

CHAPTER ONE

INTRODUCTION

1.1 General Concepts

Electric energy is an essential ingredient for the industrial and all-round development to of any country. It is a conveyed form of energy, because it can be generated centrally in bulk and transmitted economically over long distance. The electrical power system is a system that provides electric energy to consumers at constant voltage and frequency [1].

The electrical power system is a complex system, and is consisting of three main systems including: generation, transmission, and distribution.

The main components of an electrical power network are generators, transformers, transmission lines, buses, loads, and protective devices such as relays and circuit breakers [2].

To provide costumers requirement of electrical power “power quality” the power system analysis and design must be taken into consideration.

The transmission system is connected between generation and distribution system, its goal to transmit bulk power to distribution network. So it’s very important to study this system to provide maximum power flow with smallest losses.

Power flow analysis of transmission system is required to analyze the steady-state performance of a power system under various operating conditions [1].

1.2 Problem Statement

For a given power network, with known complex power loads and some set of specifications or restrictions on power generations and voltages,

Power flow problem is the computation of voltage magnitude, phase angle, and real and reactive power of any bus. Finally compute the line flow and losses in the network.

1.3 Simulation

The solution of power flow problem is so complicated and takes a long time to solve for simple power system, where for large power system we must use computer program to solve power flow problem.

There are many various computer programs used for simulating power flow problem either coded program such as matlab or graphical interface program such as PSAT matlab toolbox, Power World simulator, Neplan, and ETAP.

1.4 Objectives

The main objective of thesis is:

1. Study the construction of Sudan electric transmission national grid.
2. Study the power flow in Sudan electric transmission national grid.
3. Detect the weakness point in Sudan electric transmission national grid.
4. Suggest solution for weakness point in Sudan electric transmission national grid.
5. Expansion planning of Sudan electric transmission national grid.

1.5 Methodology

In order to achieve these objectives the following tasks will be taken:

Task 1: Study the general concept of power flow and power flow solution.

Task 2: Study the numerical method for solving power flow problem.

Task 3: Study the suitable modeling of power system for power flow problem.

Task 4: Getting network data from networks analysis centre of the Sudanese electricity transmission Co.Ltd.

Task 5: Using a computer program package “ETAP” for simulating the network and getting the result of simulation.

Task 6: Some contingencies are being taken in account.

1.6 Project Layout

The project consisting five chapters: chapter one gives an introduction about electric power system, power system components, power system and power flow analysis, simulation of power flow, and a brief research problem, objectives and methodology. Chapter two gives literature review of power flow analysis including type of buses, modeling the system, admittance matrix construction, numerical solution, and method of power flow solve. Chapter three gives an overview about “ETAP” that using to simulate the power flow problem in this project and its capability and features. Chapter four includes the simulation of real case study “Sudanese electric transmission national grid” analysis and result using “ETAP”. Finally chapter five includes the conclusion, recommendation and references.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Power flow analysis is fundamental to the study of power systems, in fact power flow forms the core of power system analysis, and power flow study plays a key role in the planning of addition or expansion of transmission and generation facilities [3].

A power flow solution is often the starting point for many other types of power system analyses such as stability analysis and contingency analysis, In addition, power flow analysis is at the heart of contingency analysis and the implementation of real-time monitoring systems [1].

2.2 Power Flow Solution

A power flow study (load-flow study) is a steady-state analysis whose target is to determine the voltages, currents, and real and reactive power flows in a system under a given load conditions.

To solve the power flow problem the buses in the system classified into three type depend on the physical aspect of the system and the specified quantities in the bus, transmission line is presented using pi model and the system is model using admittance matrix [2]..

2.2.1 Types of buses

Slack Bus: The slack bus for the system is a single bus for which the voltage magnitude and angle are specified, the real and reactive power are unknowns. The bus selected as the slack bus must have a source of both real and reactive power, since the injected power at this bus must “swing” to take up the “slack” in the solution [2].

The best choice for the slack bus (since, in most power systems, many buses have real and reactive power sources) requires experience with the particular system under study but generally is chosen as largest generation in the system. The behavior of the solution is often influenced by the bus chosen.

Load Bus (P-Q Bus): A load bus is defined as any bus of the system for which the real and reactive power are specified. Load buses may contain generators with specified real and reactive power outputs; however, it is often convenient to designate any bus with specified injected complex power as a load bus [2].

Voltage Controlled Bus (P-V Bus): Any bus for which the voltage magnitude and the injected real power are specified is classified as a voltage controlled (or P-V) bus.

The injected reactive power is a variable (with specified upper and lower bounds) in the power flow analysis [2].

A P-V bus must have a variable source of reactive power such as a generator.

Type of Bus	Known Quantities	Quantities to be specified
Slack bus	$ V , \delta$	P, Q
Generator bus	P, $ V $	Q, δ
Load bus	P, Q	$ V , \delta$

Table 2.1: Bus Classification

2.2.2 Admittance matrix construction

The first step in developing the mathematical model describing the power flow in the network is the formulation of the bus admittance matrix.

The bus admittance matrix is an $n \times n$ matrix (where n is the number of buses in the system) constructed from the admittances of the equivalent circuit elements of the segments making up the power system.

Most system segments are represented by a combination of shunt elements (connected between a bus and the reference node) and series elements (connected between two system buses).

The formulation of the bus admittance matrix follows four simple rules:

1. The admittance of elements connected between node k and reference is added to the (k, k) entry of the admittance matrix.
2. The admittance of elements connected between nodes i and k is added to the (i, i) and (k, k) entries of the admittance matrix.
3. The negative of the admittance is added to the (i, k) and (k, i) entries of the admittance matrix.
- 4- If there is no connection between node i and node j so the Y_{ik} is equal to zero [4].

These four rules can be represented in the form of the equation as follow:

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1n} \\ Y_{21} & Y_{22} & \cdots & Y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{n1} & Y_{n2} & \cdots & Y_{nn} \end{bmatrix}$$

Where the diagonal elements of matrix (self-admittance) can be determined as:

$$Y_{ii} = \sum_{k=0}^n y_{ik} \quad , \quad k \neq i \quad (2.1)$$

The off-diagonal elements of matrix (transfer admittance) can be determined as:

$$Y_{ik} = Y_{ki} = -y_{ik} \quad (2.2)$$

Where:

$$y_{ik} = \frac{1}{Z_{ik}} \quad (2.3)$$

Consider this simple example (4-bus system):

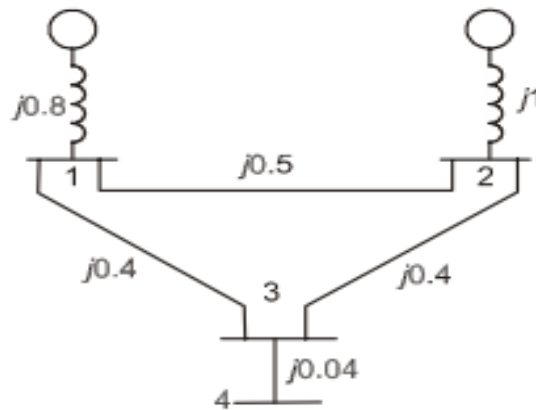


Figure 2.1: 4-bus system impedance diagram

First convert all impedances to the admittance by using the equation (2.3)

We get the bellow equivalent circuit of admittance:

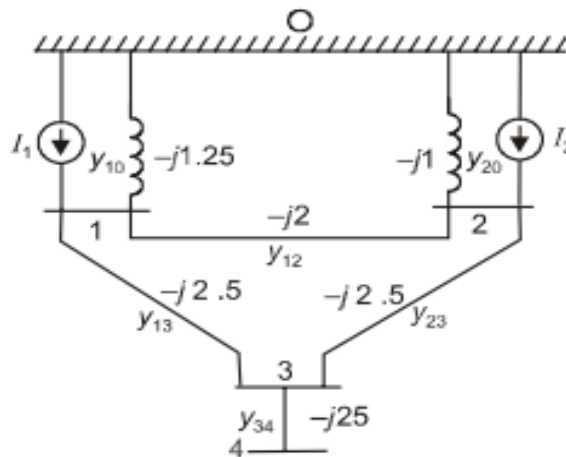


Figure 2.2: 4-bus system admittance diagram

The diagonal elements of the matrix are given by:

$$Y_{11} = y_{10} + y_{12} + y_{13} + y_{14} = -j1.25 - j2 - j2.5 + 0 = -j5.75$$

$$Y_{22} = y_{20} + y_{21} + y_{23} + y_{24} = -j1 - j2 - j2.5 + 0 = -j5.5$$

$$Y_{33} = y_{30} + y_{31} + y_{32} + y_{34} = 0 - j2.5 - j2.5 - j25 = -j30$$

$$Y_{44} = y_{40} + y_{41} + y_{42} + y_{43} = 0 + 0 + 0 - j2.5 = -j2.5$$

The off-diagonal elements of the matrix are given by:

$$Y_{12} = Y_{21} = -y_{12} = j2$$

$$Y_{13} = Y_{31} = -y_{13} = j2.5$$

$$Y_{14} = Y_{41} = -y_{14} = 0$$

$$Y_{24} = Y_{42} = -y_{24} = 0$$

$$Y_{32} = Y_{23} = -y_{32} = j2.5$$

$$Y_{34} = Y_{43} = -y_{34} = j25$$

So the overall matrix is:

$$Y_{bus} = \begin{bmatrix} -j5.75 & j2 & j2.5 & 0 \\ j2 & -j5.5 & j2.5 & 0 \\ j2.5 & j2.5 & -j30 & j25 \\ 0 & 0 & j25 & -j2.5 \end{bmatrix}$$

2.3 Static Load Flow Equation (SLFE)

The basic equation for power-flow analysis is derived from the nodal analysis equations for the power system [1].

Considering the 4-bus system:

$$\begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}$$

Where:

$[Y]$: is the elements of the bus admittance matrix.

$[V]$: is the bus voltages matrix.

$[I]$: is the currents injected at each node.

The current at node at bus (i) can be written as:

$$I_i = \sum_{j=1}^n Y_{ij} V_j \quad (2.4)$$

Relationship between per-unit real and reactive power supplied to the system at bus i and the per-unit current injected into the system at that bus:

$$S_i = V_i I_i^* = P_i + jQ_i$$

Where:

V_i : is the per-unit voltage at the bus.

I_i^* : is complex conjugate of the per-unit current injected at the bus.

P_i and Q_i : are per-unit real and reactive powers.

