Palestine Polytechnic University

College of Engineering

Title

Design of Medium Voltage Distribution System between Beat-Aulla and Al-Dahiriya

By

Mus'ab Abu-Haltam **Naseem Dayeh**

Wisam Abu-Zalatah

Supervisor:

Dr. Maher Maghalseh

Submitted to the College of Engineering

In partial fulfillment of the requirements for the

Bachelor Degree in Power Engineering

Hebron, May 2018

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In accordance with recommendation of the project supervisor, and the acceptance of the examining committee members, this project has been submitted to the Department of Electrical Power Engineering in the college of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Science in Engineering.

Project Supervisor **Department Chairman**

Hebron, May 2018

الاهداء

الى معلمنا الاول ومعلم الناس الخير نبينا محمد" صلى الله عليه وسلم"

الى من زرعوا في نفوسنا الطموح والمثابرة .... آبائنا الاعزاء

الى ينابيع المحبة والعطاء .... امهاتنا الاحبه

الى من يحملون في نفوسهم ذكريات الطفولة والشباب .... إخوتنا وأخواتنا

الى من مهّدوا لنا طريق العلم والمعرفة .... أساتذتنا الأفاضل

الى من هم احياء في قلوبنا رغم انهم غادرونا

الى من قدموا الغالي والنفيس لهذا الوطن .... اسرانا البواسل وشهدائنا الابرار

الى كافة الأصدقاء والأهل والأحبة

"ان استطعت فكن عالما ... فإن لم تستطع فكن متعلما، فإن لم تستطع فأحب العلماء ،فإن لم تستطع فلا تبغضهم"

بعد رحلة بحث وجهد تكللت بإنجاز هذا البحث، نحمد الله عز وجل على نعمه التي منَ بها علينا فهو العلي القدير، كما لا يسعنا إلا أن نتقدم بأسمى عبارات الشكر والتقدير

للدكتور ماهر مغالسة

وله نقول بشراك قول رسولنا صلى الله عليه وسلم:

"ألا أخبركم عن الأجود الأجود ؟ .الله الأجود الأجود، وأنا أجود ولد آدم،

وأجودكم من بعدي رجل علم علما فنشر علمه؛ يبعث يوم القيامة أمة وحده"

ان كان هناك اهل للشكر فـ انت اهله

فريق العمل

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First and for most we should offer our thanks obedience
And gratitude to Allah
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Palestine Polytechnic University
College of Engineering and Technology
Department of Electrical Power Engineering
Our Supervisor Dr. Maher Maghalseh

الملخص

هذا المشروع يقوم على عمل تصميم لخط توزيع كهربائي بجهد متوسط(33 كيلو فولت) ، ليربط ما بين بيت أولا والظاهرية، ليقوم بإيصال الكهرباء الى جميع المناطق التي في مسار هذا الخط، وهذا النظام يحتوي على عديد من الأجزاء مثل محطة التحويل وخط التوزيع والابراج وأنظمة الحماية وأنظمة المراقبة، وتم الاخذ بعين الاعتبار الزيادة في الاستهلاك الكهربائي، فتم القيام بعمل دراسة للاستهلاك الكهربائي خلال الفترة الواقعة ما بين (2017-2040). تم اعداد التصميم بناء على الاستهلاك الكهربائي لجميع المناطق حتى عام 2040 حيث ان الطاقة المسحوبة لهذا الخط تأتي من محطة تحويل كهربائية موجودة في بلدة بيت أولا بقدره كهربائية تصل الى (180 ميغا فولت أمبير) ، خلال فترة المشروع. بالإضافة الى ذلك تم الاخذ بعين الاعتبار زيادة الطلب على مصادر الطاقة المتجددة خاصة أنظمة الخلايا الشمسية، فتم عمل دراسة لهذا الموضوع، خاصة بما يتعلق بموضوع كمية الطاقة التي نتوقع انتاجها من هذا النظام، ومن ثم تم ادخال هذه البيانات في النظام. بناء على هذه البيانات والدراسات وابحاث سابقة تم عمل هذا المشروع بجميع المعدات المطلوبة ومن ثم تم عمل محاكاة للنظام باستخدام برنامج ال ETAP ومراقبة النظام وعمل الحلول له.

Abstract

This project aims to design an electrical distribution system work of a medium voltage distribution line 33 kilo volt (kV) to connect between Beat-Aulla and Al-Dahiriya, to connect the electricity to all the areas in the path of this line. The increase in electricity consumption has been taken into consideration. Then the study was constructed for the consumption of electricity during the period between (2017-2040), and the line was designed according to the electric consumption of all regions until 2040. As the power drawn to this line comes from an electrical substation located in Beat-Aulla town with an electrical capacity will reach to 180 mega volt ampere (MVA) during the project period. In addition, the increase in the demand for renewable energy sources, especially solar cell systems, has be taken into consideration, especially in the quantity of energy that was expected to produce from this system. Based on these data, studies and previous research, this project was done with all the required equipment and then a simulation of the system was done using the ETAP (Electrical Transmission Analysis program) program, system monitoring and solutions work.

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CHAPTER ONE INTRODUCTION

1.1 Overview

The main idea of this project is to design a Medium Voltage (MV) Distribution Line (DL) 33kV to deliver electrical power from Beat-Aulla station to Al-Dahiriya city. Southern Electric Company (SELCO), and Palestinian Energy and Natural Resources Authority (PENRA) considered this project. Load growth was evaluate for 22 years for all cities and villages, which are close to the line path. The load growth for the system was analyze depending on the maximum load for the year of 2017 [1] and insert the increase in the demand for photovoltaic system in consideration with 20% from total load as a percentage from 2040 load [2]. Then, the growth of 7% for the load was considered and calculated for the 2040 [1, 2, 3].

1.2 Project scope

The scope of this project is to design a new medium voltage distribution line between Tarqumia and Al-Dahiriya. There is many aims for this project can be summarize as follow:

- Study the load growth for the line between Tarqumia to Al-Dahiriya. The load will be estimate for the lifetime of the project.
- Design an electrical distribution system work of a medium voltage distribution line (33kV) to connect between Beat-Aulla and Al-Dahiriya.
- Study the increase in the demand for photovoltaic (PV) system.

1.3 Project Methodology

- Collect all required data for design and the simulator.
- Determine and select the component in the network.
- Sketch the path of the distribution line on the design region.
- Develop numerical model to study the network under several scenarios.
- Solving the network problem and Increase the reliability of the network.

1.4 Objective

- Modeling the mathematical method to get the predicted load for all cities that pass through electric distribution line.
- Design a medium voltage distribution line to feed the areas between Al-Tarqoumia and Al-Dahiriya for 2040.

1.5 Challenges

- Difficulties in data collection, because the required data (pregnancy prediction algorithm or load growth) is not effective for some time periods.
- The lack of a universal standard for the voltage level (33 kV).
- Lack of case studies about the voltage level (33 kV).
- Limited knowledge of the forecasting and planning process due to lack of education courses.

1.6 Time schedule

Week / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Task 1	■	■															
Task 2			■	■	■	■	■	■	■								
Task 3							■	■	■	■	■						
Task 4												■	■	■	■		
Task 5														■	■	■	■

Week / Tasks	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Task 6	■	■																	
Task 7			■	■															
Task 8					■	■	■												
Task 9								■	■	■	■	■							
Task 10													■	■	■	■	■	■	■

Task 1: Selection project

Task 2: Data collection

Task 3: Study the load growth

Task 4: Design the protection system and the substation

Task 5: Design the distribution line for the system

Task 6: Finishing the introduction to graduation project book

Task 7: Make the necessary adjustments to the content of introduction to the graduation project.

Task 8: Study the monitoring system

Task 9: Simulate the transmission system by using ETAP and Matlab.

Task 10: Finishing the graduation project book and prepare the presentation

CHAPTER TWO LITERATURE AND LOAD GROWTH

2.1 Load growth

2.1.1 Power consume

2.1.2 People growth

2.2 Symmetrical components and fault analysis

2.2.1 Faults

2.2.2 Symmetrical Components.

2.3 Reliability of transmission system

2.4 Summary

2.1 Load growth

Load forecast study is a very important step to improving and designing the power system, where this study refer to the prediction of the load behavior in the future and it aims mainly to predict to the quantity of energy needed to meet the needs of customers, which is showing in appendix-B, the total demand is equal 202 MVA.

There are two types of forecast:

1. **Demand forecast**

   To predict the generation, transmission and distribution capacity required

2. **Energy forecast**

   To determine the type of generation facilities required.

2.1.1 Power Consumption

This study to design the distribution system for the region between Tarqoumia to Al-Dahiriya.

The figure below show the relation between the number of year and power consume, this data is the power at 2017 with growing 7% each year for every town on the transmission line [1, 2, 3].

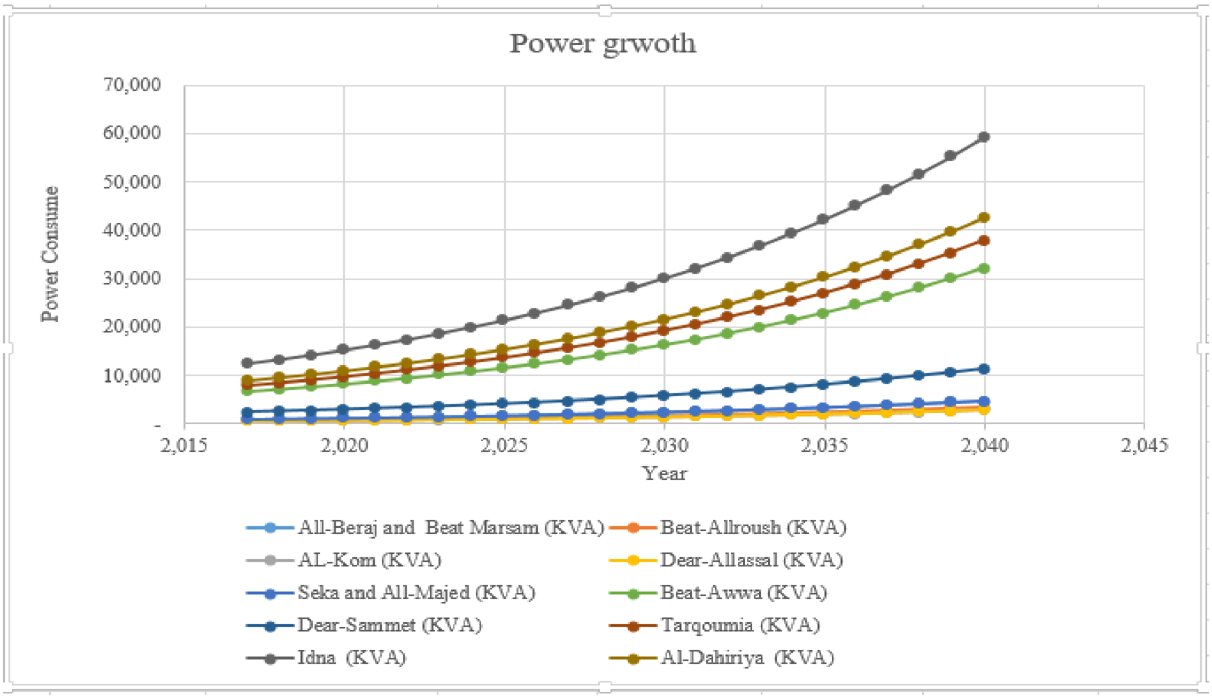


Figure 2.1: load growth for each towns

Idna load growth:

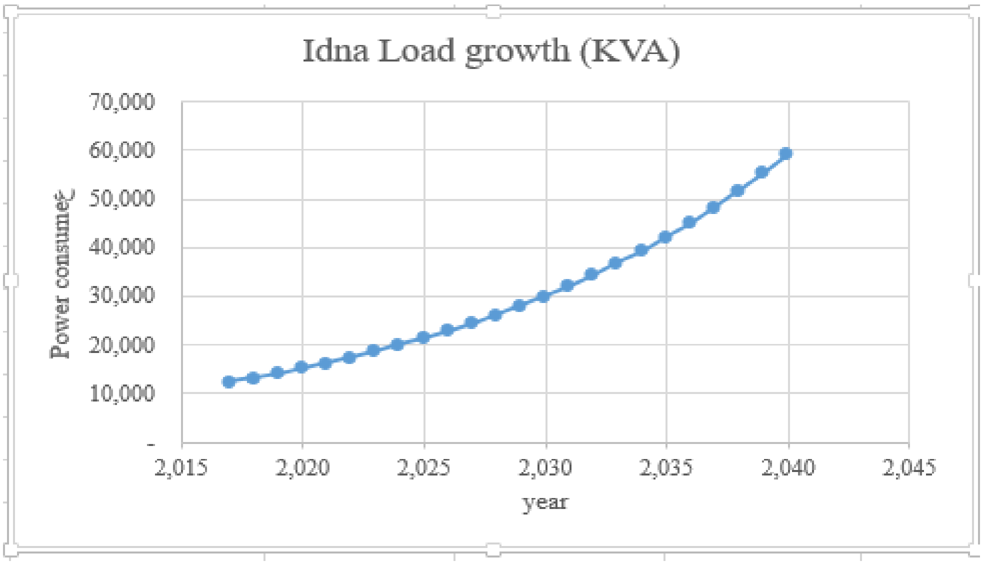


Figure 2.2: Idna demand growth

To make this study more realistic, the large demand on photovoltaic system and the output power from photovoltaic also the result on the grid and, should be insert in design. According from Palestinian Energy and (Natural Resources Authority) PENRA at 2020, the renewable energy will cover 20% from total power. So if this percentage was for 2040 and still 20% for project towns and villages the result will be at 2040 like this [2]:

Table 2.1: Expected demand from PV system

towns and villages	Demand in 2040 (MVA)	Expected demand from PV system (MVA)
Al-Dahiriya	42.665	42.665×20% = 8.533
Idna	59.257	59.257×20% = 11,852
Tarqoumia	37.924	37.924×20% = 7,585
Beat-Awwa	32.236	32.236×20% = 6,447
Dear-Sammet	11.337	11.337×20% = 2.275
Sika	2.3705	2.3705×20% = 0.474
Al-Majd	2.3705	2.3705×20% = 0.474
Dear-Allassal	2.939	2.939×20% = 0.588
Al-Kom	2.844	2.844×20% = 0.568
Beat-Alroush	3.336	3.336×20% = 0.673
Al-Birj	4.741	4.741×20% = 0.948

The selection for PV panel is → watt/panel =320 W; Voc=44.77 V; Isc=9.14 A.

Table 2.2: Expected PV system designs

Towns and Villages	Number of PV panel	Number of panel in string	Number of parallel panel
Al-Dahiriya	26192	16	1637
Idna	37056	16	2316
Tarqoumia	25024	16	1564
Beat-Awwa	20160	16	1260
Dear-Sammet	7152	16	447
Sika	1465	16	91
Al-Majd	1465	16	91
Dear-Allassal	1808	16	113
Al-Kom	1680	16	105
Beat-Alroush	2048	16	128
Al-Birj	2896	16	181

2.1.2 People growth

Estimating the population is an important estimation for load growth. The figure below show the relation between population and years for 2040 for every town in the distribution line, while the numbers and estimation showing in appendix-A [4].

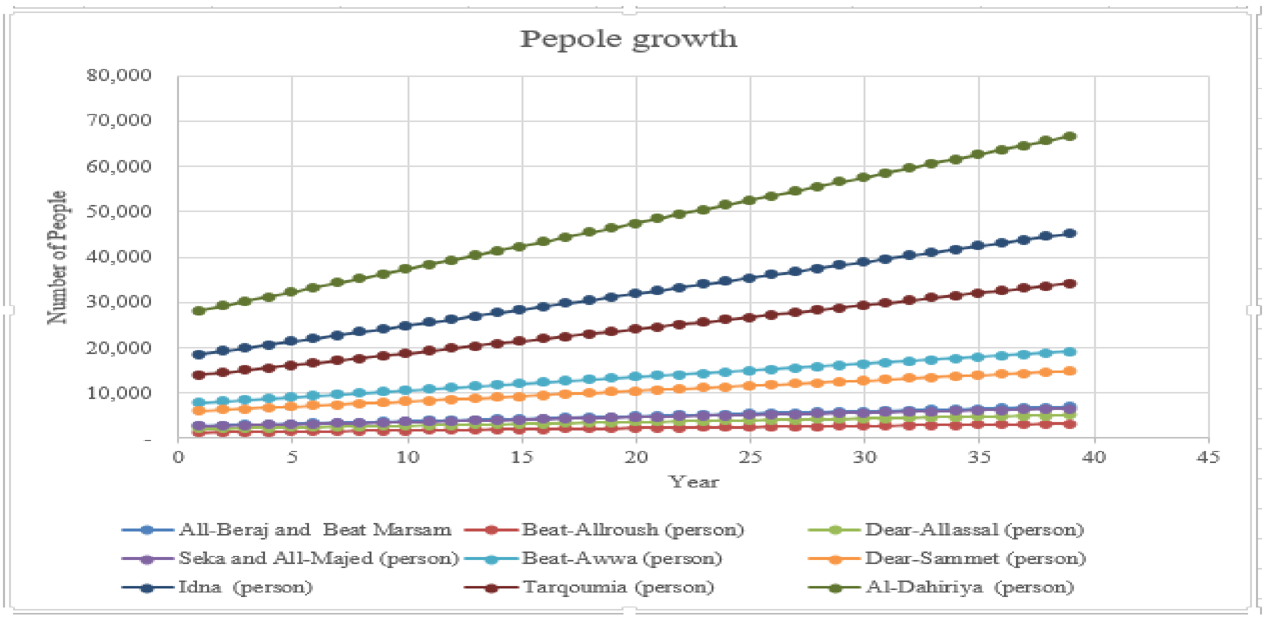


Figure 2.3: people growth

2.2 Symmetrical components and fault analysis

2.2.1 Faults

A fault in a circuit is any failure, which interferes which the normal flow of the current, or a physical change in the power system element; faults mainly caused by insulation failure, which effect on the distribution lines as short circuit, open circuit, or earth faults.

Faults Classification

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

A. 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 causing in the system accidently through:

1. Insulation failure of equipment.
2. Flash over of lines initiated by lighting stroke.
3. Accidental faulty operation.

Symmetrical faults are rare and it is not exceeding 5% of the faults of the system.

B. Asymmetrical Faults.

Unbalanced system can result due to unsymmetrical faults, then the system operation, may also become unbalanced when load not balanced. Most faults in the system are unsymmetrical so it is very important to pay attention.

The asymmetrical faults can be classify as follow:

1. Single line to ground fault (L-G).
2. Line to line fault (L-L).
3. Double line to ground fault (L-L-G)

2.2.2 Symmetrical Components

In normal mode of operation, the three-phase system is symmetrical, so to analyze this system, we analyze one of the phases; the obtained results are the same for each phase but shifted by 120.

In case of faults, we cannot apply the previous method to analyze the system due to the asymmetry, and we have to analyze each phase independently; but this method is long and hard to apply, so we use the symmetrical components and Fortescue's theorem.

2.3 Reliability of transmission system

Is a measure of the ability systems to transmit electrical power from the power generation points to all consumers, and it gives numerical indices to assess this process. The reliability of the system can be described by two basic functional features are security and adequacy.

Reliability refers to the ability of parts and components of the power system to complete the required functionality properly and in a specific time under certain conditions. Reliability is the probability of a component or system work reliably used as a characteristic reliable indicator. The reliability of electrical systems is the application of the theory of reliability and measure for the electrical systems, which provides consumers electrical energy with quantity and appropriate quality and according to the standards and from the lower number of interruption of electricity.

2.4 Summary

This chapter discussed several important and necessary issues for the distribution system design and important things for design. Always the first step in the design process is the planning, so it necessary to study the load growth in order to select the appropriate equipment for the system. This chapter also talked about the reliability and faults and there are very important things that must be consider when carrying out the transmission system design.

3.1 Introduction

An electrical substation is a subsidiary station of an electricity generation, transmission and distribution system, where voltage transformed from high to low or the reverse using transformers.

Electric power may flow through several substations between generating plant and consumer, and may be change in voltage in several steps.

A substation that has a step-up transformer increases the voltage while decreasing the current, while a step-down transformer decreases the voltage while increasing the current for domestic and commercial distribution.

Besides changing the voltage, the job of the distribution substation is to isolate faults in either the transmission or distribution systems.

Distribution substations may also be the points of voltage regulation, although on long distribution circuits (several km/miles), voltage regulation equipment may also be install along the line.

Complicated distribution substations can be find in the downtown areas of large cities, with high-voltage switching, and switching and backup systems on the low-voltage side.

Figure 3.1: Electrical Substation.

3.2 Design of Substations

Substations generally have:

1. Switching equipment
2. Protection equipment
3. Control equipment
4. One or more transformers

The substation categorized as:

1. Distribution Substations

   Distribution substation is a combination of switching, controlling, and voltage step-down equipment.

2. Switching Substations

   A switching substation is a combination of switching and controlling equipment arranged to provide circuit protection and system switching flexibility.

3. Transmission Substations

   A transmission substation is a combination of switching, controlling, and voltage step-down equipment arranged to reduce transmission voltage to sub transmission voltage for distribution of electrical energy to distribution substations. Transmission substations frequently have two or more large transformers.

In a large substation, circuit breakers are using to interrupt any short-circuits or overload currents that may occur on the network. In smaller distribution stations, recloser circuit breakers should be using for protection of distribution circuits. Other devices such as capacitors and voltage regulators may also be located at a substation. Substations may be on the surface in fenced enclosures, underground, or located in special-purpose buildings.

The design may include the following equipment:

1. The proper scheme
2. Power transformers
3. Circuit Breaker
4. Current transformers & Voltage transformers
5. Surge Arresters
6. Isolators
7. Wave trap
8. Insulator
9. Earth switch
10. Earthing system
11. Control panel
12. Cables
13. Capacitors

3.2.1 The proper scheme

The selection of a particular substation scheme is based upon

- ✓ Safety.
- ✓ Reliability.
- ✓ Economy.
- ✓ Simplicity.
- ✓ Other considerations.

The most commonly used substation bus schemes include

(1) Single bus scheme.

(2) Double bus–double breaker scheme.

(3) Main-and-transfer bus scheme.

(4)Double bus–single breaker scheme.

(5)Ring bus scheme.

(6)Breaker-and-a-half scheme.

Table 3.1: Comparison between the buses of layout system

Type of scheme	Reliability	Cost	Available Area
Single bus	Least reliable	Least cost	Least area
Sectionalized Bus	Highly reliable	High cost	Greater area
Main and transfer bus	Least reliable	Moderate cost	Low area
Ring Bus	High reliability	Moderate cost	Moderate area
Breaker-and-a-Half	Highly reliable	Moderate cost	Greater area
Double bus–double breaker	Moderately reliable	Moderate cost	Moderate area

To get main object of substation the ring bus scheme will selected; because it allows relatively faster service restoration when a fault occurs on one of the sub transmission circuits.

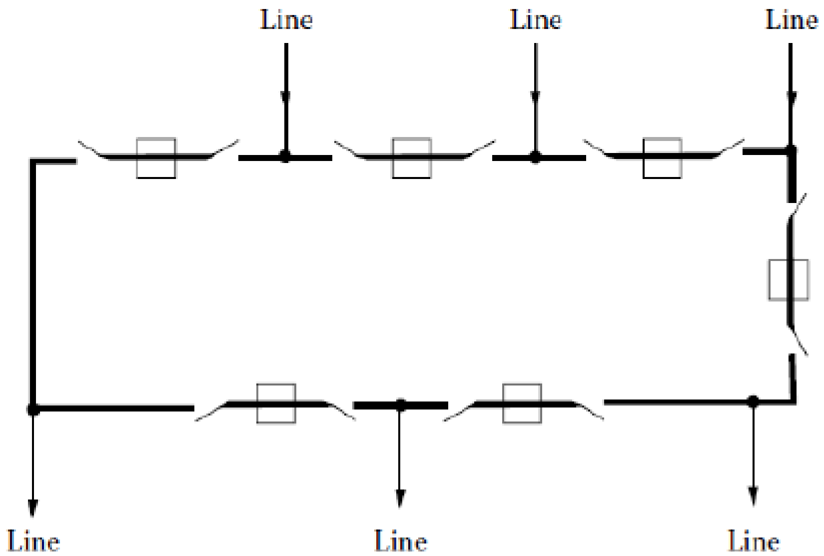


Figure 3.2: Ring bus scheme

3.2.2 Power Transformers

The transformer is the most important part of the transformer substation. The choice of transformer affects the design of the substation and is make on basis of several factors primarily:

- ✓ Characteristics of the User installation
- ✓ Level of continuity of service required
- ✓ Location of the electrical substation

Some important characteristics must consider and define according to the product standard:

- ✓ Type of transformer, for example with n separate windings or autotransformer, etc.
- ✓ Single-phase or three-phase.
- ✓ Frequency.
- ✓ Dry or in insulating liquid, and in the latter case what kind of liquid (oil, natural or synthetic liquid, etc.).
- ✓ For internal or external.
- ✓ Rated power for each winding.
- ✓ Nominal voltage for each winding (and therefore the transformation ratio).
- ✓ Type of cooling**.**
- ✓ Presence of load or no-load tap-changer.
- ✓ Earthing connections and method for each winding**.**

The transformers shall be double copper wound, three phase, oil immersed,161kV/33 kV ,50 Hz, with on –load Tap changer with Transformer only & off--load tap changer for other mounted in the high voltage End.

Selection of the location of a substation must consider many factors:

- ✓ Sufficient land area
- ✓ Necessary clearances for electrical safety
- ✓ Access to maintain large apparatus such as transformers.
- ✓ The site must have room for expansion; due to load growth or planned transmission additions.
- ✓ Environmental effects (drainage, noise and road traffic effects).
- ✓ Grounding must be taking into account to protect passers-by during a short-circuit in the transmission system
- ✓ The substation site must be reasonably central to the distribution area.

The design is typical single bus distribution substation that is feeding by single incoming 161 kV lines feeding two 161 kV/33 kV transformers.

There is one substation located at Beat-Aulla, step-down substation (161kV/33kV) and it will run with two transformer 45 MVA for each transformer at 2018. The plan for this substation, it will run with 180 MVA with four transformers.

The final single line diagram for design will be like this.

