

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



*Palestine Polytechnic University*  
*Collage of Engineering and Technology*  
*Electrical Engineering department*

**Design of Electrical Distribution System for Rawabi City**

**Project Team**

**AbdulQader Shaheen**

**Ahmad Qawasma**

**Feras Abdulbaset**

**Project Supervisor: Dr. Fouad Zaro**

**Submitted to the College of Engineering**  
**In partial fulfillment of the requirements for the**  
**Bachelor degree in Power Technology Engineering**

**Hebron, December 2017**

# اهـءاء

أهءء هءا العمل المءواضع إىلى أمى الءى زوءءنى بالءنان والمءبة

وإلى أبى الءى لم ىبءل على ىوماً بشىء

أقول لهم: أنءم وهىءمونى الءىاء والأمل والنشأة على شءف الاطلاع والمعرفة

وإلى إءوئى وأسرىءى ءمىعاً

إلى من وهبوا أرواءهم وأعمارهم فءا الوءن

إلى الشهءاء والأسرى

وإلى كل من علمنى ءرفاً أصبح سنا برقه ىضىء الطرىق أمامى

ثم إلى كل من ىءب العلم وىسعى إىه

## **Acknowledgement**

*I should offer my thanks and gratitude First to Allah*

*My Appreciation to*

*Palestine Polytechnic University*

*College of Engineering and Technology*

*Electrical Power Engineering Department*

*My Supervisor*

*Dr. Fouad Zaro*

*Eng. Basem Abu Alroos*

*Jerusalem District Electrical Company "JDECO"*

*Eng. Sari Ibrahim*

## **Abstract**

Rawabi city considered as a modern form of architectural design, which requires design modern distribution system, and to reach the most efficiency use international electrotechnical commission in the design.

This project shows stages of designing the distribution system where the process began with load estimation, designing a suitable distribution substation, choose the right components to be use, simulation and analysis, controlling and monitoring and finally the conclusion and recommendation are presented.

In first stage, the loads in the city are estimate and sorted in to four types; the residential, amphitheater and stadium, logistic and commercial loads, in designing substation stage the chosen components in the station done by depending on the result of the previous stage, choosing the component for the network is the next stage after the substation design. To make sure that the design match the real network performance the simulation and analysis is applied, in order to control and monitor the design SCADA system is used.

## المخلص

تعتبر مدينة روابي نموذجاً عصرياً للتصميم المعماري، الامر الذي يتطلب تصميم نموذج عصري لنظام توزيع الكهرباء داخل المدينة، وللوصول الى اعلى كفاءة من ناحية التصميم والأداء تم اعتماد مقاييس اللجنة التقنية الدولية للكهرباء، في عملية التصميم.

يستعرض هذا المشروع خطوات تصميم نظام التوزيع حيث بدأت العملية بتقدير الاحمال ومن ثم تصميم محطة توزيع مناسبة، يتبع هذه الخطوة عملية اختيار العناصر الملائمة من اجل استخدامها في التصميم، المحاكاة والتحليل، عملية التحكم والمراقبة باستخدام نظام SCADA.

في مرحلة حساب تقدير الاحمال تم تصنيف الاحمال الى أربعة أنواع وهي: الحمل السكني، التجاري، الصناعي، واحمال الاستاد والمدرج. وفي مرحلة تصميم المحطة تم اختيار العناصر بناء على حسابات تقدير الاحمال يتبع هذه المرحلة اختيار باقي العناصر الخاصة بنظام التوزيع. وللتأكد من عمل النظام تم استخدام برامج المحاكاة التي تعمل على إعطاء نتائج قريبة بشكل كافي من ارض الواقع، يتبع ذلك استخدام نظام مراقبة وتحكم.

# CONTENTS

Dedication.....	i
Acknowledgement.....	ii
Abstract .....	iii
Contents.....	v
List of Figures.....	ix
List of equations .....	x
Table of tables.....	x
Table of figures.....	x

## **Chapter One: Introduction**

1.1 Overview.....	2
1.2 Motivations.....	3
1.3 The objectives of project.....	3
1.4 Project Importance.....	3
1.5 Project Methodology.....	4
1.6 Project contribution.....	4
1.7 Project tools and software.....	4

## **Chapter Two: Load Estimation**

2.1 Nature of loads.....	6
2.1.1 Residential electrical loads (Dwelling Loads).....	6
2.1.2 Commercial electrical loads.....	7
2.1.3 Amphitheater and stadium loads.....	7
2.1.4 Logistic area loads.....	8

2.2 Load Estimation .....	8
2.2.1 Calculation of Residential loads.....	8
2.2.2 Streets lighting .....	9
2.2.3 Commercial electrical loads.....	13
2.2.4 Amphitheater and stadium loads.....	13
2.3 Distribute the loads on the transformers.....	12

### **Chapter Three: Main Substation Design**

3.1 Introduction. ....	17
3.2 Main Objectives of Substation. ....	17
3.3 General structure of the substation.....	18
3.3.1 Power Transformer.....	18
3.3.2 Auxiliary transformer.....	19
3.3.3 On-load tap-changers (OLTCs).....	20
3.3.4 Buses and scheme.....	20
3.3.5 Bus Protection .....	22
3.3.6 Circuit Breakers.....	22
3.3.7 Protective Relay.....	23
3.3.8 Buchholz Relay.....	25
3.3.9 Switchgear.....	26
3.3.10 Surge Arrester.....	27
3.3.11 Isolators.....	28
3.3.12 Insulation.....	29
3.3.13 Main Feeder Scheme.....	30

## **Chapter Four: Components of the distribution network**

4.1 Introduction.....	32
4.2 Distribution Transformer.....	32
4.3 Cable.....	35
4.4 Ring Main Unit (RMU).....	37
4.5 Surge arrester.....	39
4.6 Capacitor.....	40

## **Chapter Five: Simulation and Results by ETAP software**

5.1 Introduction.....	42
5.2 Modeling the network.....	42
5.2.1 Considerations of Primary Systems.....	43
5.2.2 Earthling system.....	44
5.3 sectors of network.....	46
5.3.1 commercial sector.....	46
5.3.2 Residential sector.....	47
5.4 Reports and results.....	50
5.4.1 Simulation without five and six sections.....	50
5.4.2 Simulation with five and six sections.....	50
5.5 capacitor bank calculation.....	53

## **Chapter Six: Supervisory Control and Data Acquisition (SCADA) System**

6.1 SCADA System Description.....	55
6.2 Functions of SCADA System.....	56
6.3 SCADA System Hardware.....	56
6.3.1 Programmable Logic Control (PLC) Device.....	56
6.3.2 Personal COMPUTER (PC).....	56
6.4 SCADA System Software.....	58
6.4.1 Unity Pro Program.....	58



6.4.2 Vijeo Citect Program.....	58
6.5 Practical SCADA system.....	59
6.5.1 SCHNEIDER MODICON M340 PLC.....	59
6.5.2 Simulation.....	60
6.5.3 Animation Tables.....	60
6.5.4 SCADA SCREEN.....	60
<b>Chapter Seven: Conclusion and Recommendation</b>	
7.1 Introduction.....	66
7.2 Conclusion.....	66
7.3 Recommendation.....	67
7.3.1 Recommendation for Electricity Company in Rawabi city.....	67
7.3.2 Recommendation for our university.....	67
<b>References.....</b>	<b>68</b>
<b>Appendices.....</b>	<b>70</b>

## TABLE OF FIGURES

<b>Figure No.</b>	<b>Title</b>	<b>Page</b>
Figure 2.1	Neighborhood in Rawabi city	6
Figure 2.2	Shopping center in Rawabi city	7
Figure 2.3	Amphitheater and stadium in Rawabi city	7
Figure 2.4	Logistic area in Rawabi city	8
Figure 2.5	Single sided poles	10
Figure 2.6	Staggered poles	10
Figure 2.7	Opposite poles	11
Figure 2.8	Span wire poles	11
Figure 3.1	Power Transformer	18
Figure 3.2	Auxiliary Transformer	19
Figure 3.3	OLTC	20
Figure 3.4	Single Bus Schemes	21
Figure 3.5	Buchholz Relay	25
Figure 3.6	Switchgear	26
Figure 3.7	Surge Arrester	27
Figure 3.8	Isolators	28
Figure 3.9	Insulation	29
Figure 3.10	Main feeders scheme	30
Figure 4.1	Distribution Transformer	34
Figure 4.2	Three position Isolator and circuit diagram for RMU	38
Figure 4.3	Surge arrester	39
Figure 5.1	The distribution network	42
Figure 5.2	Loop-type primary feeder	43
Figure 5.3	TT earthling system configuration	44
Figure 5.4	The fault behavior in the TT earthling system	45
Figure 5.5	commercial sector in Etap	46
Figure 5.6	First residential section in Etap	47
Figure 5.7	First residential section in Etap in case of transformer failure	47
Figure 5.8	Second residential section in Etap	48
Figure 5.9	Third residential section in Etap	48
Figure 5.10	Fourth residential section in Etap	49
Figure 5.11	Fifth residential section in Etap	49
Figure 5.12	Sixth residential section in Etap	50
Figure 6.1	SCADA System for Controlling and Monitoring	53
Figure 6.2	PLC Device	55
Figure 6.3	User interface	56
Figure 6.4	Unity Pro interface	56
Figure 6.5	Vijeo Citect Program	57
Figure 6.6	Unity Pro Practical configurations	58
Figure 6.7	Unity Pro ST Programing language	58
Figure 6.8	Animation Table	59
Figure 6.9	General form for Rawabi city substation in SCADA System	60
Figure 6.10	Monitoring for three phase voltage	61
Figure 6.11	Normal condition	61
Figure 6.12	Fault and Over current condition	62

## TABLE OF EQUATIONS

Equation No.	Title	Page
2.1	Flat load	9
2.2	Building load	9
2.3	Parking's load	9
2.4	Section load	9
2.5	Commercial electrical loads	13
3.1	The flowing current	23

## TABLE OF TABLES

TABLE No.	Title	Page
2.1	Residential loads transformers	14
2.2	Demand factor for loads	15
4.1	Distribution Transformer	34

## LIST OF ABRIVIATIONS

Abbreviation	Meaning
MDB	Main distribution board
SCADA	Supervisory control and data acquisition
IEC	International Electrotechnical Commission
ETAP	Electromagnetic transients program
ONAN	Oil natural air natural
OLTCs	On load tap changers
SF6	Sulfur Hexa Fluoride
PLC	Programmable Logic Control
PC	Personal computer

## **Chapter one**

### **Introduction**

**1.1 Overview**

**1.2 Motivations**

**1.3 The objectives of project**

**1.4 Project Importance.**

**1.5 Project Methodology**

**1.6 Project contribution**

**1.7 Project tools and software**

# Chapter one

## Introduction

### 1.1 Overview:

The main idea of this project is using International Electrotechnical Commission (IEC) standards to design a complete electrical distribution system for Rawabi city that delivers the electricity from the main substation to the customer main distribution board (MDB). Also, design a complete suitable protection system for all grid components and apply economic dispatch for the grid.

Rawabi's more than 5,000 housing units with multiple floor plans spread across 23 neighborhoods, each with its own individual aesthetic. All neighborhoods have wonderful modern amenities including ample underground parking areas, playgrounds, wide sidewalks and outdoor walking trails, pocket parks and convenience retail stores.

Located 9 km north of Ramallah and 3.5 km north of Birzeit, Rawabi lies 25 km north of Jerusalem and 25 km south of Nablus. Rawabi's municipal boundaries encompass 6,300,000 square meters of land, which will initially be home to 25,000 residents. Additional residential and commercial units slated for subsequent construction phases will ultimately serve a city with a population of more than 40,000.

The City Center offers a retail business district with hotels, cinemas and a convention center, all supported by the latest smart technologies and a high-speed fiber-optic network. Rawabi also features education and medical facilities, houses of worship, public green spaces and recreation facilities creating new Palestinian economic and cultural destination<sup>[10]</sup>.

## **1.2 Motivations:**

In general, most of the electric power networks in many places in the world suffer from many problems such as low power factor, high losses, voltage drop and many other problems.

In order to decrease these problems, an efficient electrical distribution system will be designed for a new City. Which lead to reduce losses, voltage drop, and time outage of the system and discover errors more easily.

## **1.3 The objectives of project:**

1. Design a complete Electrical Distribution System according to IEC standards.
2. Deliver the electricity from the main station to the customers MDB.
3. Monitoring and control the network using SCADA system.
4. Design a reliable distribution system.
5. Design the distribution system take in consideration the appearance of the city.

## **1.4 Project Importance:**

Normally, good design will lead to reduce losses, voltage drop, time outage of the system and discover errors more easily.

We hope to use this project in future as a reference for building standard networks.

### **1.5 Project Methodology :**

1. General design for the distribution system.
2. Estimate of power demand.
3. Estimate the load growth.
4. Select the suitable transformers for the system.
5. Select suitable conductors.
6. Study Network Reliability.
7. Monitoring and controlling the network by using Supervisory Control and Data Acquisition (SCADA) system.

### **1.6 Project contribution**

Reliability, the interruption during the peak demands will be canceled and time outage of the system will reduce.

Appearance, maintain the good look of the city by choosing the right place for the distribution station as well as the use of underground cables instead of overhead lines.

### **1.7 Project software.**

1. The Electromagnetic Transients Program (ETAP) is used to design the network.
2. Unity pro and Vijeo Citect will use in order to control and monitoring system (SCADA System).
3. Automated Computer Aided Design (AutoCAD) is used in order to draw the single line diagram

## **Chapter Two**

### **Load Estimation**

#### **2.1 Nature of loads**

#### **2.2 Load estimation**

#### **2.3 Load distribution**



## Chapter Two

### Load Estimation

#### 2.1 Nature of loads.

Rawabi city consists of different types of loads, such as:

2.1.1 Residential electrical loads (Dwelling Loads).

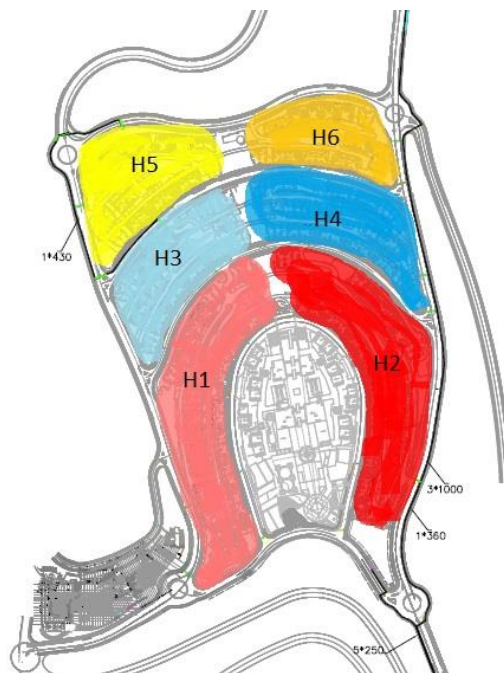
2.1.2 Commercial electrical loads.

2.1.3 Amphitheater and stadium loads.

2.1.4 Logistic area loads.

#### 2.1.1 Residential electrical loads (Dwelling Loads):

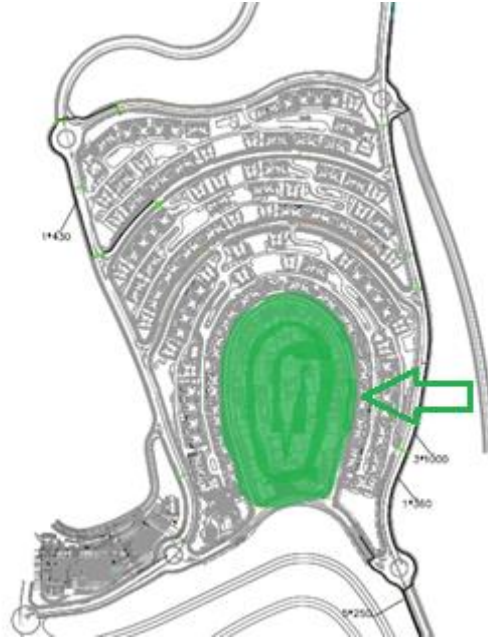
The residential loads in Rawabi city illustrated in six sections (H1, H2, H3, H4), more over a future expansion (H5, H6) is reserved, as shown in figure 2.1. There is a map for Rawabi city in appendix A.



**Figure 2.1:** neighborhood in Rawabi city.

### 2.1.2 Commercial electrical loads:

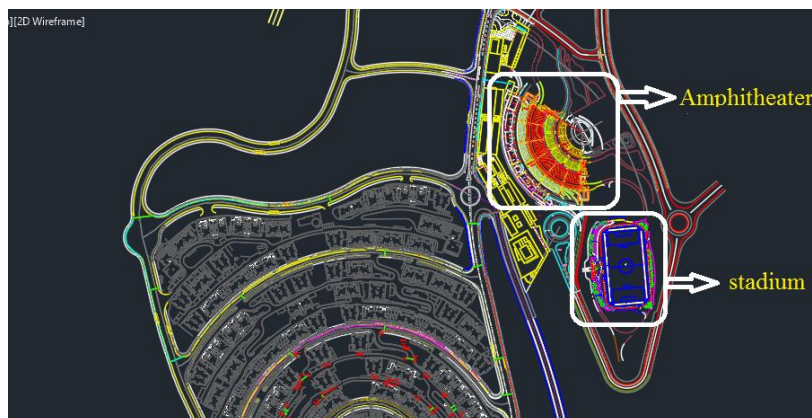
The commercial loads exist at shopping center that illustrates in figure 2.2 with an area of 30000 m<sup>2</sup>.



**Figure 2.2:** shopping center in Rawabi city.

### 2.1.3 Amphitheater and stadium loads:

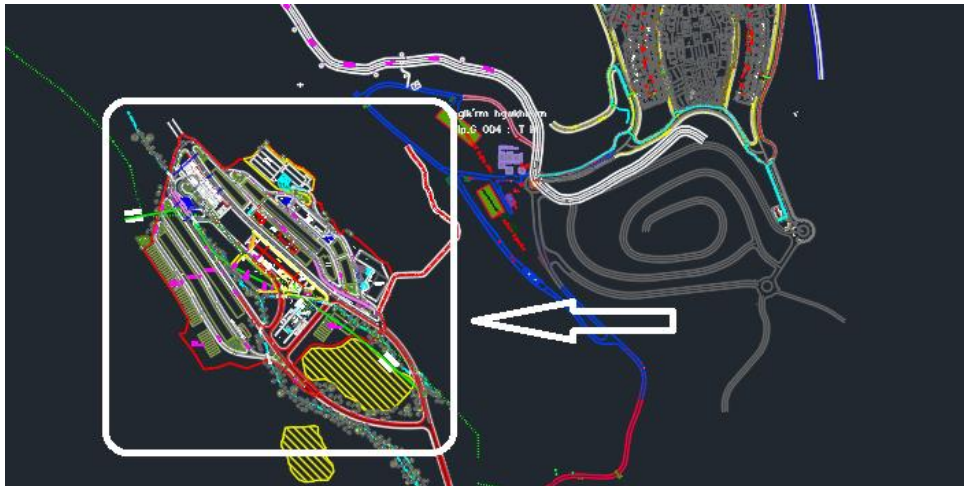
The Amphitheater and stadium loads exist at the north of Rawabi city as illustrated in figure 2.3.



**Figure 2.3:** Amphitheater and stadium in Rawabi city.

#### 2.1.4 Logistic area:

It considers as the industrial area of the city, and it is not completed yet, as shown in figure 2.4.



**Figure 2.4:** Logistic area in Rawabi city.

#### 2.2 Load estimation:

In order to design a complete electrical distribution system, the load estimation process has to be done according to IEC standards.

##### 2.2.1 Calculation of Residential loads.

As illustrated above in figure 2.1 Rawabi city contains six sections, every section includes different buildings (T1, T2, T3, T4, T5, J1), every building consist of several flats as illustrated in Appendix B.

To calculate the electric power demand of these sections we have to select a suitable demand factor ( $VA / m^2$ ), in electrical installation guide 2016 equal  $90 VA / m^2$ , and calculate the load of every flat then for every building and put them together to find the total load of these sections.

Section one for example:

The section one has 18 buildings, every buildings contains (12 – 25) flats, every flat has an area of 171.2 m<sup>2</sup>, and the load calculate as follow:

$$\begin{aligned}\text{Flat load} &= \text{area (m}^2\text{) X demand factor (VA / m}^2\text{)} & (2.1) \\ &= 171.2 \times 90 = 15.408 \text{ KVA}\end{aligned}$$

$$\text{Building load} = \text{flat load X number of flats} \quad (2.2)$$

$$\text{Building 1} = 15408 \times 16 = 246.528 \text{ KVA}$$

$$\begin{aligned}\text{Parking's load} &= \text{area (m}^2\text{) X demand factor (VA / m}^2\text{) X number of buildings} & (2.3) \\ &= 517.86 \times 10 \times 18 = 93.2148 \text{ KVA}\end{aligned}$$

$$\begin{aligned}\text{Section 1 load} &= (\sum \text{ buildings load} + \text{Parking's load}) \times \text{simultaneity factor} & (2.4) \\ &= 4392046.8 \times 0.4 = 1.75681872 \text{ MVA}\end{aligned}$$

The calculation of the remaining sections are shown in appendix C.

### **2.2.2 Streets lighting.**

The main purpose of using street lightning is to provide a safety factors and clear vision for the public, these factors can be summarized as safety in the streets, the traffic jam of cars and the public, so the street lightning has a great importance for the public safety.

#### Main types of street lighting:

- Main streets.
- Sub-streets.
- Crossroads.

In this project, we have selected the solar powered street lighting, to apply the renewable energy and the latest technology in this project.

Street light arrangement:

Poles height and street width affect lighting arrangement, and there are four main methods to arrange:

1) Single sided:

This type of arrangement used when the width of the road is less or equal the height of the pole, the poles in this method located on one side of the road.



**Figure 2.5:** Single sided poles.

This arrangement applied when:  $W \leq H$

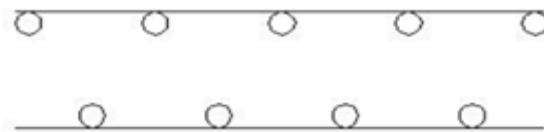
Where:

W: width of the road

H: length of the pole

2) Staggered:

This type of arrangement used when the width of the road is between 1 to 1.5 times the height of the pole, the poles in this method located on two side of the road.



**Figure 2.6:** Staggered poles.

This arrangement applied when:  $W = 1 \sim 1.5 H$

3) Opposite:

This type of arrangement used when the width of the road is more than 1.5 times the height of the pole, the poles in this method located on two side of the road.



**Figure 2.7:** Opposite poles.

This arrangement applied when:  $W > 1.5 H$

4) Span wire:

This type of arrangement, with the poles suspended along the axis of the road, is normally used for narrow roads.



**Figure 2.8:** Span wire poles.

**In Rawabi city:**

In main roads Single sided will used, in sub roads Staggered will used, And in crossroads the color of the light will change and intensity of illumination will increase to alert people.

Types of lamps used in Street lighting:

- 1) High-pressure sodium lamps (Highway Streets).
- 2) Low-pressure sodium lamps (Tunnels).
- 3) Metal halide lamps.
- 4) Mercury lamps (Internal Streets).
- 5) Light emitting diode (LED).

In Rawabi city, LED Lampe will be used because:

- 1) Long Life.
- 2) Energy Efficiency.
- 3) Ecologically Friendly.
- 4) Durable Quality (Illumination Can Withstand Rough Conditions).
- 5) Zero ultraviolet Emissions.
- 6) Design Flexibility.
- 7) Operational in Extremely Cold or Hot Temperatures.
- 8) Light Dispersement.
- 9) Instant Lighting & Frequent Switching (Can Be Turned On/Off Many Times).
- 10) Low-Voltage (Lighting Can Run on Low-Voltage Power Supply).