Therefore

$$I_i^* = \frac{(P_i + jQ_i)}{V_i} \implies I_i = \frac{(P_i - jQ_i)}{V_i^*} \quad (2.5)$$

$$P_i - jQ_i = V_i^* I_i \implies P_i - jQ_i = V_i^* \sum_{j=1}^n Y_{ij} V_j = \sum_{i=1}^n Y_{ij} V_i^* V_j \quad (2.6)$$

Let:

$$Y_{ij} = |Y_{ij}| \angle \theta_{ij} \quad V_i = |V_i| \angle \delta_i \quad V_j = |V_j| \angle \delta_j$$

Then

$$\therefore P_i - jQ_i = \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| \angle (\theta_{ij} - \delta_i + \delta_j) \quad (2.7)$$

$$\therefore P_i - jQ_i = \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| [\cos(\theta_{ij} - \delta_i + \delta_j) + j \sin(\theta_{ij} - \delta_i + \delta_j)] \quad (2.8)$$

$$\therefore P_i = \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| \cos(\theta_{ij} - \delta_i + \delta_j) \quad (2.9)$$

$$\therefore Q_i = - \sum_{j=1}^n |Y_{ij}| |V_i| |V_j| \sin(\theta_{ij} - \delta_i + \delta_j) \quad (2.10)$$

2.4 Numerical Solution of Power Flow

There are four quantities of interest associated with each bus: real power, reactive power, voltage magnitude, and voltage angle at every bus of the

system, two of these four quantities will be specified and the remaining two will be unknowns.

So there are only two equations and four variables in power flow solution so that can't be solve analytically but the solution can be done by using numerical iterative method for nonlinear equation, the most iterative method of numerical solution used for power flow solution are:

- Gauss Method.
- Gauss-Seidel Method.
- Newton-Raphson (NR) Method.
- Decoupled Newton Methods.
- Fast Decoupled Load Flow (FDLF).

2.4.1 Gauss method

This is an iterative method used in the calculation of power flow analysis. This method was named after the German mathematician Carl Friedrich Gauss and Philipp Ludwig von Seidel. It is also known as Liebmann method or the method of successive displacement. In this method an initial value of voltage is guessed and a new value for the voltage is calculated for each bus. In this method the new voltage value obtained at the other bus cannot be used for the calculation of voltage at another bus until the iteration is completed. This disadvantage is one of the disadvantages of Gauss method [5].

2.4.2 Gauss-Seidel method

This method is based on the Gauss method. In this method an initial value of voltage is guessed and the newly calculated value replaces the initial value and the iteration is stopped when the solution converges. But later this method was limited for only small problems because of the complexity in the calculations.

2.4.3 Newton-Raphson method

This is the most effective iterative method used in the present day power flow analysis. It was named after Isaac Newton and Joseph Raphson. In this method the convergence is reliable and guaranteed. If the assumed value is near the solution then the result is obtained very quickly, but if the assumed value is

farther away from the solution then the method may take longer to converge [5].

2.4.4 Fast Decoupled Power Flow method

The Fast Decoupled Power Flow Method (FDPFM) is one of the improved methods, which is based on a simplification of the Newton-Raphson method. This method, like the Newton-Raphson method, offers calculation simplifications, fast convergence and reliable results and became a widely used method in load flow analysis. However, FDPFM for some cases, where high resistance-to-reactance(R/X) ratios or heavy loading (low voltage) at some buses are present, does not converge well. For these cases, many efforts and developments have been made to overcome these convergence obstacles. Some of them targeted the convergence of systems with high R/X ratios, and others with low voltage buses. The FDPFM method has the disadvantage of not yielding the accurate solution.

2.5 Importance of load flow study

- Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.
- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines.
- It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances.
- System transmission loss minimizes.
- Economic system operation with respect to fuel cost to generate all the power needed
- The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.
- Load flow study is the first point to many other studies in a power system such as contingency analysis, stability analysis and state estimation of power system [5].

CHAPTER THREE

ETAP

3.1 Introduction

ETAP “Electrical Transient Analysis Program” is a fully graphical Enterprise package that runs on Microsoft Windows operating systems. So that users must be proficient in using basic operations of Windows® environment.

ETAP has been designed and developed to handle the diverse discipline of power systems for a broad spectrum of industries in one integrated package with multiple interface views such as AC and DC networks, cable raceways, ground grid, GIS, panels, arc flash, protective device coordination/selectivity, and AC and DC control system diagrams.

ETAP is the most comprehensive analysis tool for the design and testing of power systems available. Using its standard offline simulation modules, ETAP can utilize real-time operating data for advanced monitoring, real-time simulation, optimization, energy management systems, and high-speed intelligent load shedding [6].

ETAP allows you to easily create and edit graphical one-line diagrams (OLD), underground cable raceway systems (UGS), three-dimensional cable systems, advanced time-current coordination and selectivity plots, geographic information system schematics (GIS), as well as three-dimensional ground grid systems (GGS). The program has been designed to incorporate to three key concepts:

❖ Virtual Reality Operation

The program operation emulates real electrical system operation as closely as possible. For example, when you open or close a circuit breaker, place an element out of service, or change the operating status of motors, the de-energized elements and sub-systems are indicated on the one-line diagram

in gray. ETAP incorporates innovative concepts for determining protective device coordination directly from the one-line diagram.

❖ **Total Integration of Data**

ETAP combines the electrical, logical, mechanical, and physical attributes of system elements in the same database. For example, a cable not only contains data representing its electrical properties and physical dimensions, but also information indicating the raceways through which it is routed. Thus, the data for a single cable can be used for load flow or short-circuit analyses (which require electrical parameters and connections) as well as cable ampacity derating calculations (which require physical routing data). This integration of the data provides consistency throughout the system and eliminates the need for multiple data entry for the same element, which can be a considerable time savings.

❖ **Simplicity in Data Entry**

ETAP keeps track of the detailed data for each electrical apparatus. Data editors can speed up the data entry process by requiring the minimum data for a particular study. In order to achieve this, we have structured the property editors in the most logical manner for entering data for different types of analysis or design.

ETAP's one-line diagram supports a number of features to assist you in constructing networks of varying complexities. For example, each element can have individually varying orientations, sizes, and display symbols (IEC or ANSI). The one-line diagram also allows you to place multiple protective devices between a circuit branch and a bus.

ETAP provides you with a variety of options for presenting or viewing your electrical system. These views are called presentations. The location, size, orientation, and symbol of each element can be shown differently in each

presentation. Additionally, protective devices and relays can be displayed (visible) or hidden (invisible) for any particular presentation. For example, one presentation can be a relay view where all protective devices are displayed. Another presentation may show a one-line diagram with some circuit breakers shown and the rest hidden (a layout best suited for load flow results).

ETAP is considered to be the foremost-integrated database for electrical systems, allowing you to have multiple presentations of a system for different analysis or design purposes.

3.2 Overview

ETAP is the most comprehensive solution for the design, simulation, and analysis of generation, transmission, distribution, and industrial power systems.

ETAP organizes your work on a project basis. Each project that you create provides all the necessary tools and support for modeling and analyzing an electrical power system. A project consists of an electrical system that requires a unique set of electrical components and interconnections. In ETAP, each project provides a set of users, user access controls, and a separate database in which its elements and connectivity data are stored.

All interface views are completely graphical and the engineering properties of each circuit element can be edited directly from these views. Calculation results are displayed on the interface views for your convenience.

The Figure 3.1 shows the ETAP user interface in windows operating system.

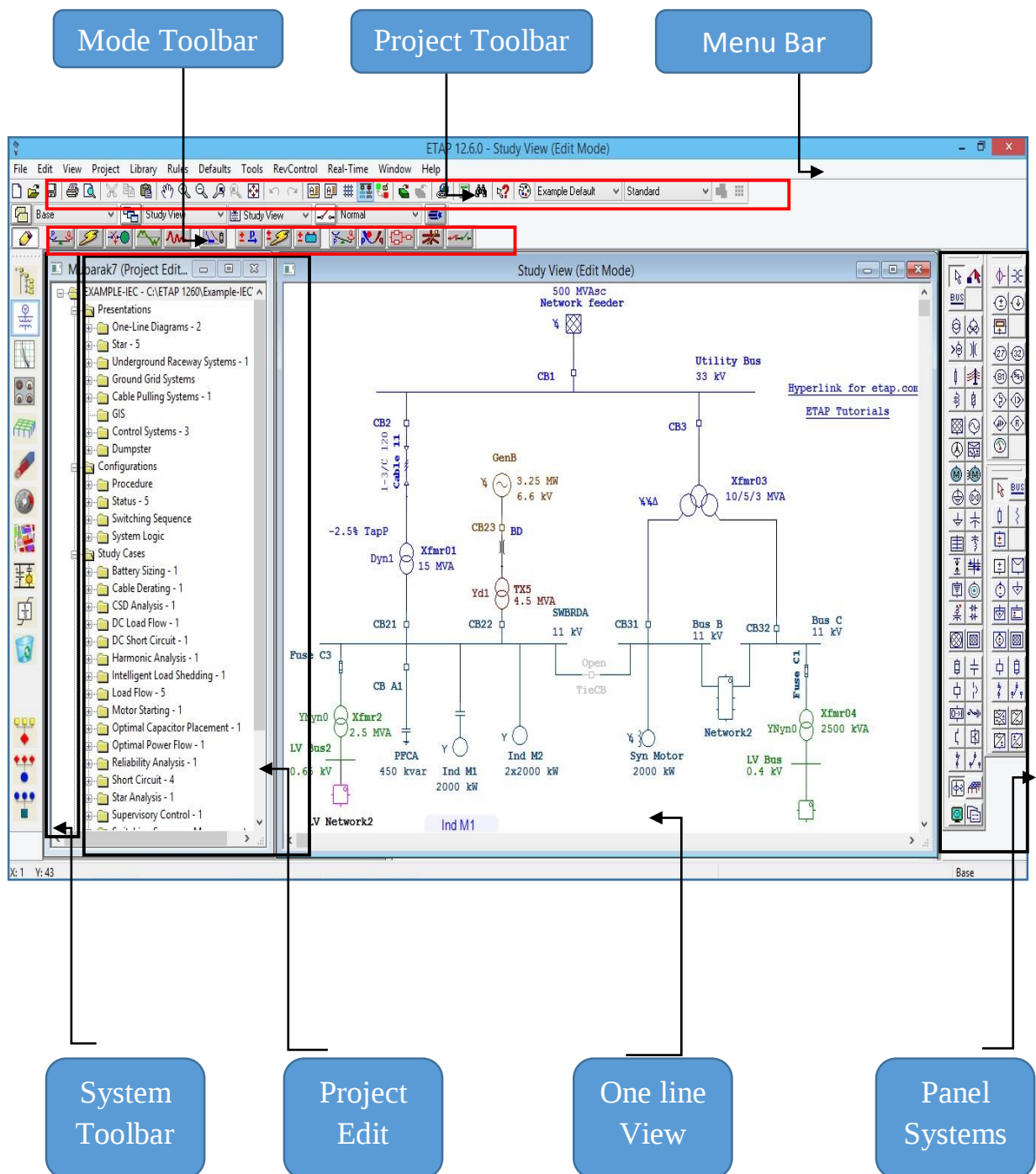
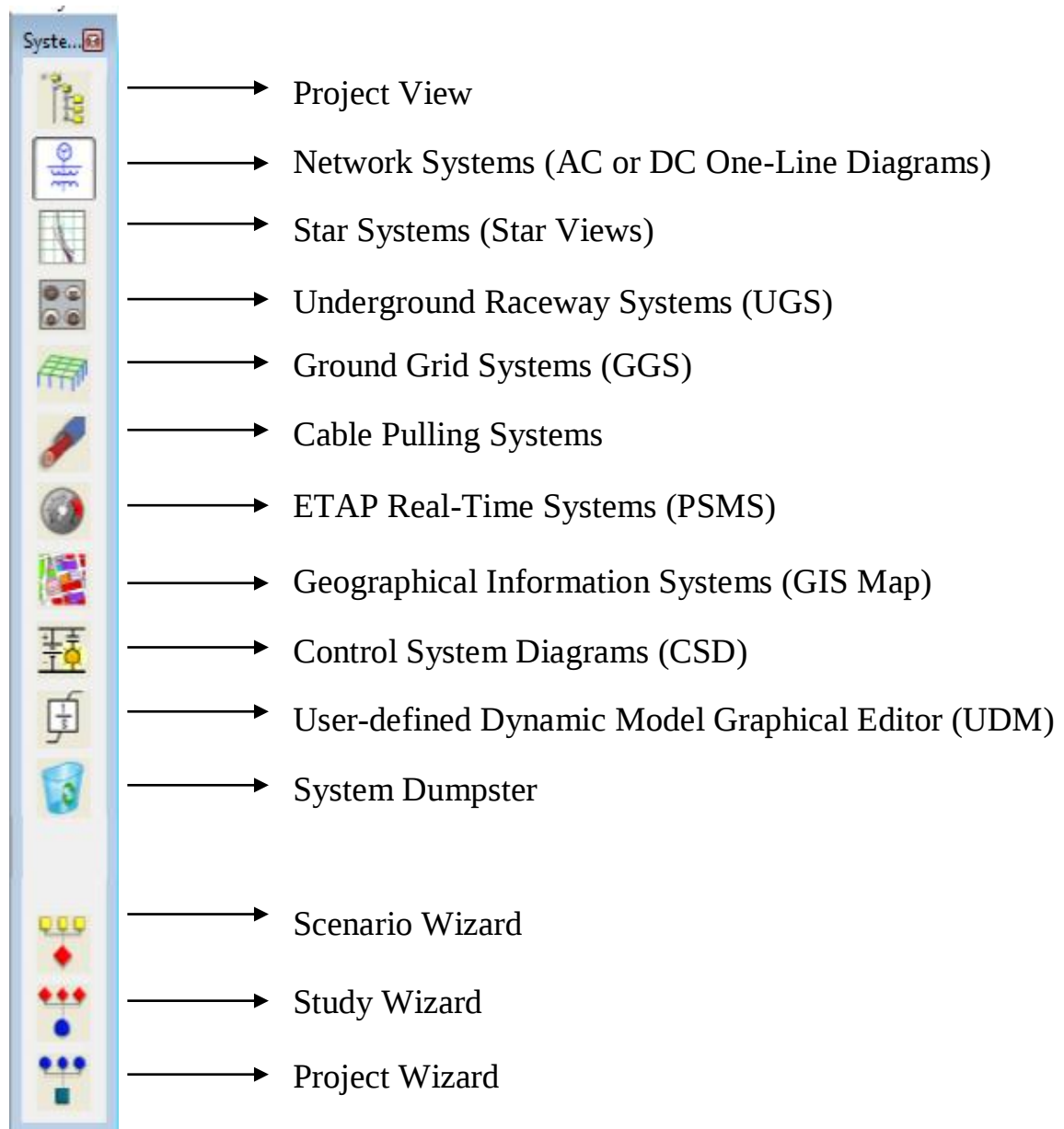