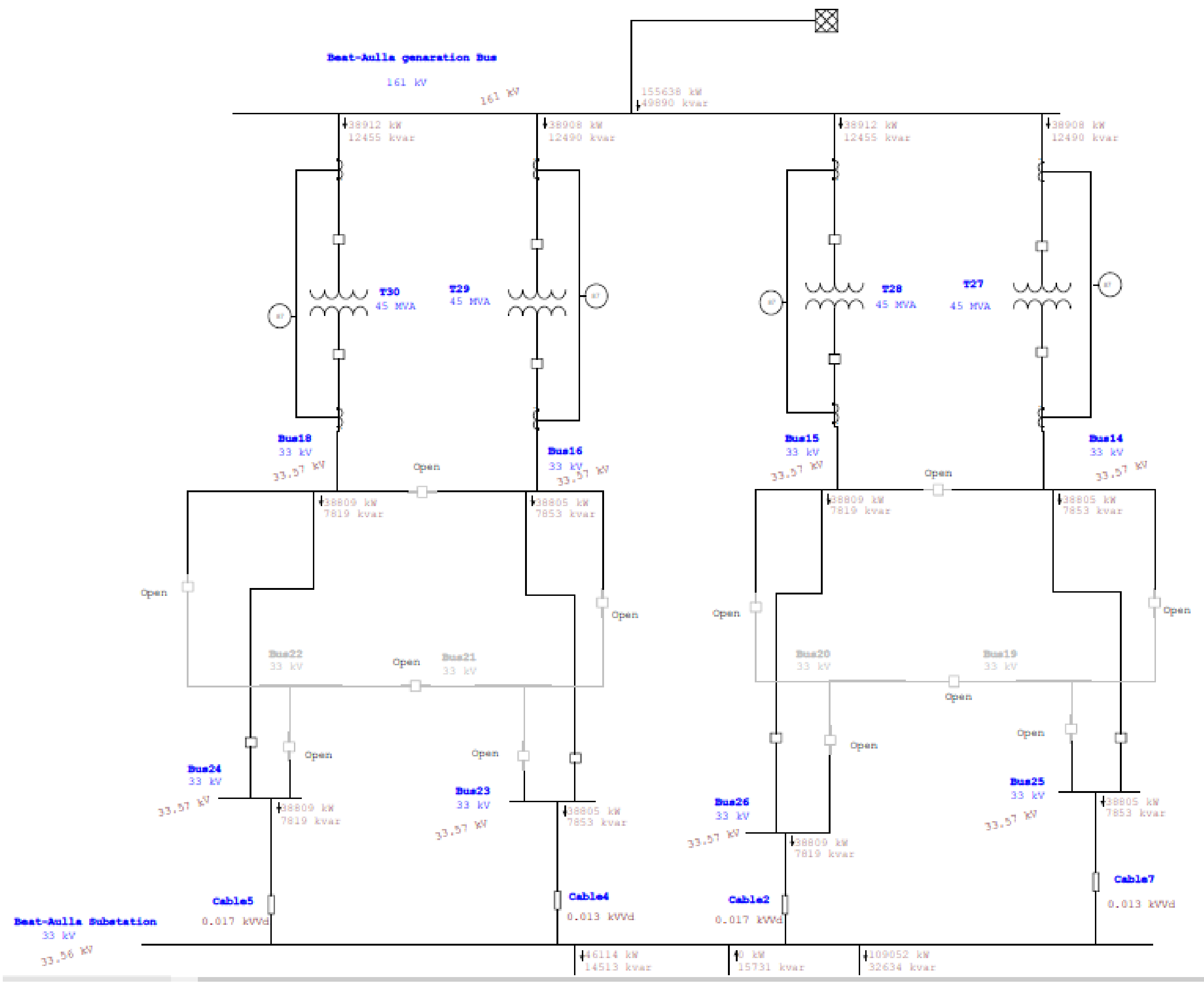


Figure 3.3: single line diagram for substation.

Impedance:

Transformer impedance affects transformer voltage regulation, efficiency, and magnitude of through short-circuit currents. Both regulation and efficiency are generally improve with lower impedance. For each transformer the impedance is 20%.

Protection:

Differential relay used to protect transformer, the currant for each transformer will be at maximum power:

$$I = \frac{s}{\sqrt{3} * V} = \frac{45M}{\sqrt{3} * 33kV} = 787.29A \tag{3.1}$$

$$I_1 - I_2 = m * \frac{I_1 + I_2}{2} \tag{3.2}$$

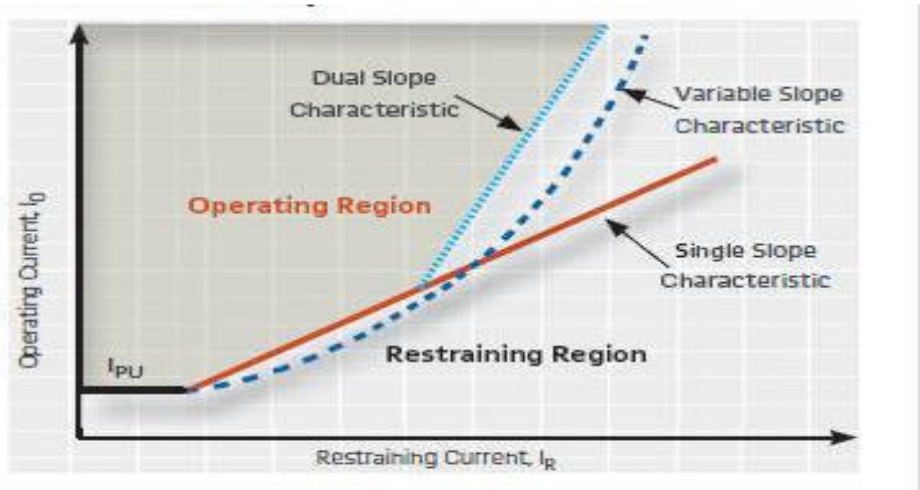


Figure 3.4: Differential relay characteristic

3.2.3 Circuit Breakers

circuit breaker is a device that closes and interrupts (opens) an electric circuit between separable contacts under both load and fault conditions, the power circuit breaker is limited to circuit breakers rated 1000 volts and above. A circuit breaker must be capable to make and break all the load and fault currents that it might be subject to at the specific installation.

Key factors with circuit breakers performance are; opening (break) and closing (make) time, rated continuous current-carrying capability, rated dynamic short circuit withstand capability, rated thermal short circuit withstand capability, maximum operation voltage and rated operation sequence.

Type of circuit breakers:

1. Vacuum circuit breaker.
2. Air circuit breaker.
3. SF_6 Circuit breaker.
4. Oil circuit breaker.

Today, these technologies re-placed with SF6-gas and vacuum technologies. SF6-gas is dominating with outdoor installations, whereas with indoor installations both vacuum and SF6-gas technologies are utilize.

Ratings:

1. Line to line primary voltage (rms) = 161 kV
2. Line to line secondary voltage (rms) = 33 kV

3. Rated Maximum Voltage: the maximum voltage for which the circuit breaker is design, also the upper limit for operation on an electric system.
4. Rated Max. Voltage (rms) = 170 kV, 38 kV (According to available standard).

3. Current:

The calculation will be for 2040. The total maximum power for this system is (202 MVA), then after step-down transformers there is two feeders, first main feeder feeding all towns except Idna town with (142.725 MVA), then there is Idna feeder feeding Idna with (59.275 MVA).

At high voltage side (161 kV), there is two circuit breaker in parallel, which divided current, so the current rated through it will be:

$$I = \frac{KVA}{\sqrt{3} * 161kV} \tag{3.3}$$

$$\frac{142.725\ MVA}{\sqrt{3} * 161kV} = 511.8\ A \tag{3.4}$$

The safety factor for circuit breaker is 1.25 the current is equal:

$$I_p = 1.25 * 511.8 = 639.77A \tag{3.5}$$

For low voltage side (33Kv) which divided as:

Main feeder (except Idna):

$$\frac{142.725\ MVA}{\sqrt{3} * 33kV} = 2497.04\ A \tag{3.6}$$

Divided on 2 to be double circuit the result will be:

$$I_{s1} = \frac{2497.04\ A}{2} = 1248.52\ A \tag{3.7}$$

Idna Town:

$$\frac{59.275\ MVA}{\sqrt{3} * 33kV} = 1037.04\ A \tag{3.8}$$

Divided on 2 to be double circuit the result will be:

$$I_{s2} = \frac{1037.04\ A}{2} = 518.52\ A \quad (3.9)$$

The safety factor for circuit breaker is 1.25 the current equal:

$$I_{t,s1} = 1.25 * 1248.52 = 1560.65\ A \quad (3.10)$$

The safety factor for circuit breaker is 1.25 the current equal:

$$I_{t,s2} = 1.25 * 518.52 = 648.15A \quad (3.11)$$

3.2.4 Instrument Transformers

Instrument Transformers are define as the instruments in which the secondary current or voltage is substantially proportional to the primary current or voltage and differs in phase from it by an angle, which is approximately zero for an appropriate direction of connection.

Direct measurement of current or voltage in high voltage system is not possible; because of high values and insulation problems of measuring instruments; because it is can’t directly used for protection purposes.

Instrument transformers are of two types:

1. Current Transformers.
2. Voltage Transformers.

Current Transformer (CT)

It is use for measurement of alternating electric current. Current transformer is a current measuring device used to measure the currents in high voltage lines directly by stepping down the currents to measurable values by means of electromagnetic circuit. When current in a circuit is too high to apply directly to measuring instruments, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can be conveniently connected to measuring and recording instruments.

The most common CT secondary full-load current is 5 amps which matches the standard 5-amp full-scale current rating of switchboard indicating devices, power metering equipment, and protective relays. CTs with a (1) ampere full-load value and matching instruments with a (1) ampere full-range value are also available. Many new protective relays are programmable for either value.

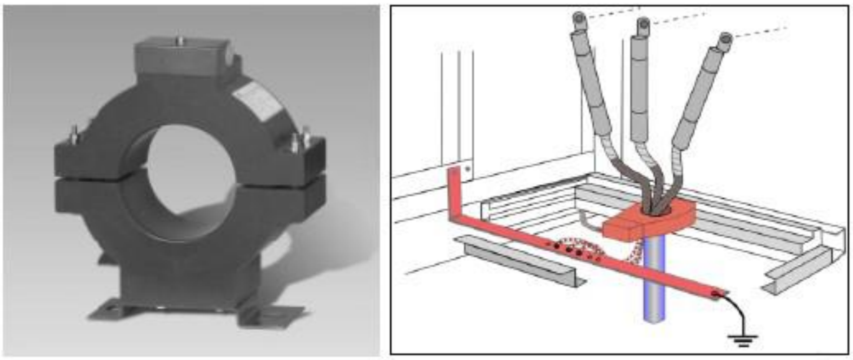


Figure 3.5: Current Transformer

The basic principle induced in designing of current transformers is Primary ampere turns = Secondary ampere turns

$$\frac{I_p}{N_p} = \frac{I_s}{N_s} \quad (3.12)$$

Where,

Ip: Primary current

Np: Primary winding Turns

Is: Secondary current

Ns: Secondary Winding Turn

The line diagram of a current transformer contains different components:

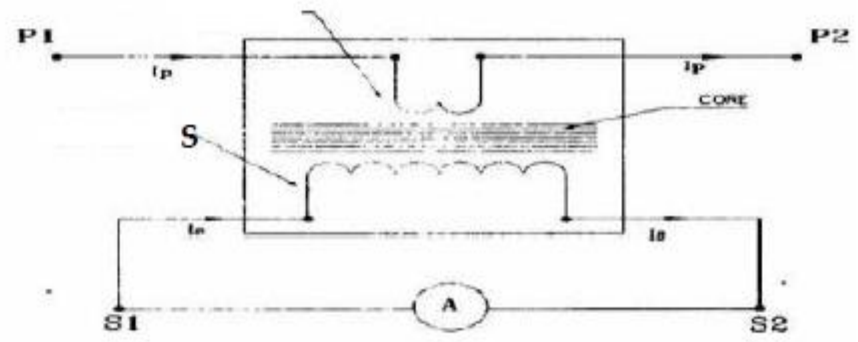


Figure 3.6: Line Diagram of C.T.

Voltage Transformers (VT)

Also called Potential Transformers (PT), parallel connect type of instrument transformer. They are design to present negligible load to the supply, being measure and have an accurate voltage ratio and phase relationship to enable accurate secondary connected metering.

It gives the reference voltage to the Relay for Over-voltage or Under-voltage Protection.

Figure 3.7: Voltage transformer.

The basic principle involved in the designing of Voltage Transformer is

$$\text{Voltage Ratio} = \text{Turns Ratio} \quad (3.13)$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \quad (3.14)$$

As heavy primary voltages will be reduce to low secondary voltages, it will have more turns in the primary and less turns in the secondary. It must always connected in parallel only.
Even if we connect it directly from high voltage to earth, it is not going to be a short circuit as its primary winding has very high resistance. Its core is a set of assembled laminations. It operates at constant flux density.

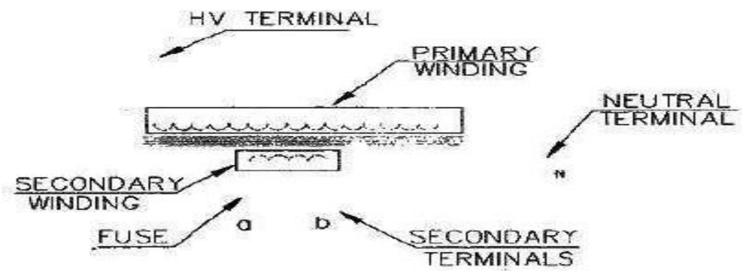


Figure 3.8: Line Diagram of VT.

3.2.5 Surge Arresters

The modern metal-oxide surge arresters are recommend because this latest advance in arrester design ensures better performance and high reliability of surge protection schemes.

Manufacturer's technical data must be consult for correct application of a given type of surge arrester. Notice that published arrester MCOV (Maximum Continuous Operating Voltage) ratings based on 40 or 45 C ambient temperature.

In general, the following guidelines are recommend for arrester selections, when installed inside Eaton's medium voltage switchgear:

Solidly Grounded Systems

Arrester MCOV rating should be equal to

$$1.05 \times \frac{V_{LL}}{1.732 \times T} \tag{3.15}$$

Where:

VLL : is nominal line-to-line service voltage,

1.05 : factor allows for +5% voltage variation above the nominal voltage according to ANSI C84.1.

T: is derating factor to allow for operation at 55 C switchgear ambient, which should be obtain from the arrester manufacturer for the type of arrester under consideration. Typical values of T are : 0.946 to 1.0.

Low Resistant Grounded Systems (systems grounded through resistor rated for 10 seconds):

Ungrounded or Systems Grounded through impedance other than 10-second resistor Arrester MCOV rating should be equal to:

$$1.05 \times \frac{V_{LL}}{T} \tag{3.16}$$

Table 3.2: Surge Arrester selections recommended ratings

Typical ANSI system Voltage			Suggested ANSI Arrester MCOV Rating			
Nom Line to Line Voltages	Max Line to Line Voltages	Max Line to Ground Voltages	Solid Multi-grounded System (3 wire)	Uni-grounded System (3 wire)	Impedance grounded, Ungrounded and Delta System	Transmission line Arrester for Lightning protection Only
kV rms	kV rms	kV rms	MCOV	MCOV	MCOV	
2.40	2.52	1.46			2.55	
4.16	4.37	2.52	2.55	5.1	5.1	
4.80	5.04	2.91			5.1	
6.90	7.25	4.19			7.65	
8.32	8.74	5.05	5.1	7.65		
12.0	12.6	7.28	7.65	10.2		
12.5	13.1	7.57	7.65	12.7		
13.2	13.9	8.01	8.4	12.7		
13.8	14.5	8.38	8.4	12.7	15.3	15.3
20.8	21.8	12.6	12.7	15.3		21
22.9	24.0	13.9	15.3	19.5		22 – 24
23.0	24.2	14.0	15.3-17		24.4	22 – 24
24.9	26.2	15.1	15.3	22		24 – 29
27.6	29.0	16.8	17	24.4		24 – 29
34.5	36.2	20.9	22	29	36 – 39	29 – 36
46.0	48.3	27.9		29	39	29 – 39
69.0	72.5	41.9		42 – 48	53 – 67	48 - 67

Good protection:

Surge Arrester in parallel with Surge Capacitor for protection from high over voltage peaks and fast rising transient. This option may not provide adequate surge protection from escalating voltages caused by circuit resonance. When applying surge capacitors on both sides of a circuit breaker, surge capacitor on one side of the breaker must be RC Snubber or ZORC, to mitigate possible virtual current chopping.

Better protection: RC Snubber in parallel with Surge Arrester for protection from high frequency transients and voltage peaks.

3.2.6 Isolator and insulator

Isolator

Electrical isolators separate a part of the system from rest for safe maintenance works. So definition of isolator can be rewritten as Isolator is a manually operated mechanical switch which separates a part of the electrical power. Isolators use to open a circuit under no load. Its main purpose is to isolate one portion of the circuit from the other and not intended to be open, while current is flowing in the line. Isolators are generally used on both ends of the breaker in order that repair or replacement of circuit breaker can be done without and danger.

Types of Electrical Isolators:

There are different types of isolators available depending upon system requirement such as

1. Double Break Isolator.
2. Single Break Isolator.
3. Pantograph type Isolator.

Depending upon the position in power system, the isolators can be categorize as

1. Bus side isolator – the isolator is directly connect with main bus.
2. Line side isolator – the isolator is situate at line side of any feeder.
3. Transfer bus side isolator – the isolator is directly connect with transfer bus.

Insulators

A very flexible coating of an insulator is often applied to electric wire and cable, this is called insulated wires commonly use just air, since a solid (e.g. plastic) coating is impractical. However, wires that touch each other produce cross connections, short circuits, and _re hazards. In coaxial cable the center conductor must be supported exactly in the middle of the hollow shield in order to prevent EM wave reflections. Finally, wires that expose voltages higher than 60 V can cause human shock and electrocution hazards. Insulating coatings help to prevent all of these problems.

Some wires have a mechanical covering with no voltage rating e.g.: service-drop, welding, doorbell, thermo-stat wire. An insulated wire or cable has a voltage rating and a maximum conductor temperature rating. It may not have an ampacity (current-carrying capacity) rating, since this is dependent upon the surrounding environment (e.g. ambient temperature).

Types of insulators

In terms of the type of material manufactured:

1. Glass insulators.
2. Rubber insulators.
3. Porcelain insulators.

In terms of design:

1. Cap & Pin type insulator.
2. Long rod type insulator.

In terms of type of tower mounted on two types:

1. Tension Insulators.
2. Suspension Insulators.

Calculation and design

For design, insulator must carry 161 kV & 33 kV and there is standard say every one cub insulate10.5 kV so for high voltage side (161kV) 16 cub Insulators, and for low voltage side (33kV) 4 cub Insulators.

Glass insulators will be used because; it is transparent and it have good Durability and Long rod type insulator will be used for more effective, and Tension Insulators and Suspension Insulators depending on the place that it use on it.

Ratings of Isolators, Insulator and Bushing (Disconnectors):

1. Rated voltage, rated current, and allowed short-circuit current must be determined.
2. Switch dis-connectors must withstand thermally and mechanically against the short circuits.

3.2.7 Wave trap

Wave trap is an instrument using for trapping of the wave. The function of this wave trap is that it traps the unwanted waves. Its shape is like a drum. It is connect to the main incoming feeder so that it can trap the waves, which may be dangerous to the instruments in the substation.

Generally, it is use to exclude unwanted frequency components, such as noise or other interference, of a wave.

Figure 3.9: Wave trap.

This is relevant in power line carrier communication (PLCC) systems, for communication among various substations without dependence on the telecom company network. The signals are primarily protection signals and in addition, voice and data communication signals. The Line trap offers high impedance to the high frequency communication signals thus obstructs the flow of these signals in to the substation bus bars. If these are not present in the substation, then signal loss is more and communication will be ineffective/probably impossible.

3.2.8 Earth switch

Earth switch is very important equipment as per safety of humans. While taking should down of any Equipment first we have to discharge the charge stored in it before doing any work on that. So in order to discharge the charge we have to connect earth switch (Out Door substation) or cable earthing trolley (In Door substation). We have to put the earth switch in close position; because of voltage will induce in dead equipment due to line running beside it.

Earthing switches are using for earthing and short circuiting disconnected sections of substation or plant. Earthing switches type TEC and TEB are suitable for outdoor installations. They can be supply as the single column free-stand earthing switch or as earthing switch built-on the same base frame together with dis-connector type SGF, TFB or SDB. In earthing switch type TEB, in the end position, the earthing blade is inserting upwards into earthing contact where it is held in place.

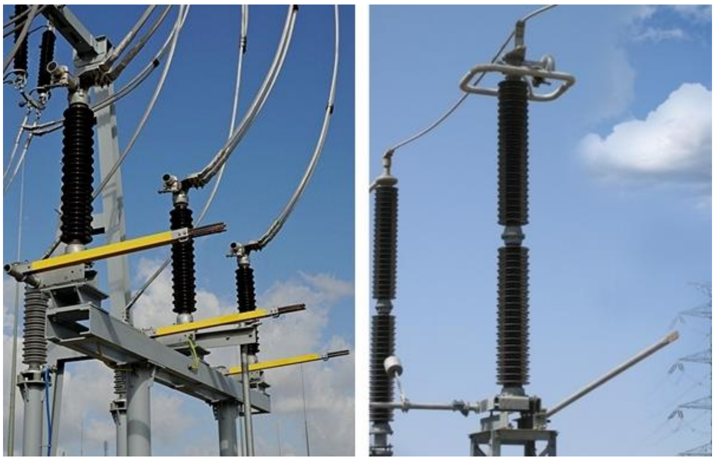


Figure 3.10: Earthing switches type TEC and TEB

3.2.9 Earthing system

The earthing of substation is one of the most important procedures that must be encouraged when designing any substation. The earthing system dose not only used to protecting workers in the substation or presence in one of its facilities only, but used to protect all components of the risk of faults and lightning. When designing a system, you should take reliability to consideration.

In principle of the safe earthing design has the following two objectives:

1. The purpose of the process is to provide a path for the current in certain circumstances without affecting the operation of the system.
2. Ensure that no person in the substation is exposing to electric shock due to faults or lightning.

The system is very important for a number of reasons, but all of them are relate to the protection of human and equipment located in the station, in addition to ensuring the optimal operation of the system. Among these reasons:

1. The earthing system provides a path for the current with low resistance for protecting both persons and equipment.
2. The earthing system provides low resistance path voltage transients such as lightning and surges or overvoltage's.
3. Equipotential bonding helps prevent electrostatic buildup and discharge, which can cause sparks with enough energy to ignite flammable atmospheres.
4. The earthing system provides a reference potential for electronic circuits and helps reduce electrical noise for electronic, instrumentation and communication systems.

Types of Earthing:

1. System Earthing. This system relates to the protection of equipment and devices located in the substation by stabilizing the voltage with respect to ground.
2. Equipment Earthing (Safety earthing). In this system, all the devices are connect with the ground in order to protect workers from the danger of electric shock.

In the earthing of the substations, the system earthing and safety earthing are interconnect to ensure the highest degree of protection and reliability.

Components of earthing system

1. Earth electrode.
2. Connecting cables.
3. Lightening arrester.
4. Earth mat.
5. Earth switch.

Types of earth electrode

1. Rod electrode.
2. Plate electrode.

3.2.10 Control Panel

The substation control panel is design to form automated control systems (SCADA) of the traction substations, using digital protection and programmable logic controllers.

Substation control panel provides:

- ✓ Telemechanical control of the substation (sending/receiving signals of telecommands, telemetry and telesignaling)
- ✓ Remote control of the substation (using integrated controls and indicating devices)
- ✓ Collection and transmission of the telemetry and diagnosing data via digital channels of the data transmission network (DTN)

Figure 3.11: Control panel.

With substation control panel, any traction substation may be reconstruct with gradual connection of the new smart controllers and bay terminals, while the unmodified equipment is still control with the existing telecommunications panel.

Substation control panel includes:

1. An operator station for remote equipment control.
2. A controller of the overall substation signaling.
3. A substation controller functioning as a concentrator of the substation information-control network.
4. An uninterruptible power system.
5. Interface convertors with galvanic separation.

3.2.11 Cables

The procedures for underground cable by standard, which Hebron electrical company are discussing in chapter four.

Calculation for current and conductor size:

For each transformer with (45 MVA), current will be equal to:

$$I = \frac{45MVA}{\sqrt{3} * 33} = 787.295\ A \quad (3.17)$$

Make it double circuit

$$I = \frac{787.295\ A}{2} = 393.65\ A \tag{3.18}$$

Table 3.3: (6-36kV) Medium Voltage Underground Power Cables XLPE insulated cables [5]

Nominal cross-sectional area	mm^2	3x70	3x95	3x120	3x150	3x185	3x240
Diameter over conductor	mm	9.8	11.5	12.8	14.3	15.9	18.4
Approximate diameter over insulation	mm	27	28.7	30	31.5	33.1	35.6
Approximate overall diameter	mm	75	79	83	86	89	95
Approximate weight of cable	kg/m	6400	7550	8550	9600	11000	13200
Minimum bending radius (static)	mm	1150	1200	1250	1300	1350	1450
Maximum pulling tension on cable	kg	1050	1425	1800	2250	2775	3600
Maximum DC resistance @20°C	Ω/km	0.2680	0.1930	0.1530	0.1240	0.0991	0.0754
Maximum AC resistance@ 90°C	Ω/km	0.3420	0.2470	0.1960	0.1590	0.1280	0.0978
Inductance	mH/km	0.427	0.405	0.387	0.375	0.365	0.348
Reactance@50Hz	Ω/km	0.134	0.127	0.122	0.118	0.115	0.109
Impedance @ 50Hz @ 90°C	Ω/km	0.367	0.277	0.23	0.198	0.172	0.147
Maximum capacitance (C)	μF/km	0.155	0.17	0.183	0.196	0.207	0.228
Maximum charging current	A/km	0.93	1.02	1.1	1.17	1.24	1.36
Short circuit ratings							
1 second short circuit-rating of conductor (90 to 250°C)	kA	9.7	13.5	17.1	21	26.3	34.6
1 second short circuit-rating of metallic screen (80 to 200°C)	kA	4.6	4.6	5	5	5.3	5.7
Nominal cross-sectional area	mm^2	3x70	3x95	3x120	3x150	3x185	3x240
Continuous current carrying capacity (as per conditions detailed below)							
Direct buried	Amps	255	295	335	375	420	490
Single way ducts	Amps	230	260	305	335	380	435
In air	Amps	290	330	390	440	500	580

So 240 mm with rated current 490A underground cable will be use; for each transformer.

3.2.12 Capacitors

According to the E-tap report, the power factor was 0.9191 so less than IEEE standard and also voltage drop in the line, so to make an improvement to increase the power factor and solve voltage drop problem by adding a capacitor bank to reach a desirable value to be 95<PF.

Depending to the data (2017-2040):

Rated max. MVA = 202.

P=152.243 MW.

Qs=66.249 MVAR.

$$PF = \cos(\theta) \tag{3.19}$$

$$\theta = cos^{-1}(0.95) = 18.1948^0$$

$$Tan(\theta) = \frac{Q}{P} \tag{3.20}$$

$$Tan(18.1948) = 0.32868$$

Q=152.243*0.32868=50.039

$$Q_c = Q_s - Q = 66.249 - 50.039 = 15.21\ MVAR$$

CHAPTER FOUR: DISTRIBUTION LINE

4.1 Introduction

Distribution line is part of an electrical circuit or power network and thus connects power source and consumer. For transport electrons flow as a conductor. The power transmission means the transfer of electrical energy from the power generation location to the distribution system.

For low voltage drop or low transport losses, the conductive material should have a high electrical conductivity, to which some metals are particularly suitable. The cross-sectional area of the conductor must take into account the permissible current density. The technical design of lines is based on the findings of the theory of conduct.

