PALESTINE POLYTECHNIC UNIVERSITY
COLLAGE OF ENGINEERING
ELECTRICAL POWER ENGINEERING

GRADUATE PROJECT

DESIGN AN ELECTRICAL NETWORK FOR INDUSTRIAL ZONE IN HEBRON CITY

PROJECT TEAM

IBRAHIM KH ALDABBAS

KARAM A ALNATSHA

MUSAB A SHROUF

PROJECT SUPERVISOR

ENG. NIZAR AMRO

HEBRON-PALESTINE

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الإهداء

إلى وطننا فلسطين

إلى شهداء فلسطين

إلى الأسرى والمعتقلين

إلى ينبوع العطاء والحنان..آباؤنا وأمهاتنا
إخواننا وأخواتنا

زملاؤنا وزميلاتنا

إلى كل محبي العلم والمعرفة .. إلى كل من ساهم في إنجاح هذا العمل

ACKNOWLEDGEMENT

First and foremost, we should offer our thanks obedience and gratitude to Allah

Second, we would like to thank Eng. Nizar Amro for his most support and encouragement

Finally, we sincerely thank to Hebron Municipality

Chamber of Commerce and Industry of Hebron

Palestinian Central Bureau of Statistics

The product of this research would not be possible without all of them.

Abstract:

This project is design a medium voltage electrical distribution network for industrial zone, in Hebron city.

Design electrical network for industrial zone, whose suggested in Hebron city, depending on classification the electrical load, standing on information for 160 consumer, so that the design depend on dividing the zone area to specific parts (large, medium, small) according the power level of loads, and then feeding every part with appropriate powers, such that we will reach three sub networks inside the main electrical network.

Furthermore, the system will be designed in electrical software program (E-tap) whose is capable to sketch the system and studying the status of network, also controlled the operation of network by SCADA system.

الملخص:

هذا المشروع هو عبارة عن تصميم شبكة توزيع كهربائية ذات جهد متوسط لمنطقة صناعية في مدينة الخليل.

تصميم شبكة كهرباء المدينة الصناعية المقترحة في مدينة الخليل يعتمد على تصنيف الأحمال الكهربائية إستناداً على معلومات 160 مشترك , حيث أن التصميم قائم على تقسيم منطقة المدينة الصناعية إلى ثلاثة مناطق حسب الحمل الكهربائي , بحيث توضع الأحمال الصغيرة في منطقة والمتوسطة في منطقة أخرى والكبيرة كذلك ,وبهذا يتم تغذية كل منطقة بالطاقة اللّازمة لها. وبهذه الطريقة يكون لدينا ثلاث شبكات فرعية داخل الشبكة الرئيسية.

وتم تصميم الشبكة باستخدام برنامج تصميم شبكات كهربائية على جهاز الكومبيوتر (E-tap), حيث سيمكن هذا التصميم من دراسة كل مكونات الشبكة وتدفق الطاقة عليها ,إضافة إلى إستخدام برنامج ال SCADA للتحكم في الشبكة.

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Collage of Engineering and Technology

Electrical Engineering department

Electrical Power Engineering

Design an electrical network for industrial zone in Hebron city

Project Team

Ibrahim Aldabbas

Karam Alnatsha

Musab Shrouf

By the guidance of supervisor, this project delivered to department of electrical engineering, to be as a partial fulfillment of the requirement of the department for the Bachelor degree of Electrical Power Engineering.

Supervisors Signature

Testing Committee Signature

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Chair of the Department Signature

May-2015

Chapter one

Introduction

1.1 Overview

The distribution network transmits the power close to the consumer where the voltage is stepped-down to appropriate levels for use by an industrial, residential, or commercial customer.

And this project come to design a medium electrical distribution network to feed industrial zone with appropriate level of voltage, this zone in Hebron city's divided in to specific parts (large, medium, small) according to the apparent power level of the loads, enumeration of this loads about 160 industrial loads located in Hebron city. Furthermore, the system was drawing in E-tap software program who's capable to sketch the system and studying the status of the network. Also controlled the operation of network by SCADA system software. Finally studying the economic feasibility study for the network.

1.2 Project general description

In general the most factories in many countries in the world suffer from absence an industrial area that's contain it, and these factories need to collected or centralized in one area ,, such that does not allowed for it between residential area, because its cause a noise and pollution .As well as it's dangerous because it deal with high voltage.

And this project offer a solution that's to collect these factory's in one area and to avoid all problems.

Adopting of this projects is to designing an electrical network using E-tap software program, the program capabilities and properties allow us to study the network from many sides, show the status and flowing study of the network components, and monitor the ordinary operation or problem and weakness if exist.

1.3. Project importance:

As we know that the factories is an important thing in all countries in the world, the factories take the largest amount of consumed energy, also the Hebron city is considered as one of the most important cities in west bank importance for industrial process, its contain many factories and it's needed an industrial area to contain it, so the electrical network design become an important thing.

This project is designing the medium electrical distribution network for industrial zone in Hebron city, and there are many aims for this project that can be summarized as follow:

- Absence an industrial zones that's containing factories within international standards
- Collect factory in industrial zones, facilitates the process of managing network sand control the flow of energy
- preserve the environment
- Protect citizens from high voltage

1.4 Project methodology

- Identify subscribers loads based on reports from Hebron Municipality
- Determining Diversity factor
- Determine appropriate transformer to be used in every load
- Determine the E-tap requirements to be used in drawing
- Plotting the network in E-tap according to the value of industrial load
- Studying and investigating ordinary operation of the net work
- Controlling the system by using SCADA system
- Studying economic feasibility study for the network.

1.5. Organization of document

This project contains 7 chapters can be summarized as follow:

Chapter one: Introduction: this chapter gives introduction and general idea about the project.

Chapter tow: Criteria for selection an industrial zone: this chapter describes the criteria for selection industrial area and suggested area to build our industrial area on it.

Chapter three: Electrical network component: this chapter describes the component we need in our electrical network and principle of operation.

Chapter four: Design chapter: this chapter illustrates the steps of design process.

Chapter five: software program: this chapter describes the design of electrical network on E-tap program and SCADA software.

Chapter six: Economic feasibility study: this chapter describes the Economic feasibility study for the network.

Chapter seven: Conclusions and Recommendations: this chapter summarize the Conclusions and Recommendations for our project.

Chapter two

Criteria for selection an industrial zone

2.1 Introduction

Industrial area supporting the infrastructure needs to be designed to be resilient and adaptable, now and into the future. Resilience, adaptability and environmentally, economically and socially responsive outcomes can be achieved through the creation of industrial developments which add value to businesses and communities by optimizing the use of energy, materials and community resources [12].

And the Industries often disturbing rest and hazardous to health and has adverse effects on neighboring land, so its location planned away from residential uses, such as iron and steel, chemical and plastics industry.

These industries require large spaces for storage of raw materials, goods-producing and also need additional space to be a barrier surrounding this industry, and separated it from the neighboring uses to reduce harassment from industry for neighbors.

2.2 Factory Site Selection

Factory’s Site Selection at the land have several criteria, including the building's orientation, so that the building is directing to the position that achieve the greatest benefit of the environmental factors that’s after studying the weather and environmental different [14], for example

- direct blanks that need fixed lighting to the North
- Avoid directing areas generate dust and toxic odors in the wind direction
- Avoid orientation of land slope in the direction of the winds and because the orientation is working to increase the speed of the wind, which could lead to volatility of materials and the occurrence of injuries.
- Exploitation of natural lighting to save energy.

2.3 Planning criteria for the industrial zones

2.3.1 Functional criteria

Where the function of the factory is not in line with the nature of the city center, so the factories are located on the outskirts of cities.

2.3.2 Environmental criteria

Related to the far distance of industrial area from city center as a result of presence of residues, whether material or sounds.

2.3.3 Economic criteria

Depending on the convergence and divergence of industrial zones from each other.

2.4 Design criteria for industrial areas:

2.4.1 Settlement sites:

The purpose of settlement sites is to employed and protection it, and this is represented by change the ground level to prepare them for the construction of buildings, streets and footpaths and public spaces, park sand control against natural disasters

2.4.2 Drainage systems:

In the past, cities suffer from floods that separate the neighborhoods and lead to sweep the bridges and roads, so we need to develop appropriate solutions for the disposal of rainwater.

2.4.3 Movement arteries:

In the past, cities characterized by narrow streets and spaces limit, but at the present time the means of transportation has changed and numerous of movement and parking requirements.

2.5 Qilqs Area

According all of these we proposed “Qilqs” area to be optimal position for a new industrial zone, and it has assessment required and the consideration of location, and site features.

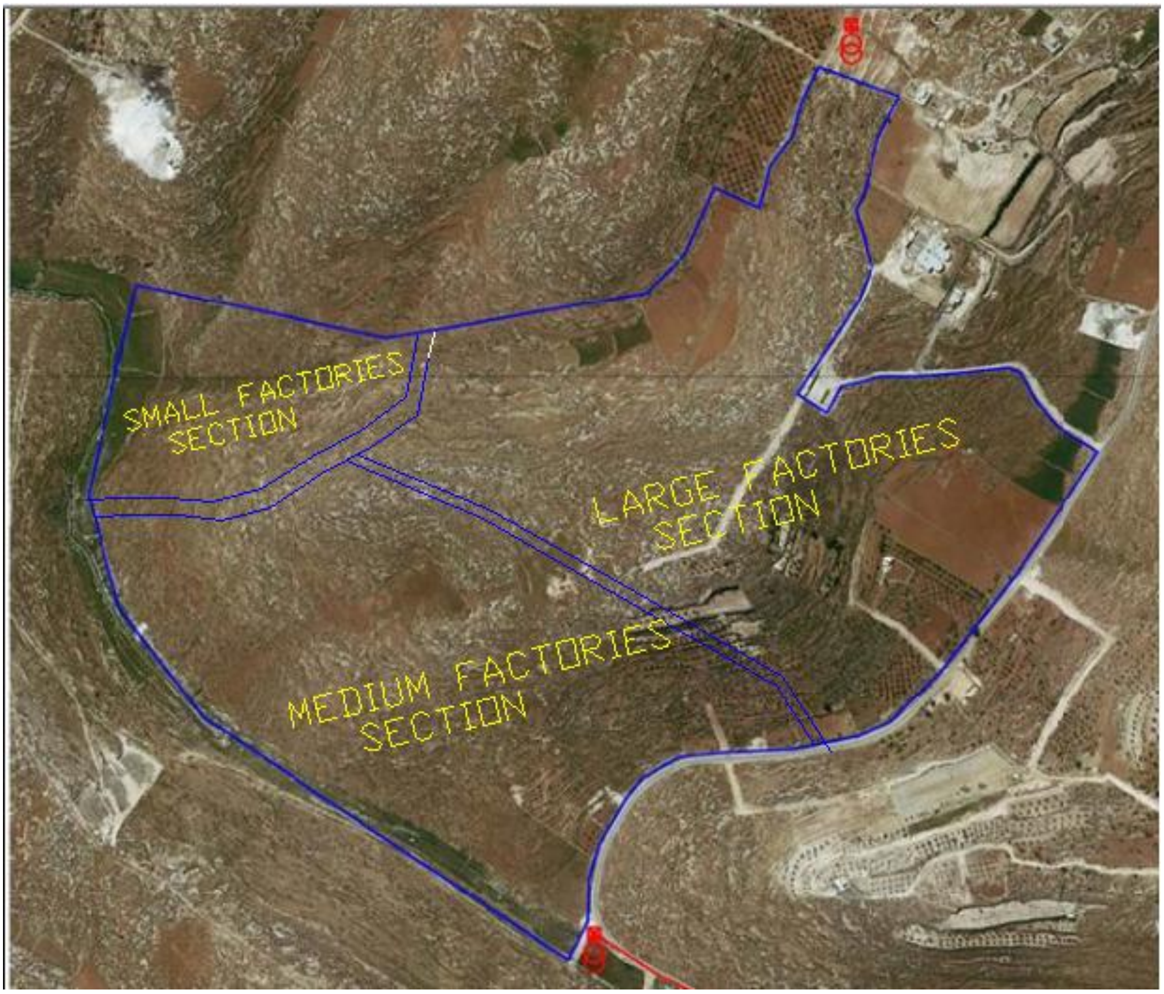


Figure 2.1: Proposed position for industrial zone Qilqs

The area of industrial zone that was selected is approximate of 400,000m^2, and these area contain 52 large and 84 medium and 24 small factories distributed, and we suppose the area for one small factory is 300 m^2 and for medium is 800m^2 and for large one is 1500m^2 according to local standers, therefore based on these divisions the industrial area exploitation 300 km^2 from the total area (total area for industries and service sector), so there is 100,000 m^2 for future expansion.

Chapter Three:

Project Components

3.1 Introduction

This chapter describes the main components of industrial area and it's approximately the same of distribution network.

Some of these components are substation and transformer and cable - major component of the system- and circuit breaker, ring main unit, control hardware.

First section is substation component, classification and some information for it.

In section of transformer there are the models that are used in project and what cooling system is used, accessories and protection for transformer.

Third section describes cable type and selection criteria and insulation types that is used, and consider difference between cable and transmission line and benefit for cable.

Forth section is circuit breaker description and fifth section that is Ring main unit and finally last section control component.

3.2. Substation (source)[6]

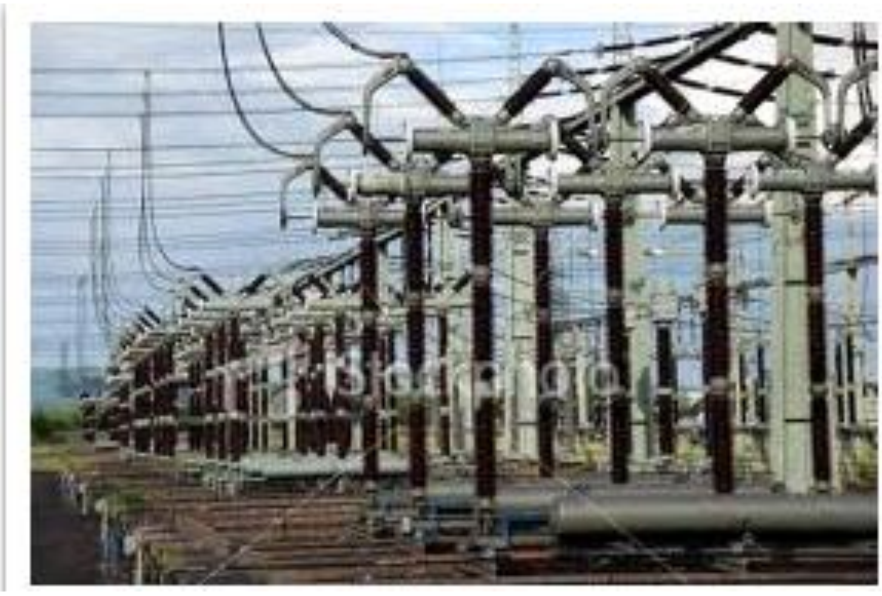


Figure 3.1. View of substation

The present day electrical power system is A.C.i.e. electrical power is generated, transmitted & distributed in the form of the alternating current. The electric power is produced at power plant stations which are located at favorable places generally quite away from the consumers. It is delivered to the consumers through a large network of transmission & distribution.

The assembly of apparatus to change some characteristic of electric power supply is called substation. The two most ways to classify substation are:-

1. **According to the service requirement:**

    - Transformer substation
    - Switch substation
    - Power factor correction substation
    - Frequency change substation
    - Converting substation
    - Industrial substation

2. **According to the constructional features:**

    - Indoor substation
    - Outdoor substation
    - Underground substation

3.2.1 Transformer substation

Figure 3.2 Transformer substation

They are known as transformer substations as because transformer is the main component employed to change the voltage level, depending upon the purposed served transformer substations may be classified into:

- **Step up substation**

The generation voltage is steeped up to high voltage to affect economy in transmission of electric power. These are generally located in the power houses and are of outdoor type.

- **Primary grid substation**

Here, electric power is received by primary substation which reduces the voltage level to 11kV for secondary transmission. The primary grid substation is generally of outdoor type.

- **Distribution substation**

These substations are located near the consumer's localities and step down to 400V, 3-phase, 4-wire for supplying to the consumers. The voltage between any two phases is 400V & between any phase and neutral it is 230V.

3.2.2. Information of main substation

The main bus 33kV is connected to grid located at Hebron city**.** Now the transmission line first parallel connected with lightning arrester to diverge surge, followed by current transformer and voltage transformer "CT&VT" connected parallel. CT&VT measures voltage and steps down at 110V. A.C. for control panel, at the location a wave trap is connected to carrier communication at higher frequencies. A current transformer is connected in series with line which measure current and step down current at ratio for control panel.

Switchgear equipment is provided, which is the combination of a circuit breaker having an isolator at each end. A transformer is connected to main bus though a bus coupler. The main bus has total capability of 25 MVA for 11 kV.

At both ends of transformer lightning arrester current transformer and switchgear equipment provided. Transformer step downs voltage from **33kV to 11kV**. The main bus is provided with switchgear equipment & a current transformer. This gives way to two feeders transmitting power to **the industrial zone.**

3.3. Transformer

3.3.1. Introduction

The main parts of a transformer are: (a) iron core, magnetic circuit, (b) high-voltage (HV) and low-voltage (LV), or multiple secondary, windings, and (c) a tank for liquid-immersed transformers and an enclosure for dry-type transformers. The basic core and coil configurations are: core type and shell type. In a core-type transformer, the core is surrounded by the winding coils, and in the shell type, the core surrounds the winding coils. The normal design is a three-phase, three-leg core type, while a five-leg core design enables a reduction in transformer height and a higher zero sequence impedance. Shell-type transformers were developed for very-high-magnitude short circuit applications such as generator step up transformers.

Transformer windings are manufactured of copper or aluminum, although the majority of users specify copper. In liquid-filled transformers, the winding terminals are brought out through bushings for connection to bare conductors or insulated power cable. In medium-voltage transformers, rated up to 35 kV, the winding terminals are brought out on the side, and the bushings are enclosed in a terminal box for cable terminations.

Transformers are designed for operation at rated kVA under the following service conditions:

1. Cooling (ambient) air temperature for liquid-immersed or dry-type transformers
   - Average temperature for any 24 h period is not to exceed 30°C.
   - Maximum temperature is not to exceed 40°C.
2. Altitude (elevation)] is not to exceed 1000 m (3300 ft).
3. Load current: Load current is approximately sinusoidal, Harmonic factor does not exceed 0.05 per unit.
4. Load power factor: Load power factor is 80% or higher.
5. Voltage and frequency: Secondary voltage and volts per hertz shall not exceed 110% at no load and 105% at rated load; Frequency is at least 95% of rated value.

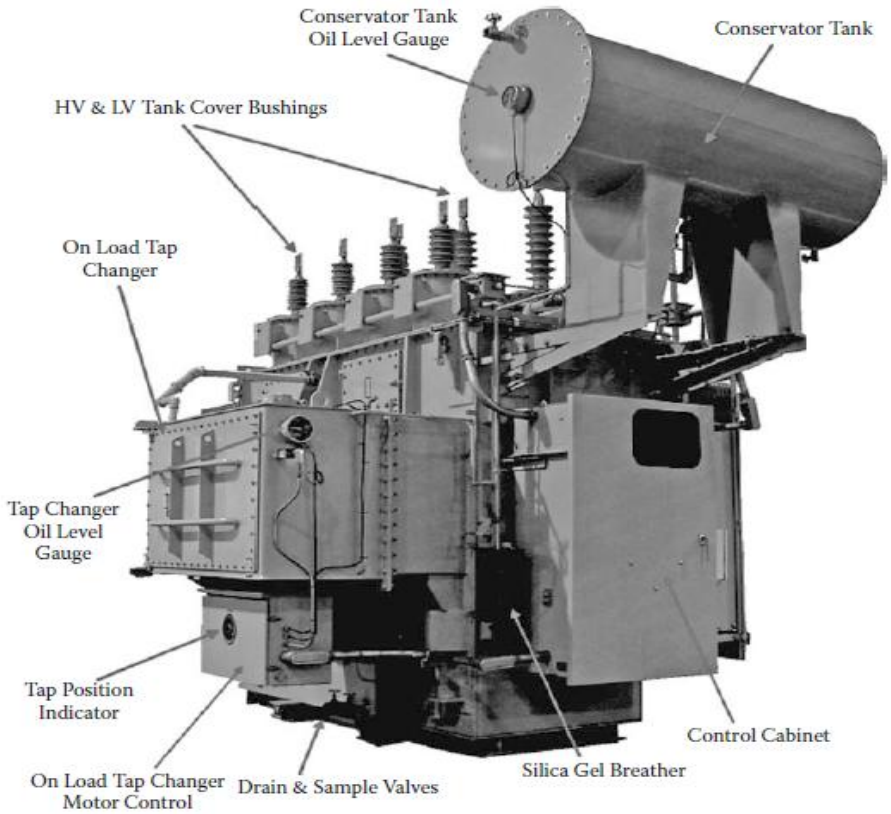


Figure 3.3. Transformer 15/20 MVA 72kV–25kV

3.3.2. Three-Phase Transformer Models [3]

A three-wire delta feeder will typically have a delta–delta transformer connection in the substation. Three-phase transformer banks out on the feeder will provide the final voltage transformation to the customer's load. A variety of transformer connections can be applied. The load can be pure three phase or a combination of single-phase lighting load and a three-phase load such as an induction motor. In the analysis of a distribution feeder, it is important that the various three-phase transformer connections be modeled correctly.