Figure 3.1: ETAP User Interface

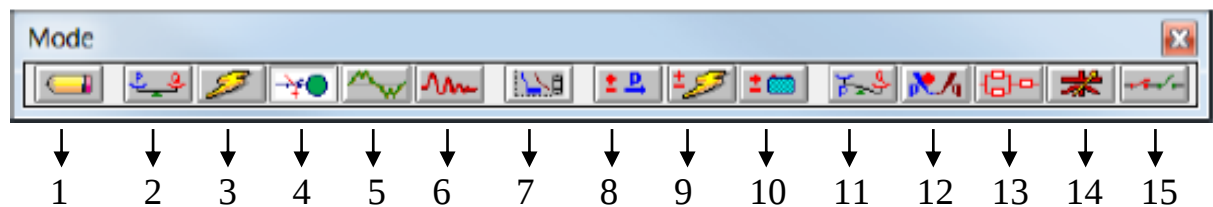
3.2.1 System Toolbar



3.2.2 Mode Toolbar

When you click the One-Line Diagram (Network Systems) button on the System toolbar, the Mode toolbar becomes available that contains all the study modules related to the one-line diagram.

In general, ETAP has three modes of operation under Network Systems; Edit, AC Study, and DC Study. The AC Study mode consists of analyses such as Load Flow, Short-Circuit, Motor Acceleration, Transient Stability, and Protective Device Coordination.



1. Edit Mode
2. Load Flow
3. Short Circuit
4. Motor Starting
5. Harmonics
6. Transient Stability
7. Protective Device Coordination
8. DC Load Flow
9. DC Short-Circuit
10. Battery
11. Unbalanced Load Flow
12. Optimal Power Flow
13. Reliability Assessment
14. Optimal Capacitor Placement
15. Switching Sequence Management

3.3 Creating Project

To create a new project choice file from main menu and then clicking to new project then enter project name, unit system, and access level permission including password if it's important.

The program will show a plain one line view “OLV” in an Edit Mode. An Edit Mode enables you to build your one-line diagram, change system connections, edit engineering properties, save your project, and generate schedule reports in Crystal Reports formats. You can select this mode by clicking the Edit button (graphically represented by a pencil). The Edit toolbars for AC Elements, DC Elements, and Instrumentation Elements will be displayed to the right side of the ETAP window [6].

This mode provides access to editing features that include:

- Dragging and Dropping Elements
- Connecting Elements
- Changing IDs
- Cutting, Copying, and Pasting Elements
- Moving Items from System Dumpster
- Inserting OLE Objects
- Cutting, Copying, and Pasting OLE Objects
- Merging Two ETAP Projects
- Hiding/Showing Groups of Protective Devices
- Rotating Elements
- Sizing Elements
- Changing Symbols
- Editing Properties
- Running Schedule Report Manage

3.4 Study Mode

Study Modes enable you to create and modify study cases, perform system analysis, view alarm/alert conditions, and view output reports and plots. When a Study Mode is active (selected), the toolbar for the selected study is displayed on the right side of the ETAP window. By clicking the buttons on the Study toolbar, you can run studies, transfer data, and change display options. The available Study Modes are shown in the figure below [6].

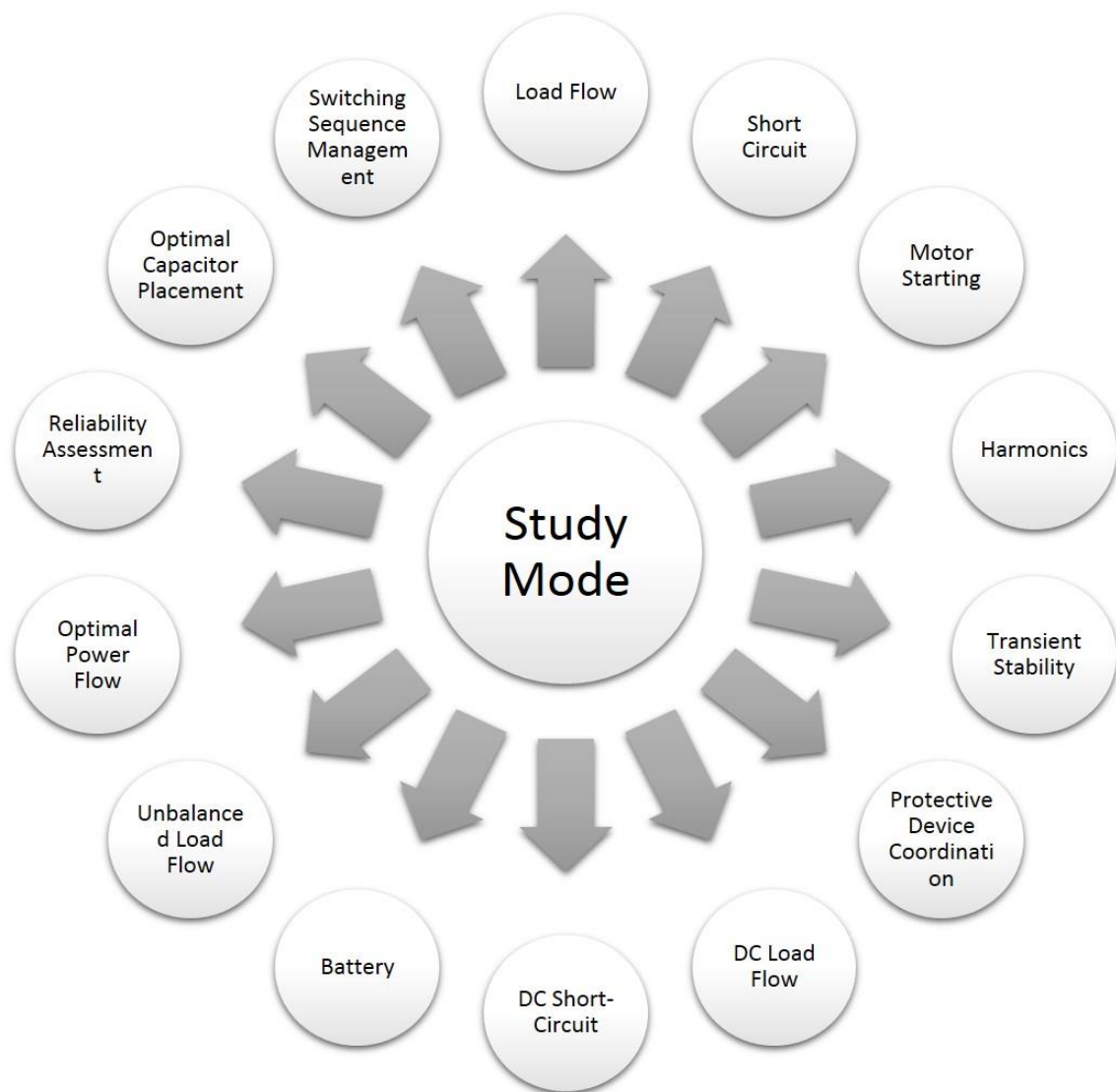


Figure 3.2 ETAP Study Mode

3.5 Working in Load Flow Mode

To work in load flow mode after creating the project, follow these instructions:

1. Go to Load Flow Mode by clicking the Load Flow Analysis button on the Mode toolbar. The Load Flow toolbar is now displayed on the right side of ETAP. Also, the top toolbar becomes the Study Case toolbar.



