Power factor correction for west of Jerusalem grid

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Contents

Abstract

Because of a large number of high harmonics are injected into power with more and more of the nonlinear semiconductor devices were widely used. Harmonic can cause the distortion in current in a power system and worsen the power quality.

The increased use of non-linear devices cause voltage distortion in the network. This leads to malfunctions of the electric facilities and to costly interruptions of production.

Some of the AC power consumed by inductive loads is used to maintain magnetic reversals due to phase shift between current and voltage. This energy can be considered as wasted energy since it is not used in performing useful work. Power factor correction circuits are used to minimize reactive power and enhance the efficiency with which inductive loads consume AC power. Capacitors are essential components in power factor compensation circuits, and this project will explore some design considerations when using these components for power factor correction.

1

Chapter One

Introduction

1.1 Overview

1.2 Objectives of project

1.3 Importance of the project

1.4 Project methodology

Chapter 1: introduction

1.1 Overview

Inductive loads such as motors, inductive heating equipment, generators, transformers, and arc welding equipment produce an electrical lag that is commonly referred to as inductance. This inductance causes a phase difference between current and voltage.

As a result of phase shift due to inductance, there are times when current and voltage have different signs. During such times, negative energy is generated and fed back into the power supply network. When the two regain same sign, a similar amount of energy is required to generate the magnetic fields. The energy that is lost due to magnetic reversals in inductive loads is commonly referred to as reactive power.[1]

In this project a part of west of Jerusalem grid will be simulated and improved. Capacitor bank will be used mainly to improve the power factor.

This project involves high voltage and high current grid, where the main substation is 33kV and the grid use a current up to 2500 Amperes.

All the data will be used in the project is real data, where it have been supplied from JEDCO (Jerusalem District Electricity Company), where the data will be studied from (1-Jan-2019) to (31-Dec-2019). The main substation is Nabi Samuel substation with 7.5 MVA capacity.

1.2 Objectives of the project

- Analysis part of west Jerusalem network through the ETAP software and by using real data.
- Minimize the technical loss of the distribution network.
- Improve the power factor to more than 0.92

These objectives improve the network performance efficiency.

1.3 Importance of the project

Due to the high loses in distribution systems this project aims to decrease the losses in real case distribution system by using capacitor bank. This project focuses on decreasing loses in sub-station by using the best economical solution.

1.4 Project methodology

- Collecting data of the distribution network.
- Creating the single line diagram for 33 kV network.
- Building the network by analyzing the network by ETAP.
- Getting the suitable and required information and statistics from the ETAP Program.
- Solving the network problems and developing its efficiency by suggesting feasible scenarios for developing and improving the network.

2

Chapter Two

Power systems components

2.1 Introduction

2.2 Power systems components

- 2.2.1 Transformers
- 2.2.2 Isolators
- 2.2.3 Grounding system
- 2.2.4 Insulators
- 2.2.5 Cables
- 2.2.6 Switches and apparatus
- 2.2.7 Surge voltage protection

Chapter 2: Power systems components

2.1 Introduction

A power station, also referred to as a power plant is an industrial facility for the generation of electric power. Most power stations contain one or more generators, a rotating machine that converts mechanical power into electrical power. The relative motion between a magnetic field and a conductor creates an electrical current. The energy source harnessed to turn the generator varies widely. Most power stations in the world burn fossil fuels such as coal, oil, and natural gas to generate electricity. Others use nuclear power, but there is an increasing use of cleaner renewable sources such as solar, wind, wave and hydroelectric.[2]

Electricity generation is the process of generating electric power from sources of primary energy. For electric utilities in the electric power industry, it is the first stage in the delivery of electricity to end users, the other stages being transmission, distribution, energy storage and recovery, using pumped-storage methods.

Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage .

Electric power transmission is the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. The interconnected lines which facilitate this movement are known as a transmission network. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution.

Electric generation system contains four stages:

- Generation and step up stage (161 kV).
- Transmission and Step down stage (161/33 kV).
- Distribution substation (33/11 kV).
- Distribution stage (11 kV / 400 V).

2.2 Power systems Components

Distribution substation is generally comprised of the following major components:

- Supply line
- Transformers
- Bus-bars
- Switchgears
- Insulators
- Outgoing feeders
- isolators
- Surge voltage protection
- Grounding
- Switching apparatus
  - Switches
  - Circuit breakers

2.1 Transformers

Transformers are devices that permit electrical power to switch between circuits. Electric transformers can be used in various ways in order to increase or lower voltage levels depending on the supply circuit.

Transformers are an essential component for power transmission and distribution systems. There is many types of transformers depending on cooling type as follow:

1. Air cooling:

- Air Natural(AN)
- Air Blast (AB)

2. Oil and Air cooling

- Oil Natural Air Natural (ONAN)

- Oil Natural Air Forced (ONAF)
- Oil Forced Air Natural (OFAN)
- Oil Forced Air Forced (OFAF)

3. Oil and Water cooling

- Oil Natural Water Forced (ONWF)
- Oil Forced Water Forced (OFWF)

Different consumers and appliances require different voltage levels to function safely and efficiently, so distribution transformers are typically used at the very beginning and the very end of the power supply chain to step up or step down the voltage as required. Though many of our distribution transformers and electrical transformers are suitable for indoor use, selected products are developed for operation outdoors and will withstand even the harshest of conditions, making them ideal for use in the oil industry or power supply sector

2.2 Isolators

- Isolators is off load devices.
- They shouldn't control the circuit which mean that the shouldn't close and open the circuit, where if the isolator closes o open the circuit there is a danger to make huge Arc between the isolator contacts which may lead to destroy it.
- The isolator should open after the circuit breaker is opened, and should close before the circuit breaker close.
- There is two types of isolators, hand operated and motorized mechanism.
- The first type can be operated manually, however the second one can be controlled from remote position.
- It is recommended for the systems below 145 KV to use the first type and for systems higher than 145 KV to use the second type.