Models for the three-phase connections are:

- Delta–Grounded Wye
- Ungrounded Wye–Delta
- Grounded Wye–Grounded Wye
- Delta–Delta
- Open Wye–Open Delta

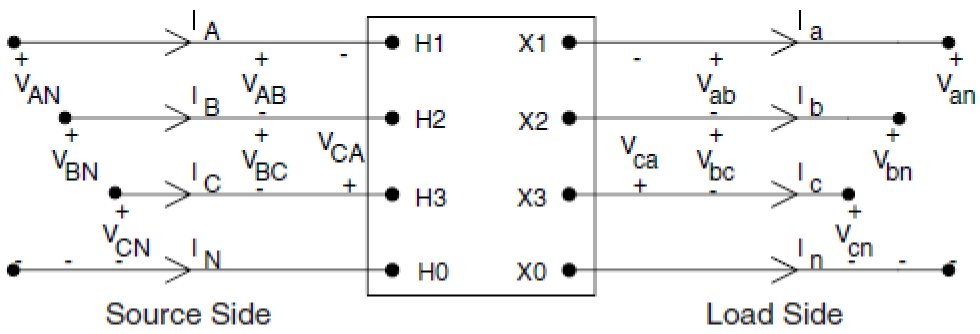


FIGURE 3.4.General three-phase transformer bank.

that the capital letters A, B, C, N will always refer to the source side (Node n) of the bank and the lower case letters a, b, c, n will always refer to the load side (Node m) of the bank. It is assumed that all variations of the delta- wye connections are connected in the distribution system connection, and next connection (3.2) is the commonly used in industrial zone [7].

The Delta–Grounded Wye Step-Down Connection

The delta–grounded wye step-down connection is a popular connection that is typically used in a distribution substation 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. Three single-phase transformers can be connected to a delta grounded wye in a standard thirty-degree step-down connection as shown in Figure 3.5 [13].

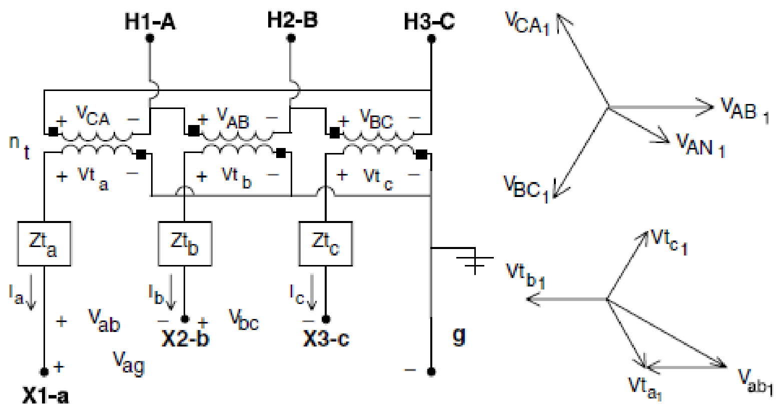


FIGURE 3.5. Standard delta–grounded wye connection with voltages.

3.3.3. Cooling Systems [2]

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^2R loss), stray loss in windings and stray loss due to leakage/high current field are mainly responsible for heat generation within the transformer.

Sometimes loose electrical connections inside the transformer, leading to a high contact resistance, cause higher temperatures. Excessive temperatures due to heating of curb bolts, which are in the path of stray field, can damage gaskets. The heat generated due to all these losses must be dissipated without allowing the core, winding and structural parts to reach a temperature which will cause deterioration of insulation. If the insulation is subjected to temperatures higher than the allowed value for a long time, it loses insulating properties; in other words the insulation gets aged, severely affecting the transformer life. There are two principle characteristics of insulation: dielectric strength and mechanical strength

Cooling Arrangements: [1]

IEEE, CSA, and IEC standards have harmonized and use the same cooling designations. The cooling method is designated by four letters in combination to define the cooling medium and the method of circulation:

- 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 300°C, and **K** (or **L** for IEC) for insulating liquid with fire point more than 300°C. These include silicone or high-molecular carbon products. **G** is also included for gas-filled designs.
- 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).
- The third letter is for the external cooling medium, **A** for air, and **W** for water.
- 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) [8].

Table 3.1 Transformer Cooling Designations

Present Designation	Previous Designation (Obsolete)	**Description**
ONAN	OA	Oil immersed, natural circulation, self-cooled
ONAF	FA	Oil-immersed, natural circulation, forced-air cooled
ONAN/ONAF/ONAF	OA/FA/FA	Oil-immersed, self cooled, plus two stages of fan cooling
ONAN/ONAF/ OFAF	OA/FA/FOA	Oil-immersed, self cooled, plus one stage of fan and one stage with forced-air and forced-oil cooling
ONAN/ODAF	OA/FOA	Oil-immersed, self-cooled, plus one stage of directed fan cooling
ONAN/ODAF/ ODAF	OA/FOA/FA	Oil-immersed, self-cooled, plus two stages of directed fan cooling
OFAF	FOA	Oil-immersed, forced-oil, and forced-air cooled (pump and fans)

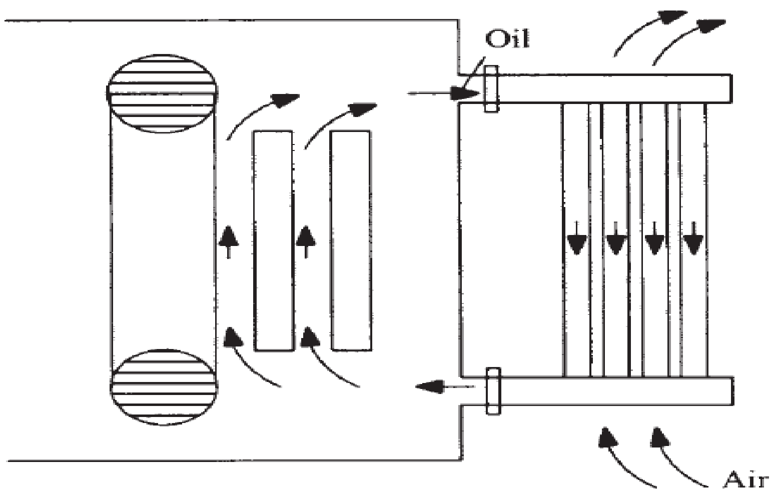


Figure 3.6. ONAN cooling

3.3.4. Accessories [1]

The accessories for mineral-oil transformers include:

- Sudden-pressure relay for sealed-tank design transformers, generally when rated 7.5 MVA and larger. The relay is calibrated for mounting either in the oil or gas space above the oil, and is equipped with a micro switch for alarm and trip.
- Gas-detector relay (known as a Buchholz relay, shown in fig. 3.7) for conservator- type transformers, generally when rated 7.5 MVA and larger. The device is mounted in the pipe between the highest part of the transformer tank and the conservator. The relay is equipped with two sets of contacts, one for alarm upon gas accumulation and one for trip upon oil surge.
- Winding-temperature indicator, responsive to the combination of top oil temperature and winding current. The device is calibrated to follow the hottest spot temperature of the winding. The temperature indicator, for forced-cooled transformers, shall be equipped with adjustable contacts for starting the cooling fans and pumps, while all transformers should be equipped with at least two contacts for alarm and trip [8].

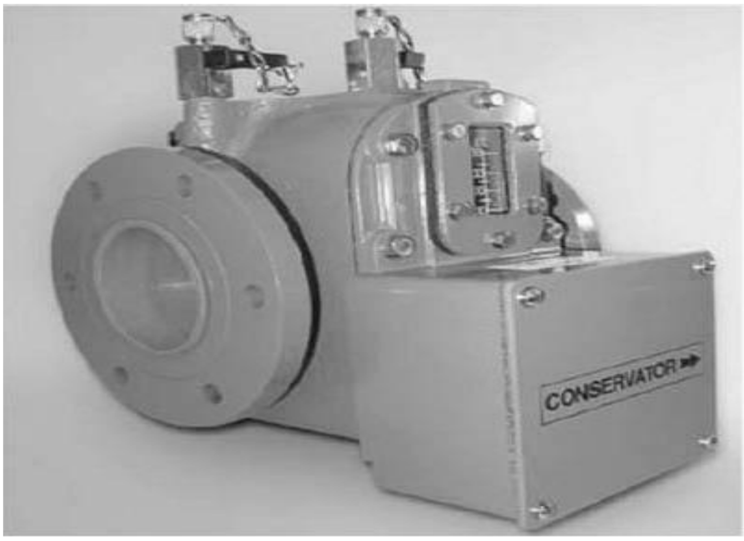


Figure3.7. Buchholz relays for protection of oil-filled transformers

These devices are fitted to the larger designs of transformer and, in some cases, are applied to reflect, separately, the primary and secondary winding temperatures.

- Oil-temperature indicator with its sensing element located in the path of the hottest oil, and mounted adjacent to the winding temperature indicator.

3.3.5. Transformer Protection [4]

A typical protection scheme, commonly used in industrial power systems for a medium or high voltage oil immersed power transformer, is shown in fig. 3.8. Descriptions some of the protection elements and devices are provided in the following subsections:

3.3.5.1. Devices Provided with the Oil-Immersed Transformers

- Gas detector relay (63P): This device, generally known as a "Boucholz relay," is used with conservator-type transformers. It is mounted on the pipe connecting the highest part of the transformer tank and the conservator. It operates in two stages and has two sets of contacts. The first stage is used for alarm, and the second stage is used for trip.

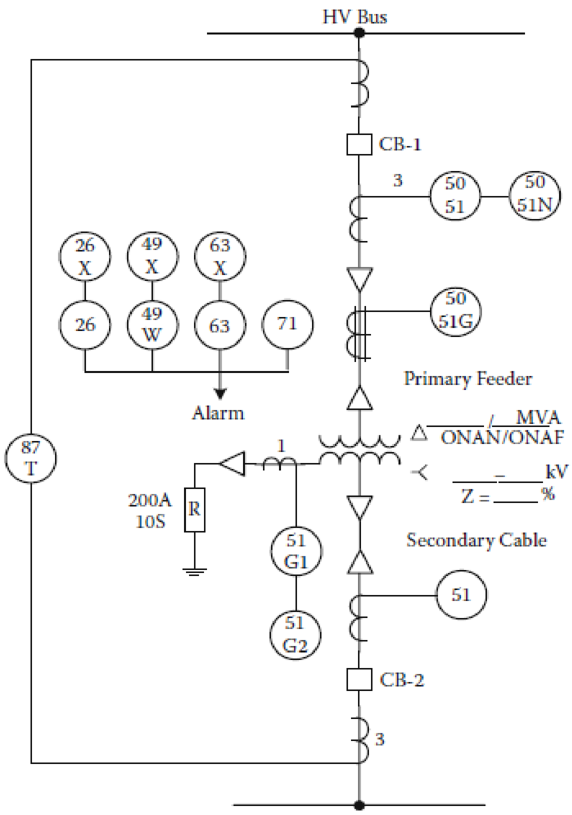


Figure3.8. Transformer protection with primary and secondary breaker

- Winding over temperature (49): This is a temperature-measuring device submerged in the transformer oil but also surrounded by a heater that is connected to the secondary of a current transformer in the winding. This is calibrated to measure the winding hot-spot temperature and has two to four adjustable temperature set points.

3.3.5.2. Primary Overcurrent Protection

The high-voltage side of a Delta-Wye step-down transformer is typically equipped with:

- Phase overcurrent, instantaneous (50): This element or device protects the feeder and the transformer against short circuits, including faults at the bushing terminals.
- Phase overcurrent, inverse time (51): This element protects the feeder and the transformer against overcurrent, and is set at about 2.0 P.U. of the transformer full load current at base rating.

3.3.5.3. Secondary Overcurrent Protection

The LV side of a resistance grounded transformer is typically provided with:

- Phase overcurrent, time (51): This element is set to protect the transformer secondary and the bus against LV faults and short time overloads, and is usually set at about 1.5 P.U. of the rated secondary current.
- Ground overcurrent, time (51G1 and 51G2): In this illustration, this relay is provided with two stages, usually provided with the same current setting, typically 20–50% of the grounding-resistor rating.

3.3.5.4. Transformer Protection with a Primary Fuse

A typical transformer-protection scheme with primary fuse, commonly used with effectively grounded power systems, is shown in fig. 3.9.

Most fuse suppliers provide recommendations for the sizes and types of transformers their fuses can protect. However, the guidelines are:

- Power fuse: 140% of the transformer self-cooled rating
- Current-limiting fuse: 150% of the transformer self-cooled rating

- Fuse time–current: below the transformer short-circuit withstand curve (SCW) and above the magnetizing inrush current
- Magnetizing inrush current: points for coordination are 10 to 12 P.U. at 0.1 s and 25 P.U. at 0.01 s

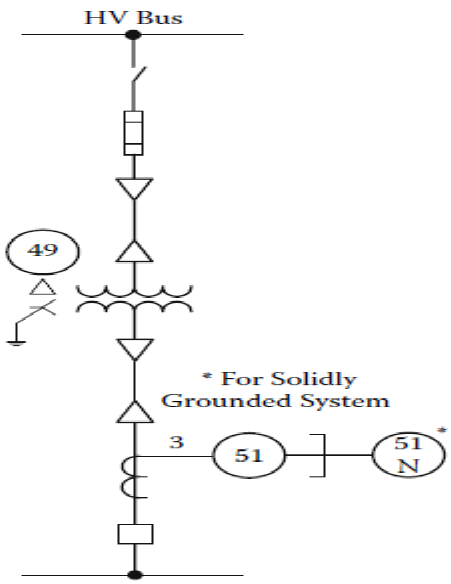


Figure 3.9. Transformer protection with primary fuse

3.3.5.5. Protection of Low-Voltage Unit Substation Transformers

A typical low-voltage (LV) unit substation connected to medium voltage switchgear is shown in fig. 3.10 The following guidelines can be used for the setting of protective devices.

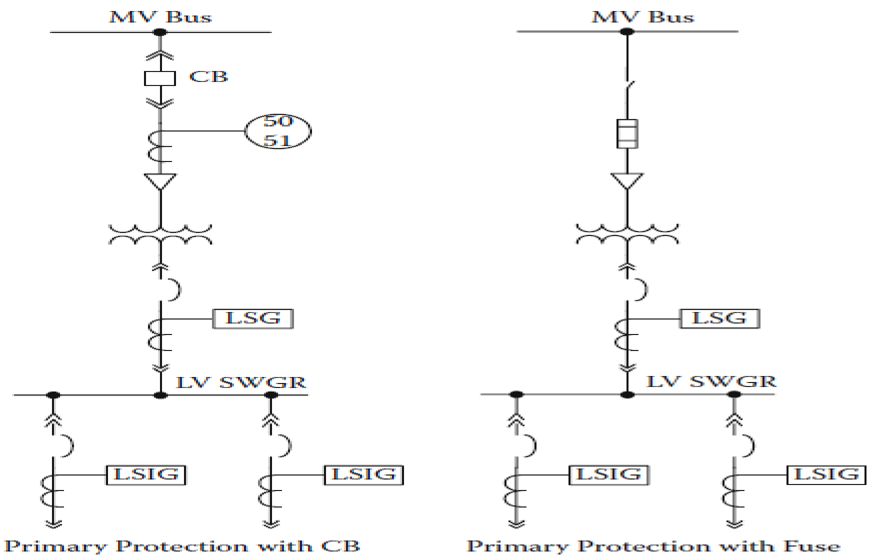


Figure 3.10. Protection of LV unit substation

3.4. Cable

The selection process is the cabling of the most important parts and equipment in the design of electrical networks in the industrial areas, so the choice of the correct cables electrical grid makes the electric grid is going correctly.

This section concentrates on the properties of different types of LV, MV power cable.

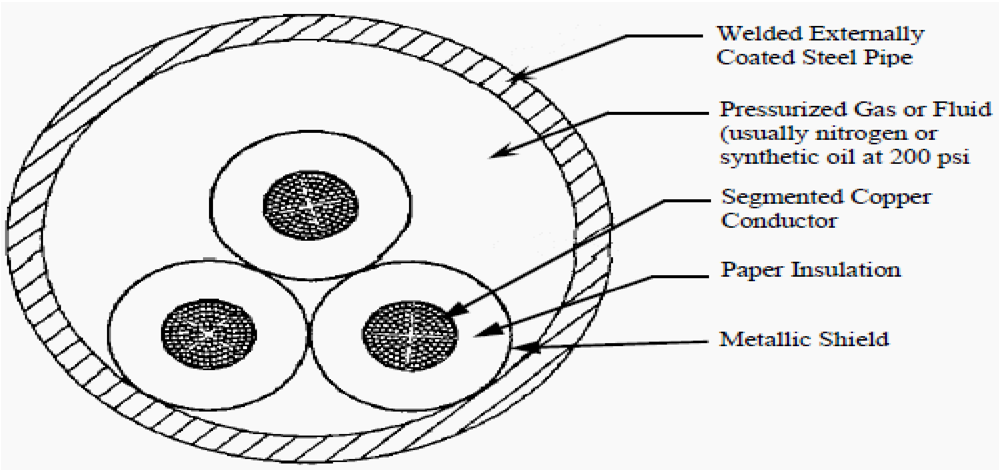


Figure 3.11. Underground cable

3.4.1. Cable Selection Criteria [1]

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 [8].

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, and this characteristic is based on the method of neutral grounding used in the system.

3.4.2. Cable Insulation [1]

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 [5].

3.4.3. General Methodology

All cable sizing methods more or less follow the same basic six step process:

1) Gathering data about the cable, its installation conditions, the load that it will carry, etc

2) Determine the minimum cable size based on continuous current carrying capacity

3) Determine the minimum cable size based on voltage drop considerations

4) Determine the minimum cable size based on short circuit temperature rise

5) Determine the minimum cable size based on earth fault loop impedance

6) Select the cable based on the highest of the sizes calculated in step 2, 3, 4 and 5

3.4.4. The main benefits of underground high voltage cables:[7]

1. Cost Effective Solution

In the past, the higher cost of underground cables was a significant deterrent to their use. However, with lower cost production methods, improved technologies and increased reliability, the cost differential between underground cables and overhead power lines is narrowing. This means that power project developers are more frequently turning to underground cables as an economic and technically effective alternative when physical obstructions or public opinion hinder the development of networks.

Apart from the reduced visual impacts, underground cables also offer lower maintenance costs than overhead lines. They are also less susceptible to weather-related issues such as storm damage, interruptions, costs of storm damage surveys and precautionary storm shutdowns. In addition, underground cables contain high quantities of copper, the most conductive engineering metal, resulting in 30 percent lower power losses than overhead lines at high circuit loads and improved system efficiency.

2. Reduced Transmission Losses

Underground extra-high voltage 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, which is especially important for remote renewable and low carbon generators. Reducing these power transmission losses makes a valuable contribution to lowering greenhouse gas emissions [6].

3.5. Ring Main Unit (RMU):

3.5.1. Introduction:

A ring-main unit is a piece of switchgear used on high voltage distribution ring-main systems (e.g. 11 kV). 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/circuit breaker is called your Turn off.

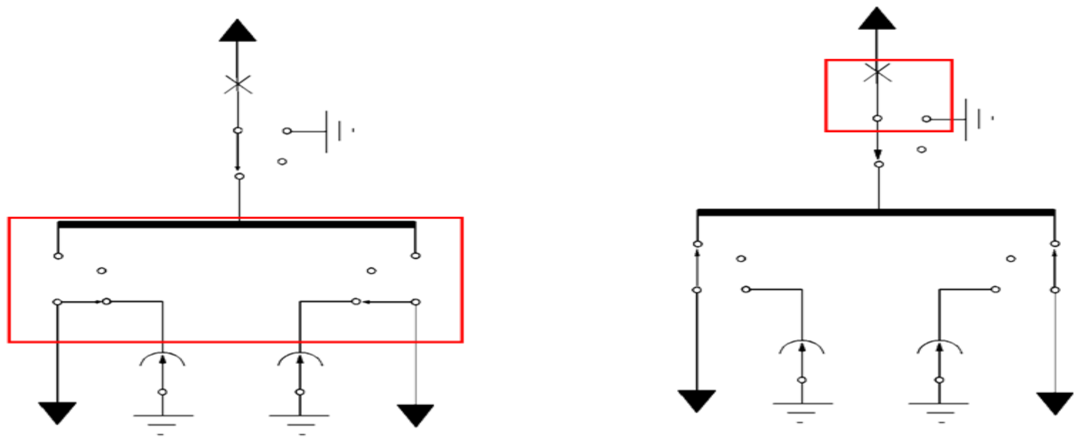


Figure3.12. Three position Isolator and circuit diagram for RMU

3.5.2. General Requirement:

The Ring Main Unit shall be installed at 22 kV and 11 kV junction points such as 630 kVA, 315 kVA distribution transformers center's to isolate faulty section. The RMU shall be both Non extensible/extensible. Two Load break isolators for incoming & outgoing cables and one Circuit breaker for transformer protection shall be enclosed in the main tank using SF6 gas as insulating and vacuum as arc quenching medium or SF6 gas as both insulating and arc quenching medium.