2. Click the Run Load Flow button on the Load Flow toolbar. The study results will be displayed on the one-line diagram.
3. Review the calculation results and familiarize yourself with the type of information displayed on your one-line diagram.
4. Click the Display Options button and explore the variety of options available for the displayed results.
5. Click the Alert button to display critical and marginal limit violations for the selected output report.
6. Click the Report Manager Button to view or print any part of the output report.
7. Click the Edit Study Case button on the Study Case toolbar and study the solution parameters and alert settings available for load flow analysis.

3.6 ETAP Capability

ETAP has many capabilities which make it the most comprehensive enterprise solution for design, simulation, operation, control, optimization, and automation of generation, transmission, distribution, and industrial power systems. These capabilities can be illustrated below:

- ❖ Network Analysis
- ❖ Real Time System
- ❖ Device Coordination & Selectivity
- ❖ Advanced Relay Testing & Transient Simulator
- ❖ Panel Systems
- ❖ Ground Grids System
- ❖ User Defined Dynamics Models
- ❖ Underground Raceway System
- ❖ Cable Pulling
- ❖ Control Systems
- ❖ Data Exchange
- ❖ GIS Maps

CHAPTER FOUR

REAL CASE STUDY

4.1 Introduction

The Sudanese electric power transmission network, operated by the Sudanese Electricity Transmission Co Ltd (SETCO), operates at high tension of 500 kv where the lower transmission voltage is 110 kv , the grid as integrated network consisting of (500/220 kv and 220/110 kv).

In this chapter executed analysis for Sudanese network at two loops, Loop one includes the following buses (Merowe, Atbara, Garry, Eid Babiker, Kilo 10, Alroseires, Rabak, Almarkhiyat, and Merowe). Loop two include (Merowe, Atbara, Alkabashi, Eid Babiker, Kilo 10, Alroseires, Rabak, Almarkhiyat, and Merowe). The reference bus for two loops is Merowe power station (slack bus).

ETAP is used for analysis of this network as shown in figure (4.1). The ETAP obtain the Voltage magnitude, voltage angle, active and reactive power at any bus, and also active and reactive power and losses in transmission lines.

4.2 Case Study

The data used in this analysis is obtained from Sudanese Electricity Transmission Co Ltd (SETCO).

The grid which used in this case consist of Merowe power station, Merowe load, Atbara substation, Garry power station, Eid Babiker substation, Kilo 10 substation, Alroseires power station, Rabak power station, Almarkhiyat substation, Atbara substation is fed from Merowe by single line, and by double line from Alkabashi which fed from Merowe to Almarkhiat by double line, also Garry power station is connected to Atbara and Eid Babikir by double line , where Eid Babikir is connected to Alkabashi and kilo 10 by double line, finally Alrosaris and Rabak power stations are connected directly with Kilo 10 and Almarkhiyat substation by double line.

ETAP has many different solution methods, Newton- Raphson (NR) has been chosen, because it is most reliable and powerful technique for solving load flow problems at very accurate solution, fast in convergence, independent size of system and not effected by choosing of slack bus.

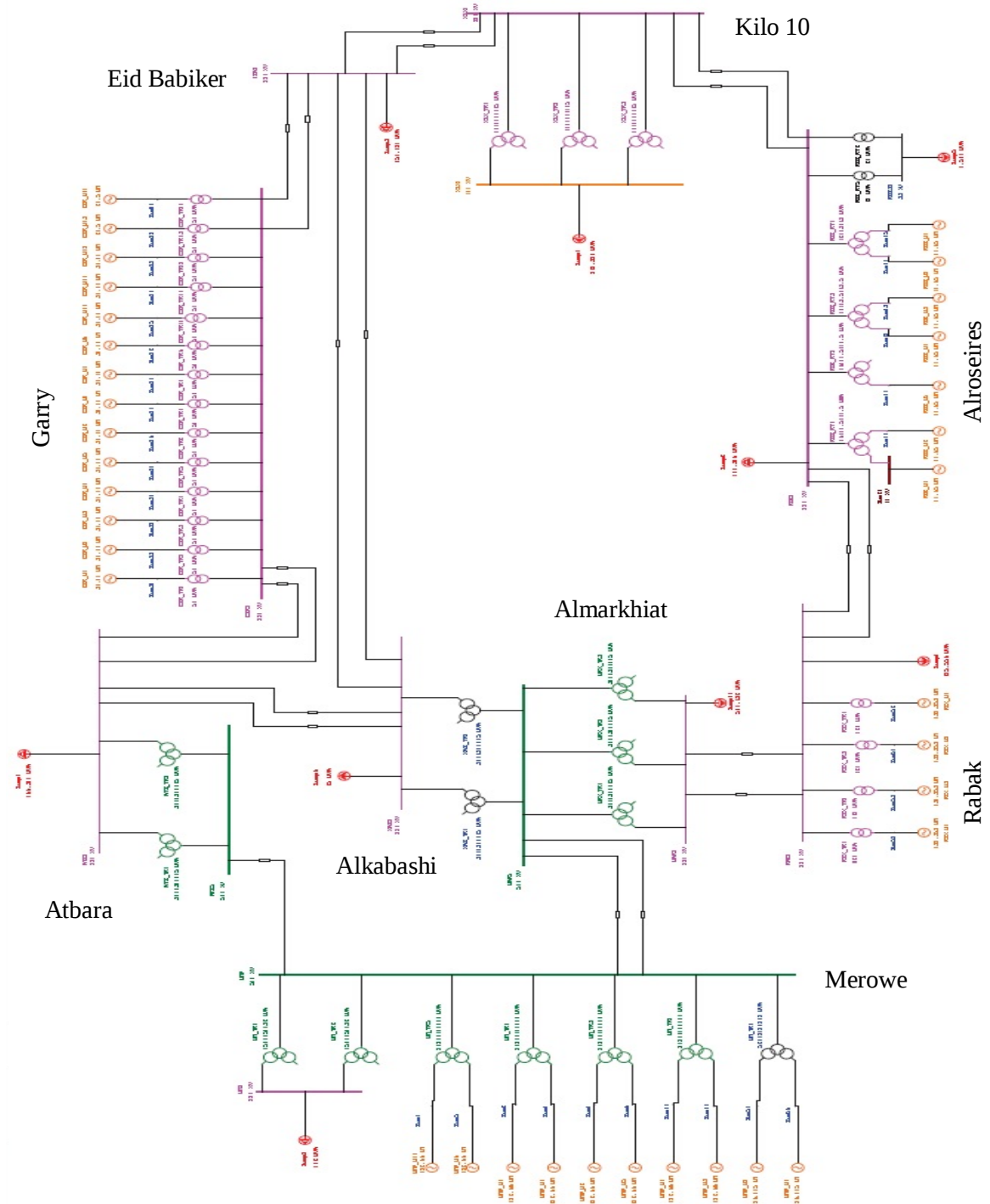


Figure 4.1: power system case study diagram

4.2.1 Case one: system at normal operation

In this case the system is simulated at normal operation as shown in Figure (4.2).

