Palestine Polytechnic University

College of Engineering

Title

Hebron —Al_Ezaria 161KV High Voltage Transmission Line Design of 1GW Power

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Abstract

This project is a Design of High Voltage Transmission system with 161KV and 1GW between Hebron and Al_Ezaria City using E-TAP Simulator, assessment program, and tools. The core of the project is to Study, Calculate and Simulate all needed of electrical, mechanical parameter and geographical data .using the E-TAP Simulator program which has Simulation property, which allows us to analyze and study status of the network more accurately.

This design faced some problems such as estimation of the load consumption to the year of 2050, huge amount of current transfer and varied topography in the designed region. So the solution was to make an estimate of the annual consumption beyond 2016 based on Statistics taken from the Palestinian Bureau of Statistics from 1996 to 2015.

In addition, there is an Effect for mechanical force such as weight, tension and conductor elongation due to change in temperature of surrounded , Number ,type of the steel tower , install and balanced all devices along the track for line over boundary of the region ,spacing between all component of the system .

For protection, the problem was in the Type, amount, rating, and location of the protection devices to operate the transmission line in the highest stability and reliability status.

And finally to approximate the cost of construction for the transmission line per kilometer.

الملخص

هذا المشروع هو تصميم لخط نقل جهد عالي 161KV و 1GW بين مدينتي الخليل والعيزرية، وذلك باستخدام برنامج ال (E-TAP Simulator) وبرامج مساعدة، وبعض الادوات المساعدة.
الهدف من هذا المشروع هو دراسة وحساب ومحاكاة جميع العوامل الكهربائية والميكانيكية والمعلومات الجغرافية المتوفرة، فبرنامج ال (E-TAP) يتيح لنا امكانية عمل تحليل و دراسة للشبكة بشكل دقيق ومعتمد.

وخلال العمل في التصميم لخط النقل واجهتنا بعض المشاكل والتي كان من أهمها هو التقدير الصحيح للاستهلاك العام للطاقة في المنطقة التي نعمل بها حتى عام ٢٠٥٠، وكذلك الكمية الكبيرة للتيار الكهربائي، وكيفية نقله في هذه المنطقة، لذلك كان الحل بعمل تقدير للاستهلاك العام للطاقة بالاعتماد على الاحصائيات المتوفرة من دائرة الاحصاء الفلسطيني من عام ١٩٩٦ حتى عام ٢٠١٥، وذلك بادخالها على برنامج Ecexl وعمل منحنًى يبين القيمة المقدرة.

كمان أن تأثيرات القوى الميكانيكية كانت من أبرز العقبات التي واجهتنا، ومن أبرز هذه العوامل : الوزن والشد واستطالة الموصلات تحت تأثير الحرارة المحيطة والزمن والنوع الامثل للموصلات وعددها وكذالك الابراج وطريقة تثبيتها وموازنتها بشكل صحيح على طول المسار المحدد والمسافات الامثل لوضعها.

أما فيما يخص الحماية، فإن التحديات كانت باختيار نوع الاجهزة الأمثل للنظام،كميتها، وكذلك التقدير والموقع المناسب لها لتقديم افضل أداء وأكبر حماية لكي يستطيع الخط العمل بأكبر كفاءة ممكنة وأكثر موثوقية بحيث يمكننا الاعتماد عليه.

بالاضافة الى ما سبق، فان المشكله الاهم عادة في أي تصميم هي التقديرات الاقتصادية للمشروع لكل وحدة كيلومتر للخط الناقل، والزمن اللازم لبدء جني الفوائد من المشروع

Dedicated

TO

Our Home Land

Our Fathers & Mothers

Our Brothers & Sisters

Our Friends

And

Every One Who Appreciate The Value of Science

Bahaá

&

Yazeed

&

Youssef

Acknowledgment

First and for most we should offer our thanks obedience and gratitude to Allah

Our Appreciation To
Palestine Polytechnic University
College of Engineering and Technology
Department of Electrical Power Engineering
Our Supervisor Eng.Nizar Amro

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Chapter 1

Introduction

1.1 Overview :

The main idea of this project is Design of High Voltage Transmission Line 161KV and1 GW double circuit Between Hebron and Al_Eizariya by Using E-TAP Simulator program, then making the essential calculation and analysis for the transmission line such as estimate the consumption, mechanical and electrical calculation, and reduction effect of the corona.

1.2 Project General Description :

As we know, in general, most Designs of the Transmission Network in many places (Countries)in the World are suffering from the amount of transfer power and Voltage levels , selection the best bath of Network , make a specific detect for any component ,need assumption to design it , and make an economical study for the project .
But this project detect all parameters, device, tools needed to make a better design And focus determination of all limitation in the Network by using a new technique which is the E-TAP Simulator program.

In our project we will Simulate, Analyze the transmission system, detect all problems and suggest the best solutions.

The project adopts on investigation and analysis of transmission network after plot it on the simulator program , the program capabilities and properties allow us to study the network from many side after make it ,show the status of the network component ,solve the existing problems and weakness in the network .

1.3 Project scope

The scope of this project is to design a new high voltage from Hebron to Al_ Ezaria Network .And there are many aims for this project can be summarized as follow:

1. Found a new transmission system independent for the generation company.

2. Estimate the cost of this project and the benefits can get.

3. Detect most problem can may face us in the network and make strategy prevent it to happen.

1.4 Project Methodology

- Getting and calculate all required data for design and the simulator .
- Determine and select all component in the network.
- Plot primary path of the transmission line on the design region.
- plot the network with theoretical value on the simulator.
- Study and investigating the network.
- Specify the network problem.
- Solving the network problem and developing its operation.

1.5 Other Study

As we mentioned in the previous that the design was for 161KV, so we looked for a similar designs but mostly designed and used other values like 132KV, 230KV and 400KV, and most of this designs used the same things we used such as the type of conductors, insulators, protection devices, and double circuit. But there is a different in the towers, its normal because its designs for another values of voltage and another topography. So, we tried in our design to followed the previous studies, specially American and European cases.

Chapter 2

Conductor and Insulator

A transmission line is the bulk transfer of electrical energy, from generating power plant to electrical substations located near demand centers. [2, 5, 6, 4]

Components of the transmission line

- **Conductor**
  The electricity is transmitted at high voltages to reduce the energy lost in long distance transmission.
- **Overhead Ground Wires**
  Shield wires are use to protect the tower from lighting.
- **Spacers**
  Spacers are designed to keep the individual wires in a bundle separated by a fixed distance.
- **Insulators**
  Transmission line insulators are devices used to contain, separate or support electrical conductors on high voltage electricity supply networks.

(a) A shield wire (b) Spacers (c) Insulators

Figure 2.1: Components of the transmission line

2.1 Type of Conductor

Transmission line conductors :

1. Can be made of Copper or aluminum.

2. However, aluminum conductor have completely replaced Coper for over head line because of the much lower cost and lighter weight of an aluminum conductor compared with a coper conductor of the same resistance

3. Symbols identifying different types of aluminum conductor are as follows :
   - **All-Aluminum Conductors (A.A.C.)**
   - **All-Aluminum Alloy Conductors (A.A.A.C.)**
   - **Aluminum Conductor Steel Reinforced (A.C.S.R.)**

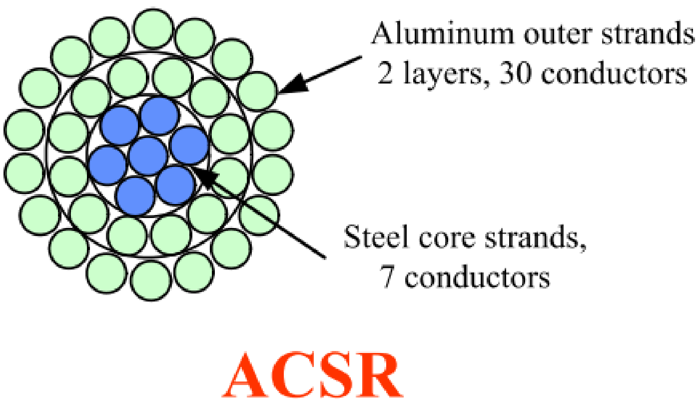


Figure 2.2: Aluminum Conductor Steel Reinforced (A.C.S.R.)

2.1.1 Specific Information for Using Conductor "ACSR"

Types of conductors for high-voltage transmission lines:

1. **All-Aluminum Conductors (A.A.C.)**
   All Aluminum bare conductors are used for aerial distribution lines - having relatively short spans, aerial feeders and bus bars of substations.

   Advantage

   (a) It has lesser strength and more sag per span length than any other category

   (b) Cost of ACSR is equal to AAC.

2. **All-Aluminum Alloy Conductors (A.A.A.C.)**
   A.A.A.C. are mainly used for overhead lines, in transmission and distribution electrical networks, having relatively long span. They are also used a messenger to support overhead electrical cables.

Advantage

(a) The presence of alloy makes it expensive.

(b) It's conductivity is less than ACSR .

3. **Aluminum Conductor Steel Reinforced (A.C.S.R.)**
A.C.S.R conductors are widely used for electrical power transmission - over long distances, since they are ideal for long overhead lines spans. They are also used as a messenger for supporting overhead electrical cables.

Advantage

(a) It is used for longer spans keeping sag minimum.

(b) It may consist of 7 or 19 strands of steel surrounding by aluminum strands concentrically.

(c) Strands provide flexibility, prevent breakage and minimize skin effect.

(d) The number of strands depends on the application, they may be 7, 19, 37, 61, 91 or more.

(e) Expanded ACSR has larger diameter and hence lower corona losses.

2.2 Mechanical Calculation

2.2.1 Sag Requirements on Conductor

Sag is defined as the different in level between points of supports and the lowest point on the conductor.

Sag Provision is Mandatory in Transmission Line Conductors
It is because of providing safety of the conductor from not to be subjected to excessive tension. In order to permit safe tension in the conductor, conductors are not fully stretched; rather they are allowed to have sag.

[5, 3] **Factors Affecting Sag**

1. Weight of conductor.
2. Location of conductor.
3. Length of span.
4. Temperature.
5. Tensile strength.
6. Tension.

Here we discuss briefly about various factors sag and tension in electrical transmission lines .

- **Weight of conductor** The sag of an overhead line is directly proportional to the weight of the conductor.This is because the weight of any body acts vertically downwards.i.e.,more the weight of the conductor more the force acting vertically downwards and hence greater is the sag value in transmission lines.
- **Location of conductor** Sag also depends on the location of conductors.If the conductors are present in area where ice formation takes place,then due the accumulation of ice on the conductor its overall weight increases.This increases the weight of the conductors which in turn increases the value of sag.
- **Length of span** Sag is proportional to the square of length of span . Hence, longer the span greater will be the sag provided the tension and weight of the conductor is constant.
- **Temperature** The value of sag greatly affected by the temperature. If the temperature is high sag will be more because rise in temperature causes the conductors to expand. Is the temperature is low, the conductor (being metallic) contracts and hence sag is less due to which the tension in the conductor is increases.
- **Tensile strength** Sag inversely proportional to the tensile strength of the conductor provided the other parameters are constant.
- **Tension** Tension on the conductor is inversely proportional to sag. If the tension is more the conductors are connected very tightly between the tower structure and hence sag is less. On the other hand is tension is less the conductors are connected loosely hands sag is more.

Sag Calculate

Sag calculation is classified to two cases:

- When supports are at equal levels
- When supports are not at equal levels

Case 1:When supports are at equal levels

Let us consider a line conductor between two equal height line supports. Line supports are A and B with O as the lowest point as shown in figure. Point O will be the lowest point as two levels are equal lowest point will be at the mid-span.

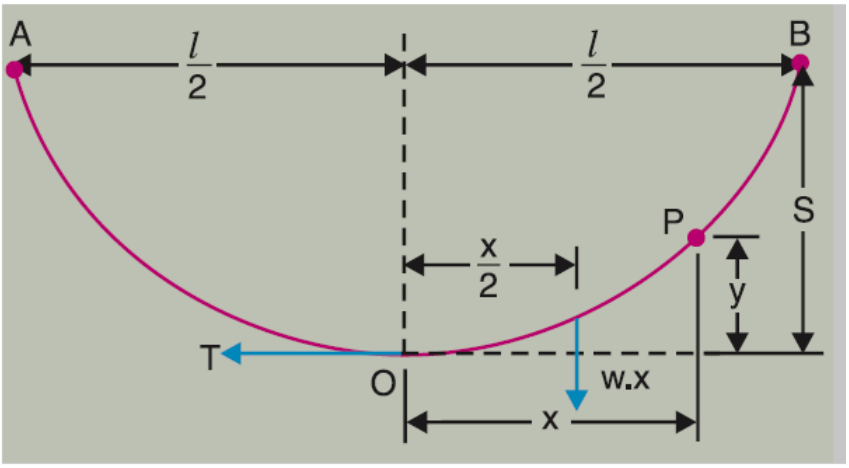


Figure 2.3: supports are at equal levels

Let
L= Length of span.
w = Weight per unit length of conductor.
T = Tension in the conductor.
Now consider any point on the conductor.Lets say point 'P'.By considering lowest point O as the origin, let the co-ordinates of point P be x and y. Assuming that the curvature is so small that curved length is equal to its horizontal projection (i.e., OP = x), the two forces acting on the portion OP of the conductor are :

- The weight wx of conductor acting at a distance x/2 from O.
- The tension T acting at O.

Equating the moments of above two forces about point O, we get,

$$T_y = w\,x\,\frac{x}{2} \tag{2.1}$$

or

$$y = T\,\frac{x^2}{2T} \tag{2.2}$$

The maximum dip (sag) is represented by the value of y at either of the supports A and B. At support A, $x = \frac{L}{2}$and$y = S$

Sag,

$$S = \frac{w(\frac{L}{2})^2}{2T} \tag{2.3}$$

$$S = \frac{wL^2}{8T} \tag{2.4}$$

Case 2 : When supports are at unequal levels
When transmission lines run on steep inclines as in the case of hilly areas, we generally come across conductors suspended between supports at unequal levels.The shape of the conductor between the supports may be assumed to be a part of the parabola. In this case, the lowest point of the conductor will not lie in the middle of the span.

Consider a conductor suspended between two supports A and B which are at different levels as shown in the following figure.