Both the load break switches and circuit breaker shall be suitable for motorization in future The total breaking time for transient fault should not exceed 40-60 mS(CB + Relay+ trip coil).

An absorption material such as activated alumina in the tank shall be provided to absorb the moisture from the SF6 gas to regenerate the SF6 gas following arc interruption. A temperature compensating gas pressure indicator offering a simple indication shall constantly monitor the SF6 insulating medium.

3.5.3. Load Break Switches (Isolators)

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 off position. The load break isolators should have the facility for future remote operation.

Chapter Four

Designing the distribution network

4.1. Introduction

Steps for designing electrical distribution networks for industrial facility

Before beginning design for industrial zone we should obtain the basic information from the company or the ministry responsible for supplying energy (HEPCO).And these information's are

- Voltage that is should fed to the factory's, in our project from (11KV) TO (400V/380V)
- Grounding type at star point, in our project solid ground and (TT- earthing system)

The most important points have to be considered, when we designing electrical distribution networks for industrial area, these point are:

4.2.Dividing the industrial loads

According to its kilo volt-ampere, into large and medium and small loads respectively, as shown in the Appendix A table, then locate each part separately inside of the industrial area.

According of HEPCO table [11] (attached in appendix A) we have (52 big and 84 medium and 24 small) factories With (32.5% and 52.5% and 15%) respectively from the total load

NO#	Size	%
52	Big	32.5
84	Medium	52.5
24	Small	15

Table 4.1: Number of load in each part and its percentage

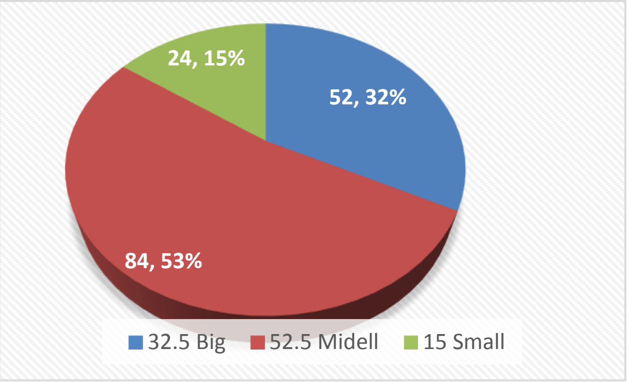


Figure 4.1: Percentage of each part

4.3.Sizing the needed supplying transformers

For each load in each part, and that's need to:

- Obtain the load duration curve for each load from HEPCO (But in our project we estimate the load duration curve for each load according to the type of factory, that's because there's no real duration curve from HEPCO)

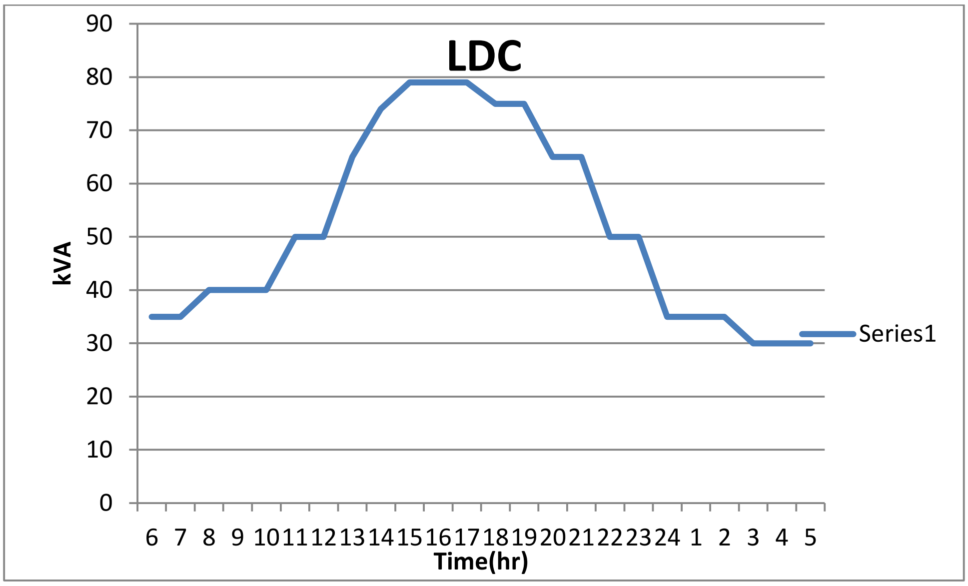


Figure 4.2: Load duration curve.

- In large loads we can connect one to three loads with one transformer according to the value of maximum diversified demand.
- In medium loads we can connect three to five loads with one transformer according to the value of maximum diversified
- In small loads have the same processes in medium load but here we can connect four to six loads with one transformer.

- Determining the total load and the maximum demand request using *Diversity factor*.
  - ✓ Diversity Factor
    Ratio of the maximum non coincident demand to the maximum diversified demand

Example: connected three medium loads with one transformer, such that the load duration curves (LDC) for these loads are.

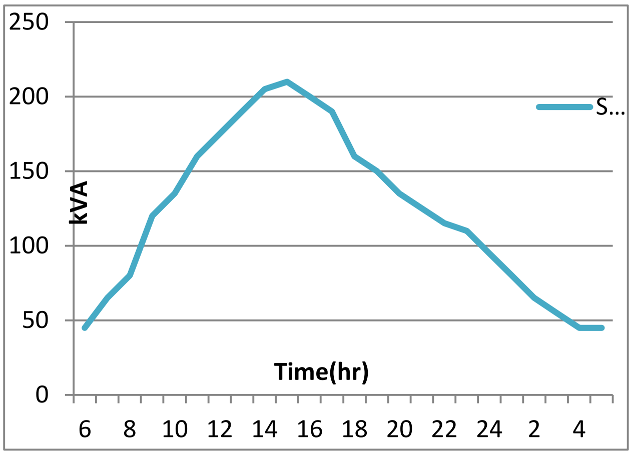


Figure 4.3: LDC for load # 1

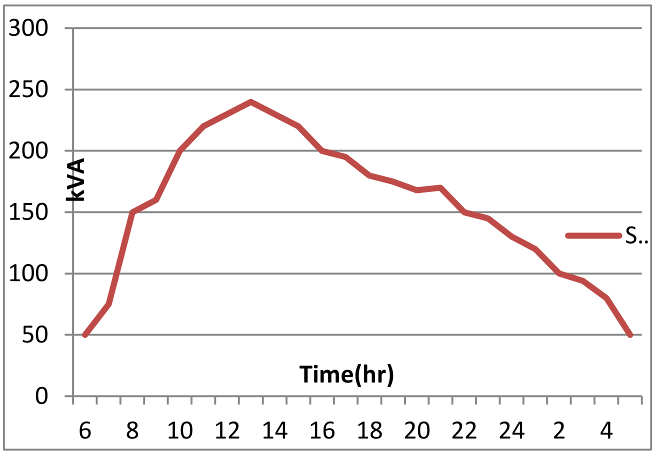


Figure 4.4: LDC for load # 2

According these load duration curves, the maximum value for

Load # 1 is 210 kVA

Load #2 is 240 kVA

load # 3 is 165 kVA

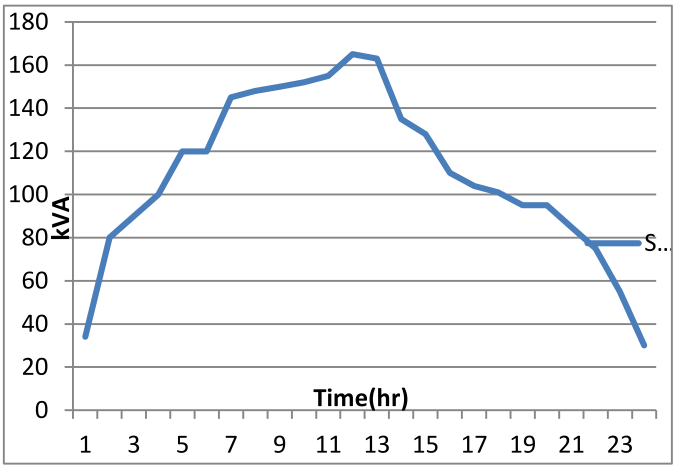


Figure 4.5: LDC for load # 3

And take the Diversity Factor equal 1.25 Such that the DF in factories has range from 1.15 to 1.5 [14]

$$\text{Diversity Factor} = \frac{\text{(maximum non coincident demand)}}{\text{(maximum diversified demand)}} \qquad (4.1)$$

And maximum diversified demand = (maximum non coincident demand) / (Diversity Factor) (4.1)

So that the maximum diversified demand = (210+240+165)/1.25

= 492 kVA

According this value 492kVA, the nearest standard value for transformer feed these loads is 500 kVA.

As we did in the previous example and as shown in the following table (Table 4.2) [11], we collect some of loads on one transformer, according to the maximum value of the load and the Diversity factor

Table 4.2: Collect loads on transformer

Size	kVA Rating	No of Load	No of load/transformer	No of Transformer	KVA of Trans	KVA of all Trans.
Small	13→42	7	7	1	250	250
Small	43→65	17	5	3	400	1200
Medium	66→85	18	6	3	500	1500
Medium	100→150	33	3	11	500	5500
Medium	151→190	33	3	11	630	6930
Large	210→274	30	3	10	800	8000
Large	274→339	10	2	5	800	4000
Large	340→380	6	2	3	800	2400
Large	520→550	3	1	3	630	1890
Large	730→789	3	1	3	800	2400
Total		160		53		34070

Hint: here in our project we have **two scenarios** for electrical network, 11kV and 33kV.

For our industrial zone the transformer in 33kV network take the same rated value in 11kV network, which is the difference between these networks only in transformation ratio and cross section area.

4.4. Sizing the needed supplying cable

In general the voltage is directly probably with insulation and current with cross section area, so the sizing of cable as follow.

- For main cable (main cable carry 33kV)

$$I = \frac{MVA}{\sqrt{3}*KV} = \frac{40MVA}{\sqrt{3}*33KV} = 700A \qquad (4.3)$$

So we will choose section area for the cable (3*(1*70mm^2) (Bundle)) according IEC 60287, the data sheet for this cable attached in appendix B

- At the first for 11kV network the suitable cables as follow.

- First main branch section

$$I = \frac{kVA}{\sqrt{3} * kV} = \frac{(6600 + 4750)kVA}{\sqrt{3} * 11kV} = 596A$$

Section area for this cable is (3*(1*50mm^2)(bundle))

- Second main branch section

$$I = \frac{kVA}{\sqrt{3} * kV} = \frac{(5600 + 5800)kVA}{\sqrt{3} * 11kV} = 598A$$

Section area for this cable is (3*(1*50mm^2)(bundle))

- Third main branch section

$$I = \frac{kVA}{\sqrt{3} * kV} = \frac{(5400 + 5500)kVA}{\sqrt{3} * 11kV} = 572A$$

Section area for this cable is (3*(1*50mm^2) (bundle))

- Now for the branches between RMU's and the transformers

  For transformer with rate value 800kVA then:
  $I = \frac{kVA}{\sqrt{3}*KV} = \frac{800KVA}{\sqrt{3}*11KV} = 42A$

Section area for this cable is (1*16mm^2)

And the same cross section for 630kVA and 500kVA transformer.

- In the 33kV the cross section will be decrease to one-third.

- First main branch section

$$I = \frac{kVA}{\sqrt{3} * kV} = \frac{(6600 + 4750)kVA}{\sqrt{3} * 33kV} = 199A$$

Section area for this cable is (1*50mm^2) without bundle. And the same cross section for other main branch.

4.4.1 Cable Selection and Coordination with Protective Devices

When sizing cables for non-motor loads, the upstream protective device (fuse or circuit breaker) is typically selected to also protect the cable against damage from thermal overload. The protective device must therefore be selected to exceed the full load current, but not exceed the cable's installed current rating, i.e. this inequality must be met:

$$I_l \leq I_p \leq I_c$$

Where I_l is the full load current (A)

I_p is the protective device rating (A)

I_c is the installed cable current rating (A)

4.4.2 Calculating Voltage Drop

For AC systems, the method of calculating voltage drops based on load power factor is commonly used. Full load currents are normally used, but if the load has high startup currents (e.g. motors), then voltage drops based on starting current (and power factor if applicable) should also be calculated.

For a three phase system:

$$V_{3\Phi} = \frac{\sqrt{3}I(R_c \cos\Phi + X_c \sin\Phi)L}{1000} \tag{4.4}$$

Where $V_{3\Phi}$ is the three phase voltage drop (V)

I is the nominal full load or starting current as applicable (A)

R_c is the ac resistance of the cable (Ω/km)

X_c is the ac reactance of the cable (Ω/km)

$\cos\Phi$ is the load power factor (pu)

L is the length of the cable (m)

4.5 Sizing the fuses

The high cutting capacity fuses must be match with international standard specifications; these fuses protect systems parts from thermal effects coming from over loaded current, and the fuses precede the entrances of transformers and cables feeding, So that the fuse value depend on cross section of cable, for example at 70 mm^2 wire size the suitable fuse size (max) is 400A [14].

4.6 Sizing the auto recloser

Auto Recloaser protect the electrical circuit from over load and short circuit, so while we sizing the AR we should feed the AR with short circuit tripping current that will operate on it.

And we use E-tap program to sizing the AR.

4.7 Sketching an initial Single line diagram for the system.

The main transformer connected on the main bus bar has a total capability of 40 MVA and transformer step down the voltage from 33kV to 11kV.

Here we have some scenarios for single line diagram for our industrial zone:

First one has two main transformers in the main bus bar as shown in figure 4.6; each transformer has rated value with 40MVA

The first transformer feed large section and second transformer feed medium and small section

Also each transformer can feed all of the loads if any problem faced in the other one

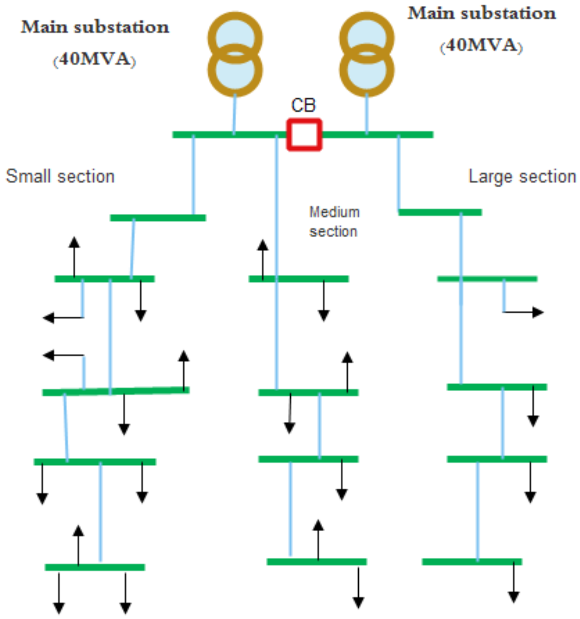


Figure 4.6: First scenario for industrial zone

Second scenario has two main transformers first one at the main bus bar in the beginning of industrial zone and the second one in the end on industrial zone as shown in figure 4.7; also each transformer has rated value with 40MVA

The first transformer feed half of industrial area and second transformer feed the same value,

And as expected we will choose this scenario to build our zone.

In this scenario, while we feed the large loads from main source at the beginning of the zone and feed the medium loads from end source, this procedure reduce the voltage drop inside the grid, and give high reliability with contentious feeding of electricity such that if any problem faced in one transformer the other one feed all of needed power

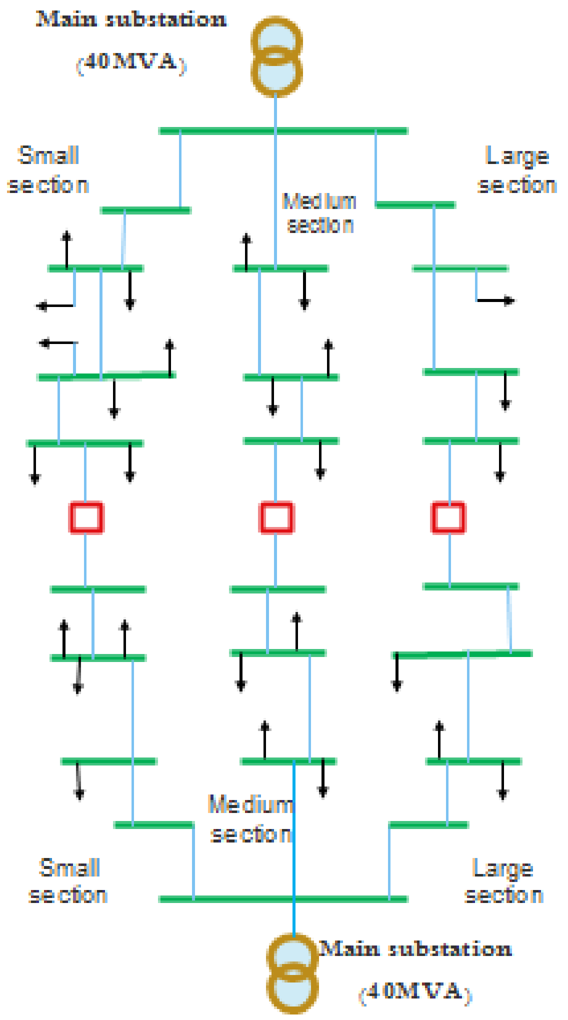


Figure 4.7: Second scenario for industrial zone

Third scenario like second scenario with two main transformers first one at the main bus bar in the beginning of industrial zone and the second one in the end on industrial zone as shown in figure 4.8; but with transformer with rated value of 20MVA, And the first transformer feed half of industrial area and second transformer feed the second half of the area.

But In this scenario like second scenario, while we feed the large loads from main source at the beginning of the zone and feed the medium loads from end source, this procedure reduce the voltage drop inside the grid,

And here give low reliability with contentious feeding of electricity such that if any problem faced in one transformer the other cannot feed the faulted area.

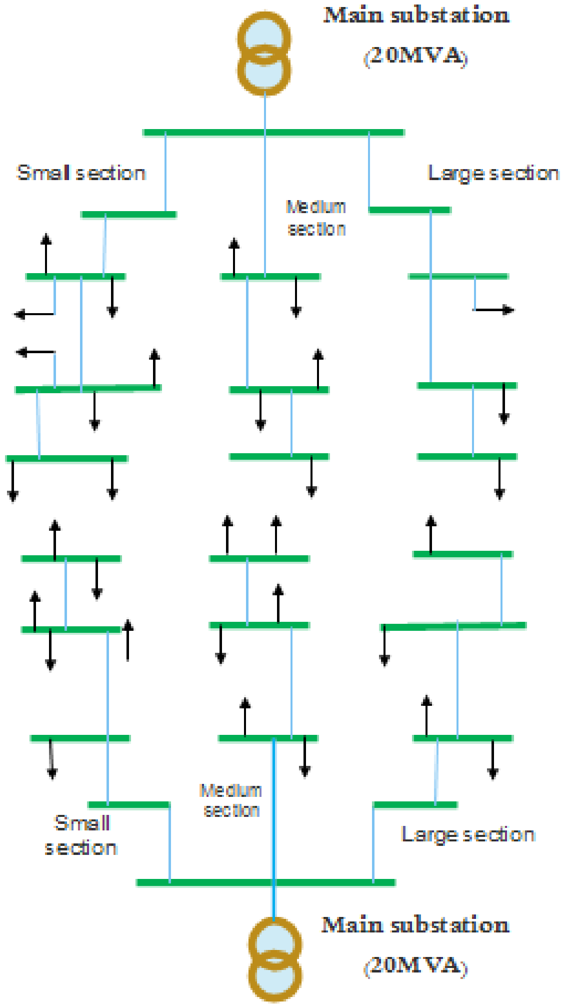


Figure 4.8 Third scenario for industrial zone

Chapter Five

Software program

5.1. Electrical network for industrial zone in ETAP Program

<table>
<tr><td colspan="2">POWER SYSTEM ANALYSIS

DESIGN AN ELECTRICAL NETWORK FOR INDUSTRIAL ZONE IN HEBRON CITY</td><td></td><td>33 KV MAIN SUBSTATION
TO 11 KV DISTRIBUTION NETWORK
ONE-LINE DIGRAM</td></tr>
<tr><td>Created by:
IBRAHIM AL-DABBAS
KARAM AL-NATSHA
MUSAB SHRUF</td><td>Date:
MAY 07, 2015</td><td>Sheet 1of 1</td><td>Revision:
3</td></tr>
<tr><td>Checked by:
ENG.NIZAR AMR</td><td>Scale:
NA</td><td>Drawing #:</td><td>Filename:
GRADUATE PROJECT</td></tr>
</table>

5.1.1. Introduction to ETAP Program: (source ETAP Demo)

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 high impact software [2].