Methods of switching of lamps:

There are various methods, some of which are:

- Photo cell.
- Control switch.
- Timer.

It is good to use Photo cell, because it's not require to set and reset its time manually, and it work automatically according to the sun light.

The distribution lighting network consists of:

- Lighting storage and control box.
- Poles.
- Lighting luminaries.
- Cables.

### 2.2.3 Commercial electrical loads.

The electrical load requirements for commercial installations result in a great deal of diversity in usage. In other words, while some types of equipment and electrical loads are in use for extended periods, others are only used occasionally or for short periods.

Common commercial occupancies include banks, stores, restaurants, and office buildings. Moreover, these loads are consisting of lighting, air conditioning, elevators, power sockets and Entertainment games.

The commercial factor has a demand factor of 150 VA/m<sup>2</sup>.

$$\begin{aligned}\text{load} &= \text{area (m}^2\text{)} \times \text{demand factor (VA / m}^2\text{)} && (2.5) \\ &= 30000 \times 150 \\ &= 4.5 \text{ MVA}\end{aligned}$$

### 2.2.4 Amphitheater and stadium loads:

$$\begin{aligned}\text{Amphitheater load} &= \text{area (m}^2\text{)} \times \text{demand factor (VA / m}^2\text{)} \\ &= 40000 \times 70 \\ &= 280.000 \text{ KVA}\end{aligned}$$

$$\begin{aligned}\text{Stadium load} &= \text{area (m}^2\text{)} \times \text{demand factor (VA / m}^2\text{)} \\ &= 30000 \times 70 \\ &= 210.000 \text{ KVA}\end{aligned}$$

$$\text{Total loud} = 280000 + 210000 = 490000 \text{ VA} = 490 \text{ KVA}$$

$$\begin{aligned}\rightarrow \text{Total load of all the city} &= \text{residential} + \text{commercial} + \text{amphitheater and stadium} \\ &= 8346 + 4500 + 490 = 13336 \text{ KVA} = 13.336 \text{ MVA}\end{aligned}$$



### 2.3 Distribute the loads on the transformers.

According to IEC standard, the selection process of transformers in the network is depending on the Simultaneity factor.

- Residential loads transformers shown in Table 2.1.

**Table 2.1: Residential loads transformers**

section	No. of buildings	Total load (KVA)	500 KVA transformer	630 KVA transformer	Avg. transformer loading
H1	18	1756.8	2	2	78 %
H2	20	1871.9	2	2	83 %
H3	14	1249.3	3	-	83 %
H4	15	1374.6	2	1	84 %
H5	13	1130.1	-	2	89 %
H6	10	963.6	1	1	85 %

Note: 1) All these transformers are 11/0.4 kV.

2) Transformers ratings and Distribute the buildings on the transformers is illustrated in appendix D.

- Commercial center transformers.

The load in commercial center was 4.5 MVA as calculated above, and to supply power to these loads we need six transformers with 1000 KVA rated.

Because we have high power consumption in a small area and far from the substation it is better to use a 33/0.4 kV transformers.

Although 33/0.4 kV transformers are more expensive than 11/0.4 kV by 15%, they will be used to reduce losses.

Average transformers loading is **75%**.

- Other transformers.

We have one more 11/0.4 kV transformer with rated of 630 KVA to supply the Stadium and Amphitheater loads. Transformer loading is 78%.

In order to increase the reliability of the system the ratio of loading transformers is chosen nearly from 75%\_ 85%, , because in case of failure one of the transformers to distribute its load on the other transformers.

**Table 2.2: Demand factor for loads**

Loud type	Demand factor (VA/m <sup>2</sup> )
Residential loud	90
Commercial loud	150
Amphitheater loud	70
Stadium loud	70
Parking loud	10

## **Chapter Three**

### **Medium Voltage Distribution Substation**

#### **3.1 Introduction**

#### **3.2 Main Objectives of Substation**

#### **3.3 General structure of the substation**

## Chapter Three

### Medium Voltage Distribution Substation

#### 3.1 Introduction.

The term "medium voltage" is commonly used for distribution systems with voltages above 11 kV and generally applied up to and including 33kV.

Electrical substations can also be divided into public and private substations:

1. Public Substations: these belong to the electricity distribution company and supply private users in single phase or three-phase (typical voltage values for the two types of power supply could be 220V and 400V).
2. Private Substations: these can often be considered as terminal type substation, i.e. substations where the MV line ends at the installation point of the substation itself.

#### 3.2 Main Objectives of Substation.

The main objectives of the substation can be summarized as the following:

1. Protection of transmission system.
2. Controlling the Exchange of Energy.
3. Ensure steady State and Transient stability.
4. Voltage Control, reducing the reactive power flow compensation of reactive power, tap Changing.
5. Data transmission via power line carrier for the purpose of network monitoring, control and protection.
6. Determining the energy transfer through transmission lines.
7. Reliable supply by feeding the network at various points.

### 3.3 General structure of the substation.

In this section, the electrical structure of the main elements of the substation will be discussed.

#### 3.3.1 Power Transformer

This is the most important component of a sub-station. The main work of a sub-station is to distribute power at a low voltage, by stepping down the voltage that it receives in its incoming lines. Power is generally transmitted over long distances at very high voltages.

Consumer requires power at rather low voltages, 11 kV for industries and 400 V or 220 V for domestic consumers. The sub-stations use step-down transformers to attain this voltage and then distribute this power. All the other equipment in a sub-station works only to facilitate the smooth working of the power transformer; it needs a protection and cooling system. and in this design a two power transformers (33/11 kV) will be used, their ratings are 10 MVA for each as show in figure 3.1.



Figure 3.1: Power Transformer

The cooling type of this type of transformers is ONAN (Oil Natural Air Natural).

### 3.3.2 Auxiliary transformer:

This type of transformer is used in the substation to step down the voltage from 33kV to 0.4 kV, in order to serve the instruments inside the substation such as measuring and control devices

In case of had itself stopped due to some essential drive failure the other drives may be kept under service by taken the power from grid and keeping the plant a live until the main problem is sorted out.

Properties:

- 1- These transformers are employed in the power plants for delivering power to low voltage loads (voltage below 1kV).
- 2- These transformers connect between voltage (33kV/11kV) distribution and voltage (11kV/0.4kV) distribution buses of the plant.
- 3- Neutral oil cooling air-cooled transformers are used.



Figure 3.2: Auxiliary Transformer

### 3.3.3 On-load tap-changers (OLTCs):

Power transformers equipped with on-load tap changers (OLTCs) have been the main components of electrical networks and industrial applications. OLTCs enable voltage regulation and/or phase shifting by varying the transformer ratio under load without interruption [1].

From the start of tap-changer development, two switching principles have been used for load transfer operation – the high-speed resistor-type OLTCs and the reactor-type OLTCs. The majority of resistor-type OLTCs are installed inside the transformer tank (in-tank OLTCs) whereas the reactor-type OLTCs are in a separate compartment, which is normally welded to the transformer tank [1].

The OLTC changes the ratio of a transformer by adding or subtracting to and turns from either the primary or the secondary winding. The transformer is therefore equipped with a regulating or tap winding which is connected to the OLTC [1].

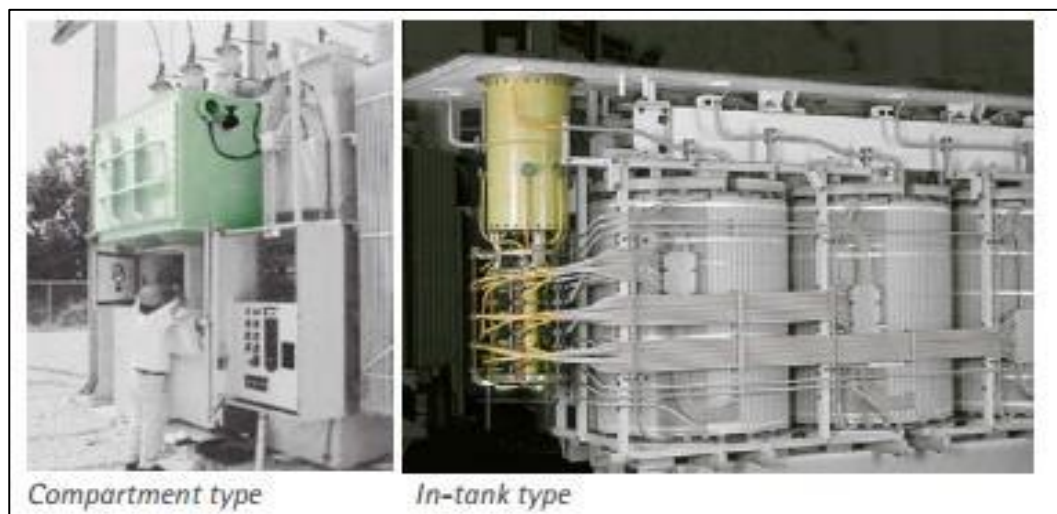


Figure 3.3: OLTC

### 3.3.4 Buses and scheme:

Bus is based on Kirchhoff's current law, which states that the sum of currents entering a node is zero. A bus is treated as a node, and current measurements are taken from all terminals connected to the bus. Under normal conditions, the currents sum to

zero. During a fault, the currents do not sum to zero. In general, the sum of measured currents is known as the operating quantity.

The selection of a particular substation scheme is based on safety, reliability, economy, simplicity, and other consideration.

The most commonly used substation bus schemes is single bus, breaker-and-a-half, double bus-double breaker and ring bus scheme arrangements. substations can be protected by high-impedance relays if suitable CTs are available [2].

**In this design:**

Although breaker-and-a-half scheme is the most efficient scheme the single bus scheme is chosen for this project, since a single power transformer is active in this substation, the efficiency of breaker-and-a-half scheme will not be different from single bus scheme, so the single bus scheme is used.

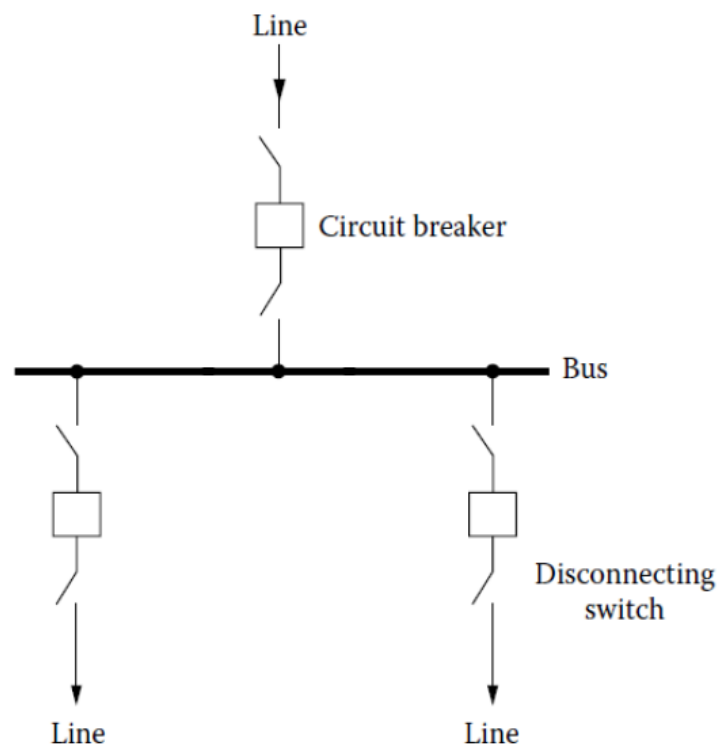


Figure 3.4: Single Bus Schemes



### **3.3.5 Bus Protection:**

Differential protection is effective for bus faults because the current leaving the bus on feeders and the current entering the bus from sources should be zero at any instant.

Additionally, differential protection can distinguish between internal bus faults and external feeder faults. A feeder fault can result in the current transformer (CTs); special care must be taken in bus differential relaying to prevent external faults from causing a trip on the circuit breakers supplying the bus.

Two major systems are used:

1. Linear coupler system, which works by eliminating the iron core of the CTs.
2. Multi-restraint, variable percentage relays.

### **3.3.6 Circuit Breakers:**

Circuit breakers contain the following elements, irrespective of the medium for arc quenching and insulation:

- 1- Main contact at system voltage.
- 2- Insulation, such as porcelain, oil or gas, between the main contacts and ground potential
- 3- Operating and supervisory accessories, of which tripping facilities are most important.

Circuit breakers are a piece of electrical device that:

1. Make or break a circuit manually or by remote control under normal conditions.
2. Break a circuit automatically under fault conditions.

In the this substation the SF6 Circuit breakers for the power transformer with rated 33kV and 11kV and the rated current as follow:

$$I = \frac{MVA}{\sqrt{3} * kV} \text{ A} \quad (3.1)$$

Where:

I: the flowing current.

MVA: Load capacity.

kV: Rated Voltage.

A: current unit (ampere).

$$ICB = 1.25 * I_{rated}$$

Where:

$I_{CB}$ : The current that make the circuit breaker will trip.

The rated current before the transformer is

$$I = \frac{8.35MVA}{\sqrt{3} * 33kV} = 146 \text{ A}$$

$$ICB = 1.25 * 146 = 182.5 \text{ A}$$

The rated current after the transformer is

$$I = \frac{8.35MVA}{\sqrt{3} * 11kV} = 483 \text{ A.}$$

$$ICB = 1.25 * 483 = 604 \text{ A.}$$

### **3.3.7 Protective Relay:**

A protective relay is a device that detects the fault and initiates the operation of the circuit breaker to isolate the defective element from the rest of the system. The relay constantly measures the electrical quantities, which are different under normal and fault condition; it must operate with suitable speed so that fault is eliminated before it can cause any damage. A relay must also be sensitive to work with low values of currents [3].

### **Classification of Relay:**

1. Electromagnetic attraction type: which operates on the principle where the relay armature is attracted by an electromagnet.
2. Electromagnetic induction type: which operates due to mutual interaction of two different fluxes, which are differing at a certain phase angles, having same or different amplitude and nearly equal frequencies.

### **Relay Types:**

1. Induction type over-current relay: In an over current relay, there would be essentially a current coil. When normal current flows through this coil, the magnetic effect generated by the coil is not sufficient to move the moving element of the relay, as in this condition the restraining force is greater than deflecting force. But when the current through the coil increased, the magnetic effect increases, and after certain level of current, the deflecting force generated by the magnetic effect of the coil, crosses the restraining force, as a result, the moving element starts moving to change the contact position in the relay [3].

2. Induction type reverse power relay: A reverse power relay is a directional power relay that is used to monitor the power from a generator running in parallel with another generator or the utility. The function of the reverse power relay is to prevent a reverse power condition in which power flows from the bus bar into the generator. This condition can occur when there is a failure in the prime mover such as an engine or a turbine which drives the generator [3].

3. Distance or Impedance relay: There is one voltage element from potential transformer and an current element fed from current transformer of the system. The deflecting torque is produced by secondary current of CT and restoring torque is produced by voltage of potential transformer [3].

3. Differential relay: When there is a difference between two or more similar electrical quantities exceeds a predetermined value. In differential relay scheme circuit, there are two currents come from two parts of an electrical power circuit [3].

### **3.3.8 Buchholz Relay:**

Buchholz relay is a safety device which is generally used in large oil immersed transformers (rated more than 500 KVA). It is a type of oil and gas actuated protection relay. It is used for the protection of a transformer from the faults occurring inside the transformer, such as impulse breakdown of the insulating oil, insulation failure of turns and others.

#### **Advantages of Buchholz Relay:**

1. Buchholz relay indicates the internal faults due to heating and it helps in avoiding the major faults.
2. Fault can be determined without even dismantling the transformer.
3. If a major fault occurs, the transformer can be isolated with the help of buchholz relay.



Figure 3.5: Buchholz Relay

### 3.3.9 Switchgear:

Refers to the combination of electrical disconnects, fuses and/or circuit breakers used to isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream.

Power levels and voltages rapidly escalated, making open manually-operated switches too dangerous to use for anything other than isolation of a de-energized circuit. Air-blast, vacuum, or SF<sub>6</sub> equipment, allowing large currents and power levels to be safely controlled by automatic equipment incorporating digital controls, protection, metering and communications [4].

Metal clad switchgear: Requires that the main switching and interrupting device be draw out, it may be either a circuit breaker (usual) or a load-break interrupter switch (unusual).



Figure 3.6: Switchgear

### 3.3.10 Surge Arrester:

Is a device to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. The original lightning arrester was nothing more than a spark air gap with one side connected to a line conductor and the other side connected to earth ground. When the line-to-ground voltage reached the spark-over level, the voltage surge would be discharged to earth ground [5].

#### Types of Lightning Arresters:

1. Rod gap arrester: This is constituted of a plain air-gap between two square rods (1cm<sup>2</sup>) bent at right angles and connected between the line and earth.
2. Horn gap arrester
3. Multigap arrester
4. Expulsion type lightning arrester: It is improvement over a rod gap and is commonly used on system operating at voltages up to 33kV.
5. Valve type lightning arrester: The valve type lightning arrester consists of two assemblies namely series spark gaps and nonlinear resistor discs in series.

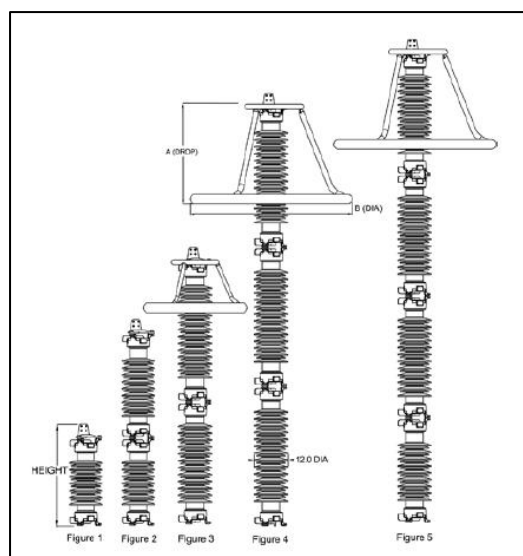


Figure 3.7: Surge Arrester

### 3.3.11 Isolators:

Isolators are mechanical switching devices capable of opening or closing a circuit when a negligible current is broken or made, or only a small charging current is to be interrupted, or when no significant voltage difference exists across the terminals of each pole [6].

Isolators are capable of carrying current under normal conditions and short circuit currents for a specified time.

In open position, the isolator should provide an isolating distance between the terminals. The standard value of rated duration of short time current capacity withstand for isolator and earthing switch is normally 1 second, a value of 3 seconds is also sometimes specified [6].

For 33 kV, horizontal type isolating switches are used, also the rated normal current is 630 A at 36 kV.

For 11 kV, both horizontal and vertical mounting isolating switches of 400 A at 12 kV are used.

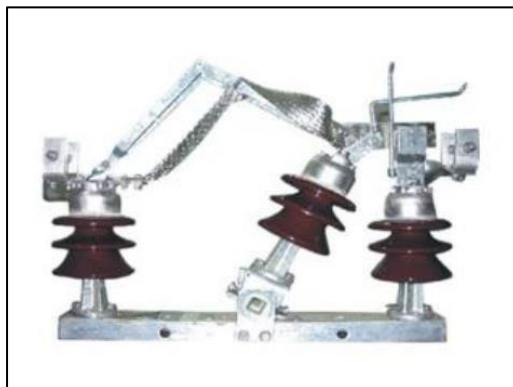


Figure 3.8: Isolators

### 3.3.12 Insulation:

Insulation coordination is the process of determining the proper insulation levels of various components in a power system as well as their arrangements. It is the selection of an insulation structure that will withstand voltage stresses to which the system or equipment will be subjected to, together with the proper surge arrester. Its final objective is to ensure safe, optimized distribution of electric power [6].

We use Porcelain in our project that is made of ceramic material and it was widely used voltages because of its efficiency and price comparing to the other one.

To achieve the necessary electrical characteristics, a number of suspension insulators are strung together in series. It is important to coordinate the insulation characteristics of suspension insulator strings with the insulation systems of other substation equipment and the characteristics of various insulation protective devices. The quantity of suspension insulators chosen for a particular application should be large enough to prevent unnecessary flashovers. Over insulation, however, can result in flashovers occurring from phase to phase rather than from phase to ground. Consequently, the quantity of insulators should be small enough that all flashovers occur to ground [6].



Figure 3.9: Insulation



### 3.3.13 Main Feeder Scheme

The following figure shows the main feeders for the substation, which is fed by three feeders, two from Sengle and the third one from AL-Nabi Saleh, as shown in figure 3.10.

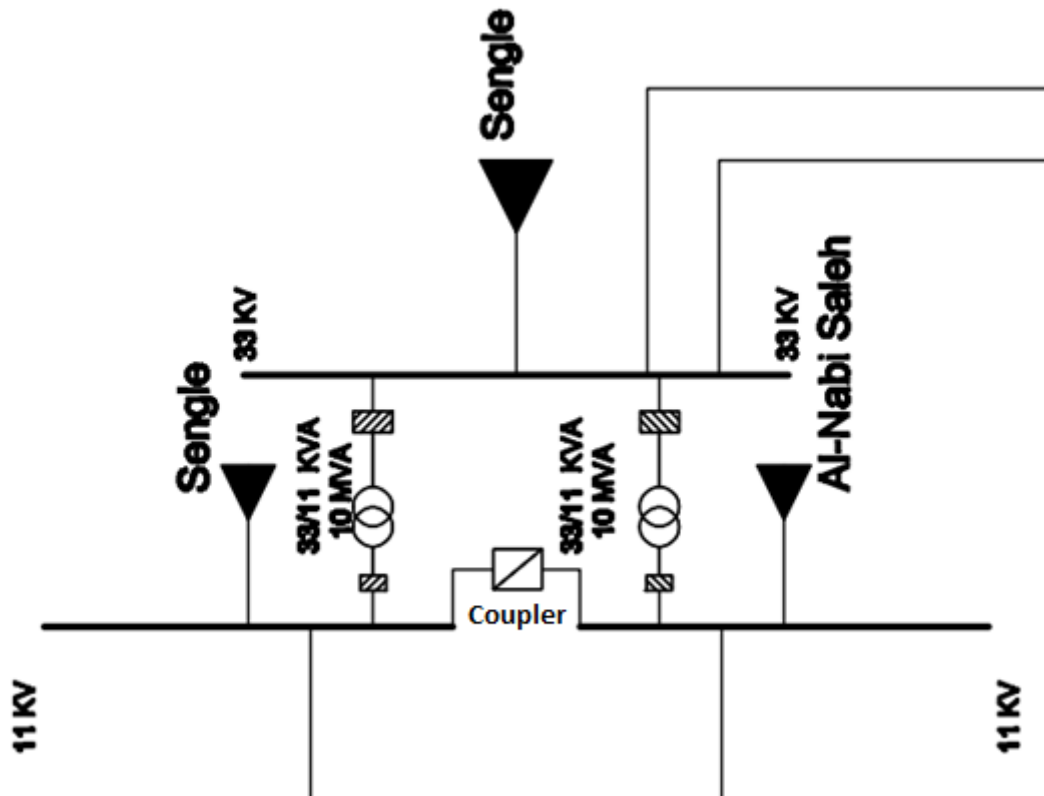


Figure 3.10: Main feeders scheme

The full single line diagram of the substation and all the network is illustrated in appendix E.

## **Chapter Four**

### **Components of the distribution network**

#### **4.1 Introduction**

#### **4.2 Distribution Transformer**

#### **4.3 Cable**

#### **4.4 Ring Main Unit (RMU)**

#### **4.5 Surge arrester**

#### **4.6 Capacitors**

## **Chapter Four**

### **Components of the distribution network**

#### **4.1 Introduction**

This chapter describes the main components of Distribution network. Some of these components are transformer, cable - major component of the system-, ring main unit, surge arrester and capacitor bank. In section of transformer, there are the models that are used in project and what cooling system is used, accessories and protection for distribution transformer. Third section describes cable type and selection criteria and insulation types that is used and, and consider difference between cable and overhead line and benefits for cable. Forth section is circuit breaker and fuses description and fifth section that is Ring main unit and finally Surge arrester.