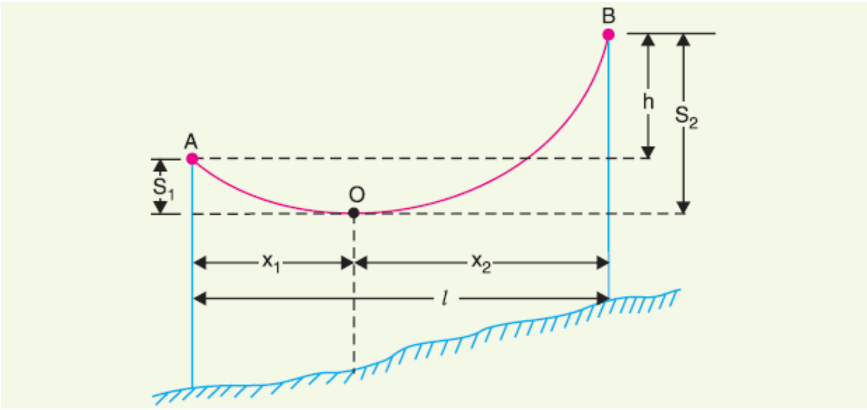


Figure 2.4: supports are at unequal levels

Let
L = Span length
h = Difference in levels between two supports
x_1 = Distance of support at lower level (i.e., A) from O
x_2 = Distance of support at higher level (i.e. B) from O
T = Tension in the conductor.
w = the weight per unit length of the conductor
s_1 = sag at point A .
s_2 = sag at point B.

$$S_1 = \frac{wx_1^2}{2T} \tag{2.5}$$

$$S_2 = \frac{wx_2^2}{2T} \tag{2.6}$$

also

$$x_1 + x_2 = l$$

then ,

$$X_1 = \frac{l}{2} - \frac{Th}{wl} \tag{2.7}$$

$$X_2 = \frac{l}{2} + \frac{Th}{wl} \tag{2.8}$$

2.2.2 Effect of Ice and Wind on Sag

- The weight per unit length of the conductor is changed when wind blows at a certain force on the conductor and ice accumulate around the conductor.
- Wind force acts on the conductor to change the conductor self weight per unit length horizontally in the direction of the air flow.

- Ice loading acts on the conductor to change the conductor self weight per unit length vertically downward.
- Considering wind force and ice loading both at a time, the conductor will have a resultant weight per unit length.
- The resultant weight will create an angle with the ice loading down ward direction.

Let us assume, w is the weight of the conductor per unit length. wi is the weight of ice per unit length

$$w_i = density\, of\, ice \times volume\, of\, ice\, per\, unit \tag{2.9}$$
$$= density\, of\, ice \times \pi t(t + d)$$

where ,
density of ice =0.9167 g cm^3
t = thickness of the coating ice = 0.5 cm.
d = diameter of the conductor = 20.46 mm.

the expression for sag and tension derived was under normal conditions at normal temperature and the weight acting on the conductor was only its own weight. But in cold places there is a ice coating formed on the conductor and also wind pressure nets horizontally on the line conductor. The ice coating on the line conductor increases the total diameter of the conductor and also the weight of the Conductor increases.

The total weight of the conductor i.e., both the conductor weight and the weight of the ice acts vertically downwards whereas the wind force acts horizontally on the conductor. Therefore, the vector sum of horizontal and vertical forces acting on the conductor gives the total force shown in figure

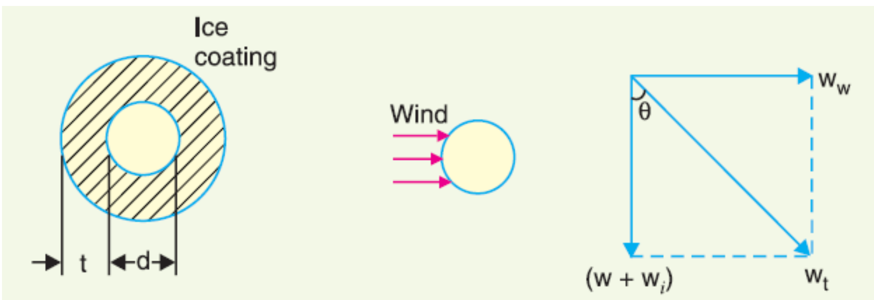


Figure 2.5: Effect of wind and ice loading on the conductor

$W = weight of conductor per unit length$
$= conductor\, material\, density \times volume\, per\, unit\, length$

$$W_t = \sqrt{(W + Wi)^2 + (Ww)^2} \tag{2.10}$$

$ww = wind\, force\, per\, unit\, length$
$= wind\, pressure\, per\, unit\, area \times projected\, area\, per\, unit$

$$W_w = wind\, pressure \times [(d + 2t) \times 1] \tag{2.11}$$

2.3 Corona

It is defined as ionization of air due to higher voltage (usually voltage above critical voltage) which causes violet light around the conductor and hissing sound. It also produces ozone gas therefore it is undesirable condition.

2.3.1 Corona Effect

Factors effecting Corona :

1. Atmosphere
2. Conductor size
3. Spacing between conductors
4. Line voltage

- Atmosphere Corona is affected by the physical state of atmosphere. In the stormy weather, the number of ions is more than normal. and this leads to corona occurs at much less voltage as compared with fair weather.
- Conductor size The corona effect depends upon the shape and conditions of the conductors.The rough and irregular surface will give rise to more corona because unevenness of the surface decreases the value of breakdown voltage.Thus a stranded conductor has irregular surface and hence gives rise to more corona than a solid conductor.
- Spacing between conductors If the spacing between the conductors is made very large as compared to their diameters, there may not be any corona effect. Larger distance between conductors reduces the electro-static stresses at the conductor surface, thus avoiding corona formation.
- Line voltage The line voltage greatly affects corona.If it is low, there is no change in the condition of air surrounding the conductors and hence no corona is formed.However, if the line voltage has such a value that electrostatic stresses developed at the conductor surface make the air around the conductor conducting, then corona is formed.

Advantages of Corona

- Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electrostatic stresses between the conductors.
- Corona reduces the effects of transients produced by surges.

Disadvantages of Corona

- Corona is accompanied by a loss of energy.This affects the transmission efficiency of the line.
- Ozone is produced by corona and may cause corrosion of the conductor due to chemical action.
- The current drawn by the line due to corona is non-sinusoidal and hence non-sinusoidal voltage drop occurs in the line. This may cause inductive interference with neighbouring communication lines.

2.3.2 Corona Reduction Method

- ***By increasing conductor size.***

  An increase in diameter reduces the surface field gradient and it helps to decrease the Corona loss. Higher is the conductor size, the greater is the probability of roughness of the conductor . the probability of increased corona loss is thus directly related with the conductor surface for increased sizes of the conductors.

- ***By increasing spacing conductor***

- ***By increasing number of conductor per phase***
  in bundled conductor, the mutual shielding effect of the sub conductors reduce the potential gradient on the individual conductors leading to decrease in corona loss .

2.4 Insulator

An electrical insulator is a material whose internal electric charges do not flow freely, and therefore make it nearly impossible to conduct an electric current under the influence of an electric field. This contrasts with other materials, semiconductors and conductors, which conduct electric current more easily. [7]

2.4.1 Properties of Insulating Material

The materials generally used for insulating purpose is called ***insulating material***. For successful utilization, this material should have some specific properties as listed below

1. It must be mechanically strong enough to carry tension and weight of conductors.
2. It must have very high dielectric strength to withstand the voltage stresses in High Voltage system.
3. It must possesses high Insulation Resistance to prevent leakage current to the earth.
4. The insulating material must be free from unwanted impurities.
5. It should not be porous.
6. There must not be any entrance on the surface of electrical insulator so that the moisture or gases can enter in it.
7. There physical as well as electrical properties must be less effected by changing temperature.

2.4.2 Types of Insulators

Porcelain Insulator
Porcelain is commonly used material for over head insulator. The porcelain is aluminum silicate. The aluminum silicate is mixed with plastic kaolin, feldspar and quartz to obtain final hard and glazed porcelain insulator material. The surface of the insulator should

be glazed enough so that water should not be traced on it. Porcelain also should be free from porosity since porosity is the main cause of deterioration of its dielectric property. It must also be free from any impurity and air bubble inside the material which may affect the insulator properties.

Glass Insulator
Now days glass insulator has become popular in transmission and distribution system.Annealed tough glass is used for insulation purpose . Glass insulator has numbers of advantages over conventional porcelain insulator.

Polymer Insulator In a polymer insulator has two parts, one is glass fiber reinforced epoxy resin rod shaped core and other is silicone rubber or EPDM (Ethylene Propylene Diene Monomer) made weather sheds. Rod shaped core is covered by weather sheds. Weather sheds protect the insulator core from outside environment. As it is made of two parts, core and weather sheds, polymer insulator is also called composite insulator. The rod shaped core is fixed with Hop dip galvanized cast steel made end fittings in both sides.
Advantages of Polymer Insulator

- It is very light weight compared to porcelain and glass insulator.
- As the composite insulator is flexible the chance of breakage becomes minimum.
- Because of lighter in weight and smaller in size, this insulator has lower installation cost.
- It has higher tensile strength compared to porcelain insulator.
- Its performance is better particularly in polluted areas.
- Due to lighter weight polymer insulator imposes less load to the supporting structure.
- Less cleaning is required due to hydrophobic nature of the insulator.

Disadvantages of Polymer Insulator

- Moisture may enter in the core if there is any unwanted gap between core and weather sheds. This may cause electrical failure of the insulator.
- Over crimping in end fittings may result to cracks in the core which leads to mechanical failure of polymer insulator

Chapter 3

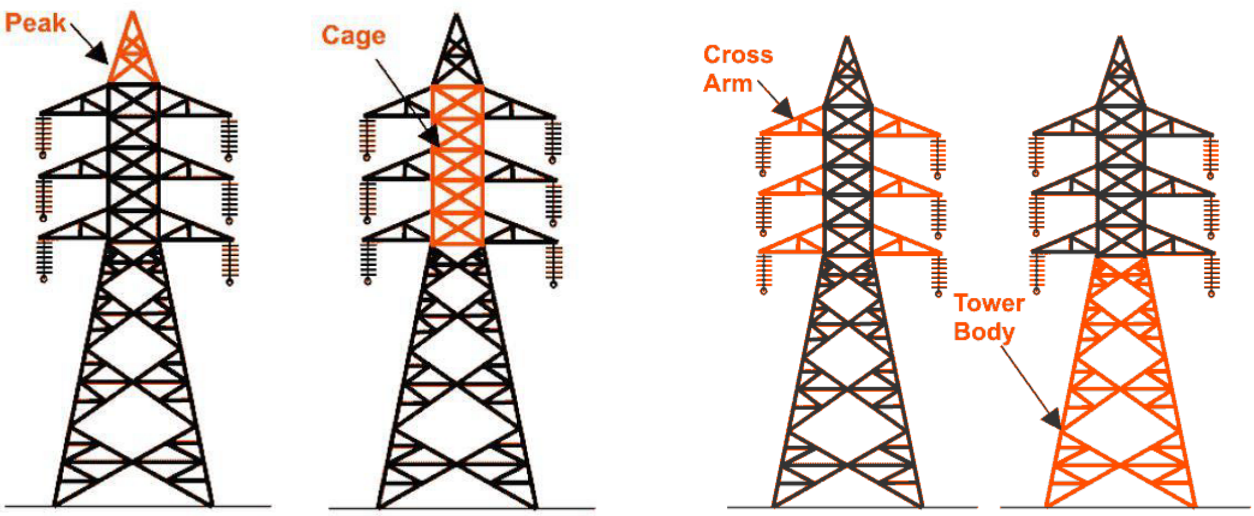
Steel Tower

The main parts of transmission towers are:[6, 4, 3]

- Peak of transmission tower.
- Cross arm of transmission tower.
- Cage of transmission tower.
- Transmission Tower Body.

1. **Peak of Transmission Tower**
   The portion above the top cross arm is called peak of transmission tower. Generally earth shield wire connected to the tip of this peak.

2. **Cage of Transmission Tower**
   The portion between tower body and peak is known as cage of transmission tower. This portion of the tower holds the cross arms.



(a) Peak (b) Cage (c) Body & Cross Arm

Figure 3.1: Parts of Transmission Towers

3. **Body of Transmission Tower**
   The portion from bottom cross arms up to the ground level is called transmission tower body. This portion of the tower plays a vital role for maintaining required ground clearance of the bottom conductor of the transmission line.

3.1 Transmission Tower

To determine the actual transmission tower height by considering the above points, we have divided the total height of tower in four parts.

1. Minimum permissible ground clearance (H1).
2. Maximum sag of the conductor (H2).
3. Vertical spacing between top and bottom conductors (H3).
4. Vertical clearance between ground wire and top conductor (H4).

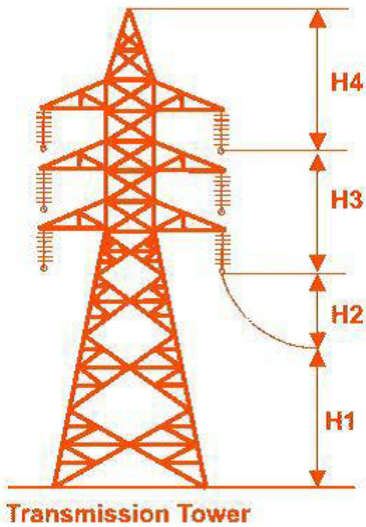


Figure 3.2: height of tower in four parts

3.2 Types of transmission towers.

According to different considerations, there are different types of transmission towers. The transmission line goes as per available corridors. Due to unavailability of shortest distance straight corridor transmission line has to deviate from its straight way when obstruction comes. In total length of a long transmission line there may be several deviation points. According to the angle of deviation there are four types of transmission tower

1. A Type tower angle of deviation 0 to 2.
2. B Type tower angle of deviation 2 to 15.

3. C Type tower angle of deviation 15 to 30.
4. D Type tower angle of deviation 30 to 60.

As per the force applied by the conductor on the cross arms, the transmission towers can be categorized in another way

- Tangent suspension tower and it is generally A type tower.
- Angle tower or tension tower or sometime it is called section tower. All B, C and D types of transmission towers come under this category.

Apart from the above customized type of tower, the tower is designed to meet special usages listed below; these are called **special type Towers:**

1. **Tension Towers:** The benefits in tensile thread.
2. **Suspension Towers.** The towers constitute about 80% of the total number of towers in the font used in the load conductor.
3. **Transposition Towers:** They are exchanged phases on equal distances along the line to occur equal to or equal to the power capacitance and inductance of the three-line length phases.
4. **Angle Towers.** Benefits and change the font path.
5. **Crossing Towers:** Used when crossing rivers or at least lines low voltage lines effortlessly.
6. **Terminal Towers:** Used at the beginning and end of the transmission line or inlet and outlet transport stations, a tightening of electrical towers and utility withstand tensile from one side.

Classification of Transmission Tower
Based on numbers of circuits carried by a transmission tower, it can be classified as:

1. Single circuit tower
2. Double circuit tower
3. Multi circuit tower.

3.3 Tower Accessories

- Danger boards
- Number plate
- Phase plate
- Anti Climbing Device
- Anti perch / Bird guards for suspension towers
- Hanger rods

Chapter 4

Protection Device

Power-system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults. The objective of a protection scheme is to keep the power system stable and to minimize the damage of the equipments and property that would be caused by system faults, and maintain the delivery of electrical energy to the consumers and protect humans from any electrical risks.[9, 10, 11, 2, 4]

4.1 Faults Classification

Faults have two main types according to the symmetry of the system:

- Symmetrical Faults.
  In the balanced system the system impedance in each phase are identical and the three-phase voltages and currents through the system are completely balanced. Faults under symmetrical conditions are caused in the system accidentally through:
  1. Insulation failure of equipment.
  2. Flash over of lines initiated by lighting stroke.
  3. Accidental faulty operation.
- Asymmetrical Faults.
  Unbalanced system can result due to unsymmetrical faults, then system operation may also become unbalanced when load not balanced. Most faults in the system are unsymmetrical so it's very important to pay attention.

The asymmetrical faults can be classified as follow:

- Shunt Type Faults:
  - Single line to ground fault (L-G).
  - Line to line fault (L-L).
  - Double line to ground fault (L-L-G)
- Series Type Fault:
  It is the open conductor fault.