5.1.2. Network component required data:

When designing any electrical Network or any simple line from the beginning or adding and removing any electrical line from the network, it will be contains many of the elements and electrical components and to find out what will happen to the changes on the network and at the same ingredients and choose the components and elements best suited then you have to hold all the necessary calculations are accurate and fast at the same time.

If you do the above, we need an accounting program is doing all the necessary calculations when giving him all the required data for each element of the network.

ETAP program containing the above and he depends in his calculations on Newton-raphson method.

Now, we will show the main components of the network components we used in the design process.

- **Transformer in ETAP:**

Transformer MVA Sizing:

The 2-Winding Transformer MVA Sizing calculation sizes the transformer rated MVA, maximum MVA, and %Z based on the transformer loading, installation, insulation level, and short-circuit duties. Load variation factors can also be included in the sizing calculation.

And its Includes ANSI & IEC Standard Types, Classes & Ratings and Considers Ambient Temperature Altitude, Growth, & Loading Factors, etc.

- **Cable in ETAP:**

In this part we can put cable parameters and how put the information of impedance and how put parameter to calculation the sizing of cable.

And we see Conductor ampacity vs. temperature and Physical parameter to impedance calculator and how protection this cable and to sit the length type, standard, and maximum loading of this cable.

- **Fuse in ETAP:**

  When we use fuse in Electrical network to protect transformer or cable generally and installed that in ETAP you must choose rating value and goes to library manufacturer, model, Max kV, speed, size and other.

5.1.3 Load Flow:

The load flow in Etap program can perform the following

- Voltage drop calculations
- Load forecasting
- New alert view to display critical and marginal limit violations
- Bus/transformer/cable overload warning
- Single phase load flow display
- Option to select any loading category
- Power factor correction

5.1.4 General description for our network

The following figure shows the one line diagram for all network, outer view.

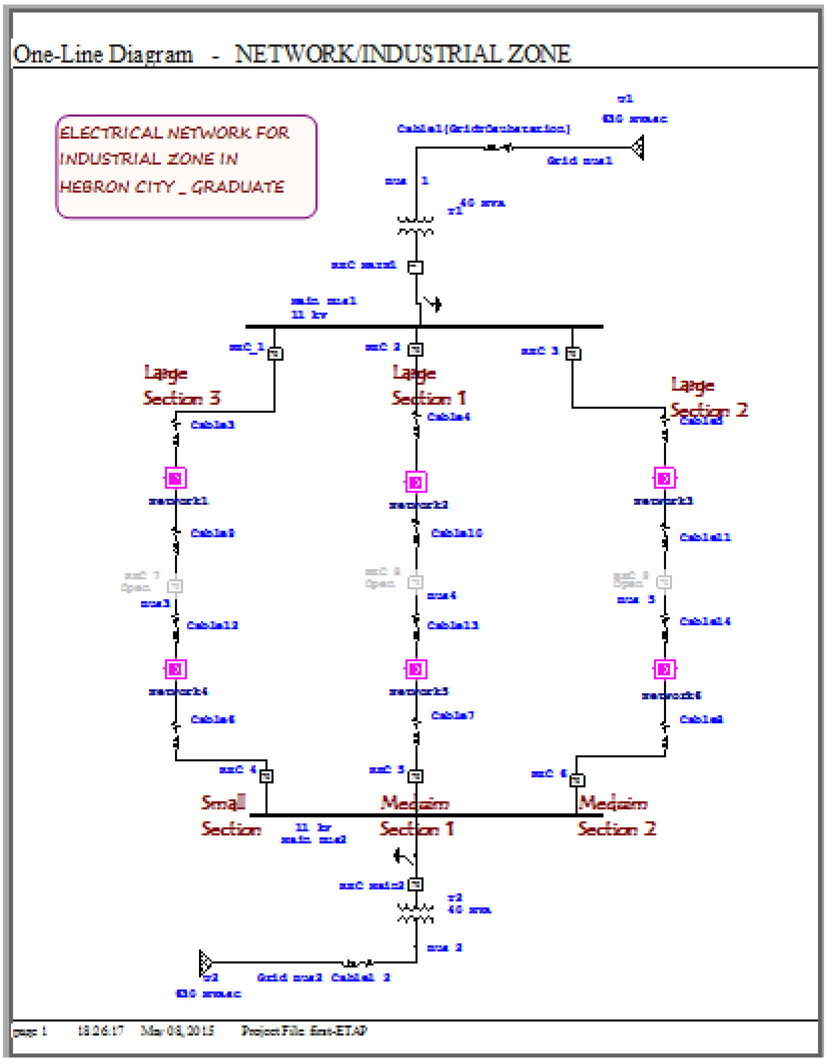


Figure 5.1. Main network on Etap

At the first, the main source for the network comes from the distribution point (NAMIRA), which is 1600 meters from the electrical distribution network of the industrial zone.

And this power will be transferred by using the transmission cable have diameter (3*(1*70mm^2) (Bundle)) from the source of supplying, to the two main transformers in the network, where each transformer have rated value 40MVA, followed by AutoRecloser" AR" to control the operation and fire the whole network.

Secondly, Industrial zone is divided into, two main sections; the northern and southern section such that each partition contains half amount from the total load. i.e. the zone divide into two part's approximately equal in kVA.

And each section contains 3 internal networks, are approximately equal in kVA

Each major section will be feed from transformer, where the loading rate for each transformer is 50% of the nominal, so that the transformer achieve high efficiency.

Thirdly, Industrial zone sections

First Section (northern) that have a factories where categories in large-size, such that it contain 3 electrical networks.

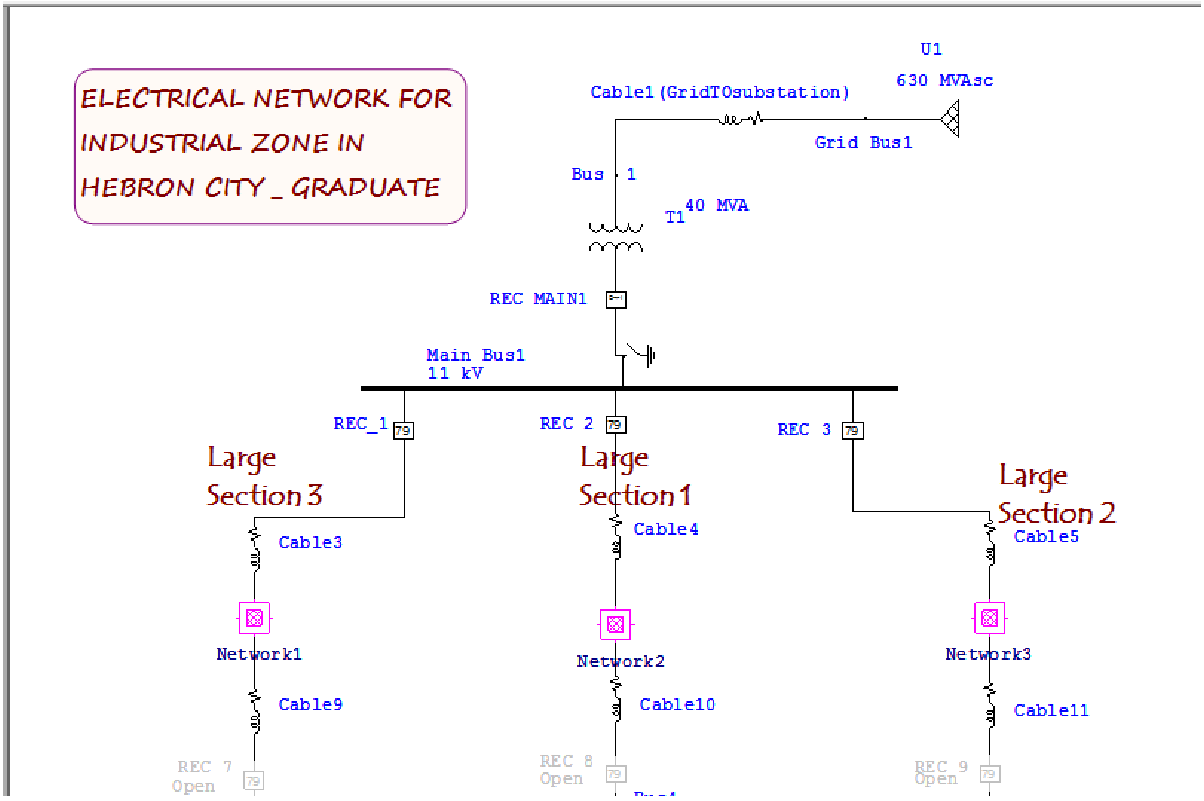


Figure 5.2. First section (Large Sections)

Now the general description for each sub network inside the northern Section

The first electrical network (network # 1) it’s contain the following...

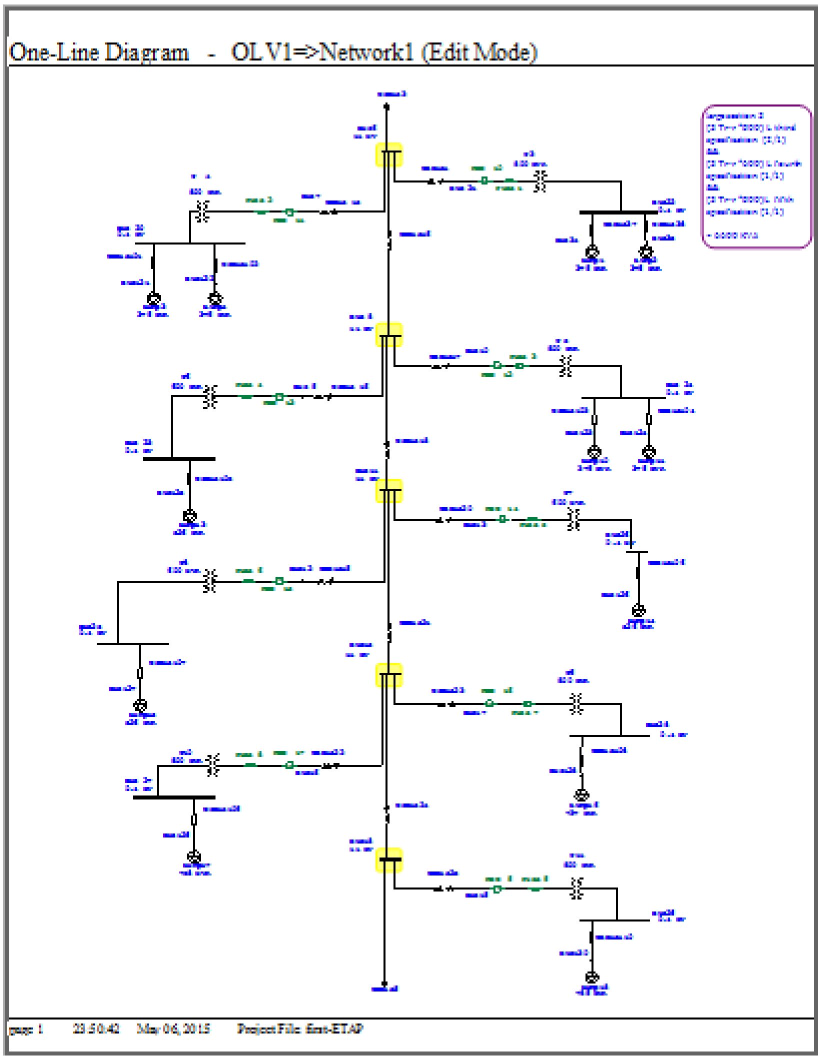


Figure 5.3. Network 1

- 3 transformers each one 800kVA and every transformer connected with one load (factory), Such that the transformer value has been developed to accommodate the max demand of the connected load.
- 3 transformers each one 630kVA and every transformer connected with one load (factory), Such that the transformer value has been developed to accommodate the max demand of the connected load.
- 3 transformers each one 800kVA and every transformer connected with two load (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor as previously explained.
- 5 connected points (RMU) with type TTCC.

- main cables that connect every "RMU with the other" its ground cables each one (3*(1*50mm^2) (bundle)) and this value is based on identifying private tables as we mentioned earlier, and As for determining the total length will explain later.
- Sub cable reached between the "RMU and transformer" ground cables is (1*25mm^2)(bundle)
- Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable based on each load as follows:
    - Large loads that has been connected on a one transformer, connected by cable with value is (3*(1*185mm^2) (bundle)) for each cable load
    - Large loads that has been connected (two load on one transformer), connected by cable with value is (3*(1*70mm^2) (bundle)) for each cable load
- Fuse and auto recloser, between RMU’s and each transformer.

The second electrical network (network # 2) and it’s contain the following...

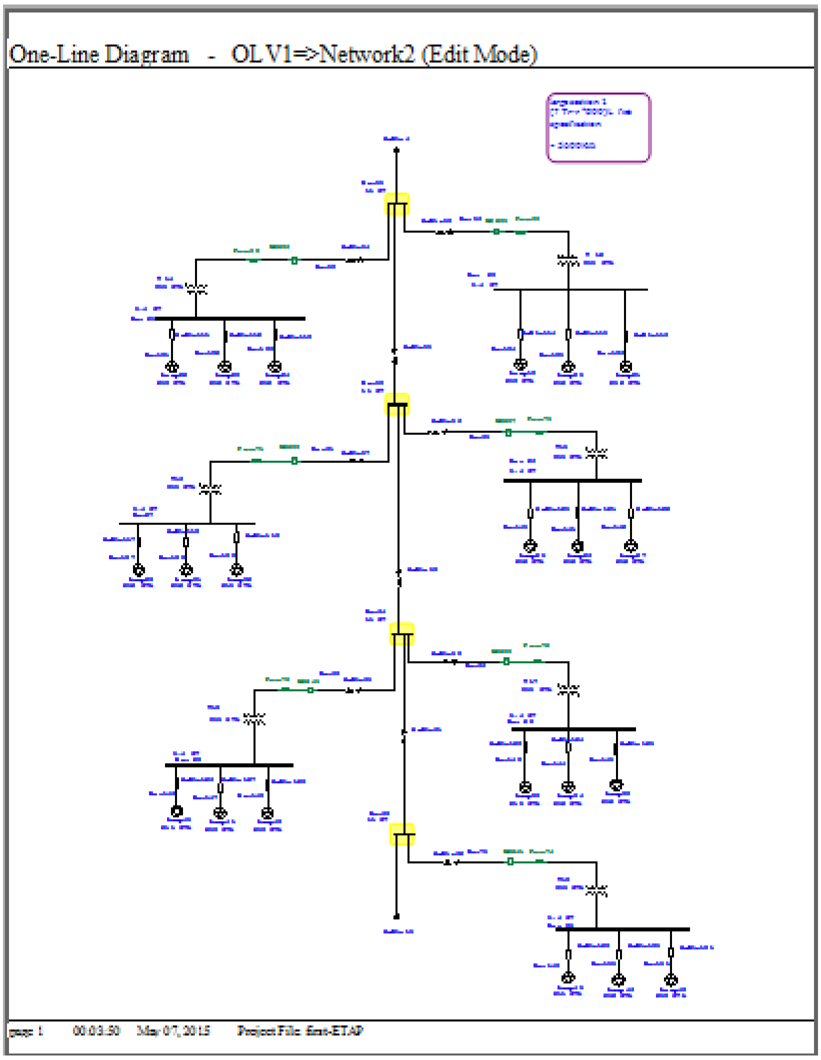


Figure 5.4. Network 2

- 7 transformers each one 800kVA and every transformer connected with three loads (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor as previously explained.
- 4 connected points (RMU) with type TTCC.
- Main cables that connect every "RMU with the other" its ground cables each one is (3*(1*50mm^2) (bundle)) and this value is based on identifying private tables as we mentioned earlier.

- Sub cable reached between the "RMU and transformer" ground cables is (1*25mm^2) (bundle) Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable is (3*(1*35mm^2) (bundle)).
- Fuse and AutoRecloser, between RMU's and each transformer, adjusted based on the SC analysis.

The third electrical network (network # 3) and it's contain the following...

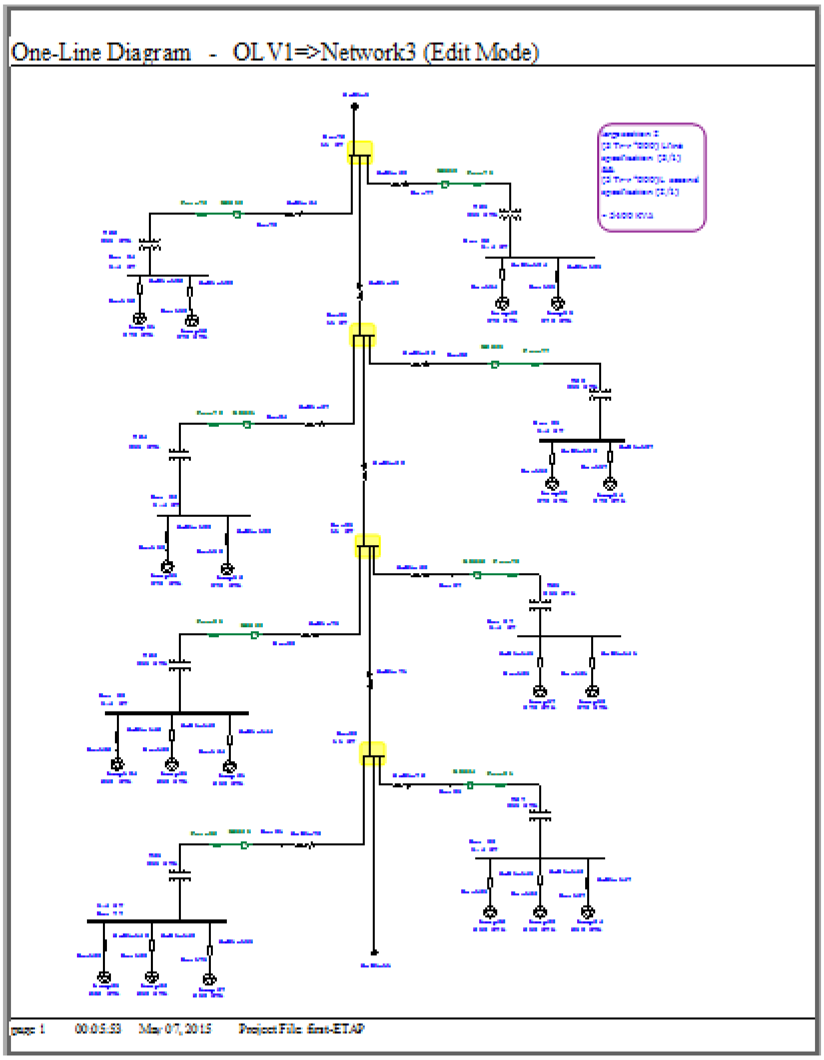


Figure 5.5. Network 3

- 5 transformers each one 800kVA and every transformer connected with two load (factories), Such that the transformer value has been developed to

accommodate the demand of the connected load according to the diversity factor.

- 3 transformers each one 800kVA and every transformer connected with three loads (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor as previously explained.
- 4 connected points (RMU) with type TTCC.
- main cables that connect every "RMU with the other" its ground cables each one is (3*(1*50mm^2)(bundle)) and this value is based on identifying private tables as we mentioned earlier
- Sub cable reached between the "RMU and transformer" ground cables is (1*25mm^2)(bundle)
- Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable based on each load as follows:

  - Large loads that has been connected (two load on one transformer), connected by cable with value is (3*(1*70mm^2) (bundle)) for each cable load.
  - Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable is (3*(1*35mm^2) (bundle)).
- Fuse and AutoRecloser, between RMU’s and each transformer.

Second Section (southern) that have a factories where categories in Medium and Small-size, such that it contain 3 electrical networks.