2.3 Grounding system

The grounding system in substation is very important. The functions of grounding systems or earth mat in include:

- To ensure safety to personnel in stations against electrical shocks.
- To provide the ground connection for connecting the neutrals of star connected transformer winding to earth (neutral earthing).
- To discharge the over voltages from overhead ground wires or the lightning masts to earth. To provide ground path for surge arresters.
- To provide a path for discharging the charge between phase and ground by means of earthing switches.
- To provide earth connections to structures and other non-current carrying metallic objects in the station (equipment earthing).

2.3.1 Stations and sub-station grounding

The grounding system in stations and substation is very important. The functions of grounding systems or earth mat in include:

- To ensure safety to personnel in substations against electrical shocks.
- To provide the ground connection for connecting the neutrals of star connected transformer winding to earth (neutral earthing).
- To discharge the over voltages from overhead ground wires or the lightning masts to earth. To provide ground path for surge arresters.
- To provide a path for discharging the charge between phase and ground by means of earthing switches.
- To provide earth connections to structures and other non-current carrying metallic objects in the sub-station (equipment earthing).

If the switchyards have a soil of low resistivity, earth resistance of the earthing system would be low. If the soil resistivity is high, the mesh rods are laid at closer spacing. More electrodes are inserted in the ground.

The mesh is formed by placing mild steel bars placed in X and Y directions in mesh formation in the soil at a depth of about 0.5 m below the surface of substation floor in the entire substation area except the foundations.

The crossings of the horizontal bars in X and Y directions are welded.

The earthing rods are also placed the border of the fence, surrounding building foundations, surrounding the transformer foundations, inside fenced areas etc. The mesh ensures uniform and zero potential distribution on horizontal surface of the floor of the substation hence low “step potential" in the event of flow of earth fault current.[3]

2.4 insulators

It is obvious that if overhead power lines are not properly insulated from their support poles/towers, the current will flow towards the ground through the poles/towers which also become hazardous. Of course, the power line won't even work in that case! Hence, overhead power lines are always supported on insulators mounted on their support poles/towers.

Overhead line insulators should have the following properties:

- High mechanical strength in order to withstand the conductor load, wind load etc.
- High electrical resistance in order to minimize the leakage currents
- High relative permittivity of insulating material so that the dielectric strength is high
- High ratio of puncture strength to flashover

2.5 Cables

2.5.1 Power cables

Power Cables play the main role in terms of carrying the power system current along system's substations and levels, Modern power cables come in a variety of sizes, materials, and types, each particularly adapted to its uses. Large single insulated conductors are also sometimes called power cables in the industry.

Cables consist of three major components: conductors, insulation, and protective jacket. The makeup of individual cables varies according to application. The construction and material are determined by four main factors:

- Working voltage, determining the thickness of the insulation.
- Current-carrying capacity, determining the cross-sectional size of the conductor(s).
- Environmental conditions such as temperature, water, chemical or sunlight exposure, and mechanical impact, determining the form and composition of the outer cable jacket.
- Short circuit current may also play role in terms of cross-sectional size of the conductor.

2.5.2 Control cables

Control cable main role is to be used within stations equipment, such as switchgears, isolators, transformers, reactors, and capacitors to be connected with control panels & RTU system (SCADA).

2.6 Switches and apparatus

2.6.1 Circuit breakers

A circuit breaker must be capable to make and break all the load and fault currents that it might be subjected 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. Earlier, the small-oil circuit breakers were common on medium-voltage indoor installations and air-blast or oil breakers in outdoor installations. Today, these technologies have been 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 utilized.

Switchgears advantages over standalone circuit breakers

- The ability to control the rated current and tripping over current.
- Voltage, current and power measurements.
- Could be easily connected to SCADA (RTU) system.
- The ability for smart control of tripping and reclosing activities.
- Availability of fuses, disconnect switches, earth switches.

Each switchgear unit came with sub control panel that allow the electrical personnel to calibrate internal components including the circuit breaker on system's rated quantities (voltage, current and power), these control panels could be connected to utility SCADA system in order to monitor and control these quantities and the state of each circuit breaker.

2.6.2 Earthing switches

Earthing switches are safety devices which are integral parts of circuit breakers. When a circuit breaker is removed and racked out, the sections of the bus bar adjacent to the circuit breaker are automatically earthed by means of these switches. This protects the maintenance personnel from accidental voltages. Earthing switches are usually dimensioned to withstand short circuit currents. Earthing switches can also be motorized. Earthing switches are usually used in conjunction with isolators. When the isolator isolates the circuits, the earthing switches make contact with the bus-bar and discharge any charges which may have accumulated there.

2.6.3 High voltage arc fuse (HRC)

HRC high voltage fuses are used to protect transformers, capacitor banks, cable networks and overhead lines against short-circuits. HRC HV fuses protect switchgears from thermal and electromagnetic effects of heavy short-circuit currents by limiting the peak current values (cut-off characteristics) and interrupting the currents in several milliseconds.

2.6.4 Switch disconnector

Switch disconnector is used to ensure that an electrical circuit is completely de-energized for service or maintenance.

