT4);
res4=round (res4);
%
PPT5=[abs(SS5)];
Tar5=[str(:,5)];



new5=newff(minmax(PPT5), [16,16 ] , {'tansig','purelin'},'trainlm');
new5.trainParam.show = 50;
new5.trainParam.lr = 0.005;
new5.trainParam.epochs  =1000;
new5.trainParam.goal = 0;

n5w= trainlm (new5 , PPT5 ,Tar5);
n5w= trainlm (new5 , PPT5 ,Tar5);
n5w= trainlm (new5 , PPT5 ,Tar5);
res5=sim(n5w, PPT5);
res5=round (res5);
%
PPT6=[abs(SS6)];
Tar6=[str(:,6)];
```

```
new6=newff(minmax(PPT6), [16,16 ] , {'tansig','purelin'},'trainlm');
new6.trainParam.show = 50;
new6.trainParam.lr = 0.005;
new6.trainParam.epochs  =1000;
new6.trainParam.goal = 0;

n6w= trainlm (new6 , PPT6 ,Tar6);
n6w= trainlm (new6 , PPT6 ,Tar6);
n6w= trainlm (new6 , PPT6 ,Tar6);
;

res6=sim(n6w,  PPT6);
res6=round (res6);
%
PPT7=[abs(SS7)];
Tar7=[str(:,7)];



new7=newff(minmax(PPT7), [16,16 ] , {'tansig','purelin'},'trainlm');
new7.trainParam.show = 50;
new7.trainParam.lr = 0.005;
new7.trainParam.epochs  =1000;
new7.trainParam.goal = 0;

n7w= trainlm (new7 , PPT7 ,Tar7);
n7w= trainlm (new7 , PPT7 ,Tar7);
n7w= trainlm (new7 , PPT7 ,Tar7);
res7=sim(n7w, PPT7);
res7=round (res7);
%
PPT8=[abs(SS8)];
Tar8=[str(:,8)];



new8=newff(minmax(PPT8), [16,16 ] , {'tansig','purelin'},'trainlm');
new8.trainParam.show = 50;
new8.trainParam.lr = 0.005;
new8.trainParam.epochs  =1000;
new8.trainParam.goal = 0;

n8w= trainlm (new8 , PPT8 ,Tar8);
n8w= trainlm (new8 , PPT8 ,Tar8);
n8w= trainlm (new8 , PPT8 ,Tar8);
```

```
res8=sim(n8w,  PPT8);
res8=round (res8);
%
%voltage profile
amm=[
mean(v1),mean(v2),mean(v3),mean(v4),mean(v5),mean(v6),mean(v7),mean(v8
)];
%system lossess per lines
PTotla=[ ppp1, ppp2, ppp3, ppp4, ppp5, ppp6, ppp7, ppp8];
%%%
RRV=max(amm);

RRP=min (PTotla);

Vok=find (amm==RRV);
Pok=find (PTotla==RRP);
RSER=[res1,  res2,res3,res4,res5,res6,res7,res8];
RSER(:,Vok);

figure ()

plot (abs(LOON),'g');
title ('Power losses monitered for all cases of reconfiguration');
legend();
grid on
ylabel ('MVA Total Losses');
xlabel ('Ituration number');
hold on
plot(abs(LOON),'r*');

hold off

%
figure ()

plot (abs(amm),'y');
title ('voltage profile');
legend();
grid on
ylabel ('Voltage in p.u.');
xlabel ('Bas bar number');
hold on
plot(Vok,abs(amm(Vok)),'r*');
legend('* the optimum result of voltage');
hold off
% print the results of command bar %
optim voltage
%optim  configuration
% losses in node
fprintf('$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$\n\n');
fprintf('$$$$$$$$$ R E S E L T S $$$$$$$$$$$\n\n');
fprintf('minimum power losses: %i\n\n',RRP);
fprintf('max voltage : %i\n\n',RRV);
fprintf('best configuration: %i\n',RSER(:,Vok));
```