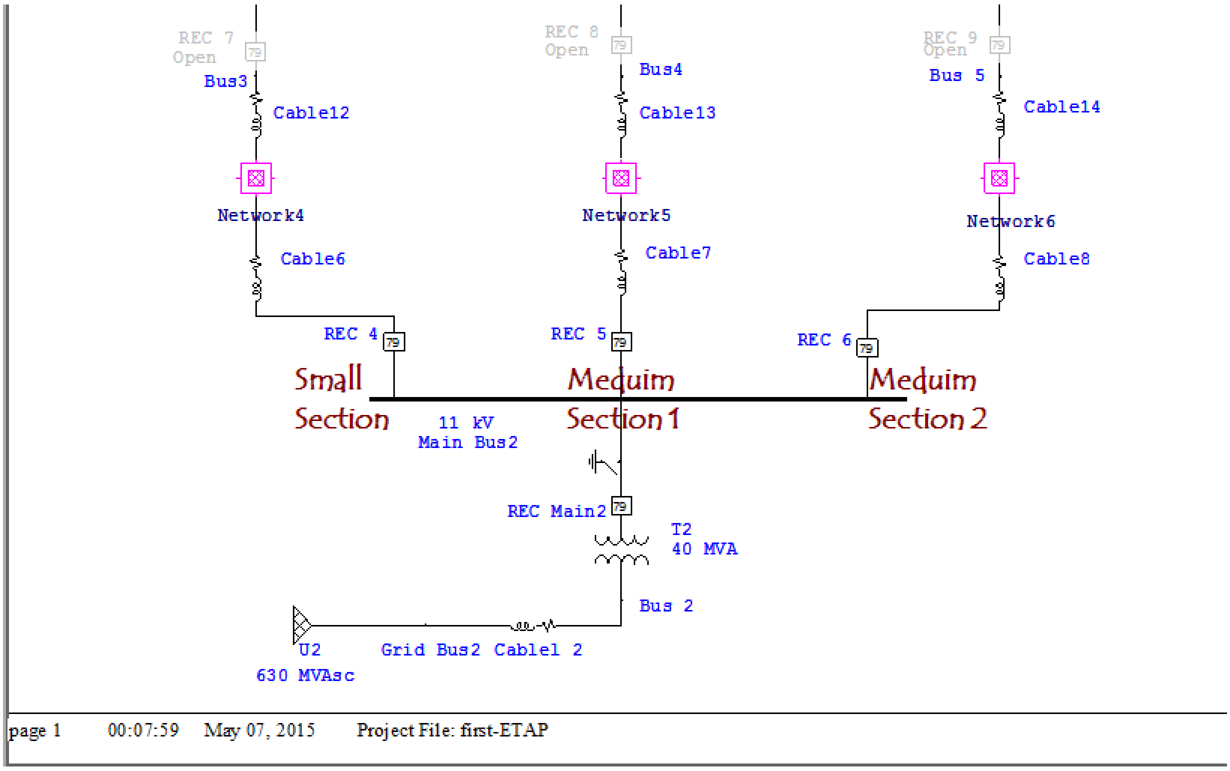


Figure 5.6. Southern main section (medium and small)

The general description for each sub network inside the northern Section

Fourth electrical network (network # 6) and it's contains the following...

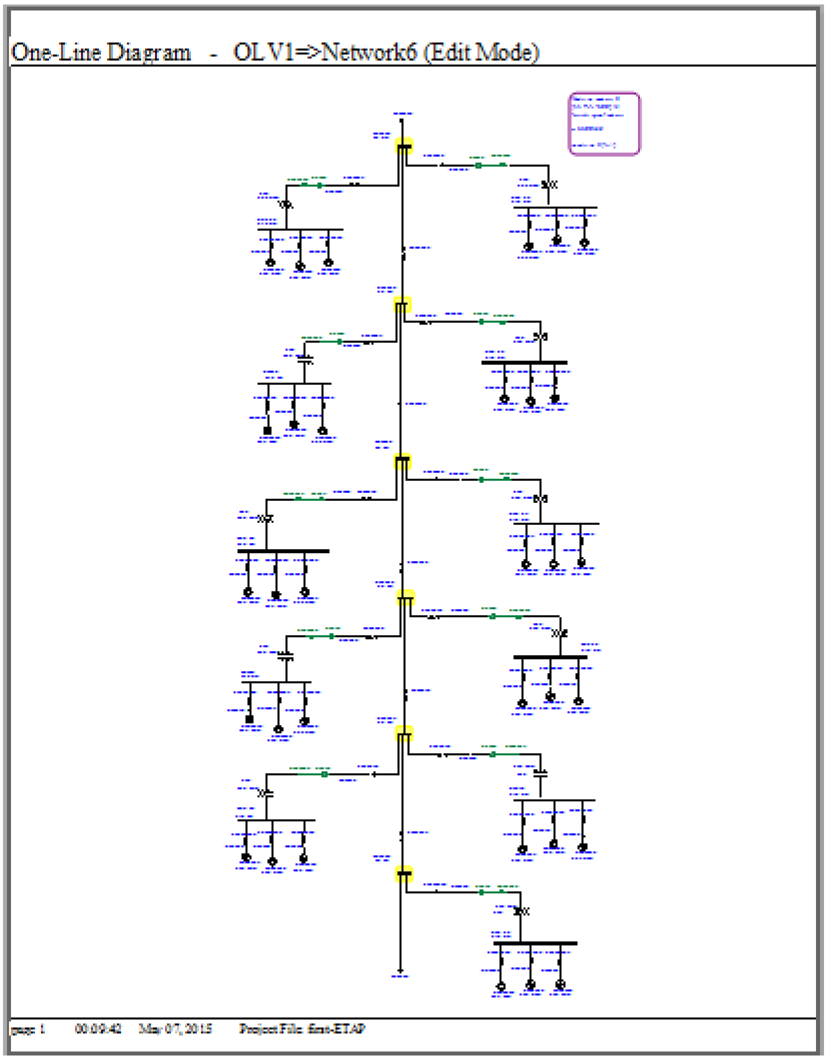


Figure 5.7. Network 6

- 11 transformers each one 500kVA and each transformer connected with three loads (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor.
- 6 connected points (RMU) with type TTCC.
- Main cables that connect every "RMU with the other" its ground cables each one is (3*(1*50mm^2) (bundle)) and this value is based on identifying private tables as we mentioned earlier.

- Sub cable reached between the "RMU and transformer" ground cables is ($1*25mm^2$) (bundle) Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable is ($3*(1*16mm^2$) (bundle)).
- Fuse and AutoRecloser, between RMU's and each transformer.

The fifth electrical network (network # 5) and it's contains the following...

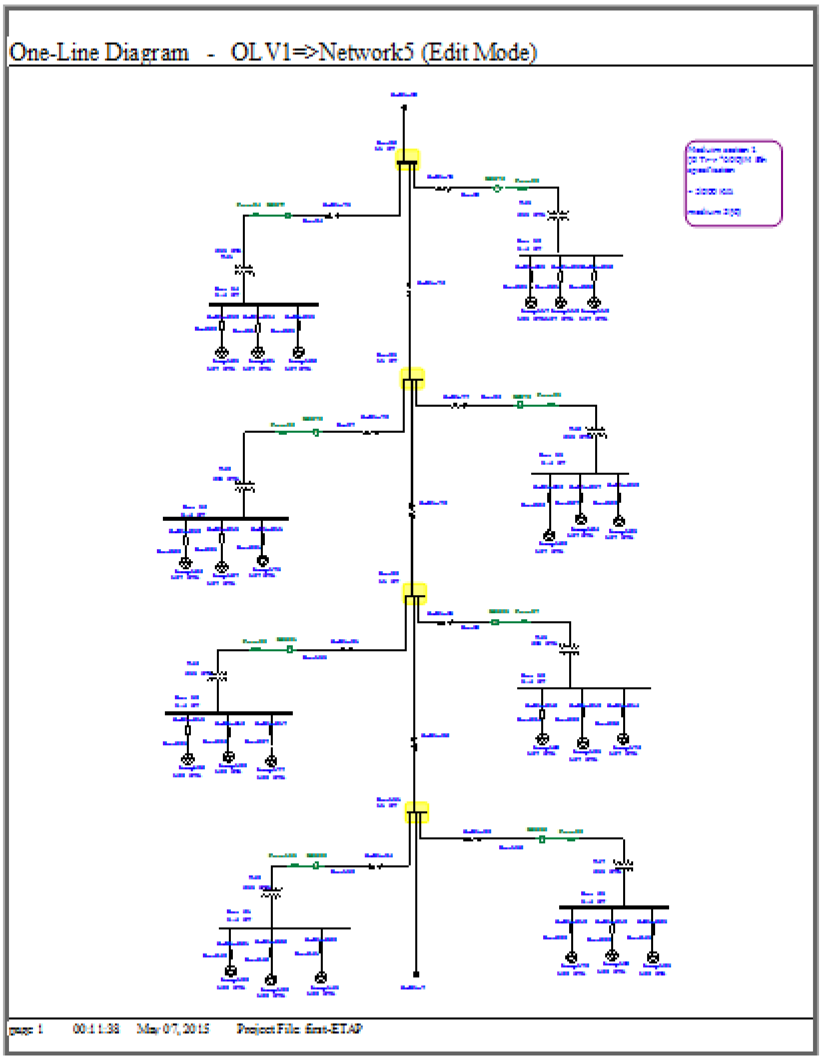


Figure 5.8. Network 5

- 8 transformers each one 630kVA and each transformer connected with three loads (factories), Such that the transformer value has been developed to

accommodate the demand of the connected load according to the diversity factor.

- 4 connected points (RMU) with type TTCC.
- Main cables that connect every "RMU with the other" its ground cables each one is (3*(1*50mm^2) (bundle)) and this value is based on identifying private tables as we mentioned earlier.
- Sub cable reached between the "RMU and transformer" ground cables is (1*25mm^2) (bundle).
- Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable is (3*(1*16mm^2) (bundle)).
- Fuse and AutoRecloser, between RMU's and each transformer.

The six electrical network (network # 4) and it's contains the following...

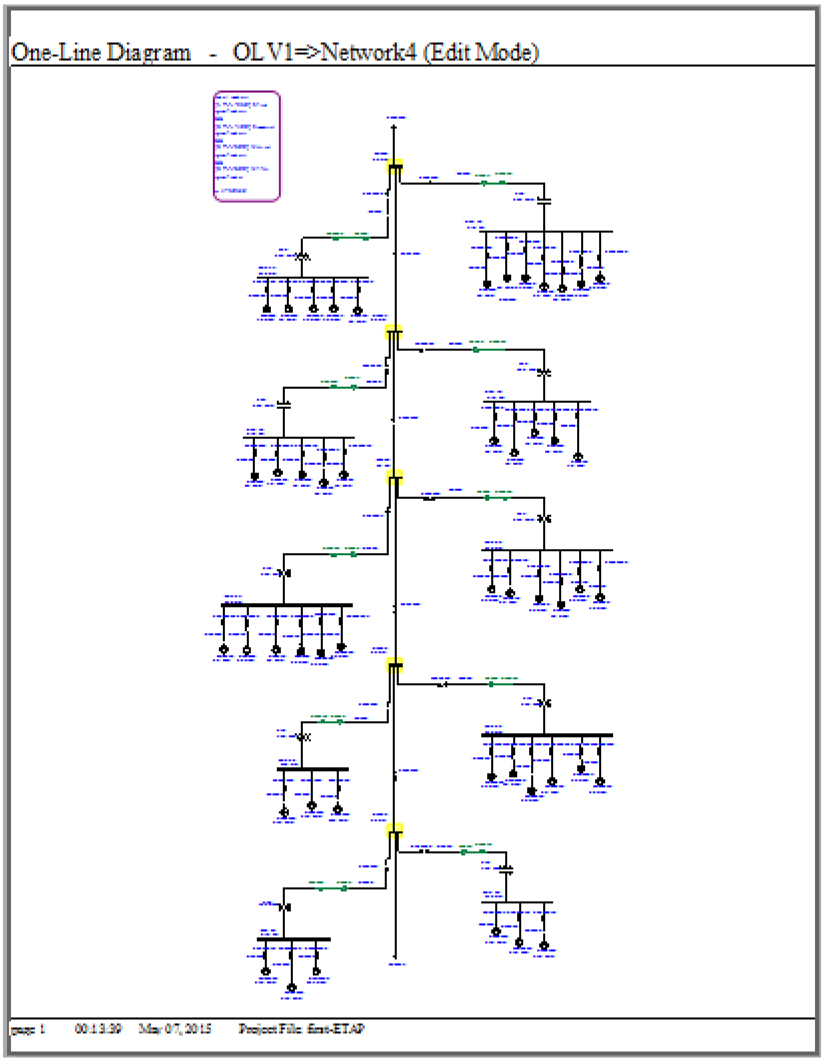


Figure 5.9. Network 4

- 1 transformer 250kVA and connected with 7 loads (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor.
- 3 transformers each one 400kVA and every transformer connected with 5 loads (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor.
- 3 transformers each one 500kVA and every transformer connected with 6 loads (factories), Such that the transformer value has been developed to

accommodate the demand of the connected load according to the diversity factor.

- 3 transformers each one 630kVA and every transformer connected with 3 loads (factories), Such that the transformer value has been developed to accommodate the demand of the connected load according to the diversity factor as previously explained.
- 5 connected points (RMU) with type TTCC.

- main cables that connect every "RMU with the other" its ground cables each one is (3*(1*50mm^2) (bundle)) and this value is based on identifying private tables as we mentioned earlier, and As for determining the total length will explain later.
- Sub cable reached between the "RMU and transformer" ground cables is (1*25mm^2) (bundle)).
- Distribution cables for customer, connect between "transformer and industrial loads" are ground cables, value of each cable based on each load as follows:

    - Small loads that has been connected (seven load on one transformer), connected by cable with value is (1*16mm^2) (bundle) for each cable load.

    - Small loads that has been connected (five load on one transformer), connected by cable with value is (1*16mm^2) (bundle) for each cable load.

    - Small loads that has been connected (six load on one transformer), connected by cable with value (1*16mm^2) (bundle)) for each cable load.

    - Small loads that has been connected (three load on one transformer), connected by cable with value (3*(1*16mm^2) (bundle)) for each cable load.

- Fuse and AutoRecloser, between RMU’s and each transformer.

Fourthly, the lengths of the cables have been selected based on the given ground area," QILQS ", where the streets is sketched inside of this land, and the factories distributed on it, by using AutoCAD program.

This program shows distance from each plant to main source or connecting point (RMU's), that's lead to put the cable lengths, as shown in the attached picture

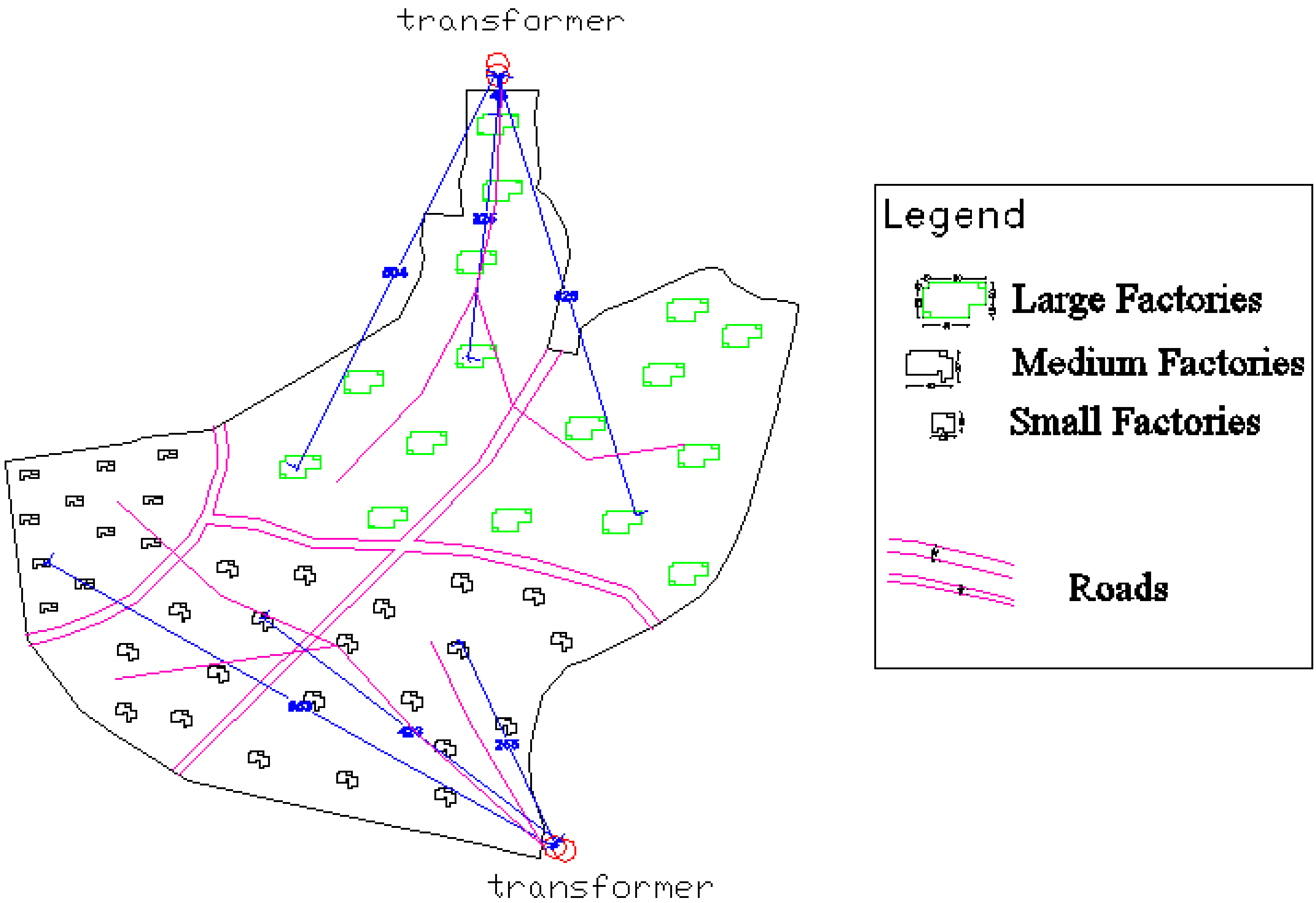


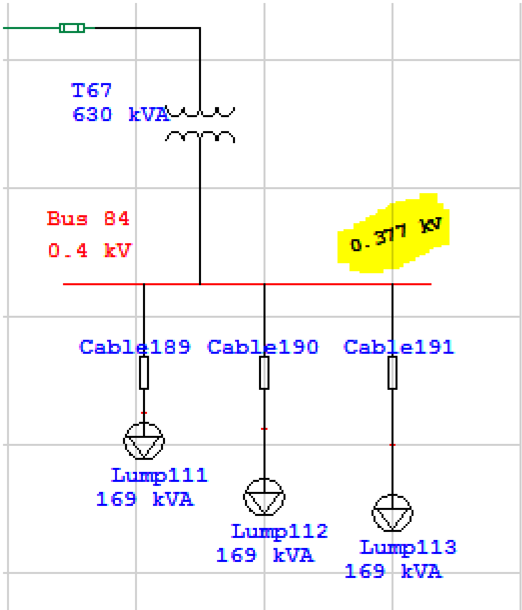
Figure 5.10. Cable length selection using AUTOCAD

Fifthly, Load flow for the network 11kv and 33kv attached in outer paper in the end of chapter 5

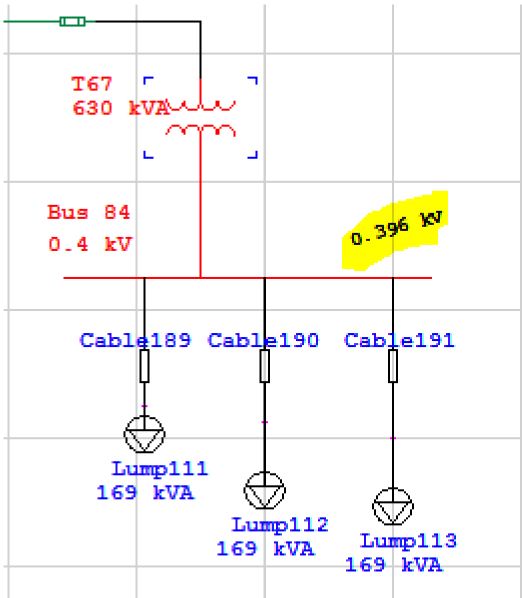
Some of problems that we faced during network design and their solutions:.[E-tap]

problems that we faced	**Their solutions**
• Under voltage of busies	increasing the tap of transformers

BEFORE

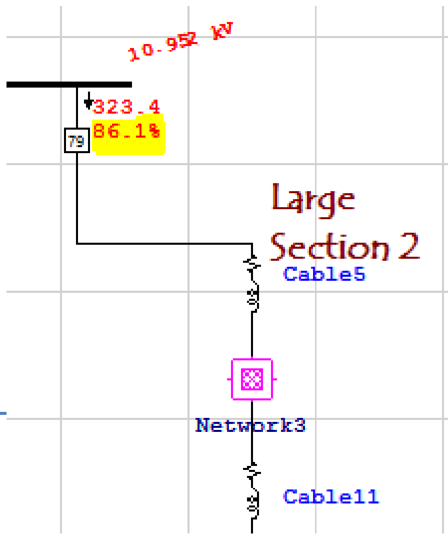


AFTER

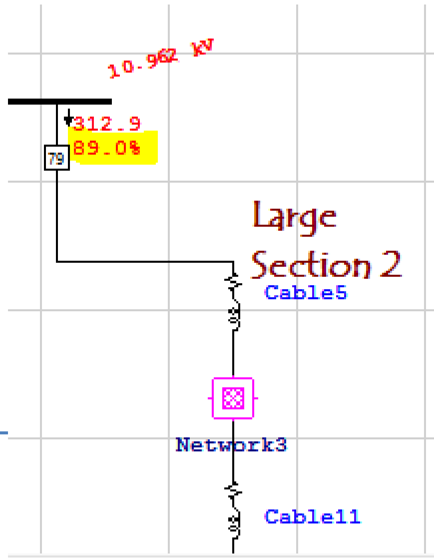


• Over loading of transformer	Making the alter-max KVA equal rating kVA
• Low of power factor	Capacitor bank