2.7 Surge voltage protection

Lightning and switching transients along with ground faults create significant voltage anomalies on transmission and some distribution circuits. Not only direct strikes, but nearby strikes, create significant voltage anomalies and subsequent line outages. Recent developments have made it possible to provide a solution to lightning and surge problems, and also reduce the overall cost of substation designs.[4]

Surge arresters are mainly used to protect substations from lightning voltage.

3

Chapter three

Importance of power factor correction in the system

Chapter 3: Importance of power factor correction in the system

3.1 introduction

the power factor of an AC electrical power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit, and is a dimensionless number in the closed interval of −1 to 1. A power factor of less than one indicates the voltage and current are not in phase, reducing the average product of the two. Real power is the instantaneous product of voltage and current and represents the capacity of the electricity for performing work. Apparent power is the product of RMS current and voltage. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power may be greater than the real power. A negative power factor occurs when the device (which is normally the load) generates power, which then flows back towards the source.[5]

In an ideal world, a Power Factor should be unity (1.0); typically the Power Factor should be between 0.90and 0.95. If the Power Factor is below 0.90, it is economical to install capacitors to correct the Power Factor.

3.2 Correcting power factor

Power factor correction increases the power factor of a load, improving efficiency for the distribution system to which it is attached. Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.[6]

3.3 Importance of power factor correction

Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (Watts). This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively, all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current. When the power factor is close to unity, for the same kVA rating of the transformer more load current can be supplied.

3.4 Calculations

One can relate the various components of AC power by using the power triangle in vector space. Real power extends horizontally in the î direction as it represents a purely real component of AC power. Reactive power extends in the direction of ĵ as it represents a purely imaginary component of AC power. Complex power (and its magnitude, Apparent power) represents a combination of both real and reactive power, and therefore can be calculated by using the vector sum of these two components. [7]

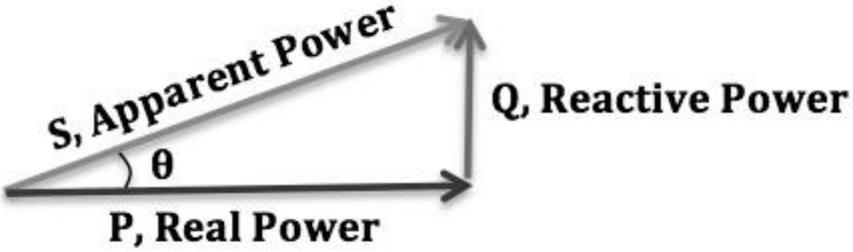

Figure (3.1) Power triangle

For the busses (399,402,400) the power factor is law, we will add for each bus capacitor bank. The goal is increase the power factor for these buses to 0.98.

$$PF = \frac{Real\ power\ (kW)}{Apparent\ power\ (kVA)} = Cos\ \theta \tag{5.1}$$

$$\sin\theta = \frac{Reactive\ power(KVar)}{Apparent\ power(KVA)} \tag{5.2}$$

$$kVA\ = \sqrt{kW^2 + kVar^2} \tag{5.3}$$

$$Qc = Qold - Qnew \tag{5.4}$$

$$Qc = Pnew(tan\theta\ old - tan\theta\ new) \tag{5.5}$$

According to the equations above:

- For bus 399 the capacitor bank needed is 22kVar
- For bus 402 the capacitor bank needed is 52kVar
- For bus 400 the capacitor bank needed is 87kVar

After a study of economic feasibility the cost of the capacitor banks is 20,000 NIS, and the cost of the installation and maintenance is 12,000 NIS.

4

Chapter four

Grid losses

Chapter 4: Grid losses

4.1 Introduction

The power losses of an electric conductor depend on the resistance of the conductor itself and on the square of the current flowing through it. Since, with the same value of transmitted active power, the higher the power factor, the lower the current, it follows that when the power factor rises, the losses in the conductor on the supply side of the point of application of power factor correction equipment will decrease.[8]

In a three phase system the losses are expressed as follows:

$$P_{losses} = 3 * I * R^2 \qquad (4.1)$$

Therefore, improvement in power factor results in a corresponding decrease in current which results in a reduction in power losses by the square of the current reduction. Electric utilities can often justify power factor correction on the basis of loss reduction due to the resistance and magnitude of power flow associated with long transmission and distribution lines. For industrial customers, justification of power factor correction on the basis of loss reduction is difficult as losses are comparably lower.[8]

Power factor correction on industrial power systems is most often cost justified (or mandated) based on power factor penalties and/or KVA charges, released system capacity, or the production benefits associated with improvements in power quality with the application of power factor correction equipment and harmonic filters.

In addition to losses associated with I2R losses from current flow through series resistance of power conductors, and transformer windings, a portion of power system losses come from hysteresis and eddy currents in the iron laminations of motors, generators, and transformers. These losses are not reduced by power factor correction and are largely dependent on system voltage rather than system current.