Figure shows these types of faults.

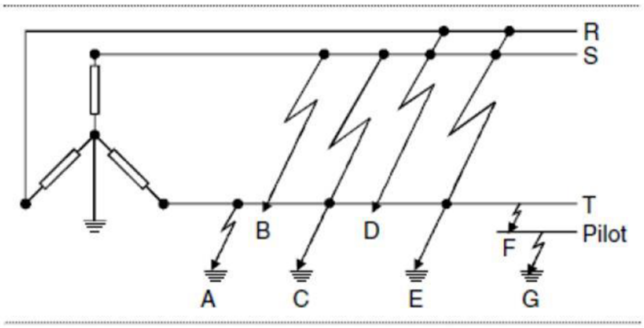


Figure 4.1: How Faults Occur

Faults may occur as a cross country fault. Phase to earth fault has a current that depends on the earthling system. Most faults on the transmission lines are caused by lightning which results in the flash over of insulations.

4.2 Requirements of Protection System

- **Sensitivity:** It means the ability of the protection system to detect all faults and abnormal conditions in the protective zone where the detection needed for the minimum fault current. In this requirement there are three cases:
- **Selectivity:** The circuit breaker must be able to detect and isolate the fault item only.
- **Fast operating:** It means the ability of the protection system to isolate the faulty part quickly, which leads to minimize the effect of the fault and increase the stability of the power system.
- **Reliability:** It means the dependability, in other word we can depends in the protection system in all cases such as the arc rare, and it must operate even after years of operation.
- **Economical** It means obtaining the maximum protection with lower cost, but we have to use a high quality protection devices which means more cost needed.
- **Simplicity** The protection system must be simple to help us during maintenance, but the protection level increase the complexity of the protection system.

4.3 Types of protection devices

1. **Circuit breaker**
   The circuit breaker is one of the most important devices that used in the protection system. The circuit breakers are generally classified based on the way of extinguish

the spark resulting from arc. Accordingly, there are four types of circuit breakers are:

(a) Oil circuit breakers The oil circuit breaker is widely used in industrial fields. This type used the oil in the process of extinguish the electrical spark when the electric arc occurrence of bubbles forming working to extinguish the sparks.

(b) Air-blast circuit breakers
These circuit breaker used mainly in the high voltage applications. When the fault happens cause separate the contacts then the electric arc is formed and this leads to rush of air which acts to cool the spark and thus extinguish.

(c) Sulphur hexafluoride circuit breakers
This type of circuit breakers used SF6 gas, which has a great tendency to gain electrons . Upon separation of the gas starts to flow contractors transforms gas to negative ions. Lost electrons leads to the weakening of the electric arc and thus extinguish the spark.

(d) **Vacuum circuit a breaker**
In this type of circuit breakers uses a vacuum that could be up to 10-7 Tor. This vacuum provides a very high isolation. This isolation leads to extinguish the spark too quickly.

2. **Autorecloser**
Is a self-controlling circuit breaker equipped with mechanism to being able to reconnect the circuit after separating because of a fault in the system.

3. **Current transformer (CT)**
This type of transformer is used within the system of equipment protection. This transformer works to step down the current that flowing in it for measurement processes and also protect protection devices where this transformer connected in series with an electrical system.

4. **Voltage transformer**
Like the current transformer, this transformer works to step down the voltage between its parties for different measurement processes where the transformer is connected in parallel with the system.

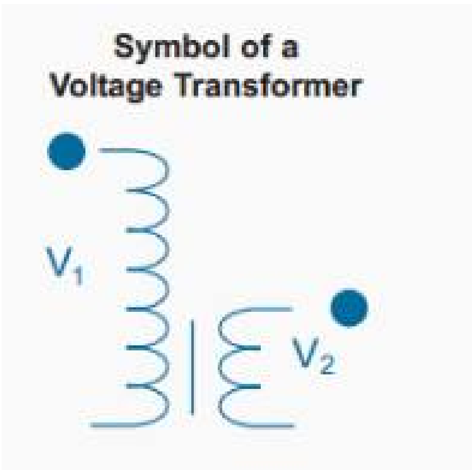


Figure 4.2: Voltage transformer

5. **Surge Arresters**
   Surge arresters are equipment used to eliminate the sudden impact of the lightning on the system. Surge arresters used to protect a variety of devices and equipment in the transmission system such as transformers.

6. **Relays**
   Relays are developed and installed to protect the lines. The transmission line protection Relays, in the industry, are based on the fundamental frequency components of the voltages and currents.

   Principle of Operation

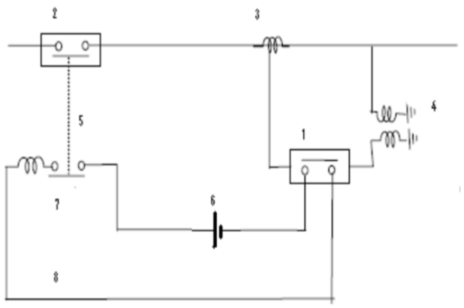


Figure 4.3: The basic circuit of a simple protection system

Where;

- Protective relay.
- Circuit breaker (CB).
- Current transformer (CT).
- Voltage transformer (VT)
- Coil of tripping the CB.
- Battery.
- Auxiliary switch.
- Circuit of tripping the CB

In summary the basic function of protection is to detect faults and to clear them as soon as possible. It is also important that in the process the minimum amount of equipment should be disconnected. Faults cause large amounts of currents to flow in the components that would burn out if current flows are not promptly interrupted. The voltages of the faulted phases decrease on the occurrence of a fault.

7. **Protection zone:**
   As mentioned before, the aims of the power system is to generate, transmit, and distribute the electrical energy, these aims need several equipment such as generators, transformers, transmission lines all these equipment are important so we have to protect it to provide a continuity and safety supplying. We cannot protect it randomly, so we divide the system into zones each zone called protection zone. The figure below shows a simple power system divided into protection zones.

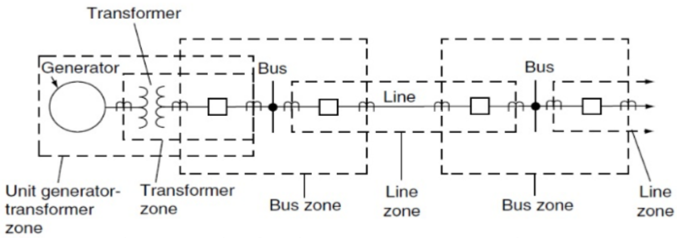


Figure 4.4: simple power system divided into protection zones

Chapter 5

Design of the Transmission Line System

5.1 Load Growth

The estimated consumption will be equal to 8.8 GW,Based on that we decided to transfer 1 GW in the transmission line system. *"To more details see APPENDIX A "*[12, 5]

5.2 Conductor size

At the beginning we calculated the current that would flow the transmission line by the equation below:

$$P = \sqrt{3}VICOS(\Theta) \tag{5.1}$$

When,
$V = 161KV \qquad ,COS(\Theta) = 0.92 \qquad , P = 1GW$

$$I = \frac{p}{\sqrt{3}VCOS(\Theta)} = 3897.854A \tag{5.2}$$

We noticed that the current is too high and the cross section area for the chosen conductor is too large ,so we decides to choose double circuit, and the current will be

$$I_{circuit} = \frac{I}{2} = 1948.93A \tag{5.3}$$

Even after selecting to divide the current into two circuits the current still high so we decided to use three bundles for each phase

$$I_{bundle} = \frac{I_{circuit}}{2} = 649.64A \tag{5.4}$$

Referred to the ACSR product catalog ,We choose ***flicker*** conductor

ASTM CONDUCTOR SIZES - METRIC UNITS

Code Word	Nominal Size (AWG or KCM)	Nominal Size (mm^2)	Stranding (Al/Stl)	Diameter (mm) Individual Wires Al	Diameter (mm) Individual Wires Stl	Diameter (mm) Steel Core	Diameter (mm) Complete Cable	Weight[1] (kg/krn) At	Weight[1] (kg/krn) Stl	Weight[1] (kg/krn) Total	Content % Al	Content % Stl	Rated Strength[2] kg	Resistance[3] ohms/km DC@ 20 °C	Resistance[3] ohms/km AC @ 75 °C	Current Rating[4] (Amps)
Turkey	6	13.30	6/1	1.679	1.679	1.68	5.04	36.4	17.2	53.7	67.90	32.10	540	2.10	2.64	105
Swan	4	21.15	6/1	2.118	2.118	2.12	6.36	58.0	27.4	85.4	67.90	32.10	844	1.32	1.69	140
Swanate	4	21.15	7/1	1.961	2.614	2.61	6.54	58.0	41.7	99.7	58.13	41.87	1070	1.31	1.70	140
Sparrow	2	33.63	6/1	2.672	2.672	2.67	8.02	92.3	43.6	135.9	67.90	32.10	1293	.832	1.09	184
Sparate	2	33.63	7/1	2.474	3.299	3.30	8.25	92.3	66.5	158.8	58.13	41.87	1651	.823	1.11	184
Robin	1	42.41	6/1	3.000	3.000	3.00	9.00	116.3	55.0	171.4	67.90	32.10	1615	.660	.878	212
Raven	1/0	53.51	6/1	3.371	3.371	3.37	10.11	146.9	69.4	216.2	67.90	32.10	1987	.523	.711	242
Quail	2/0	67.44	6/1	3.782	3.782	3.78	11.35	184.9	87.4	272.3	67.90	32.10	2404	.415	.579	276
Pigeon	3/0	85.03	6/1	4.247	4.247	4.25	12.47	233.1	110.2	343.3	67.90	32.10	3003	.329	.474	315
Penguin	4/0	107.22	6/1	4.770	4.770	4.77	14.31	294.1	139.0	433.1	67.90	32.10	3787	.261	.390	357
Waxwing	266.8	135.19	18/1	3.091	3.091	3.09	15.46	372.4	58.4	430.7	86.45	13.55	3121	.211	.259	449
Partridge	266.8	135.19	26/7	2.573	2.002	6.00	16.30	374.5	172.0	546.5	68.53	31.47	5126	.209	.255	457
Ostrich	300.0	152.01	2617	2.728	2.121	6.36	17.27	421.0	193.1	614.0	68.53	31.47	5761	.186	.227	492
Merlin	336.4	170.46	18/1	3.472	3.472	3.47	17.36	469.8	73.6	543.5	86.45	13.55	3937	.167	.205	519
Linnet	336.4	170.46	26/7	2.891	2.248	6.74	18.29	471.8	216.4	688.2	68.53	31.47	6396	.166	.203	529
Oriole	336.4	170.46	30/7	2,690	2.690	8.07	18.83	473.4	310.9	784.3	60.35	39.65	7847	.165	.201	535
Chickadee	297.5	201.42	18/1	3.774	3.774	3.77	18.87	555.2	87.0	642.2	86.45	13.55	4509	.142	.174	576
Brant	397.5	201.42	24/7	3.269	2.179	6.54	19.61	558.0	203.9	761.9	73.23	26.77	6622	.141	.172	584
Ibis	397.5	201.42	26/7	3.139	2.441	7.32	19.88	557.5	255.7	813.3	68.53	31.47	7394	.140	.172	587
Lark	397.5	201.42	30/7	2.924	2.924	8.77	20.46	559.2	367.2	926.5	60.35	39.65	9208	.139	.170	594
Pelican	477.0	241.70	18/1	4.135	4.135	4.14	20.68	666.4	104.4	770.8	86.45	13.55	5352	.118	.144	646
Flicker	477.0	241.70	24/7	3.581	2.388	7.16	21.49	669.8	244.7	914.9	73.23	26.77	7802	.117	.144	655

Figure 5.1: Aluminum Conductor Steel Reinforced (A.C.S.R.)

For *ground conductor* Usually for selection the ground conductor we take the half of the bundle current referred to equation

$$I_{ground} = \frac{I_{bundle}}{2} = 324.82A \tag{5.5}$$

Referred to the ACSR product catalog ,We choose ***Pigeon*** conductor

5.3 Choice of the number of insulator in a string of minimum insulating distances

Tension insulator used to insulate 11 Kv , and

$$\frac{161}{11} = 14.63 \cong 15$$

So we chose 15 pieces of ball-and-socket insulators attached to each other to form a string by inserting the ball in the socket and securing the connection with a locking key.

Table 5.1: Technical Data of a Standard Insulator

Diameter	25.4 cm (10 in.)
Spacing	14.6 cm (5-3/4 in.)
Leakage distance	305 cm (12 ft)
Typical operating voltage	10 kV
Mechanical strength	75 kN (15 klb)

And we chose polymer insulator as the data sheet in the appendix The polymer catalog number is 5110091201

5.4 Corona losses

The disruptive critical voltage is given by :

$$V_d = g_d\, m_d\, r\, \delta\, \ln \frac{D}{r} \tag{5.6}$$

where
g_d = disruptive critical voltage gradient (Crest KV/cm)
m_d= roughness factor =0.98 to 0.93 for roughened and weather wires
r = radius of the conductor
δ = relative air density
D = separation between phase wire

Disruptive critical voltage (The Peel's formula)

$$V_d = 123\, m_d\, r\, \delta\, \log \frac{D}{r} \quad KV \quad to \quad neutral \quad (RMS) \tag{5.7}$$

- The dielectric of air is proportional to its relative air density (δ)
  where

$$\delta = \frac{0.386p}{273 + t} \tag{5.8}$$

where
p = atmospheric pressure (mm of Hg)
t = temperature pressure (C)
When
p=950 mm of Hg, t =25 c ;

$$\delta = 1.23$$

note :
1. Any increase in temperature raises ionisation and Corona starts at lower voltage
2.any decrease in pressure increases the Volume and decreases the density .This result in increased free-paths and there for decreased ionsation .

when
D = 31 cm , r = 1.023 cm , $\delta = 1.23$, $m_d = 0.95$,

$$V_d = 123 \times 0.95 \times 1.023 \times 1.25 \log(\frac{31}{1.023}) = 221.36 \quad KV \quad to \quad neutral$$

$$V_d = 383.41 \quad KV \quad to \quad line \quad (RMS)$$

when
D = ? cm , r = 1.023 cm , $\delta = 1.23$, $m_d = 0.95$, $V_d = \frac{161}{\sqrt{3}} = 93KV \quad to \quad neutral$

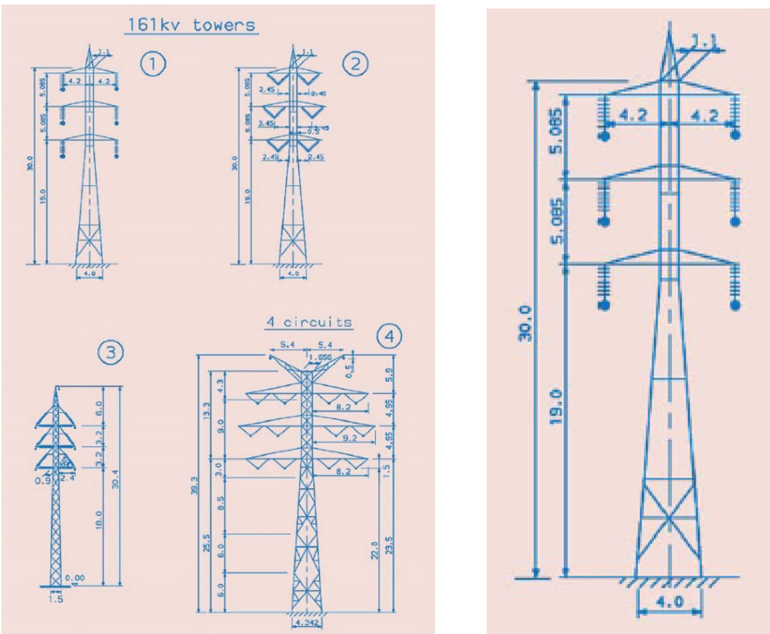
$$D = r\,10^{(\frac{V_d}{123\,m_d\,r\,\delta})} = 4.29\,cm$$

5.5 Transmission Tower

During Design of transmission tower the following points to be considered in mind.