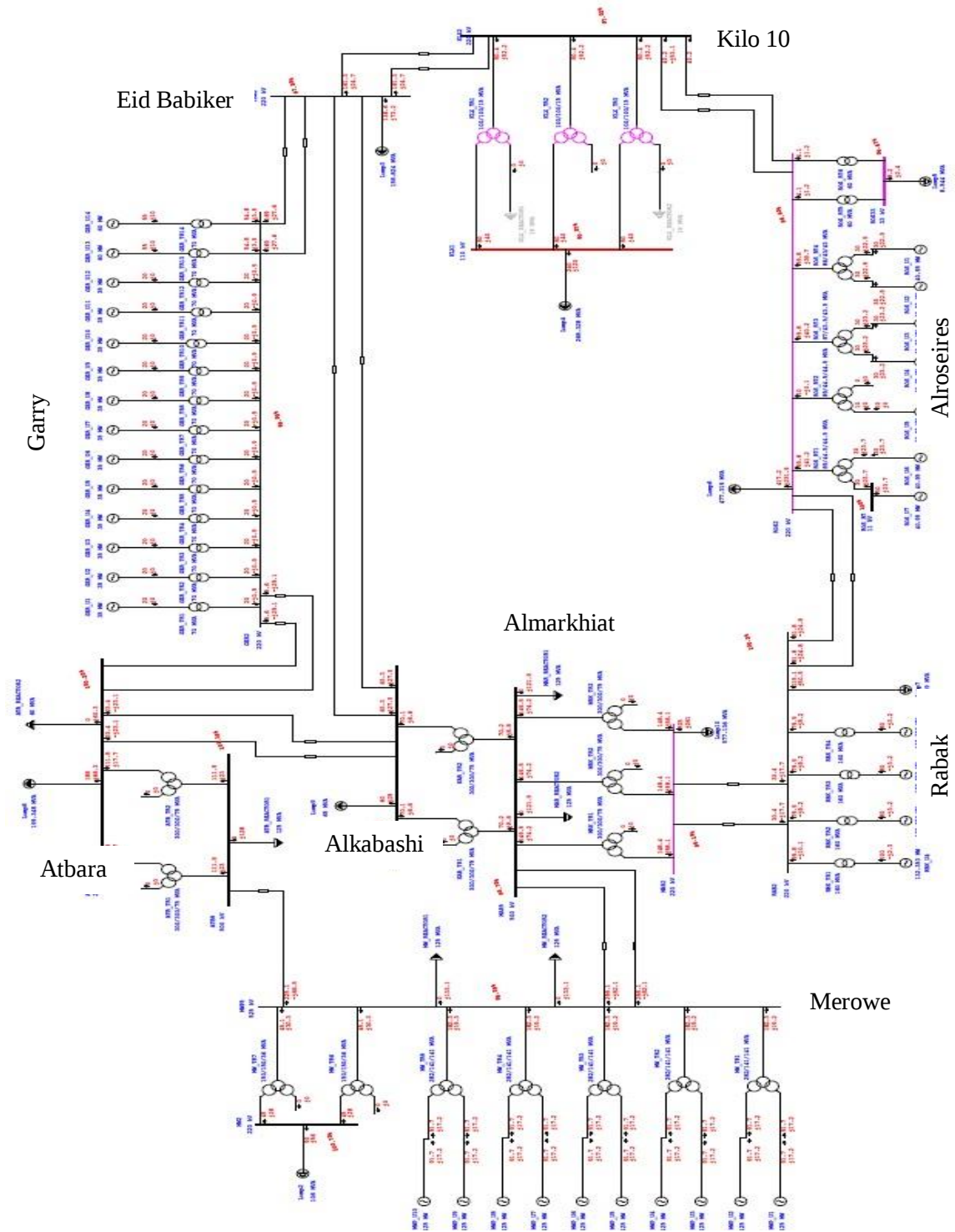


Figure 4.2: System at normal operation

Table 4.1: Bus result at normal operation

Bus ID	Nominal kV	Type	Voltage (%)	Angle (degree)	MW Loading	Mvar Loading
ATB2	220	Load	100.25	-10.36	234.712	126.597
ATB5	500	Load	101.18	-7.73	223.784	174.02
GER2	220	Load	99.95	-9.81	349.214	65.367
GER_B1	10.5	Gen.	100	-7.36	20	0.003
GER_B2	10.5	Gen.	100	-7.36	20	0.003
GER_B3	10.5	Gen.	100	-7.36	20	0.003
GER_B4	10.5	Gen.	100	-7.36	20	0.003
GER_B5	10.5	Gen.	100	-7.36	20	0.003
GER_B6	10.5	Gen.	100	-7.36	20	0.003
GER_B7	10.5	Gen.	100	-7.36	20	0.003
GER_B8	11	Gen.	100	-7.36	20	0.003
GER_B9	11	Gen.	100	-7.36	20	0.003
GER_B10	11	Gen.	100	-7.36	20	0.003
GER_B11	11	Gen.	100	-7.36	20	0.003
GER_B12	11	Gen.	100	-7.36	20	0.003
GER_B13	11	Load	101.78	-3.21	55	10
GER_B14	11	Load	101.78	-3.21	55	10
IBA2	220	Load	97.55	-13.05	459.202	122.681
KAB2	220	Load	98.34	-12.48	186.52	79.969
KLX1	110	Load	90.57	-20.23	240	120
KLX2	220	Load	97.02	-13.73	321.503	156.556
MAR2	220	Load	96.19	-15.79	505.034	261.038
MAR5	500	Load	98.75	-10.76	588.946	484.071
MW2	220	Load	100.73	-6.63	90	56
MWP5	500	Load	98.29	-4.60	911.46	326.884
MWP_B1	13.8	SWNG	100	0.0	91.65	17.19
MWP_B2	13.8	SWNG	100	0.0	91.65	17.19
MWP_B3	13.8	SWNG	100	0.0	91.65	17.19
MWP_B4	13.8	SWNG	100	0.0	91.65	17.19
MWP_B5	13.8	SWNG	100	0.0	91.65	17.19
MWP_B6	13.8	SWNG	100	0.0	91.65	17.19
MWP_B7	13.8	SWNG	100	0.0	91.65	17.19
MWP_B8	13.8	SWNG	100	0.0	91.65	17.19
MWP_B9	13.8	SWNG	100	0.0	91.65	17.19
MWP_B10	13.8	SWNG	100	0.0	91.65	17.19
RAB2	220	Load	100.3	-12.80	339.456	85.112
RBK_B1	11	Gen.	100	-9.23	80	3.187
RBK_B2	11	Gen.	100	-9.23	80	3.187
RBK_B3	11	Gen.	100	-9.23	80	3.187
RBK_B4	11	Gen.	100	-8.33	100	2.258
ROS2	220	Load	96.93	-21.03	425.402	234.521
ROS33	33	Load	96.67	-21.49	8.2	2.4
ROS_B1	11	Gen.	100	-17.18	30	22.938
ROS_B2	11	Gen.	100	-17.18	30	22.938
ROS_B3	11	Gen.	100	-17.22	30	23.192
ROS_B4	11	Gen.	100	-17.22	30	23.192
ROS_B5	11	Load	96.96	-20.18	10	0
ROS_B6	11	Gen.	100	-17.31	30	23.7
ROS_B7	11	Gen.	100	-17.31	30	23.7

Table 4.2: Line flow and losses at normal operation

From	To	Line flow		Line Losses	
		MW	MVAR	KW	KVAR
MWP5	MAR5	294.473	242.036	3630	-324089
IBA2	KAB2	63.049	32.329	211	-4844
IBA2	KAB2	63.049	32.329	211	-4844
MWP5	MAR5	294.473	242.036	3630	-324089
ATB5	MWP5	223.784	174.02	1360	-240545
ATB2	KAB2	23.121	33.341	236	-56401
ATB2	KAB2	23.121	33.341	236	-56401
GER2	ATB2	5.586	-29.144	15.299	-51669
GER2	ATB2	5.586	-29.144	15.299	-51669
IBA2	GER2	169.021	27.561	2469	-1451
IBA2	GER2	169.021	27.561	2469	-1451
IBA2	KLX2	161.295	24.748	544	-392
IBA2	KLX2	161.295	24.748	544	-392
KLX2	ROS2	40.216	-53.138	1213	-87631
KLX2	ROS2	40.216	-53.138	1213	-87631
RAB2	ROS2	81.777	-24.814	2804	-47035
ROS2	RAB2	81.777	-24.814	2804	-47035
MAR2	RAB2	29.859	43.358	524	-61099
MAR2	RAB2	29.859	43.358	524	-61099

Comment on the results:

After executing the program the results as shown in Table 4.1 and Table 4.2 show that the value of voltage at bus (KLX10) is out of tolerance (critical under voltage) where the value of voltage at buses (MAR2,ROS_B5, ROS2, and ROS33) are marginally under voltage.

4.2.3 Case two: system with SVC

In this case the system is simulated with Static Var Compensator (SVC) as shown in Figure (4.3) to implement its effect in system.

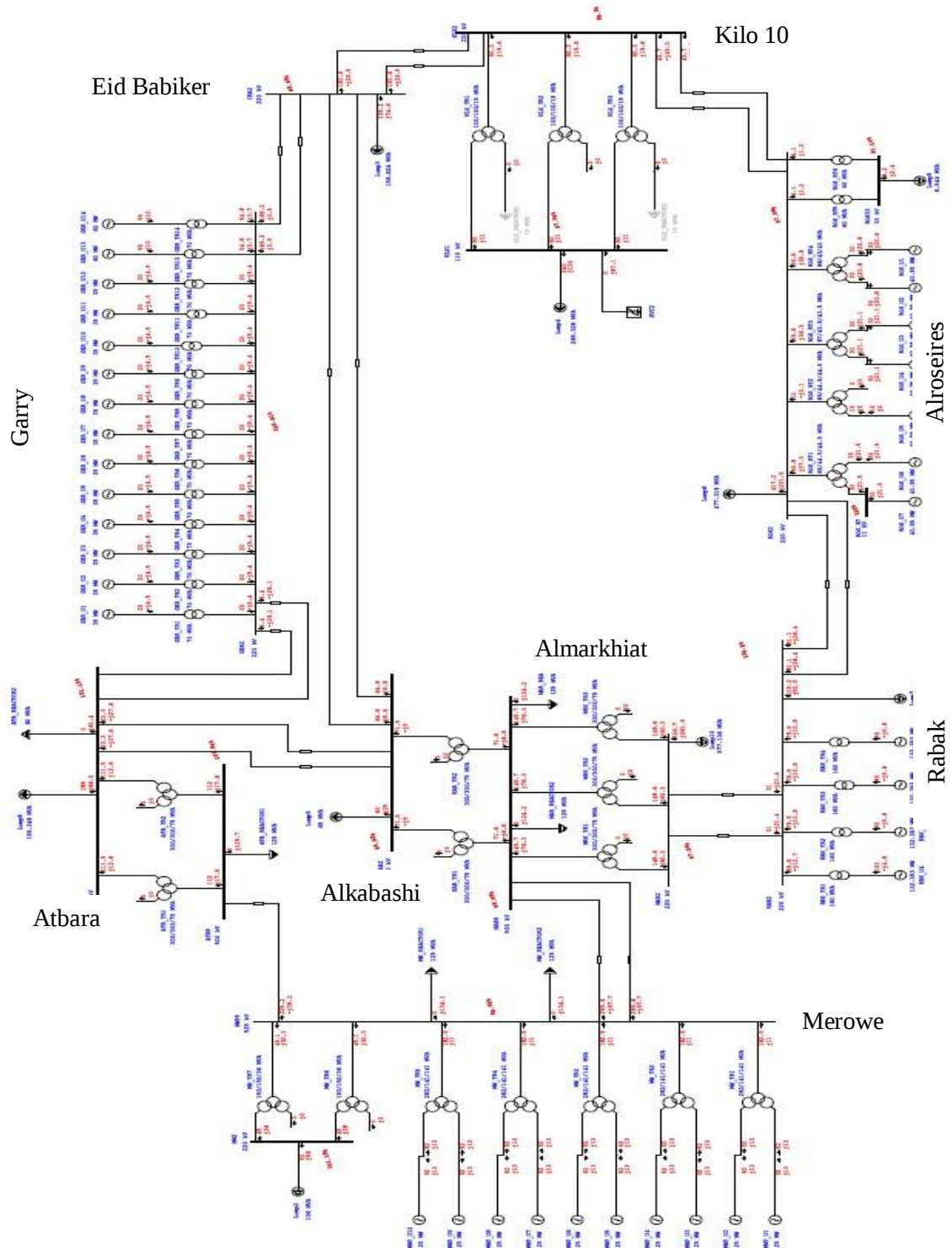


Figure 4.3: System with SVC

Table 4.3: Bus result of system with SVC

Bus ID	Nominal kV	Type	Voltage (%)	Angle (degree)	MW Loading	Mvar Loading
ATB2	220	Load	101.13	-10.32	234.558	127.661
ATB5	500	Load	101.84	-7.73	223.926	165.258
GER2	220	Load	100.91	-9.81	349.204	65.499
GER_B1	10.5	Gen.	100	-7.36	20	4.475
GER_B2	10.5	Gen.	100	-7.36	20	4.475
GER_B3	10.5	Gen.	100	-7.36	20	4.475
GER_B4	10.5	Gen.	100	-7.36	20	4.475
GER_B5	10.5	Gen.	100	-7.36	20	4.475
GER_B6	10.5	Gen.	100	-7.36	20	4.475
GER_B7	10.5	Gen.	100	-7.36	20	4.475
GER_B8	11	Gen.	100	-7.36	20	4.475
GER_B9	11	Gen.	100	-7.36	20	4.475
GER_B10	11	Gen.	100	-7.36	20	4.475
GER_B11	11	Gen.	100	-7.36	20	4.475
GER_B12	11	Gen.	100	-7.36	20	4.475
GER_B13	11	Load	102.73	-3.33	55	10
GER_B14	11	Load	102.73	-3.33	55	10
IBA2	220	Load	99.45	-13.08	462.467	74.591
KAB2	220	Load	99.92	-12.48	189.162	60.513
KLX1	110	Load	97.06	-19.78	240	120.01
KLX2	220	Load	99.3	-13.85	322.193	98.596
MAR2	220	Load	97.04	-15.69	506.728	261.914
MAR5	500	Load	99.68	-10.76	592.146	477.415
MW2	220	Load	101.13	-6.63	90	56
MWP5	500	Load	98.65	-4.61	914.57	328.828
MWP_B1	13.8	SWNG	100	0.0	91.957	13.012
MWP_B2	13.8	SWNG	100	0.0	91.957	13.012
MWP_B3	13.8	SWNG	100	0.0	91.957	13.012
MWP_B4	13.8	SWNG	100	0.0	91.957	13.012
MWP_B5	13.8	SWNG	100	0.0	91.957	13.012
MWP_B6	13.8	SWNG	100	0.0	91.957	13.012
MWP_B7	13.8	SWNG	100	0.0	91.957	13.012
MWP_B8	13.8	SWNG	100	0.0	91.957	13.012
MWP_B9	13.8	SWNG	100	0.0	91.957	13.012
MWP_B10	13.8	SWNG	100	0.0	91.957	13.012
RAB2	220	Load	100.5	-12.58	339.455	95.544
RBK_B1	11	Gen.	100	-9.01	80	5.767
RBK_B2	11	Gen.	100	-9.01	80	5.767
RBK_B3	11	Gen.	100	-9.01	80	5.767
RBK_B4	11	Gen.	100	-8.12	100	4.84
ROS2	220	Load	97.39	-20.72	425.402	234.519
ROS33	33	Load	97.14	-21.17	8.2	2.4
ROS_B1	11	Gen.	100	-16.88	30	20.829
ROS_B2	11	Gen.	100	-16.88	30	20.829
ROS_B3	11	Gen.	100	-16.92	30	21.058
ROS_B4	11	Gen.	100	-16.92	30	21.058
ROS_B5	11	Load	97.43	-19.88	10	0
ROS_B6	11	Gen.	100	-17.01	30	21.517
ROS_B7	11	Gen.	100	-17.01	30	21.517