4.2 Losses in distribution systems

Power generated in power stations pass through large and complex networks like transformers, overhead lines, cables and other equipment and reaches at the end users. It is fact that the unit of electric energy generated by Power Station does not match with the units distributed to the consumers. Some percentage of the units is lost in the distribution network. This difference in the generated and distributed units is known as Transmission and Distribution loss. Transmission and Distribution loss are the amounts that are not paid for by users. [9]

T&D Losses = (Energy Input to feeder (kWh) – Billed Energy to Consumer (kWh)) / Energy Input kWh x 100 (4.2)

There are two types of Transmission and Distribution Losses:

1. Technical Losses
2. Non-Technical Losses

Technical Losses The technical losses are due to energy dissipated in the conductors, equipment used for transmission line, transformer, sub transmission line and distribution line and magnetic losses in transformers. The major amount of losses in a power system is in primary and secondary distribution lines. While transmission and sub-transmission lines account for only about 30% of the total losses. Therefore the primary and secondary distribution systems must be properly planned to ensure within limits.[9]

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4.3 Losses reduction advantages

- Technical advantages cover a wide variety of issues such as peak load saving, good voltage profile, reduced system losses, improved continuity and reliability, removal of some power quality problems.

- Besides the financial implications, low-loss design improves reliability, lessens power quality concerns, and better accommodates customer load growth.

- There's an environmental twist to lowering distribution losses: Lowering distribution losses reduces the amount of pollutants and greenhouse gasses from hydro-carbon based power plants.

- Utilities can reduce distribution losses by concentrating on the design and operation of the distribution system.

- Some of loss-reduction measures require financial commitment, forcing energy-conscious utilities to balance loss savings with capital investment.

- Reducing the total system losses could be of interest to some utilities in the developing countries as some of them are losing 15-20% of their total generation as losses while this figure for a well-developed power system is well under 10%. However, the placement and size of the DG are two crucial factors in loss reduction.

- System Losses in the Grid Transmission and distributions losses constitute a major portion of system losses. This is an old and well-researched area. However, there is a great potential for loss reduction in some of the developing countries in Asia, System losses, in practice, mean two types; one is the capacity or kW loss and the other one is energy or kWh loss, which can result in a larger monetary value at the end of each year. Even though the losses cannot be completely removed, they can be brought down to an acceptable value

Technical losses can be reduced by taking the following actions:

1. Install capacitor banks.
2. Re-conducting overloaded lines with bigger conductors.
3. Avoid any overloading of system and monitor the progress in losses reduction.
4. Disconnect unloaded transformers to avoid no-load losses.
5. Balance the transformer loading to reduce the neutral current and power losses.
6. Upgrade transformers to match the load and the installed capacity, and to replace old/degraded ones.
7. Ensure that all industrial customers are meeting the requirement of 0.9 PF.
8. Perform regular preventive maintenance.
9. Ensure the frequent live-line washing to reduce the leakage current.

4.4 Drawbacks of network losses

High rate of technical and non-technical losses might cause:

1. Poor quality of service offered to customers.
2. High cost due to useless or premature investments.

Reduction in revenue resulting in cash difficulties with all ensuing economic consequences.

Technical losses are part of the electric losses in the system, resulting from: losses in drivers, corona effect, eddy currents, and Ohmic losses.

These losses can still be grouped according to the segment of the electric system where it happens, being subdivided into:

- Losses in the transmission system.
- Substation power transformers.
- Primary distribution system.
- Secondary distribution system.
- Connection extensions.
- Measurement systems.

4.5 Ring Main Electrical Power Distribution System

The drawback of a radial electrical power distribution system can be overcome by introducing a ring main electrical power distribution system.

In this network topology, one ring network of distributors is fed by more than one feeder. In this case, if one feeder is under fault or maintenance, the ring distributor is still energized by other feeders connected to it. In this way, the supply to the consumers is not affected even when any feeder becomes out of service.[10]

In addition to that, the ring main system is also provided with different section isolates at different suitable points. If any fault occurs on any section, of the ring, this section can easily be isolated by opening the associated section isolators on both sides of the faulty zone transformer directly.

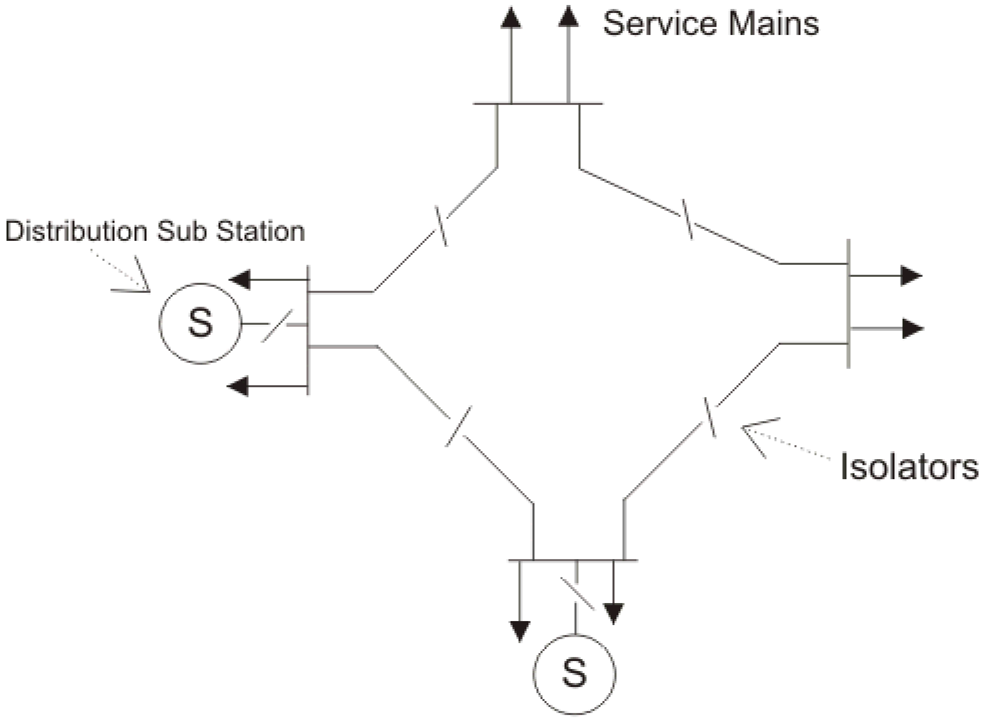


Figure (4.1) Ring distribution system

In this way, supply to the consumers connected to the healthy zone of the ring can easily be maintained even when one section of the ring is under the shutdown. The number of feeders connected to the ring main electrical power distribution system depends upon the following factors.[10]

Maximum Demand of the System: If it is more, then more numbers of feeders feed the ring.