BEFORE



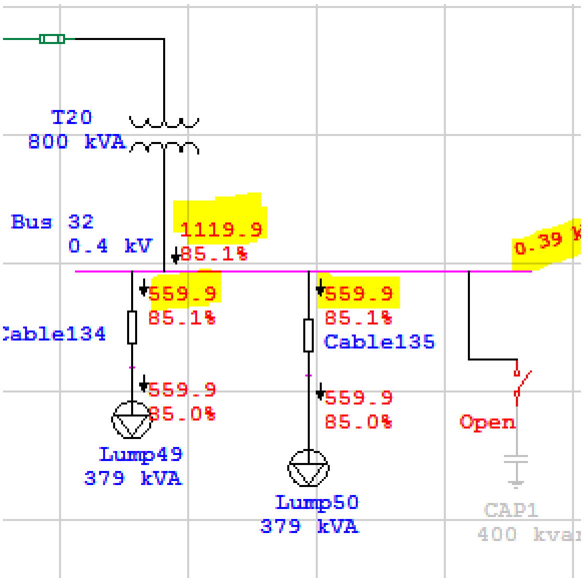
AFTER

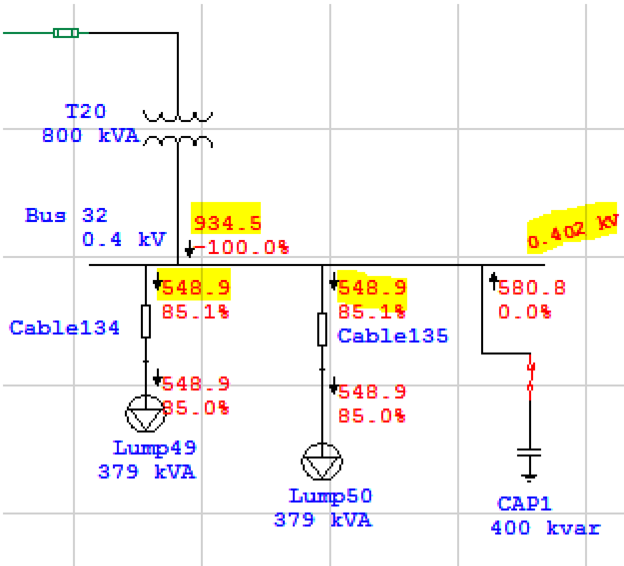


And the capacitor bank case to reduce the current consumed by load form the source. Also increase the bus voltage as we see in the following picture's

AFTER

BEFORE





Summary:

Table 5.1: SUMMARY OF TOTAL GENERATION, LOADING & DEMAND

<u>**SUMMARY OF TOTAL GENERATION , LOADING & DEMAND**</u>

	MW	Mvar	MVA	% PF
Source (Swing Buses):	27.584	14.169	31.011	88.95 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	27.584	14.169	31.011	88.95 Lagging
Total Motor Load:	18.288	8.086	19.996	91.46 Lagging

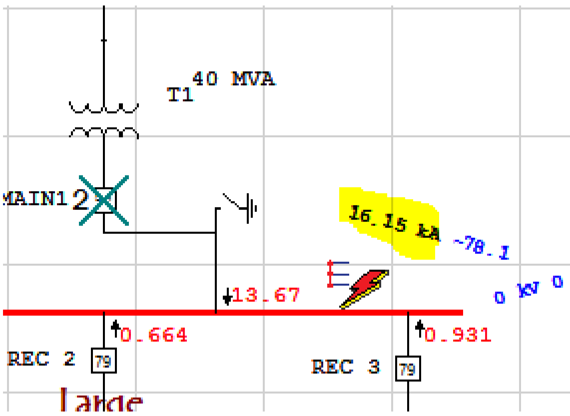
Total Static Load:	8.216	3.602	8.971	8.971	Lagging
Total Constant I Load:	0.000	0.000	0.000		
Total Generic Load:	0.000	0.000	0.000		
Apparent Losses:	1.081	2.481			
System Mismatch:	0.000	0.000			
Number of Iterations: 3					

5.1.5. Protection device

We use AutoRecloaser’s, to protect the main source of the network and the main branch also the transformers, and we use Fuse for protect transformers.

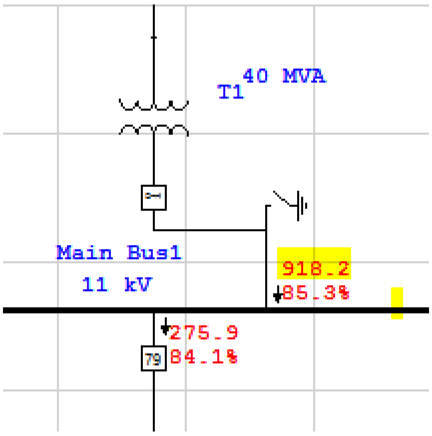
The adjusting of these protection devices depend on consumed current by the branch and the three phase short circuit for the nearest bus bar.

At the first for AutoRecloaser in the main source the short circuit at the main bus (Main bus1) equal 16.15KA,

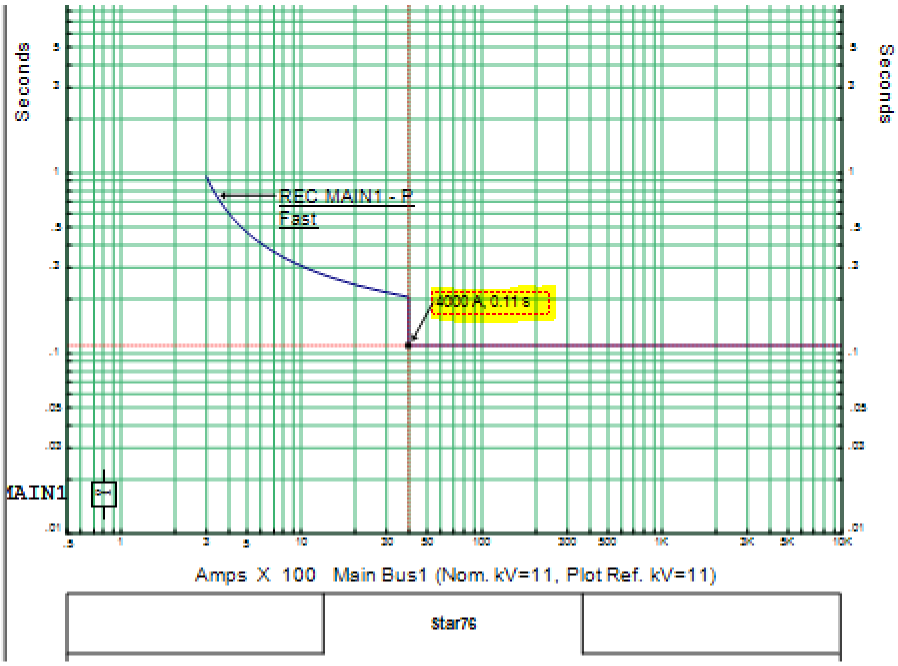


So we should use AutoRecloaser accommodate these value, such that the nearest value for16.15KA its 20KA from library in Etap program.

Now the current flow from the main source is 918.2A,



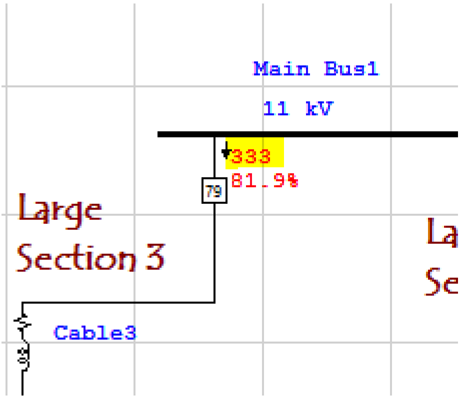
So we will adjust the tripping current for AutoRecloaser (Ia) about Four times the rated current. Is approximately equal 4000A.



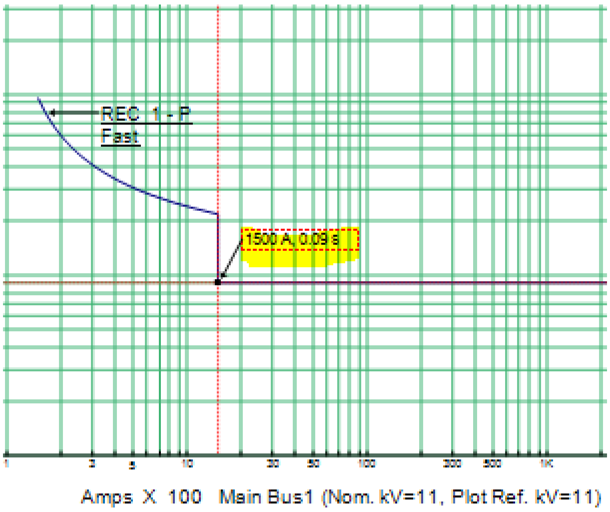
Secondly AutoRecloaser in the main branch:

The short circuit at the main bus (Main bus1) equal 16.15KA, the same bus as the previous case, so we should use AutoRecloaser accommodate these value, such that the nearest value for16.15KA its 20KA from library in Etap program.

Now the current flow from the main branch is 333A,



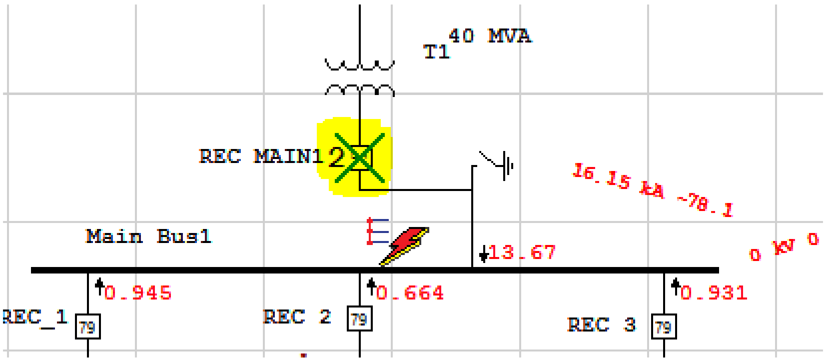
So we will adjust the tripping current for AutoRecloaser (Ia) about Four times the rated current. Ia approximately equal 1500A.



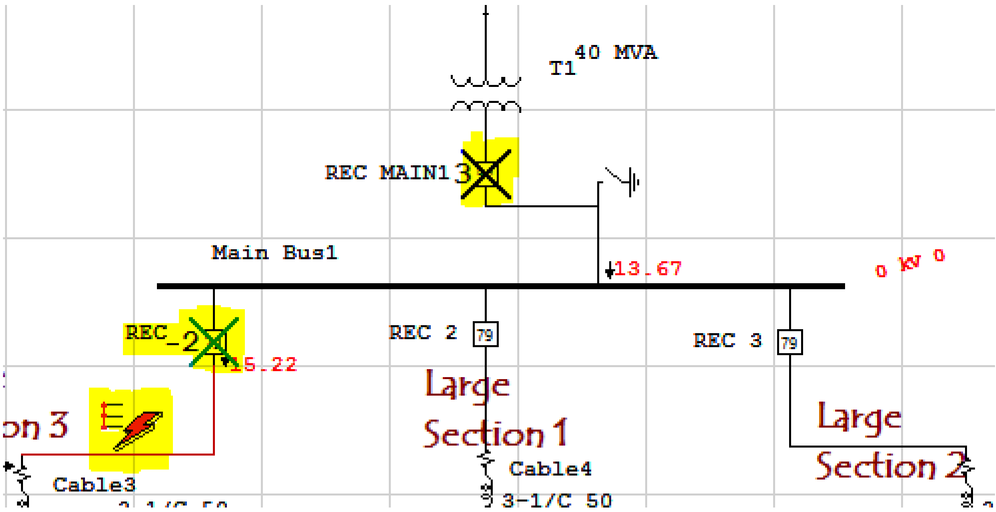
And repeat these steps for the all AutoRecloaser

Now the coordination between protection devices:

If the fault occur at the main bus the REC MAIN1 responsible for protection this part, as we see in next picture

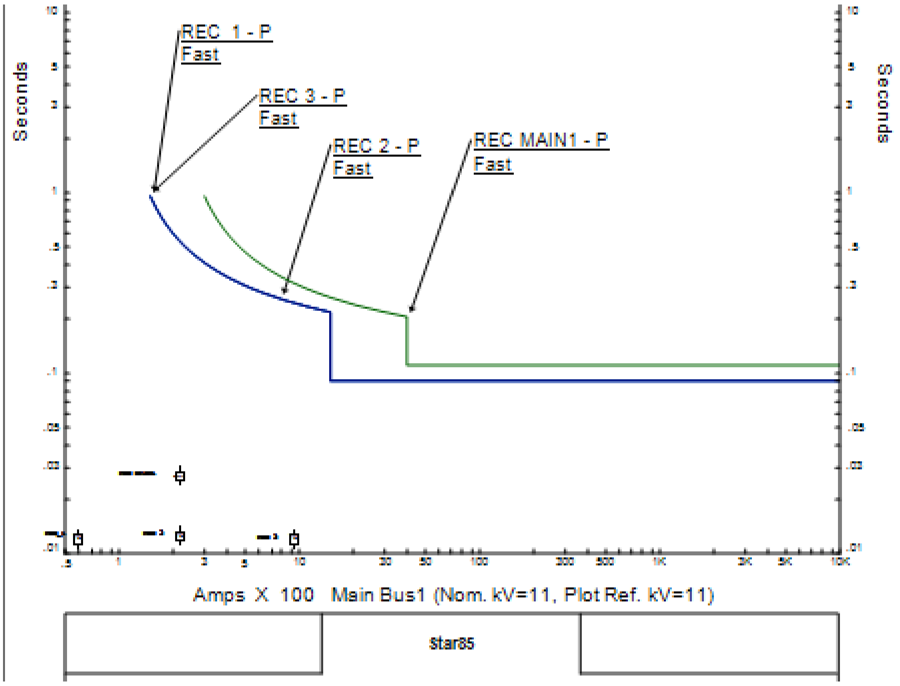


But if the fault occur in the first branch, the REC_1 is responsible for protect this part ”will shut off”, and if the REC_1 does not operate for any reason the REC_MAIN1 will be operate as backup to protect this zone.



And the same properties for REC_2 REC_3, if these does not operate for any reason the REC_MAIN1 will be operate as backup.

And the curve show the coordination between them.



By this way, we achieved the security and dependability for the network protection.

5.2. SCADA System

SCADA is ‘Supervisory Control and Data Acquisition’. The major function of SCADA is for acquiring data from remote devices such as valves, pumps, transmitters etc. and providing overall control remotely from a SCADA Host software platform. This provides process control locally so that these devices turn on and off at the right time, supporting your control strategy and a remote method of capturing data and events (alarms) for monitoring these processes. SCADA Host platforms also provide functions for graphical displays, alarming, trending and historical storage of data.

Looking at the overall structure of a SCADA system, there are four distinct levels within SCADA, these being;

i. Field instrumentation,
ii. PLCs and / or RTUs,
iii. Communications networks and

iv. SCADA host software.

Figure 5.11: SCADA Room

5.2.1. Field Instrumentation:

You can't control what you don't measure" is an old adage, meaning that instrumentation is a key component of a safe and optimized control system. Slowly over time, these instruments would have been fitted with feedback sensors, such as limit switches, providing connectivity for these wired devices into a local PLC or RTU, to relay data to the SCADA host software.

5.2.2. SCADA systems Benefits for Electrical Distribution

- Increases reliability through automation
- Eliminates the need for manual data collection
- Alarms and system-wide monitoring enable operators to quickly spot and address problems

- Automation protects workers by enabling problem areas to be detected and addressed automatically
- Operators can use powerful trending capabilities to detect future problems, provide better routine maintenance of equipment and spot areas for improvement
- Historians provides the ability to view data in various ways to improve efficiency

5.2.3. How SCADA Works

A SCADA system for a power distribution application is a typically a PC-based software package. Data is collected from the electrical distribution system, with most of the data originating at substations. Depending on its size and complexity, a substation will have a varying number of controllers and operator interface points.

In a typical configuration, a substation is controlled and monitored in real time by a Programmable Logic Controller (PLC) and by certain specialized devices such as circuit breakers and power monitors. Data from the PLC and the devices is then transmitted to a PC-based SCADA node located at the substation.

One or more PCs are located at various centralized control and monitoring points. The links between the substation PCs and the central station PCs are generally Ethernet-based and are implemented via the Internet, an intranet and/or some version of cloud computing.

In addition to data collection, SCADA systems typically allow commands to be issued from central control and monitoring points to substations. If desired and as circumstances allow, these commands can enable full remote control.

5.2.4. Component of SCADA system

This component that use with SCADA software for distribution network:

- **Control Server**. The control server hosts the DCS or PLC supervisory control software that is designed to communicate with lower-level control devices.
- **SCADA Server or Master Terminal Unit (MTU).** The SCADA Server is the device that acts as the master in a SCADA system. Remote terminal units and PLC devices located at remote field sites usually act as slaves.

- **Remote Terminal Unit (RTU).** The RTU, also called a remote telemetry unit, is special purpose data acquisition and control unit designed to support SCADA remote stations. RTUs are field devices often equipped with wireless radio interfaces to support remote situations where wire based communications are unavailable. Sometimes PLCs are implemented as field devices to serve as RTUs; in this case, the PLC is often referred to as an RTU.
- **Programmable Logic Controller (PLC).** The PLC is a small industrial computer originally designed to perform the logic functions executed by electrical hardware (relays, drum switches, and mechanical timer/counters). PLCs have evolved into controllers with the capability of controlling complex processes, and they are used substantially in SCADA systems.
- **Intelligent Electronic Devices (IED).** An IED is a “smart” sensor/actuator containing the intelligence required to acquire data, communicate to other devices, and perform local processing and control. An IED could combine an analog input sensor, analog output, low-level control capabilities, a communication system, and program memory in one device. The use of IEDs in SCADA and DCS systems allows for automatic control at the local level.
- **Human-Machine Interface (HMI).** The HMI is software and hardware that allows human operators to monitor the state of a process under control, modify control settings to change the control objective, and manually override automatic control operations in the event of an emergency..
- **Input /Output (IO) Server.** The IO server is a control component responsible for collecting, buffering and providing access to process information from control sub-components such as PLCs, RTUs and IEDs. An IO server can reside on the control server or on a separate computer platform. IO servers are also used for interfacing third-party control components, such as an HMI and a control server.

5.2.5. SCADA Software

In project Control and monitoring the system is divided to three parts: Main substation, Feeders, and Users. And we mainly concentrate on main substation.

In project we need to monitor Main substation and alarm feeder if any fault happen. And control of the main recloser to have distribution network with high reliability to construct.