(a) The minimum ground clearance of the lowest conductor point above the ground level.
(b) The length of the insulator string.
(c) The minimum clearance to be maintained between conductors & between conductor and tower.
(d) The location of ground wire with respect to outer most conductors.
(e) The distance between the first circuit and, the second circuit.

In our project, we will work on 161-kv towers, this towers under national electrical standards.



(a) Diffrent Shape (b) Selected tower

Figure 5.2: shape of Transmission Towers

- The vertical distance between the first cross-arm and the second cross-arm = 5.085 m.
- The vertical distance between the second cross-arm and the third cross-arm = 5.085 m.
- The vertical distance between the third cross-arm and the ground = 19 m.
- The horizontal distance between the first circuit and, the second circuit = 1.1 m.
- The horizontal distance from the end of cross arm to the tower cage = 4.2 m.
- The height of the tower = 30 m.
- The horizontal distance between the tower legs = 4 m.
- weight of the tower =2570kg.

Typical Overhead line clearances (based on maximum conductor temperature the load EN 50341)

Table 5.2: Clearance (in [m]unit) from line with highest system voltage of:

Clearance consideration	161kV
To ground in unobstructed countryside	6.2
To rock face or steep slope	3.2
To trees which cannot be climbed	1.2
To trees which can be climbed	2.7
To buildings with fire-resistance roofs and roofs with slope < 15o to horizontal	5.2
To buildings with fire-resistance roofs and roofs with slope > 15o to horizontal	3.2
Horizontal clearance to buildings	3.2
To fire sensitive installations	11.2
To antennae, lamp posts, etc. which cannot stoop upon	3.2
Line crossing of minor roads, railways and waterways	3.2-7.2 depending on nature of roads, railways

The normal span between towers is 350 m.

$$Number of towers = \frac{disnance}{span\,between\,towers + horizantal\,tower\,base} \tag{5.9}$$

$$= \frac{75km}{350m + 4m} = 212\,tower$$

So, we will use 212 tower and it will be contain:

- Suspension towers.
- Tension towers.
- Angle towers.
- End tower.

Tension

$$T = \frac{w\,g\,L^2}{8\,S}$$

where ,
w= weigh of conductor per unit length (kg/m)
L= span of the conductor (m)
g = gravitational constant (9.81 N)
S= sag(m)

w=926.5kg/km
L=350m
g=9.81N
so,
we take the min. sag = 3m.
so,
the tension

$$T = \frac{926.5kg/km \times 9.81 \times 350^2}{8.3} = 46.39\,kN\,for\,each\,conductor.$$

For the sag, we take the min. sag which give the max tension.

Guy and stay wire

Stay wires or guys wire are galvanized steel wire strands that are used for sustaining mechanical load. Generally, they are made up of 6 wires stranded around 1 wire, twisting 7 wires together.

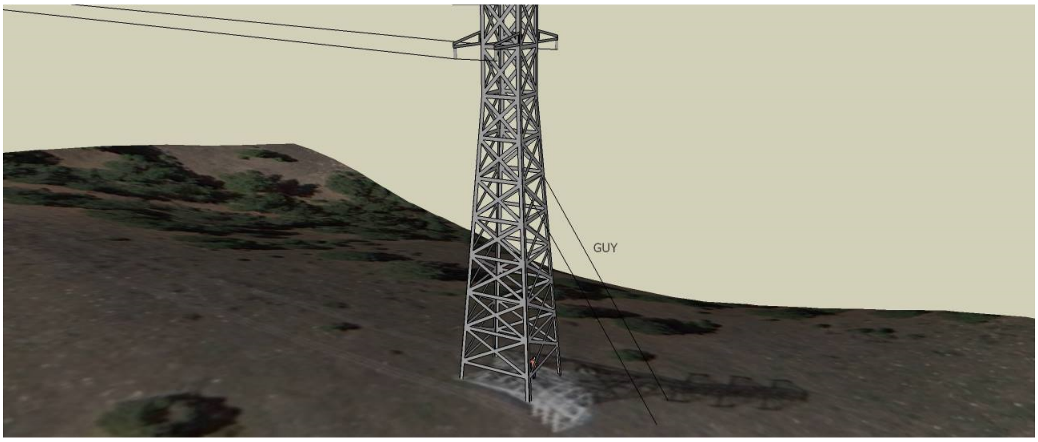


Figure 5.3: Guy-in tower

$$T_h = \frac{T_1\, h_1 + T_2\, h_2 + T_3\, h_3}{h_g} \tag{5.10}$$

$$T_h = \frac{1}{15}(46.39 \times 29 + 46.39 \times 24 + 46.39 \times 19) = 222.672\, KN.$$

Where,
Th= is the horizontal component of guy wire tension.
T1 =is the horizontal load at height h1.
T2 =is the horizontal load at height h2.
T3 =is the horizontal load at height h3.
hg= is the height of attachment point of guy.
h1 =is the height of horizontal load T1.
h2 =is the height of horizontal load T2.
h3 =is the height of horizontal load T3.

$$\tan\beta = \frac{h_g}{L} \tag{5.11}$$

$$\tan\beta = \frac{15}{5} = 3$$

$$\beta = arctan\frac{h_g}{L} = 71.5$$

L= is the lead of the guy.

$$T_g = \frac{T_h}{cos\beta} \tag{5.12}$$

$$T_g = \frac{222.672\, kN}{cos\, 71.5} 701.7\, KN$$

This tension will be for the first guy for the first circuit, we will use two guy wire for the tower who will have tension from one side or, tension from two side but, with angle between them.

Tower grounding

Used to reduce earth wire potential and stress on insulators at the time of stroke and also for safety.
Tower footing resistance will be 10 and should not be more than 20Ω under any condition throughout the year.
Earth resistance depend upon soil resistivity (general 100 Ω-m).

(a) **Buried conductor**
one or more conductor is connected to towers legs and buried in back filled of tower foundation. Used where soil resistivity is low.

(b) **Counterpoise wire**
A length of wire of 50 m is buried horizontally at depth of 0.5 m below ground. This wire is connected to tower legs. Used when earth resistance is very high and soil conductivity is mostly confined to upper layer.

5.6 Tower base

First case: when we have tension from one side.

- *For rocky soil.* The dimension for this base is (6.5×6.5)m in X-Y,with depth 3.5 m.
- *For sandy soil.* The dimension for this base is (7.5×7.5) m in X-Y, with depth 4 m.

Second case: when we have tension from two side.

- *For rocky soil.* The dimension for this base is (55) m in X-Y, with depth 2.5 m.
- *For sandy soil.* The dimension for this base is (66) m in X-Y, with depth 3 m.

We used for the two cases, reinforced concrete type 350B.

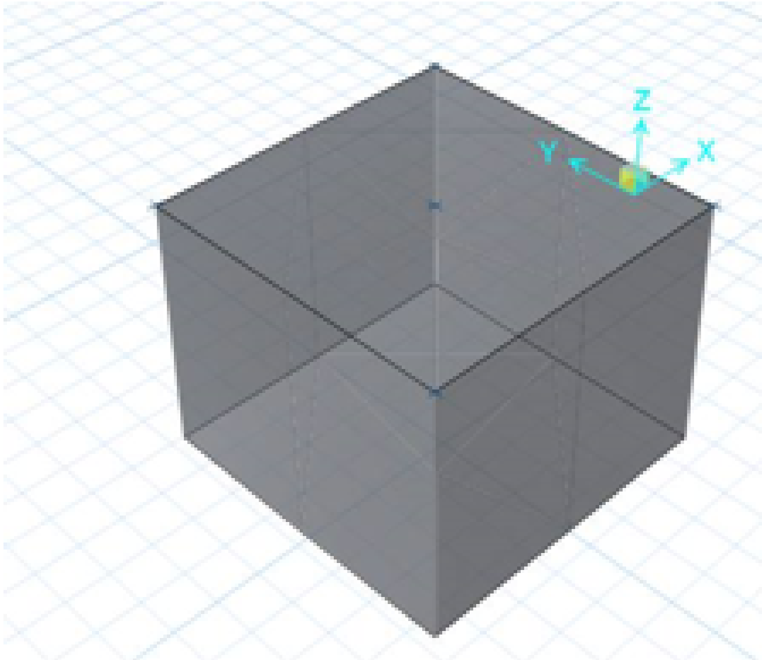


Figure 5.4: Tower base

5.7 Protection of Transmission line

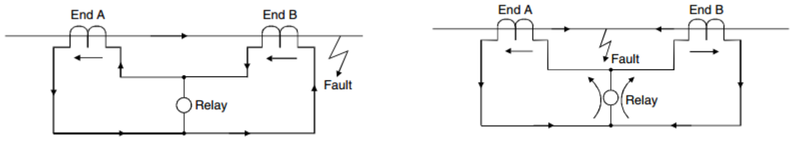
5.7.1 Differential protection

This protection system is use the current difference as criteria. The differential protection system consisting of:

- Current transformer (CT).
- Relay.

The differential protection is used for the very high devices cost such as power transformer which have rating higher than 5 MVA because the cost of this system is very high and there are two type of this protection:

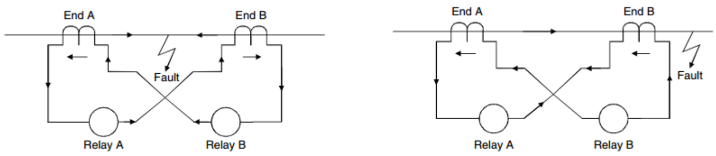
(a) **Balanced current** The principle of this type of protection system is shown in the figure. The current transformers are connected in series with the system. The Relay connected across the midpoint between them and the voltage on the relay is equal zero. When the fault occurs outside the protective zone, there is no current flow through the relay. So the differential relay does not activate. In the case of the fault occurs inside the protective zone, the difference between the current that flow in the CTs is flow through the relay then the relay interrupted the circuit as shown in the figure.



(a) Internal fault (b) External fault

Figure 5.5: the relay interrupted the circuit

(b) **Balanced voltage** In this type of differential protection, the current flow the current transformers produce a voltage on the relays. The voltage on the two relays is equal when the occurrence of the fault is outside the protective zone. Accordingly, the Relay does not activate. But if the fault occurs inside protective zone there is difference in the value of current in the secondary of CTs. And therefore the relay activate and make interruption in the circuit as shown in the figure.



(a) Internal fault (b) External fault

Figure 5.6: the relay activate and make interruption in the circuit

5.7.2 Distance Protection Relay

Distance protection relay is the name given to the protection, whose action depends on the distance of the feeding point to the fault. The time of operation of such protection is a function of the ratio of voltage and current, i.e., impedance. This impedance between the relay and the fault depends on the electrical distance between them.

Distance protection relay principle differs from other forms of protection because their performance does not depend on the magnitude of the current or voltage in the protective circuit but it depends on the ratio of these two quantities. It is a double actuating quantity relay with one of their coil is energized by voltage and the other coil is energized by the current.

The relay operates only when the ratio of voltage and current falls below a set value. During the fault the magnitude of current increases and the voltage at the fault point decreases. The ratio of the current and voltage is measured at the point of the current and potential transformer. The voltage at potential transformer region depends on the distance between the PT and the fault.

If the fault is nearer, measured voltage is lesser, and if the fault is farther, measured voltage is more. Hence, assuming constant fault impedance each value of the ratio of voltage and current measured from relay location comparable to the distance between the relaying point and fault point along the line. Hence such protection is called the distance protection or impedance protection.

Distance zone is non-unit protection, i.e., the protection zone is not exact. The distance protection is high-speed protection and is simply to apply. It can be employed as a primary as well as backup protection. It is very commonly used in the protection of transmission lines.

Distance relays are used for both phase fault and ground fault protection, and they provide higher speed for clearing the fault. It is also independent of changes in the magnitude of the short circuits, current and hence they are not much affected by the change in the generation capacity and the system configuration. Thus, they eliminate long clearing times for the fault near the power sources required by over current relay if used for the purpose.

Design

Distance protection is so called because it is based on an electrical measure of distance along a transmission line to a fault. The distance along the transmission line is directly proportional to the series electrical impedance of the transmission line. Impedance is defined as the ratio of voltage to current. Therefore, distance protection measures distance to a fault by means of a measured voltage to measured current ratio computation the philosophy of setting relay at Sonelgaz Group is three forward zones and one reverse zone to protect HV transmission line between bus bar A and B with total impedance Z_{AB} as shown in figure.

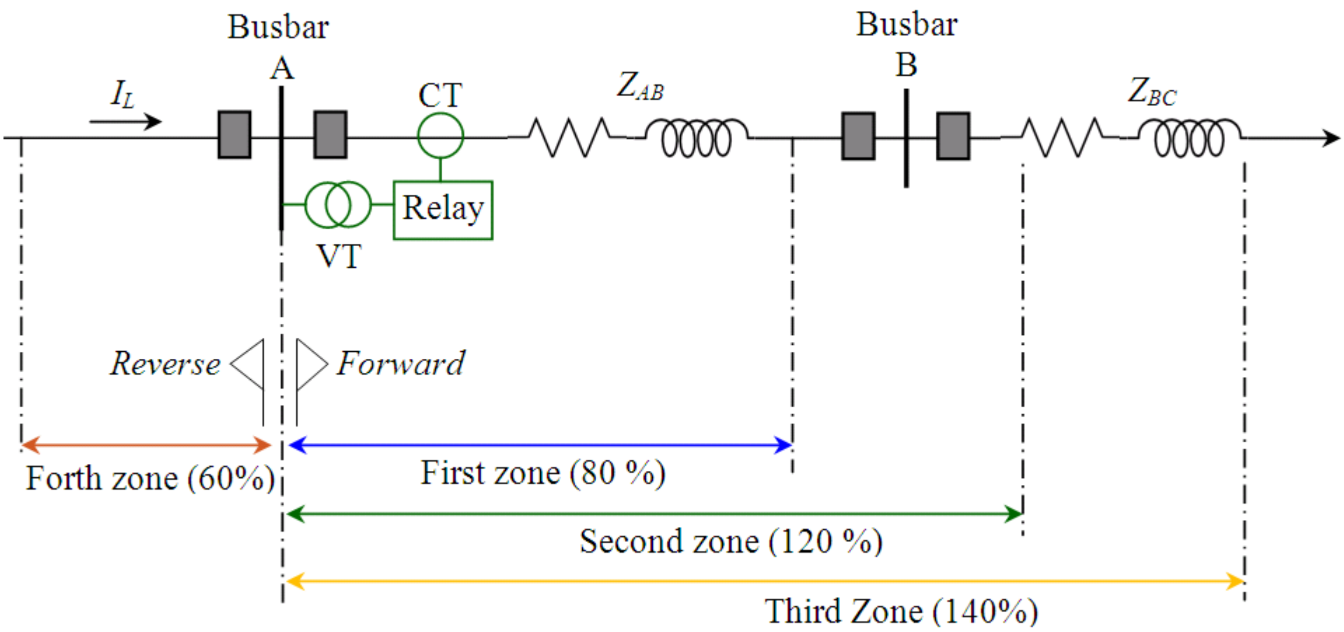


Figure 5.7: Distance Protection Relay

In our design, we used a distance relay every 5 km. Every relay has four zones, three of them used for forward protection, the fourth one used as a reverse protection.