#### **4.2 Distribution Transformer**

A distribution transformer or service transformer is a transformer that provides the final voltage transformation in the electric power distribution system, stepping down the voltage used in the distribution lines to the level used by the customer.

##### **The Delta Grounded Wye Step-Down Connection**

The delta grounded wye step-down connection is a popular connection that is typically used in serving a four-wire wye feeder system. Another application of the connection is to provide service to a load that is primarily single-phase. Because of the wye connection, three single-phase circuits are available, thereby making it possible to balance the single phase loading on the transformer bank.

## **Cooling system**

The magnetic circuit and windings are the principal sources of losses and resulting temperature rise in various parts of a transformer. Core loss, copper loss in windings ( $I^2/R$  loss), stray loss in windings and stray loss due to leakage/high current field are mainly responsible for heat generation within the transformer.

## **Cooling Arrangements**

The cooling arrangements has been chosen according to IEC standards.

Four letters in combination to define designate the cooling method the cooling medium and the method of circulation:

1. The first letter is used for internal cooling medium in contact with the winding, O for mineral oil or synthetic liquid with fire point less than 300C, and K (or L for IEC) for insulating liquid with fire point more than 300C. These include silicone or high-molecular carbon products. G is also included for gas-filled designs.
2. The second letter is the circulation mechanism for the internal cooling medium, N for natural convection flow through cooling equipment and winding, F for forced circulation through cooling equipment, and D for forced circulation through cooling equipment (directed from the cooling equipment to the winding).
3. The third letter is for the external cooling medium, A for air, and W for water.
4. The fourth letter is for the circulation mechanism for the external cooling medium, N for natural convection, F for forced circulation (fan for air cooling, pump for water-cooling) [7].

The distribution transformers that used in this project is shown in the following in the table 4.1:

Table 4.1: Distribution Transformer

Transformer Type	500 KVA	630 MVA	1000 MVA
Rated Voltage	11/0.4 kV	11/0.4 kV	33/0.4 kV
No. of Transformers	9	9	6

To see the distribution of the transformer over the city see appendix D.

Since the percentage of loading of the distribution transformers, the cooling arrangement that chosen is ONAN.



Figure 4.1: Distribution Transformer

### Protection of low Voltage Transformer

A typical low-voltage (LV) unit substation connected to medium voltage switchgear can be used for the setting of protective devices.

#### Protection with Circuit Breaker

1. Phase overcurrent, instantaneous: This element or device protects the feeder and the transformer against short circuits, including faults at the terminals.
2. Ground overcurrent: This element is used in resistance grounded systems, and can be set at the maximum ground-fault current to provide protection

against line to ground faults.

### **4.3 Cable**

The selection process is the cabling of the most important parts and equipment in the design of electrical networks, so the choice of the correct cables electrical grid makes the electric grid is going correctly, There are also many factors necessitate you how to choose the electric grid is the most important economic aspect. in this section we will talk about underground cables and overhead lines and which the best between this types and talk about isolation of this cables This section concentrates on the properties of different types of LV, MV power cable, For current calculations see Appendix F.

#### **Cable Selection Criteria**

The main factors that influence the choice of cable to be employed for any particular application are the cable size and whether single or three-core cables or more than one cable per phase needs to be used in any particular feeder. The type and size of the cable are selected based on four criteria:

1. The maximum loading of the feeder.
2. The maximum voltage drop that can be allowed.
3. The fault current to which the cable is exposed.
4. The level of insulation used in the cable. Over and above that applicable to the voltage rating that has been chosen for the network.

## **Cable Insulation**

A very important parameter in cable selection is the insulation type. Insulation selection should be based on service life, dielectric characteristics, resistance to flame, mechanical strength and flexibility, temperature capability, moisture resistance, and the type of location where the cable is to be installed. Common insulation types applicable to medium-voltage cables are:

- \_ Ethylene propylene rubber (EPR).
- \_ Cross-linked polyethylene (XLPE).
- \_ Tree-retardant cross-linked polyethylene (TR-XLPE). These insulation materials have replaced the impregnated-paper designs that may still be found in some older installations.
- \_ Polyvinyl chloride (PVC).

For Cross section area see Appendix G.

### **The main benefits of underground high voltage cables:**

1. Underground cables have unique properties for transmitting power, often require only a narrow band of land to install, emit no electric field and can be engineered to emit no magnetic fields, have better power loss Characteristics and can absorb emergency power loads.
2. Increased Reliability Today's cable systems, using cross-linked polyethylene (XLPE) as the primary insulation material, have been performance tested to ensure reliability. New cables based on this technology have been running for over 20 years with an excellent reliability record.
3. Reduced Losses Underground cables generally have more efficient copper conductors and operate at lower temperatures than overhead lines. These properties

combine to transmit energy to end users as efficiently as possible.

4. The cable impedance is less than line impedance, The X/R ratio of cable is much lower than that of line, The series inductance of cable is 30-50% lower than that of Line.

#### **Cables characteristics that used in this design:**

There are two types of the conductors materials copper and aluminum, Copper has historically been used for conductors of insulated cables primarily for its desirable electrical and mechanical properties, Aluminum requires larger conductor sizes to carry the same current as copper.

For the previous reasons we choose the copper cables that have XLPE insulation and PVC outer sheath.

#### **4.4 Ring Main Unit (RMU)**

A ring-main unit is a piece of switchgear used on medium-voltage distribution ring-main systems. Essentially its three switches incorporated into one device used to connect a transformer to a high voltage ring main. It allows the transformer to be connected/disconnected to the ring main and it also allows the ring main to be 'broken'. Each of the switches has three positions: open, closed, or earthed (grounded); the earth position allows the transformer or either (or both) halves of the ring main to be earthed when maintenance is required.

It is basically used for an uninterrupted power supply. Alongside, it also protects your secondary side transformer from the occasional transient currents. Depending on your applications and loading conditions you can use a switch fuse combination or a circuit breaker to protect the transformer. This transformer connected to the switch fuse/ is called your Turn off.



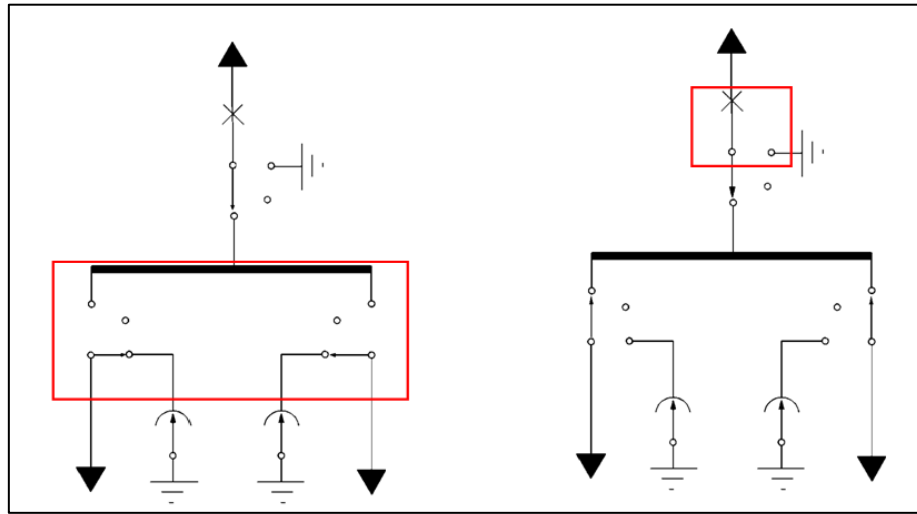


Figure 4.2: Three position Isolator and circuit diagram for RMU

The Load Break Isolators for Incoming and Outgoing supply must be provided and the load break isolators are fully insulated by SF6 gas. The operating mechanism shall be spring assisted mechanism with operating handle for ON /OFF. Earth positions with arrangement for pad locking in each position, also independent manual operations with mechanically operated indicator. The earth switch shall be naturally interlocked to prevent the main and earth switch being switched ON at the same time. The selection of the main and earth switch is made by a lever on the facial, which is allowed to move only if the main or earth switch is in the o\_ position. The load break isolators should have the facility for future remote operation.

## 4.5 Surge arrester

Surge arresters are devices that help prevent damage to apparatus due to high voltages. The arrester provides a low-impedance path to ground for the current from a lightning strike or transient voltage and then restores to a normal operating conditions. It will release high pressure until a normal operating condition is reached. When the pressure is returned to normal, the safety valve is ready for the next operation.

When a high voltage (greater than the normal line voltage) exists on the line, the arrester immediately furnishes a path to ground and thus limits and drains o\_ the excess voltage. The arrester has two functions; it must provide a point in the circuit at which an over-voltage pulse can pass to ground and second, to prevent any follow-up current from owing to ground.

Duty cycle rating: Duty cycle testing of an arrester is performed by subjecting an arrester to an AC rms voltage equal to its rating for 24minutes. During which the arrester must be able to withstand lightning surges at 1-minute intervals. Maximum continuous operating voltage rating is usually 80 to 90% of the duty cycle rating.

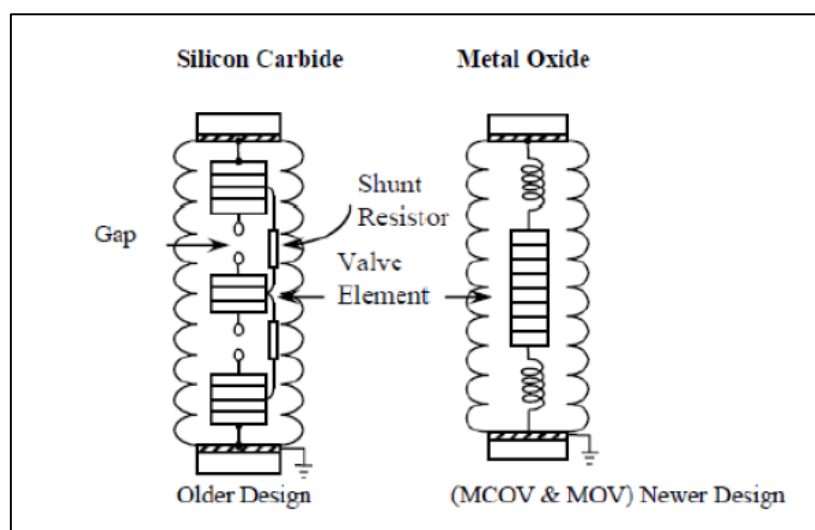


Figure 4.5: Surge arrester

## 4.6 Capacitors:

The main aim of the capacitor in the power systems is to reduce the inductive current "Power Factor Correction", Capacitors can be grouped into either transmission or distribution classes. In either case, they should be installed electrically at near to the load as possible for maximum effectiveness.

When applied properly, capacitors balance out most of inductive component of current to the load, leaving essentially a unity Power Factor Load. The result is to reduce the size of the conductor required to serve a given load and a reduction of  $I^2R$  losses.

The advantages of capacitor are reduce losses, easy to install and require little maintenance.

The Disadvantages of it are short service life (10-15) years, easily damaged if voltage increase and uneconomical to repair it.

## **Chapter Five**

### **Simulation and Results by ETAP software**

#### **5.1 Introduction**

#### **5.2 Modeling the network**

#### **5.2 Sectors of network**

#### **5.4 Reports and results**

#### **5.5 capacitor bank calculation**

## Chapter Five

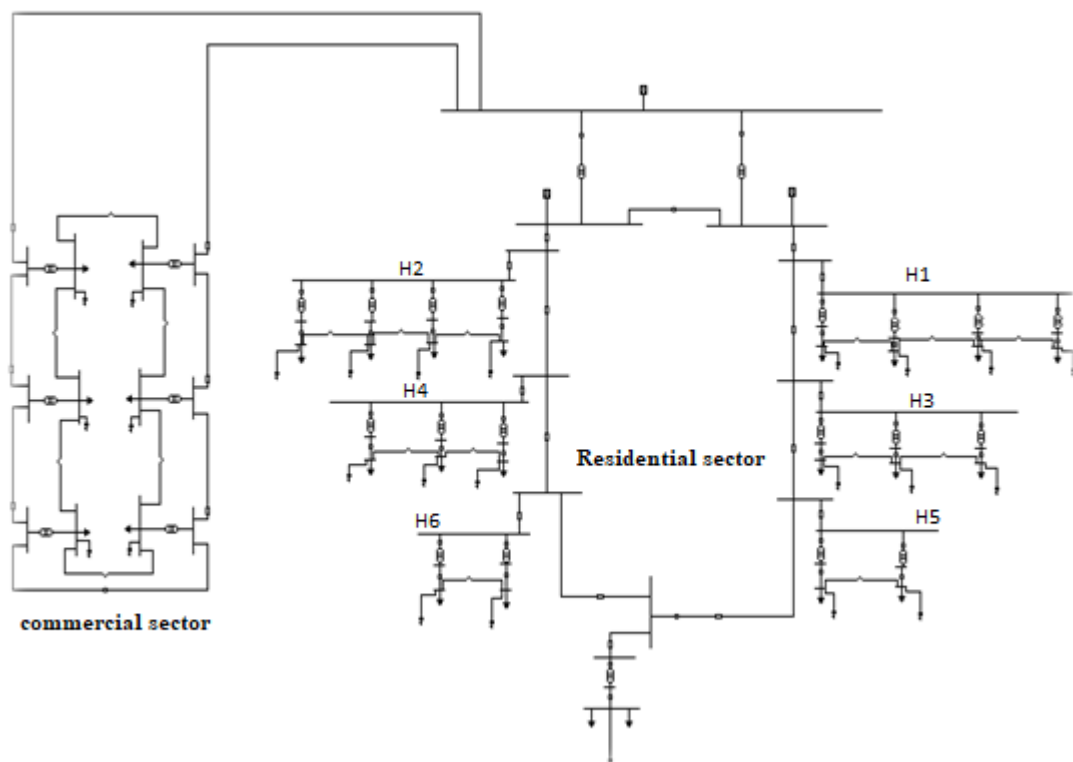
### Simulation and Results by ETAP software

#### 5.1 Introduction

ETAP is the most comprehensive analysis platform for the design, simulation, operation, and automation of generation, distribution, and industrial power systems. ETAP is developed under an established quality assurance program and is used worldwide as a high impact software. ETAP is completely localized in four languages with translated output reports in six languages. [8]

#### 5.2 Modeling the network

Under the current circumstances, there are three main feeders that supplying the distribution network, the process of modeling the network demands working on the substation in the first place, after that the design of the loop type of primary feeders of the distribution network will be simulated by ETAP as shown in figure 5.1.

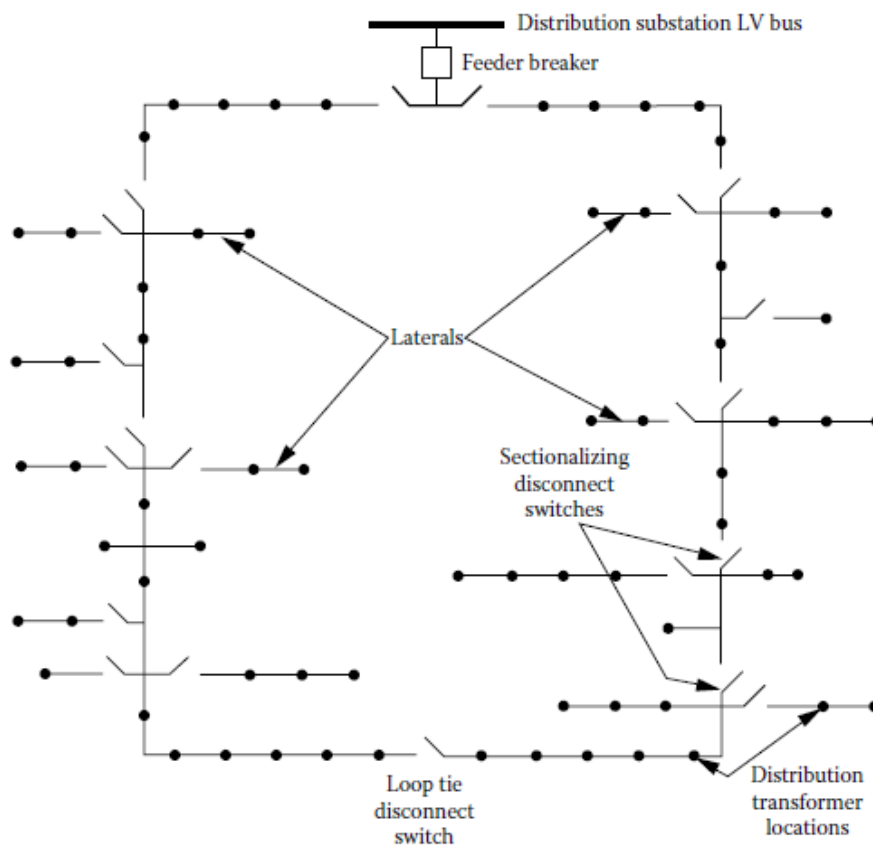


**Figure 5.1:** The distribution network

### 5.2.1 Considerations of Primary Systems

The part of the electric utility system that is between the distribution substation and the distribution transformers is called the primary system. It is made of circuits known as primary feeders or primary distribution feeders [9].

In this design, a loop-type primary feeder that loops through the feeder load area and returns back to the bus will be used.



**Figure 5.2:** Loop-type primary feeder.

Usually, the size of the feeder conductor is kept the same throughout the loop. It is selected to carry its normal load plus the load of the other half of the loop. This arrangement provides two parallel paths from the substation to the load when the loop is operated with normally open tiebreakers or disconnect switches [9].

A primary fault causes the feeder breaker to be open. The breaker will remain open until the fault is isolated from both directions. The loop-type primary-feeder arrangement is especially beneficial to provide service for loads where high service

reliability is important. In general, a separate feeder breaker on each end of the loop is preferred, despite the cost involved. The parallel feeder paths can also be connected to separate bus sections in the substation and supplied from separate transformers. In addition to main feeder loops, normally open lateral loops are also used, particularly in underground systems [9].

## 5.2.2 Earthing system

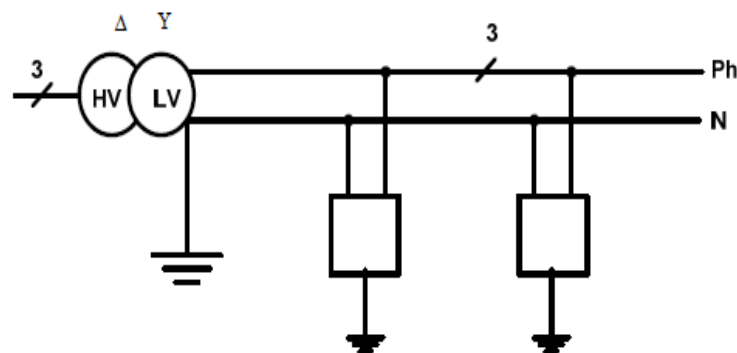
A low voltage (LV) distribution system may be identified according to its earthing system. There are three possible configurations.

- 1) **TT**: transformer neutral earthed and frame earthed.
- 2) **TN**: transformer neutral earthed, frame connected to neutral.
- 3) **IT**: unearthed transformer neutral, earthed frame.

The TN system includes three sub-systems: TN-C, TN-S and TN-C-S, as discussed in the following sub-sections.

### TT Earthing System

In this system, the supply source has a direct connection to earth. All exposed conductive parts of an installation also are connected to an earth electrode that is electrically independent of the source earth. The structure of TT system is shown in Figure 5.3.

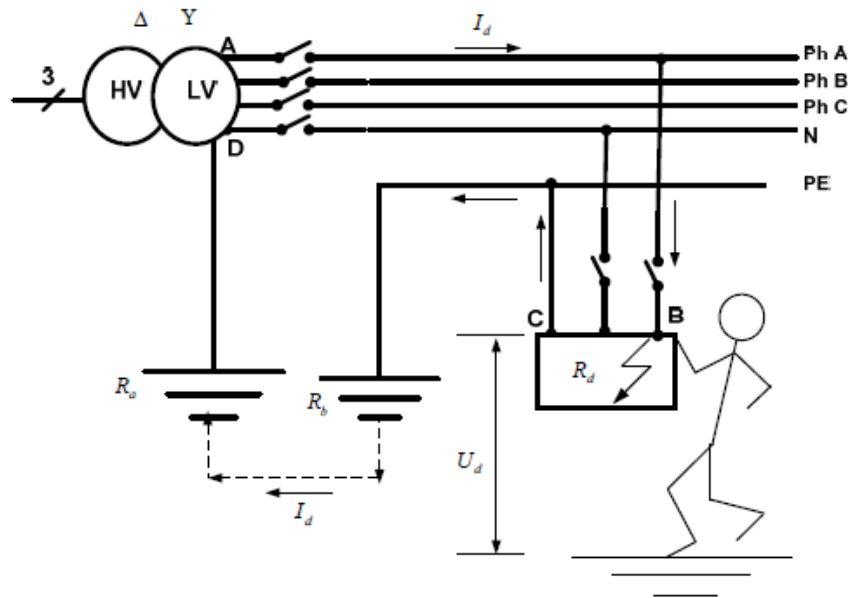


**Figure 5.3:** TT earthing system configuration

### Fault Behavior in the TT Earthing System

Figure 5.4 explain fault occurs in TT earthing system. When an insulation fault occurs, the fault current  $I_d$  is mainly limited by the earth resistances ( $R_a$  and  $R_b$ ). At

least one residual current device (RCD) must be fitted at the supply end of the installation. In order to increase availability of electrical power, use of several RCDs ensures time and current discrimination on tripping.



**Figure 5.4:** The fault behavior in the TT earthing system

### Advantages of the TT Earthing System

- 1) The most commonly found earthing system.
- 2) Faults in the LV and MV grid do not migrate to other customers in the LV grid.
- 3) Good security condition, as the potential rise of the grounded conductive part must be limited at 50 V for a fault inside the installation and at 0V for a fault on the network.
- 4) Simple earthing of the installation and the easiest to implement.
- 5) No influence of extending the network.

### Disadvantages of the TT Earthing System

- 1) Each customer needs to install and maintain its own ground electrode. Safety and protection depends on the customer, thus complete reliability is not assured.
- 2) High over voltages may occur between all live parts and between live parts and PE conductor.

**For the previous reasons we choose the TT Earthing system in our project.**



### 5.3 sectors of network

#### 5.3.1 commercial sector

This sector contains six transformer 33/11 each one has a capacity of 1MVA, and the type of cable used is cooper XLPE with cross section area of 50mm<sup>2</sup>.