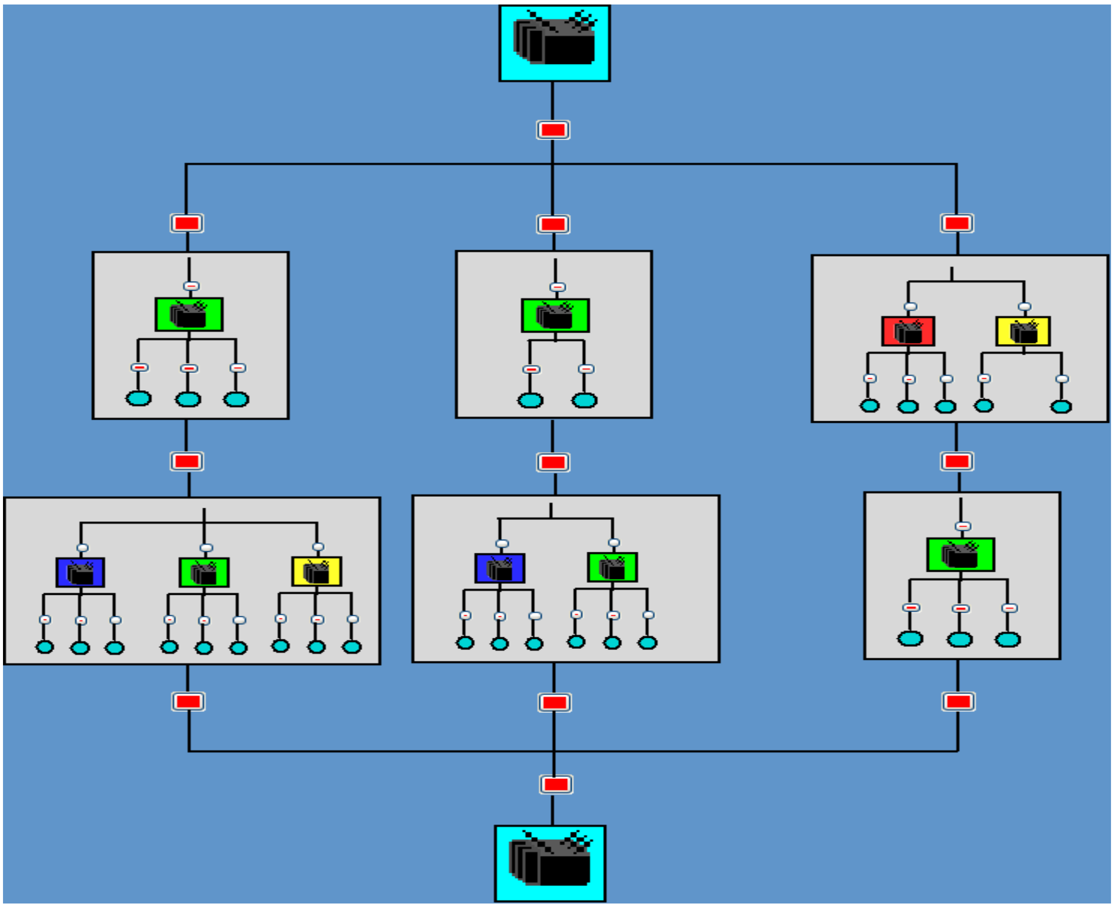


Figure 5.12: Main substation on SCADA software

The software that use to Supervisory Control and Data Acquisition in the project is "Vijeo Citect" version 7.30, this SCADA software for Schneider Electric Company,

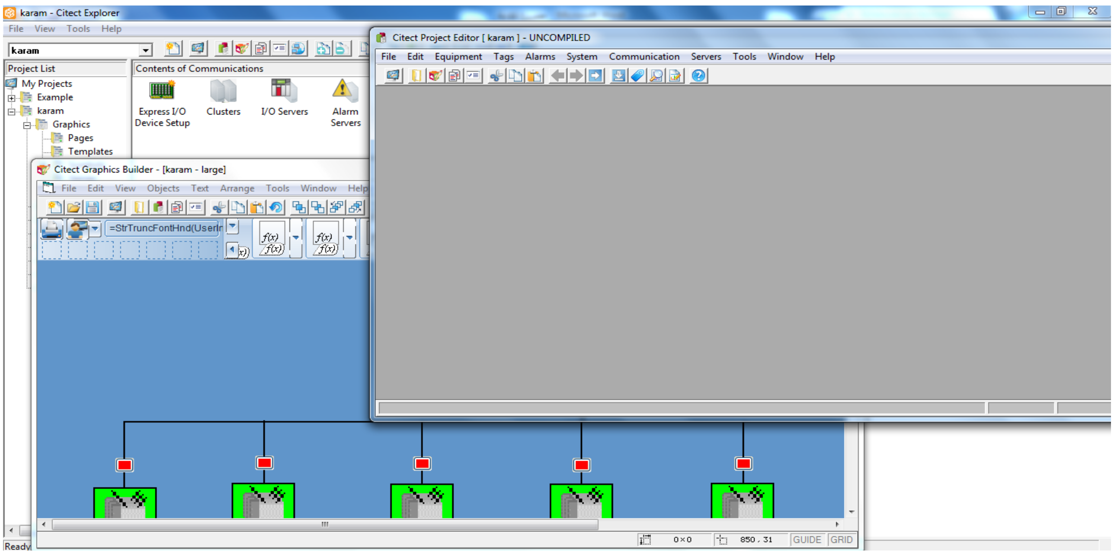


Figure 5.13: Vijeo Citect Program

Cluster and servers and used in project like Alarm and input/output server are make and many tags are defined.

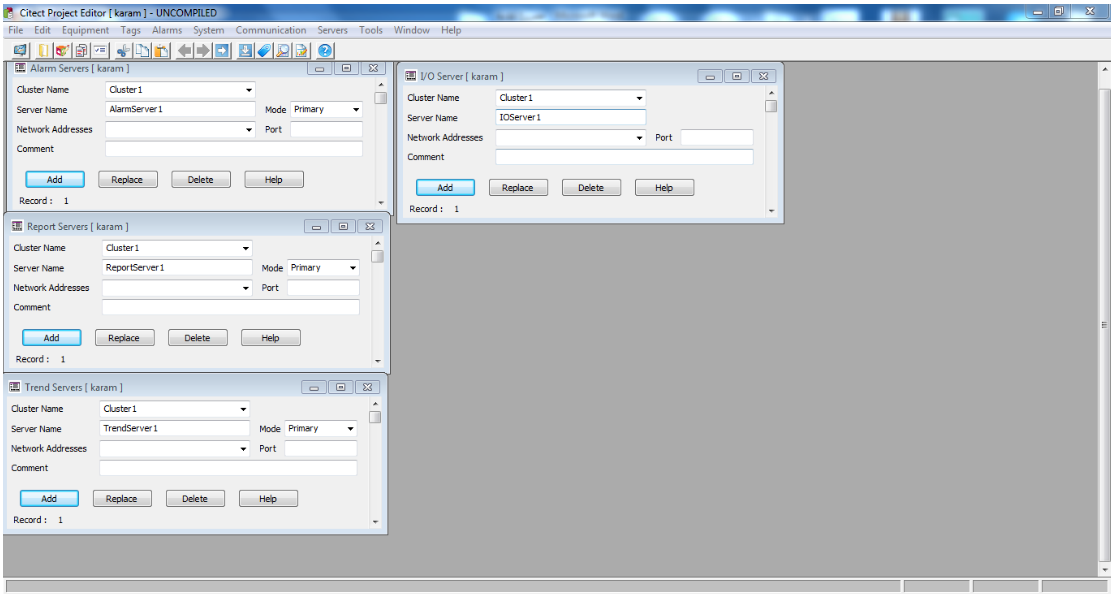


Figure 5.14: Cluster and servers

This software is connected with Unit Pro. Program connected with PLC to control of input and output for system.

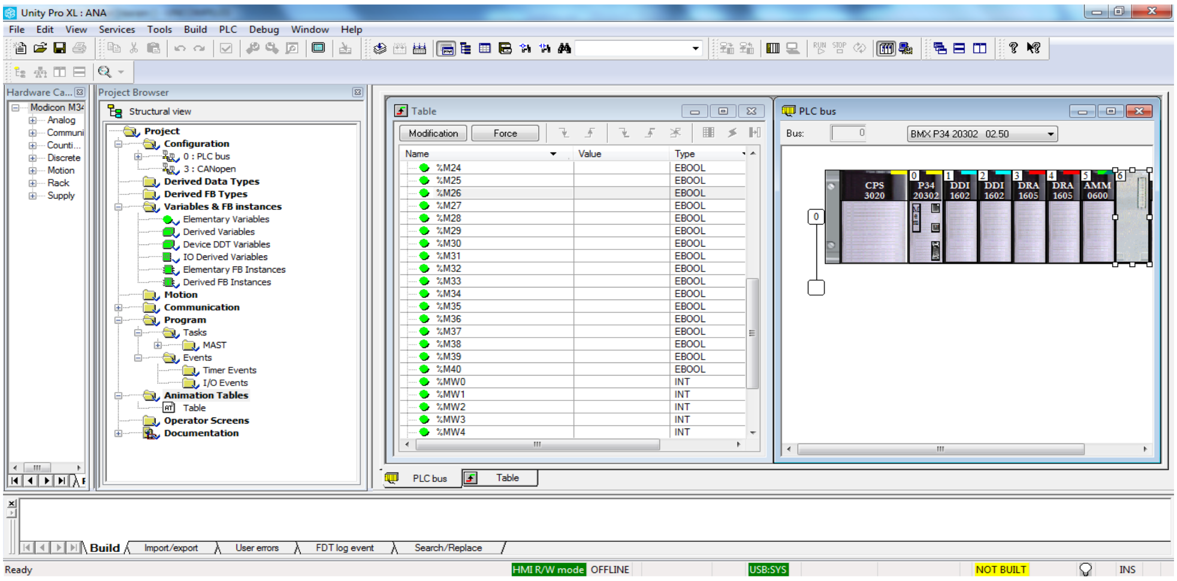


Figure 5.15: Unit Pro. Program

With SCADA software it become easy to defined error and fault on utility on computer unnecessarily to disconnect electrical energy for all users and this will make maintenance speed by knew where fault happen exactly.

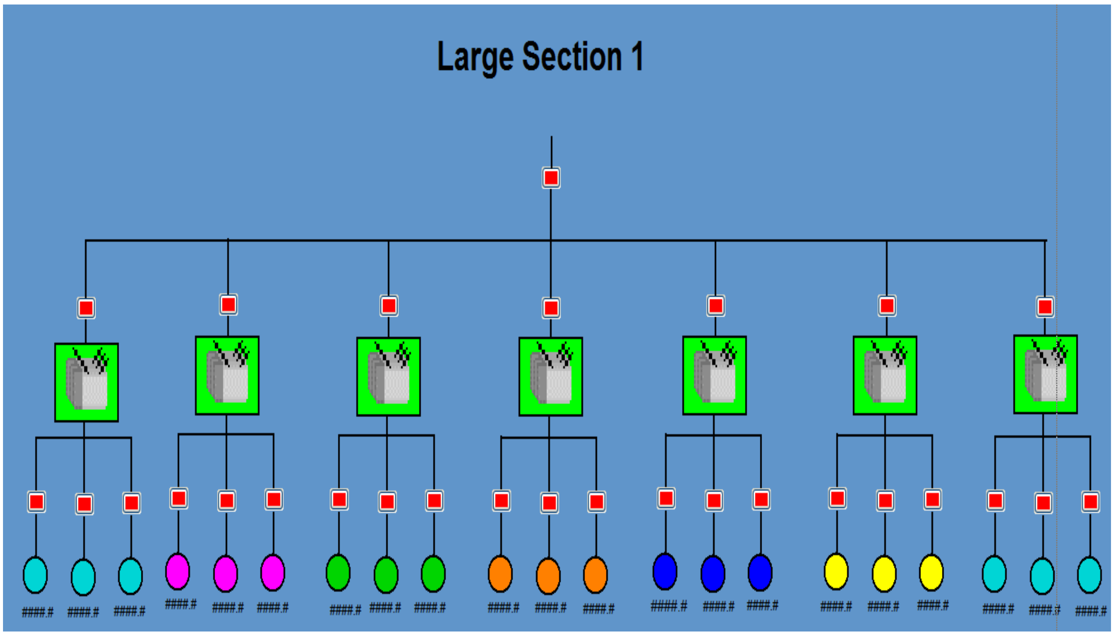


Figure 5.16: Feeder (Large section) on SCADA software

Chapter six

Economic feasibility study

6.1 Introduction

In this chapter we will talk about the project and cost economy that you need to work the electrical network of the industrial zone.

The economic feasibility study for any project is one of the most important points that we need to set up a network because the construction of the electricity network depends on this study and what is the feasibility of establishing this network.
In the economic feasibility study we will work on two cases and they are as follows
-The first case: a study where the distribution network 11kV, and we get in this case to **subscribers transformers** that convert to the consumer voltage level 0.4 kV.
-The second case: a study where the distribution network on 33kV to get to the consumer where the **transformer are transfer** from 33kV to 0.4kV directly without conversion to 11kV.
The second method can be used in the industrial area are not used in residential areas because it is in this case have a significant impact on the population of high-voltage and be very dangerous.

6.2 Project financial costs

- There are three main kinds of costs. Those are investment costs, operating costs, and working capital.
- Those costs are usually broken down into several different items as discussed below.

6.2.1 Investment costs

The items included under investment costs are

1. Initial costs

Initial costs refer to those costs involved in construction and commissioning, including land, civil works, equipment and installations

2. Replacement costs

Replacement costs refer to the costs of equipment and installations procured during the operating phase of the project, to maintain its original productive capacity.

3. Residual values.

Residual values refer to the value of these investment items (Rent, land, etc.) at the end of the project's useful life. However, residual values are usually small and do not have a major impact on decision making.

6.2.2 Operating costs

- Operating costs are a combination of fixed and variable costs.
- Fixed costs will be incurred whatever the level of productions, like salaries, cost of management, and part of the maintenance cost.
- Variable costs will depend upon the level of production and include those items like fuel and energy, water, lubricants, and part of the Maintenance cost (in the case of industrial projects, the cost of raw Materials is also included).
- In general, production will never start at the maximum capacity of the project.
- Capacity utilization may increase over time or may fluctuate according to time of day or to season.
- The variable cost will increase as production increases and will stabilize when maximum sustainable production capacity is reached.
- The total operating cost is the sum of the fixed and variable cost.

6.2.3 Working capital

- Working capital refers to the physical stock needed to allow continuous production (spare parts, fuel, raw materials).
- The stock has to be built up at the commissioning phase and before the beginning of the commercial operation

- For power plants and network projects, there is usually one component of working capital, which is the initial stock of material necessary for commercial operation.
- But for industrial projects, there are three components of working capital:
  i. Initial stock of material,
  ii. Work in progress
  iii. Final stock of production.

6.3 Financial benefits of the project

- Financial benefits of the project are brought about by selling the project product.
- These benefits are usually equal to the amount of production multiplied by the estimated base price.
- Not all projects in the electrical power industry imply production. Some, like efficiency improvement, lead to cost reduction, which is equal to the benefit.
- In the electrical power industry, calculation of benefits is not easy.
- A new power station would normally not only increase production, but also contribute towards reduction of the overall system cost of generation.
- It may also reduce system losses and delay the implementation of some projects for network strengthening.
- There are many methods for financial evaluation and comparing alternatives. The most important and useful ones are:

1. The present value method, and
2. The annual cost method (the equivalent uniform annual cost method).

In this study, we worked on the economic analysis of twenty-five years Future where we calculate the total cost and it calculates the cost of all equipment that includes transformers, cables and protective equipment and connecting equipment, where the cost network for the first scenario as we mentioned earlier is **4,563,150$** In the second scenario is **5,272,850$.**

And also we used the maintenance coefficient in the year is almost **0.08** of the network cost, so the cost of maintenance in the first scenario is **365,052$** and in the second **421,828$.**

The total cost, it includes the cost of the network in addition to the cost of maintenance where it was in the first scenario **4,564,000$** In the second scenario, it **5,694,678$.**

The total cost after **25** years it is the cost of maintenance for a period of **25** years plus the cost of the network where it was in the first scenario**13,690,300$** and in the second **15,818,550$.**

Put a daily salary was operational for engineers and technicians who will build their own network and an estimated **850 US$.**

As for the sale of electricity, we adopted in our calculations process of KWh we took the average consumption of factories and then struck it the number of working hours of the factories in the year as the average working factories **18** hours a day and we have not Friday calculation of days and days holidays and bank holidays where the rest of our **300** days, so the number of hours annual was almost **5,400** hours.So The total average consumption is **24,237 kW** So it is sold annually around **130,882,245 kWh**. Also we buy the kWh of the company's country of approximately US **0.126$** and the sale of approximately **0.147$** and here we would like to point out that not everything that is bought is sold, but there is little loss in the network so it was sold approximately **0.89** of a purchased account.

6.4 Equation used in economical calculation for project:

- Maintenance Cost ($) =0.05* network cost
- Total network Cost ($) = Contracting Engineers/day + network cost
- Total expenditure (25 yr) =Total network Cost ($) + (Maintenance Cost ($)*expected life time (yr))
- Sell (kWh) after losses =0 .95* Buy(kWh)
- Gross yearly Income = (Sell (kWh) after losses * Price of electricity ($/kWh) sell) – (Price of electricity ($/kWh) Buy * Buy(kWh))
- Depreciation Credit = Total network Cost ($)*Annual deprec. Expense

- Tax payment per yr = Tax Rate*(Annual deprec. Expense- Maintenance Cost ($))
- Net Tax = Tax payment per yr- Depreciation Credit
- Net income Stream / yr.= Gross yearly Income - Maintenance Cost ($) - Net Tax
- Net present value of income stream = sum of Net income Stream / yr for 25yr
- Net real rate of return / yr = Net present value of income stream/(Total network Cost ($) * 25yr)
- present value of electricity /kWh = Net present value of income stream/(Buy(kWh) * 25yr)
- Net Cash flow = **Net income Stream ($) - Cost ($)**

All these calculation are made in Excel Table as following, see appendix c.

Table 6.1: Initial costs

Type	rating	Number	Cost	Total Cost
Transformer(33-11)KV	40MVA	2	1,200,000	2,400,000
Transformer(11-0.4)KV	**(250-1000)KVA**	53	15,000	23,850
RMU	TTCC	30	10,000	300,000
Recloser	Diff.	93	15,000	1,395,000
Fuse		82	250	20,500
Total				4,563,150$

Table 6.2: Running Cost

Construction stage	
expected life time (yr)	25
network cost	$4,563,150.00
Maintenance Cost ($)	$365,052.000
Total network Cost ($)	$4,564,000.00
Total expenditure (25 yr)	$13,690,300.000
Contracting Engineers/day	$850.00
Real Rate Of Interest	3.00%
Operation Stage	
Price of electricity ($/kWhr) Buy	0.126
Buy(kWh)	130,882,245.00
Price of electricity ($/kWhr) sell	$0.147
sell(kWh) after losses	$121,720,487.85
Gross yearly Income	$1,401,748.84

Economics	
Annual deprec. Expense	2.50%
Tax Rate	18.00%
Depreciation Credit	$114,100.00
Tax payment per yr	$186,605.43
Net Tax	$72,505.43
Net income Stream / yr.	$964,191.41
Net present value of income stream	$12,225,607.46
Net real rate of return / yr	10.71%
present value of electricity /kWhr	$0.00373637
Price (NIS) شيكل	0.014272928