First zone In practice it is normal to adjust the first zone relays (Z1) at A to protect only up to 80% of the protective line (AB). This is a high speed unit and is used for the primary protection of the protected line. This unit is not set to protect the entire line to avoid undesired tripping due to over reach. Over reach may occur due to transients during the fault condition.

Second zone It is set to cover about 20% of the second line (BC). The main object of the second zone unit is to provide protection to the end zone of the first section which is beyond the reach of the first unit. The setting of the second unit is so adjusted that it operates the relay even for arcing faults at the end of the line. To achieve this, the unit must take care beyond the end of the line. In other words its setting must take care of under reach caused by arc resistance.

Under reach is also caused by intermediate current sources, errors in CT, and VT and measurement performed by the relay. To take into account the under reaching tendency caused by these factors, the normal practice is to set the second zone reach up to 20% of the shortest adjoining line section. The protective zone of the second unit is known as the second zone of protection. The second zone unit operates after a certain time delay. Its operating time is 0,3 sec.

Third zone It is provided for back-up protection of the adjoining line. Its reach should extend beyond the end of the adjoining line under the maximum under reach, which may be caused by arcs, intermediate current sources and errors in CT, VT and measuring unit The protective zone of the third stage is known as the third zone of protection.

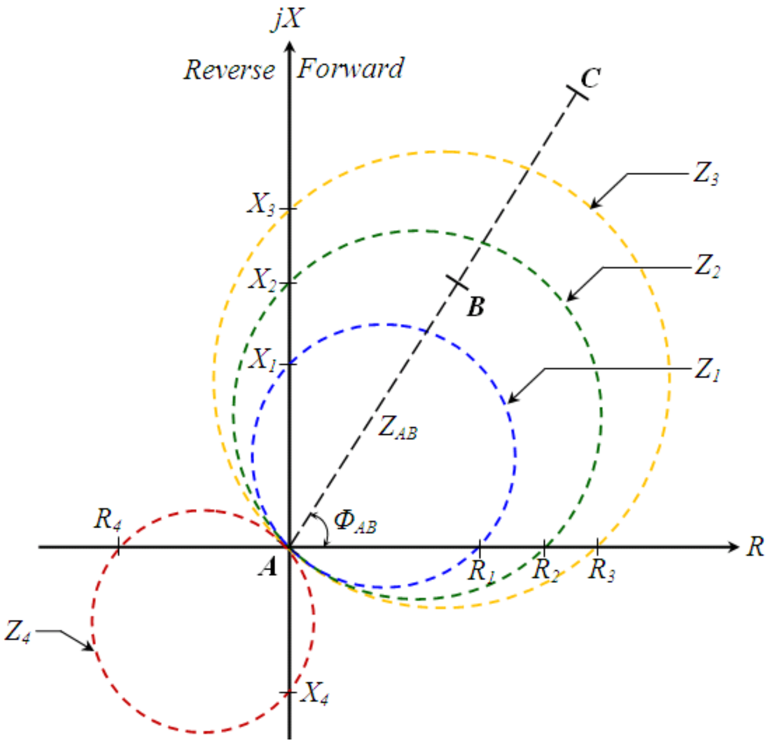


Figure 5.8: Characteristic curve X (R) for setting zones for distance protection.

Figure represents the tripping time T1, T2 and T3 correspond to these three zones of operation for circuit breaker installed at bus-bar A and MHO distance relay (RA).

The fourth setting zones for protected transmission line (forward and reverse) without series FACTS.

$$Z_1 = R_1 + jX_1 = 80\% Z_{AB} = 0,8(R_{AB} + jX_{AB})$$

$$Z_2 = R_2 + jX_2 = R_{AB} + jX_{AB} + 0,2(R_{BC} + jX_{BC})$$

$$Z_3 = R_3 + jX_3 = R_{AB} + jX_{AB} + 0,4(R_{BC} + jX_{BC})$$

$$Z_4 = R_4 + jX_4 = -60\% Z_{AB} = -0,6(R_{AB} + jX_{AB})$$

The total impedance of transmission line AB measured by MHO distance relay is:

$$Z_{AB} = K_Z \, Z_L$$

$$K_Z = \frac{K_{VT}}{K_{CT}}$$

Where, Z_{AB} is real total impedance of line AB, and KVT and KCT is ratio of voltage to current respectively.

Chapter 6

Economy

The transmission line Life cycle costing model helps in accessing the total cost of ownership of the project from the beginning to the end of its operational life covering various stages like design, construction, operation and maintenance, and repair of the line . Each transmission line project is unique and depends on the geography, regulations and local conditions. The factors which influence the life cycle costs also vary from project to project. The typical transmission line life cycle cost model incorporating various stages is given by

$$C_{LC} = C_{CI} + C_{OM} + C_{EL} \tag{6.1}$$

where,C_{LC} is life cycle cost, $C_{CI}$is capital investment cost, C_{OM} is operation and maintenance cost and C_{EL} is cost due to energy loss.

6.1 Capital Cost

The capital investment for a new transmission line consists of cost of structures, conductors, civil works, engineering, administration and management. The factors influencing the costs are right of way , local regulations, land rights and issues, construction material and labor cost escalations etc. Out of these, right of way and land rights are highly variable and site specific. Based on the data collected from the utilities the various cost components of the lines which make up the capital investment are summarized in Table 1. All costs are expressed in US$/km . The capital investment cost for constructing the lines can be assigned to one or more years before the lineis energized . In this study, it is assumed that all the capital costs occur in the construction starting year. right of way costs are not included in capital investment. The cost assumptions used in this paper for calculation purposes do not refer to any specific project and are merely rough approximations, which helps in demonstrating the methodology.

Table 6.1: Quantities Table

Type	Quantities	Price/unit	Price
Towers & Foundation	310	4187585	4187585
Acsr	1098 Km	2.75$/m	3019500
Ground Wire	61 Km	1.23$/m	75303
Earth Wire	3720	1.85$/m	6882
Hanger Rods	11800	3.5$/unit	41300
Insoulators	5890	135$/unit	795150
Currents transformer	50	800$/unit	40000
Voltage Transformer	10	500$/unit	5000
Relays	30	74$/unit	2220
Power Transformers	6	100000$/unit	600000
Bus Bars	15	215$/unit	3225
Data Cable	61 Km	1.5$/m	91500
Aerial Marker Balls	700	14$/unit	9800
Damper	1856	4$/unit	7424
Spacer	3700	9$/unit	33300
Unti-Bird	310	10$/unit	3100
Surge Arrestor	160	25$/unit	4000
Warning Plate	310	10$/unit	3100
Number Plate	310	5$/unit	1550
Unti Clamping	310	18$/unit	5580
Pine	3720	1$/unit	3720
Total :	8939239		

6.2 Operation and maintenance costs

Operation and maintenance costs(C_{OM}) are estimated as a percentage of the total capital investment. Operation and maintenance of the line is essential to supply power to the consumers reliably and economically and is generally a preventive measure. The Operation and maintenance expenses include charges of personnel for operating and controlling the line according to schedule, personnel deployed for inspection of the line as part of routine maintenance activity, labor cost for tree removal on right of way , general repairs and replacement of damaged items due to adverse climate conditions, live line maintenance activities, testing of cable joints, verifying soil conditions, on line monitoring and other necessary activities to keep the line in proper operating condition. The factors which impact the Operation and maintenance costs are age of the line, weather conditions and length of the line. In the present study, the Operation and maintenance costs are assumed as 1.5% of capital investment cost, for Over head Transmission line . The Present Value (PV) of the annual Operation and maintenance costs is given by

$$C_{OM} = 1.5\% \times 116000 = 174\$$$

$$PV of C_{OM} = \frac{(1+i)^2 - 1}{i\,(1+i)^2} C_{OM} \tag{6.2}$$

6.3 Energy loss costs

The cost of energy losses (C_{EL}) reflects to the cost of resistive electrical energy loss occurring in a line during operation. Some of the important factors which influence the losses in the line are line length, conductor parameters, loading of the line, loss factor, load growth and voltage level. The PV of the annual cost of energy loss is given by

$$PVofC_L^n = \frac{(1+i)^2 - 1}{i\,(1+i)^2}\,C_L^n \tag{6.3}$$

The initial cost of losses is computed according to the formula given

$$C_{IL} = 3 \times I^2 \times R \times C_{IE} \times L_f \tag{6.4}$$

where, CIL is the initial cost of losses, I is the peak load current in amperes, R is the resistance of the conductor in Ω/km, C_{IE} is the incremental cost of energy in $/kWh and Lf is the loss factor. The cost of losses for any year during the useful life can be calculated using

$$C_L^n = C_{IL} \times C_{EE} \times L_g \tag{6.5}$$

where, C_{Ln} is the cost of losses for any year n, $C_{IL}$is the initial cost of losses, C_{EE} is the energy cost escalation and L_g is the load growth. [13]

6.4 Conductor Material

- Annual capital cost for conductor conductor materials= K.A $/annual
- Annual cost of energy loss = $\frac{M}{A}$ " Kilven law"
  where,
  KA :fixed cost .
  $\frac{M}{A}$= variable cost .
- Total annual cost = $K\,A + \frac{M}{A} + N$ "modified Kilven law "
  where,
  N=Cost of tower,cost of insularities.
  Then,
  $$A = \sqrt{\frac{M}{K'}}$$
- If we have transmission line delivered certain power "p" is dependent on the length of the line "L".

$$I = \frac{P}{\sqrt{3}\,V\;\cos\theta}$$

$$Ploss = I^2\,R = (\frac{P}{\sqrt{3}\,V\;\cos\theta})^2\,R$$

$$P\,loss \propto \frac{1}{V}$$

Then

$$V_{economical} = 5.5\sqrt{L + \frac{KVA}{150}} \qquad KV$$

Where,
L:length of the line
KVA:transmitted /circuit.
OR

$$V_{economical} = 5.5\sqrt{L + \frac{KW}{100}} \qquad KV$$

- $$Total\,Cost = KA + \frac{M}{A} + N \qquad \$/annual$$

hr: working hours/annual =8760hr

- For most economical cross-sectional area

$$\frac{d\,(cost)}{d\,(Area)} = 0.0$$

Then,

$$(Economical\,Area)A = \sqrt{\frac{M}{K}} \tag{6.6}$$

Then,

$$(Economical\,Area) = I^2\,\frac{R}{s.w\,L}\,\frac{c_{kwhr}}{c_{unit}}\,(hr)^2 \tag{6.7}$$

Then,

$$Cost\,of\,Conductor\,material = C_c = k\sqrt{\frac{M}{K}} = \sqrt{M\,K} \tag{6.8}$$

And also = cost of energy loss
N is Constant ,Then $N = k\,A$

$$Total\,Cost = K'\,A + \frac{M}{A} \tag{6.9}$$

Where $K' = k + K, \qquad K' > K$

Chapter 7

E-TAP Program

7.1 Introduction

ETAP Power Station is a fully graphical electrical transient analyzer program that can run under the Microsoft Windows 98. NT. 4.0. 2000. Me. and XP environments. The Windows NT, 4.0 and 2000 platforms provide the highest performance level for demanding applications, such as large network analysis requiring intensive computation and online monitoring and control applications.

Windows NT. 4.0. And 2000 also provide the highest levels of reliability, protection. And security of critical applications. Large Power Station projects (approximately 500 buses and larger) should be built and maintained via Windows NT. 4.0. Or 2000. The Windows 98 and me platforms provide excellent performance for analysis of small and medium size systems (a few hundred buses) and support a variety of other popular applications.

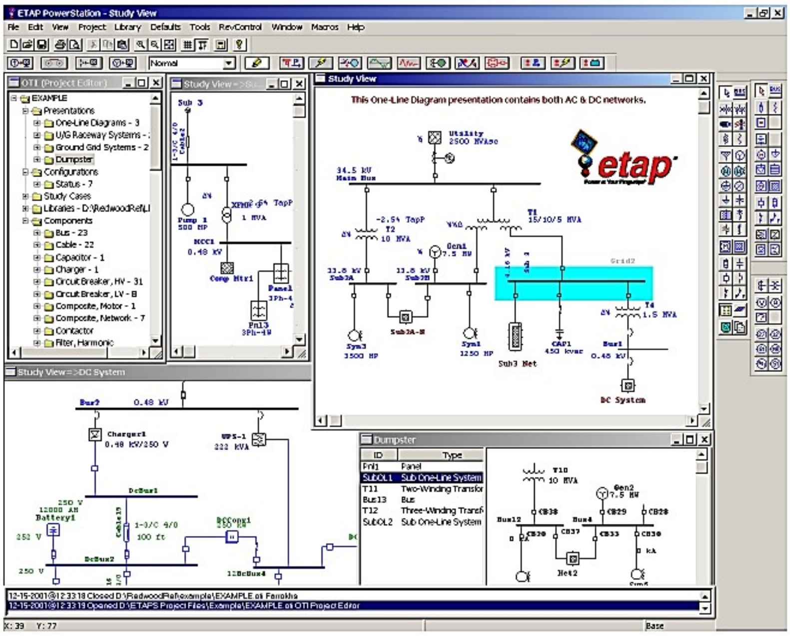


Figure 7.1: E-TAP configuration

7.2 ETAP Description

Modeling:

1. Virtual reality operation.
2. Total integration of data (electrical, logical, mechanical, and physical attributes).
3. Ring and radial systems.
4. Unlimited isolated subsystems.
5. No system connection limitations.
6. Multiple loading conditions.
7. User access control and data validation.
8. Asynchronous calculations, allow multiple modules to calculate simultaneously.
9. 3-phase and single-phase modeling including panels and sub-panels.

7.3 Filling data

To run the program we must to enter the data in filling spaces transmission line, transmission line, transformer, and load.

7.3.1 Transformers

From the data for transformer Specifications and data we can fill this parameter rating. In the E-TAP window below shows voltage rating and power rating that needed for power flow calculation and short circuit analysis.