Figure 4.1: Distribution Line

4.2 Distribution line

The power transmission is the main function of the transmission system. The power transmission means the transfer of electrical energy from the power generation location to the distribution system. The electrical power generation usually at 11-33 kV then steps up this voltage to the high or extra high level of voltage to reduce the loss in the electrical power in the transmission lines. This transmission system connected to the distribution system or load center through sub transmission network that operates at medium voltage (normally used 33 kV).

The important considerations in the design and operation of a transmission line are the determination of voltage drop, line losses and efficiency of transmission. These values are greatly influence by the line constants R, L and C of the transmission line. For instance, the voltage drop in the line depends upon the values of above three line constants. Similarly, the resistance of transmission line conductors is the most important cause of power loss in the line and determines the transmission efficiency.

The prediction for the path of transmission line is show in chapter five.

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

Figure 4.2: Components of the Distribution line

4.2.1 Components of transmission line

A transmission line consists of different components. The conductors through which the electrical energy is to be transfer are to be support by insulators and pylons.

The main component consists in transmission line are:

1. Conductor.
2. Earth wire (Ground wire).
3. Insulators.
4. Towers.
5. Cross arms.
6. Foundation.

4.2.2 Comparison between overhead line and underground cable

Underground cables is use for power applications, where it is impractical, difficult, or dangerous to use the overhead lines. They are widely used in densely populated urban areas in factories to supply power from the overhead posts to the consumer premises. The underground cables have several advantages over the overhead lines they have smaller voltage drops, low chances of developing faults and have low maintenance costs. However, they are more expensive to manufacture, and their cost may vary depending on the construction as well as the voltage rating.

Overhead lines are the primary energy transportation links, forming the connections between the individual substations within high and medium voltage grids. Depending on the network parameters and other project-specific conditions, we optimize the design of the overhead lines, including the selection between aluminum or copper conductors, supported by lattice steel towers, or steel or concrete poles and equipped with porcelain, glass or polymeric insulators. Submarine or underground cables have their own special requirements for the material of the conductors, and in particular for the most appropriate type of insulation, mass or plastic.

Table 4.1: comparing between overhead and underground cable [6]

	underground cables	**Overhead lines**
Cost	Great cost	Low cost
Crash	The difficulty of locating Crash	Ease of locating crash
Maintenance	Cheep	Expensive
Loss in transmitted power	Low quantity	High quantity

The overhead lines are the main type used in the transmission system, so the design will be overhead line for main path and underground cable for distribution parts.

4.3 Overhead distribution lines

There are two types connection for transmission lines:

- T – Circuit.
- Pi – Circuit.

Any pi network can be transform to an equivalent T network. Also known as the Wye-Delta transformation, which is the terminology used in power distribution and electrical engineering. The pi is equivalent to the Delta and the T is equivalent to the Wye (or Star) form. This is often referrers to as a pi model for the line because of its form. Note that the series resistance of the line is neglect in this model. This is a limitation on the accuracy of line representation. The series resistance of a good transmission line is quite small compared with the reactance.

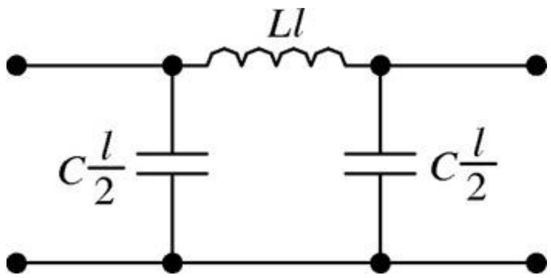


Figure 4.3: Standard 'Pi' model for a transmission line

4.3.1 Classification of overhead transmission lines

1. **Short transmission lines:**
   When the length of an overhead transmission line is up to about 50 km and the line voltage is comparatively low (< 20 kV), it is usually considered as a short transmission line. Due to smaller length and lower voltage, the capacitance effects are small and can neglected it. Therefore, while studying the performance of a short transmission line, only resistance and inductance of the line are take into account.
2. **Medium transmission lines:**
   When the length of an overhead transmission line is about 50- 150 km and the line voltage is moderately high (>20 kV < 100 kV), it is considered as a medium transmission line. Due to sufficient length and voltage of the line, the capacitance effects are take into account. For purposes of calculations, the distributed capacitance of the line is divide and lumped in the form of condensers shunted across the line at one or more points.
3. **Long transmission lines:**
   When the length of an overhead transmission line is more than 150 km and line voltage is very high (> 100 kV), it is considered as a long transmission line. For the treatment of such a line, the line constants are consider uniformly distributed over the whole length of the line and rigorous methods are employed for solution.

It may be emphasize here that exact solution of any transmission line must consider the fact that the constants of the line are not lumped but are distribute uniformly throughout the length of the line.

However, reasonable accuracy can be obtain by considering these constants as lumped for short and medium transmission lines.

The distance of this project is almost 22 km, so the short transmission line will be use.

4.3.2 Suitable material for distribution line

Selecting a proper type material of conductor for overhead lines is as important as selecting economic conductor size and economic transmission voltage. A good conductor should have the following properties:

1. High electrical conductivity.
2. High tensile strength in order to withstand mechanical stresses.
3. Relatively lower cost without compromising much of other properties.
4. Lower weight per unit volume.

The most commonly used conductor materials for overhead lines are copper, aluminum, steel- cored aluminum, galvanized steel and cadmium copper.

Table 4.2: Comparison between types of transmission line [7].

	Copper	**Aluminum**	**Steel-cored aluminum**	**Galvanized steel**	**Cadmium copper**
Wight	High	Low	Low	High	High
Conductivity	High Conductivity	Low conductivity	High conductivity	Low conductivity	High
Tensile Strength	Very high	High	Very high	High	Very High
Cost	Expensive	Cheap	Cheap	Cheap	Expensive

Choose Steel-cored aluminum (ACSR) to use in the transmission system and this type of conductor is the most commonly and used.

ACSR consists of a core of steel wire surrounded by a number of Aluminum strands. The steel conductor used in center is galvanized in order to avoiding rusting and electrolytic corrosion. ACSR conductor being of high tensile strength and lighter in weight which produces smaller sag. Therefore, linger spams can be used consequently cost of supporting structure is reduces.

4.4 Design of distribution line

4.4.1 Conductor size

Conductor is one of important parts on transmission line; because of this, the selection should be smart; because of the huge amount of power. The value of current is so much high, so the biggest and necessary town that consume power (Idna town) be deleted form main path, to make the total power is 143 MVA acceptable, then Idan town with 60 MVA at 2040 take a feeder alone.

The current at the main feeder transmission line will be:

$$P = \sqrt{3}VIcos(\theta) \tag{4.1}$$

Where:

P: Power in (KVA)

V: voltage in (kV)

I: current (A)

For main feeder of transmission line (without Idna).

P=143 MVA, V=33 kV and cos (θ) =0.92.

$$I = \frac{P}{\sqrt{3}Vcos(\theta)} \tag{4.2}$$

$$= \frac{143000}{\sqrt{3} * 33 * 0.95} = 2633.5A \tag{4.3}$$

Make the system double circuit system, so the current will be:

$$I = \frac{2633.5}{2} = 1316.76\ A \tag{4.4}$$

The current of bundle:

$$I = \frac{1316.76}{3} = 439\ A \tag{4.5}$$

For Idna town the currant is:

$$I = \frac{60000}{\sqrt{3} * 33 * 0.95} = 1104.97A \tag{4.6}$$

Make the system double circuit system, so the current will be:

$$I = \frac{1104.97}{2} = 525.48A \tag{4.7}$$

Table 4.3: Aluminum Conductor Steel Reinforced (A.C.S.R.) [8]

ASTM-B-232 METRIC UNITS

Code	Size	Stranding		Areas		Diameter	Mass per Unit Length				Rated Strength	Electrical Resistance			Current Carrying Capacity
		Al	Steel	Total	Al	Total	Core	Total	Al	Steel		D.C.@ 20ºC	A.C.@ 25ºC	A.C.@ 75ºC	
	AWG-MCM	No. x Ømm	No. x Ømm	mm²	mm²	mm	mm	kg/km	kg/km	kg/km	kN	Ω/km	Ω/km	Ω/km	1 (A)
Turkey	6	6x1,68	1x1,68	15,52	13,3	5,04	1,68	53,8	36,5	17,3	5,295	2,114	2,15	2,685	110
Swan	4	6x2,12	1x2,12	24,71	21,18	6,36	2,12	85,4	58	27,4	8,28	1,328	1,354	1,717	145
Swanate	4	7x1,96	1x2,61	26,53	21,12	6,53	2,61	99,7	58	41,7	10,5	1,131	1,339	1,738	145
Sparrow	2	6x2,67	1x2,67	39,2	33,6	8,01	2,67	135,9	92,3	43,6	12,68	0,834	0,853	1,108	195
Sparate	2	7x2,47	1x3,30	42,09	33,54	5,24	3,3	158,8	92,3	66,51	6,2	0,825	0,844	1,118	195
Robin	1	6x3,00	1x3,00	49,48	42,41	9	3	171,4	116,4	55	15,8	0,662	0,677	0,891	200
Raven	1/0	6x3,37	1x3,37	62,44	53,52	10,11	3,37	216,1	146,7	69,4	19,49	0,524	0,537	0,717	255
Quail	2/0	6x3,78	1x3,38	78,55	67,33	11,34	3,78	272,5	185	87,5	23,63	0,416	0,427	0,58	295
Pigeon	3/0	6x4,25	1x4,25	99,31	85,12	12,75	4,25	343,5	233,2	110,3	29,46	0,33	0,339	0,471	340
Penguin	4/0	6x4,77	1x4,77	125,09	107,22	14,31	4,77	433,2	294,2	139	37,16	0,261	0,27	0,383	390
Waxwing	266,8	18x3,09	1x3,09	142,5	135	15,45	3,09	431,6	372,9	58,7	30,62	0,212	0,217	0,26	480
Partridge	266,8	26x2,57	7x2,00	156,9	134,9	16,28	6	546,1	374,3	171,8	50,28	0,21	0,217	0,257	490

ASTM-B-232 METRIC UNITS

Code	Size	Stranding		Areas		Diameter	Mass per Unit Length				Rated Strength	Electrical Resistance			Current Carrying Capacity
		Al	Steel	Total	Al	Total	Core	Total	Al	Steel		D.C.@ 20ºC	A.C.@ 25ºC	A.C.@ 75ºC	
	AWG-MCM	No. x Ømm	No. x Ømm	mm²	mm²	mm	mm	kg/km	kg/km	kg/km	kN	Ω/km	Ω/km	Ω/km	1 (A)
Ostrich	300	26x2,73	7x2,12	176,9	152,2	17,28	6,36	614,6	421,3	193,3	56,52	0,187	0,191	0,228	530
Merlin	336,4	18x3,47	1x3,47	179,7	170,2	17,35	3,47	543,2	469,7	73,5	38,36	0,168	0,172	0,206	560
Linnet	336,4	26x2,89	7x2,25	198,4	170,6	18,31	6,75	689	472,2	216,8	62,75	0,166	0,167	0,204	570
Oriole	336,4	30x2,69	7x2,69	210,3	170,5	18,83	8,07	784,3	473,2	311,1	76,98	0,165	0,169	0,202	575

For main feeder the required conductor is Waxwing type with cross sectional area 142.5 mm2, with rated current 480 A and Merlin type for Idna feeder with cross section area 179.7mm2, with rated current 560 A.

The clearance between the conductors in every bundle is as following:

$$D = \left(\frac{VPUa}{500K}\right)^{1.667} bc \tag{4.8}$$

Where:

D: The spacing between the wires.

V: Operating voltage.

PU: maximum switching-surge factor.

a = 1.15, the allowance for three standard deviations.

b = 1.03, the allowance for nonstandard atmospheric conditions.

c = 1.2, the margin of safety.

K = 1.4, the configuration factor for conductor-to-plane gap.

The line to line voltage is =33 KV.

$$\text{Line to ground voltage } = \frac{33\text{KV}}{\sqrt{3}} = 19.05\text{KV } \&\& \text{ PU} = 2.35. \qquad (4.9)$$

$$D = \left(\frac{19.05K * 2.35 * 1.15}{500K}\right)^{1.667} * 1.03 * 1.2 = 10\ cm \qquad (4.10)$$

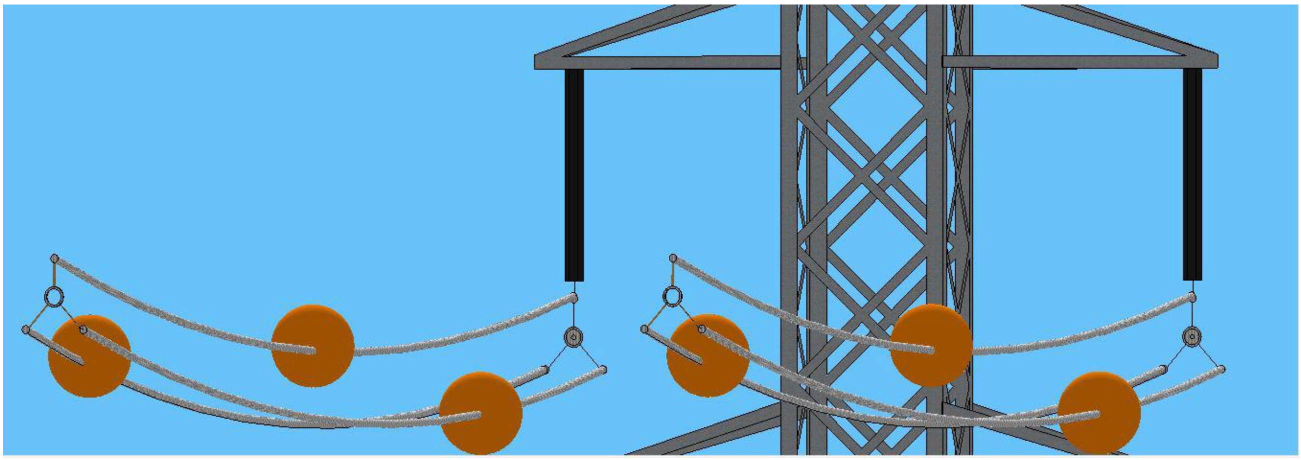


Figure 4.4: Towers Accessories

For the other feeders the current and cables will be as table 3.2. From this catalog and after making calculation and depending on distribution path, the result will be like this:

Table 4.4: Cruse section area for underground cables.

Town	Current (A)	Cruse section area	Current rating	Length
Al-Kom	54,1 A	70 mm^2	255 A	0.346 Km
Dear-Samet	216.5 A	70mm^2	255 A	1.302 Km

Beat-Awwa	613/2=307 A	120 mm^2	335 A	0.426 Km
Sika	45.1 A	70 mm^2	255 A	2.371 Km
Al-Majed	47 A	70 mm^2	255 A	0.678 Km
Dear-Alassal	56 A	70 mm^2	255 A	0.462 Km
Beat-Alroush	64 A	70 mm^2	255 A	0.677 Km
Al-Burj	90.2 A	70 mm^2	255 A	0.926 Km

The procedures for underground cable by standard, which Hebron electrical company is work like this:

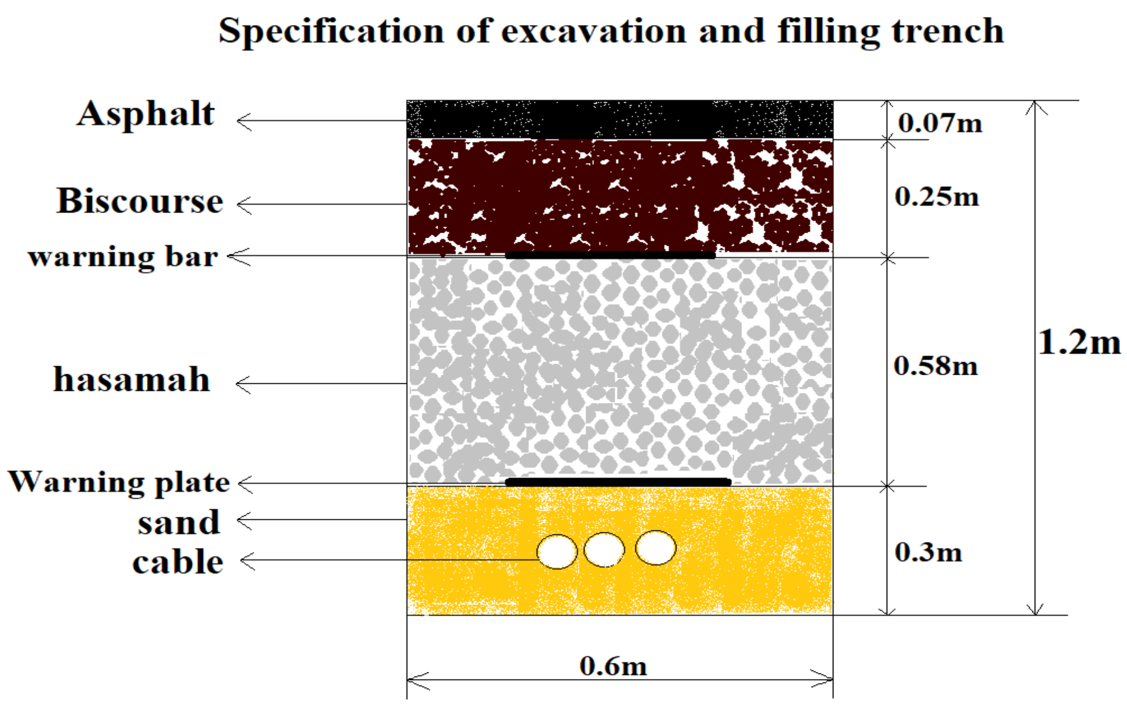


Figure 4.5: Specification of excavation and filling trench [9]

Figure 4.6: Plastci ribbon warning[9]

Figure 4.7: Steal plate warning [9]

4.4.2 Sag of distribution line

The sag of a transmission lime is impact by several phenomena including changes in heating, changes in loading, and long-term creep. The distance that a cable will sag depends on the length of the conductor span, the weight of the conductor, its initial tension, and its material properties. Decreasing the sag of a cable can increase the capacity of the transmission line or decrease the number of support structures that a design requires [10, 11].

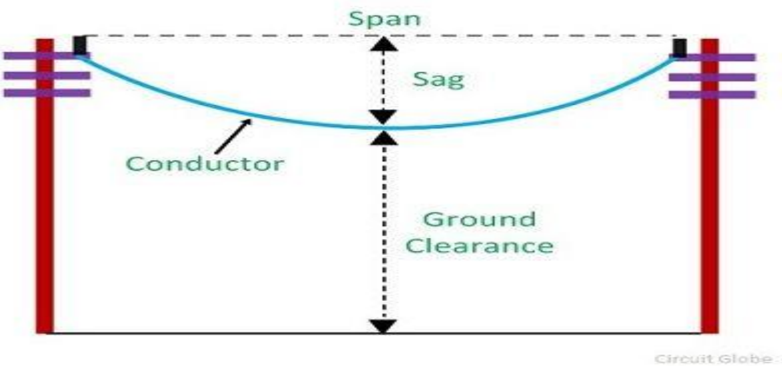


Figure 4.8: sag of distribution line

Sag can be decreased by several means increasing the stringing tension of the cable, increasing the conductive material in a line (thus, decreasing its operating temperature), or using a high-temperature low-sag conductor which elongates less under increased temperatures.

Sag calculation is classify on two conditions:

1. When supports are at equal levels.
2. When supports are not at equal levels.

Case 1:

Sag calculation for supports are at equal levels:

For a cable with a span-length l, weight w, and horizontal tension H, the maximum sag distance S (the vertical distance between the point of attachment and the cable, at the lowest point in the span) is described by the hyperbolic function:

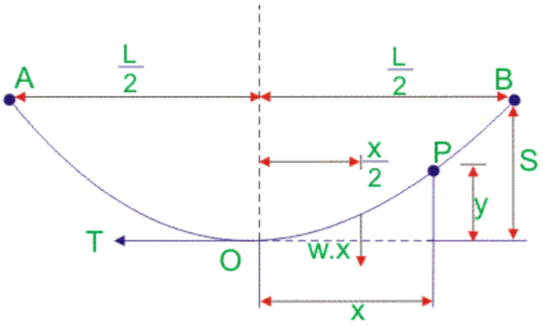


Figure 4.9: sag of distribution line, equal level [2].

$$S = \frac{\mathrm{WL}^2}{8\mathrm{T}}\ (m) \tag{4.11}$$

Where

S: Maximum sag distance

W: Weight per unit length

L: Length (Span)

T: tension at each end (Horizontal).

Table 4.5: Sag at Ultimate strength and variable span

span(m)	Ultimate strength(kg)	Horizontal distance(m)	mass(Kg/Km)	Sag(m) Safety factor = 0	Sag(m) Safety factor = 2
100	3122.37	50	0.4316	0.172785416	0.345570832
110	3122.37	55	0.4316	0.209070354	0.418140707
120	3122.37	60	0.4316	0.248810999	0.497621999
130	3122.37	65	0.4316	0.292007353	0.584014707
140	3122.37	70	0.4316	0.338659416	0.677318832
150	3122.37	75	0.4316	0.388767186	0.777534373

160	3122.37	80	0.4316	0.442330665	0.884661331
170	3122.37	85	0.4316	0.499349853	0.998699706
190	3122.37	80	0.4316	0.623755353	1.247510705
200	3122.37	100	0.4316	0.691141665	1.38228333
220	3122.37	110	0.4316	0.836281414	1.672562829

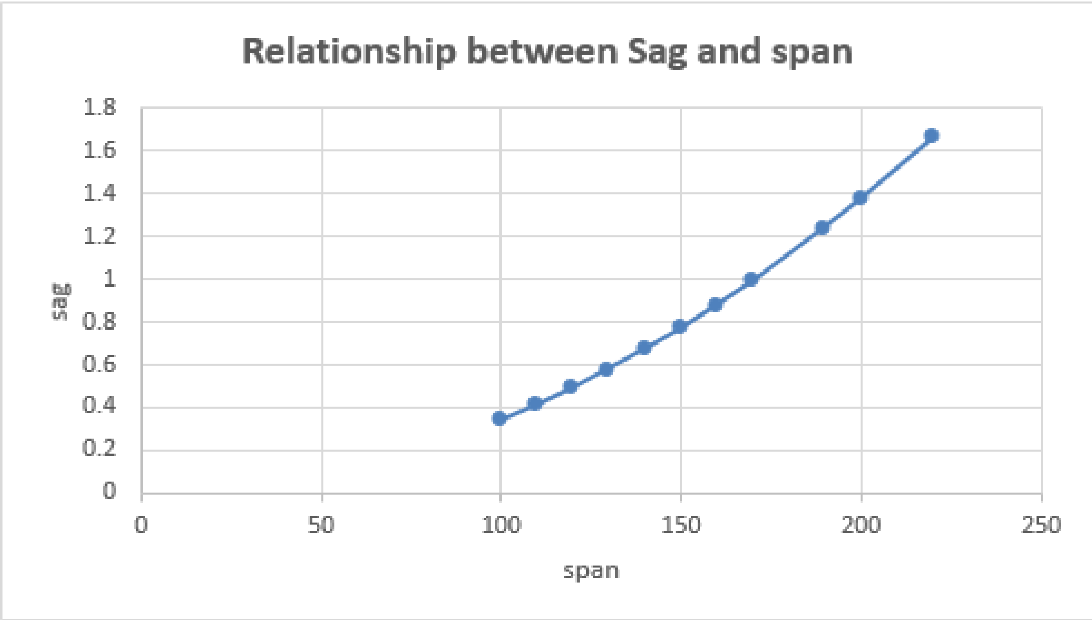


Figure 4.10: Relationship between Sag and span

Table 4.6: Sag at span (180 m) and variable tension

span(m)	Ultimate strength(kg)	Horizontal distance(m)	mass(Kg/Km)	Sag(m) Safety factor = 0	Sag(m) Safety factor = 2
180	122.37	50	0.4316	14.28438343	28.56876685
180	422.37	55	0.4316	4.138504155	8.27700831
180	722.37	60	0.4316	2.419784875	4.83956975
180	1022.37	65	0.4316	1.709733267	3.419466534
180	1322.37	70	0.4316	1.321853944	2.643707888
180	1622.37	75	0.4316	1.077423769	2.154847538
180	1922.37	80	0.4316	0.909283853	1.818567705
180	2222.37	85	0.4316	0.786538695	1.57307739
180	2522.37	80	0.4316	0.692991115	1.385982231
180	2822.37	100	0.4316	0.619330563	1.238661125
180	3122.37	110	0.4316	0.559824749	1.119649497

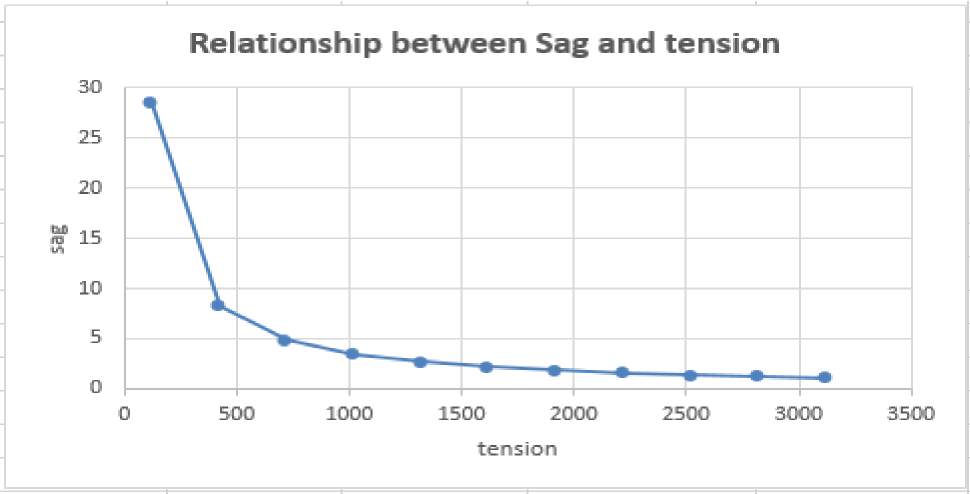


Figure 4.11: Relationship between Sag and tension

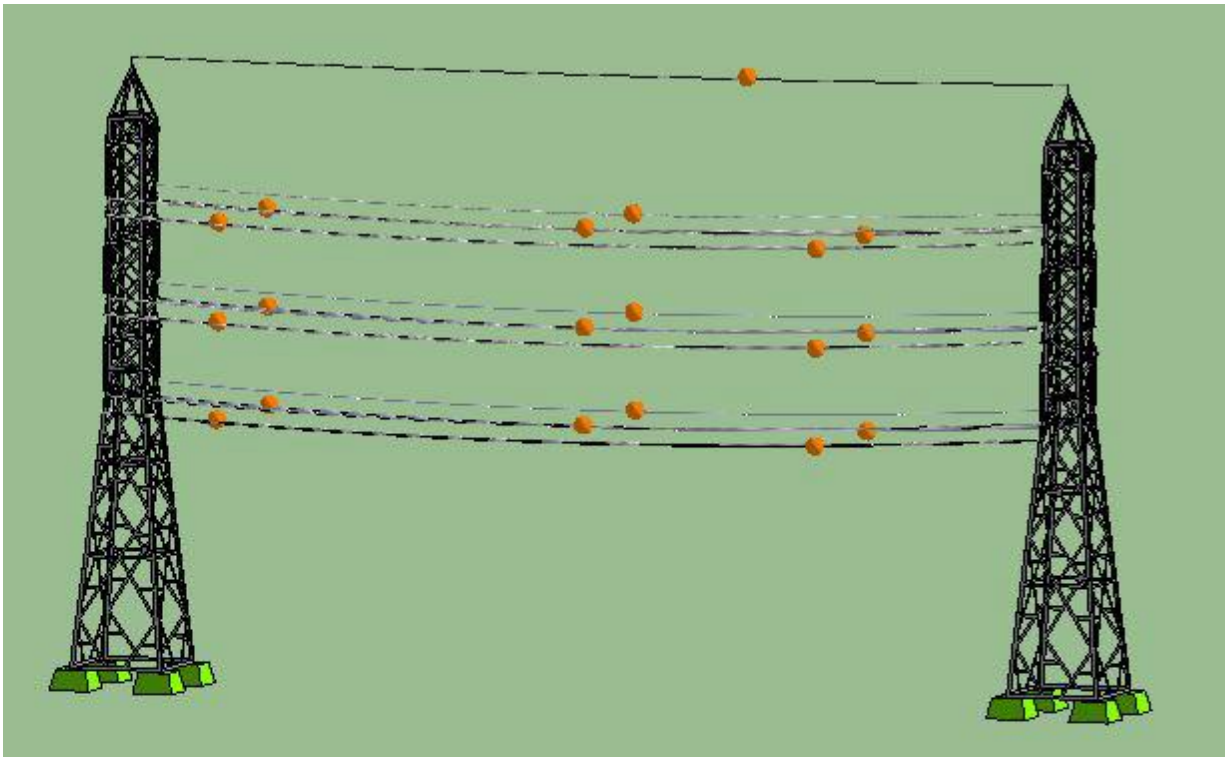


Figure 4.12: Towers at Equal Level

Case 2:

Sag calculation for supports are at unequal levels:

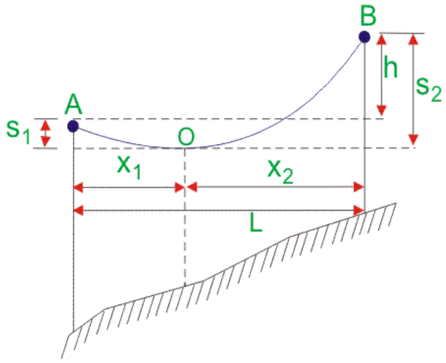


Figure 4.13: sag of distribution line, unequal level [12].