Total Length of the Ring Main Distributors: Its length is more, to compensate for the voltage drop in the line, more feeders to be connected to the ring system.

Required Voltage Regulation: The number of feeders connected to the ring also depends upon the permissible allowable, voltage drop of the line.

The sub-distributors and service mains are taken off maybe via distribution transformer at different suitable points on the ring depending upon the location of the consumers.

Sometimes, instead of connecting the service main directly to the ring, sub-distributors are also used to feed a group of service mains where direct access to the ring distributor is not possible.[10]

Advantages if using ring distribution systems:

- Voltage fluctuation at consumer's terminal would be less.
- As there are several feeders though power failure occur in one feeder wouldn't affect for continuity supply.
- As this is a ring system there won't be heavy voltage fluctuations.
-

Advantages if using ring distribution systems:

- Ring distribution system can't be expanded.
- Due to additional power lines and a greater circuit complexity, this is very expensive method to install.
- It is very difficult to maintain the system.
- Justification of the loop in required areas is tedious.

5

Chapter Five

Case study

Chapter 5: Case study

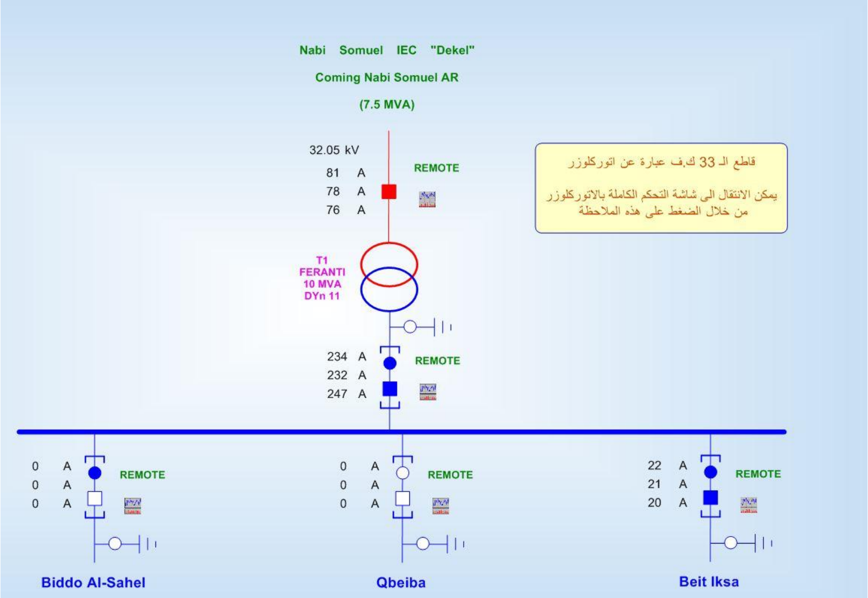
5.1 Introduction to Jerusalem district electricity company (JDECO)

The Jerusalem District Electricity Company (JDECO), previously the Jerusalem Electric and Public Service Corporation, is an electricity company established in its current form in 1956 that has the exclusive rights to supply electricity to consumers in the districts of East Jerusalem, Bethlehem, Ramallah and Jericho. The company does not have its own power stations, but buys over 95% of its electricity from Israel Electric Corporation (IEC) and the remainder from Jordanian National Electric Power Company. Jordanian electricity is only used in the Jericho district.

JDECO supplies electricity to 30% of households in the West Bank and East Jerusalem. JDECO supplies electricity in its license area, while IEC sells electricity directly to the PA to distribute in areas not covered by JDECO.[11]

5.2 West of Jerusalem grid diagram

The grid contains main substation (Nabi-somuel substation) with capacity of 7.5MVA, where the substation has two transformers 33/11 kV. The substation supply three main feeders with 11kV for three areas (Biddo Al-Sahel, Qbeiba, and Beit Iksa).



قاطع الـ 33 ك.ف عبارة عن اتوركلوزر

يمكن الانتقال الى شاشة التحكم الكاملة بالاتوركلوزر
من خلال الضغط على هذه الملاحظة