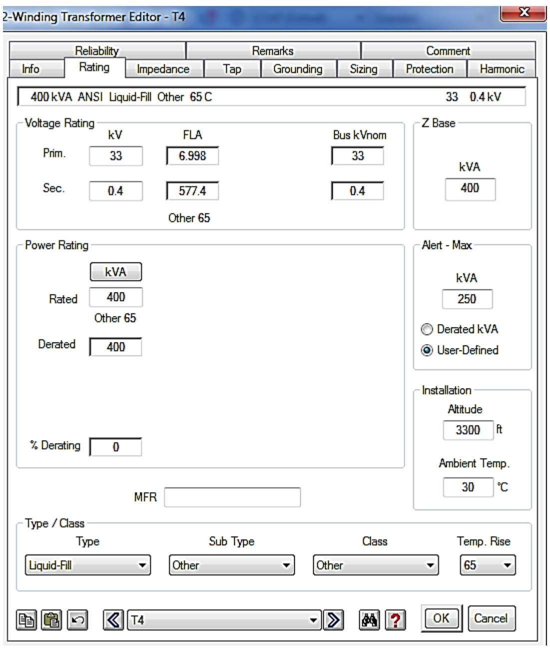


Figure 7.2: Transformers data in E-TAP

7.3.2 Transmission line

In this part we can put transmission line parameters and how to put the information of impedance and how to fill the parameter to calculate the sizing of correct conductor And we see Conductor resistance vs. temperature and Physical parameter.

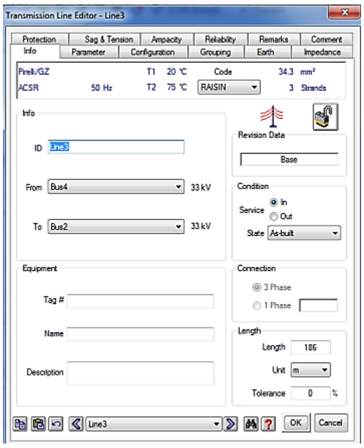


Figure 7.3: Transmission line data in E-TAP

7.3.3 Load

In the following parameter that concerning load we put the power in MVA for lumped load rating and choose a value of resistive load between 15% and 20% in domestic transformer and smaller or larger value of " R " percentage in the industrial region because of induction and synchronous motors, the E-TAP window show the parameter that filled for a Sponge factory.

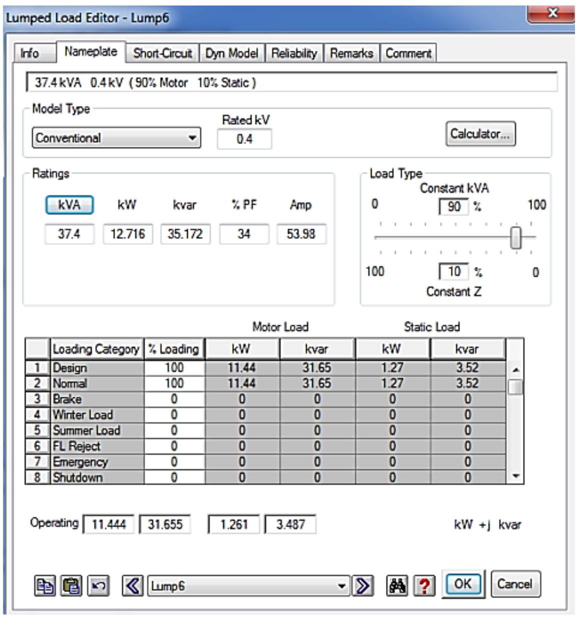
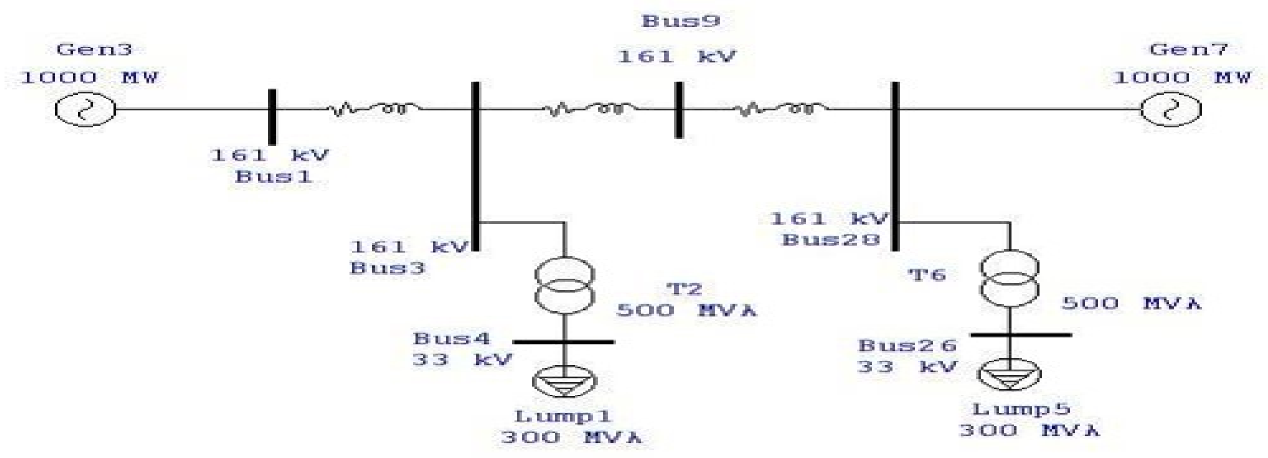