Where:

Suppose AOB is the conductor that has point O as the lowest point.

L: is the Span of the conductor.

h: is the difference in height level between two supports.

X_1: is the distance of support at the lower level point A from O.

X_2: is the distance of support at the upper level point B from O.

T: is the tension of the conductor.

W: is the weight per unit length of the conductor**.**

$$X1 = \frac{L}{2} - \frac{Th}{WL} (m) \tag{4.12}$$

$$X2 = \frac{L}{2} + \frac{Th}{WL} (m) \tag{4.13}$$

$$S1 = \frac{WX1^2}{2T} \ (m) \tag{4.14}$$

$$S1 = \frac{WX2^2}{2T} \ (m) \tag{4.15}$$

Table 4.7: Sag at 0.25 &0.15 of rated tension and 180m span

h (m)	X1 at 0.25 R.T	X1 at 0.15 R.T	X2 at 0.25 R.T	X2 at 0.15 R.T	S1 at 0.25 R.T	S1 at 0.15 R.T	S2 at 0.25 R.T	S2 at 0.15 R.T
1	143.97	146.38	156.03	153.62	1.43	1.48	1.68	1.63
3	131.91	139.15	168.09	160.85	1.20	1.34	1.95	1.79
5	119.86	131.91	180.14	168.09	0.99	1.20	2.24	1.95
7	107.80	124.68	192.20	175.32	0.80	1.07	2.55	2.12
9	95.74	117.45	204.26	182.55	0.63	0.95	2.88	2.30
11	83.68	110.21	216.32	189.79	0.48	0.84	3.23	2.49
13	71.63	102.98	228.37	197.02	0.35	0.73	3.60	2.68
15	59.57	95.74	240.43	204.26	0.25	0.63	4.00	2.88
17	47.51	88.51	252.49	211.49	0.16	0.54	4.41	3.09

Where:

R.T: Rated tension.

W=0.4316 kg/m.

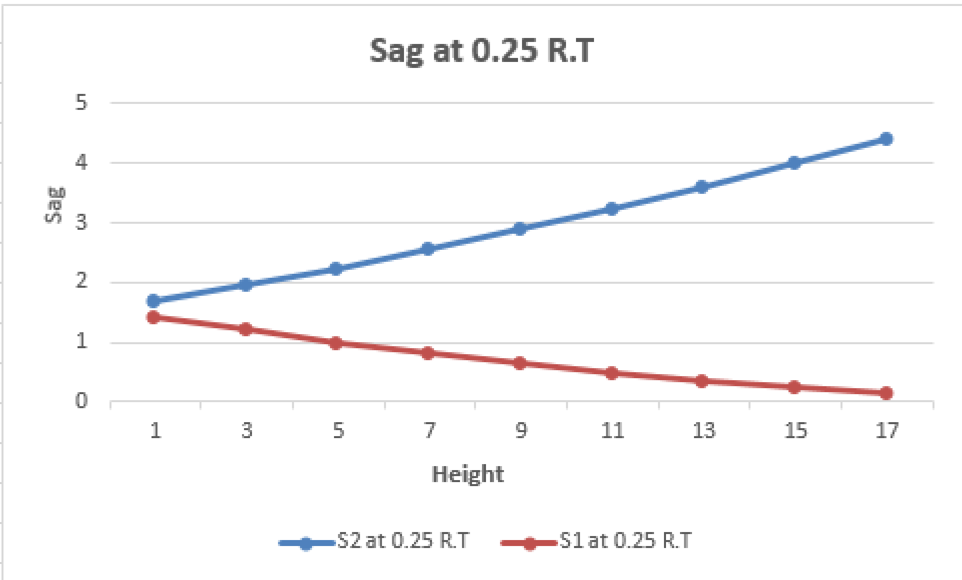


Figure 4.14: Sag at 0.25 of rated tension

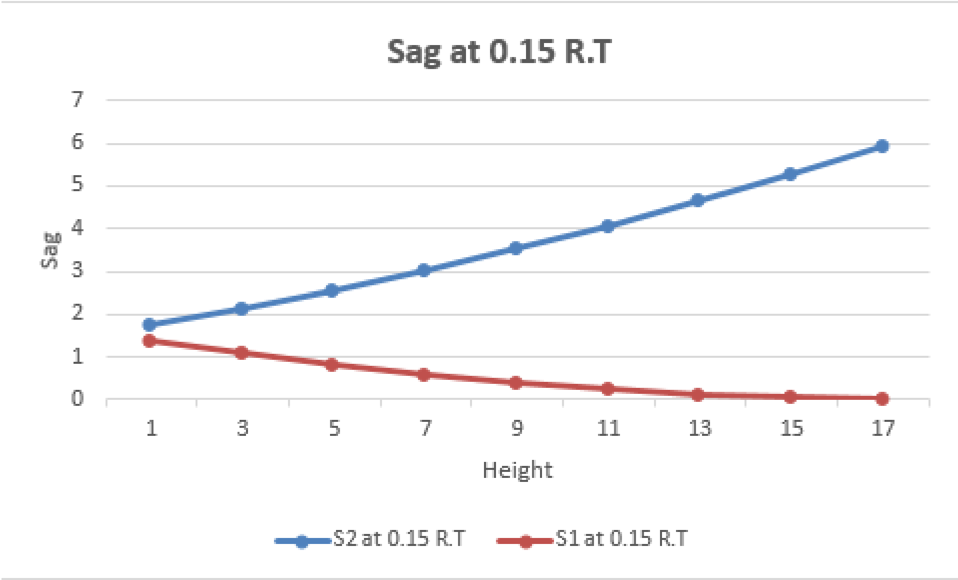


Figure 4.15: Sag at 0.15 of rated tension

The sag of a transmission lime is impact by several phenomena including:

1. Changes in heating.
2. Changes in loading.
3. Wind speed.

The effect of temperature is very low, so we can neglected it.

The Effect of Ice and Wind on Sag:

- The weight per unit length of the conductor is change 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 airflow.
- 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.

If the wind speed = 80 km/h, Ice thickness = 1cm, Ice density =0.934 g/cm^3

$$\text{Wt} = \sqrt[2]{(W + Wi)^2 + (Ww)^2} \tag{4.16}$$

$$\text{Wi} = ice\ density \times \frac{\pi}{4}[(d + 2t)^2 - d^2] \tag{4.17}$$

$$W_w = \text{wind pressure} \times (d+2t) \tag{4.18}$$

Where:

W_t: Total weight of conductor per unit length.

W: weight of conductor per unit length.

W_i: weight of ice per unit length.

W_w: wind force per unit length.

t: Ice thickness

$$\text{Tan}\theta = \frac{Ww}{\text{W+Wi}} \tag{4.19}$$

$$\text{S} = \frac{WtL^2}{8\text{T}}(m) \tag{4.20}$$

4.4.3 Parameters of distribution line

The distribution line resistance

The first transmission line parameter is the resistance of the conductor. The resistance cause I^2R loss and lead to IR voltage drop. Resistance of line depends on the length and cross-section area of the transmission line. The dc resistance of the line given by the following equation:

$$\text{R} = \rho\frac{L}{A} \tag{4.21}$$

Where:

The resistivity of the conductor (Ω-m) ρ, The resistance R of a conductor of length 'l' and cross section 'a' is given by the formula. The resistance of transmission line affected by the operating temperature of the conductor, where the relationship between temperature and resistance of the conductor is direct relationship. The resistance of conductor dependence on temperature given by the following equation:

$$R_2=R_1\,[1+\alpha*(T_2-T_1)] \tag{4.22}$$

Where:

R_1 & R_2 is the resistance at temperatures T_2 and T_1 respectively.

α : The temperature coefficient of resistance.

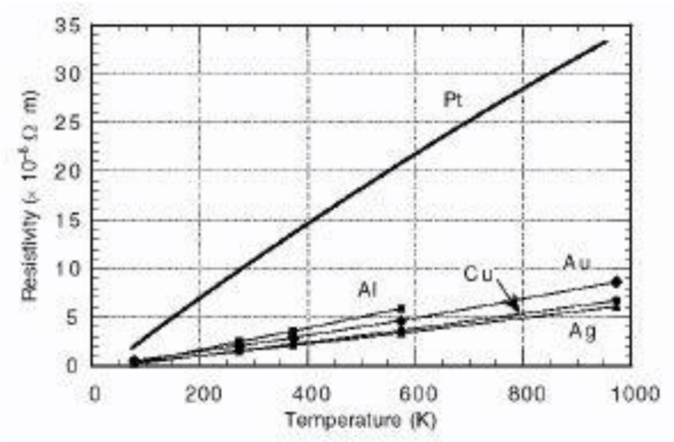


Figure 4.16: The Relationship between resistance and temperature.

$$\rho_0 = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}} \tag{4.23}$$

Where:

ρ_o =Apparent resistivity of the soil in W-m.

R = Measured resistance in ohms.

a = Distance between adjacent electrodes in meters.

b = Depth of the electrodes in meters.

$$R_g = \rho\left[\frac{1}{LT} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1 + h\sqrt{\frac{20}{A}}}\right)\right] \tag{4.24}$$

Where:

ρ = soil resistivity Ω.m.

Lt = total length of grid conductor m.

A = total area enclosed by earth grid $m2$.

h = depth of earth grid conductor m.

Table 4.8 Soil resistivity

Type	**Resistivity (Ohm meter)**
Sea water	0.1-1
Garden soil, alluvial clay	5-50
Clay	5-100
Clay, sand and gravel	40-250
Porous chalk	30-100
Quartzite, crystalline limestone	+300
Rock	1000-10000
Gneiss, igneous rock	+2000
Dry concrete	2000-10000
Wet concrete	30-100
Ice	10000-100000

Terms & Definitions

1. Ground Potential Rise (GPR)

   The maximum voltage that a ground grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. The GPR is equal to the product of the earth current and the equivalent impedance of the grounding system.

$$GPR = (I_G \times R_G) \quad (4.25)$$

   Where:

   IG: Maximum earth grid current.

   Rg: Earth Grid resistance.

2. Step Voltage

   The difference in surface potential experienced by a person bridging a distance of 1 meter with his feet without contacting any other grounded object

3. Touch Voltage

   The potential difference between the ground potential rise and the surface potential at the point where a person is standing while at the same time having his hands in contact with a grounded structure.

4. Mesh voltage

   The maximum touch voltage within a mesh of a ground grid.

5. Metal-to-metal touch voltage

   The difference in potential between metallic objects or structures within the substation site that may be bridge by direct hand-to-hand or hand-to-feet contact.

6. Transferred voltage

   A special case of touch potential where a potential is transferred into or out of the substation from or to a remote point external to the sub-station site. A person standing in a substation, being expose to say rails neutral coming from an adjacent substation at the time of occurrence of earth-fault at that substation is exposed to the transferred potential, which equals difference in GPRs of the two substations.

The factors, which influence the earth mat design, are:

1. Magnitude of Fault Current.
2. Duration of Fault.
3. Soil Resistivity.
4. Resistivity of Surface Material.
5. Shock Duration.
6. Material of Earth Mat Conductor.
7. Earthing Mat Geometry.

The design parameters are:

1. Size of Earth Grid Conductor.
2. Safe Step and Touch Potential.
3. Mesh Potential.
4. Grid configuration for Safe Operation.
5. Number of Electrodes required.

4.5 Surge arrestor

A surge arrester is a device to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. Also called a surge protection device (SPD) or transient voltage surge suppressor (TVSS), this class of device is use to protect equipment in power transmission and distribution systems. A surge arrester should have a low impulse ratio, so that a surge incident on the surge arrester may be bypass to the ground instead of passing through the apparatus.

To protect a unit of equipment from transients occurring on an attached conductor, a surge arrester is connect to the conductor just before it enters the equipment. The surge arrester is also connect to ground and functions by routing energy from an over-voltage transient to ground if one occurs, while isolating the conductor from ground at normal operating voltages. This is usually achieve through use of a varistor, which has substantially different resistances at different voltages.

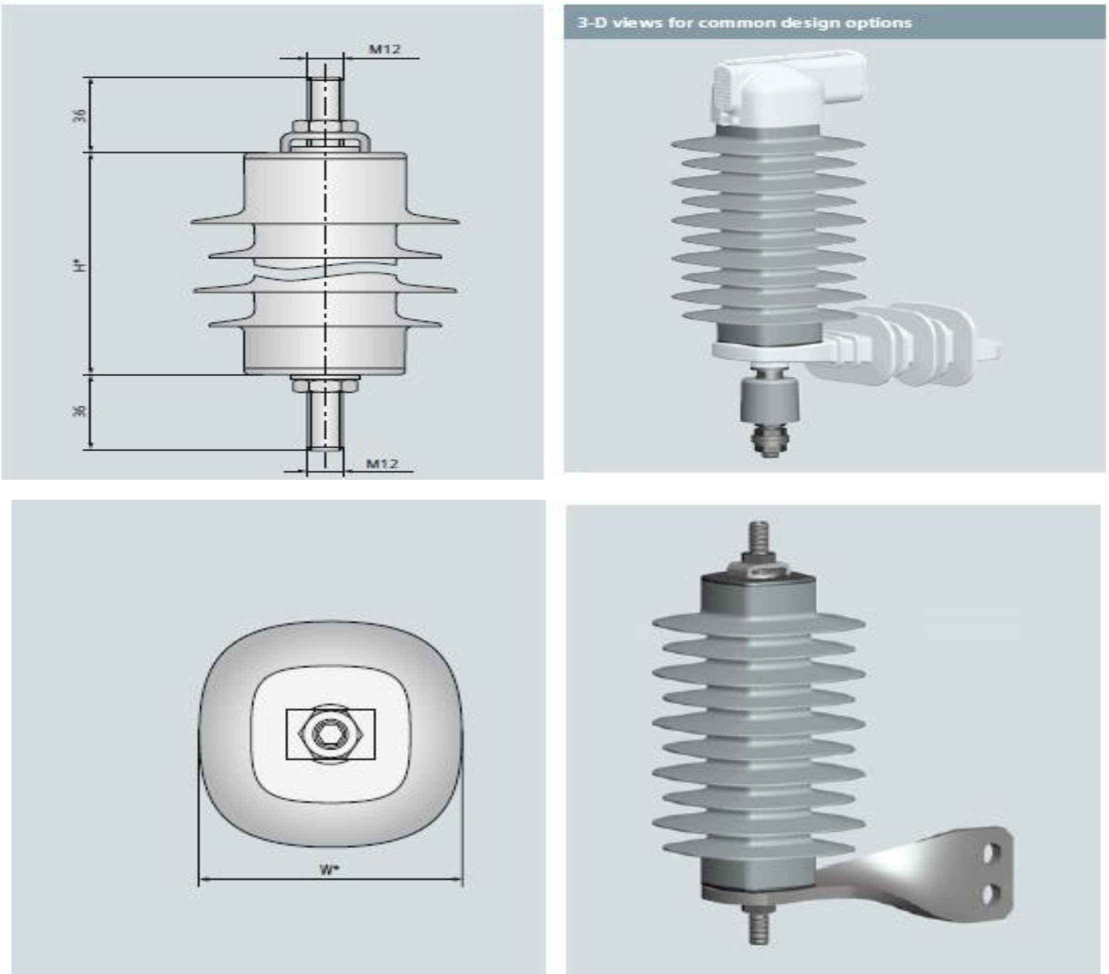


Figure 4.17: 3EK4 surge arrester overall dimensions

Table 4.9: 3EK4 surge arrester general technical data

Nominal discharge current I_n	8/20 µs	10 kA
Line discharge class (LDC)		1
Maximum continuous operating voltage U_c		28.8 kV
Rated voltage U_r		36 kV
Long duration current impulse	2 ms	325 A
High current pressure relief		20 kA
Low current pressure relief		600 A
High-current impulse	4/10 µs	100 kA
Specified long-term load SLL (M_{stat})		175 Nm
Specified short-term load SSL (M_{dyn})		250 Nm
Energy absorption capability (thermal)		3.5 kJ/kV$_r$

Table 4.10: 3EK4 part numbers and technical data (other voltages available on request)

Rated voltage U_r	Continuous operating voltage U_c	Part number	Maximum values of the residual voltages at discharge currents of the following impulses					Flashover distance	Housing insulation		Height H (see fig. 1)	Width W (see fig. 1)	Creepage distance	Net weight
[kV]	[kV]		8/20 µs 1 kA [kV]	8/20 µs 5 kA [kV]	8/20 µs 10 kA [kV]	8/20 µs 20 kA [kV]	30/60 µs 500 A [kV]	[mm]	Lightning impulse withstand voltage 1.2/50 µs [kV]	Power frequency withstand voltage 1 min., wet [kV]	[mm]	[mm]	[mm]	[kg]
22	17.6	3EK4 220-1CJ4	47.8	54.2	58.3	67.0	44.9	212	123	51	204	111	690	2.1
24	19.2	3EK4 240-1CK4	52.2	59.1	63.6	73.1	49.0	242	140	58	234	111	820	2.3
25	20.0	3EK4 250-1CK4	54.3	61.6	66.3	76.2	51.0	242	140	58	234	111	820	2.3
27	21.6	3EK4 270-1CM4	58.7	66.5	71.6	82.3	55.1	278	161	67	270	111	960	2.7
30	24.0	3EK4 300-1CM4	65.2	73.9	79.5	91.4	61.2	278	161	67	270	111	960	2.8
31.5	25.2	3EK4 315-1CM4	68.4	77.6	83.5	96.0	64.3	278	161	67	270	111	960	2.8
33	26.4	3EK4 330-1CR4	71.7	81.3	87.5	101.0	67.3	330	191	79	320	111	1.200	3.2

For this design, for distribution line (33 kV). The selection for surge arrestor will be like this 3EK4 330-1CR4, H=320 mm, W=111 mm.

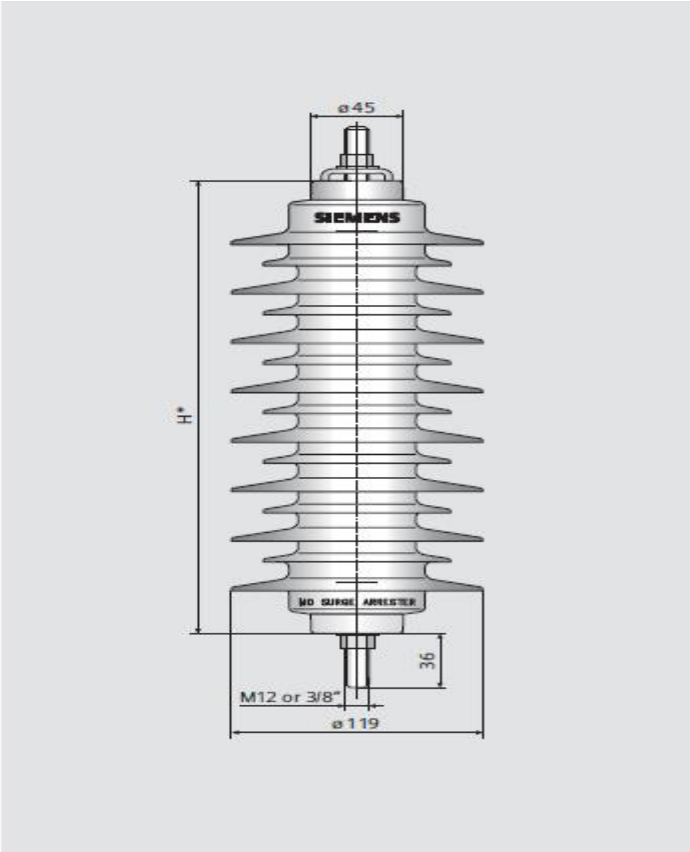


Figure 4.18: surge arrestor main diminution

CHAPTER FIVE: TOWERS

5.1 Distribution Towers

The structures of overhead distribution lines, comprising essentially the supports and foundations, have the role of keeping the conductors at the necessary distance form one another and form earth, with the specified factor of safety to facilitate the flow of power through conductor form one point to another with reliability, security and safety.

5.2 Main Components

A distribution line consists of different components. The conductors through which the electrical energy is to be transfer supported by insulators and towers. Therefor a main component, which consists in distribution line are:

1. Conductor.
2. Earth wire (Ground wire).
3. Insulators.
4. Towers.
5. Cross arms.
6. Foundation.

5.3 Tower configuration and types

The configuration of a distribution line tower depends on the following factors:

1. The length of the insulator assembly.
2. The minimum clearances to be maintain between conductors, and between conductor and tower.
3. The location of ground wire or wires with respect to the outermost conductor.
4. The mid-span clearance required from consideration of the dynamic behavior of conductors and lightning protection of the line.
5. The minimum clearance of the lowest conductor above ground level.

The tower configuration is determine essentially by three factors:

1. Tower height.
2. Base-width.
3. Top hamper-width.

In general, the towers should have the following properties:

1. High mechanical strength to withstand the weight of conductors and wind loads.
2. Having low Wight without effect on the mechanical strength.
3. Cheap in cost and economical to maintain.
4. Have long life.
5. Easy accessibility of conductors for maintenance.

Classification of towers depending on the different considerations:

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)

According the number of circuits:

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

According method of tower erection:

1. Build-up method.
2. Section method.
3. Ground assembly method.
4. Helicopter method.

According to function, it is divide to four main types:

1. Suspension towers.
2. Tension towers.
3. Angle towers.
4. End tower.

5.4 Determination of tower height

The factors governing height of a tower are:

1. Minimum permissible ground clearance (h1).
2. Maximum sag (h2).
3. Vertical spacing between conductors (h3).
4. Vertical clearance between ground wire and top conductor (h4).

The following aspects are consider essential for fixing the tower outline:

1. Maximum sag of lower conductor.
2. Height and location of ground wire.
3. Length of cross arm and conductor spacing.
4. Minimum mid-span clearance.
5. Tower width at base and at top hamper.

5.5 Clearances

5.5.1 General Remarks

Power conductors along the entire route of the transmission line should maintain requisite clearance to ground over open country, national highways, important roads, electrified and un-electrified tracks, navigable and non-navigable rivers, telecommunication and power lines etc. as laid down in the various national standards issued by the respective authorities.

The height of tower in the system with 33 kV approximately 20 m [9], as shown in the figure bellow:

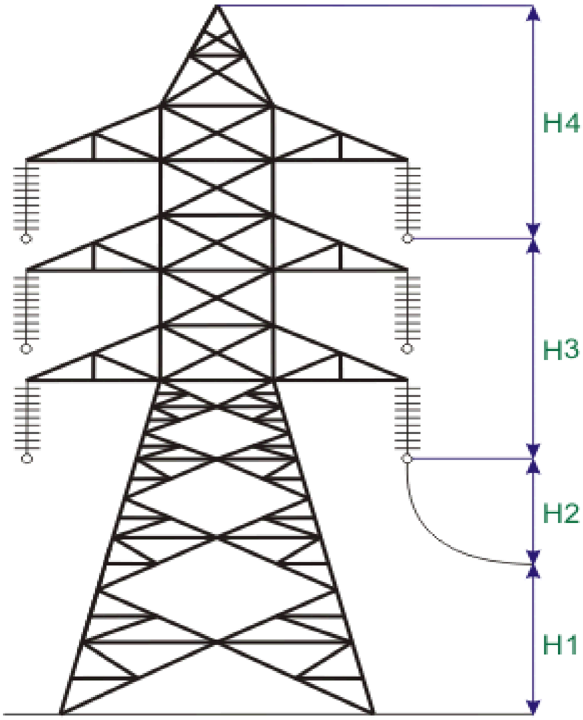


Figure 5.1 Double circuit tower.

$$\text{Height of tower} = H1+H2+H3+H4 \quad (5.1)$$

5.5.2 Ground Clearance

Indian electricity rules (1956), under Clause 77 (incorporating amendments), stipulates clearance above the ground of the lowest point of the conductor. For Extra High Voltage (EHV) lines, this clause stipulates that the clearance above the ground shall not be less than 5.1 m plus 0.3 m for every 33,000 volts or part thereof by which the voltage of the line exceeds 33,000 volts. The permissible minimum ground clearance for different voltages adopted in India are furnish in table 5.1 and these are applicable for transmission lines running in the open country.

h1: Distance represents safety, the distance between the last line on the tower and the ground. We can calculate it by using the following equation:

$$C_{L(h1)} = 5.182 + 0.305 \times K \quad (5.2)$$

Where:

$$K = \frac{V - 33}{33} \quad (5.3)$$

V: Voltage (kV)

Table 5.1: Standard ground clearance [13].