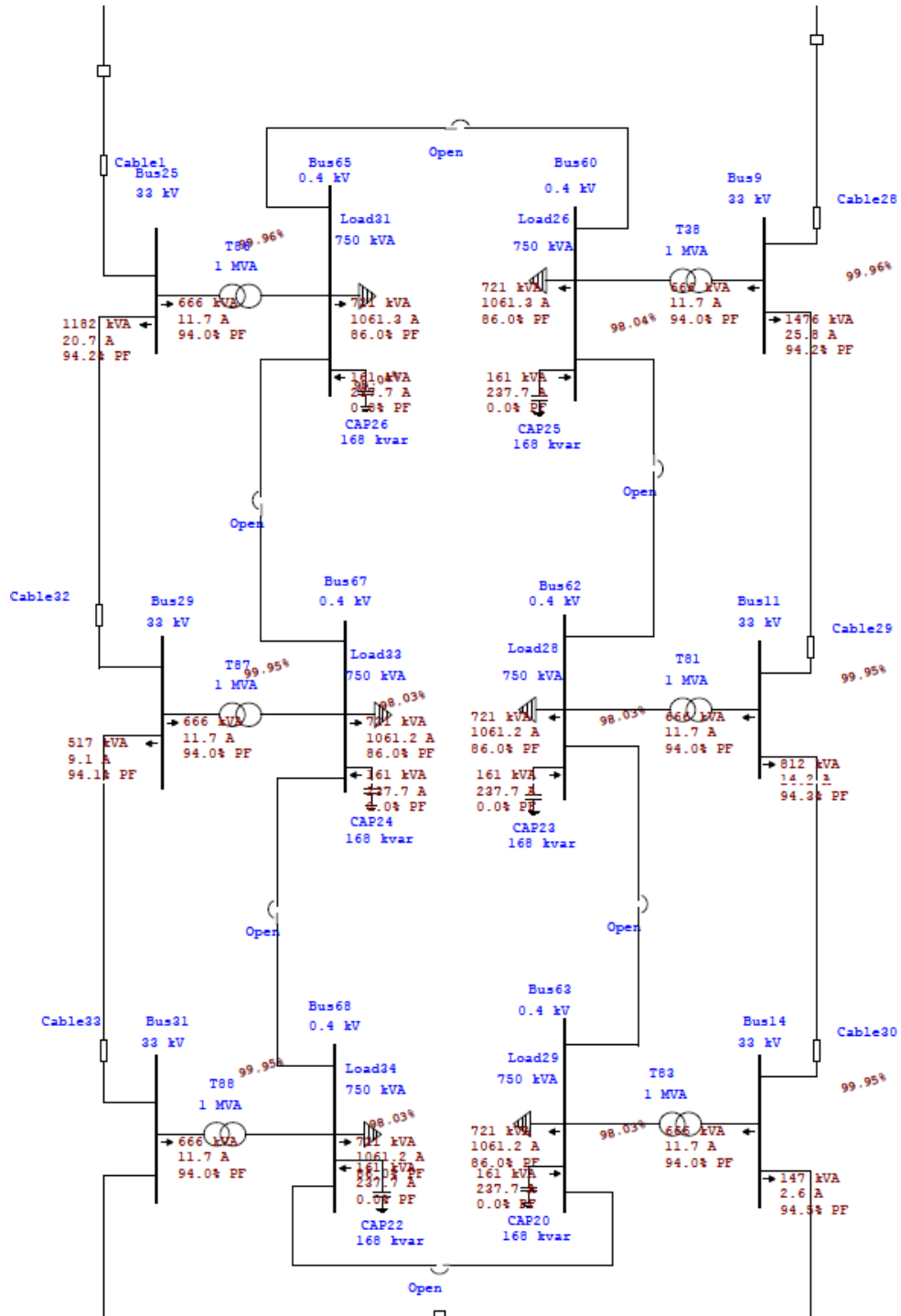


Figure 5.5: commercial sector in Etap

### 5.3.2 Residential sector

#### 1) First section (H1)

This section contains four transformers 11/0.4 kV, two of them are 630kVA rating and the others are 500kVA.

The type of cable that go from the ring to the section used is cooper XLPE with cross section area of 25mm<sup>2</sup>.

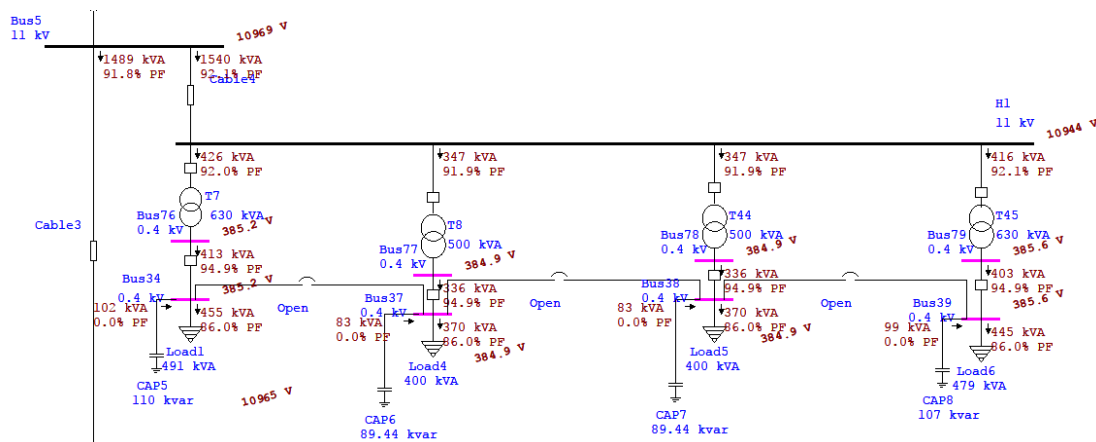


Figure 5.6: First residential section in Etap

In this section and other sections a normally open disconnectors connected between the low voltage buses at 0.4kV side, to provide more reliability to the low voltage network.

In case of failure of one transformer, the load of it will divide on the other three transformer as shown in figure 5.7.

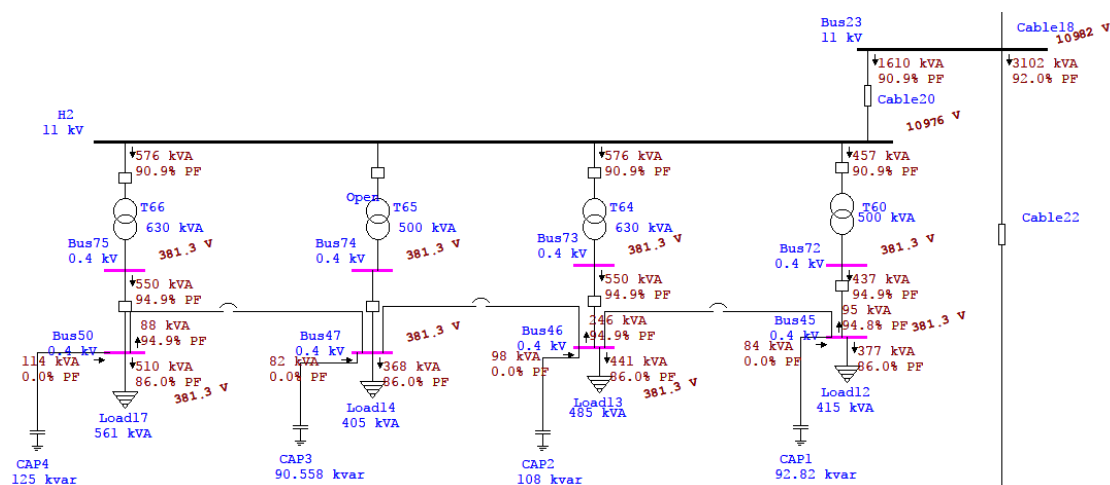


Figure 5.7: First residential section in Etap in case of transformer failure

## 2) Second section (H2)

This section contains four transformers 11/0.4 kV, two of them are 630kVA rating and the others are 500kVA.

The type of cable that go from the ring to the section used is cooper XLPE with cross section area of 25mm<sup>2</sup>.

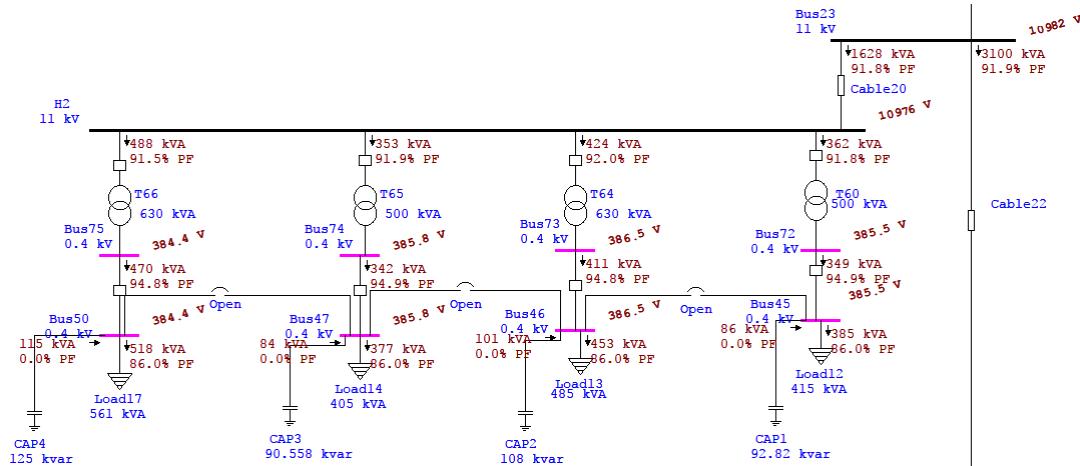


Figure 5.8: Second residential section in Etap

## 3) Third section

This section contains three transformers 11/0.4 kV, two of them are 500kVA rating and the other is 630kVA.

The type of cable that go from the ring to the section used is cooper XLPE with cross section area of 25mm<sup>2</sup>.

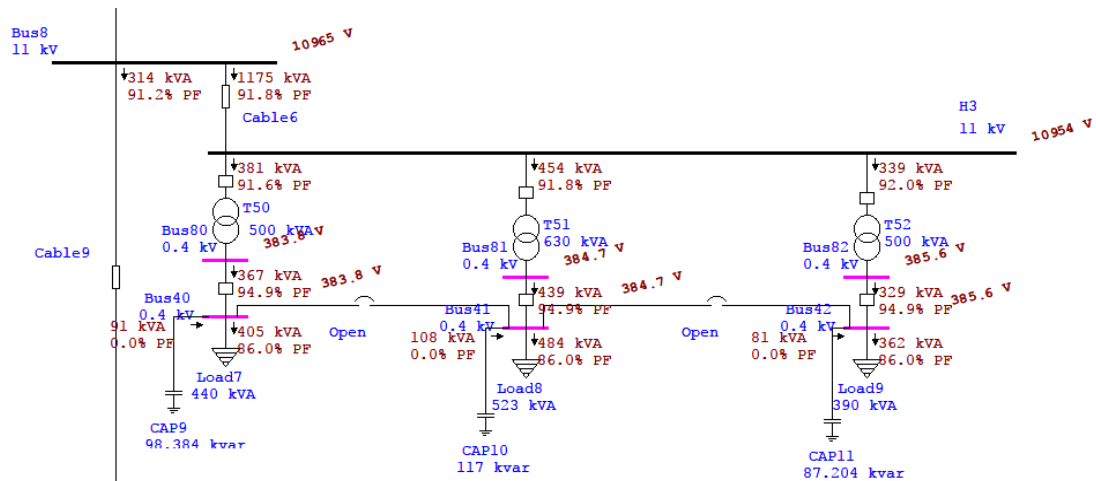


Figure 5.9: Third residential section in Etap

#### 4) Fourth section

This section contains three transformers 11/0.4 kV, two of them are 500kVA rating and the other is 630kVA.

The type of cable that go from the ring to the section used is cooper XLPE with cross section area of 25mm<sup>2</sup>.

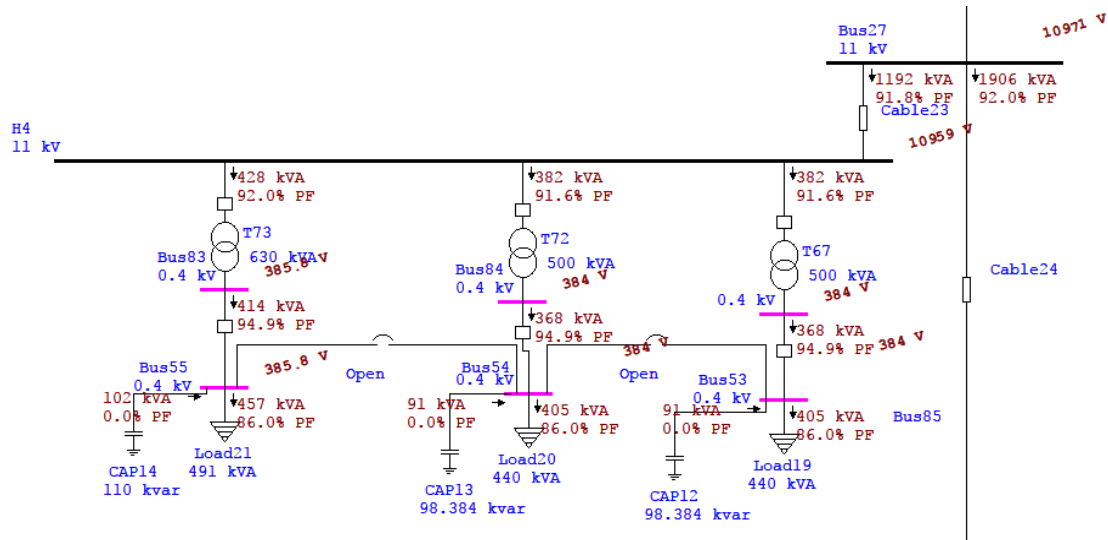


Figure 5.10: Fourth residential section in Etap

#### 5) Fifth section

This section contains three transformers 11/0.4 kV, and 630kVA rating.

The type of cable that go from the ring to the section used is cooper XLPE with cross section area of 25mm<sup>2</sup>.

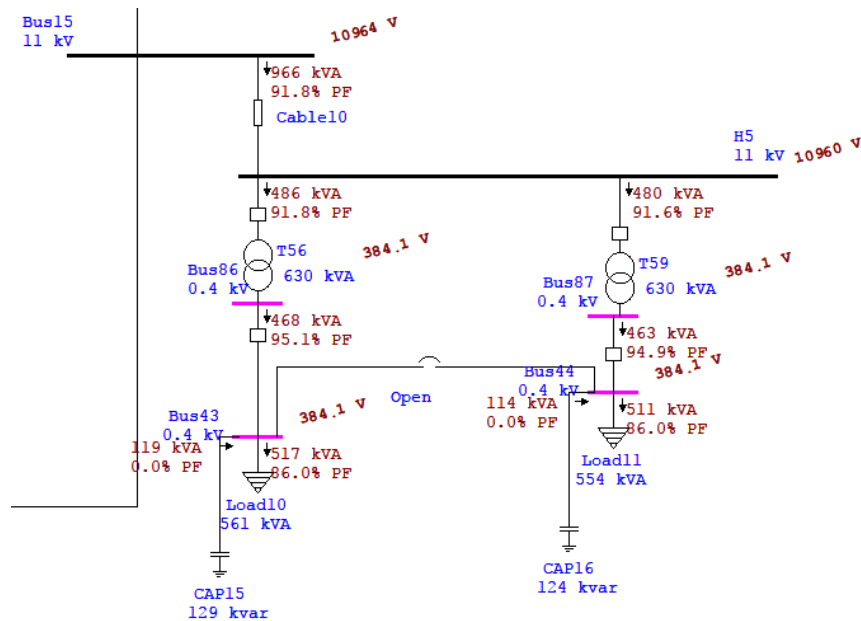
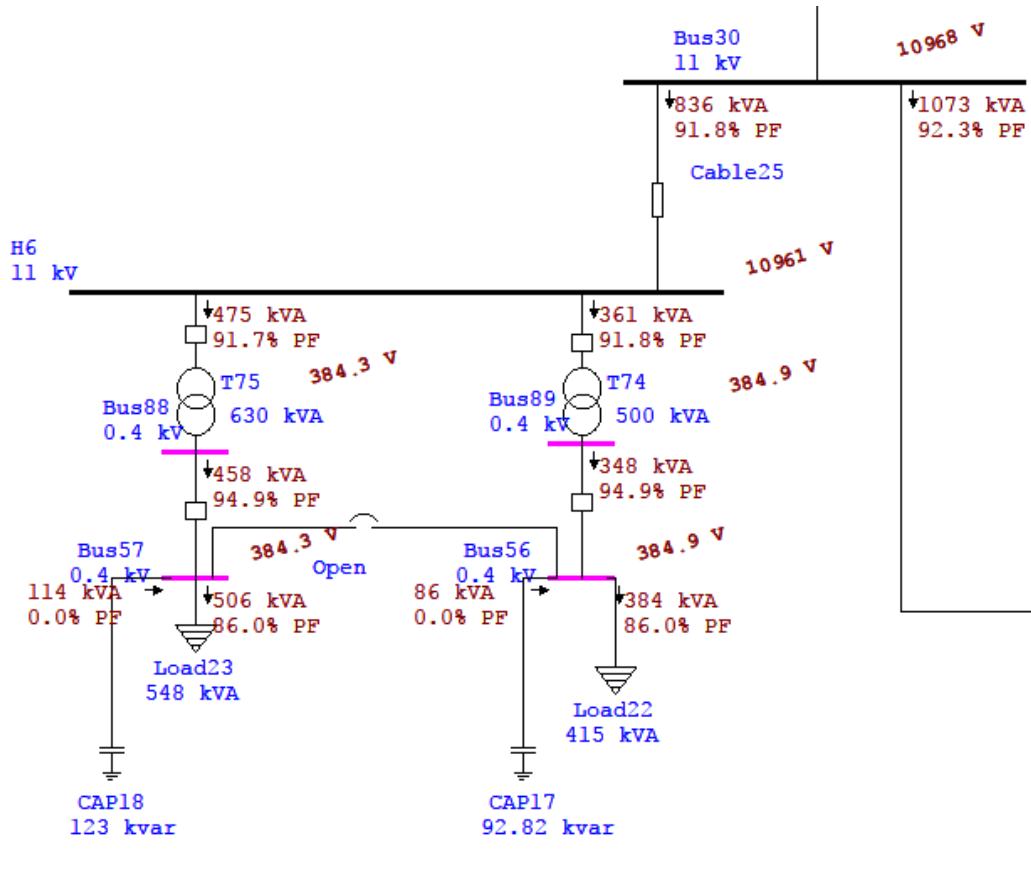


Figure 5.11: Fifth residential section in Etap

### 6) Sixth section

This section contains three transformers 11/0.4 kV, one of them is 500kVA rating and the other is 630kVA.

The type of cable that go from the ring to the section used is cooper XLPE with cross section area of 25mm<sup>2</sup>.



**Figure 5.12:** Sixth residential section in Etap

### 5.4 Reports and results

In order to reach the best results in simulations the process should go through several steps

- 1) Do the simulation without five and six sections, since they are not built now.
- 2) Do the simulation with five and six sections, in order to see the result for over all the network.

#### **5.4.1 Simulation without five and six sections**

Doing the simulation for the sections all over the city shows the details of voltage drop and power factor -there is no capacitor bank added-. After doing the simulation the observation results was low power factor, slightly voltage drop, which lead to a high power loss, the circuit and the results of this case, are illustrated in Appendix H.

To solve the previous problem, a capacitor bank at each distribution transformer in the sections added, after using capacitor bank the voltage drop decreased and the power factor improved, the results of this case is illustrated in Appendix I.

#### **5.4.2 Simulation with five and six sections**

Doing the simulation for the sections all over the city shows the details of voltage drop and power factor -there is no capacitor bank added-. After doing the simulation the observation results was low power factor, slightly voltage drop, which lead to a high power loss, the circuit and the results of this case, are illustrated in Appendix J.

To solve the previous problem, a capacitor bank at each distribution transformer in the sections added, after using capacitor bank the voltage drop decreased and the power factor improved, the results of this case is illustrated in Appendix K.

After adding sections five and six in to the simulation, the results of the simulation shows that the voltage drop and power factor does not affected by the load increasing, and that proved the efficiency of the chosen cables and the efficiency of over all design.

Taking the third section as a sample that under the effect –in case there was an effect - to compare the values of the power factor and the voltage near the load in this section before and after adding the fifth and sixth sections.

Figure 5.13 and 5.14 before and after adding the fifth and sixth sections respectively, the marked values in the red circles represent the power factor and the blue circles represent the voltage value near the loads. And all the values of power factor and the voltage almost the same, that means, the network is ready to accept increasing in the load according to the design.

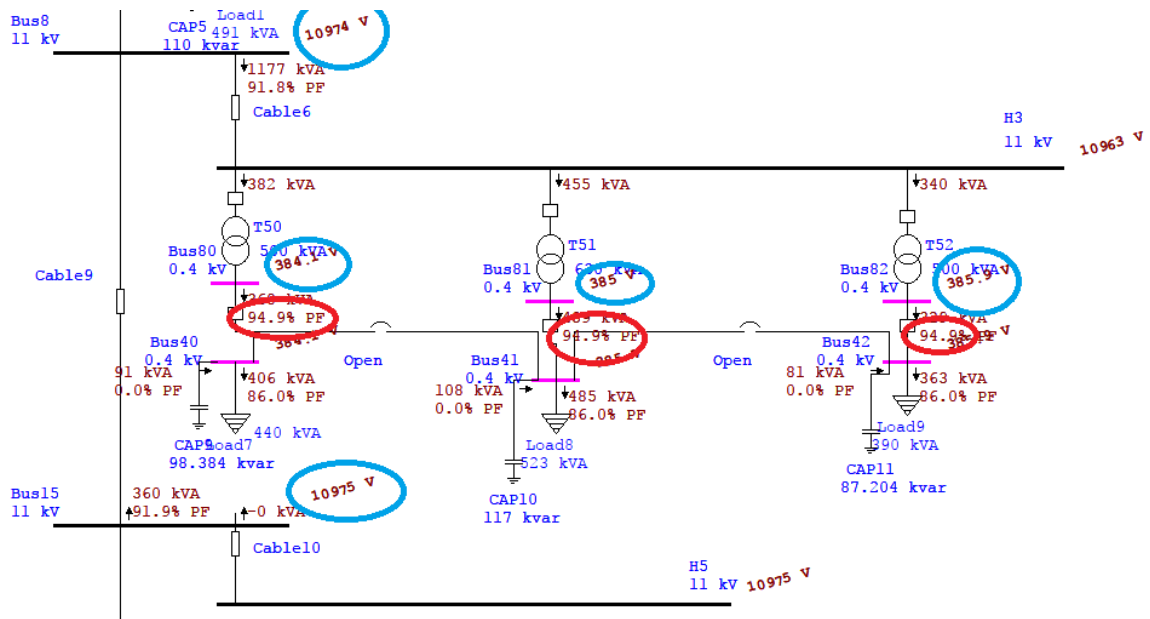


Figure 5.13: Third section before adding the load.

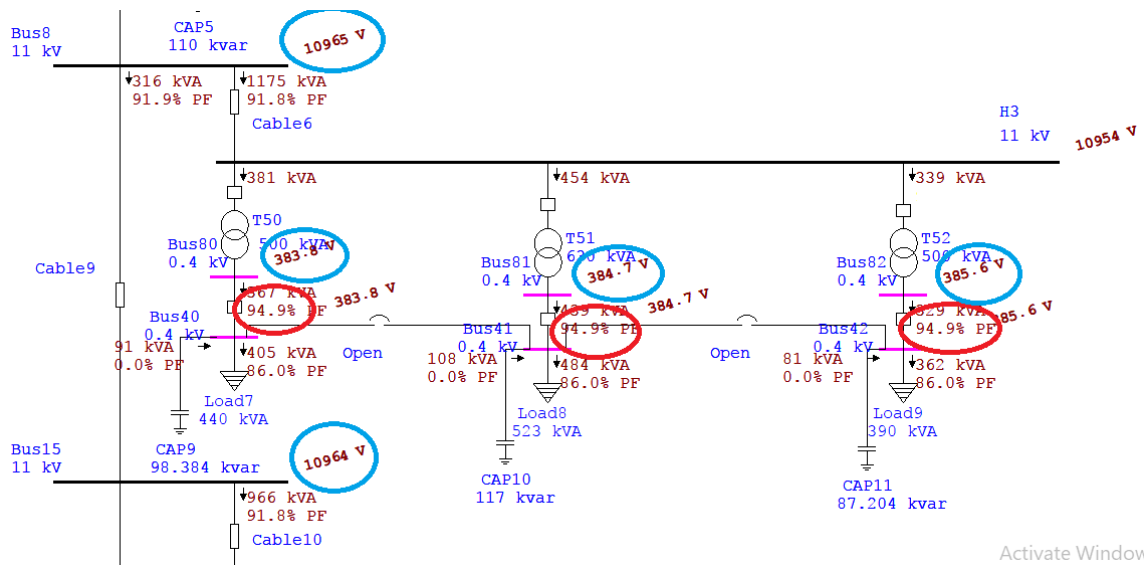


Figure 5.14: Third section after adding the load.