Table 4.4: Line flow and losses of system with SVC

From	To	Line flow		Line Losses	
		MW	MVAR	KW	KVAR
MWP5	MAR5	296.073	231.924	3534	-329664
IBA2	KAB2	64.402	13.987	179	-5182
IBA2	KAB2	64.402	13.987	179	-5182
MWP5	MAR5	296.073	231.924	3534	-329664
ATB5	MWP5	223.926	165.258	1321	-243533
ATB2	KAB2	23.062	30.257	217	-57904
ATB2	KAB2	23.062	30.257	217	-57904
GER2	ATB2	5.432	-29.091	13.212	-52633
GER2	ATB2	5.432	-29.091	13.212	-52633
IBA2	GER2	169.17	0.5	2338	-2327
IBA2	GER2	169.17	0.5	2338	-2327
IBA2	KLX2	161.615	-20.481	519	-608
IBA2	KLX2	161.615	-20.481	519	-608
KLX2	ROS2	40.716	-49.298	1155	-90521
KLX2	ROS2	40.716	-49.298	1155	-90521
RAB2	ROS2	81.14	-26.376	2744	-47678
ROS2	RAB2	81.14	-26.376	2744	-47678
MAR2	RAB2	30.477	40.495	496	-61890
MAR2	RAB2	30.477	40.495	496	-61890

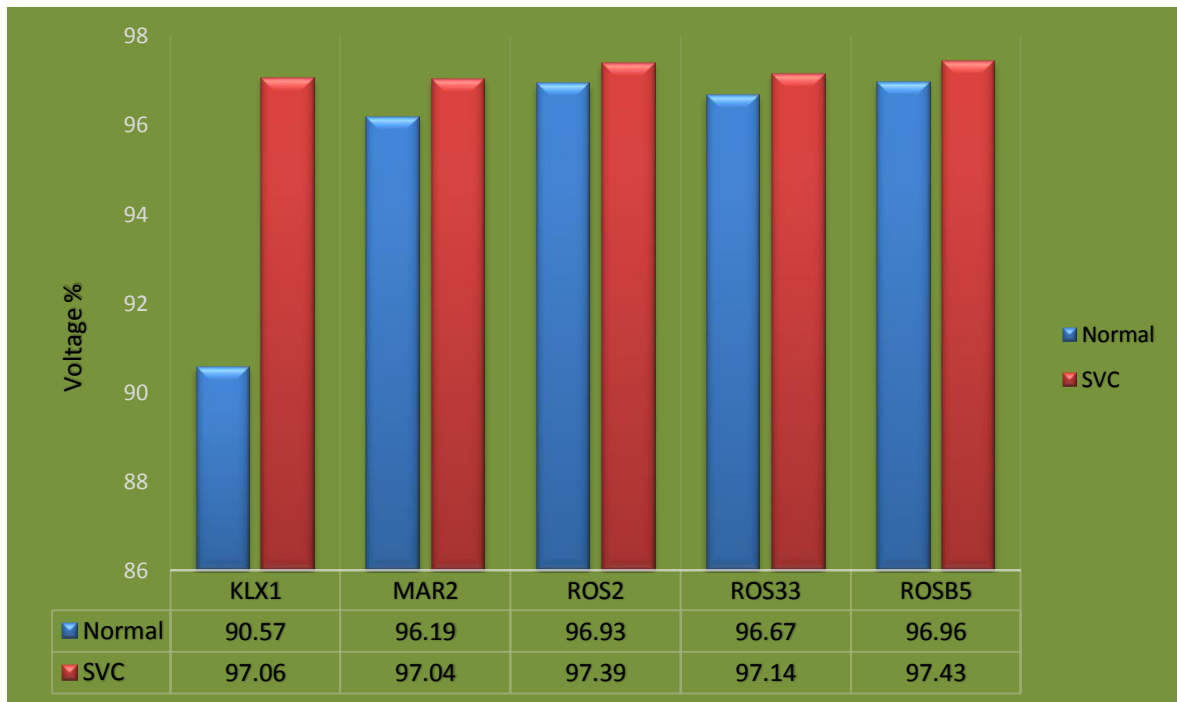


Figure 4.4: Comparison of bus voltages at normal operation & SVC cases

Comment on the results:

After executing the program the results as shown in Table 4.3 and Table 4.4 show that there are no buses voltage out of tolerance. So SVC compensated the reactive power as result is improving the bus voltage as refer to Figure (4.4).

4.2.4 Case three: system at one line open (Merowe – Atbara)

In this case the system is simulated with opening the line between (Merowe – Atbara) as contingency case as shown in Figure (4.5).