Voltage level	clearance
Up to 33kV	5.8 m
33 kV – 66 kV	6 m
66 kV – 132 kV	6.7 m
132 kV – 273 kV	7 m
275 kV – 400 kV	7.3 m

For 33 kv, the distance between lower point of sage and ground (H1) should not be less than 5.8 m.

5.5.3 Horizontal Clearance

Clause 80(2) of Indian electricity rules (1956) stipulates that the horizontal clearance between the nearest conductor and any part of the structure shall base on maximum deflection due to wind pressure. It should not be less than the values shown in Table 5.2 corresponding to the voltage.

Table 5.2: Horizontal Clearance [13]

a.	For high voltage lines up to and including 11,000 volts	1.219 m
b.	For high voltage above 11,000 volts and up to and including 33,000 volts	1.829 m
c.	For Extra High Voltage Lines (EHV) (plus 0.305 m for every additional 33,000 volts or part thereof)	1.829 m

5.5.4 Spacing of Conductors

Considerable differences are founding in the conductor spacing, adopted in different countries and on different transmission line systems in the same country. The spacing of conductors is determine by considerations, which is part electrical and part mechanical. The material and diameter of the conductors should also be consider, when deciding the spacing, because a smaller conductor, especially made of aluminum, having a small weight in relation to the area presented to the crosswind, will swing out of vertical plane farther than a conductor of larger cross-section. Usually, conductors will swing synchronously (in phase) with the wind, but with long spans and small wires, there is always a possibility of the conductor swinging non-synchronously, and the conductor and the maximum sag at the center of the span are factors, which taken into account in determining the distance apart, at which they are strung.

There are a number of empirical formulae in use, deduced from spacing, which have successfully operated in practice, while research continues on minimum spacing, which could be employee. The spacing, both horizontal and vertical, between conductors commonly adopted on typical transmission lines in India are giving in Table 5.3.

Table 5.3: Minimum clearances for voltage range 1 kV < Um up to and including 245 kV [13]

Nominal system voltage (Un) (kV)	Minimum phase to earth (N) & phase to phase clearance (mm)
11	500
22	500
33	500
50	500
66	630
110	1100
220	2100

5.6 Critical parameters of tower

The following aspects are consider essential for fixing the tower outline:

1. Maximum sag of lower conductor.
2. Height and location of ground wire.
3. Length of cross arm and conductor spacing.
4. Minimum mid-span clearance.
5. Tower width at base and at top hamper.

5.6.1 Maximum Sag of Lower Conductor

The size and type of conductor, wind, climatic conditions of the region and span determines the conductor sag and tension. Span length is fixe from economic consideration. The maximum sag for conductor span occurs at the maximum temperature and still wind conditions. The maximum value of sag is take into consideration in fixing the overall height of the steel tower structure. In regions prone to snowfall, the maximum sag may occur at 0°, with the conductor loaded with ice, in still wind condition. While working out tension for arriving at the maximum sag, the following stipulations laid down in Indian electricity rules (1956) are to be satisfied.

1. The minimum factor of safety shall be two based on their ultimate tensile strength.
2. Conductor tension at 32° Centigrade (90°F) without external load shall not exceed the following percentage of the ultimate tensile strength of the conductor.

The Components of distribution Tower:

1. Peak of the transmission tower.
2. Cage of transmission tower.
3. Cross arm of the transmission tower.
4. Body of tower.

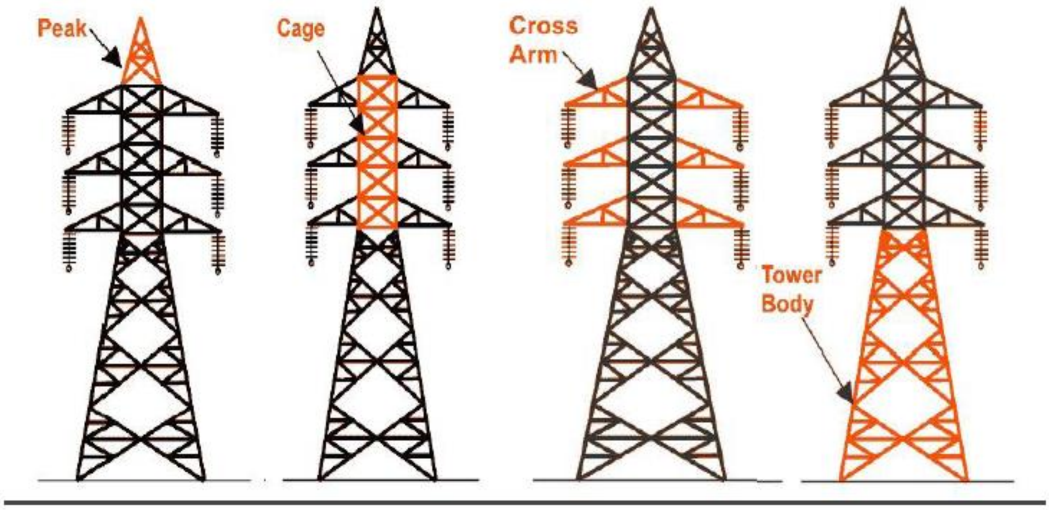


Figure 5.2 Components of tower.

Selection of Tower Structure:

1. Number of circuits.
2. Length of insulator.
3. Minimum clearances between the conductors.
4. Location of ground wire.
5. Mid-span clearance.
6. Minimum clearance of the lowest conductor above ground level.

5.6.2 Cross arm's length

The cross arms is a parts of the transmission towers used mainly to install insulators and lines. The cross arm length depends on the operating voltage value.

Number of arms depends on the type of the tower according the number of circuit. Where each circuit needs three cross arms and the minimum distance between every arm and other in 33 kV level is 0.5 m [13].

The length of every arm is approximately 1.829 m [13].

5.7 Path and number of towers

The number of towers that needed to cover the specific area on the distance between the starting point and ending point. In addition to the distance between the towers. As mentioned earlier that the distance between the towers ranging between (100-190) m.

The distance between Tarqoumia and Al-Dahiriya is 22 km.

The number of towers for this path will be 373 towers distribute as

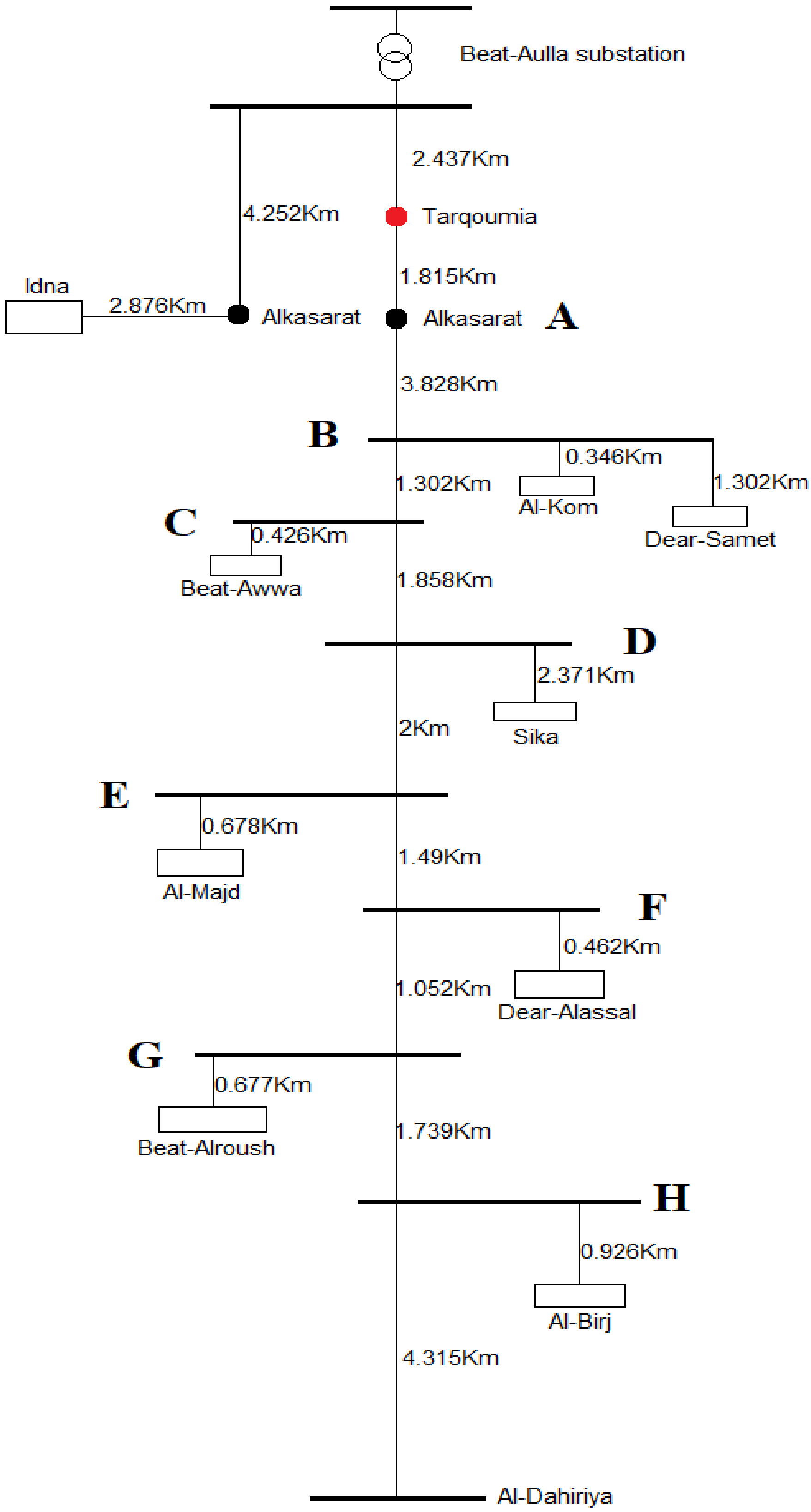
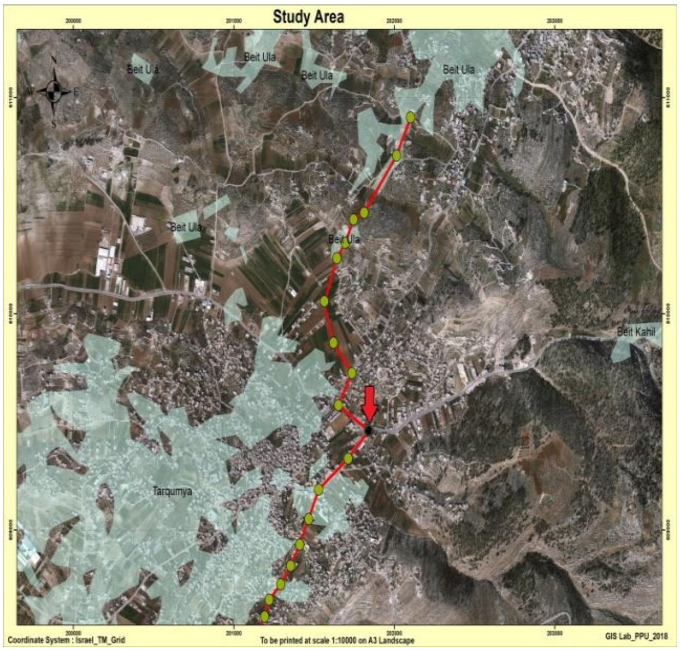
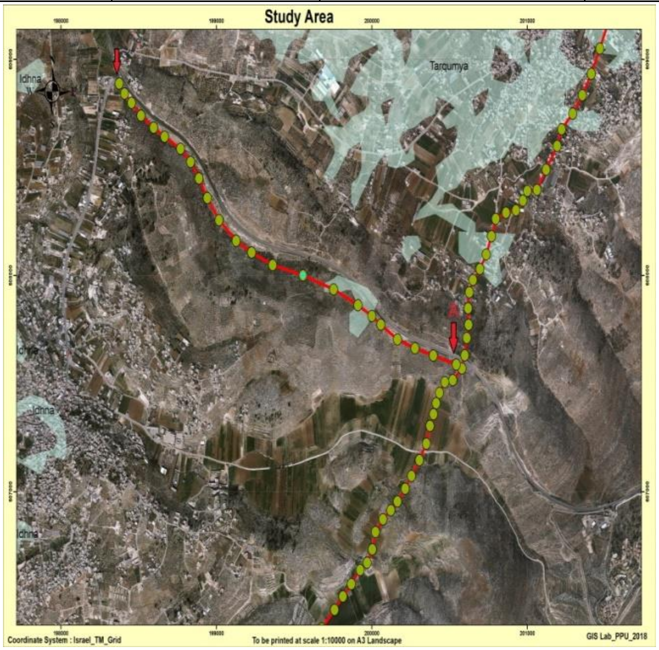


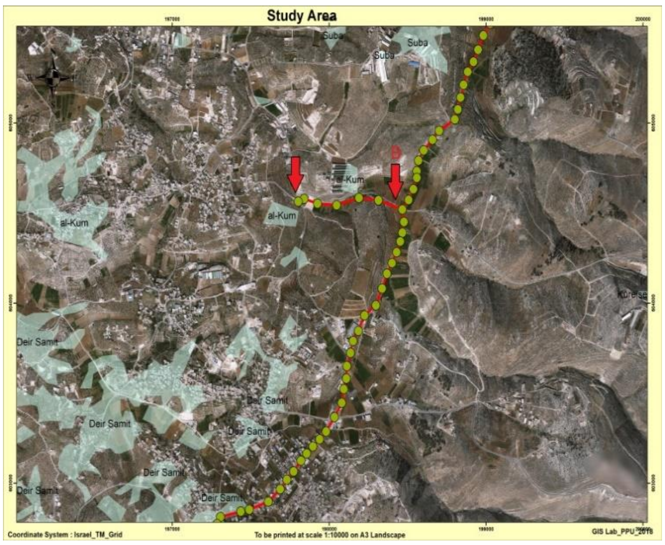
Figure 5.3 Path of line [14].

Path From Beat-Aulla substation to Idna [14]					
path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total
From station to A	21	7	6	2	36
From A to Adna	31	9	17	2	23



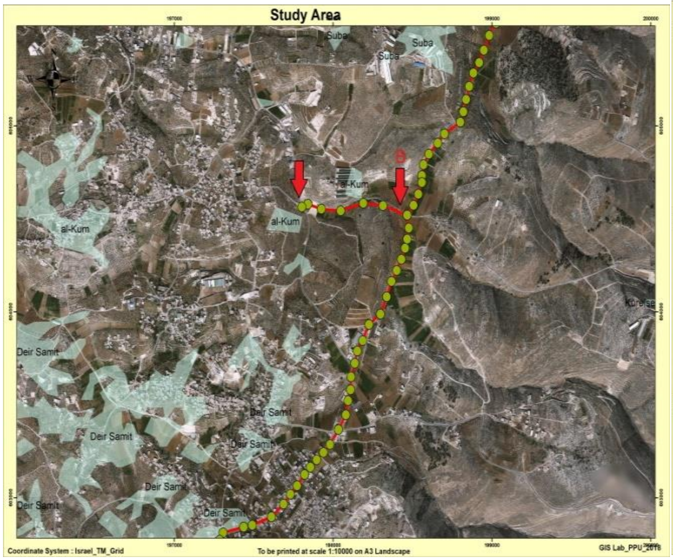


Path From A to B [14]					
Path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total
From A to B	27	9	13	2	51

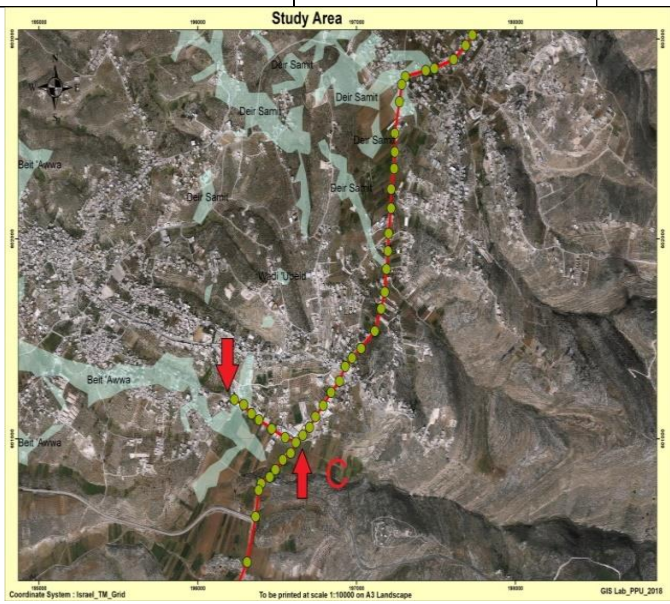


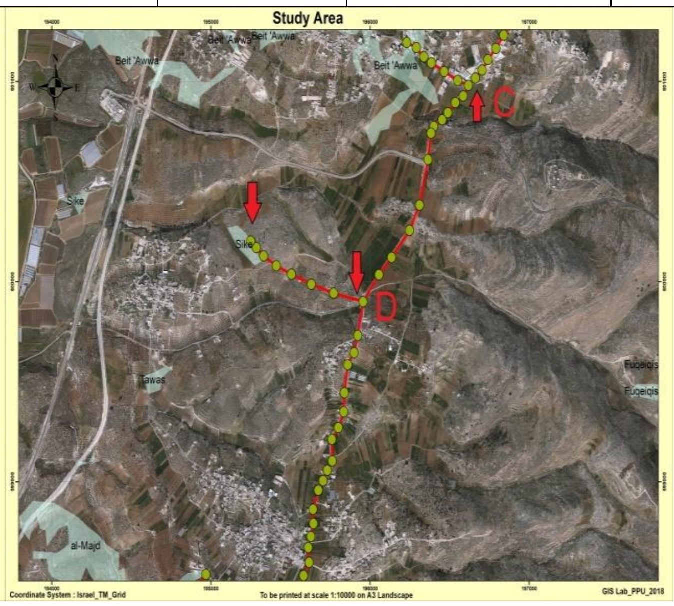
Path From B to C [14]					
Path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total

From B to Al-Kom	2	0	3	1	6
From B to C	31	12	7	2	52



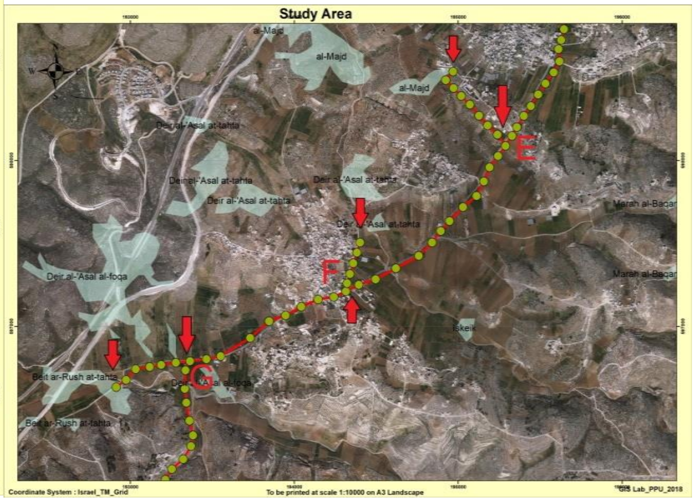
Path From C to D [14]					
Path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total
From C to Beat-Awwa	4	1	0	1	6
From C to D	4	3	3	2	12





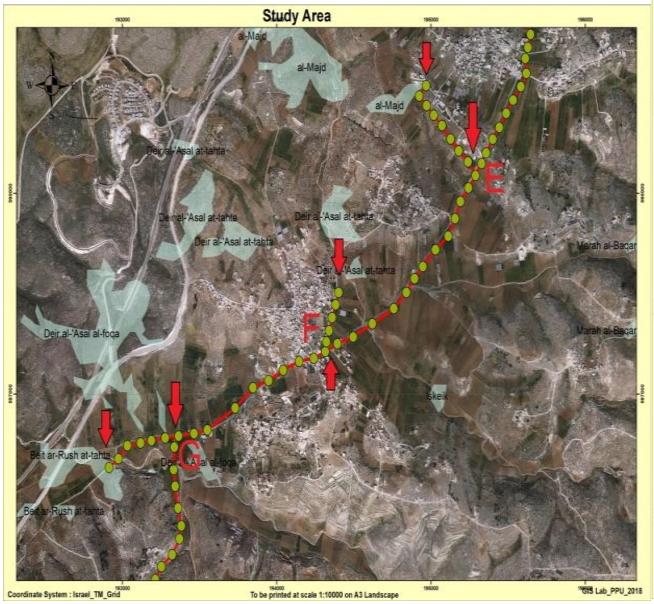
Path From D to G [14]					
Path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total
From D to G	16	8	18	4	46
From D to Sika	5	1	0	1	7

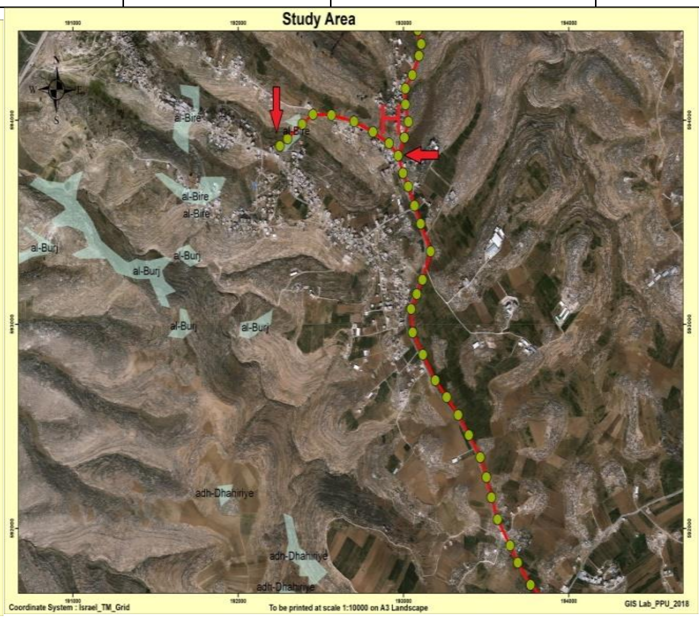
From E to Al-Majed	6	0	1	1	8
From F to Dear-Allassal	3	1	0	1	5
From G to Beat-Alroush	4	0	1	1	6



Path From G to H [14]

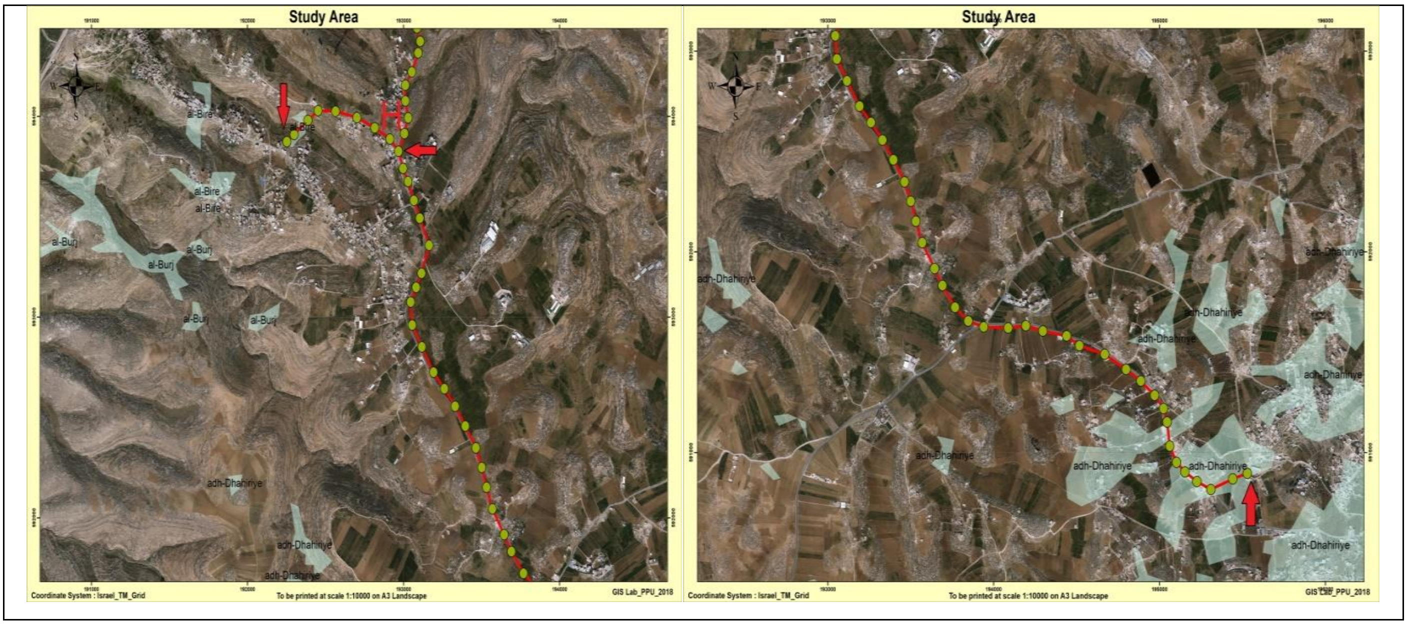
Path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total
From G to H	16	13	7	2	38
From H to Al-Burj	4	2	1	1	8





Path From H to Al-Dahiriya city [14]

Path	Suspension towers	Tension towers	Angle towers	Start and End tower	Total
From H to Al-Dahiriya	19	13	7	2	41



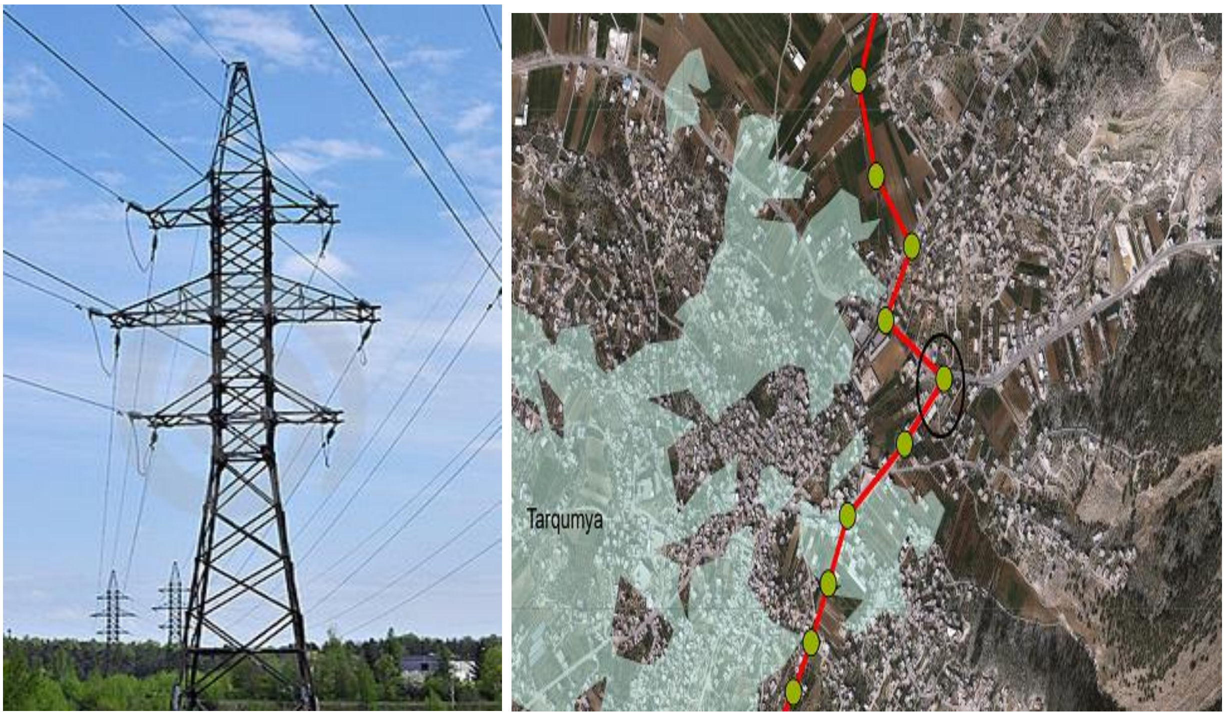


Figure 5.4 Angle tower.