## 5.5 capacitor bank calculation

The main purpose of the capacitor bank is to pump the require kvar in to the network in order to increase the power factor.

A based on specific power factor correction table, the calculation done, the importance of these tables comes from the accuracy and speed of selecting the factor that requires in calculation.

The procedure of the calculation done as the following:

1. Identify the current power factor.
2. Select the desired power factor in the tables.
3. The intersection between the current and desired power factor in the table leads to a constant.
4. Use the constant that found in the previous step by multiplying it with the real power of the load of the transformer.
5. The result of the previous step is the value of the rated reactive power of the capacitor bank.

All the calculation that related to the distribution transformer is shown in appendix L.



## **Chapter Six**

### **Supervisory Control and Data Acquisition (SCADA) System**

#### **6.1 SCADA System Description**

#### **6.2 Functions of SCADA System**

#### **6.3 SCADA System Hardware and Software**

#### **6.4 SCADA System Software**

#### **6.5 Practical SCADA system**

## Chapter Six

### Supervisory Control and Data Acquisition (SCADA) System

#### 6.1 SCADA System Description.

SCADA (Supervisory Control and Data Acquisition) is a category of software application program for process control, the gathering of data in real time from remote locations in order to control equipment and conditions.

SCADA is used in power stations and substations as well as in oil and in gas refining, telecommunications, power distribution, energy management, transportation, and water and waste control[10].



**Figure 6.1:** SCADA System for Controlling and Monitoring

## **6.2 Functions of SCADA System:**

The SCADA system linked together the city's power options to use the most efficient power option to meet the power demands on the city municipal power system. The SCADA system is also used by neighboring communities to control their power systems.

SCADA system has many functions, and modern SCADA systems is responsible for the following controlling purposes, electrical circuit breaker control, load management, fault isolation and over current isolation.

In addition to the controlling, SCADA system is also responsible for the monitoring of the distribution system such as remote status (Digital), remote status (Analog), status sequence of events, analog sequence of events[10].

### **Advantages of SCADA system:**

- 1) The electrical network will become more flexible and controllable.
- 2) We can receive signals tell us if hazards occurred in the system.
- 3) Allow us to connect two or more electric systems together, and control them.
- 4) Allow us to monitoring and controlling the networks from far distances.

## **6.3 SCADA System Hardware**

### **6.3.1 Programmable Logic Control (PLC) Device:**

PLC is a solid-state device stands for Programmable Logic Control. The function of the PLC is to performs the various logic function previously accomplished by the devices such as electromechanical relays, switches for the control and operation of equipment. It is control system designed for the automation. The PLC is real computer in which it is capable of receiving data via inputs their sending

commands by its output Even though the electromechanical relay have served good for many generation, often under adverse condition, but the development of modern technology equipment's requires faster response, which electromechanical relays cannot offer.



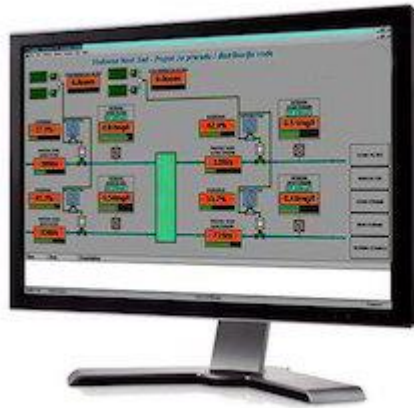
**Figure 6.2:** PLC Device

The Schneider PLC is using for the automation purposes because the simulation can be done without connecting the PLC. In the M340 PLC we can increase the number of input and output by increasing the number of racks.

A PLC can be programmed to sense, control and activate various equipment's. Thus, PLC includes a number of input output points, which allow interfacing of electrical, signals. First the input and output components are connected to PLC and then the control program is loaded onto PLC memory[11].

### **6.3.2 Personal Computer (PC):**

PC is the device by which the processed data is presented to the any person or operator. With the help of this processed data the person is monitor, control and interacts with the process. The PLC can transfer and collected and receive data from various devices by the use of programming through serial port.

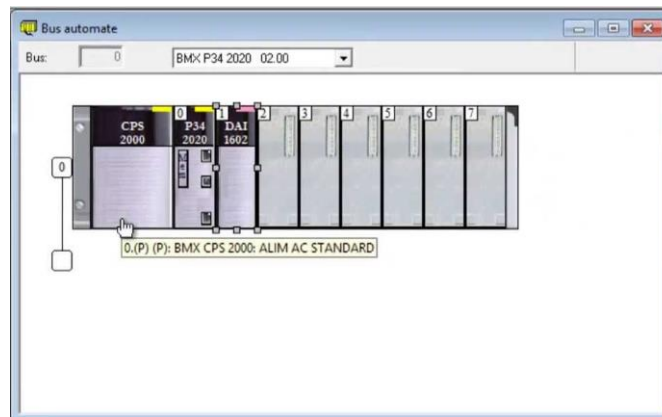


**Figure 6.3:** User interface

## 6.4 SCADA System Software

### 6.4.1 Unity Pro Program:

The software used for PLC System is the Unity-Pro Program where the Unity-Pro is connected with PLC-devices to download programs on it.



**Figure 6.4:** Unity Pro interface

### 6.4.2 Vijeo Citect Program:

This software used for SCADA System where the PLC is connected with it, we can Control and Monitoring Systems by this program for Huge factories and plants converting and distribution of electricity That needed to monitor and control every

moment, Vijeo Citect Program is Controls and monitors the long-distance up to a few kilometers while Unity Pro software used for Medium-sized factories and does not need long distances.



**Figure 6.5:** Vijeo Citect Program

## **6.5 Practical SCADA system.**

### **6.5.1 SCHNEIDER MODICON M340 PLC:**

We are using the Schneider PLC for the automation purposes because the simulation can be done without connecting the PLC.

In the M340 PLC we can increase the number of input and output by increasing the number of racks.

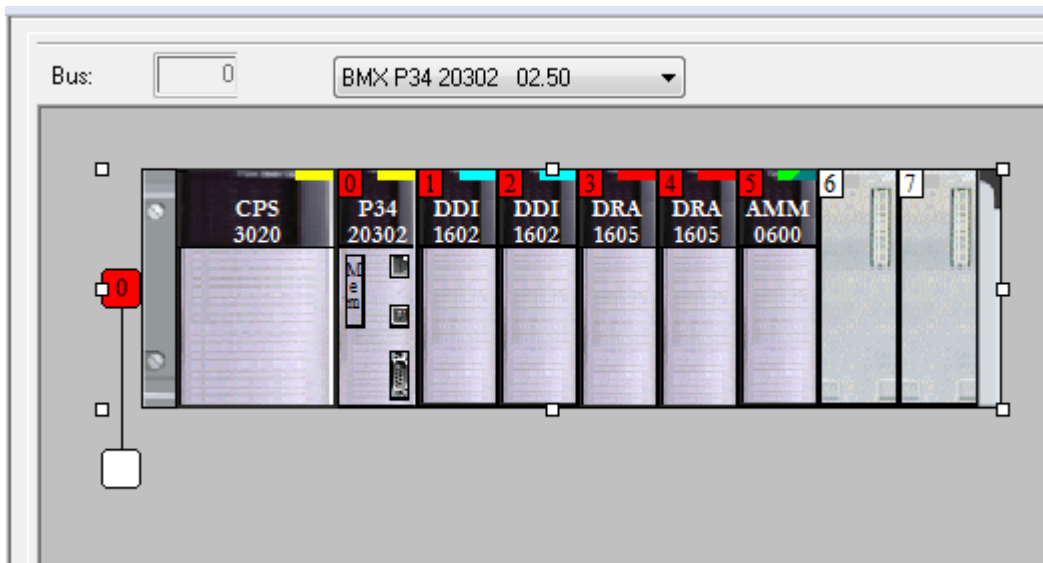
BMX P34 20302 Modicon M340 PLC

BDX DDI 1602 Discrete Inputs Module

BDX DRA 1605 Relay Outputs Module

BMX AMM 0600 Analog Inputs/Outputs module

First the input and output components are connected to PLC and then the control program is loaded onto PLC memory.



**Figure 6.6:** Unity Pro Practical configurations

### 6.5.2 Simulation

The PLC is programmed according to the network. The ST programming for PLC is being used for various operations and introduce in the thesis work.

```

CB_tie_point:=0;
if ( temp_sensor > 0.0 & temp_sensor < 6.1 & switch=1) then d:= 1;

if (V1_tie_point > 6.8 & V1_tie_point < 7.6 & d=1) then a:= 1;
else CB_tie_point:=0;
a:= 0;

end if;
if (V2_tie_point > 6.8 & V2_tie_point < 7.6 & d=1) then b:= 1;
else CB_tie_point:=0;
b:= 0;

end if;
if (V3_tie_point > 6.8 & V3_tie_point < 7.6 & d=1) then c:= 1;
else CB_tie_point:=0;
c:= 0;

end if;

if ((I1_tie_point = 0.0 or (I1_tie_point > 0.0 & I1_tie_point < 7.0)) & d=1) then aa:= 1;
else CB_tie_point:=0;
aa:= 0;

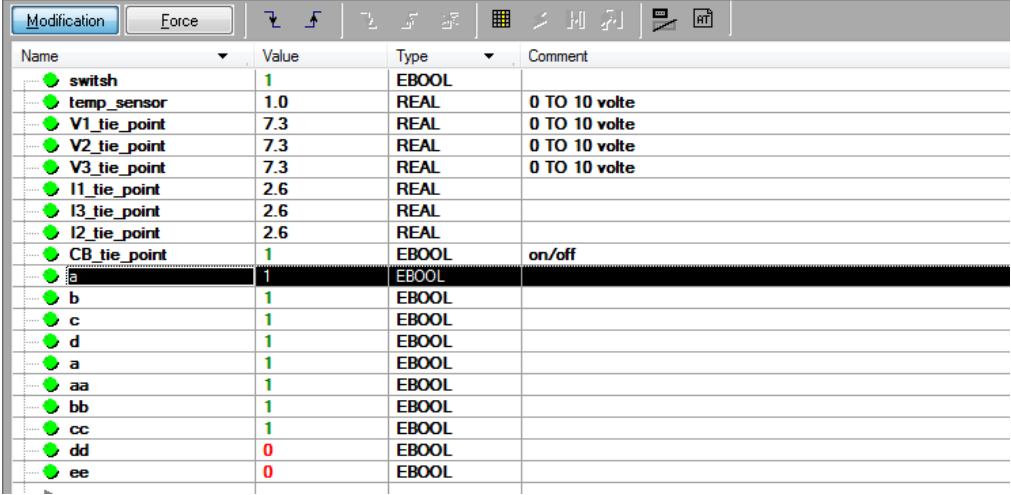
```

**Figure 6.7:** Unity Pro ST Programming language

The full code in appendix M.

### 6.5.3 Animation Tables

The animation table is used to display the values of the variables used in the programming. To run the program without connecting the PLC, the values of various parameters are forced into the animation table. With the help of these values we can run the project in the software part. The values of all the variables or the parameters are of real type or Boolean type values.



Name	Value	Type	Comment
switch	1	EBOOL	
temp_sensor	1.0	REAL	0 TO 10 volte
V1_tie_point	7.3	REAL	0 TO 10 volte
V2_tie_point	7.3	REAL	0 TO 10 volte
V3_tie_point	7.3	REAL	0 TO 10 volte
I1_tie_point	2.6	REAL	
I3_tie_point	2.6	REAL	
I2_tie_point	2.6	REAL	
CB_tie_point	1	EBOOL	on/off
a	1	EBOOL	
b	1	EBOOL	
c	1	EBOOL	
d	1	EBOOL	
a	1	EBOOL	
aa	1	EBOOL	
bb	1	EBOOL	
cc	1	EBOOL	
dd	0	EBOOL	
ee	0	EBOOL	

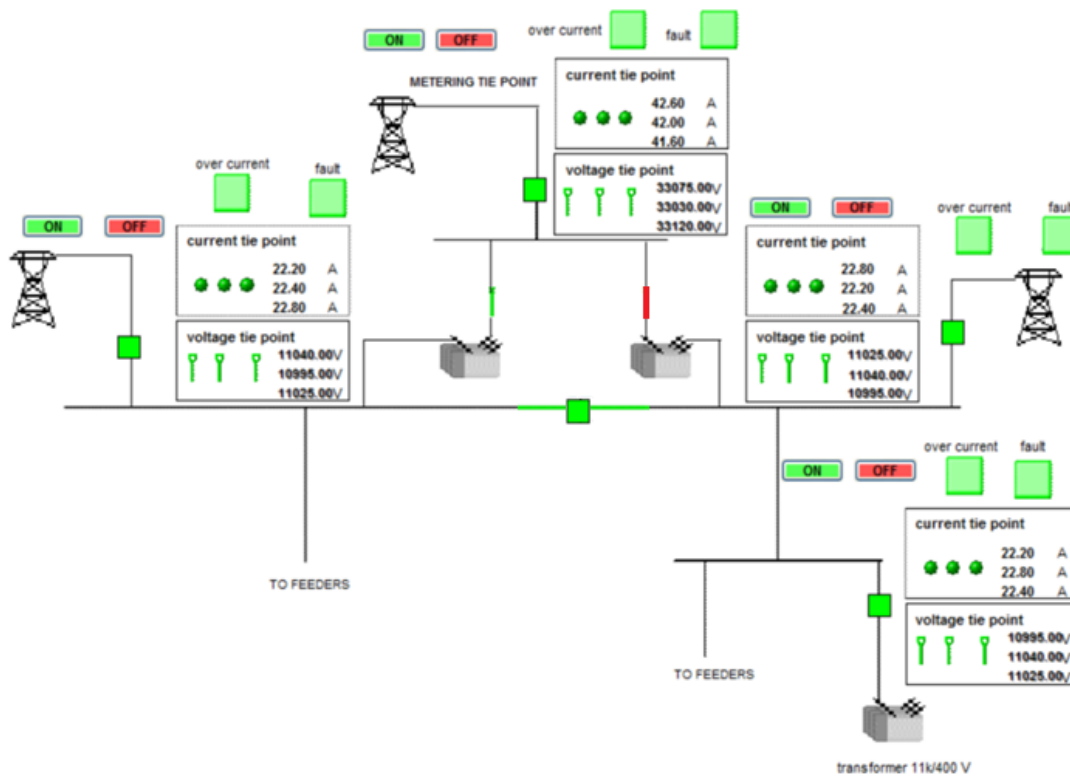
Figure 6.8: Animation Table

### 6.5.4 SCADA SCREEN

Vijeo citect software of SCADA is used for the online monitoring and control of various electrical parameters.

Figure 6.8 shows the main components of the measuring system in Rawabi city substation –Current transformer and Voltage transformer- readings that appears on the user interface , it also shows the main three tie points and the circuit breakers





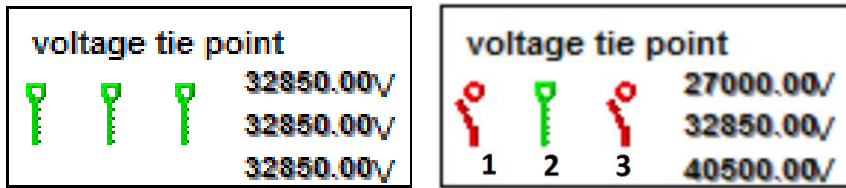
**Figure 6.9:** General form for Rawabi city substation in SCADA System

From this SCADA system, we can control with Push-buttons to switch it ON or to switch it OFF, the relays used for monitoring the Feeders loading and Main transformer loading.

In this project there are three tie points two of them are 11kV and the last one is 33kV, those tie points are tied to the substation with circuit breakers which are shown on the SCADA system interface, the circuit breakers can be switch ON and OFF by the push-button.

The first criteria to operate the circuit breaker is the temperature sensor, which used to measure the temperature of the switching components, so as long as the temperature under  $30C^0$  according to the IEC 60986:2000 standard.

The following figure show the state of three-phase voltage range, it's responsible for monitoring, in normal condition the voltage



**Figure 6.10:** Monitoring for three phase voltage

For the cases in figure 6.9:

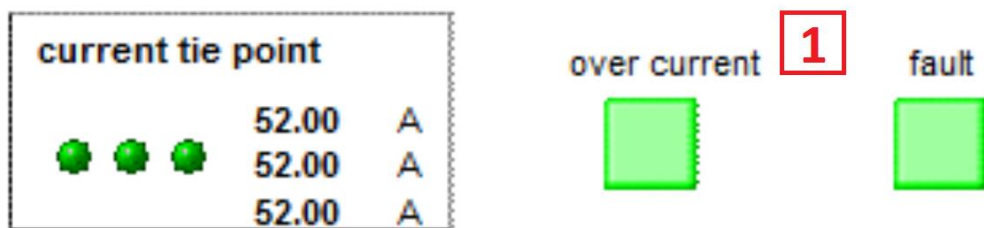
Case 1: Under voltage condition.

Case 2: Normal voltage condition.

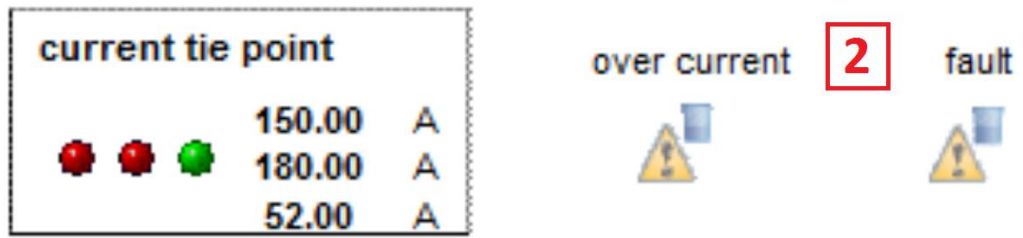
Case 3: Over voltage condition.

And finally, the measuring of current using current transformer in order to be measurable by the PLC Devices.

The following figures shows the difference between normal condition of operating system and the fault and over current condition



**Figure 6.11:** Normal condition



**Figure 6.12:** Fault and Over current condition

SCADA warns when conditions become hazardous by sounding alarms, SCADA system are successful multipurpose utility management and control tools. The state of art in SCADA has advance so rapidly, that even experienced utility engineers are not fully aware of all functions provide by SCADA.

## **Chapter Seven**

### **Conclusion and Recommendation**

#### **4.1 Introduction**

#### **4.2 Conclusion**

#### **4.3 Recommendation**

## Chapter Seven

### Conclusion and Recommendation

#### 7.1 Introduction.

After the discussion and calculation that has been made by our decision, and the sequences that led to the final design, there should be a conclusion and recommendation about the work that done, to make sure the success of the design and to provide a useful instructions for the future projects.

#### 7.2 Conclusion.

- 1) A complete Electrical Distribution System designed according to IEC standards.
- 2) Designing a suitable substation based on the three feeders that supplies the city, and the rating of the feeders are 11kV for two of them, 33kV for the third one.
- 3) A reliable distribution system designed by loop type primary feeder.
- 4) Delivering the electricity from the substation to the load achieved with high efficiency.
- 5) Simulation and analysis of the network done by using software ETAP program, and the result was sufficient.
- 6) Monitoring and controlling the network done by using SCADA system.
- 7) Using solar dependent street lighting improved the appearance of the city.
- 8) In order to decrease the losses on the transformers and achieve the reliability, the rated loading on the distribution transformer should be (75%\_89%).

- 9) Using Underground Cables reduce losses, because cable resistance is less twice than overhead line resistance.
- 10) All of sections has a Nominal voltage with acceptable voltage drop.
- 11) There are no overloaded conductors.
- 12) In order to improve the power factor a capacitor bank added alongside with the load.
- 13) The Load flow results show that the Power factor is from 94% to 95.1%.

### **7.3 Recommendation.**

#### **7.3.1 Recommendation for Electricity Company in Rawabi city**

1. Increase the number of transformers by use transformers with less capacity, which lead to increase the reliability of the network in case of disrupt any transformer.
2. In order to reduce the losses, replace the 11kv feeders with 33kv.

#### **7.3.2 Recommendation for our university**

1. Enforce relationship between the university and the governmental or private power sector, in order to facility collection data.
2. Change the Field Training system in the university to insure that power student can deal with medium voltage in training place.

## References

- [1] on-load tap-changers for power transformers, author Dr. Dieter Dohnal.
- [2] Bus Protection Considerations for Various Bus Types, Steven Chase, Thanh-Xuan Nguyen, Dereje Jada Hawaz, Jeff Pope, and Casper Labuschagne Schweitzer Engineering Laboratories, Inc.
- [3] ABB [Online] [Cited: October 10, 2017.] <http://new.abb.com/low-voltage/products/relay>
- [4] Metal-Clad Switchgear or Metal-Enclosed Switchgear: Which is it? , Powell Industries, Inc.
- [5] Keith Hill. Surge arresters and testing. Doble Engineering Company, 2004.
- [6] William H. Kersting. Distribution System Modeling and Analysis. CRC Press, 2001.
- [7] Electrical installation guide according to IEC international standards 2016, Schneider.
- [8] Etap. E-tap 7 Demo. E-tap web, 2008.
- [9] Electric Power Distribution Engineering, Turan Gonen, third edition.
- [10] Role of Controlling of Substation Using PLC And SCADA K.P. Satheyamoorthy.
- [11] Modicon M580 - ePac Controller - Ethernet Programmable Automation controller & Safety PLC
- [10] Rawabi [Online] [Cited: April 4, 2017.] <http://www.rawabi.ps/about.php>

[11] geomolge [Online] [Cited: November 11, 2017.] <http://www.geomolge.ps>

[12] Electrical installation guide according to IEC international standards  
2016, Schneider.

[13] Planning of electric power distribution technical principles, Siemens.