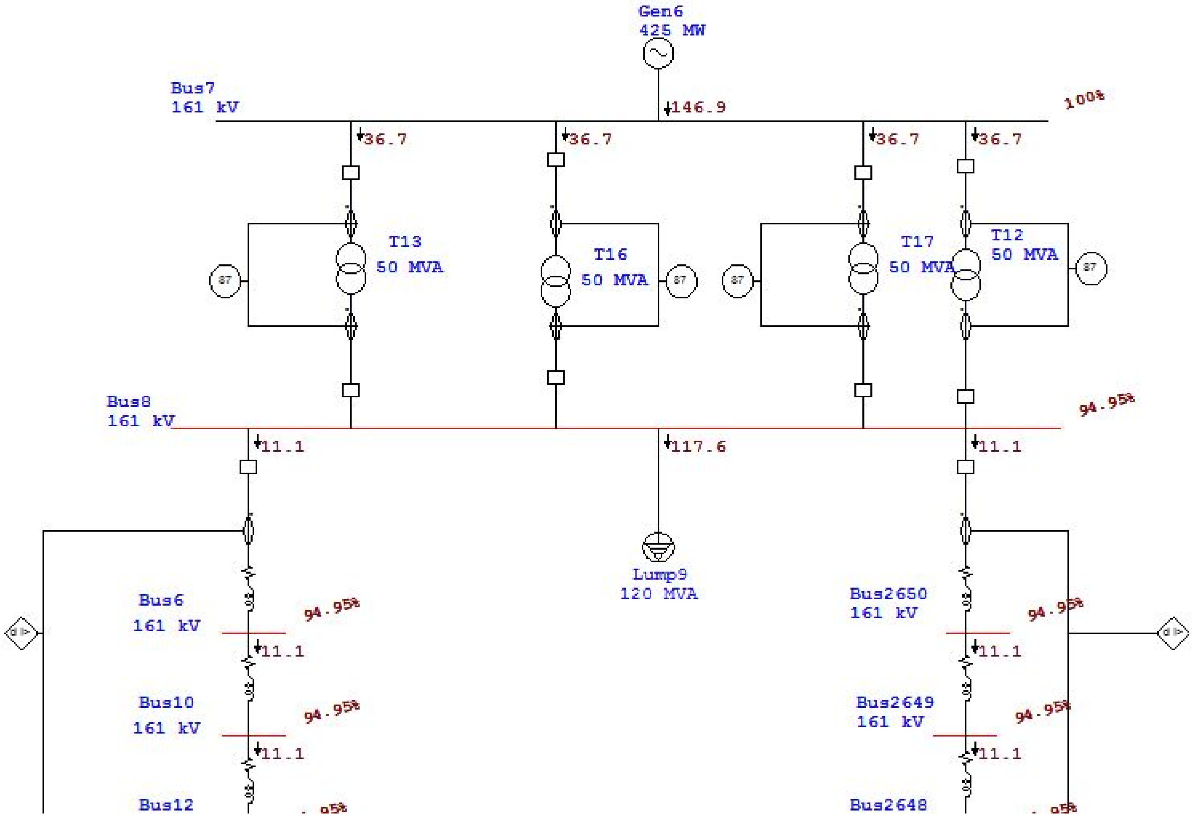
Figure 7.4: Load data in E-tab

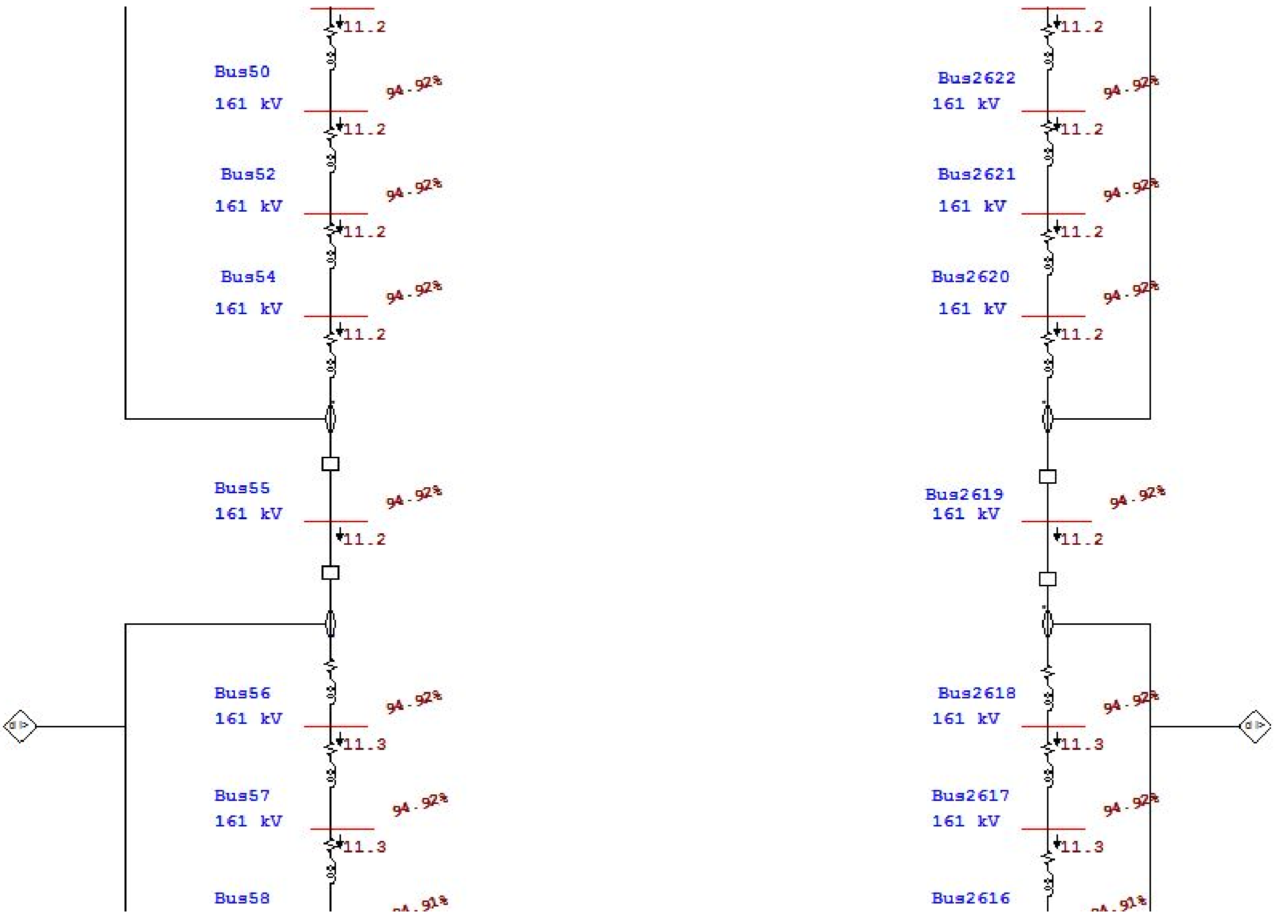
7.4 Single Line Diagram

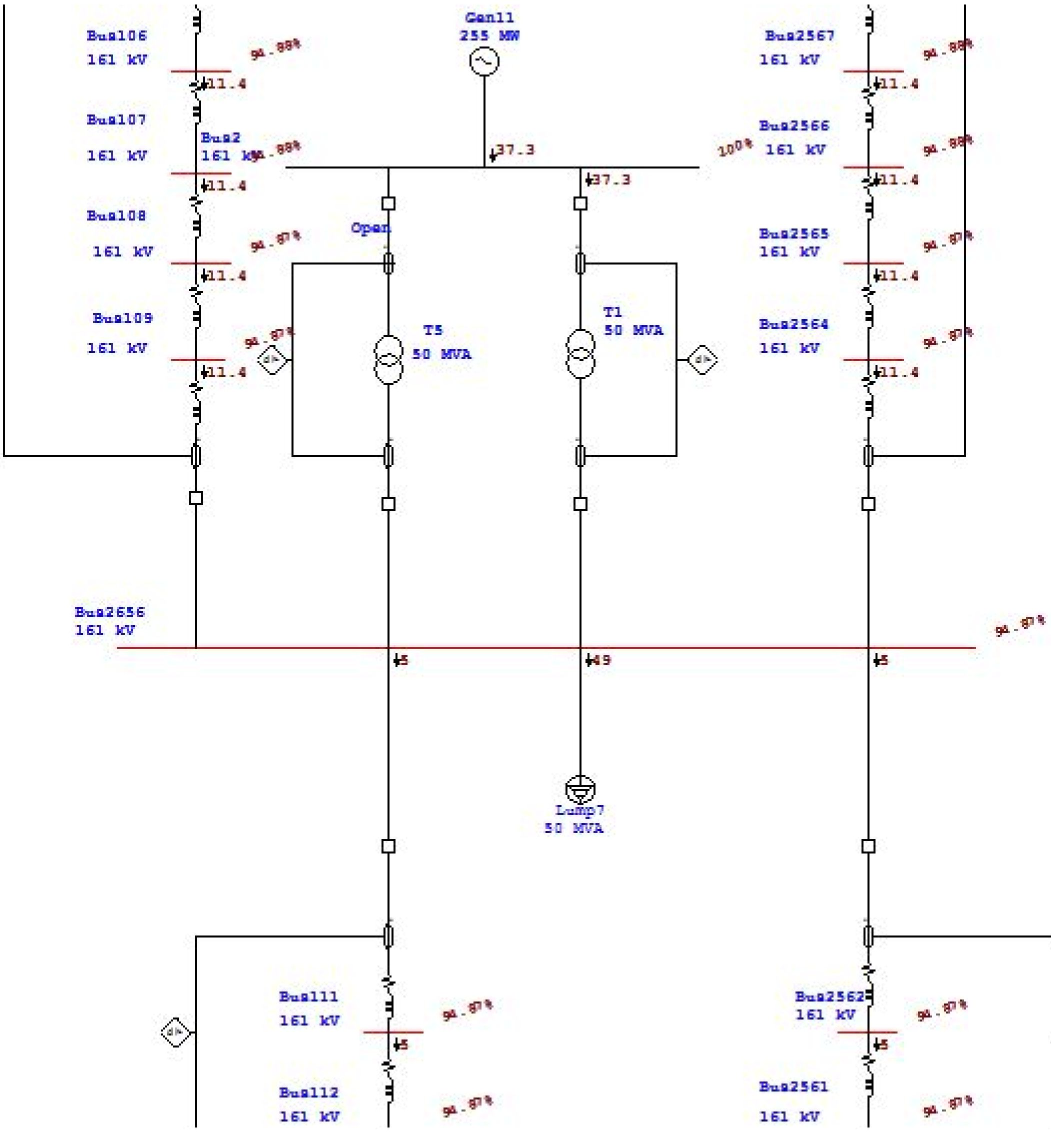


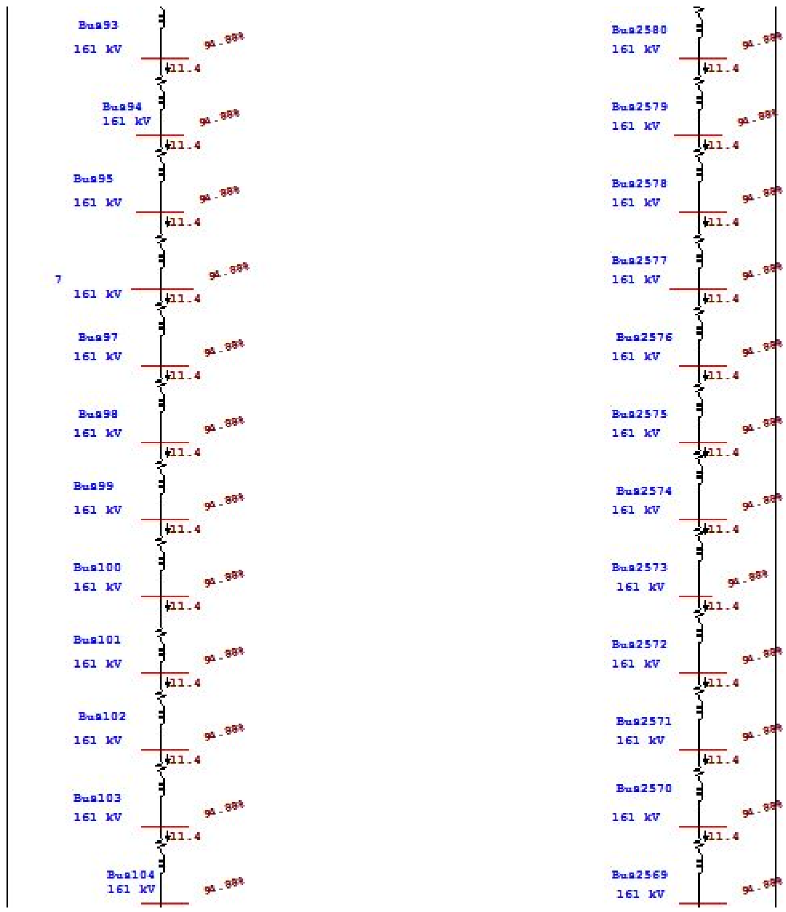
7.5 E-TAP Simulation

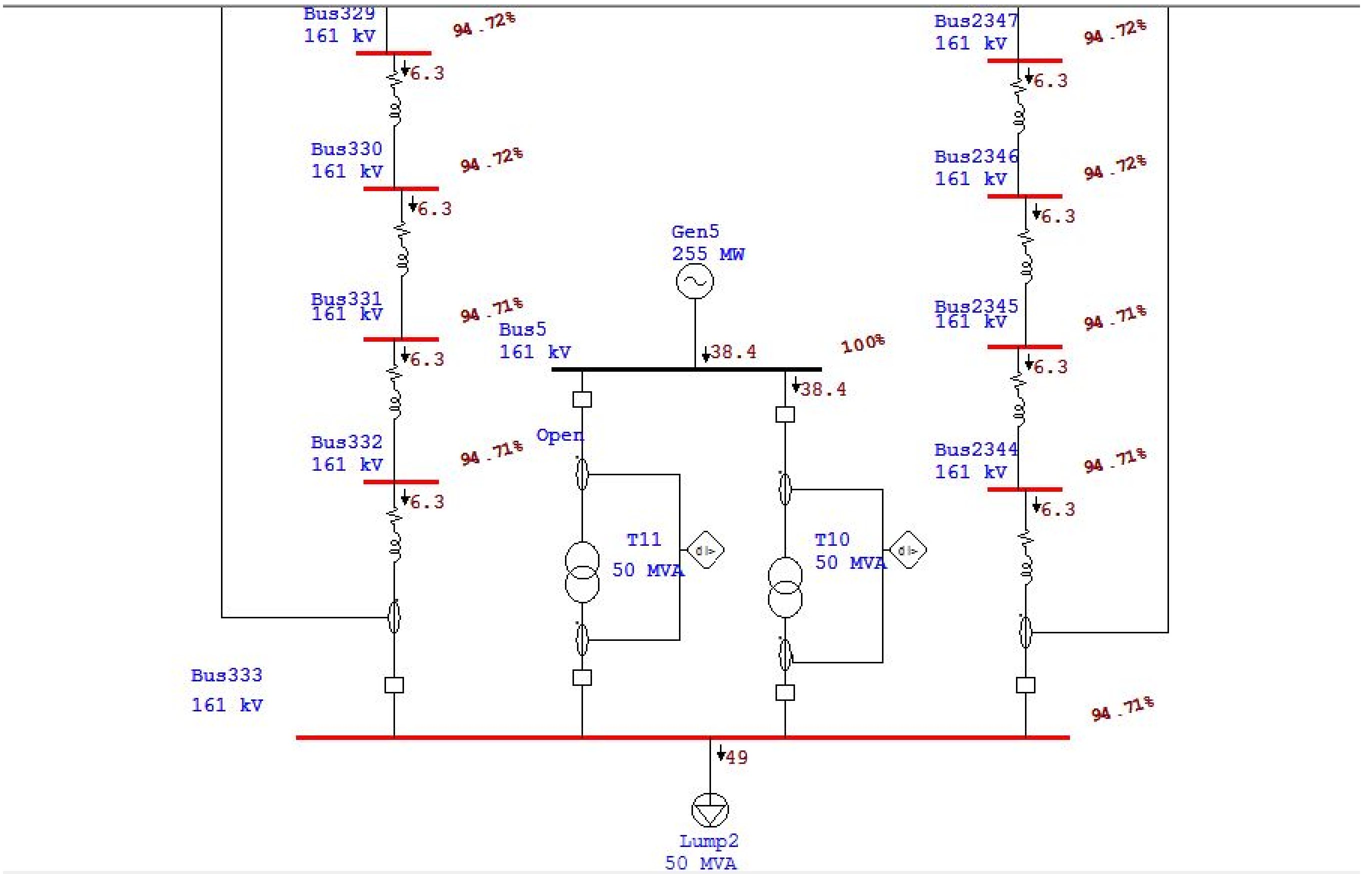
In the following some sketches of our E-TAP simulation, to see the full line find the attachment on the CD drive.


Gen6
425 MW
Bus7
161 kV
146.9
100%
36.7
36.7
36.7
36.7
T13
50 MVA
T16
50 MVA
T17
50 MVA
T12
50 MVA
87
87
87
87
Bus8
161 kV
94.95%
11.1
117.6
11.1
Lump9
120 MVA
Bus6
161 kV
94.95%
11.1
Bus10
161 kV
94.95%
11.1
Bus12
Bus2650
161 kV
94.95%
11.1
Bus2649
161 kV
94.95%
11.1
Bus2648


11.2
Bus50
161 kV
94.92%
11.2
Bus52
161 kV
94.92%
11.2
Bus54
161 kV
94.92%
11.2
Bus55
161 kV
94.92%
11.2
Bus56
161 kV
94.92%
11.3
Bus57
161 kV
94.92%
11.3
Bus58
11.2
Bus2622
161 kV
94.92%
11.2
Bus2621
161 kV
94.92%
11.2
Bus2620
161 kV
94.92%
11.2
Bus2619
161 kV
94.92%
11.2
Bus2618
161 kV
94.92%
11.3
Bus2617
161 kV
94.92%
11.3
Bus2616


Gen11
255 MW
Bus106
161 kV
Bus107
161 kV
Bus2
161 kV
Bus108
161 kV
Bus109
161 kV
Open
T5
50 MVA
T1
50 MVA
Bus2567
161 kV
Bus2566
161 kV
Bus2565
161 kV
Bus2564
161 kV
Bus2656
161 kV
Lump7
50 MVA
Bus111
161 kV
Bus112
161 kV
Bus2562
161 kV
Bus2561
161 kV


Bus93
161 kV
Bus94
161 kV
Bus95
161 kV
161 kV
Bus97
161 kV
Bus98
161 kV
Bus99
161 kV
Bus100
161 kV
Bus101
161 kV
Bus102
161 kV
Bus103
161 kV
Bus104
161 kV
Bus2580
161 kV
Bus2579
161 kV
Bus2578
161 kV
Bus2577
161 kV
Bus2576
161 kV
Bus2575
161 kV
Bus2574
161 kV
Bus2573
161 kV
Bus2572
161 kV
Bus2571
161 kV
Bus2570
161 kV
Bus2569
161 kV
11.4
94.88%



Bus329
161 kV
94.72%
6.3
Bus330
161 kV
94.72%
6.3
Bus331
161 kV
94.71%
6.3
Bus332
161 kV
94.71%
6.3
Bus333
161 kV
Gen5
255 MW
Bus5
161 kV
38.4
100%
38.4
Open
T11
50 MVA
T10
50 MVA
49
Lump2
50 MVA
Bus2347
161 kV
94.72%
6.3
Bus2346
161 kV
94.72%
6.3
Bus2345
161 kV
94.71%
6.3
Bus2344
161 kV
94.71%
6.3
94.71%

Chapter 8

GIS &Sketch up

8.1 GIS

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.
The acronym GIS is sometimes used for geographic information science (GIScience) to refer to the academic discipline that studies geographic information systems and is a large domain within the broader academic discipline of Geo informatics.
GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations. Geographic information science is the science underlying geographic concepts, applications, and systems. *To more details and Tower Coordination see appendix B*

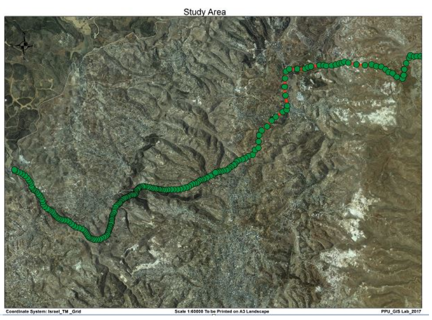


Figure 8.1: Transmission line path-part(1)

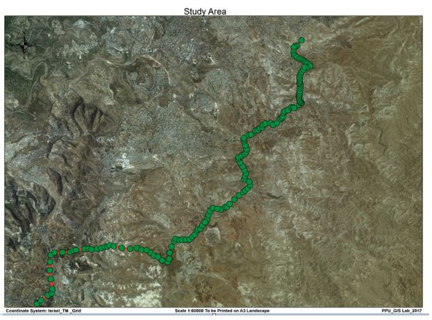


Figure 8.2: Transmission line path-part(2)

8.2 Sketch up

is a 3D modeling computer program for a wide range of drawing applications such as architectural, interior design, landscape architecture, civil , mechanical and electrical engineering . The program includes drawing layout functionality, allows surface rendering in variable " styles ", supports third-party "plug-in" programs hosted on a site called Extension Warehouse to provide other capabilities.

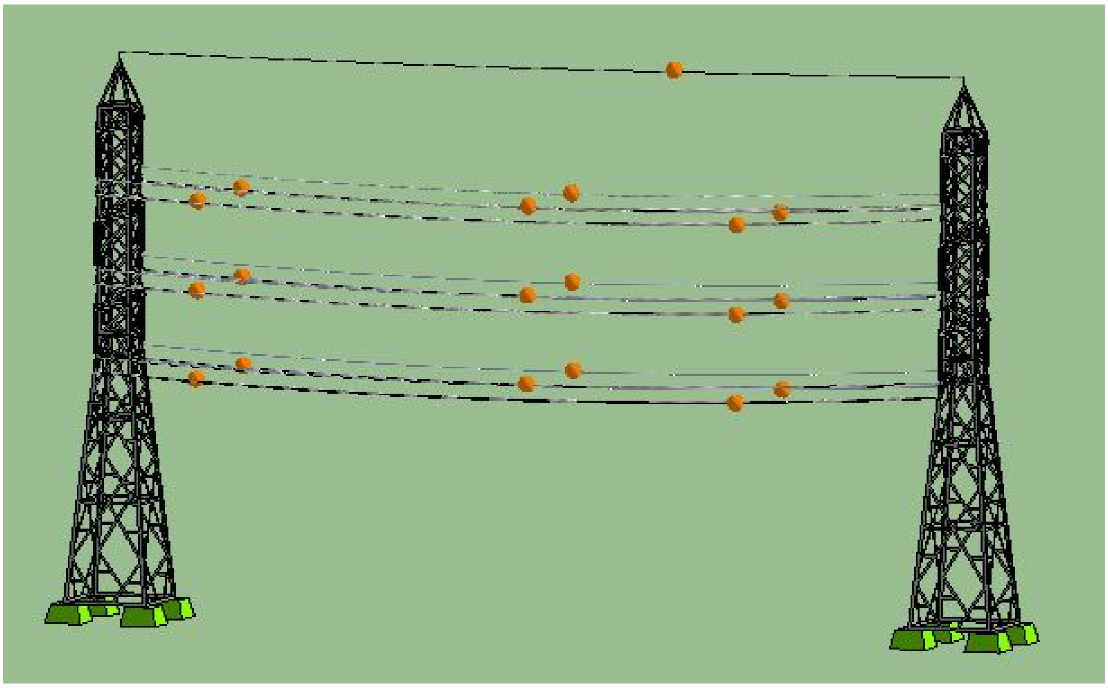


Figure 8.3: Towers At Equal Level

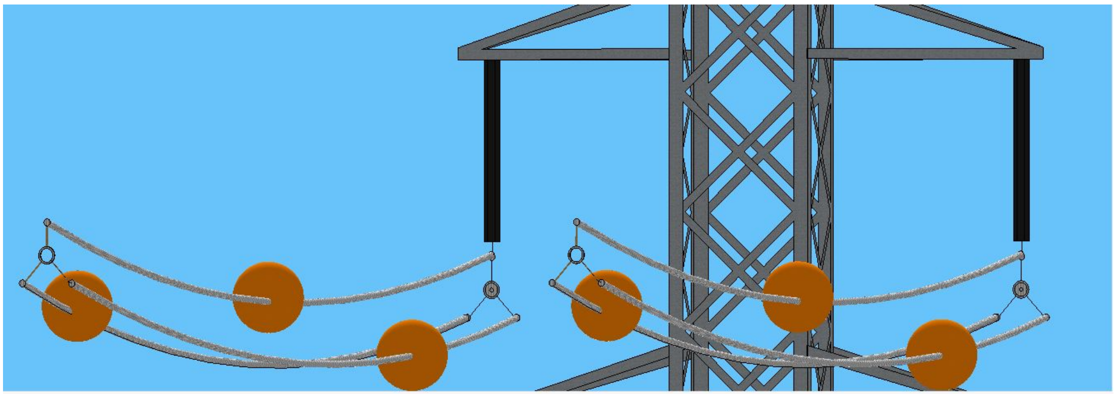


Figure 8.4: Towers Accessories

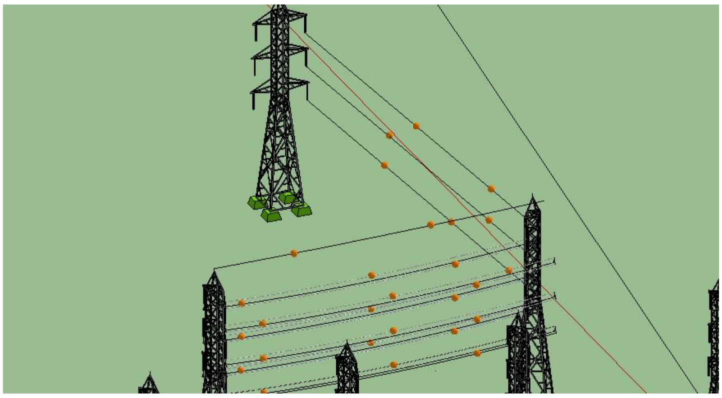


Figure 8.5: Angle Tower

Refrences

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[12] Bisnath, S. The Planning, Design and Construction of Overhead Power Lines. Johannesburg, South Africa: Crown Publications, 2005. Print.