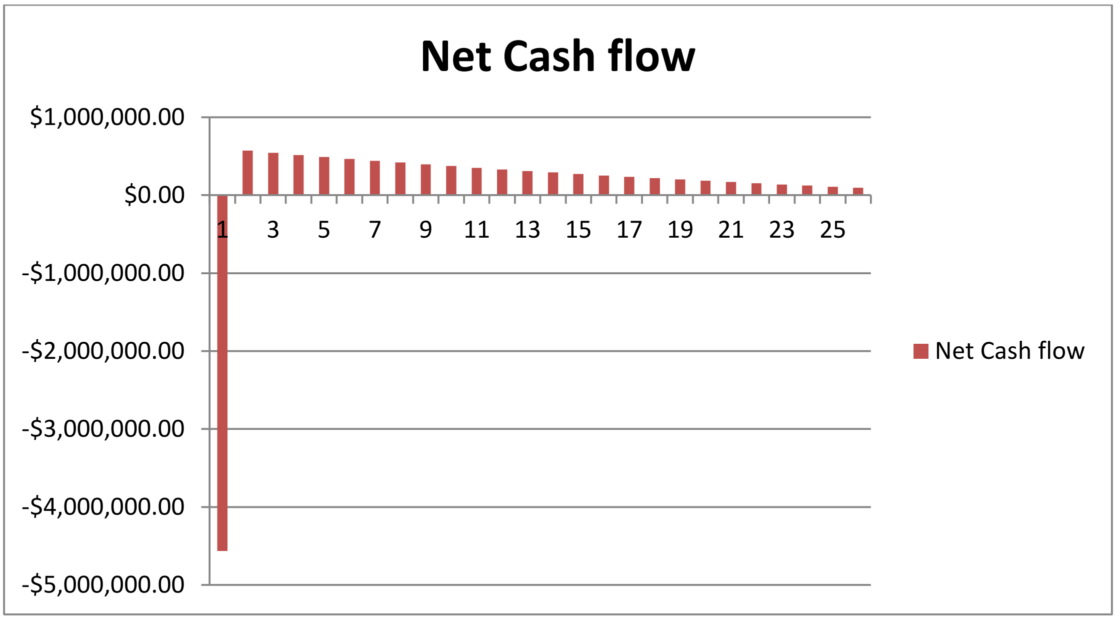


Figure 6.1: Net cash flow

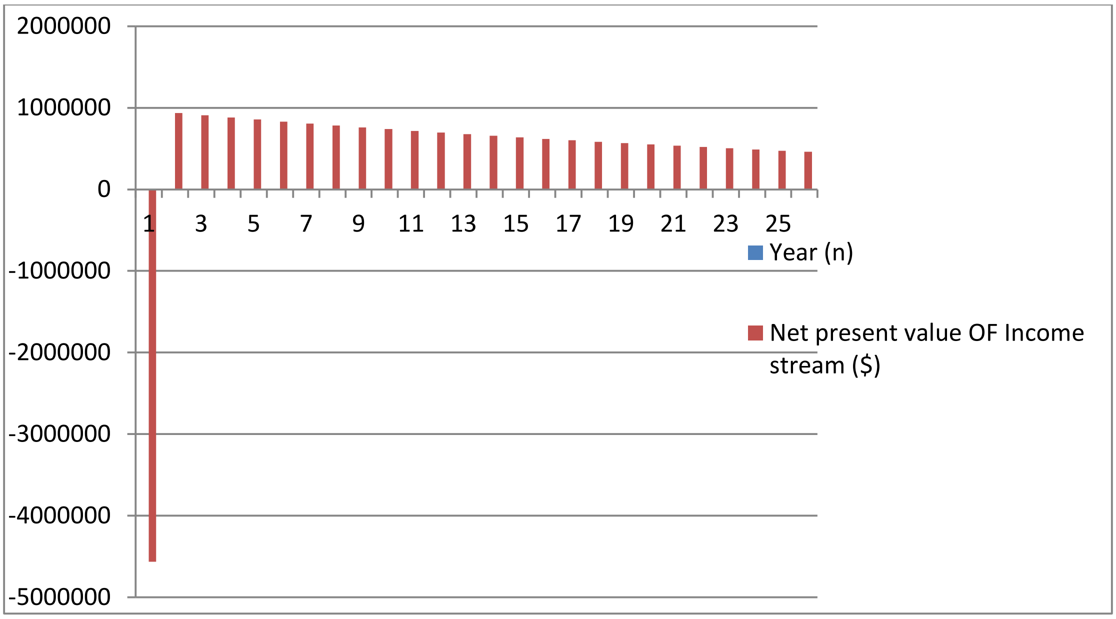


Figure 6.2: Net Present value

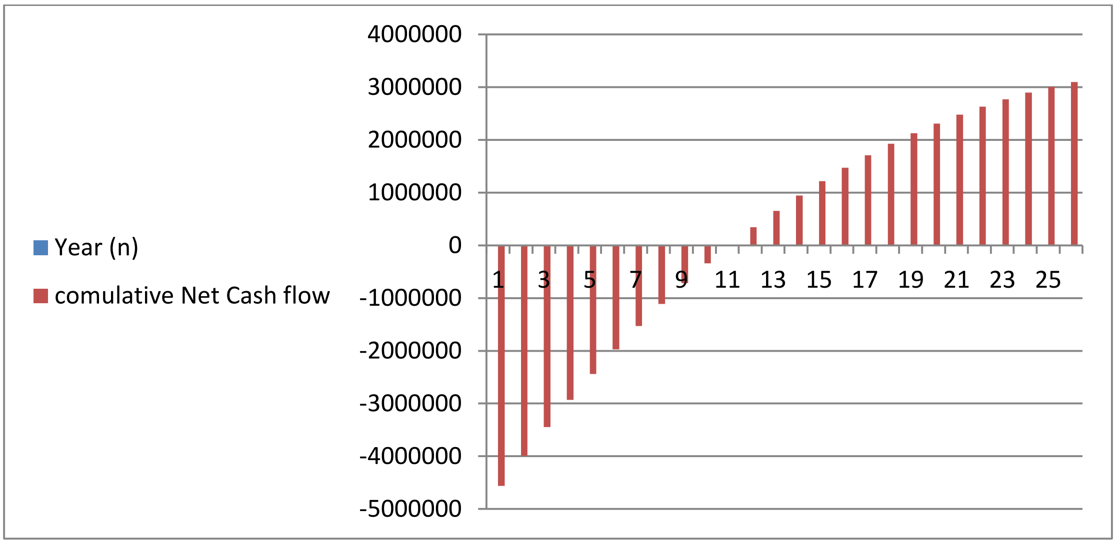


Figure 6.3: Payback period

Summary:

Feasibility study for the project show that the 11kV network scenario is more economical than 33kV network scenario, that's because in 11kV network the transformers are exist, and we does not have to buy new transformer, and on the contrary, at 33kV we need to buy a new transformers.

Chapter Seven

Conclusions and Recommendations

Conclusions

- **Problems:**

The project conclusions can be summarized as follow:

- **There is no security and no dependability for medium network for factories.**

That mean if the fault happen, the protection devices that are close to fault must disconnect before damage reach factory.

- **Random arrangement of factories in Hebron city.**

This distortion (randomly) make factories owners are confused, when they want to dealing with each other.

- **Negative environmental effect on Hebron citizen.**

The presence of factories between populated areas, this will make noises and maybe Pollution effect on their health.

- **There is electrical network problems in factories network.**

That's mean the medium network has problems like losses, low power factor, voltage drop, unbalance load...etc.

- **There is no continuously source for factories medium network.**

That mean if the power is disconnect from source there is no another source to take place.

- **Problems solution :**

- In project collected all factories in one region will increase Investment rate.
- In this project the industrial zone is away from population areas.
- To solve non security and non-dependability problems we choose recloser and we make coordination on Etap such that this coordination is work successfully.
- To solve non-continuously source problem we choose the scenario that use tow substation with two sources.
- To solve network problems we design the network in E-tap and justified the ordinary operation of all network without any previous problem.

Recommendations

- **Recommendation for HEPCO:**

- Concern for establishment an industrial zone in Hebron city, such that 11kV electrical network is more economical than 33kV electrical network.
- Use Etap program to develop and create power flow for industrial zone.
- Work to use SCADA system and apply it on the network, by using SCADA system we can:

  * Disconnect the electricity if the bill is not paid.

  * Disconnect the electricity if the PF go down a certain limit.

  * Disconnect the electricity if the Harmonics goes up a certain limit.

  * controlled the operation ON/OFF of the main branch and sub branch of the network.

  * get feedback of the load flow network in SCADA human machine interface 'HMI'.

- **Recommendation for Future Studies:**

- Make studies for low voltage electric power network for industrial zone.

- Study the effect of such company on the electric system quality.
- Make research to apply SCADA system on low voltage.
- Use Etap program to networks for distribution networks.
- Make study of possibility apply network on real.
- Aware the society about the economic benefits of renewable energy.
- Make GIS system for industrial zone with Etap.

➢ **Recommendation for our university:**

- Work to provide license for Etap program.
- Make it easy for any student to use Etap program.
- Work to make relationships with Institutions that concern with distribution network (Palestinian Energy Authority, HEPCO).

By adopting this project and applying in practical life, the operation of Hebron distribution network will be improved, and the network problems will be eliminated, and using SCADA system network will be easy controllable.

References

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Appendix A

Table A.1: Loads value of manufactures (these data collected from HEPCO).

MaxKVA/D.F	Size	Min.Load(KVA)	Max. Load(KVA)	KVA	الاشتراك
789.792	large	345.534	789.792	987.24	1500
758.20032	large	331.71264	758.20032	947.7504	1440
737.1392	large	322.4984	737.1392	921.424	1400
526.528	large	230.356	526.528	658.16	1000
526.528	large	230.356	526.528	658.16	1000
526.528	large	230.356	526.528	658.16	1000
379.10016	large	207.3204	473.8752	592.344	900
379.10016	large	207.3204	473.8752	592.344	900
379.10016	large	207.3204	473.8752	592.344	900
379.10016	large	207.3204	473.8752	592.344	900
379.10016	large	207.3204	473.8752	592.344	900
379.10016	large	207.3204	473.8752	592.344	900
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
336.97792	large	184.2848	421.2224	526.528	800
315.9168	large	172.767	394.896	493.62	750
273.79456	large	149.7314	342.2432	427.804	650
265.370112	large	145.12428	331.71264	414.6408	630
265.370112	large	145.12428	331.71264	414.6408	630
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600

252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
252.73344	large	138.2136	315.9168	394.896	600
210.6112	large	115.178	263.264	329.08	500
210.6112	large	115.178	263.264	329.08	500
210.6112	large	115.178	263.264	329.08	500
210.6112	large	115.178	263.264	329.08	500
189.55008	Medium	103.6602	236.9376	296.172	450
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400

168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
168.48896	Medium	92.1424	210.6112	263.264	400
147.42784	Medium	80.6246	184.2848	230.356	350
147.42784	Medium	80.6246	184.2848	230.356	350
147.42784	Medium	80.6246	184.2848	230.356	350
147.42784	Medium	80.6246	184.2848	230.356	350
147.42784	Medium	80.6246	184.2848	230.356	350
132.685056	Medium	72.56214	165.85632	207.3204	315
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
126.36672	Medium	69.1068	157.9584	197.448	300
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
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105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
105.3056	Medium	57.589	131.632	164.54	250
101.093376	Medium	55.28544	126.36672	157.9584	240
101.093376	Medium	55.28544	126.36672	157.9584	240
84.24448	Medium	46.0712	105.3056	131.632	200

84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
84.24448	Medium	46.0712	105.3056	131.632	200
67.395584	Medium	36.85696	84.24448	105.3056	160
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
63.18336	Small	34.5534	78.9792	98.724	150
58.971136	Small	32.24984	73.71392	92.1424	140
58.971136	Small	32.24984	73.71392	92.1424	140
50.546688	Small	27.64272	63.18336	78.9792	120
50.546688	Small	27.64272	63.18336	78.9792	120
50.546688	Small	27.64272	63.18336	78.9792	120
42.12224	Small	23.0356	52.6528	65.816	100
42.12224	Small	23.0356	52.6528	65.816	100
42.12224	Small	23.0356	52.6528	65.816	100
42.12224	Small	23.0356	52.6528	65.816	100
25.273344	Small	13.82136	31.59168	39.4896	60
25.273344	Small	13.82136	31.59168	39.4896	60
12.636672	Small	6.91068	15.79584	19.7448	30

Appendix B

Appendix B: this appendix contain some of table used to measure cross section for cables

Current Ratings

Nominal conductor area (mm²)	In air – Solid Bond	In air – Solid Bond	In air – Solid Bond	In air – Solid Bond	In air – Solid Bond	In ground – Solid Bond	In ground – Solid Bond	In ground – Solid Bond	In underground ducts – Solid Bond	In underground ducts – Solid Bond	In underground ducts – Solid Bond	In underground ducts – Solid Bond	Fault current carrying capacity for 1 second – Cond. kA	Fault current carrying capacity for 1 second – Screen kA
16	114	134	106	112	81	116	118	113	103	104	101	91	2.29	2.36
25	148	173	137	145	103	148	150	145	131	131	129	117	3.57	3.62
35	182	211	168	178	125	177	179	174	156	156	154	140	5.00	5.09
50	216	251	201	213	150	208	208	204	181	180	180	167	7.15	7.22
70	269	308	251	266	184	251	248	249	216	212	217	204	10.0	10.1
95	323	368	302	321	219	297	291	296	253	246	256	242	13.6	10.1
120	370	420	348	370	257	334	325	336	284	274	289	279	17.1	10.2
150	416	468	393	419	288	370	356	374	314	300	322	311	21.4	10.2
185	471	525	448	478	325	412	392	420	347	328	359	350	26.4	10.2
240	548	602	525	561	376	467	439	482	391	365	410	402	34.3	10.2
300	617	670	598	639	438	516	478	538	431	397	457	462	42.9	10.2
400	701	750	687	735	497	571	522	605	474	431	510	519	57.2	10.2
500	787	831	782	837	558	627	565	674	520	466	568	580	71.5	10.2
630	877	911	886	948	624	683	607	746	560	496	620	642	90.0	10.2
800	986	1014	1008	1082	727	740	651	822	616	537	693	734	114	10.2

In substation

Large factory

Current Ratings

Nominal conductor area (mm²)	In air – Solid Bond	In air – Solid Bond	In air – Solid Bond	In air – Solid Bond	In air – Solid Bond	In ground – Solid Bond	In ground – Solid Bond	In ground – Solid Bond	In underground ducts – Solid Bond	In underground ducts – Solid Bond	In underground ducts – Solid Bond	In underground ducts – Solid Bond	Fault current carrying capacity for 1 second – Cond. kA	Fault current carrying capacity for 1 second – Screen kA
16	114	134	106	112	81	116	118	113	103	104	101	91	2.29	2.36
25	148	173	137	145	103	148	150	145	131	131	129	117	3.57	3.62
35	182	211	168	178	125	177	179	174	156	156	154	140	5.00	5.09
50	216	251	201	213	150	208	208	204	181	180	180	167	7.15	7.22
70	269	308	251	266	184	251	248	249	216	212	217	204	10.0	10.1
95	323	368	302	321	219	297	291	296	253	246	256	242	13.6	10.1
120	370	420	348	370	257	334	325	336	284	274	289	279	17.1	10.2
150	416	468	393	419	288	370	356	374	314	300	322	311	21.4	10.2
185	471	525	448	478	325	412	392	420	347	328	359	350	26.4	10.2
240	548	602	525	561	376	467	439	482	391	365	410	402	34.3	10.2
300	617	670	598	639	438	516	478	538	431	397	457	462	42.9	10.2
400	701	750	687	735	497	571	522	605	474	431	510	519	57.2	10.2
500	787	831	782	837	558	627	565	674	520	466	568	580	71.5	10.2
630	877	911	886	948	624	683	607	746	560	496	620	642	90.0	10.2
800	986	1014	1008	1082	727	740	651	822	616	537	693	734	114	10.2

Medium factory

Current Ratings

Nominal conductor area	Continuous current-carrying capacity, A — In air					In ground			In underground ducts				Fault current carrying capacity for 1 second	
mm^2	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Solid Bond	Cond. kA	Screen kA
16	114	134	106	112	81	116	118	113	103	104	101	91	2.29	2.36
25	148	173	137	145	103	148	150	145	131	131	129	117	3.57	3.62
35	182	211	168	178	125	177	179	174	156	156	154	140	5.00	5.09
50	216	251	201	213	150	208	208	204	181	180	180	167	7.15	7.22
70	269	308	251	266	184	251	248	249	216	212	217	204	10.0	10.1
95	323	368	302	321	219	297	291	296	253	246	256	242	13.6	10.1
120	370	420	348	370	257	334	325	336	284	274	289	279	17.1	10.2
150	416	468	393	419	288	370	356	374	314	300	322	311	21.4	10.2
185	471	525	448	478	325	412	392	420	347	328	359	350	26.4	10.2
240	548	602	525	561	376	467	439	482	391	365	410	402	34.3	10.2
300	617	670	598	639	438	516	478	538	431	397	457	462	42.9	10.2
400	701	750	687	735	497	571	522	605	474	431	510	519	57.2	10.2
500	787	831	782	837	558	627	565	674	520	466	568	580	71.5	10.2
630	877	911	886	948	624	683	607	746	560	496	620	642	90.0	10.2
800	986	1014	1008	1082	727	740	651	822	616	537	693	734	114	10.2

Small factories

Current Ratings

Nominal conductor area	Continuous current-carrying capacity, A — In air			In ground		Fault current carrying capacity for 1 second	
mm^2						Conductor kA	Screen kA
16	104	110	78	113	89	2.29	2.52
25	134	143	100	145	114	3.57	3.79
35	162	173	120	173	136	5.00	5.05
50	194	208	145	204	162	7.15	7.32
70	241	259	178	249	199	10.0	10.1
95	295	317	220	299	242	13.6	10.1
120	340	367	252	340	276	17.1	10.1
150	385	415	284	380	310	21.4	10.1
185	440	476	322	429	350	26.4	10.1
240	519	563	389	497	416	34.3	10.1
300	594	645	442	560	470	42.9	10.1
400	685	746	505	635	534	57.2	10.1
500	779	850	569	710	597	71.5	10.1

Appendix C

Year (n)	Expenditures ($)	Gross Income Stream ($)	Tax 18% Gross-Exp	Linear Depr. 2.5% / yr	Net Taxes (Tax-Dep.)	Net income Stream ($)	P.V.F, 1/(1+r)^n	Net present value OF Income stream ($)
0	-$4,564,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	1	-$4,564,000.00
1	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.9709	$936,108.17
2	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.9426	$908,842.88
3	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.9151	$882,371.73
4	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.8885	$856,671.58
5	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.8626	$831,719.98
6	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.8375	$807,495.13
7	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.8131	$783,975.85
8	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.7894	$761,141.60
9	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.7664	$738,972.43
10	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.7441	$717,448.96
11	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.7224	$696,552.39
12	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.7014	$676,264.46
13	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.6810	$656,567.43
14	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.6611	$637,444.11
15	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.6419	$618,877.78
16	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.6232	$600,852.21
17	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.6050	$583,351.66
18	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.5874	$566,360.84
19	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.5703	$549,864.89
20	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.5537	$533,849.41
21	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.5375	$518,300.40
22	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.5219	$503,204.27
23	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.5067	$488,547.83
24	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.4919	$474,318.28
25	-$365,052.000	$1,401,748.84	$186,605.43	$114,100.00	$72,505.43	$964,191.41	0.4776	$460,503.19
Total	**-$13,690,300.000**	**$35,043,721.10**	**$4,665,135.80**	**$2,852,500.00**	**$1,812,635.80**	**$24,104,785.30**		**$12,225,607.46**

Appendix c: Table 1 this table show net present value of income stream and it is equal 12,225,607.46 $

Year (n)	Cost($)	Net income Stream ($)	Net Cash flow	cumulative Net Cash flow
0	$4,564,000.00	$0.00	-$4,564,000.00	-$4,564,000.00
1	$365,052.00	$936,108.17	$571,056.17	-$3,992,943.83
2	$365,052.00	$908,842.88	$543,790.88	-$3,449,152.95
3	$365,052.00	$882,371.73	$517,319.73	-$2,931,833.22
4	$365,052.00	$856,671.58	$491,619.58	-$2,440,213.64
5	$365,052.00	$831,719.98	$466,667.98	-$1,973,545.66
6	$365,052.00	$807,495.13	$442,443.13	-$1,531,102.53
7	$365,052.00	$783,975.85	$418,923.85	-$1,112,178.68
8	$365,052.00	$761,141.60	$396,089.60	-$716,089.08
9	$365,052.00	$738,972.43	$373,920.43	-$342,168.64
10	$365,052.00	$717,448.96	$352,396.96	$10,228.32
11	$365,052.00	$696,552.39	$331,500.39	$341,728.71
12	$365,052.00	$676,264.46	$311,212.46	$652,941.17
13	$365,052.00	$656,567.43	$291,515.43	$944,456.60
14	$365,052.00	$637,444.11	$272,392.11	$1,216,848.71
15	$365,052.00	$618,877.78	$253,825.78	$1,470,674.49
16	$365,052.00	$600,852.21	$235,800.21	$1,706,474.70
17	$365,052.00	$583,351.66	$218,299.66	$1,924,774.36
18	$365,052.00	$566,360.84	$201,308.84	$2,126,083.20
19	$365,052.00	$549,864.89	$184,812.89	$2,310,896.09
20	$365,052.00	$533,849.41	$168,797.41	$2,479,693.49
21	$365,052.00	$518,300.40	$153,248.40	$2,632,941.89
22	$365,052.00	$503,204.27	$138,152.27	$2,771,094.16
23	$365,052.00	$488,547.83	$123,495.83	$2,894,589.99
24	$365,052.00	$474,318.28	$109,266.28	$3,003,856.27
25	$365,052.00	$460,503.19	$95,451.19	$3,099,307.46

Appendix c: Table2 this table shows cumulative Net Cash flow

Appendix c: Table 3. Cost of equipment for 11KV net work

Type	rating	Number	Cost	Total Cost
Transformer(33-11)KV	40MVA	2	1200000	2400000
Transformer(11-0.4)KV	**(250-1000)KVA**	53	15000	238500
RMU	TTCC	30	10000	300000
Recloser	Diff.	93	15000	1395000
Fuse		82	250	20500
Total				4354000

Appendix c: Table4. Cost of cable for 11kV net work

11Kv			
Size Cable (mm^2)	**Length**	**Cost**	**Total cost**
400	1600	45	72000
300	400	40	16000
240	2000	35	70000
185	650	25	16250
150	1600	20	32000
16	400	5	2000
6	300	3	900
Total			**209150**

Total cost for 11KV network	4563150

Appendix c: Table 5. Cost of equipment for 33kV net work

Type	rating	Number	Cost	Total Cost
Transformer(33-0.4)KV	(100-500)KVA	18	16000	288000
Transformer(33-0.4)KV	**(500-1000)KVA**	35	35000	1225000
RMU	TTCC	30	25000	750000
Recloser	Diff.	93	30000	2790000
Fuse		82	350	28700
Total				5081700

Appendix c: Table6. Cost of cable for 33KV net work

33Kv			
Size Cable (mm^2)	**Length**	**Cost**	**Total cost**
400	1600	45	72000
240	400	35	14000
200	2000	27	54000
185	650	25	16250
120	1600	20	32000
16	400	5	2000
6	300	3	900
Total			191150

Total cost for 33kV network	5272850