## **Appendix A**

Rawabi city map

## **Appendix B**

Buildings type and flats area

## Appendix B

### Buildings type and flats area

App. Type	Flat	Flat	Area of flat (M <sup>2</sup> )	Quantity of flats
T1	a- DB-F1	lower level	171.2	4
	a- DB-F1	Ground level	171.2	2
	a- DB-F1	Upper level	171.2	8
	b- DB-P	Parking	517.86	1
T2	a- DB-F1	lower level 1	171.2	2
	a- DB-F1	lower level 2	171.2	2
	a- DB-F1	Ground level	171.2	2
	a- DB-F1	Upper level	171.2	6
	b- DB-P	Parking	517.86	1
T3	a- DB-F1	lower level	171.2	2
	a- DB-F1	Ground level	171.2	2
	a- DB-F1	Upper level	171.2	10
	b- DB-P	Parking	517.86	1
T4	a- DB-F1	lower level	171.2	2
	a- DB-F1	Ground level	171.2	2
	a- DB-F1	Upper level	171.2	7
	a- DB-F2	Upper level	171.2	14
	b- DB-P	Parking	517.86	1
T5	a- DB-F1	lower level	171.2	4
	a- DB-F1	Ground level	171.2	2
	a- DB-F1	Upper level	171.2	6
	b- DB-P	Parking	517.86	1
1J	a- DB-F1	lower level 1	171.2	2
	a- DB-F1	lower level 2	171.2	2
	a- DB-F1	lower level 3	171.2	2
	a- DB-F1	Ground level	171.2	2
	a- DB-F1	Upper level	171.2	8
	b- DB-P	Parking	517.86	1

**Appendix C**  
**Buildings load**

# H1

Building No.	Building type	No. of flats	Area of flat (m2)	Demand factor (VA/m2)	P.F	Total building load (VA)
1	1j	16	171.2	90	0.86	246528
2	1j	16	171.2	90	0.86	246528
3	1j	16	171.2	90	0.86	246528
4	1j	16	171.2	90	0.86	246528
5	1j	16	171.2	90	0.86	246528
6	T2	12	171.2	90	0.86	184896
7	T2	12	171.2	90	0.86	184896
8	T2	12	171.2	90	0.86	184896
9	T1	14	171.2	90	0.86	215712
10	T4	25	171.2	90	0.86	385200
11	1j	16	171.2	90	0.86	246528
12	1j	16	171.2	90	0.86	246528
13	1j	16	171.2	90	0.86	246528
14	1j	16	171.2	90	0.86	246528
15	T1	14	171.2	90	0.86	215712
16	1j	16	171.2	90	0.86	246528
17	1j	16	171.2	90	0.86	246528
18	T3	14	171.2	90	0.86	215712
					sum =	4298832

Parking: Area of parking x No. of parking x Demand factor = (517.86 X 18 X 10) = 93.2148 KVA

Total sum = 4298.832 + 93.2148 = 4392.0468 KVA

Simultaneity factor = 0.4

Total load = Total sum x Simultaneity factor = 4392.0468 \* 0.4 = 1756.81872 KVA

## H2

Building No.	Building type	No. of flats	Area of flat (m2)	Demand factor (VA/m20)	P.F	Total building load (VA)
1	T3	14	171.2	90	0.86	215712
2	T3	14	171.2	90	0.86	215712
3	T2	12	171.2	90	0.86	184896
4	T2	12	171.2	90	0.86	184896
5	T3	14	171.2	90	0.86	215712
6	T3	14	171.2	90	0.86	215712
7	T2	12	171.2	90	0.86	184896
8	T2	12	171.2	90	0.86	184896
9	T1	14	171.2	90	0.86	215712
10	T1	14	171.2	90	0.86	215712
11	T4	25	171.2	90	0.86	385200
12	1j	16	171.2	90	0.86	246528
13	1j	16	171.2	90	0.86	246528
14	1j	16	171.2	90	0.86	246528
15	1j	16	171.2	90	0.86	246528
16	1j	16	171.2	90	0.86	246528
17	1j	16	171.2	90	0.86	246528
18	T1	14	171.2	90	0.86	215712
19	T3	14	171.2	90	0.86	215712
20	1j	16	171.2	90	0.86	246528
					sum =	4576176

Parking: Area of parking x No. of parking x Demand factor = (517.86 X 20 X 10) = 103.572

KVA

Total sum = 4679.748+ 103.572 = 4679.748 KVA

Simultaneity factor = 0.4

Total load = Total sum x Simultaneity factor = 4679.748 \* 0.4 = 1871.8992 KVA

### H3

Building No.	Building type	No. of flats	Area of flat (m <sup>2</sup> )	Demand factor (VA/m <sup>2</sup> 0)	P.F	Total building load (VA)
1	T3	14	171.2	90	0.86	215712
2	T3	14	171.2	90	0.86	215712
3	T2	12	171.2	90	0.86	184896
4	T2	12	171.2	90	0.86	184896
5	T3	14	171.2	90	0.86	215712
6	T1	14	171.2	90	0.86	215712
7	T1	14	171.2	90	0.86	215712
8	T5	12	171.2	90	0.86	184896
9	T3	14	171.2	90	0.86	215712
10	1j	16	171.2	90	0.86	246528
11	1j	16	171.2	90	0.86	246528
12	1j	16	171.2	90	0.86	246528
13	1j	16	171.2	90	0.86	246528
14	T3	14	171.2	90	0.86	215712
					sum =	3050784

Parking: Area of parking x No. of parking x Demand factor = (517.86 X 14 X 10) = 72.500 KVA

Total sum = 3050.784 + 72.500 = 3123.284 KVA

Simultaneity factor = 0.4

Total load = Total sum x Simultaneity factor = 3123.28 \* 0.4 = 1249.3136 KVA

#### H4

Building No.	Building type	No. of flats	Area of flat (m2)	Demand factor (VA/m20)	P.F	Total building load (VA)
1	T3	14	171.2	90	0.86	215712
2	T1	14	171.2	90	0.86	215712
3	T1	14	171.2	90	0.86	215712
4	T1	14	171.2	90	0.86	215712
5	T3	14	171.2	90	0.86	215712
6	T1	14	171.2	90	0.86	215712
7	T3	14	171.2	90	0.86	215712
8	T3	14	171.2	90	0.86	215712
9	T1	14	171.2	90	0.86	215712
10	T3	14	171.2	90	0.86	215712
11	1j	16	171.2	90	0.86	246528
12	1j	16	171.2	90	0.86	246528
13	1j	16	171.2	90	0.86	246528
14	1j	16	171.2	90	0.86	246528
15	T3	14	171.2	90	0.86	215712
					sum =	3358944

Parking: Area of parking x No. of parking x Demand factor = (517.86 X 15 X 10) = 77.679 KVA

Total sum = 3358.944 + 77.679 = 3436.623 KVA

Simultaneity factor = 0.4

Total load = Total sum x Simultaneity factor = 3436.623 \* 0.4 = 1374.6492 KVA



## H5

Building No.	Building type	No. of flats	Area of flat (m2)	Demand factor (VA/m20)	P.F	Total building load (VA)
1	T1	14	171.2	90	0.86	215712
2	T2	12	171.2	90	0.86	184896
3	T2	12	171.2	90	0.86	184896
4	T1	14	171.2	90	0.86	215712
5	T4	25	171.2	90	0.86	385200
6	T3	14	171.2	90	0.86	215712
7	T1	14	171.2	90	0.86	215712
8	T3	14	171.2	90	0.86	215712
9	T3	14	171.2	90	0.86	215712
10	1j	16	171.2	90	0.86	246528
12	1j	16	171.2	90	0.86	246528
13	T3	14	171.2	90	0.86	215712
					sum =	2758032

Parking: Area of parking x No. of parking x Demand factor = (517.86 X 13 X 10) = 67.321 KVA

Total sum = 2758.032 + 67.321 = 2825.353 KVA

Simultaneity factor = 0.4

Total load = Total sum x Simultaneity factor = 2825.353 \* 0.4 = 1130.1412 KVA

## H6

Building No.	Building type	No. of flats	Area of flat (m2)	Demand factor (VA/m20)	P.F	Total building load (VA)
1	T3	14	171.2	90	0.86	215712
2	T2	12	171.2	90	0.86	184896
3	T3	14	171.2	90	0.86	215712
4	T5	12	171.2	90	0.86	184896
5	T1	14	171.2	90	0.86	215712
6	T4	25	171.2	90	0.86	385200
7	1j	16	171.2	90	0.86	246528
8	1j	16	171.2	90	0.86	246528
9	1j	16	171.2	90	0.86	246528
10	T3	14	171.2	90	0.86	215712
					sum =	2357424

Parking: Area of parking x No. of parking x Demand factor = (517.86 X 10 X 10) = 51.786 KVA

Total sum = 2357.424 + 51.786 = 2409.210 KVA

Simultaneity factor = 0.4

Total load = Total sum x Simultaneity factor = 2409.210 \* 0.4 = 963.684 KVA

Total Residential Load = **8.34650592** MVA

## **Appendix D**

### **Distribution transformers**

	Transformer	Tr. name	Tr. Rated	Tr. buildings	loading
H1	T1	H1-T1-A5	630	2 – 6	78 %
	T2	H1-T2-B4	500	7 – 10	80 %
	T3	H1-T3-B4	500	11 – 14	80 %
	T4	H1-T4-A5	630	1 , 15 – 18	76 %
H2	T1	H2-T1-B5	500	2 – 6	83 %
	T2	H2-T2-A5	630	7 – 11	77 %
	T3	H2-T3-B4	500	12 – 15	81 %
	T4	H2-T4-A6	630	1 , 16 - 20	89 %
H3	T1	H3-T1-B5	500	1,2,8,9,10	88 %
	T2	H3-62-B5	630	3 – 7	83 %
	T3	H3-T3-B4	500	11 – 14	78 %
H4	T1	H4-T1-B5	500	1,2,8,9,10	88 %
	T2	H4-T2-B5	500	3 – 7	88 %
	T3	H4-T3-A5	630	11 – 15	78 %
H5	T1	H5-T1-A7	630	1 – 7	89 %
	T2	H5-T2-A6	630	8 – 13	88 %
H6	T1	H6-T1-B5	500	1 – 5	83 %
	T2	H6-T2-A5	630	6 – 10	87 %

**Appendix E**  
**Single line diagram**

**Appendix F**  
**Current calculation**

## Appendix F

### Current calculation

The current for the Residential and Stadium

$$I = \frac{MVA}{\sqrt{3} * KV} A$$

$$I = \frac{(8346+490)KVA}{\sqrt{3} * 11KV} = 464 A$$

The following calculations are for the six sections in Rawabi city

**For Section one (H1):**

$$I = \frac{(1757)KVA}{\sqrt{3} * 11KV} = 92 A$$

---

The current before the transformer (11Kv)

$$T1: I = \frac{(491)KVA}{\sqrt{3} * 11KV} = 25.8 A$$

The current after the transformer (0.4Kv)

$$T1: I = \frac{(491)KVA}{\sqrt{3} * 0.4KV} = 708 A$$

---

The current before the transformer (11Kv)

$$T2: I = \frac{(400)KVA}{\sqrt{3} * 11KV} = 20.9A$$

The current after the transformer (0.4Kv)

$$T2: I = \frac{(400)KVA}{\sqrt{3} * 0.4KV} = 577 A$$

The current before the transformer (11Kv)

$$T3: I = \frac{(400)KVA}{\sqrt{3} * 11KV} = 20.9 A$$

The current after the transformer (0.4Kv)

$$T3: I = \frac{(400)KVA}{\sqrt{3} * 0.4KV} = 577 A$$

---

The current before the transformer (11Kv)

$$T4: I = \frac{(479)KVA}{\sqrt{3} * 11KV} = 25.2 A$$

The current after the transformer (0.4Kv)

$$T4: I = \frac{(479)KVA}{\sqrt{3} \cdot 0.4KV} = 691 \text{ A}$$

---

**For Section two (H2):**

$$I = \frac{(1872)KVA}{\sqrt{3} \cdot 11KV} = 98.3 \text{ A}$$

---

The current before the transformer (11Kv)

$$T1: I = \frac{(415)KVA}{\sqrt{3} \cdot 11KV} = 21.7 \text{ A}$$

The current after the transformer (0.4Kv)

$$T1: I = \frac{(415)KVA}{\sqrt{3} \cdot 0.4KV} = 600 \text{ A}$$

---

The current before the transformer (11Kv)

$$T2: I = \frac{(485)KVA}{\sqrt{3} \cdot 11KV} = 25.5 \text{ A}$$

The current after the transformer (0.4Kv)

$$T2: I = \frac{(485)KVA}{\sqrt{3} \cdot 0.4KV} = 700 \text{ A}$$

---

The current before the transformer (11Kv)

$$T3: I = \frac{(405)KVA}{\sqrt{3} \cdot 11KV} = 21.3 \text{ A}$$

The current after the transformer (0.4Kv)

$$T3: I = \frac{(405)KVA}{\sqrt{3} \cdot 0.4KV} = 585 \text{ A}$$

---

The current before the transformer (11Kv)

$$T4: I = \frac{(560)KVA}{\sqrt{3} \cdot 11KV} = 29.5 \text{ A}$$

The current after the transformer (0.4Kv)

$$T4: I = \frac{(560)KVA}{\sqrt{3} \cdot 0.4KV} = 809 \text{ A}$$



**For Section three (H3):**

$$I = \frac{(1249)KVA}{\sqrt{3} * 11KV} = 65.5 \text{ A}$$

---

The current before the transformer (11Kv)

$$T1: I = \frac{(440)KVA}{\sqrt{3} * 11KV} = 23 \text{ A}$$

The current after the transformer (0.4Kv)

$$T1: I = \frac{(440)KVA}{\sqrt{3} * 0.4KV} = 635 \text{ A}$$

---

The current before the transformer (11Kv)

$$T2: I = \frac{(523)KVA}{\sqrt{3} * 11KV} = 27.5 \text{ A}$$

The current after the transformer (0.4Kv)

$$T2: I = \frac{(523)KVA}{\sqrt{3} * 0.4KV} = 755 \text{ A}$$

---

The current before the transformer (11Kv)

$$T3: I = \frac{(390)KVA}{\sqrt{3} * 11KV} = 20.5 \text{ A}$$

The current after the transformer (0.4Kv)

$$T3: I = \frac{(390)KVA}{\sqrt{3} * 0.4KV} = 563 \text{ A}$$

---

**For Section four (H4):**

$$I = \frac{(1375)KVA}{\sqrt{3} * 11KV} = 72.2 \text{ A}$$

---

The current before the transformer (11Kv)

$$T1: I = \frac{(440)KVA}{\sqrt{3} * 11KV} = 23 \text{ A}$$

The current after the transformer (0.4Kv)

$$T1: I = \frac{(440)KVA}{\sqrt{3} * 0.4KV} = 635 \text{ A}$$

The current before the transformer (11Kv)

$$T2: I = \frac{(440)KVA}{\sqrt{3} * 11KV} = 23 \text{ A}$$

The current after the transformer (0.4Kv)

$$T2: I = \frac{(440)KVA}{\sqrt{3} * 0.4KV} = 635 \text{ A}$$

---

The current before the transformer (11Kv)

$$T3: I = \frac{(491)KVA}{\sqrt{3} * 11KV} = 25.8 \text{ A}$$

The current after the transformer (0.4Kv)

$$T3: I = \frac{(491)KVA}{\sqrt{3} * 0.4KV} = 709 \text{ A}$$

---

**For Section five (H5):**

$$I = \frac{(1130)KVA}{\sqrt{3} * 11KV} = 59.3 \text{ A}$$

---

The current before the transformer (11Kv)

$$T1: I = \frac{(560)KVA}{\sqrt{3} * 11KV} = 29.4 \text{ A}$$

The current after the transformer (0.4Kv)

$$T1: I = \frac{(560)KVA}{\sqrt{3} * 0.4KV} = 809 \text{ A}$$

---

The current before the transformer (11Kv)

$$T2: I = \frac{(555)KVA}{\sqrt{3} * 11KV} = 29.1 \text{ A}$$

The current after the transformer (0.4Kv)

$$T2: I = \frac{(555)KVA}{\sqrt{3} * 0.4KV} = 800 \text{ A}$$

---

**For Section six (H6):**

$$I = \frac{(964)KVA}{\sqrt{3} * 11KV} = 51 \text{ A}$$

---

The current before the transformer (11Kv)

$$T1: I = \frac{(415)KVA}{\sqrt{3} \cdot 11KV} = 21.8 \text{ A}$$

The current after the transformer (0.4Kv)

$$T1: I = \frac{(415)KVA}{\sqrt{3} \cdot 0.4KV} = 600 \text{ A}$$

---

The current before the transformer (11Kv)

$$T2: I = \frac{(548)KVA}{\sqrt{3} \cdot 11KV} = 28.8 \text{ A}$$

The current after the transformer (0.4Kv)

$$T2: I = \frac{(548)KVA}{\sqrt{3} \cdot 0.4KV} = 791 \text{ A}$$

---

### **Stadium and amphitheater**

The current before the transformer (11Kv)

$$I = \frac{(490)KVA}{\sqrt{3} \cdot 11KV} = 26 \text{ A}$$

The current after the transformer (0.4Kv)

$$I = \frac{(490)KVA}{\sqrt{3} \cdot 0.4KV} = 708 \text{ A}$$

$$I_{\text{stadium}} = \frac{(210)KVA}{\sqrt{3} \cdot 0.4KV} = 303 \text{ A}$$

$$I_{\text{Amphitheater}} = \frac{(280)KVA}{\sqrt{3} \cdot 0.4KV} = 405 \text{ A}$$

### For commercial load

Total load = 4500 KVA

We use two cables with the same capacity  $4500/2 = 2250$  KVA

$$I_1 = I_2 = \frac{(2250) \text{KVA}}{\sqrt{3} * 33 \text{KV}} = 39.36 \text{ A}$$

The current before the transformer (33KV)

$$I = \frac{(750) \text{KVA}}{\sqrt{3} * 33 \text{KV}} = 13.2 \text{ A}$$

The current after the transformer (0.4KV)

$$T1: I = \frac{(750) \text{KVA}}{\sqrt{3} * 0.4 \text{KV}} = 1083$$

And so on for the other commercial load transformer due to the similarity

## **Appendix G**

### **Cables characteristics**

## Appendix G

### Cables characteristics

Area	Location	Current (A)	Cross Sectional Area (mm <sup>2</sup> )	Length of Cable (m)
<b>Main Road</b>	From substation around all sections	464	240	2230
<b>H1</b>	Form RMU to H1 joint point	92	16	205
	From joint point to T1	25.8	6	120
	From joint point to T2	20.9	6	120
	From joint point to T3	20.9	6	120
	From joint point to T4	25.2	6	50
<b>H2</b>	Form RMU to H2 joint point	98.2	16	145
	From joint point to T1	21.7	6	120
	From joint point to T2	25.5	6	80
	From joint point to T3	21.3	6	120
	From joint point to T4	29.5	6	120
<b>H3</b>	Form RMU to H3 joint point	65.9	16	115
	From joint point to T1	23	6	80

	From joint point to T2	27.5	6	55
	From joint point to T3	20.5	6	55
<b>H4</b>	Form RMU to H4 joint point	72.2	16	125
	From joint point to T1	23	6	80
	From joint point to T2	23	6	55
	From joint point to T3	25.8	6	20
<b>H5</b>	Form RMU to H5 joint point	59.3	16	45
	From joint point to T1	29.4	6	5
	From joint point to T2	29.1	6	80
<b>H6</b>	Form RMU to H6 joint point	51	16	105
	From joint point to T1	21.8	6	5
	From joint point to T2	28.2	6	30
<b>Amphitheater And Stadium</b>	From RMU to Transformer	26	16	700
	From T to Amphitheater	405	120	100
	From T to Stadium	303	90	100
<b>Commercial</b>	From substation to commercial left side joint point	39.36	16	725

	From substation to commercial right side joint point	39.36	16	625
	From joint point to T1 <sub>c</sub>	13.12	16	40
	From joint point to T2 <sub>c</sub>	13.12	16	40
	From joint point to T3 <sub>c</sub>	13.12	16	40
	From joint point to T4 <sub>c</sub>	13.12	16	40
	From joint point to T5 <sub>c</sub>	13.12	16	40
	From joint point to T6 <sub>c</sub>	13.12	16	40



## **Appendix H**

**The network of Rawabi city in Etap without five and six sections before adding the capacitor bank**

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 1  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