Figure (5.1) Nabi sumoel substation feeders

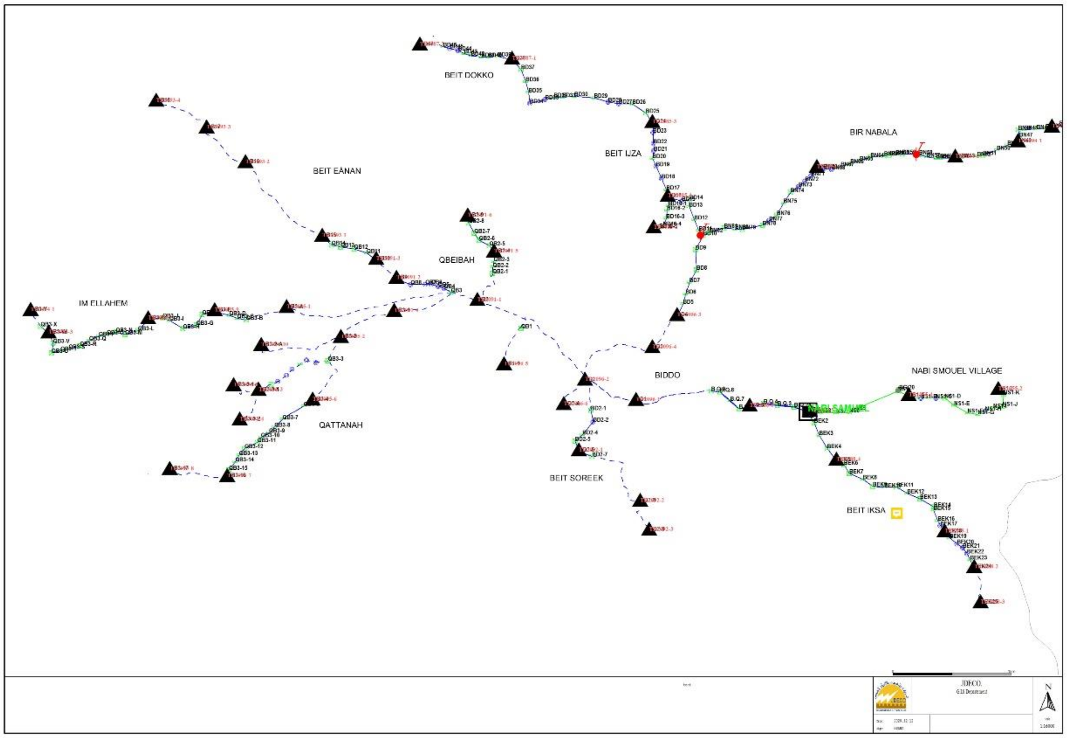


Figure (5.2) West of Jerusalem grid transmission line diagram

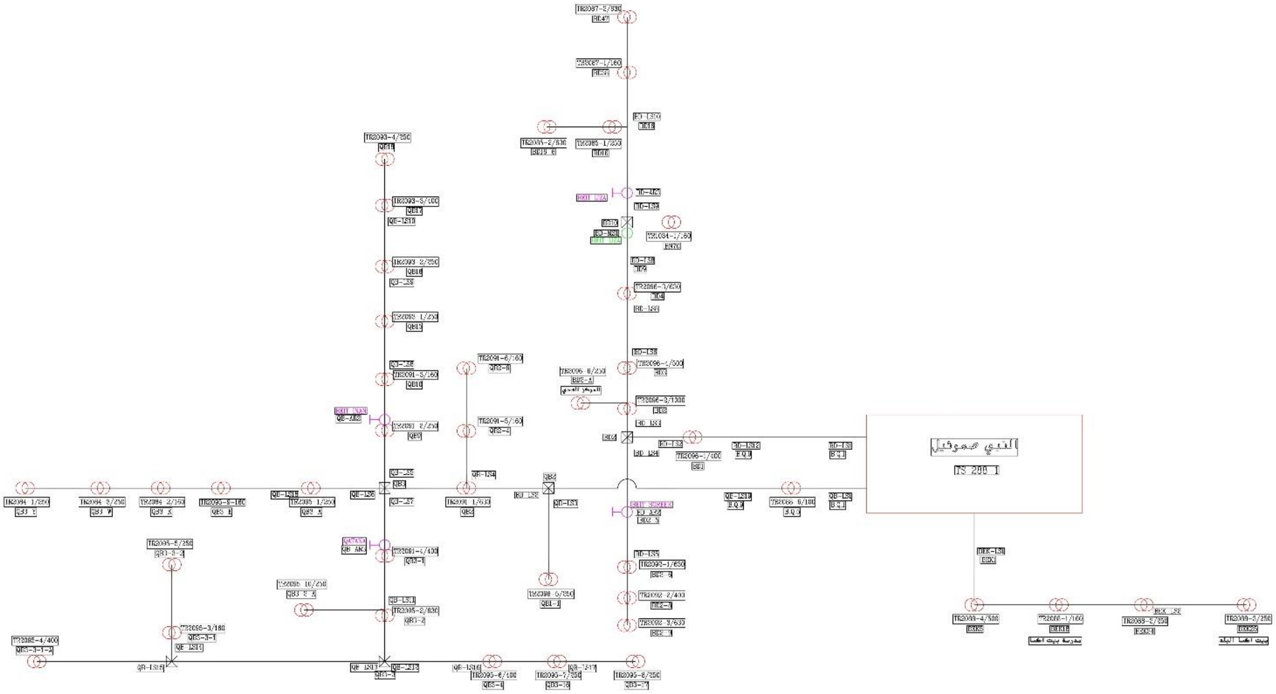


Figure (5.3) west of Jerusalem grid transformers

5.3 single line diagram for west of Jerusalem grid

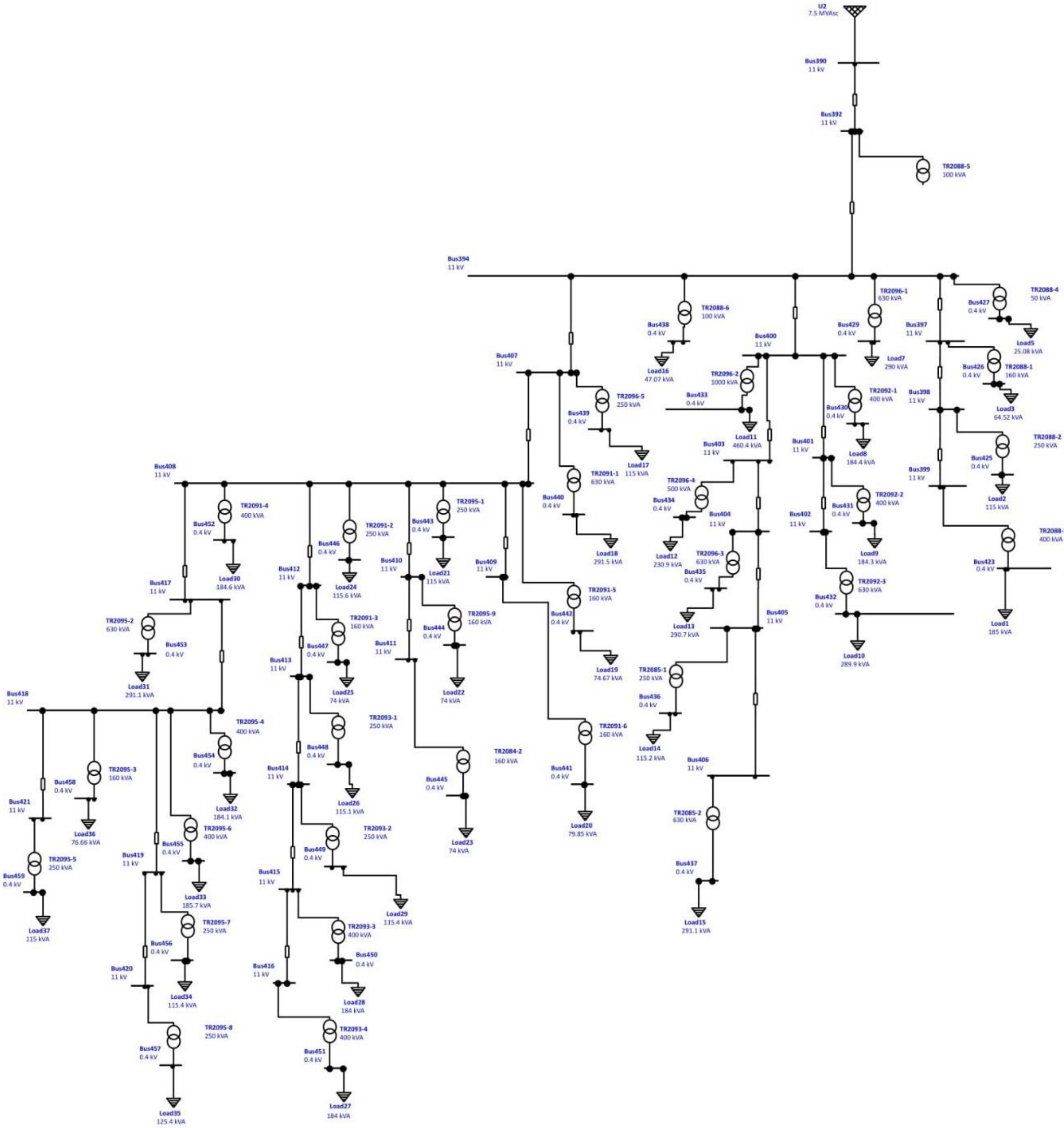


Figure (5.4) West of Jerusalem single line diagram

5.4 Network transformers and transmission lines

The network where choose for the case study have a total of 31 transformers. The main substation contains two transformers with a total capacity of 7.5 MVA, where the substation step down the voltage level from 33kV to 11kV.

Table (A.1) shows the grid transformers with capacity of each of them.

6

Chapter Six

Data and simulation results

Chapter 6: Data and simulation results

6.1 Load curve

As many of the city's residents rely on electrical heating devices, the household loads, commercial and industrial share during 2019 as shown in figure (6.1.1) the composition of the maximum load of the electricity network of west of Jerusalem has reached the maximum load for 2019 in 31-Dec-2019.