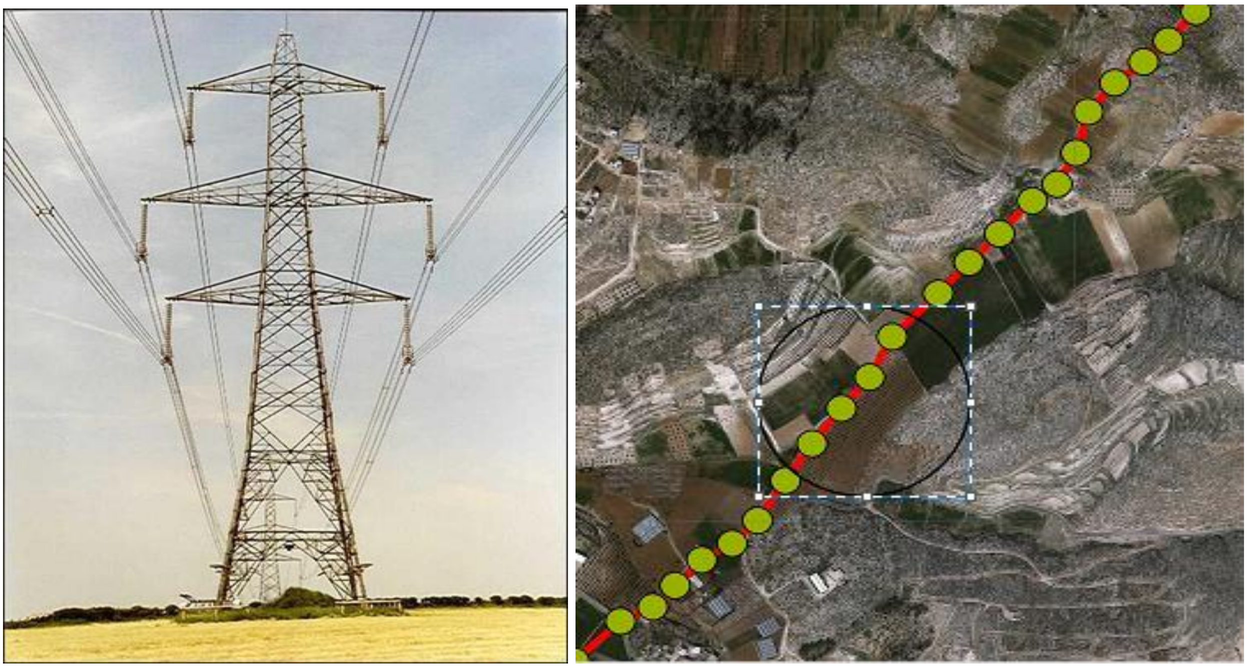


Figure 5.5 Suspension tower.

5.8 Tower Earthing

Earthing is one of the most important elements in the power systems. This element is design to ensure the safety of people and equipment in the network of the dangerous of high current flow in the system and this current caused by fault or short circuit and the surge current by a lightning discharge can occur. Therefore, the earthing resistance should be made as low as possible, to ensure a greater amount of current flow through the ground to minimize the impact of this current on the system.

The following figure shows the earthing system:

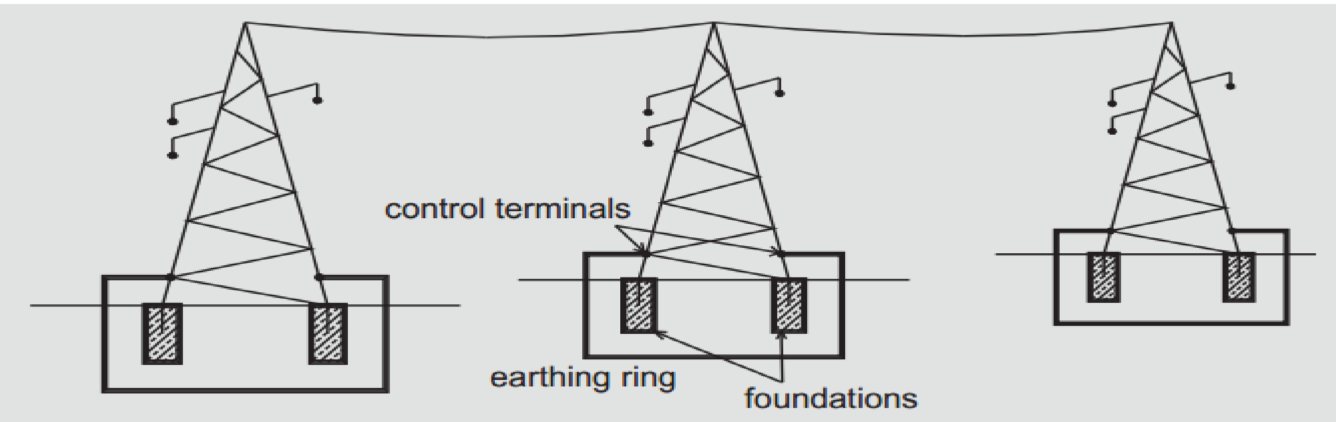


Figure 5.6 Earthing of towers

Earth resistance depends upon soil resistivity and the tower footing resistance will be 10Ω and should not be more than 20 Ω under any condition throughout the year.

Method of tower grounding:

1. Buried Conductor

   This method is use when resistance is low soil. By using this method, one or more conductor connected to the legs buried in the foundations of the tower.

2. Counterpoise wire

   This method is use when the soil resistance is high and the conductivity mostly in the upper layer of the soil. The conductor is burring at a depth of 0.5 m of the earth's surface and are connecting to the legs of towers.

3. Rod pipe

   This method is use when increasing conductivity with the increase of soil depth. It is buried conductor length of 3 to 4 m in the ground and connected the conductor with the tower through appropriate wire.

4. Treated earth pits

   The latter method to the process of grounding is use when the resistant around the tower is very high. As in the previous method, the use of connector length of 3-4 meters and buried in treated earth pits to increase conductivity of the soil.

Choose any of the methods previously mentioned is heavily dependent on the resistance to the soil around the tower.

5.9 Summary

- ✓ The ground clearance is 6 m.
- ✓ In the voltage level (33kV), the standard clearance between conductors is 0.5 m [13].
- ✓ The distance between the two circuits and the tower is 1.829 m [13].
- ✓ The width of cage of tower is approximately 1.1 m [9].
- ✓ For the main feeder the highest of tower will be 20m and the width cage will be 1.1m*1.1m[9]
- ✓ For distribution feeders, the highest of towers will be 12m with 1m *1m width cage [9].

Table 5.4: Number of main towers

From Beat-Aulla to A	36
From A to B	51
From B to C	52
From C to D	12
From D to E	24

From E to F	13
From F to G	9
From G to H	38
From H to Al-Dahiriyea	41
Total	276

Table 5.5: Number of distribution towers

From Beat-Aulla to Idna	59
From B to Al-Kom	6
From C to Beat-Awwa	6
From D to Sika	7
From E to Al-Majed	8
From F to Dear-Allassal	5
From G to Beat-Alroush	6
From H to Al-Burj	8
Total all towers	381

Table 5.6: Type and number of all towers.

	Suspension towers	**Tension towers**	**Angle towers**	**Start and End tower**
For main feeder	177	28	61	10
From station to Idna	31	9	17	2
From B to Al-Kom	2	0	3	1
From C to Beat-Awwa	4	1	0	1
From D to Sika	5	1	0	1
From E to Al-Majed	6	0	1	1
From F to Dear-Allassal	3	1	0	1
From G to Beat-Alroush	4	0	1	1
From H to Al-Burj	4	2	1	1
Total all towers	236	42	84	19

CHAPTER SIX E-TAP

6.1 Introduction

6.2 ETAP Description

6.3 Filling data

6.3.1 Transformers

6.3.2 Distribution line

6.3.3 Load

6.3.4 Photovoltaic system

6.3.5 E-TAP Simulation

6.1 Introduction

ETAP Power Station is a 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. Moreover, 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.

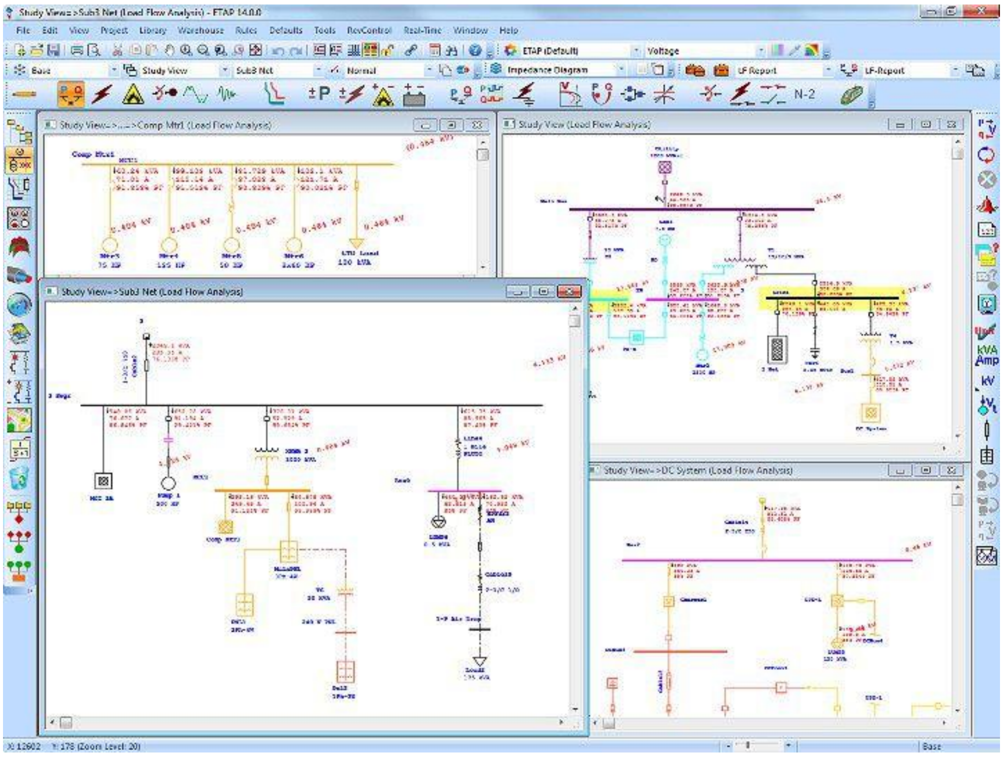


Figure 6.1 ETAP Load Flow Software

6.2 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. Multiple loading conditions.
6. User access control and data validation.
7. Asynchronous calculations, allow multiple modules to calculate simultaneously.
8. 3-phase and single-phase modeling including panels and sub-panels.

6.3 Filling data

To run the program we must to enter the data in filling spaces distribution line, transformers, and load, source, PV system.

6.3.1 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.

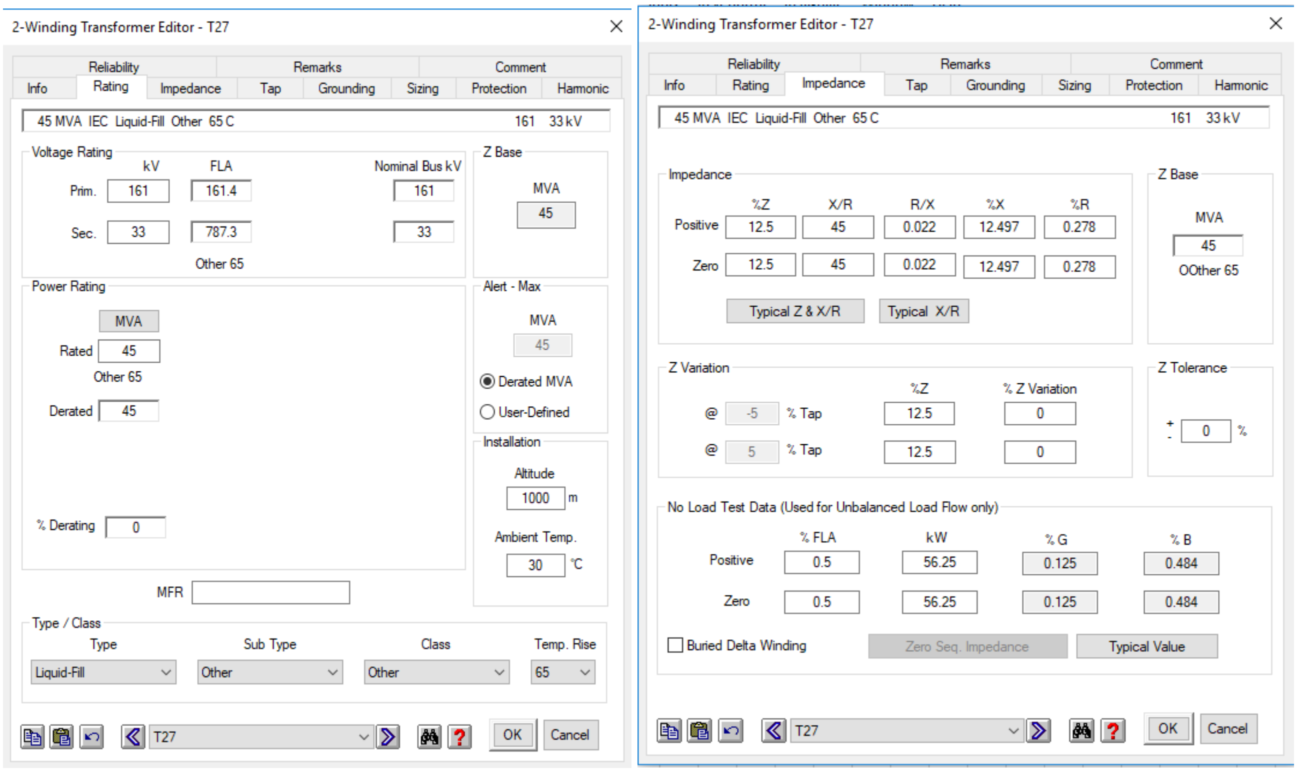


Figure 6.2: substation Transformers data in ETAP

Figure 6.3: Idna Transformer data for PV in ETAP

6.3.2 Distribution line

In this part, we can put distribution line parameters and the information of impedance and we can insert a new distribution line and its parameter if we do not found the same distribution line.

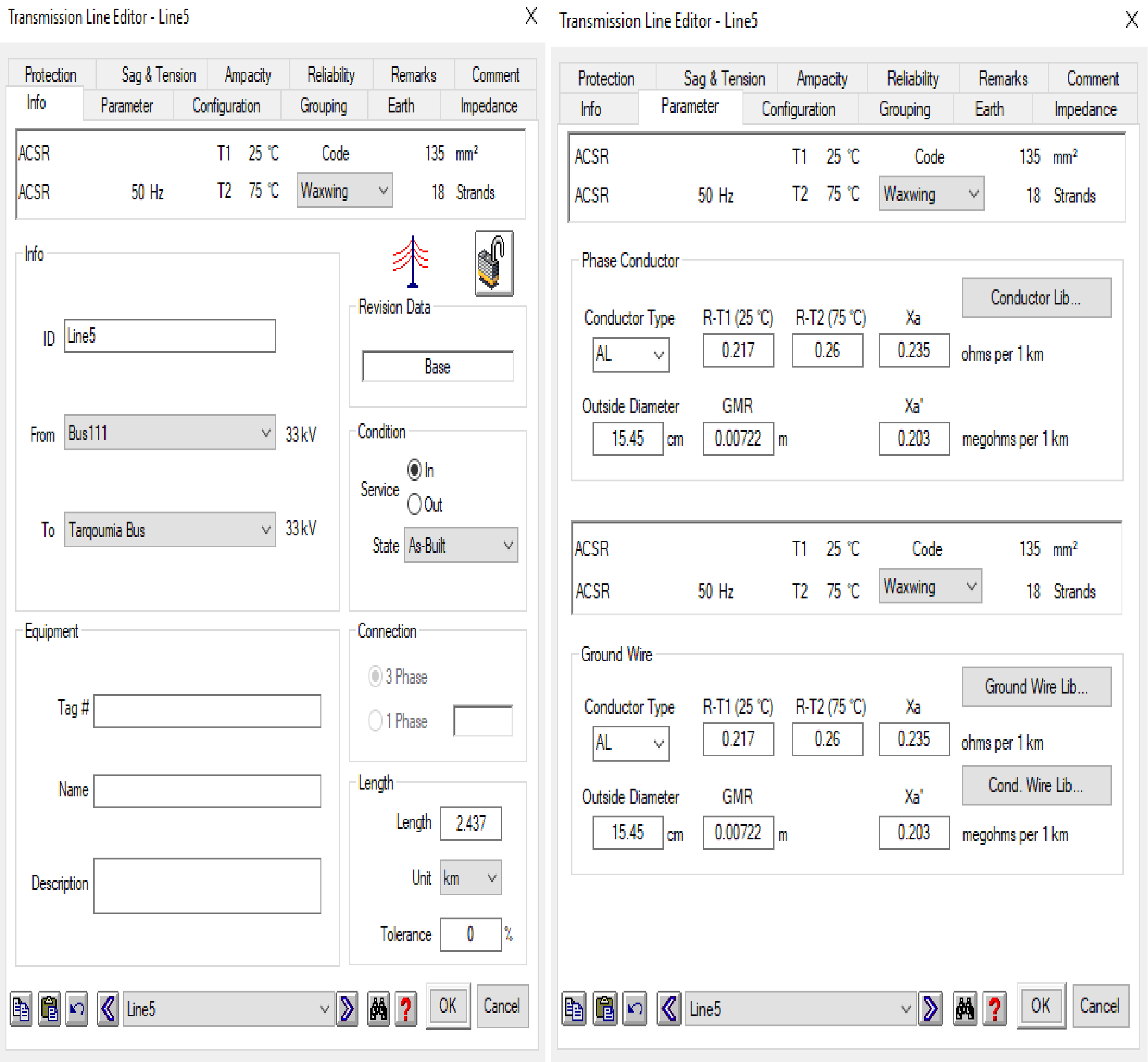


Figure 6.4: Distribution line data in ETAP

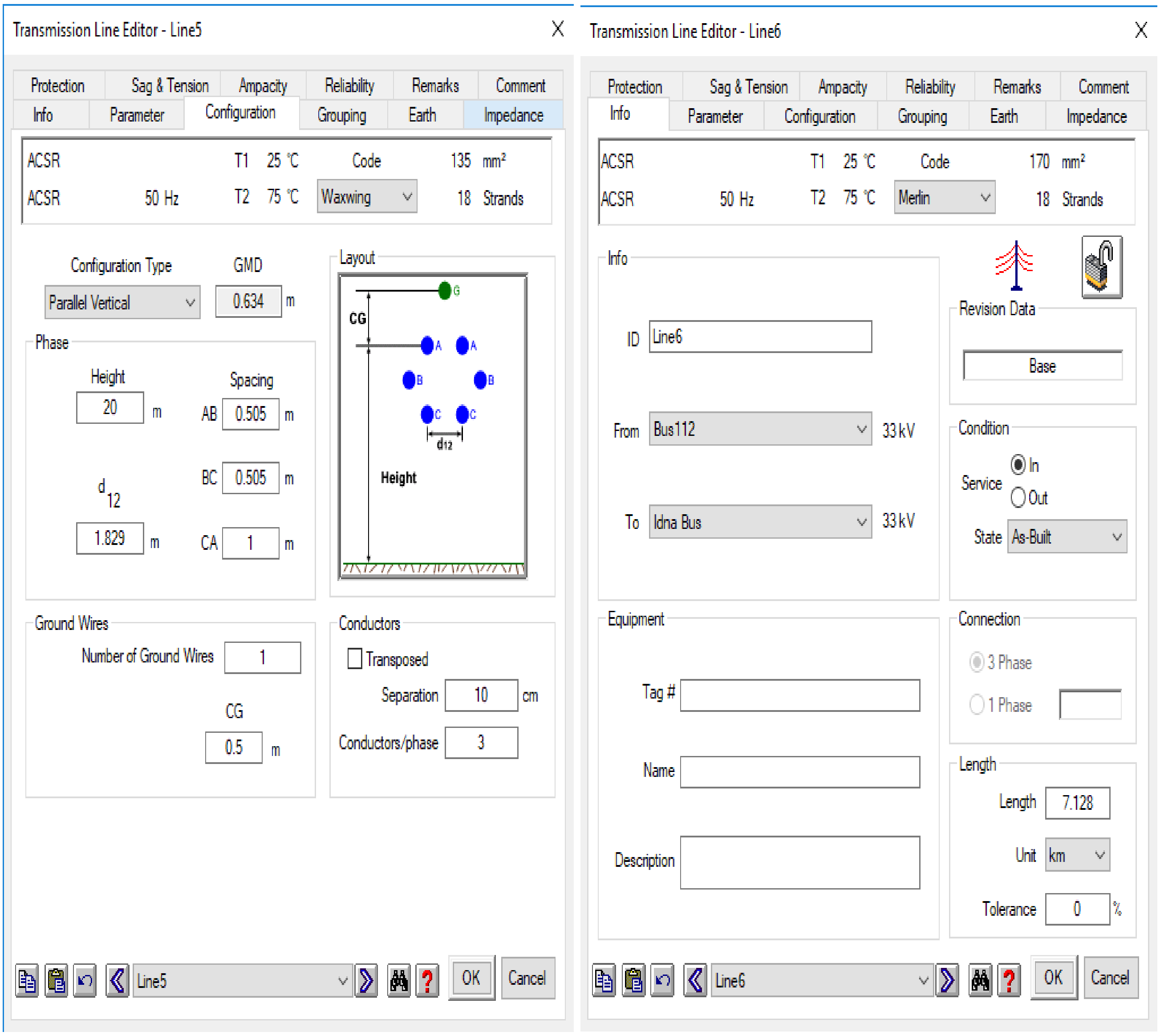


Figure 6.5: Distribution line data in ETAP

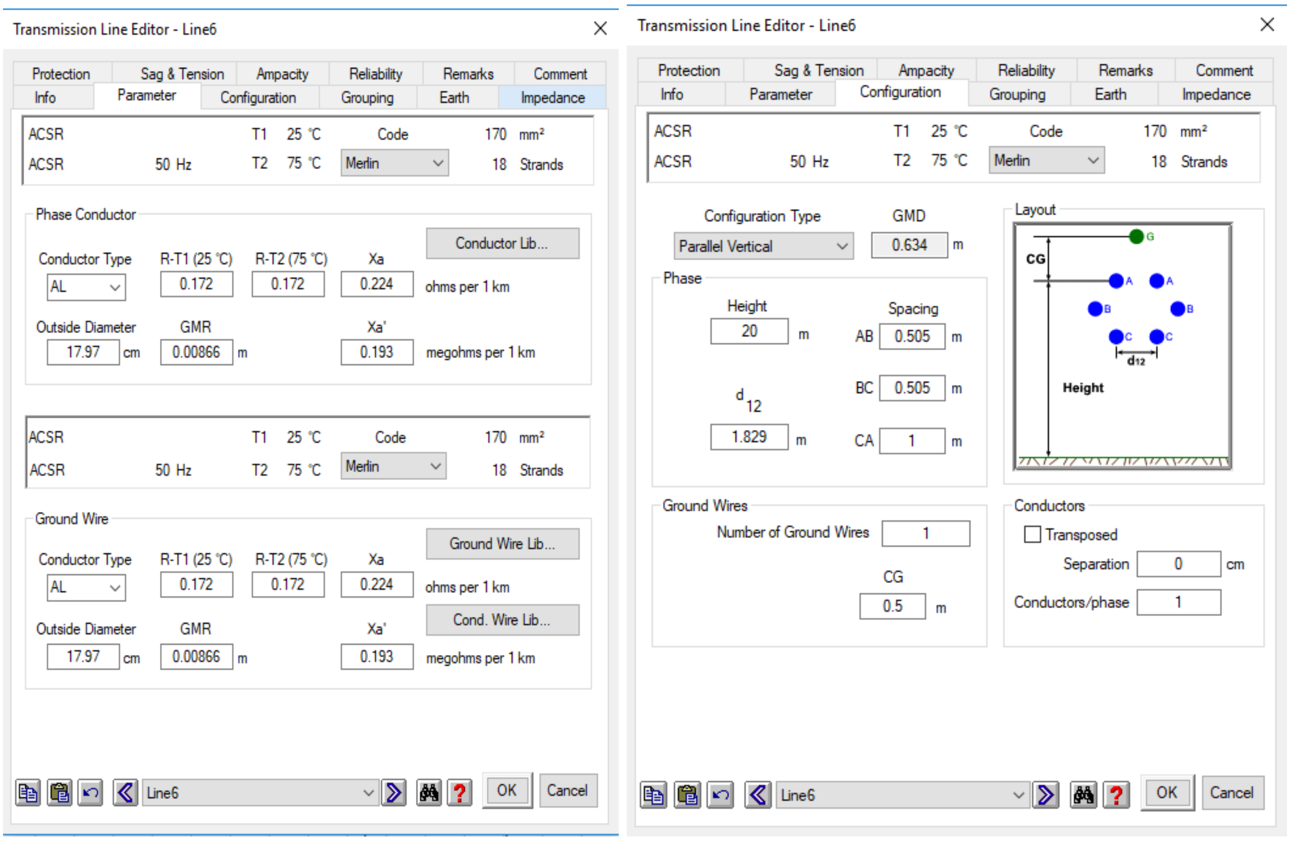


Figure 6.6: Distribution line data in ETAP

6.3.3 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 " Z " percentage in the industrial region because of induction and synchronous motors, the ETAP window show the parameter that filled for a Sponge factory.