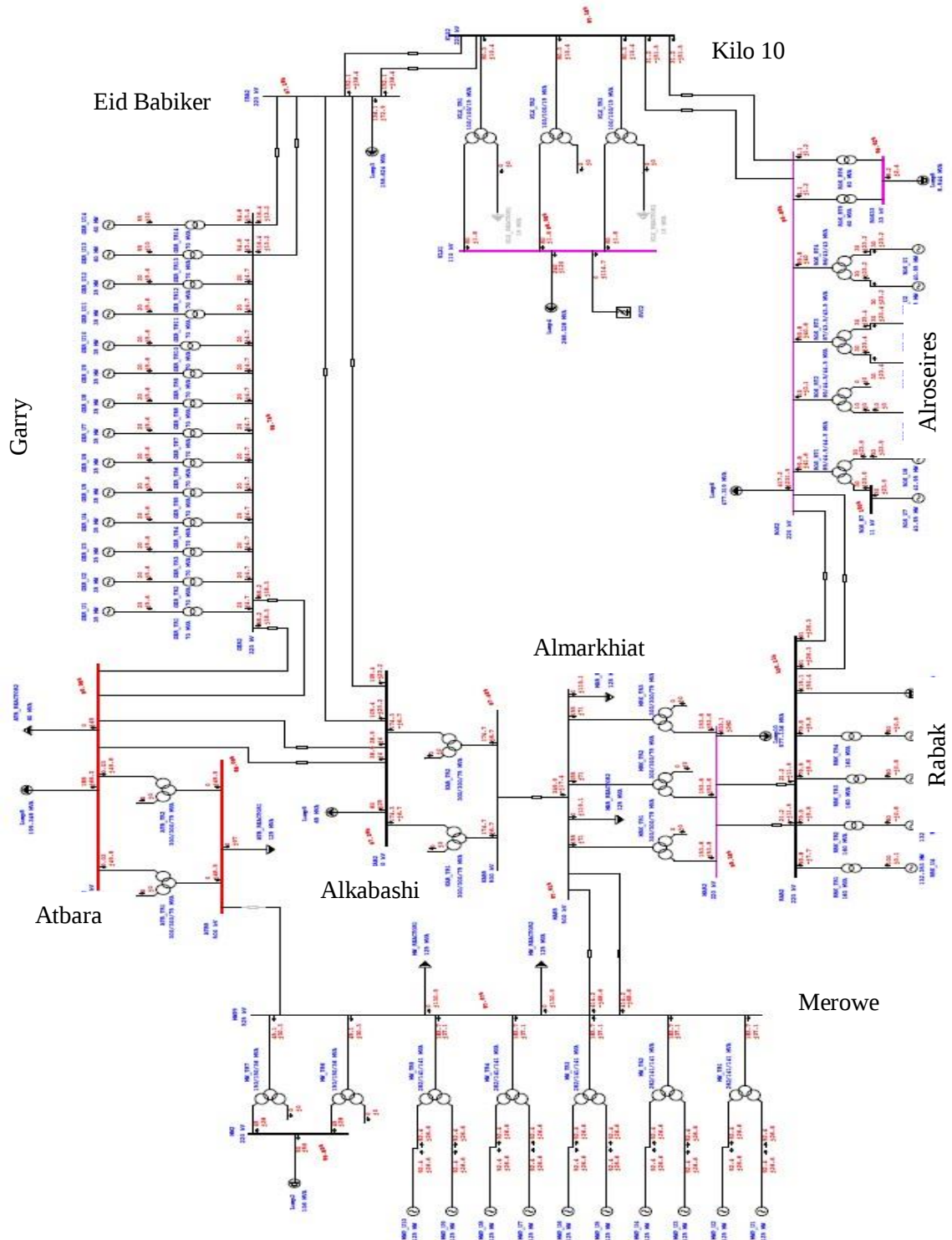


Figure 4.5: System at one line open

Table 4.5: Bus result at one line open

Bus ID	Nominal kV	Type	Voltage (%)	Angle (degree)	MW Loading	MVar Loading
ATB2	220	Load	90.38	-10.32	188.051	214.822
ATB5	500	Load	88.09	-7.73	0	96.987
GER2	220	Load	98.74	-9.81	349.176	63.005
GER_B1	10.5	Gen.	100	-7.36	20	5.61
GER_B2	10.5	Gen.	100	-7.36	20	5.61
GER_B3	10.5	Gen.	100	-7.36	20	5.61
GER_B4	10.5	Gen.	100	-7.36	20	5.61
GER_B5	10.5	Gen.	100	-7.36	20	5.61
GER_B6	10.5	Gen.	100	-7.36	20	5.61
GER_B7	10.5	Gen.	100	-7.36	20	5.61
GER_B8	11	Gen.	100	-7.36	20	5.61
GER_B9	11	Gen.	100	-7.36	20	5.61
GER_B10	11	Gen.	100	-7.36	20	5.61
GER_B11	11	Gen.	100	-7.36	20	5.61
GER_B12	11	Gen.	100	-7.36	20	5.61
GER_B13	11	Load	100.58	-3.33	55	10
GER_B14	11	Load	100.58	-3.33	55	10
IBA2	220	Load	97.18	-13.08	440.275	112.243
KAB2	220	Load	97.26	-12.48	348.575	46.416
KAB5	500	Load	97.48	0.0	349.361	13.394
KLX1	110	Load	96.08	-19.78	240	120.01
KLX2	220	Load	97.18	-13.85	303.162	102.939
MAR2	220	Load	95.18	-15.69	503.059	260.017
MAR5	500	Load	97.61	-10.76	814.765	451.263
MW2	220	Load	99.85	-6.63	90	56
MWP5	500	Load	97.47	-4.61	918.531	322.557
MWP_B1	13.8	SWNG	100	0.0	92.389	26.574
MWP_B2	13.8	SWNG	100	0.0	92.389	26.574
MWP_B3	13.8	SWNG	100	0.0	92.389	26.574
MWP_B4	13.8	SWNG	100	0.0	92.389	26.574
MWP_B5	13.8	SWNG	100	0.0	92.389	26.574
MWP_B6	13.8	SWNG	100	0.0	92.389	26.574
MWP_B7	13.8	SWNG	100	0.0	92.389	26.574
MWP_B8	13.8	SWNG	100	0.0	92.389	26.574
MWP_B9	13.8	SWNG	100	0.0	92.389	26.574
MWP_B10	13.8	SWNG	100	0.0	92.389	26.574
RAB2	220	Load	100.11	-12.58	339.457	75.571
RBK_B1	11	Gen.	100	-9.01	80	0.818
RBK_B2	11	Gen.	100	-9.01	80	0.818
RBK_B3	11	Gen.	100	-9.01	80	0.818
RBK_B4	11	Gen.	100	-8.12	100	0.112
ROS2	220	Load	96.88	-20.72	425.402	234.521
ROS33	33	Load	96.62	-21.17	8.2	2.4
ROS_B1	11	Gen.	100	-16.88	30	23.152
ROS_B2	11	Gen.	100	-16.88	30	23.152
ROS_B3	11	Gen.	100	-16.92	30	23.408
ROS_B4	11	Gen.	100	-16.92	30	23.408
ROS_B5	11	Load	96.91	-19.88	10	0
ROS_B6	11	Gen.	100	-17.01	30	23.921
ROS_B7	11	Gen.	100	-17.01	30	23.921

Table 4.6: Line flow and losses at one line open

From	To	Line flow		Line Losses	
		MW	MVAR	KW	KVAR
MWP5	MAR5	407.383	216.912	6827	-285526
IBA2	KAB2	105.434	-23.208	506	-3545
IBA2	KAB2	105.434	-23.208	506	-3545
MWP5	MAR5	407.383	216.912	6827	-285526
ATB5	MWP5	37.78	50.869	1074	-46859
ATB2	KAB2	37.78	50.869	1074	-46859
ATB2	KAB2	56.245	56.542	1948	-38235
GER2	ATB2	56.245	56.542	1948	-38235
GER2	ATB2	116.395	13.196	1185	-6555
IBA2	GER2	116.395	13.196	1185	-6555
IBA2	GER2	152.081	-36.371	500	-567
IBA2	KLX2	152.081	-36.371	500	-567
IBA2	KLX2	31.2	-51.469	726	-89740
KLX2	ROS2	31.2	-51.469	726	-89740
KLX2	ROS2	90.977	-26.28	3474	-44136
RAB2	ROS2	90.977	-26.28	3474	-44136
ROS2	RAB2	20.814	49.301	412	-60806
MAR2	RAB2	20.814	49.301	412	-60806
MAR2	RAB2	349.892	-17.439	531	-30833
KAB5	MAR5	407.383	216.912	6827	-285526

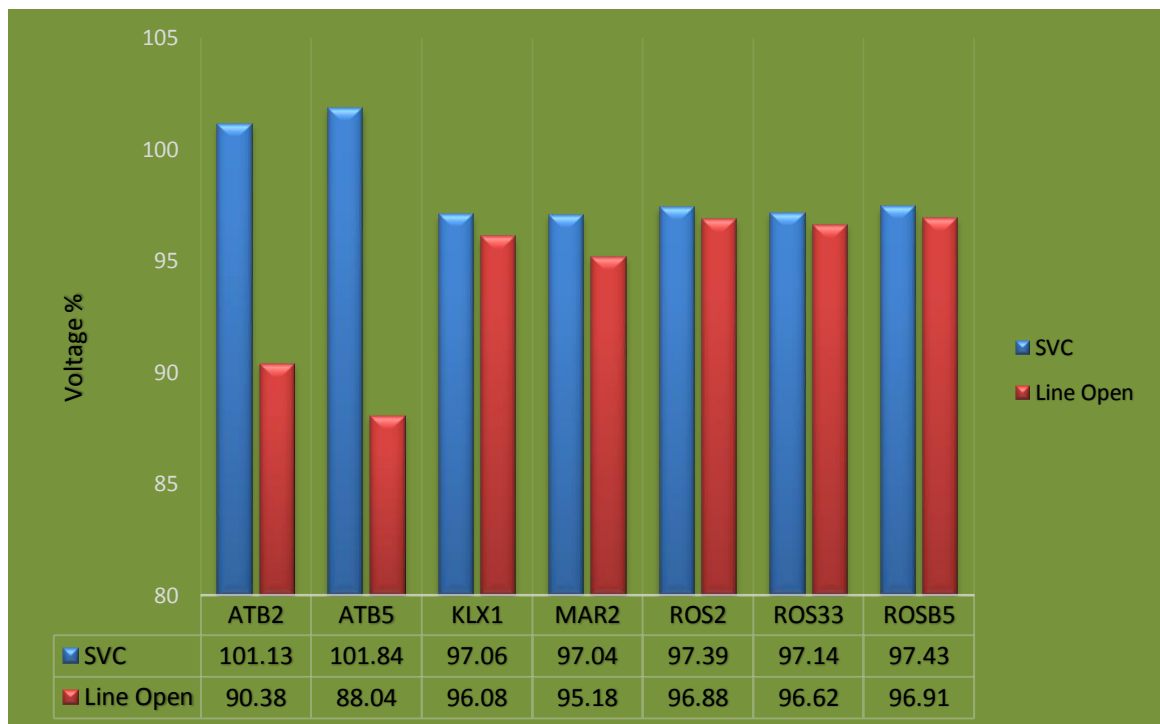


Figure 4.6: Comparison of bus voltages at SVC & one line open cases

Comment on the results:

After executing the program the results as shown in Table 4.5 and Table 4.6 show that the voltages level at Atbara buses are out of tolerance and voltage at buses (KLX1,MAR2,ROSB5, ROS2, and ROS33) are marginally under voltage referred to Figure (4.6).

4.2.4 Case four: system at new planning (200 MW)

In this case the capability of the system for new planning is checked by adding 200 MW load placed in Alkabashi as shown in Figure (4.7).

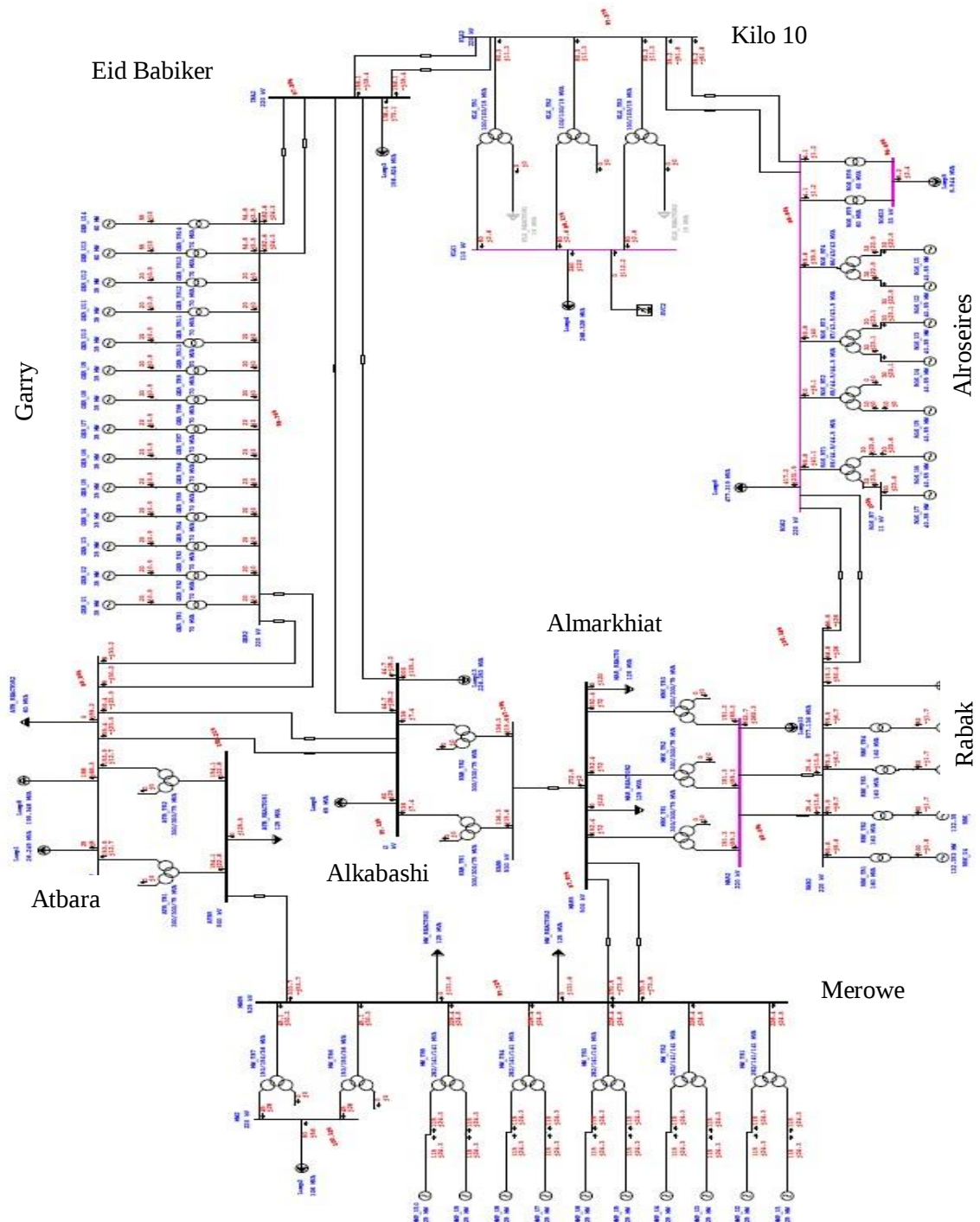


Figure 4.7: System at new planning (200MW)