[13] Farr, John Vail V. Systems Life Cycle Costing: Economics Analysis, Estimation, and Management. Boca Raton: Taylor & Francis, 2011. Print.

Appendix A

Load Growth

Estimation is the process of finding an **estimate**, or approximation, which is a value that is usable for some purpose even if input data may be incomplete, uncertain, or unstable. We have taken the annual consumption of electric power from the Palestinian Statistical Center from 1996 to 2014. And based on the values that we have obtained we estimated the expected consumption for 2050.

load development
if we start from real value P_0 and built the load grow for its value by **x** "*average rate of grow* ".
when

$$P_0 = real\, value\, of\, consumption$$

then,

$$P_1 = P_0(1 + x) \tag{A.1}$$
$$P_2 = P_1(1 + x) \tag{A.2}$$
$$P_2 = P_0(1 + x)^2 \tag{A.3}$$
$$P_n = P_0(1 + x)^n \tag{A.4}$$
$$\log p_n = \log p_0 + nlog(1 + x) \tag{A.5}$$

And the estimated consumption will be equal to 8.8 GW,Based on that we decided to transfer 1 GW in the transmission line system. AS shown in figure A.1

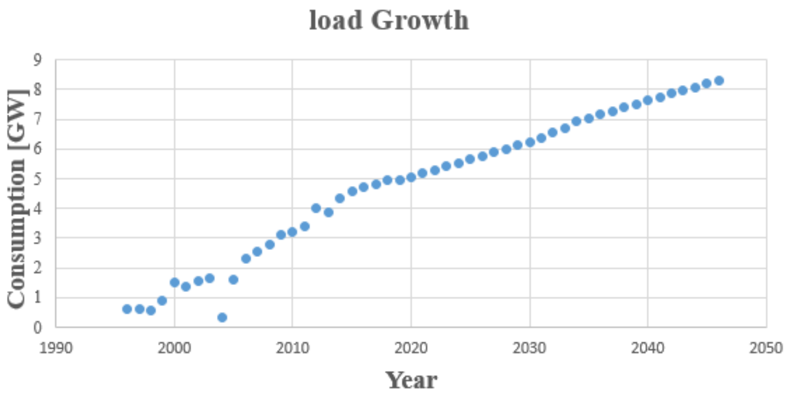

Figure A.1: Load Growth for the year of 2050

The table A.1 contain all real and estimation consumption over the period [1996-2050]

Table A.1: Load Estimation for the year of 2050

Year	Consumption [GW]	Year	Consumption [GW]
1996	0.61919800000000003	2024	5.5351334999999997
1997	0.62286200000000003	2025	5.6517819999999999
1998	0.57318999999999998	2026	5.7684305
1999	0.87705	2027	5.8850790000000002
2000	1.5110980000000001	2028	6.0017275000000003
2001	1.351736	2029	6.1183759999999996
2002	1.578244	2030	6.2350244999999997
2003	1.6395947	2031	6.3516729999999999
2004	0.31980370000000002	2032	6.5783215000000004
2005	1.6165639999999999	2033	6.6949699999999996
2006	2.3311099999999998	2034	6.9216185000000001
2007	2.56555	2035	7.0382670000000003
2008	2.7999900000000002	2036	7.1549155000000004
2009	3.1004925000000001	2037	7.2715639999999997
2010	3.2009949999999998	2038	7.3882124999999998
2011	3.4014975000000001	2039	7.504861
2012	4.0019999999999998	2040	7.6215095000000002
2013	3.8686484999999999	2041	7.7381580000000003
2014	4.3352969999999997	2042	7.8548064999999996
2015	4.5852969999999997	2043	7.9714549999999997
2016	4.7019454999999999	2044	8.0881035000000008
2017	4.818594	2045	8.2047519999999992
2018	4.9352425000000002	2046	8.3214004999999993
2019	4.9518909999999998	2047	8.4380489999999995
2020	5.0685395	2048	8.5546974999999996
2021	5.1851880000000001	2049	8.6713459999999998
2022	5.3018365000000003	2050	8.7879944999999999
2023	5.4184850000000004		

Appendix B

GIS Data

The pictures below shows the transmission path from Tarqumia to Al-Ezaria in sections.

Figure B.1: Transmission line path-section(1)

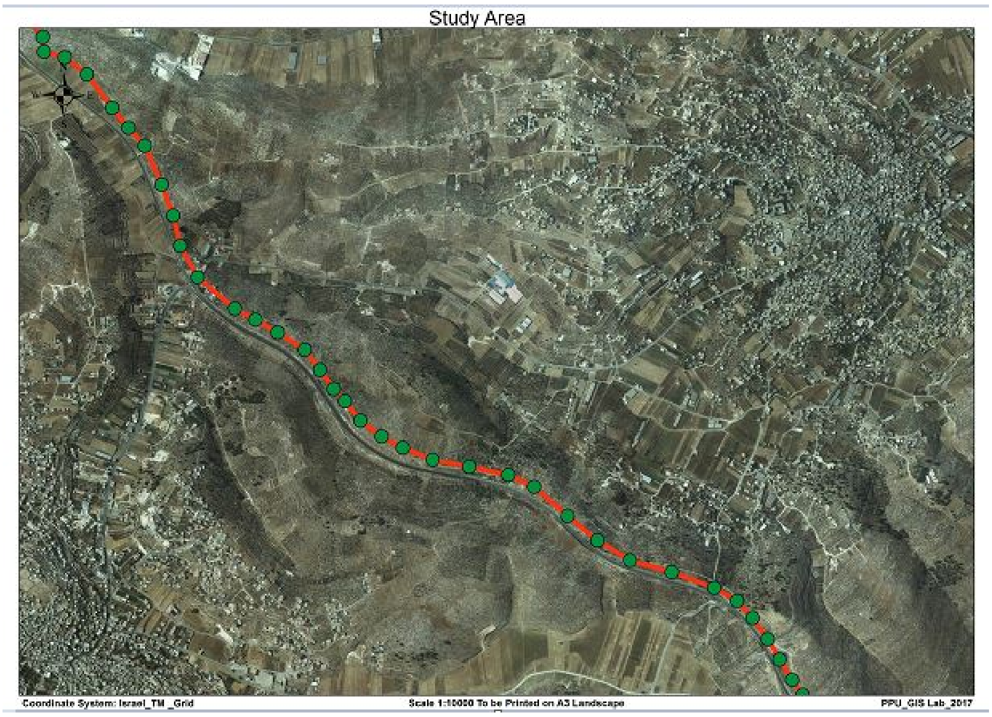

Figure B.2: Transmission line path-section(2)

Figure B.3: Transmission line path-section(3)

Figure B.4: Transmission line path-section(4)

Figure B.5: Transmission line path-section(5)

Figure B.6: Transmission line path-section(6)

Figure B.7: Transmission line path-section(7)

Figure B.8: Transmission line path-section(8)

Figure B.9: Transmission line path-section(9)

Figure B.10: Transmission line path-section(10)

Figure B.11: Transmission line path-section(11)

Figure B.12: Transmission line path-section(12)

Figure B.13: Transmission line path-section(13)

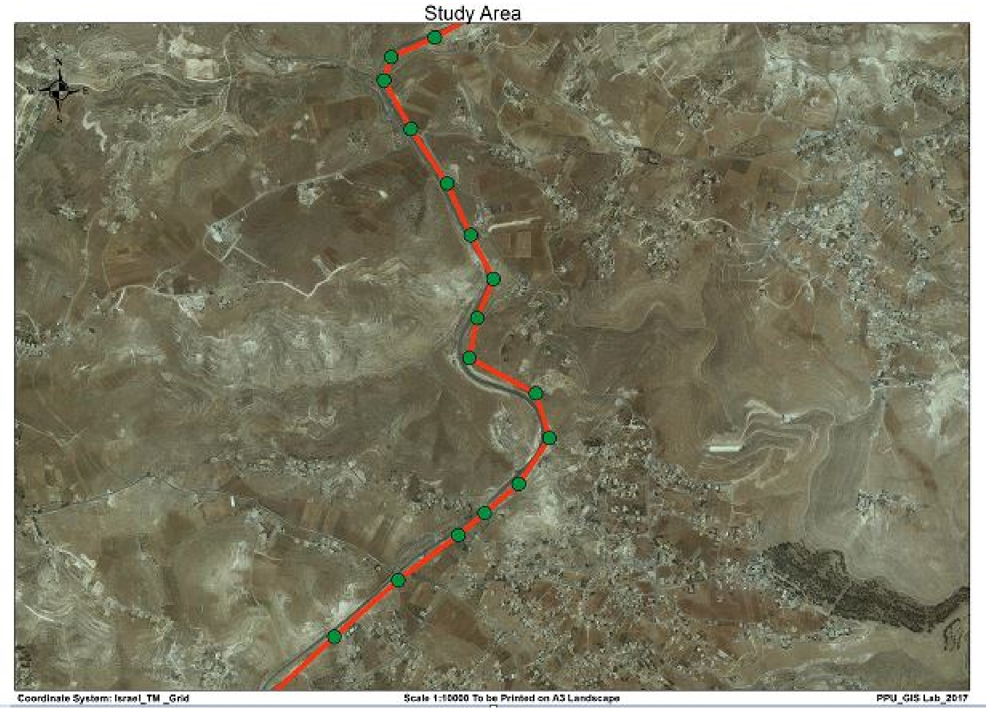

Figure B.14: Transmission line path-section(14)

Figure B.15: Transmission line path-section(15)

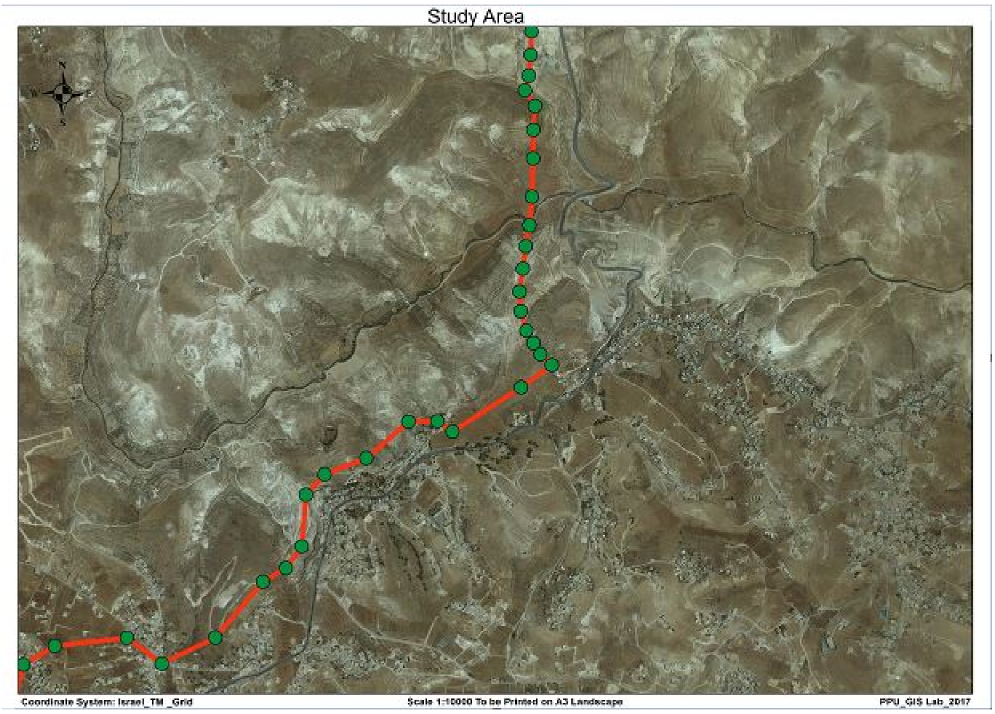

Figure B.16: Transmission line path-section(16)

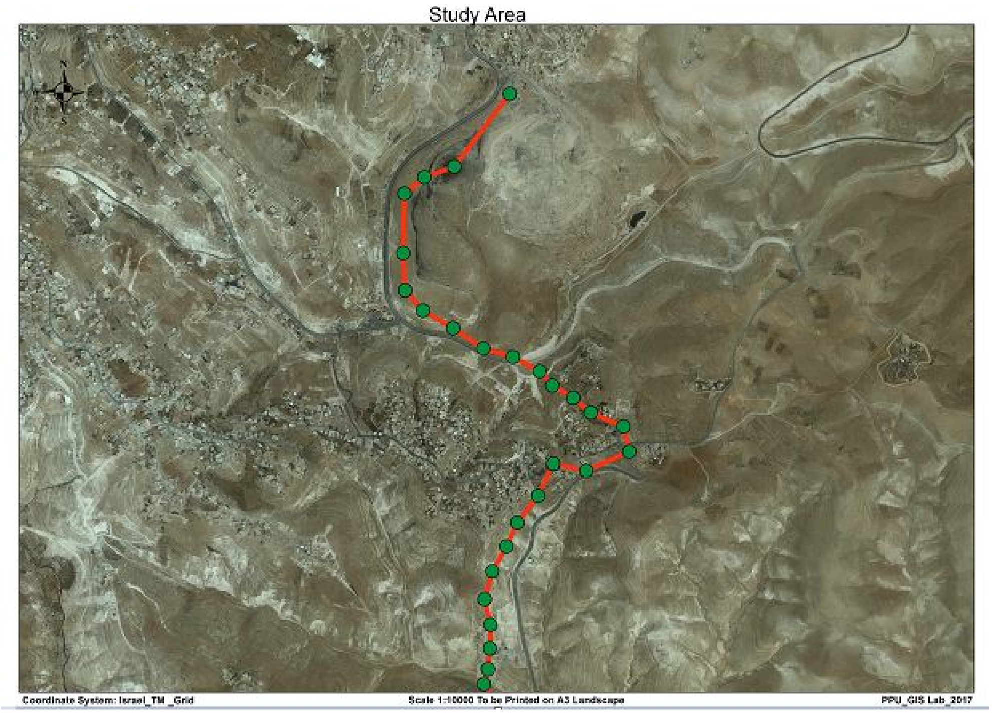

Figure B.17: Transmission line path-section(17)