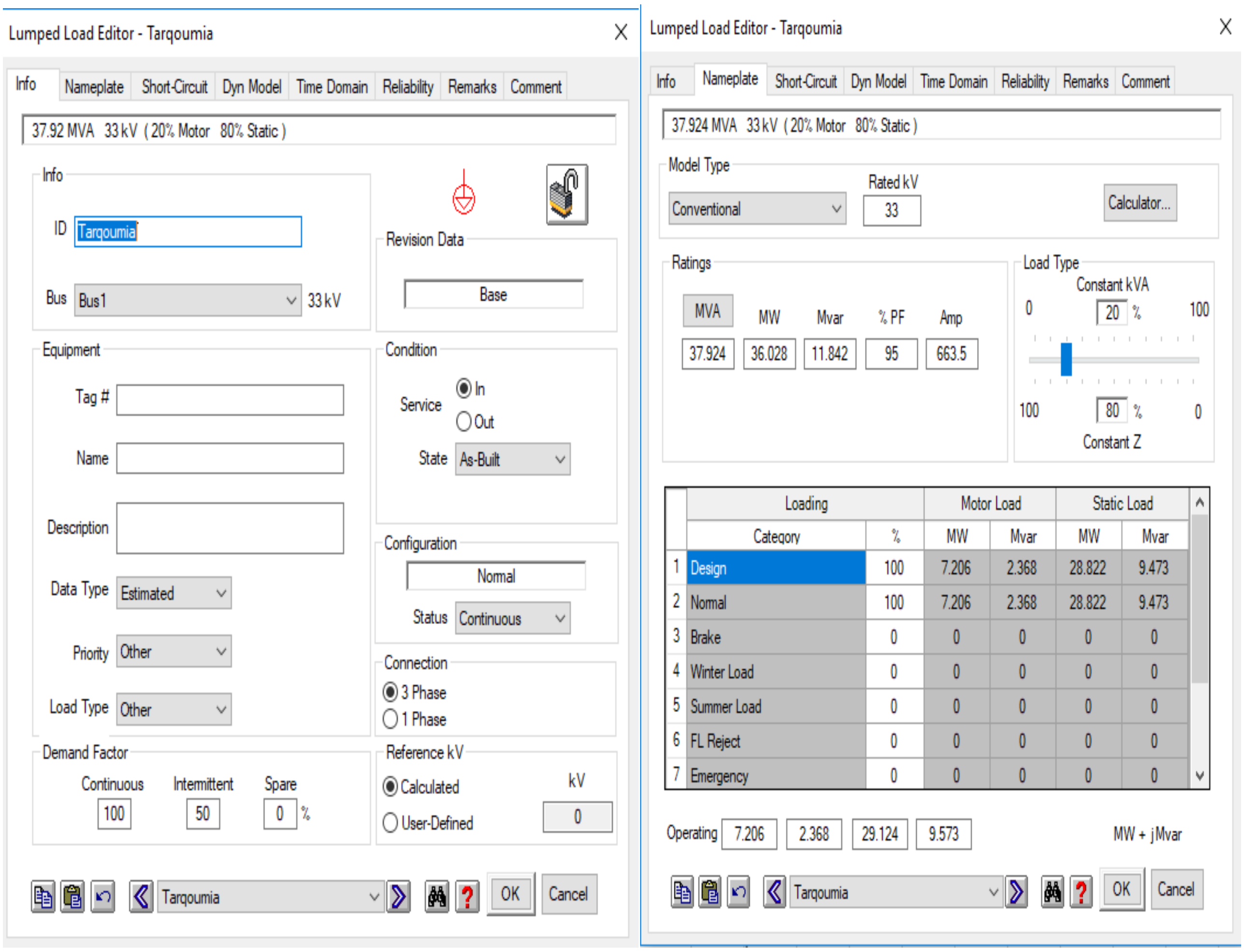


Figure 6.7: Tarqoumia Load data in E-tab

6.3.4 Photovoltaic system

Photovoltaic (PV) Array comprising of solar panels are the predominant power generation components of renewable distributed energy resources (DER), solar farms with grid-tied inverters, islanding micro grids, and smart grids. PV Array converts solar radiation energy into direct current using semiconductors and then to alternating current electric power through inverters.

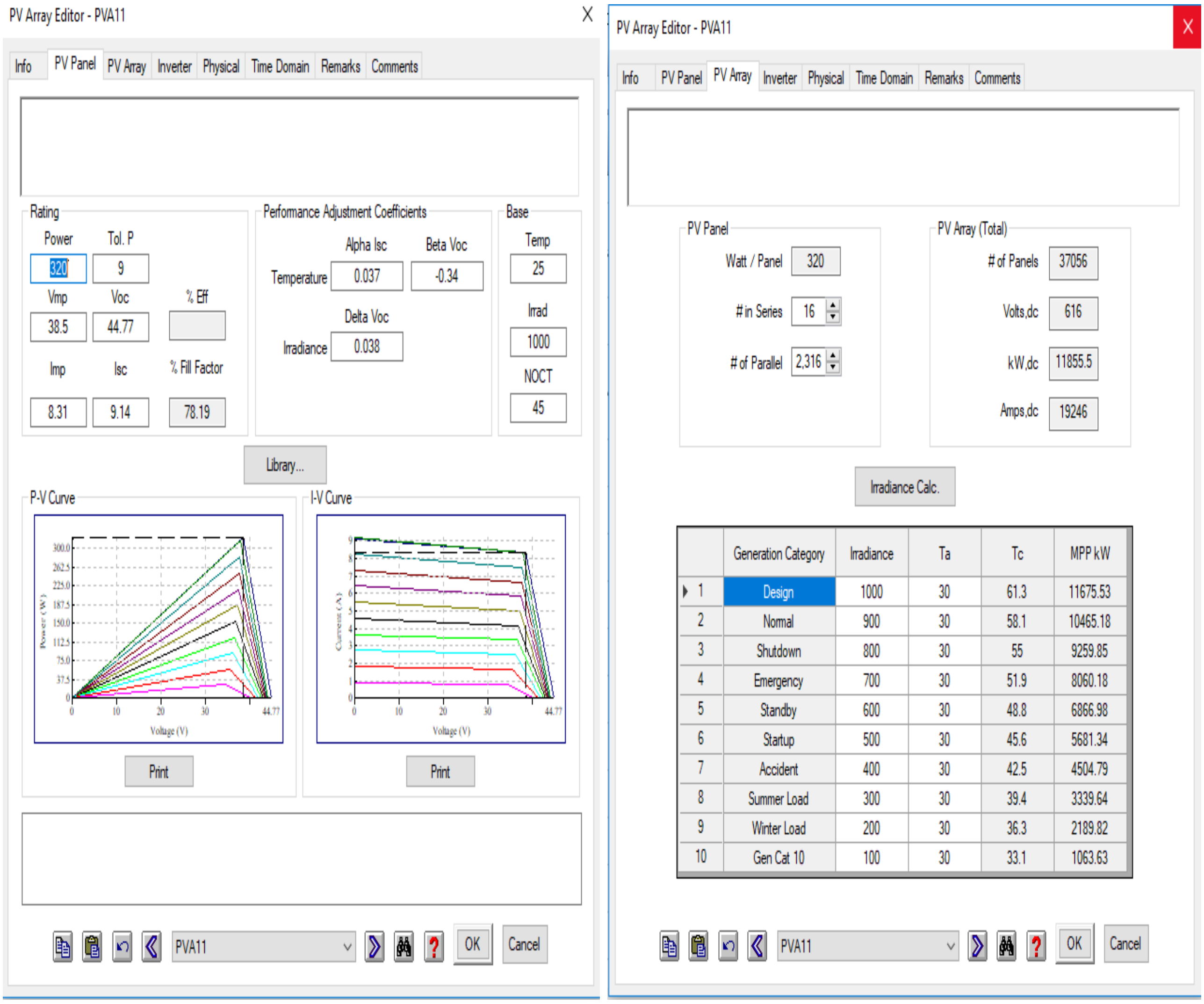


Figure 6.8: Idna PV source sitting data in E-tab

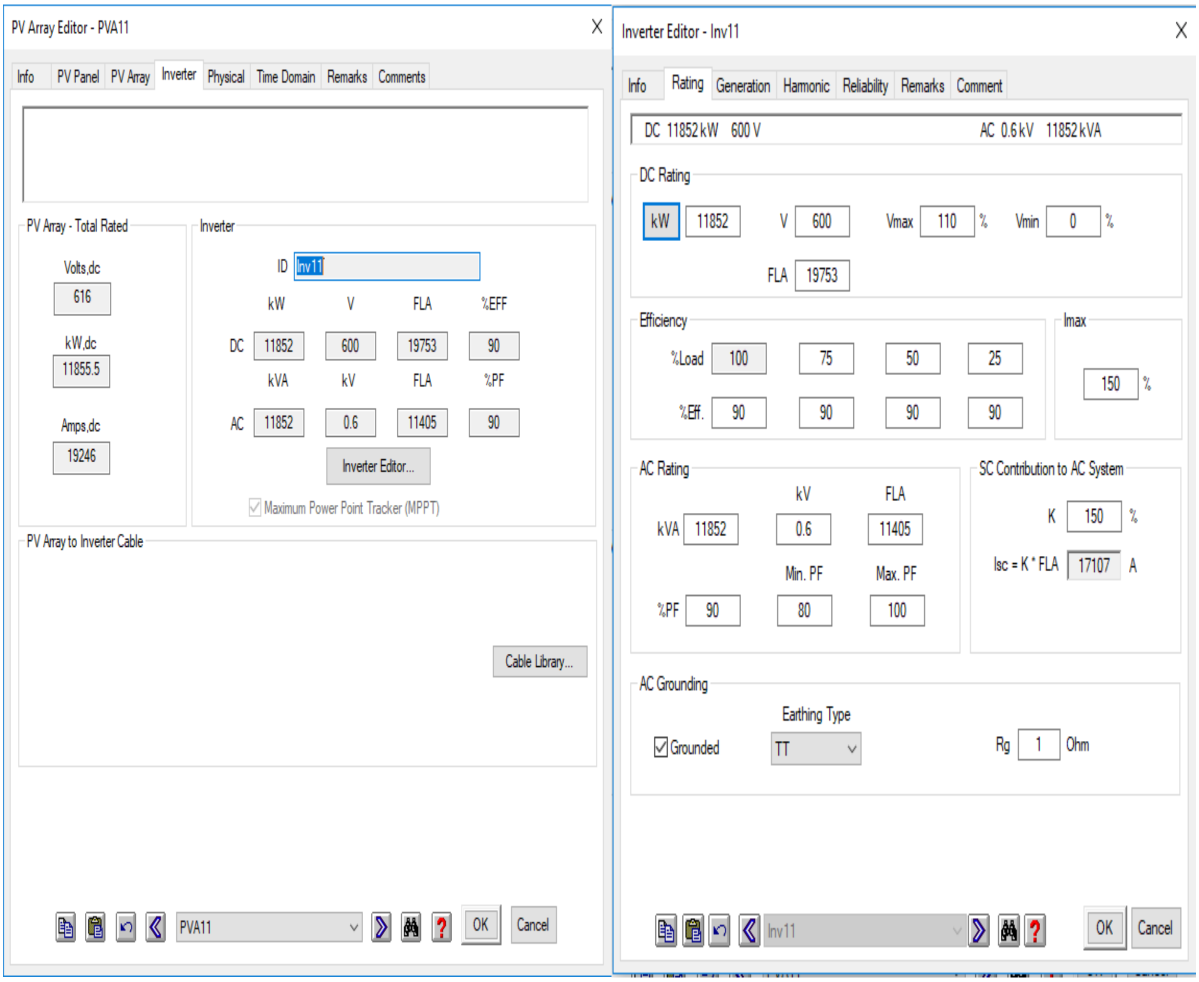


Figure 6.9: Idna PV source sitting data in E-tab

6.3.5 ETAP Simulation

In the following, the sketch for our distribution line by using ETAP simulation.

6.3.6 Load Flow

In the following, the result from distribution line by using ETAP simulation.

Result and comments on ETAP Simulation:

1. We improve the power factor by adding capacitor bank to the circuit.

2. Increase the voltage drop after built the circuit by change the taps of transformer.

3. We protect the distribution line by using overcurrent relay and differential relay to protect the transformer.

Conclusion:

In this project, we designed a Distribution line system from Beat-Aulla to Al-Dahiriya. The appropriate design for towers, conductors, insulators has been done as well as for protection system, considering future loads for the area of the project in the period of (2017-2040).

Using ETAP program, we noticed during design the substation on ETAP that the power factor needs to improve so we add capacitor bank to improve it and to reach the desirable value.

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Appendices

Appendix A: People growth

Appendix B: Load growth

Appendix C: GIS Data

Appendix A

Table A.1: People Estimation for the year of 2045

	Al-Dahiriya	Tarqoumia	Idna	Dear-Sammet	Beat-Awwa
year	(person)	(person)	(person)	(person)	(person)
2007	28252	14,019	18,565	6,090	7,874
2008	29264	14,549	19,267	6,320	8,172
2009	30276	15,080	19,970	6,551	8,470
2010	31288	15,610	20,672	6,781	8,768
2011	32300	16,141	21,375	7,012	9,066
2012	33312	16,671	22,077	7,242	9,364
2013	34324	17,202	22,780	7,473	9,662
2014	35336	17,732	23,482	7,703	9,960
2015	36348	18,263	24,185	7,934	10,258
2016	37360	18,793	24,887	8,164	10,556
2017	38372	19,324	25,590	8,395	10,854
2018	39384	19,854	26,292	8,625	11,152
2019	40396	20,385	26,995	8,856	11,450
2020	41408	20,915	27,697	9,086	11,748
2021	42420	21,446	28,400	9,317	12,046
2022	43432	21,976	29,102	9,547	12,344
2023	44444	22,507	29,805	9,778	12,642
2024	45456	23,037	30,507	10,008	12,940
2025	46468	23,568	31,210	10,239	13,238
2026	47480	24,098	31,912	10,469	13,536
2027	48492	24,629	32,615	10,700	13,834
2028	49504	25,159	33,317	10,930	14,132
2029	50516	25,690	34,020	11,161	14,430
2030	51528	26,220	34,722	11,391	14,728
2031	52540	26,751	35,425	11,622	15,026
2032	53552	27,281	36,127	11,852	15,324
2033	54564	27,812	36,830	12,083	15,622
2034	55576	28,342	37,532	12,313	15,920
2035	56588	28,873	38,235	12,544	16,218
2036	57600	29,403	38,937	12,774	16,516
2037	58612	29,934	39,640	13,005	16,814
2038	59624	30,464	40,342	13,235	17,112
2039	60636	30,995	41,045	13,466	17,410
2040	61648	31,525	41,747	13,696	17,708
2041	62660	32,056	42,450	13,927	18,006
2042	63672	32,586	43,152	14,157	18,304
2043	64684	33,117	43,855	14,388	18,602

2044	65696	33,647	44,557	14,618	18,900
2045	66708	34,178	45,260	14,849	19,198

Table A.2: People Estimation for the year of 2045

	Sika and All-Majed	Dear-Allassal	Beat-Allroush	All-Beraj and Beat Marsam	**Total**
year	(person)	(person)	(person)	(person)	(person)
2007	2,716	2,100	1,320	2,813	**83,747**
2008	2,818	2,180	1,370	2,923	**86,863**
2009	2,921	2,260	1,420	3,033	**89,979**
2010	3,023	2,340	1,470	3,143	**93,095**
2011	3,126	2,420	1,520	3,253	**96,211**
2012	3,228	2,500	1,570	3,363	**99,327**
2013	3,331	2,580	1,620	3,473	**102,443**
2014	3,433	2,660	1,670	3,583	**105,559**
2015	3,536	2,740	1,720	3,693	**108,675**
2016	3,638	2,820	1,770	3,803	**111,791**
2017	3,741	2,900	1,820	3,913	**114,907**
2018	3,843	2,980	1,870	4,023	**118,023**
2019	3,946	3,060	1,920	4,133	**121,139**
2020	4,048	3,140	1,970	4,243	**124,255**
2021	4,151	3,220	2,020	4,353	**127,371**
2022	4,253	3,300	2,070	4,463	**130,487**
2023	4,356	3,380	2,120	4,573	**133,603**
2024	4,458	3,460	2,170	4,683	**136,719**
2025	4,561	3,540	2,220	4,793	**139,835**
2026	4,663	3,620	2,270	4,903	**142,951**
2027	4,766	3,700	2,320	5,013	**146,067**
2028	4,868	3,780	2,370	5,123	**149,183**
2029	4,971	3,860	2,420	5,233	**152,299**
2030	5,073	3,940	2,470	5,343	**155,415**
2031	5,176	4,020	2,520	5,453	**158,531**
2032	5,278	4,100	2,570	5,563	**161,647**
2033	5,381	4,180	2,620	5,673	**164,763**
2034	5,483	4,260	2,670	5,783	**167,879**
2035	5,586	4,340	2,720	5,893	**170,995**
2036	5,688	4,420	2,770	6,003	**174,111**
2037	5,791	4,500	2,820	6,113	**177,227**
2038	5,893	4,580	2,870	6,223	**180,343**
2039	5,996	4,660	2,920	6,333	**183,459**

2040	6,098	4,740	2,970	6,443	**186,575**
2041	6,201	4,820	3,020	6,553	**189,691**
2042	6,303	4,900	3,070	6,663	**192,807**
2043	6,406	4,980	3,120	6,773	**195,923**
2044	6,508	5,060	3,170	6,883	**199,039**
2045	6,611	5,140	3,220	6,993	**202,155**

Appendix B

Table B.1: Load Estimation for the year of 2040

	Al-Dahiriya	Idna	Tarqoumia	Dear-Sammet	Beat-Awwa	Sika and Al-Majed	Dear-Allassal
year	(KVA)	(KVA)	(KVA)	(KVA)	(KVA)	(KVA)	(KVA)
2,017	9,000	12,500	8,000	2,400	6,800	1,000	620
2,018	9,630	13,375	8,560	2,568	7,276	1,070	663
2,019	10,304	14,311	9,159	2,748	7,785	1,145	710
2,020	11,025	15,313	9,800	2,940	8,330	1,225	760
2,021	11,797	16,385	10,486	3,146	8,913	1,311	813
2,022	12,623	17,532	11,220	3,366	9,537	1,403	870
2,023	13,507	18,759	12,006	3,602	10,205	1,501	930
2,024	14,452	20,072	12,846	3,854	10,919	1,606	996
2,025	15,464	21,477	13,745	4,124	11,684	1,718	1,065
2,026	16,546	22,981	14,708	4,412	12,502	1,838	1,140
2,027	17,704	24,589	15,737	4,721	13,377	1,967	1,220
2,028	18,944	26,311	16,839	5,052	14,313	2,105	1,305
2,029	20,270	28,152	18,018	5,405	15,315	2,252	1,396
2,030	21,689	30,123	19,279	5,784	16,387	2,410	1,494
2,031	23,207	32,232	20,628	6,188	17,534	2,579	1,599
2,032	24,831	34,488	22,072	6,622	18,761	2,759	1,711
2,033	26,569	36,902	23,617	7,085	20,075	2,952	1,830
2,034	28,429	39,485	25,271	7,581	21,480	3,159	1,958
2,035	30,419	42,249	27,039	8,112	22,984	3,380	2,096
2,036	32,549	45,207	28,932	8,680	24,592	3,617	2,242
2,037	34,827	48,371	30,957	9,287	26,314	3,870	2,399
2,038	37,265	51,757	33,124	9,937	28,156	4,141	2,567
2,039	39,874	55,380	35,443	10,633	30,127	4,430	2,747
2,040	42,665	59,257	37,924	11,377	32,236	4,741	2,939

Table B.2: Load Estimation for the year of 2040

year	Al-Kom	Beat-Allroush	Al-Beraj and Beat Marsam	**Total load**	**Total load without Idna**
	(KVA)	(KVA)	(KVA)	**(MVA)**	**(MVA)**
2,017	600	710	1,000	**43**	**30**
2,018	642	760	1,070	**46**	**32**
2,019	687	813	1,145	**49**	**35**
2,020	735	870	1,225	**52**	**37**
2,021	786	931	1,311	**56**	**40**
2,022	842	996	1,403	**60**	**42**
2,023	900	1,066	1,501	**64**	**45**
2,024	963	1,140	1,606	**68**	**48**
2,025	1,031	1,220	1,718	**73**	**52**
2,026	1,103	1,305	1,838	**78**	**55**
2,027	1,180	1,397	1,967	**84**	**59**
2,028	1,263	1,494	2,105	**90**	**64**
2,029	1,351	1,599	2,252	**96**	**68**
2,030	1,446	1,711	2,410	**103**	**73**
2,031	1,547	1,831	2,579	**110**	**78**
2,032	1,655	1,959	2,759	**118**	**83**
2,033	1,771	2,096	2,952	**126**	**89**
2,034	1,895	2,243	3,159	**135**	**95**
2,035	2,028	2,400	3,380	**144**	**102**
2,036	2,170	2,568	3,617	**154**	**109**
2,037	2,322	2,747	3,870	**165**	**117**
2,038	2,484	2,940	4,141	**177**	**125**
2,039	2,658	3,146	4,430	**189**	**134**
2,040	2,844	3,366	4,741	**202**	**143**

Appendix C

The pictures below shows the distribution path from Beat Aulla to Al-Dahiriya in sections.

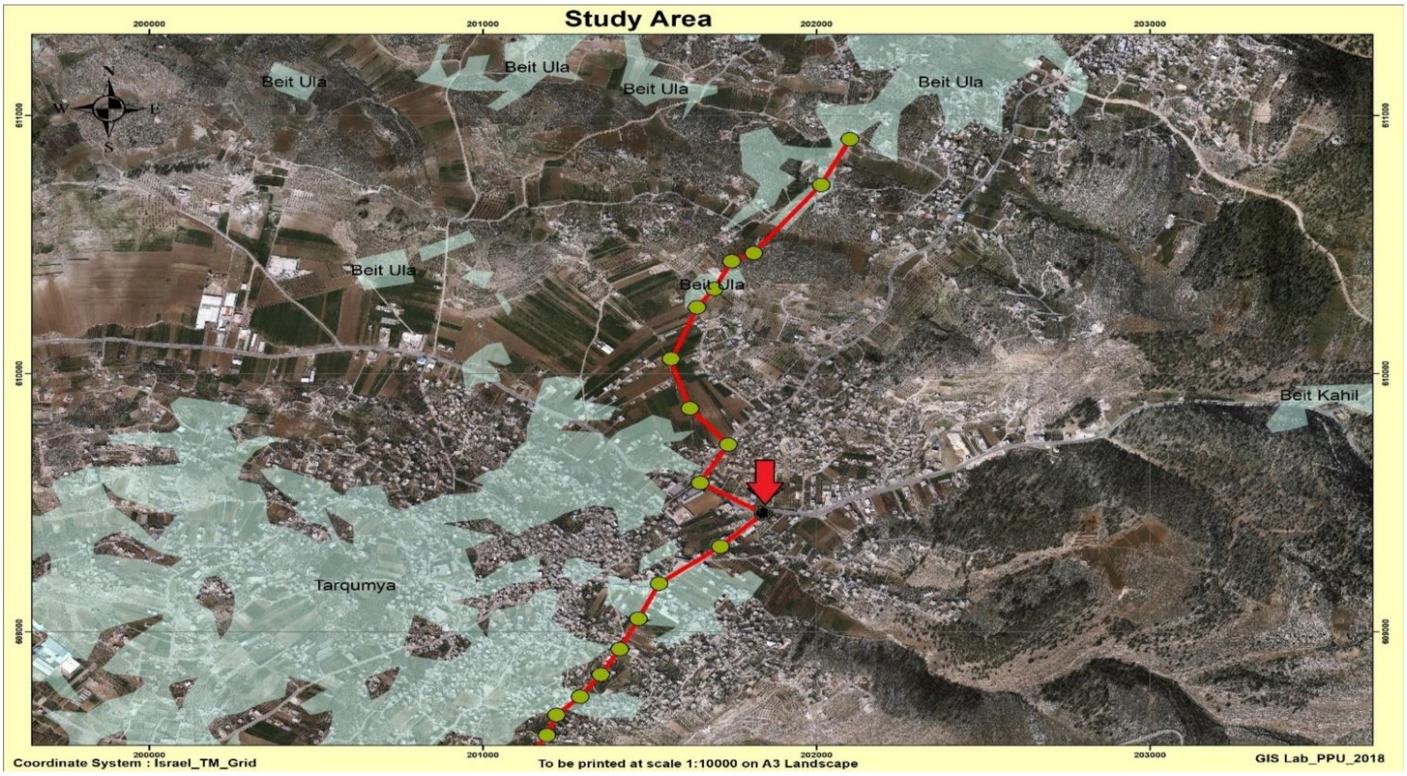

Figure C.1: Distribution line path-section (1)

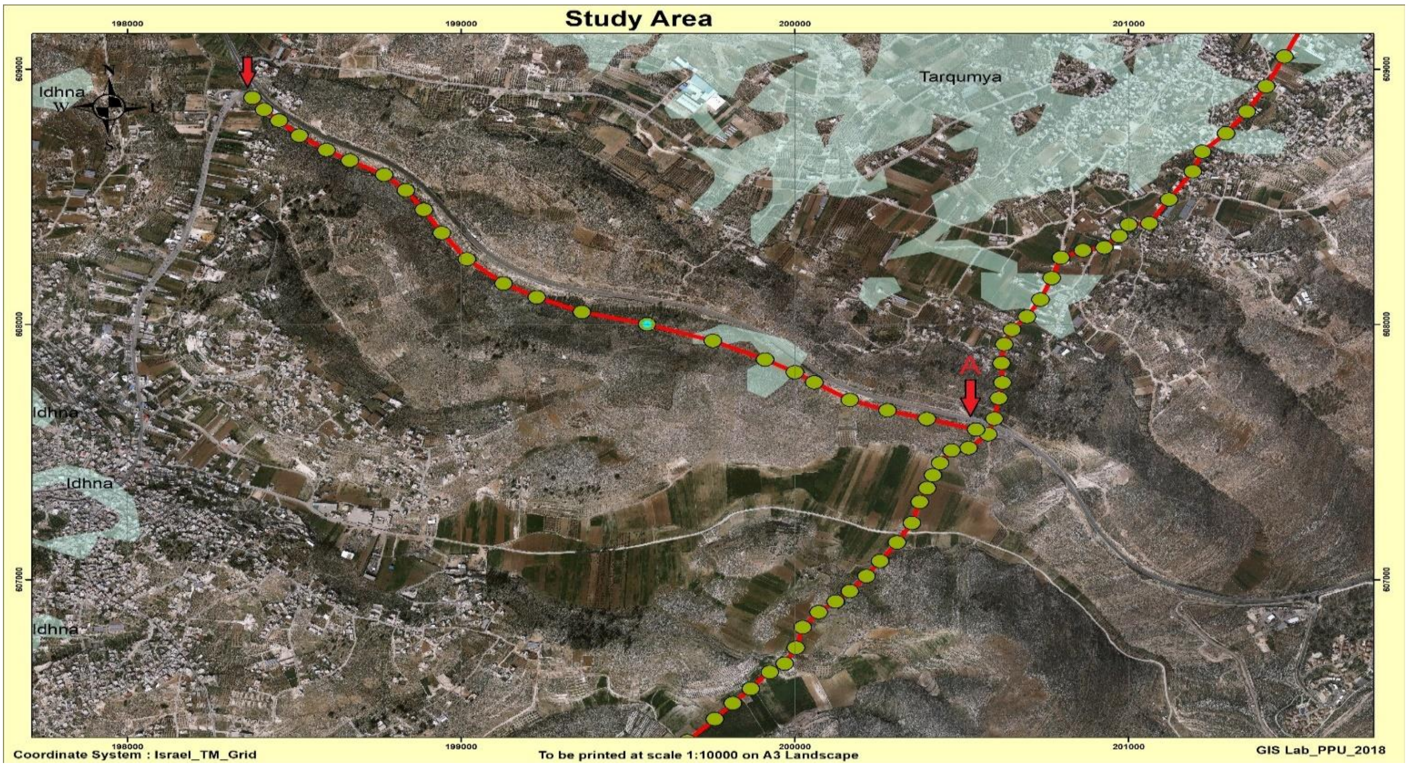

Figure C.2: Distribution line path-section (2)