**LOAD FLOW REPORT**

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
* Bus1	33.000	100.000	0.0	3.707	2.263	0	0	Bus25	1.716	1.045	35.2	85.4	
								Bus9	1.991	1.218	40.8	85.3	
								Bus3	0.000	0.000	0.0	0.0	
* Bus3	11.000	100.000	0.0	3.418	2.077	0	0	Bus23	3.418	2.077	209.9	85.5	
								Bus1	0.000	0.000	0.0	0.0	
* Bus4	11.000	100.000	0.0	2.236	1.354	0	0	Bus5	2.236	1.354	137.2	85.5	
Bus5	11.000	99.748	-0.1	0	0	0	0	Bus4	-2.232	-1.355	137.4	85.5	
								Bus8	0.773	0.467	47.5	85.6	
								H1	1.458	0.888	89.8	85.4	
Bus8	11.000	99.723	-0.1	0	0	0	0	Bus5	-0.773	-0.469	47.6	85.5	
								H3	1.113	0.680	68.7	85.3	
								Bus15	-0.340	-0.211	21.1	84.9	
Bus9	33.000	99.956	0.0	0	0	0	0	Bus1	-1.990	-1.237	41.0	84.9	
								Bus11	1.372	0.850	28.3	85.0	
								Bus60	0.618	0.388	12.8	84.7	
Bus11	33.000	99.949	0.0	0	0	0	0	Bus9	-1.372	-0.854	28.3	84.9	
								Bus14	0.755	0.467	15.5	85.1	
								Bus62	0.618	0.388	12.8	84.7	
Bus14	33.000	99.945	0.0	0	0	0	0	Bus11	-0.755	-0.471	15.6	84.8	
								Bus63	0.617	0.388	12.8	84.7	
								Bus31	0.137	0.084	2.8	85.3	
Bus15	11.000	99.740	-0.1	0	0	0	0	Bus8	0.340	0.208	21.0	85.3	
								H5	0.000	0.000	0.0	0.0	
								Bus32	-0.340	-0.208	21.0	85.3	
Bus23	11.000	99.854	0.0	0	0	0	0	Bus3	-3.414	-2.074	210.0	85.5	
								H2	1.540	0.942	94.9	85.3	
								Bus27	1.874	1.132	115.1	85.6	
Bus25	33.000	99.953	0.0	0	0	0	0	Bus1	-1.715	-1.070	35.4	84.9	
								Bus29	1.098	0.682	22.6	84.9	
								Bus65	0.618	0.388	12.8	84.7	
Bus27	11.000	99.781	-0.1	0	0	0	0	Bus23	-1.873	-1.133	115.2	85.6	
								H4	1.128	0.690	69.6	85.3	
								Bus30	0.745	0.443	45.6	85.9	
Bus29	33.000	99.947	0.0	0	0	0	0	Bus25	-1.098	-0.687	22.7	84.8	
								Bus31	0.480	0.299	9.9	84.9	
								Bus67	0.618	0.388	12.8	84.7	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 2  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus30	11.000	99.766	-0.1	0	0	0	0	Bus27	-0.745	-0.445	45.6	85.9	
								H6	0.000	-0.001	0.0	0.0	
								Bus32	0.745	0.445	45.7	85.8	
Bus31	33.000	99.945	0.0	0	0	0	0	Bus29	-0.480	-0.304	9.9	84.5	
								Bus68	0.617	0.388	12.8	84.7	
								Bus14	-0.137	-0.084	2.8	85.3	
Bus32	11.000	99.752	-0.1	0	0	0	0	Bus33	0.404	0.241	24.8	85.9	
								Bus30	-0.745	-0.446	45.7	85.8	
								Bus15	0.340	0.206	20.9	85.6	
Bus33	11.000	99.717	-0.1	0	0	0	0	Bus32	-0.404	-0.247	24.9	85.3	
								Bus90	0.404	0.247	24.9	85.3	
Bus34	0.400	96.777	-0.8	0	0	0.395	0.235	Bus76	-0.395	-0.235	685.9	86.0	
Bus35	0.400	96.988	-0.8	0	0	0.396	0.235	Bus90	-0.396	-0.235	686.0	86.0	
Bus37	0.400	96.707	-0.8	0	0	0.322	0.191	Bus77	-0.322	-0.191	558.3	86.0	
Bus38	0.400	96.707	-0.8	0	0	0.322	0.191	Bus78	-0.322	-0.191	558.3	86.0	
Bus39	0.400	96.842	-0.7	0	0	0.386	0.229	Bus79	-0.386	-0.229	669.5	86.0	
Bus40	0.400	96.545	-0.9	0	0	0.353	0.209	Bus80	-0.353	-0.209	613.1	86.0	
Bus41	0.400	96.714	-0.8	0	0	0.421	0.250	Bus81	-0.421	-0.250	730.1	86.0	
Bus42	0.400	96.885	-0.8	0	0	0.315	0.187	Bus82	-0.315	-0.187	545.4	86.0	
Bus45	0.400	96.888	-0.8	0	0	0.335	0.199	Bus72	-0.335	-0.199	580.4	86.0	
Bus46	0.400	97.094	-0.8	0	0	0.393	0.233	Bus73	-0.393	-0.233	679.7	86.0	
Bus47	0.400	96.957	-0.8	0	0	0.327	0.194	Bus74	-0.327	-0.194	566.8	86.0	
Bus50	0.400	96.682	-0.9	0	0	0.451	0.268	Bus75	-0.451	-0.268	782.9	86.0	
Bus53	0.400	96.590	-0.9	0	0	0.353	0.209	Bus85	-0.353	-0.209	613.4	86.0	
Bus54	0.400	96.590	-0.9	0	0	0.353	0.209	Bus84	-0.353	-0.209	613.4	86.0	
Bus55	0.400	96.933	-0.8	0	0	0.397	0.235	Bus83	-0.397	-0.235	687.0	86.0	
Bus60	0.400	97.273	-1.4	0	0	0.610	0.362	Bus9	-0.610	-0.362	1053.0	86.0	
Bus62	0.400	97.266	-1.4	0	0	0.610	0.362	Bus11	-0.610	-0.362	1052.9	86.0	
Bus63	0.400	97.262	-1.4	0	0	0.610	0.362	Bus14	-0.610	-0.362	1052.9	86.0	
Bus65	0.400	97.270	-1.4	0	0	0.610	0.362	Bus25	-0.610	-0.362	1053.0	86.0	
Bus67	0.400	97.264	-1.4	0	0	0.610	0.362	Bus29	-0.610	-0.362	1052.9	86.0	
Bus68	0.400	97.262	-1.4	0	0	0.610	0.362	Bus31	-0.610	-0.362	1052.9	86.0	
Bus72	0.400	96.888	-0.8	0	0	0	0	H2	-0.335	-0.199	580.4	86.0	
								Bus45	0.335	0.199	580.4	86.0	
Bus73	0.400	97.094	-0.8	0	0	0	0	H2	-0.393	-0.233	679.7	86.0	
								Bus46	0.393	0.233	679.7	86.0	
Bus74	0.400	96.957	-0.8	0	0	0	0	H2	-0.327	-0.194	566.8	86.0	
								Bus47	0.327	0.194	566.8	86.0	
Bus75	0.400	96.682	-0.9	0	0	0	0	H2	-0.451	-0.268	782.9	86.0	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 3  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus50	0.451	0.268	782.9	86.0	
Bus76	0.400	96.777	-0.8	0	0	0	0	H1	-0.395	-0.235	685.9	86.0	
								Bus34	0.395	0.235	685.9	86.0	
Bus77	0.400	96.707	-0.8	0	0	0	0	H1	-0.322	-0.191	558.3	86.0	
								Bus37	0.322	0.191	558.3	86.0	
Bus78	0.400	96.707	-0.8	0	0	0	0	H1	-0.322	-0.191	558.3	86.0	
								Bus38	0.322	0.191	558.3	86.0	
Bus79	0.400	96.842	-0.7	0	0	0	0	H1	-0.386	-0.229	669.5	86.0	
								Bus39	0.386	0.229	669.5	86.0	
Bus80	0.400	96.545	-0.9	0	0	0	0	H3	-0.353	-0.209	613.1	86.0	
								Bus40	0.353	0.209	613.1	86.0	
Bus81	0.400	96.714	-0.8	0	0	0	0	H3	-0.421	-0.250	730.1	86.0	
								Bus41	0.421	0.250	730.1	86.0	
Bus82	0.400	96.885	-0.8	0	0	0	0	H3	-0.315	-0.187	545.4	86.0	
								Bus42	0.315	0.187	545.4	86.0	
Bus83	0.400	96.933	-0.8	0	0	0	0	H4	-0.397	-0.235	687.0	86.0	
								Bus55	0.397	0.235	687.0	86.0	
Bus84	0.400	96.590	-0.9	0	0	0	0	H4	-0.353	-0.209	613.4	86.0	
								Bus54	0.353	0.209	613.4	86.0	
Bus85	0.400	96.590	-0.9	0	0	0	0	H4	-0.353	-0.209	613.4	86.0	
								Bus53	0.353	0.209	613.4	86.0	
Bus90	0.400	96.988	-0.8	0	0	0	0	Bus33	-0.396	-0.235	686.0	86.0	
								Bus35	0.396	0.235	686.0	86.0	
H1	11.000	99.506	0.0	0	0	0	0	Bus5	-1.454	-0.889	89.9	85.3	
								Bus76	0.403	0.247	24.9	85.3	
								Bus77	0.328	0.201	20.3	85.3	
								Bus78	0.328	0.201	20.3	85.3	
								Bus79	0.394	0.241	24.3	85.3	
H2	11.000	99.798	0.0	0	0	0	0	Bus23	-1.539	-0.942	94.9	85.3	
								Bus72	0.342	0.210	21.1	85.3	
								Bus73	0.401	0.245	24.7	85.3	
								Bus74	0.334	0.205	20.6	85.3	
								Bus75	0.461	0.283	28.5	85.2	
H3	11.000	99.619	0.0	0	0	0	0	Bus8	-1.112	-0.681	68.7	85.3	
								Bus80	0.361	0.221	22.3	85.2	
								Bus81	0.430	0.263	26.5	85.3	
								Bus82	0.321	0.196	19.8	85.3	
H4	11.000	99.667	0.0	0	0	0	0	Bus27	-1.127	-0.690	69.6	85.3	
								Bus85	0.361	0.222	22.3	85.2	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 4  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus84	0.361	0.222	22.3	85.2	
								Bus83	0.405	0.247	25.0	85.3	
H5	11.000	99.740	-0.1	0	0	0	0	Bus15	0.000	0.000	0.0	0.0	
H6	11.000	99.766	-0.1	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	

\* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than 0.1 MVA

## **Appendix I**

**The network of Rawabi city in Etap without five and six sections after adding the capacitor bank**

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 1  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

**LOAD FLOW REPORT**

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
* Bus1	33.000	100.000	0.0	3.758	1.303	0	0	Bus25	1.740	0.601	32.2	94.5	
								Bus9	2.018	0.702	37.4	94.4	
								Bus3	0.000	0.000	0.0	0.0	
* Bus3	11.000	100.000	0.0	3.442	1.212	0	0	Bus23	3.442	1.212	191.5	94.3	
								Bus1	0.000	0.000	0.0	0.0	
* Bus4	11.000	100.000	0.0	2.245	0.799	0	0	Bus5	2.245	0.799	125.1	94.2	
Bus5	11.000	99.794	-0.1	0	0	0	0	Bus4	-2.241	-0.801	125.2	94.2	
								Bus8	0.785	0.262	43.5	94.9	
								H1	1.457	0.540	81.7	93.8	
Bus8	11.000	99.774	-0.1	0	0	0	0	Bus5	-0.785	-0.264	43.5	94.8	
								H3	1.123	0.396	62.6	94.3	
								Bus15	-0.338	-0.132	19.1	93.1	
Bus9	33.000	99.958	0.0	0	0	0	0	Bus1	-2.017	-0.722	37.5	94.2	
								Bus11	1.391	0.494	25.8	94.2	
								Bus60	0.626	0.228	11.7	94.0	
Bus11	33.000	99.952	0.0	0	0	0	0	Bus9	-1.391	-0.499	25.9	94.1	
								Bus14	0.765	0.271	14.2	94.3	
								Bus62	0.626	0.228	11.7	94.0	
Bus14	33.000	99.948	0.0	0	0	0	0	Bus11	-0.765	-0.276	14.2	94.1	
								Bus63	0.626	0.228	11.7	94.0	
								Bus31	0.139	0.048	2.6	94.5	
Bus15	11.000	99.787	-0.1	0	0	0	0	Bus8	0.338	0.129	19.1	93.4	
								H5	0.000	0.000	0.0	0.0	
								Bus32	-0.338	-0.129	19.1	93.4	
Bus23	11.000	99.880	0.0	0	0	0	0	Bus3	-3.439	-1.210	191.6	94.3	
								H2	1.553	0.549	86.6	94.3	
								Bus27	1.886	0.661	105.0	94.4	
Bus25	33.000	99.956	0.0	0	0	0	0	Bus1	-1.739	-0.625	32.3	94.1	
								Bus29	1.113	0.398	20.7	94.2	
								Bus65	0.626	0.228	11.7	94.0	
Bus27	11.000	99.821	-0.1	0	0	0	0	Bus23	-1.885	-0.662	105.1	94.4	
								H4	1.139	0.401	63.5	94.3	
								Bus30	0.747	0.261	41.6	94.4	
Bus29	33.000	99.950	0.0	0	0	0	0	Bus25	-1.113	-0.402	20.7	94.0	
								Bus31	0.487	0.175	9.1	94.1	
								Bus67	0.626	0.228	11.7	94.0	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 2  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus30	11.000	99.809	-0.1	0	0	0	0	Bus27	-0.747	-0.262	41.6	94.4	
								H6	0.000	-0.001	0.0	0.0	
								Bus32	0.747	0.263	41.6	94.3	
Bus31	33.000	99.948	0.0	0	0	0	0	Bus29	-0.487	-0.179	9.1	93.8	
								Bus68	0.626	0.228	11.7	94.0	
								Bus14	-0.139	-0.048	2.6	94.5	
Bus32	11.000	99.798	-0.1	0	0	0	0	Bus33	0.408	0.137	22.6	94.8	
								Bus30	-0.747	-0.264	41.6	94.3	
								Bus15	0.339	0.127	19.0	93.6	
Bus33	11.000	99.770	-0.1	0	0	0	0	Bus32	-0.408	-0.143	22.7	94.3	
								Bus90	0.408	0.143	22.7	94.3	
Bus34	0.400	96.372	-4.7	0	0	0.392	0.131	Bus76	-0.392	-0.131	619.1	94.9	
Bus35	0.400	97.585	-1.1	0	0	0.401	0.133	Bus90	-0.401	-0.133	625.5	94.9	
Bus37	0.400	97.317	-1.1	0	0	0.326	0.109	Bus77	-0.326	-0.109	509.3	94.9	
Bus38	0.400	97.317	-1.1	0	0	0.326	0.109	Bus78	-0.326	-0.109	509.3	94.9	
Bus39	0.400	97.427	-1.0	0	0	0.391	0.130	Bus79	-0.391	-0.130	610.7	94.9	
Bus40	0.400	97.206	-1.2	0	0	0.358	0.119	Bus80	-0.358	-0.119	559.6	94.9	
Bus41	0.400	97.344	-1.1	0	0	0.426	0.142	Bus81	-0.426	-0.142	666.1	94.9	
Bus42	0.400	97.482	-1.0	0	0	0.319	0.106	Bus82	-0.319	-0.106	497.5	94.9	
Bus45	0.400	97.495	-1.1	0	0	0.339	0.113	Bus72	-0.339	-0.113	529.4	94.9	
Bus46	0.400	97.659	-1.0	0	0	0.398	0.133	Bus73	-0.398	-0.133	619.9	94.8	
Bus47	0.400	97.550	-1.1	0	0	0.331	0.110	Bus74	-0.331	-0.110	516.9	94.9	
Bus50	0.400	97.325	-1.1	0	0	0.457	0.153	Bus75	-0.457	-0.153	714.6	94.8	
Bus53	0.400	97.243	-1.2	0	0	0.358	0.119	Bus85	-0.358	-0.119	559.8	94.9	
Bus54	0.400	97.243	-1.2	0	0	0.358	0.119	Bus84	-0.358	-0.119	559.8	94.9	
Bus55	0.400	97.522	-1.0	0	0	0.402	0.134	Bus83	-0.402	-0.134	626.4	94.9	
Bus60	0.400	98.040	-1.6	0	0	0.620	0.206	Bus9	-0.620	-0.206	962.0	94.9	
Bus62	0.400	98.033	-1.6	0	0	0.620	0.206	Bus11	-0.620	-0.206	961.9	94.9	
Bus63	0.400	98.030	-1.6	0	0	0.620	0.206	Bus14	-0.620	-0.206	961.9	94.9	
Bus65	0.400	98.037	-1.6	0	0	0.620	0.206	Bus25	-0.620	-0.206	962.0	94.9	
Bus67	0.400	98.032	-1.6	0	0	0.620	0.206	Bus29	-0.620	-0.206	961.9	94.9	
Bus68	0.400	98.030	-1.6	0	0	0.620	0.206	Bus31	-0.620	-0.206	961.9	94.9	
Bus72	0.400	97.495	-1.1	0	0	0	0	H2	-0.339	-0.113	529.4	94.9	
								Bus45	0.339	0.113	529.4	94.9	
Bus73	0.400	97.659	-1.0	0	0	0	0	H2	-0.398	-0.133	619.9	94.8	
								Bus46	0.398	0.133	619.9	94.8	
Bus74	0.400	97.550	-1.1	0	0	0	0	H2	-0.331	-0.110	516.9	94.9	
								Bus47	0.331	0.110	516.9	94.9	
Bus75	0.400	97.325	-1.1	0	0	0	0	H2	-0.457	-0.153	714.6	94.8	



Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 3  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus50	0.457	0.153	714.6	94.8	
Bus76	0.400	96.372	-4.7	0	0	0	0	H1	-0.392	-0.131	619.1	94.9	
								Bus34	0.392	0.131	619.1	94.9	
Bus77	0.400	97.317	-1.1	0	0	0	0	H1	-0.326	-0.109	509.3	94.9	
								Bus37	0.326	0.109	509.3	94.9	
Bus78	0.400	97.317	-1.1	0	0	0	0	H1	-0.326	-0.109	509.3	94.9	
								Bus38	0.326	0.109	509.3	94.9	
Bus79	0.400	97.427	-1.0	0	0	0	0	H1	-0.391	-0.130	610.7	94.9	
								Bus39	0.391	0.130	610.7	94.9	
Bus80	0.400	97.206	-1.2	0	0	0	0	H3	-0.358	-0.119	559.6	94.9	
								Bus40	0.358	0.119	559.6	94.9	
Bus81	0.400	97.344	-1.1	0	0	0	0	H3	-0.426	-0.142	666.1	94.9	
								Bus41	0.426	0.142	666.1	94.9	
Bus82	0.400	97.482	-1.0	0	0	0	0	H3	-0.319	-0.106	497.5	94.9	
								Bus42	0.319	0.106	497.5	94.9	
Bus83	0.400	97.522	-1.0	0	0	0	0	H4	-0.402	-0.134	626.4	94.9	
								Bus55	0.402	0.134	626.4	94.9	
Bus84	0.400	97.243	-1.2	0	0	0	0	H4	-0.358	-0.119	559.8	94.9	
								Bus54	0.358	0.119	559.8	94.9	
Bus85	0.400	97.243	-1.2	0	0	0	0	H4	-0.358	-0.119	559.8	94.9	
								Bus53	0.358	0.119	559.8	94.9	
Bus90	0.400	97.585	-1.1	0	0	0	0	Bus33	-0.401	-0.133	625.5	94.9	
								Bus35	0.401	0.133	625.5	94.9	
H1	11.000	99.561	-0.1	0	0	0	0	Bus5	-1.453	-0.541	81.7	93.7	
								Bus76	0.393	0.167	22.5	92.0	
								Bus77	0.331	0.117	18.5	94.3	
								Bus78	0.331	0.117	18.5	94.3	
								Bus79	0.397	0.140	22.2	94.3	
H2	11.000	99.827	0.0	0	0	0	0	Bus23	-1.552	-0.550	86.6	94.3	
								Bus72	0.345	0.122	19.3	94.3	
								Bus73	0.404	0.143	22.5	94.3	
								Bus74	0.337	0.119	18.8	94.3	
								Bus75	0.466	0.166	26.0	94.2	
H3	11.000	99.673	-0.1	0	0	0	0	Bus8	-1.122	-0.397	62.7	94.3	
								Bus80	0.364	0.129	20.4	94.2	
								Bus81	0.434	0.153	24.2	94.3	
								Bus82	0.324	0.114	18.1	94.3	
H4	11.000	99.710	-0.1	0	0	0	0	Bus27	-1.137	-0.402	63.5	94.3	
								Bus85	0.364	0.129	20.4	94.2	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 4  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus84	0.364	0.129	20.4	94.2	
								Bus83	0.408	0.144	22.8	94.3	
H5	11.000	99.787	-0.1	0	0	0	0	Bus15	0.000	0.000	0.0	0.0	
H6	11.000	99.809	-0.1	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	

\* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than 0.1 MVA

## **Appendix J**

**The network of Rawabi city in Etap with five and six sections before adding the capacitor bank**

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 1  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

**LOAD FLOW REPORT**

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
* Bus1	33.000	100.000	0.0	3.707	2.263	0	0	Bus25	1.716	1.045	35.2	85.4	
								Bus9	1.991	1.218	40.8	85.3	
								Bus3	0.000	0.000	0.0	0.0	
* Bus3	11.000	100.000	0.0	4.482	2.733	0	0	Bus23	4.482	2.733	275.5	85.4	
								Bus1	0.000	0.000	0.0	0.0	
* Bus4	11.000	100.000	0.0	2.875	1.748	0	0	Bus5	2.875	1.748	176.6	85.4	
Bus5	11.000	99.676	-0.1	0	0	0	0	Bus4	-2.868	-1.746	176.8	85.4	
								Bus8	1.412	0.859	87.0	85.4	
								H1	1.456	0.887	89.8	85.4	
Bus8	11.000	99.630	-0.1	0	0	0	0	Bus5	-1.411	-0.860	87.1	85.4	
								H3	1.111	0.679	68.6	85.3	
								Bus15	0.300	0.181	18.5	85.6	
Bus9	33.000	99.956	0.0	0	0	0	0	Bus1	-1.990	-1.237	41.0	84.9	
								Bus11	1.372	0.850	28.3	85.0	
								Bus60	0.618	0.388	12.8	84.7	
Bus11	33.000	99.949	0.0	0	0	0	0	Bus9	-1.372	-0.854	28.3	84.9	
								Bus14	0.755	0.467	15.5	85.1	
								Bus62	0.618	0.388	12.8	84.7	
Bus14	33.000	99.945	0.0	0	0	0	0	Bus11	-0.755	-0.471	15.6	84.8	
								Bus63	0.617	0.388	12.8	84.7	
								Bus31	0.137	0.084	2.8	85.3	
Bus15	11.000	99.616	-0.1	0	0	0	0	Bus8	-0.300	-0.184	18.6	85.2	
								H5	0.914	0.560	56.5	85.3	
								Bus32	-0.613	-0.376	37.9	85.3	
Bus23	11.000	99.808	0.0	0	0	0	0	Bus3	-4.476	-2.727	275.6	85.4	
								H2	1.538	0.941	94.8	85.3	
								Bus27	2.937	1.785	180.8	85.5	
Bus25	33.000	99.953	0.0	0	0	0	0	Bus1	-1.715	-1.070	35.4	84.9	
								Bus29	1.098	0.682	22.6	84.9	
								Bus65	0.618	0.388	12.8	84.7	
Bus27	11.000	99.693	-0.1	0	0	0	0	Bus23	-2.935	-1.784	180.8	85.4	
								H4	1.126	0.688	69.5	85.3	
								Bus30	1.808	1.096	111.3	85.5	
Bus29	33.000	99.947	0.0	0	0	0	0	Bus25	-1.098	-0.687	22.7	84.8	
								Bus31	0.480	0.299	9.9	84.9	
								Bus67	0.618	0.388	12.8	84.7	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 2  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus30	11.000	99.658	-0.1	0	0	0	0	Bus27	-1.808	-1.096	111.4	85.5	
								H6	0.791	0.483	48.8	85.3	
								Bus32	1.017	0.613	62.5	85.7	
Bus31	33.000	99.945	0.0	0	0	0	0	Bus29	-0.480	-0.304	9.9	84.5	
								Bus68	0.617	0.388	12.8	84.7	
								Bus14	-0.137	-0.084	2.8	85.3	
Bus32	11.000	99.639	-0.1	0	0	0	0	Bus33	0.404	0.240	24.7	85.9	
								Bus30	-1.017	-0.614	62.6	85.6	
								Bus15	0.614	0.374	37.8	85.4	
Bus33	11.000	99.604	-0.1	0	0	0	0	Bus32	-0.403	-0.247	24.9	85.3	
								Bus90	0.403	0.247	24.9	85.3	
Bus34	0.400	96.707	-0.8	0	0	0.395	0.234	Bus76	-0.395	-0.234	685.4	86.0	
Bus35	0.400	96.878	-0.8	0	0	0.395	0.235	Bus90	-0.395	-0.235	685.2	86.0	
Bus37	0.400	96.636	-0.8	0	0	0.321	0.191	Bus77	-0.321	-0.191	557.9	86.0	
Bus38	0.400	96.636	-0.8	0	0	0.321	0.191	Bus78	-0.321	-0.191	557.9	86.0	
Bus39	0.400	96.772	-0.8	0	0	0.386	0.229	Bus79	-0.386	-0.229	669.1	86.0	
Bus40	0.400	96.454	-0.9	0	0	0.352	0.209	Bus80	-0.352	-0.209	612.6	86.0	
Bus41	0.400	96.624	-0.9	0	0	0.420	0.249	Bus81	-0.420	-0.249	729.4	86.0	
Bus42	0.400	96.795	-0.8	0	0	0.314	0.186	Bus82	-0.314	-0.186	544.9	86.0	
Bus43	0.400	96.473	-0.9	0	0	0.449	0.266	Bus86	-0.449	-0.266	781.2	86.0	
Bus44	0.400	96.511	-0.9	0	0	0.444	0.263	Bus87	-0.444	-0.263	771.7	86.0	
Bus45	0.400	96.844	-0.8	0	0	0.335	0.199	Bus72	-0.335	-0.199	580.1	86.0	
Bus46	0.400	97.050	-0.8	0	0	0.393	0.233	Bus73	-0.393	-0.233	679.4	86.0	
Bus47	0.400	96.912	-0.8	0	0	0.327	0.194	Bus74	-0.327	-0.194	566.5	86.0	
Bus50	0.400	96.638	-0.9	0	0	0.451	0.267	Bus75	-0.451	-0.267	782.5	86.0	
Bus53	0.400	96.506	-0.9	0	0	0.352	0.209	Bus85	-0.352	-0.209	612.9	86.0	
Bus54	0.400	96.506	-0.9	0	0	0.352	0.209	Bus84	-0.352	-0.209	612.9	86.0	
Bus55	0.400	96.849	-0.8	0	0	0.396	0.235	Bus83	-0.396	-0.235	686.4	86.0	
Bus56	0.400	96.687	-0.9	0	0	0.334	0.198	Bus89	-0.334	-0.198	579.2	86.0	
Bus57	0.400	96.551	-0.9	0	0	0.439	0.261	Bus88	-0.439	-0.261	763.7	86.0	
Bus60	0.400	97.273	-1.4	0	0	0.610	0.362	Bus9	-0.610	-0.362	1053.0	86.0	
Bus62	0.400	97.266	-1.4	0	0	0.610	0.362	Bus11	-0.610	-0.362	1052.9	86.0	
Bus63	0.400	97.262	-1.4	0	0	0.610	0.362	Bus14	-0.610	-0.362	1052.9	86.0	
Bus65	0.400	97.270	-1.4	0	0	0.610	0.362	Bus25	-0.610	-0.362	1053.0	86.0	
Bus67	0.400	97.264	-1.4	0	0	0.610	0.362	Bus29	-0.610	-0.362	1052.9	86.0	
Bus68	0.400	97.262	-1.4	0	0	0.610	0.362	Bus31	-0.610	-0.362	1052.9	86.0	
Bus72	0.400	96.844	-0.8	0	0	0	0	H2	-0.335	-0.199	580.1	86.0	
								Bus45	0.335	0.199	580.1	86.0	
Bus73	0.400	97.050	-0.8	0	0	0	0	H2	-0.393	-0.233	679.4	86.0	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 3  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus46	0.393	0.233	679.4	86.0	
Bus74	0.400	96.912	-0.8	0	0	0	0	H2	-0.327	-0.194	566.5	86.0	
								Bus47	0.327	0.194	566.5	86.0	
Bus75	0.400	96.638	-0.9	0	0	0	0	H2	-0.451	-0.267	782.5	86.0	
								Bus50	0.451	0.267	782.5	86.0	
Bus76	0.400	96.707	-0.8	0	0	0	0	H1	-0.395	-0.234	685.4	86.0	
								Bus34	0.395	0.234	685.4	86.0	
Bus77	0.400	96.636	-0.8	0	0	0	0	H1	-0.321	-0.191	557.9	86.0	
								Bus37	0.321	0.191	557.9	86.0	
Bus78	0.400	96.636	-0.8	0	0	0	0	H1	-0.321	-0.191	557.9	86.0	
								Bus38	0.321	0.191	557.9	86.0	
Bus79	0.400	96.772	-0.8	0	0	0	0	H1	-0.386	-0.229	669.1	86.0	
								Bus39	0.386	0.229	669.1	86.0	
Bus80	0.400	96.454	-0.9	0	0	0	0	H3	-0.352	-0.209	612.6	86.0	
								Bus40	0.352	0.209	612.6	86.0	
Bus81	0.400	96.624	-0.9	0	0	0	0	H3	-0.420	-0.249	729.4	86.0	
								Bus41	0.420	0.249	729.4	86.0	
Bus82	0.400	96.795	-0.8	0	0	0	0	H3	-0.314	-0.186	544.9	86.0	
								Bus42	0.314	0.186	544.9	86.0	
Bus83	0.400	96.849	-0.8	0	0	0	0	H4	-0.396	-0.235	686.4	86.0	
								Bus55	0.396	0.235	686.4	86.0	
Bus84	0.400	96.506	-0.9	0	0	0	0	H4	-0.352	-0.209	612.9	86.0	
								Bus54	0.352	0.209	612.9	86.0	
Bus85	0.400	96.506	-0.9	0	0	0	0	H4	-0.352	-0.209	612.9	86.0	
								Bus53	0.352	0.209	612.9	86.0	
Bus86	0.400	96.473	-0.9	0	0	0	0	H5	-0.449	-0.266	781.2	86.0	
								Bus43	0.449	0.266	781.2	86.0	
Bus87	0.400	96.511	-0.9	0	0	0	0	H5	-0.444	-0.263	771.7	86.0	
								Bus44	0.444	0.263	771.7	86.0	
Bus88	0.400	96.551	-0.9	0	0	0	0	H6	-0.439	-0.261	763.7	86.0	
								Bus57	0.439	0.261	763.7	86.0	
Bus89	0.400	96.687	-0.9	0	0	0	0	H6	-0.334	-0.198	579.2	86.0	
								Bus56	0.334	0.198	579.2	86.0	
Bus90	0.400	96.878	-0.8	0	0	0	0	Bus33	-0.395	-0.235	685.2	86.0	
								Bus35	0.395	0.235	685.2	86.0	
H1	11.000	99.434	0.0	0	0	0	0	Bus5	-1.452	-0.888	89.8	85.3	
								Bus76	0.403	0.246	24.9	85.3	
								Bus77	0.328	0.201	20.3	85.3	
								Bus78	0.328	0.201	20.3	85.3	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 4  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
H2	11.000	99.753	0.0	0	0	0	0	Bus79	0.393	0.240	24.3	85.3	
								Bus23	-1.537	-0.941	94.9	85.3	
								Bus72	0.342	0.209	21.1	85.3	
								Bus73	0.401	0.245	24.7	85.3	
								Bus74	0.334	0.204	20.6	85.3	
H3	11.000	99.526	-0.1	0	0	0	0	Bus75	0.461	0.283	28.5	85.2	
								Bus8	-1.110	-0.679	68.6	85.3	
								Bus80	0.360	0.221	22.3	85.2	
								Bus81	0.429	0.263	26.5	85.3	
								Bus82	0.321	0.196	19.8	85.3	
H4	11.000	99.579	0.0	0	0	0	0	Bus27	-1.125	-0.689	69.5	85.3	
								Bus85	0.360	0.221	22.3	85.2	
								Bus84	0.360	0.221	22.3	85.2	
								Bus83	0.404	0.247	25.0	85.3	
								Bus15	-0.913	-0.560	56.5	85.2	
H5	11.000	99.582	-0.1	0	0	0	0	Bus86	0.459	0.282	28.4	85.2	
								Bus87	0.454	0.278	28.1	85.2	
								Bus30	-0.790	-0.484	48.8	85.3	
								Bus89	0.341	0.209	21.1	85.3	
								Bus88	0.449	0.275	27.8	85.2	
H6	11.000	99.591	-0.1	0	0	0	0						

\* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than 0.1 MVA

## **Appendix K**

**The network of Rawabi city in Etap with five and six sections after adding the capacitor bank**



Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 1  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

**LOAD FLOW REPORT**

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
* Bus1	33.000	100.000	0.0	3.758	1.303	0	0	Bus25	1.740	0.601	32.2	94.5	
								Bus9	2.018	0.702	37.4	94.4	
								Bus3	0.000	0.000	0.0	0.0	
* Bus3	11.000	100.000	0.0	4.522	1.587	0	0	Bus23	4.522	1.587	251.5	94.4	
								Bus1	0.000	0.000	0.0	0.0	
* Bus4	11.000	100.000	0.0	2.900	1.013	0	0	Bus5	2.900	1.013	161.2	94.4	
Bus5	11.000	99.735	-0.1	0	0	0	0	Bus4	-2.894	-1.012	161.4	94.4	
								Bus8	1.425	0.497	79.4	94.4	
								H1	1.469	0.515	81.9	94.4	
Bus8	11.000	99.698	-0.1	0	0	0	0	Bus5	-1.425	-0.498	79.5	94.4	
								H3	1.121	0.395	62.6	94.3	
								Bus15	0.304	0.103	16.9	94.7	
Bus9	33.000	99.958	0.0	0	0	0	0	Bus1	-2.017	-0.722	37.5	94.2	
								Bus11	1.391	0.494	25.8	94.2	
								Bus60	0.626	0.228	11.7	94.0	
Bus11	33.000	99.952	0.0	0	0	0	0	Bus9	-1.391	-0.499	25.9	94.1	
								Bus14	0.765	0.271	14.2	94.3	
								Bus62	0.626	0.228	11.7	94.0	
Bus14	33.000	99.948	0.0	0	0	0	0	Bus11	-0.765	-0.276	14.2	94.1	
								Bus63	0.626	0.228	11.7	94.0	
								Bus31	0.139	0.048	2.6	94.5	
Bus15	11.000	99.686	-0.1	0	0	0	0	Bus8	-0.304	-0.106	16.9	94.4	
								H5	0.923	0.324	51.5	94.4	
								Bus32	-0.619	-0.218	34.6	94.3	
Bus23	11.000	99.843	-0.1	0	0	0	0	Bus3	-4.516	-1.582	251.6	94.4	
								H2	1.552	0.549	86.5	94.3	
								Bus27	2.964	1.033	165.0	94.4	
Bus25	33.000	99.956	0.0	0	0	0	0	Bus1	-1.739	-0.625	32.3	94.1	
								Bus29	1.113	0.398	20.7	94.2	
								Bus65	0.626	0.228	11.7	94.0	
Bus27	11.000	99.750	-0.1	0	0	0	0	Bus23	-2.962	-1.033	165.1	94.4	
								H4	1.137	0.401	63.4	94.3	
								Bus30	1.825	0.632	101.6	94.5	
Bus29	33.000	99.950	0.0	0	0	0	0	Bus25	-1.113	-0.402	20.7	94.0	
								Bus31	0.487	0.175	9.1	94.1	
								Bus67	0.626	0.228	11.7	94.0	



Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 3  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus46	0.398	0.133	619.7	94.8	
Bus74	0.400	97.513	-1.1	0	0	0	0	H2	-0.331	-0.110	516.7	94.9	
								Bus47	0.331	0.110	516.7	94.9	
Bus75	0.400	97.289	-1.2	0	0	0	0	H2	-0.457	-0.153	714.3	94.8	
								Bus50	0.457	0.153	714.3	94.8	
Bus76	0.400	97.317	-1.1	0	0	0	0	H1	-0.400	-0.133	625.1	94.9	
								Bus34	0.400	0.133	625.1	94.9	
Bus77	0.400	97.259	-1.1	0	0	0	0	H1	-0.325	-0.108	509.0	94.9	
								Bus37	0.325	0.108	509.0	94.9	
Bus78	0.400	97.259	-1.1	0	0	0	0	H1	-0.325	-0.108	509.0	94.9	
								Bus38	0.325	0.108	509.0	94.9	
Bus79	0.400	97.368	-1.0	0	0	0	0	H1	-0.391	-0.130	610.3	94.9	
								Bus39	0.391	0.130	610.3	94.9	
Bus80	0.400	97.133	-1.2	0	0	0	0	H3	-0.357	-0.119	559.2	94.9	
								Bus40	0.357	0.119	559.2	94.9	
Bus81	0.400	97.270	-1.1	0	0	0	0	H3	-0.426	-0.142	665.6	94.9	
								Bus41	0.426	0.142	665.6	94.9	
Bus82	0.400	97.409	-1.1	0	0	0	0	H3	-0.318	-0.106	497.1	94.9	
								Bus42	0.318	0.106	497.1	94.9	
Bus83	0.400	97.452	-1.1	0	0	0	0	H4	-0.401	-0.133	626.0	94.9	
								Bus55	0.401	0.133	626.0	94.9	
Bus84	0.400	97.173	-1.2	0	0	0	0	H4	-0.357	-0.119	559.4	94.9	
								Bus54	0.357	0.119	559.4	94.9	
Bus85	0.400	97.173	-1.2	0	0	0	0	H4	-0.357	-0.119	559.4	94.9	
								Bus53	0.357	0.119	559.4	94.9	
Bus86	0.400	97.177	-1.2	0	0	0	0	H5	-0.456	-0.149	711.8	95.1	
								Bus43	0.456	0.149	711.8	95.1	
Bus87	0.400	97.190	-1.2	0	0	0	0	H5	-0.450	-0.150	704.5	94.9	
								Bus44	0.450	0.150	704.5	94.9	
Bus88	0.400	97.220	-1.2	0	0	0	0	H6	-0.445	-0.148	696.9	94.9	
								Bus57	0.445	0.148	696.9	94.9	
Bus89	0.400	97.328	-1.1	0	0	0	0	H6	-0.338	-0.113	528.5	94.9	
								Bus56	0.338	0.113	528.5	94.9	
Bus90	0.400	97.495	-1.1	0	0	0	0	Bus33	-0.401	-0.133	624.9	94.9	
								Bus35	0.401	0.133	624.9	94.9	
H1	11.000	99.501	-0.1	0	0	0	0	Bus5	-1.465	-0.516	81.9	94.3	
								Bus76	0.407	0.143	22.7	94.3	
								Bus77	0.331	0.117	18.5	94.3	
								Bus78	0.331	0.117	18.5	94.3	

Project: Rawabi city network  
 Location: palestine  
 Contract:  
 Engineer:  
 Filename: 12122017

**ETAP**  
 12.6.0H

Study Case: LF

Page: 4  
 Date: 01-14-2018  
 SN:  
 Revision: Base  
 Config.: Normal

Bus		Voltage		Generation		Load		Load Flow				XFMR	
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
H2	11.000	99.790	-0.1	0	0	0	0	Bus79	0.397	0.140	22.2	94.3	
								Bus23	-1.551	-0.549	86.5	94.3	
								Bus72	0.345	0.122	19.2	94.3	
								Bus73	0.404	0.143	22.5	94.3	
								Bus74	0.337	0.119	18.8	94.3	
H3	11.000	99.598	-0.1	0	0	0	0	Bus75	0.465	0.166	26.0	94.2	
								Bus8	-1.120	-0.396	62.6	94.3	
								Bus80	0.364	0.129	20.3	94.2	
								Bus81	0.433	0.153	24.2	94.3	
								Bus82	0.324	0.114	18.1	94.3	
H4	11.000	99.639	-0.1	0	0	0	0	Bus27	-1.136	-0.402	63.5	94.3	
								Bus85	0.364	0.129	20.3	94.2	
								Bus84	0.364	0.129	20.3	94.2	
								Bus83	0.408	0.143	22.8	94.3	
								Bus15	-0.923	-0.324	51.5	94.4	
H5	11.000	99.654	-0.1	0	0	0	0	Bus86	0.464	0.161	25.9	94.5	
								Bus87	0.458	0.162	25.6	94.3	
								Bus30	-0.798	-0.282	44.6	94.3	
								Bus89	0.344	0.122	19.2	94.3	
								Bus88	0.454	0.160	25.3	94.3	

\* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than 0.1 MVA

## **Appendix L**

### **Power factor correction table**

Uncorrected		Desired cos $\varphi$						
$\tan \varphi$	$\cos \varphi$	0,80	0,85	0,90	0,92	0,95	0,98	1,00
3.18	0.30	2.43	2.56	2.70	2.75	2.85	2.98	3.18
2.96	0.32	2.21	2.34	2.48	2.53	2.63	2.76	2.96
2.77	0.34	2.02	2.15	2.28	2.34	2.44	2.56	2.77
2.59	0.36	1.84	1.97	2.10	2.17	2.26	2.39	2.59
2.43	0.38	1.68	1.81	1.95	2.01	2.11	2.23	2.43
2.29	0.40	1.54	1.67	1.81	1.87	1.96	2.09	2.29
2.16	0.42	1.41	1.54	1.68	1.73	1.83	1.96	2.16
2.04	0.44	1.29	1.42	1.56	1.61	1.71	1.84	2.04
1.93	0.46	1.18	1.31	1.45	1.50	1.60	1.73	1.93
1.83	0.48	1.08	1.21	1.34	1.40	1.50	1.62	1.83
1.73	0.50	0.98	1.11	1.25	1.31	1.40	1.53	1.73
1.64	0.52	0.89	1.02	1.16	1.22	1.31	1.44	1.64
1.56	0.54	0.81	0.94	1.07	1.13	1.23	1.36	1.56
1.48	0.56	0.73	0.86	1.00	1.05	1.15	1.28	1.48
1.40	0.58	0.65	0.78	0.92	0.98	1.08	1.20	1.40
1.33	0.60	0.58	0.71	0.85	0.91	1.00	1.13	1.33
1.30	0.61	0.55	0.68	0.81	0.87	0.97	1.10	1.30
1.27	0.62	0.52	0.65	0.78	0.84	0.94	1.06	1.27
1.23	0.63	0.48	0.61	0.75	0.81	0.90	1.03	1.23
1.20	0.64	0.45	0.58	0.72	0.77	0.87	1.00	1.20
1.11	0.67	0.36	0.49	0.63	0.68	0.78	0.90	1.11
1.08	0.68	0.33	0.46	0.59	0.65	0.75	0.88	1.08
1.05	0.69	0.30	0.43	0.56	0.62	0.72	0.85	1.05
1.02	0.70	0.27	0.40	0.54	0.59	0.69	0.82	1.02
0.99	0.71	0.24	0.37	0.51	0.57	0.66	0.79	0.99
0.96	0.72	0.21	0.34	0.48	0.54	0.64	0.76	0.96
0.94	0.73	0.19	0.32	0.45	0.51	0.61	0.73	0.94
0.91	0.74	0.16	0.29	0.42	0.48	0.58	0.71	0.91
0.88	0.75	0.13	0.26	0.40	0.46	0.55	0.68	0.88
0.86	0.76	0.11	0.24	0.37	0.43	0.53	0.65	0.86
0.83	0.77	0.08	0.21	0.34	0.40	0.50	0.63	0.83
0.80	0.78	0.05	0.18	0.32	0.38	0.47	0.60	0.80
0.78	0.79	0.03	0.16	0.29	0.35	0.45	0.57	0.78
0.75	0.80	-	0.13	0.27	0.32	0.42	0.55	0.75
0.72	0.81	-	0.10	0.24	0.30	0.40	0.52	0.72
0.70	0.82	-	0.08	0.21	0.27	0.37	0.49	0.70
0.67	0.83	-	0.05	0.19	0.25	0.34	0.47	0.67
0.65	0.84	-	0.03	0.16	0.22	0.32	0.44	0.65
0.62	0.85	-	-	0.14	0.19	0.29	0.42	0.62
0.59	0.86	-	-	0.11	0.17	0.26	0.39	0.59
0.57	0.87	-	-	0.08	0.14	0.24	0.36	0.57
0.54	0.88	-	-	0.06	0.11	0.21	0.34	0.54
0.51	0.89	-	-	0.03	0.09	0.18	0.31	0.51
0.48	0.90	-	-	-	0.06	0.16	0.28	0.48
0.46	0.91	-	-	-	0.03	0.13	0.25	0.46
0.43	0.92	-	-	-	-	0.10	0.22	0.43
0.40	0.93	-	-	-	-	0.07	0.19	0.40
0.36	0.94	-	-	-	-	0.03	0.16	0.36
0.33	0.95	-	-	-	-	-	0.13	0.33
0.29	0.96	-	-	-	-	-	0.09	0.29

## Calculation

section	trans.	KW	uncorrected P.F	corrected P.F	constant	Capacitor rated (KVar)
<b>H1</b>	T1	422.6	0.86	0.95	0.26	109.876
	T2	344	0.86	0.95	0.26	89.44
	T3	344	0.86	0.95	0.26	89.44
	T4	411.7	0.86	0.95	0.26	107.042
<b>H2</b>	T1	357	0.86	0.95	0.26	92.82
	T2	417	0.86	0.95	0.26	108.42
	T3	348.3	0.86	0.95	0.26	90.558
	T4	482.2	0.86	0.95	0.26	125.372
<b>H3</b>	T1	378.4	0.86	0.95	0.26	98.384
	T2	450	0.86	0.95	0.26	117
	T3	335.4	0.86	0.95	0.26	87.204
<b>H4</b>	T1	378.4	0.86	0.95	0.26	98.384
	T2	378.4	0.86	0.95	0.26	98.384
	T3	422.6	0.86	0.95	0.26	109.876
<b>H5</b>	T1	482.2	0.86	0.95	0.26	125.372
	T2	476.8	0.86	0.95	0.26	123.968
<b>H6</b>	T1	357	0.86	0.95	0.26	92.82
	T2	471.3	0.86	0.95	0.26	122.538

## **Appendix M**



CB\_tie\_point:=0;

if ( temp\_sensor> 0.0 & temp\_sensor < 6.1 & switsh=1) then d:= 1;

if (V1\_tie\_point > 6.8 & V1\_tie\_point < 7.6 & d=1) then a:= 1;

else CB\_tie\_point:=0;

a:= 0;

end\_if;

if (V2\_tie\_point > 6.8 & V2\_tie\_point < 7.6 & d=1) then b:= 1;

else CB\_tie\_point:=0;

b:= 0;

end\_if;

if (V3\_tie\_point > 6.8 & V3\_tie\_point < 7.6 & d=1) then c:= 1;

else CB\_tie\_point:=0;

c:= 0;

end\_if;

if ((I1\_tie\_point = 0.0 or (I1\_tie\_point > 0.0 & I1\_tie\_point < 7.0)) & d=1) then aa:= 1;

else CB\_tie\_point:=0;

aa:= 0;

end\_if;

if ((I2\_tie\_point = 0.0 or ( I2\_tie\_point > 0.0 & I2\_tie\_point < 7.0)) & d=1) then bb:= 1;

else CB\_tie\_point:=0;

bb:= 0;

end\_if;

```
if ((I3_tie_point = 0.0 or ( I3_tie_point > 0.0 & I3_tie_point < 7.0)) & d=1) then cc:= 1;
    else CB_tie_point:=0;
        cc:= 0;
```

```
    end_if;
```

```
else d:=0;
```

```
end_if;
```

```
if(a=1 & b=1 & c=1 & d=1 & aa=1 & bb=1 & cc=1)then CB_tie_point:=1;
```

```
end_if;
```

```
if(aa=1 & bb=1 & cc=1 ) then dd:=0; ee:=0;
```

```
elseif((I1_tie_point > 7.0 & I1_tie_point <8.0) or
```

```
)    I2_tie_point > 7.0 & I2_tie_point <8.0) or
```

```
)    I3_tie_point > 7.0 & I3_tie_point <8.0))then dd:=1;
```

```
elseif(I1_tie_point > 8.0 or I2_tie_point > 8.0 or I3_tie_point > 8.0 )then ee:=1;
```

```
else dd:=0; ee:=0;
```

```
end_if;
```

```
V1_tie_point_M:=V1_tie_point;
```

```
V2_tie_point_M:=V2_tie_point;
```

```
V3_tie_point_M:=V3_tie_point;
```

```
I1_tie_point_M:=I1_tie_point;
```

```
I2_tie_point_M:=I2_tie_point;
```

```
I3_tie_point_M:=I3_tie_point;
```

```
CB_tie_point_M:=CB_tie_point;
```

```
if ( temp_sensor> 0.0 & temp_sensor < 6.1 & switsh_H1=1) then d_H1:= 1;
```

```
if (V1_H1 > 6.8 & V1_H1 < 7.6 & d_H1=1) then a_H1:= 1;
```

```
else CB_H1:=0;
```

```
    a_H1:= 0;
```

```
end_if;
```

```
if (V2_H1 > 6.8 & V2_H1 < 7.6 & d_H1=1) then b_H1:= 1;
```

```
else CB_H1:=0;
```

```
    b_H1:= 0;
```

```
end_if;
```

```
if (V3_H1 > 6.8 & V3_H1 < 7.6 & d_H1=1) then c_H1:= 1;
```

```
else CB_H1:=0;
```

```
    c_H1:= 0;
```

```
end_if;
```

```
if ((I1_H1 = 0.0 or (I1_H1 > 0.0 & I1_H1 < 7.0)) & d_H1=1) then aa_H1:= 1;
```

```
else CB_H1:=0;
```

```
    aa_H1:= 0;
```

```
end_if;
```

```
    if ((I2_H1 = 0.0 or ( I2_H1 > 0.0 & I2_H1 < 7.0)) & d_H1=1) then bb_H1:= 1;
```

```
else CB_H1:=0;
```

```
    bb_H1:= 0;
```

```
end_if;
```

```
if ((I3_H1 = 0.0 or ( I3_H1 > 0.0 & I3_H1 < 7.0)) & d_H1=1) then cc_H1:= 1;
```

```
else CB_H1:=0;
```

```
cc_H1:= 0;
```

```
end_if;
```

```
else d_H1:=0;
```

```
end_if;
```

```
if(a_H1=1 & b_H1=1 & c_H1=1 & d_H1=1 & aa_H1=1 & bb_H1=1 & cc_H1=1)then CB_H1:=1;
```

```
else CB_H1:=0;
```

```
end_if;
```

```
if(aa_H1=1 & bb_H1=1 & cc_H1=1 ) then dd_H1:=0; ee_H1:=0;
```

```
elseif((I1_H1 > 7.0 & I1_H1 < 8.0) or
```

```
) I2_H1 > 7.0 & I2_H1 < 8.0) or
```

```
) I3_H1 > 7.0 & I3_H1 < 8.0))then dd_H1:=1;
```

```
elseif(I1_H1 > 8.0 or I2_H1 > 8.0 or I3_H1 > 8.0 )then ee_H1:=1;
```

```
else dd_H1:=0; ee_H1:=0;
```

```
end_if;
```

```
V1_H1_M:=V1_H1;
```

```
V2_H1_M:=V2_H1;
```

```
V3_H1_M:=V3_H1;
```

```
I1_H1_M:=I1_H1;
```

```
I2_H1_M:=I2_H1;
```

```
I3_H1_M:=I3_H1;
```

```
CB_H1_M:=CB_H1;
```