Table 4.7: Bus result at new planning (200 MW)

Bus ID	Nominal kV	Type	Voltage (%)	Angle (degree)	MW Loading	Mvar Loading
ATB2	220	Load	99.34	-10.32	188.051	214.822
ATB5	500	Load	100.21	-7.73	0	96.987
GER2	220	Load	99.76	-9.81	349.176	63.005
GER_B1	10.5	Gen.	100	-7.36	20	5.61
GER_B2	10.5	Gen.	100	-7.36	20	5.61
GER_B3	10.5	Gen.	100	-7.36	20	5.61
GER_B4	10.5	Gen.	100	-7.36	20	5.61
GER_B5	10.5	Gen.	100	-7.36	20	5.61
GER_B6	10.5	Gen.	100	-7.36	20	5.61
GER_B7	10.5	Gen.	100	-7.36	20	5.61
GER_B8	11	Gen.	100	-7.36	20	5.61
GER_B9	11	Gen.	100	-7.36	20	5.61
GER_B10	11	Gen.	100	-7.36	20	5.61
GER_B11	11	Gen.	100	-7.36	20	5.61
GER_B12	11	Gen.	100	-7.36	20	5.61
GER_B13	11	Load	101.6	-3.33	55	10
GER_B14	11	Load	101.6	-3.33	55	10
IBA2	220	Load	97.39	-13.08	440.275	112.243
KAB2	220	Load	97.13	-12.48	348.575	46.416
KAB5	500	Load	97.79	0.0	349.361	13.394
KLX1	110	Load	96.17	-19.78	240	120.01
KLX2	220	Load	97.37	-13.85	303.162	102.939
MAR2	220	Load	95.49	-15.69	503.059	260.017
MAR5	500	Load	97.97	-10.76	814.765	451.263
MW2	220	Load	100.12	-6.63	90	56
MWP5	500	Load	97.72	-4.61	918.531	322.557
MWP_B1	13.8	SWNG	100	0.0	92.389	26.574
MWP_B2	13.8	SWNG	100	0.0	92.389	26.574
MWP_B3	13.8	SWNG	100	0.0	92.389	26.574
MWP_B4	13.8	SWNG	100	0.0	92.389	26.574
MWP_B5	13.8	SWNG	100	0.0	92.389	26.574
MWP_B6	13.8	SWNG	100	0.0	92.389	26.574
MWP_B7	13.8	SWNG	100	0.0	92.389	26.574
MWP_B8	13.8	SWNG	100	0.0	92.389	26.574
MWP_B9	13.8	SWNG	100	0.0	92.389	26.574
MWP_B10	13.8	SWNG	100	0.0	92.389	26.574
RAB2	220	Load	100.18	-12.58	339.457	75.571
RBK_B1	11	Gen.	100	-9.01	80	0.818
RBK_B2	11	Gen.	100	-9.01	80	0.818
RBK_B3	11	Gen.	100	-9.01	80	0.818
RBK_B4	11	Gen.	100	-8.12	100	0.112
ROS2	220	Load	96.94	-20.72	425.402	234.521
ROS33	33	Load	96.69	-21.17	8.2	2.4
ROS_B1	11	Gen.	100	-16.88	30	23.152
ROS_B2	11	Gen.	100	-16.88	30	23.152
ROS_B3	11	Gen.	100	-16.92	30	23.408
ROS_B4	11	Gen.	100	-16.92	30	23.408
ROS_B5	11	Load	96.98	-19.88	10	0
ROS_B6	11	Gen.	100	-17.01	30	23.921
ROS_B7	11	Gen.	100	-17.01	30	23.921

Table 4.8: Line flow and losses at new planning (200 MW)

From	To	Line flow		Line Losses	
		MW	MVAR	KW	KVAR
MWP5	MAR5	365.025	226.996	5498	-300781
IBA2	KAB2	44.744	-28.174	116	-5156
IBA2	KAB2	44.744	-28.174	116	-5156
MWP5	MAR5	365.025	226.996	5498	-300781
ATB5	MWP5	308.11	171.045	2569	-224750
ATB2	KAB2	38.724	29.625	647	-53493
ATB2	KAB2	38.724	29.625	647	-53493
GER2	ATB2	7.983	-30.187	31.336	-51041
GER2	ATB2	7.983	-30.187	31.336	-51041
IBA2	GER2	182.557	24.35	2858	192
IBA2	GER2	182.557	24.35	2858	192
IBA2	KLX2	156.13	-35.394	522	-487
IBA2	KLX2	156.13	-35.394	522	-487
KLX2	ROS2	35.227	-51.785	918	-89197
KLX2	ROS2	35.227	-51.785	918	-89197
RAB2	ROS2	86.827	-25.962	3161	-45504
ROS2	RAB2	86.827	-25.962	3161	-45504
MAR2	RAB2	24.899	47.202	461	-60847
MAR2	RAB2	24.899	47.202	461	-60847
KAB5	MAR5	272.52	31.141	322	-33144

Comment on the results:

After executing the program the results as shown in Table 4.7 and Table 4.8 show that the voltages at buses (KLX1, MAR2, ROSB5, ROS2, and ROS33) are marginally under voltage.

So the system has capability to operate stable with new planning (200 MW) placed in Alkabashi substation.

CHAPTRE FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Power flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line.

Through this project, the data collected from Sudanese Electrical Transmission Company (SECTO) was analyzed using ETAP 12.6 simulator and presented the results, there are some bus voltages less than permissible level and the opened line between (Merowe - Atbara) makes instability in the system, also the system is capable to accept an additional load of (200 MW) for future planning without affecting it's stability.

ETAP is the most powerful program to study power flow analysis compering with other program because it's easy in use and faster solution.

5.2 Recommendations

- This project simulated in power flow analysis by using cracked version of ETAP program it is limit capability and take long time we recommended searching by original version to analysis large system.
- Search about other software program to analysis the power flow of the system.
- Propose constructing other transmission line between (Merowe - Atbara) to be double circuit for backup and maintenance in Sudan electrical network.
- Propose to adding static compensator in Kilo X station to improve steady state voltage and capacity of the system.

REFERENCES

- [1] D. P. Kothari, I. J. Nagrath, “ Modern Power System Analysis”, Tata McGraw-Hill Education, 2003.
- [2] J.Duncan Glover , Mulukutl Thomas J. Overbye A S. Sarma , “Power System Analysis And Design” ,Stamford USA, 1996.
- [3] Hadi Saadat , “Power System Analysis” , Tata MCGraw Hill ,1999.
- [4] D.Das , “Power System Analysis” , New Age International (p) Ltd , Publishers ,2006.
- [5] J.B. Gupta, “A Course In Power Systems”, S. K. Kataria & Sons, 2009.
- [6] “ETAP User Guide 12.6”, Operation Technology, Inc, 2014.

APPENDIXES

Table A.1: Generation Data

Gen .NO	Gen .Name	Voltage Magnitude (KV)	Generation		MVAR Limit	
			MW	MVAR	Min	Max
1	MWP_U1	13.8	108	16.795	-60	60
2	MWP_U2	13.8	108	16.795	-60	60
3	MWP_U3	13.8	108	16.795	-60	60
4	MWP_U4	13.8	108	16.795	-60	60
5	MWP_U5	13.8	108	16.795	-60	60
6	MWP_U6	13.8	108	16.795	-60	60
7	MWP_U7	13.8	108	16.795	-60	60
8	MWP_U8	13.8	108	16.795	-60	60
9	MWP_U9	13.8	108	16.796	-60	60
10	MWP_U10	13.8	108	16.796	-60	60
11	ROS-G1	11	21	17.679	-16	21.7
12	ROS-G2	11	21	17.679	-16	21.7
13	ROS-G3	11	21	17.872	-16	21.7
14	ROS-G4	11	35	17.872	-16	21.7
15	ROS-G5	11	35	25.395	-16	21.7
16	ROS-G6	11	20	18.258	-16	21.7
17	ROS-G7	11	20	18.258	-16	21.7
18	RBK-G1	11	80	1.236	-50	50
19	RBK-G2	11	80	1.236	-50	50
20	RBK-G3	11	80	1.236	-50	50
21	RBK-G4	11	100	2.168	-50	77.46
22	GER- U1	10.5	20	-0.585	-20	18
23	GER1- U2	10.5	20	-0.585	-20	18
24	GER1- U3	10.5	20	-0.585	-20	18
25	GER1- U4	10.5	20	-0.585	-20	18
26	GER1- U5	10.5	20	-0.585	-20	18
27	GER1- U6	10.5	20	-0.585	-20	18
28	GER1- U7	10.5	20	-0.585	-20	18
29	GER1- U8	10.5	20	-0.585	-20	18
30	GER2- U9	10.5	20	-0.585	-20	18
31	GER2- U10	10.5	20	-0.585	-20	18
32	GER2- U11	10.5	20	-0.585	-20	18
33	GER2- U12	10.5	20	-0.585	-20	18
34	GER4- U13	11	45	25	-20	45
35	GER4- U14	11	29	25	-20	45

Table A.2: Load data

Bus	load	
	MW	MVAR
MW2	90	56
ATB2	188	66.3
KAB2	60	25
IBA2	140	75
KLX1	240	120
ROS33	8.2	2.4
ROS2	417	231.9
RBK2	115	50.4
MAR2	512.7	265

Table A.3: Line data

From	To	No. of circuit	Length (km)	R (ohm / km)	X (ohm / km)	B (Siemens / km)
MWP5	ATB5	1	236.7	0.028	0.276	4.019
MWP5	MAR5	2	345	0.028	0.276	4.109
ATB2	KAB2	2	293	0.067	0.276	4.103
ATB2	GER2	2	260	0.067	0.276	4.103
GER2	IBA2	2	60	0.067	0.276	4.103
IBA2	KLX2	2	14	0.067	0.276	4.103
IBA2	KAB2	2	30	0.067	0.276	4.103
ROS2	KLX2	2	246	0.067	0.276	4.103
ROS2	RAB2	2	303.3	0.067	0.276	4.103
RAB2	MAR2	2	329.9	0.067	0.276	4.103

Table A.4: Two winding transformer data

TRS Name	Number	MVA Rated	Primary (KV)	Secondary (KV)
GER_TRS	7	50	10.5	220
	7	50	11	220
ROS_TRS	2	60	220	33
RBK_TRS	4	160	11	220

Table A.5: Three winding transformer data

TRS Name	Number	MVA Rating			Rated Voltage (KV)		
		Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
MW_TRS	5	282	141	141	500	13.8	13.8
	2	150	150	36	500	220	33
ATB_TRS	2	300	300	75	500	220	33
KAB_TRS	2	300	300	75	500	220	33
KLX_TRS	3	100	100	15	220	110	11
ROS_TRS	1	86	43	43	220	11	11
	1	87	43.5	43.5	220	11	11
	2	89	44.5	44.5	220	11	11
MRK_TRS	3	300	300	75	500	220	33