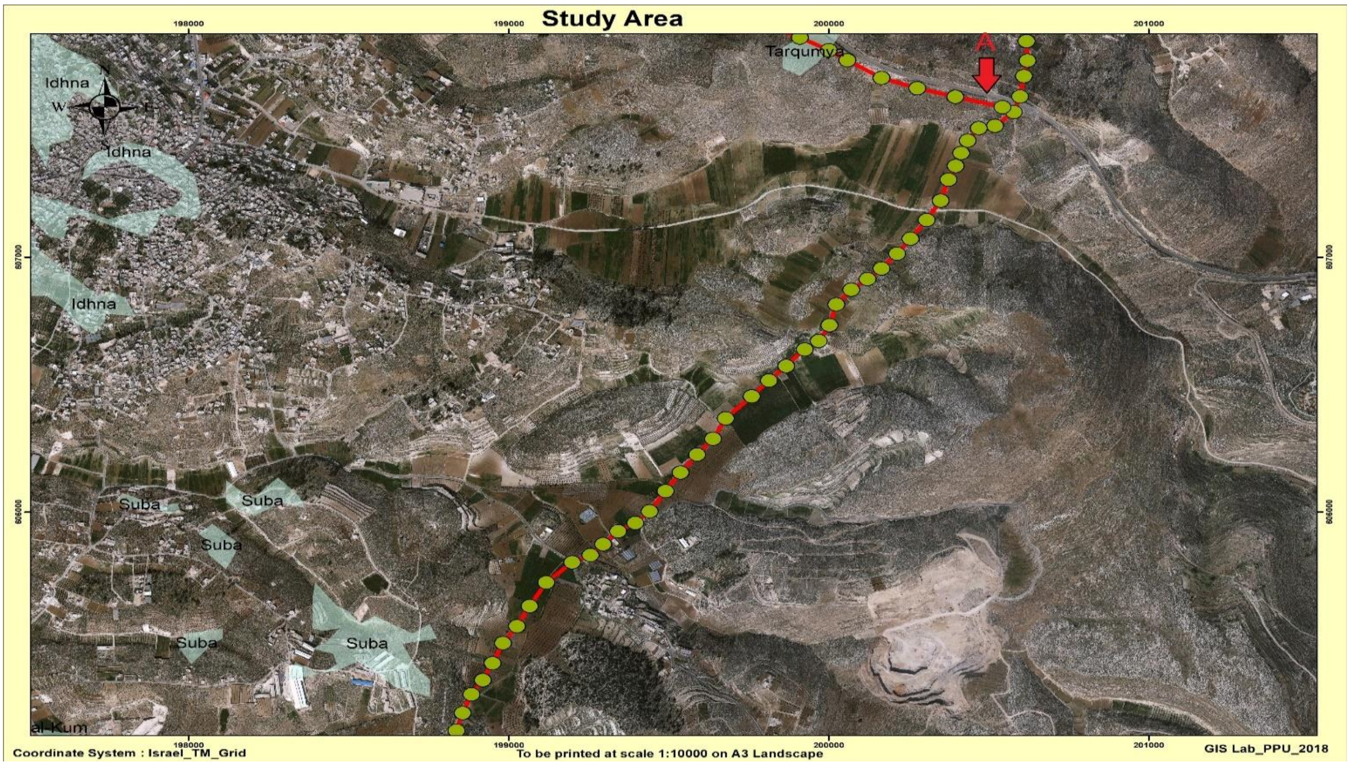

Figure C.3: Distribution line path-section (3)

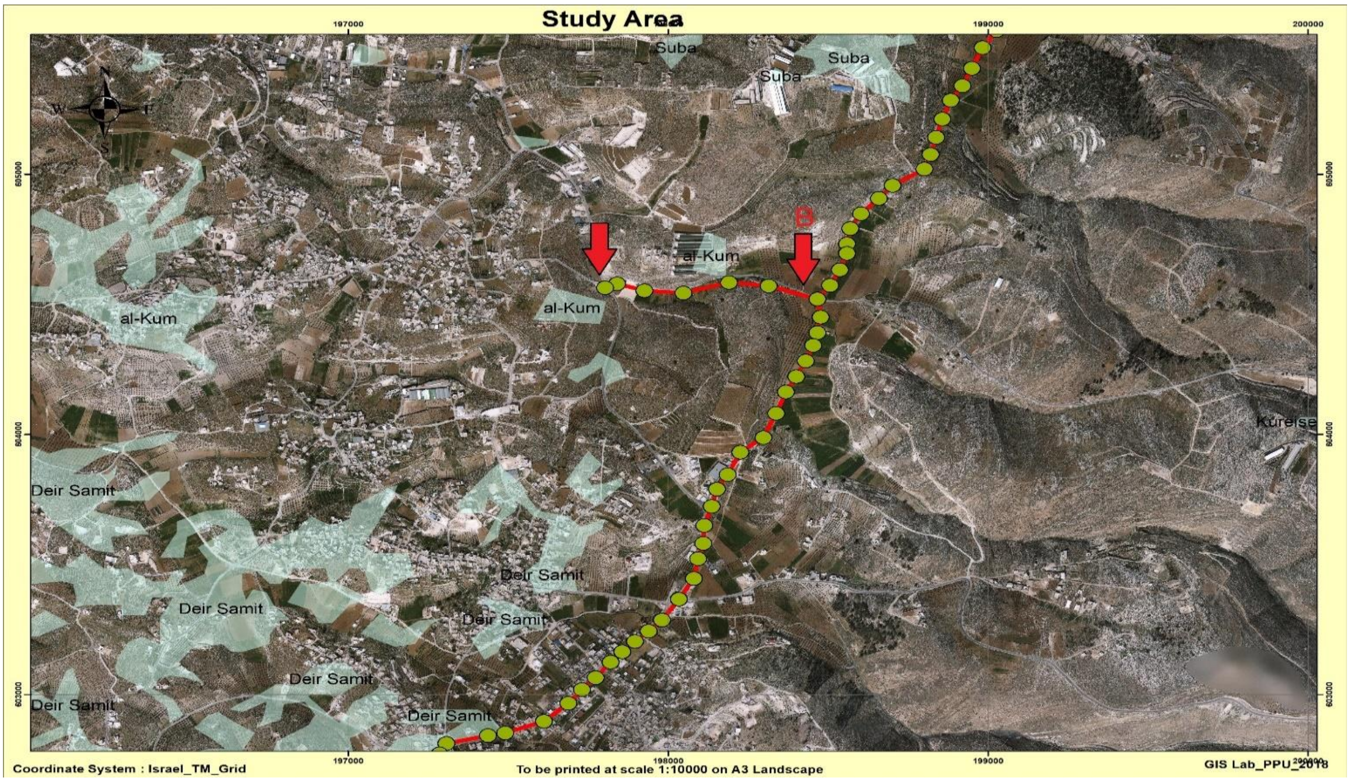

Figure C.4: Distribution line path-section (4)

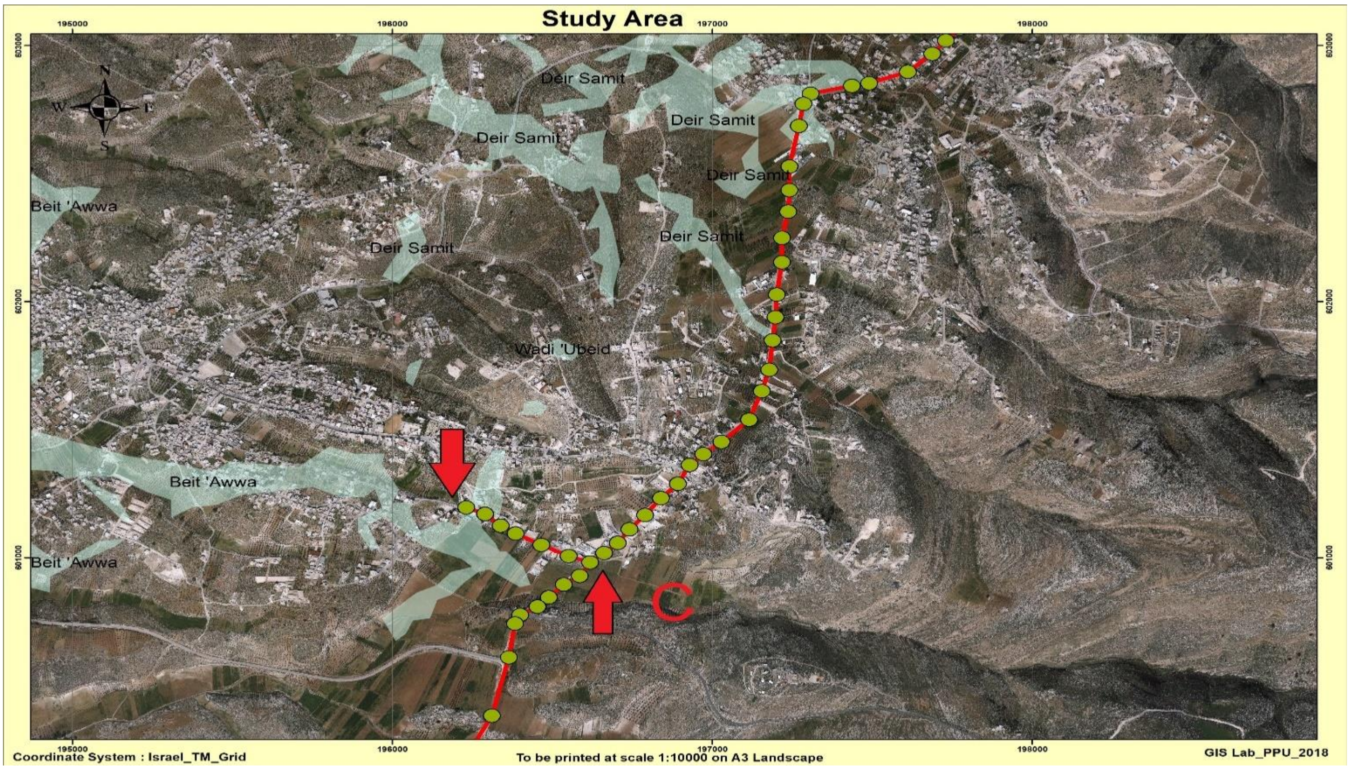

Figure C.5: Distribution line path-section (5)

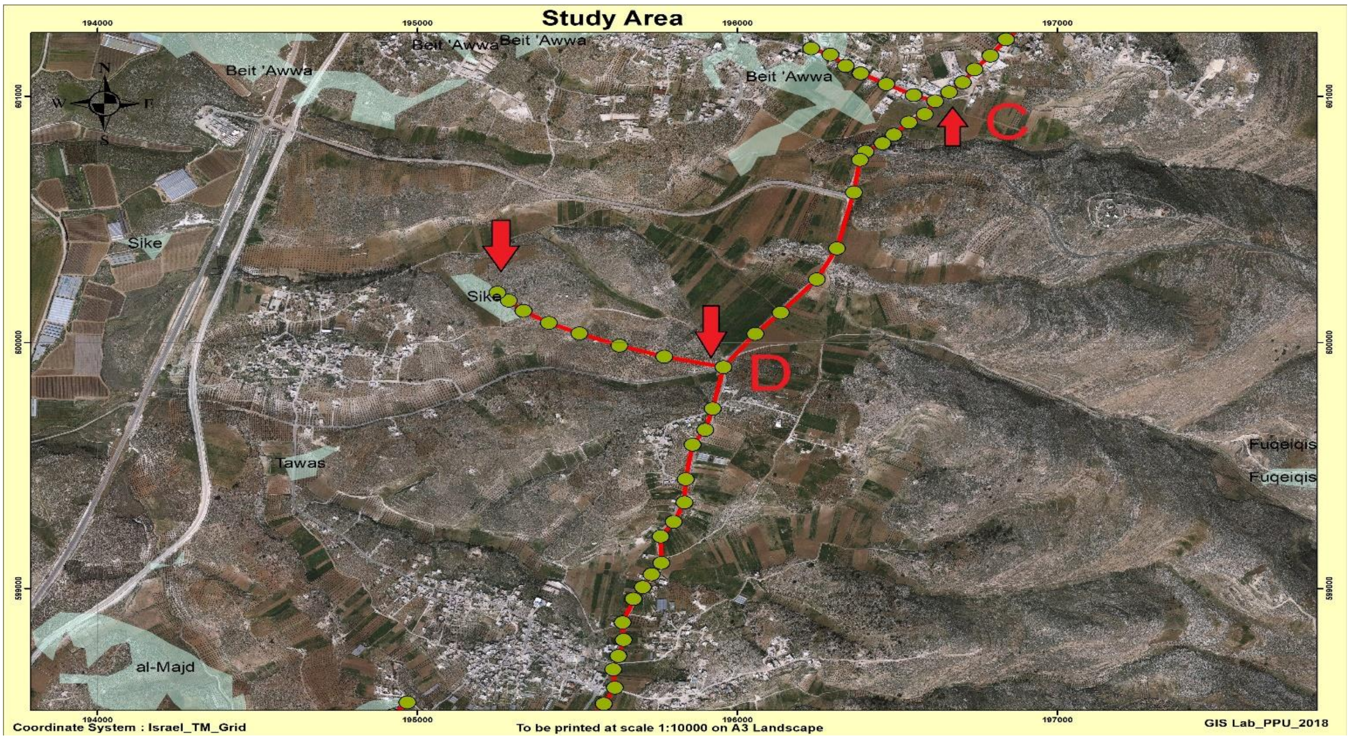

Figure C.6: Distribution line path-section (6)

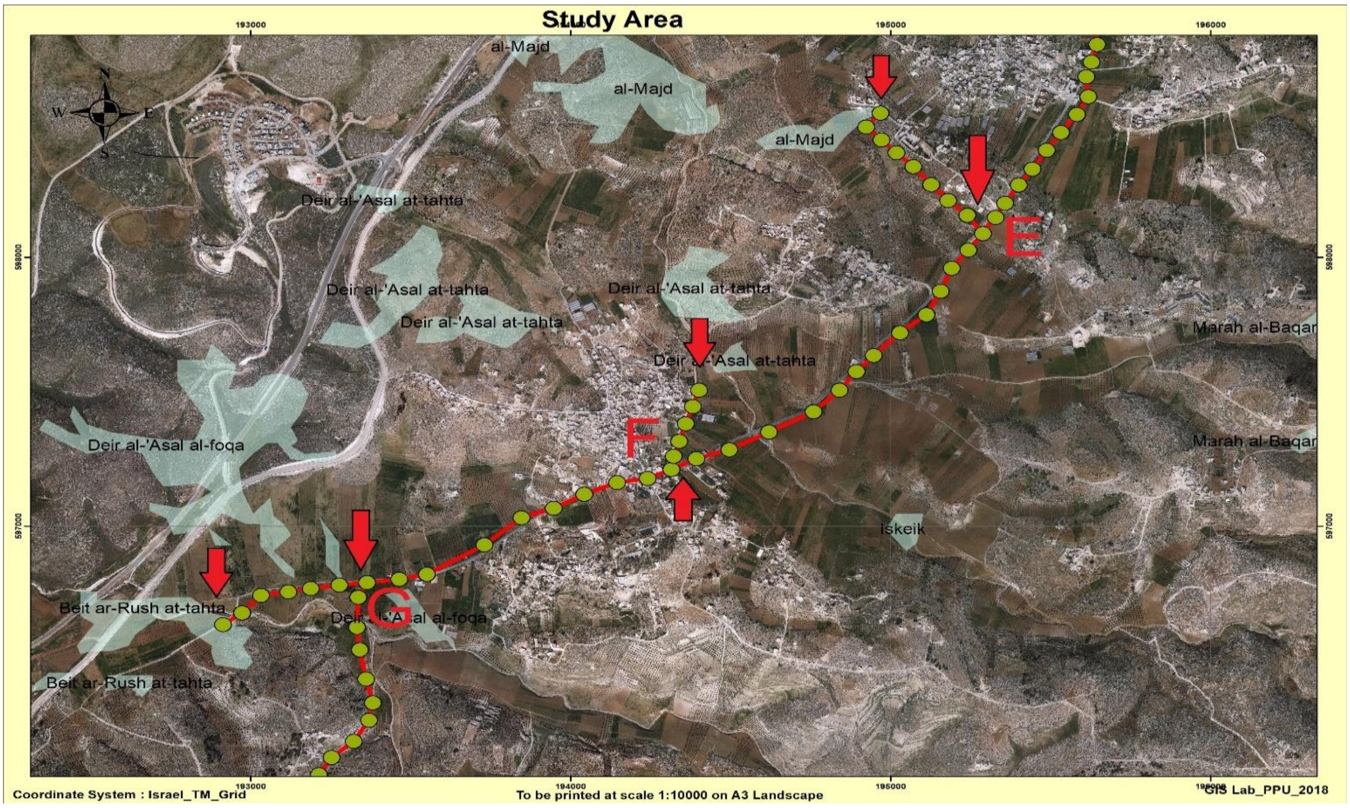

Figure C.7: Distribution line path-section (7)

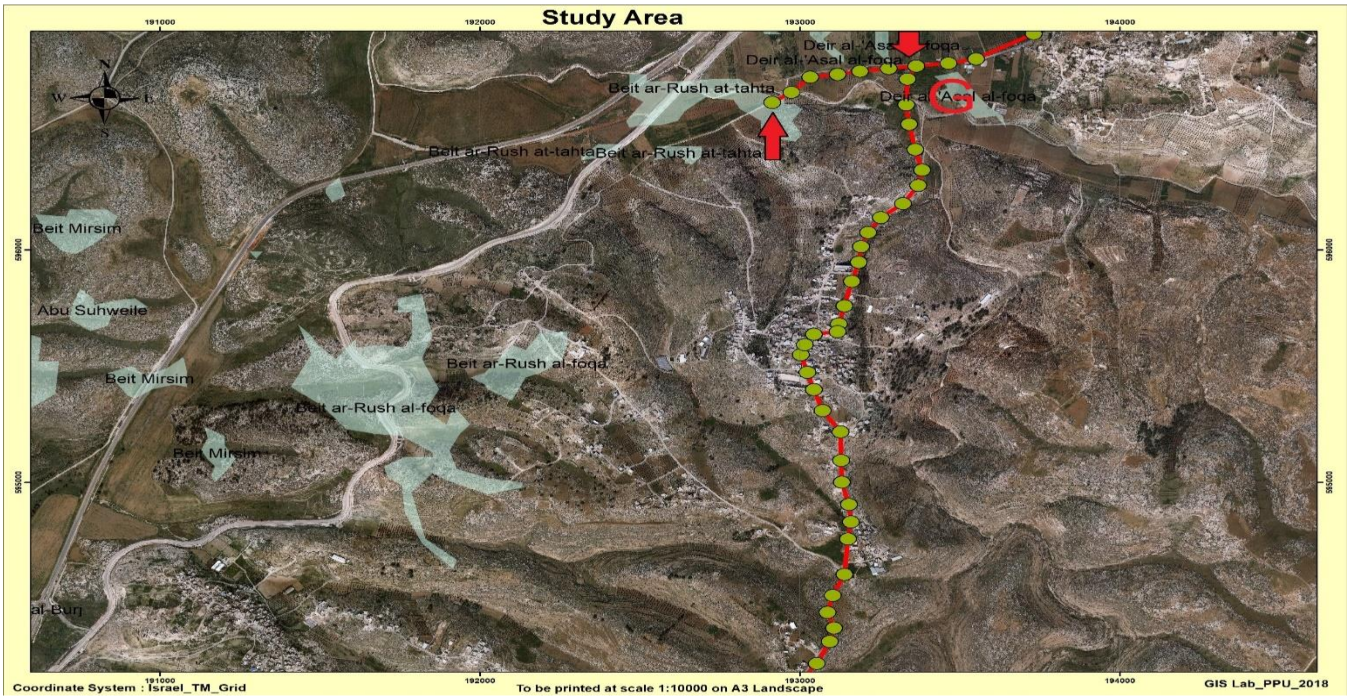

Figure C.8: Distribution line path-section (8)

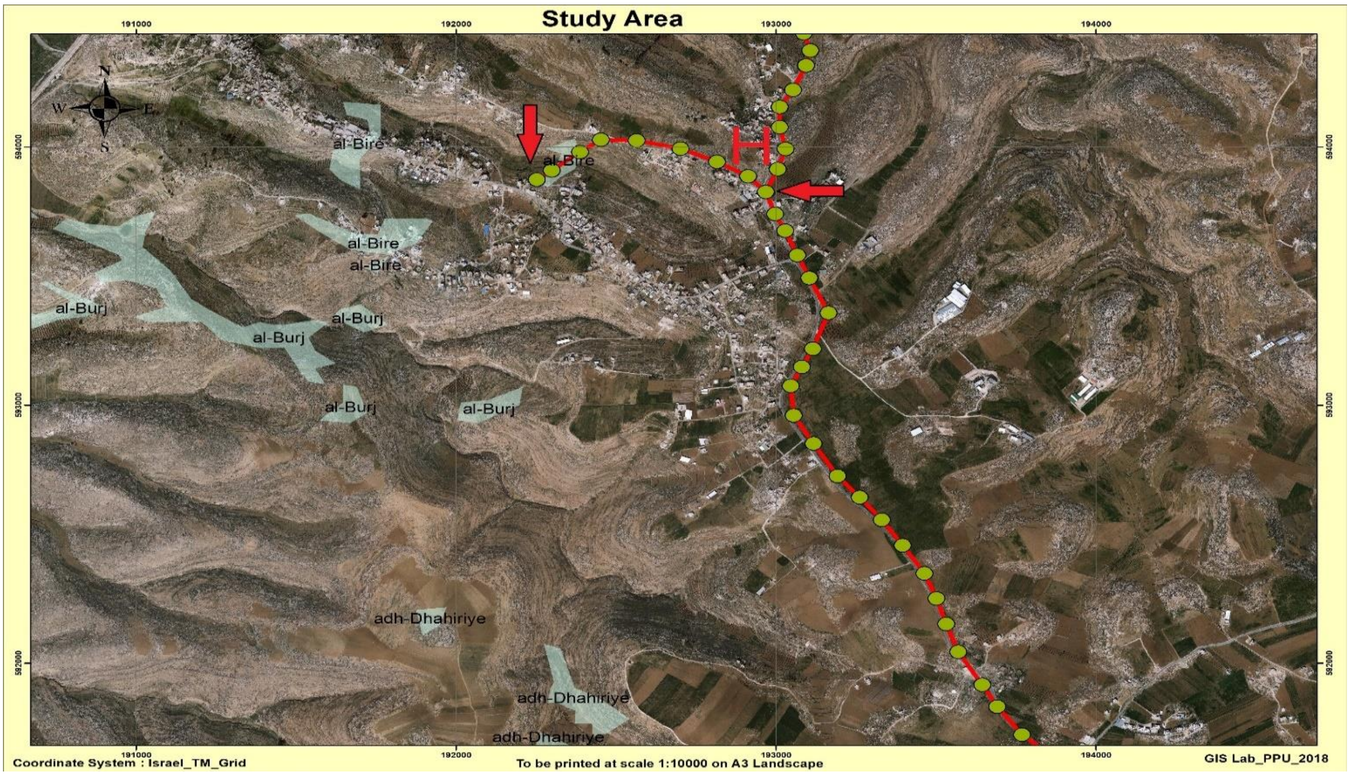

Figure C.9: Distribution line path-section (9)

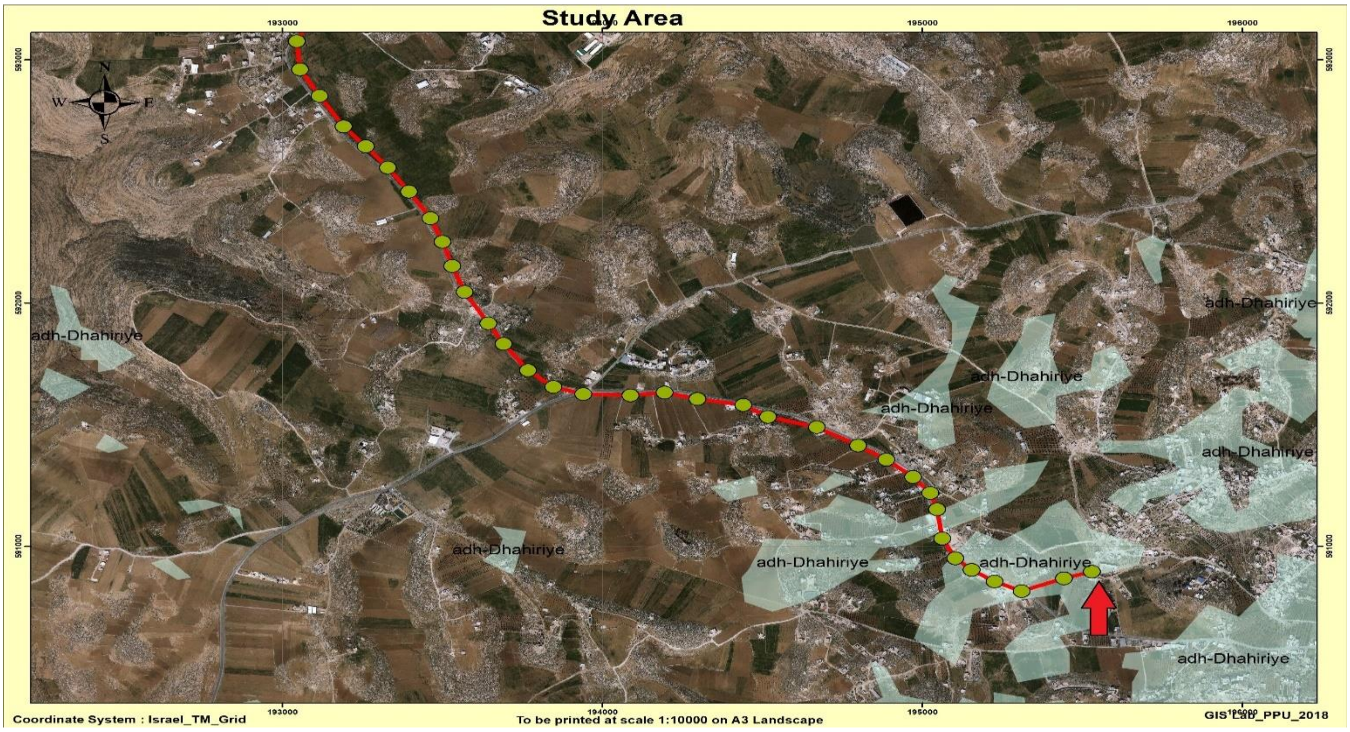

Figure C.10: Distribution line path-section (10)