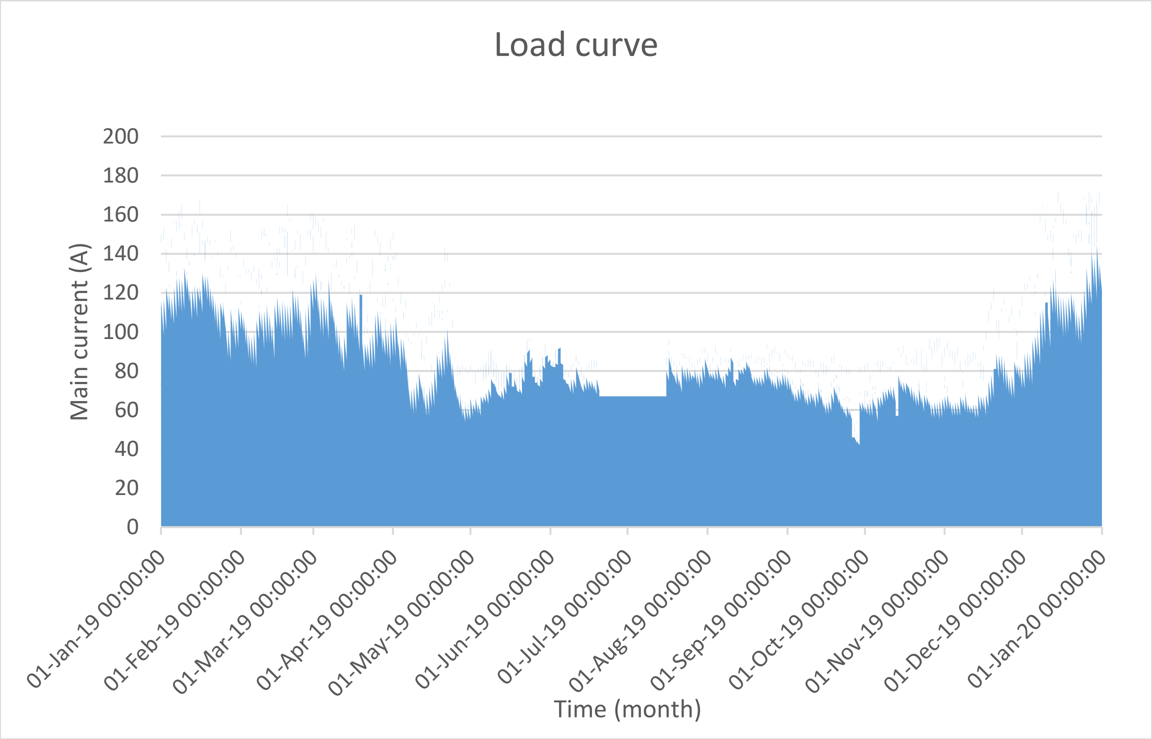


Figure (6.1) Load curve for the main substation

Figure (6.1) represents the relationship between the main current and the time for the substation (Nabi Samuel substation) for 2019.

6.2 Simulation results comparison

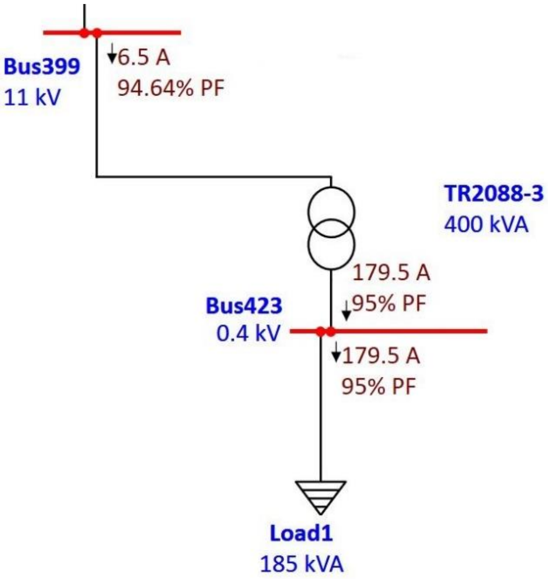


Figure (6.2) Bus 399 before adding the capacitor bank

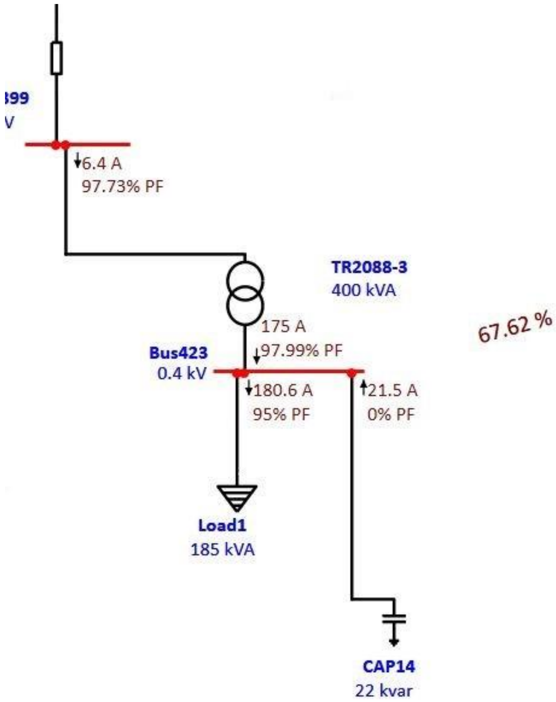


Figure (6.3) Bus 399 after adding the capacitor bank

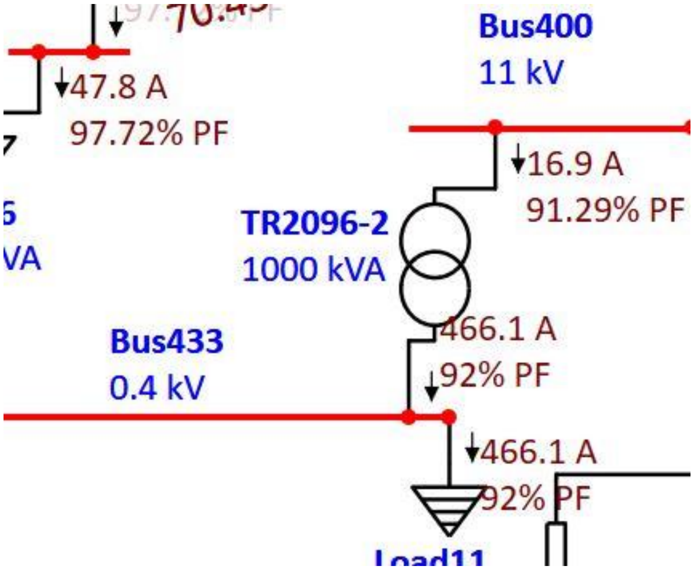


Figure (6.4) Bus 400 before adding the capacitor bank

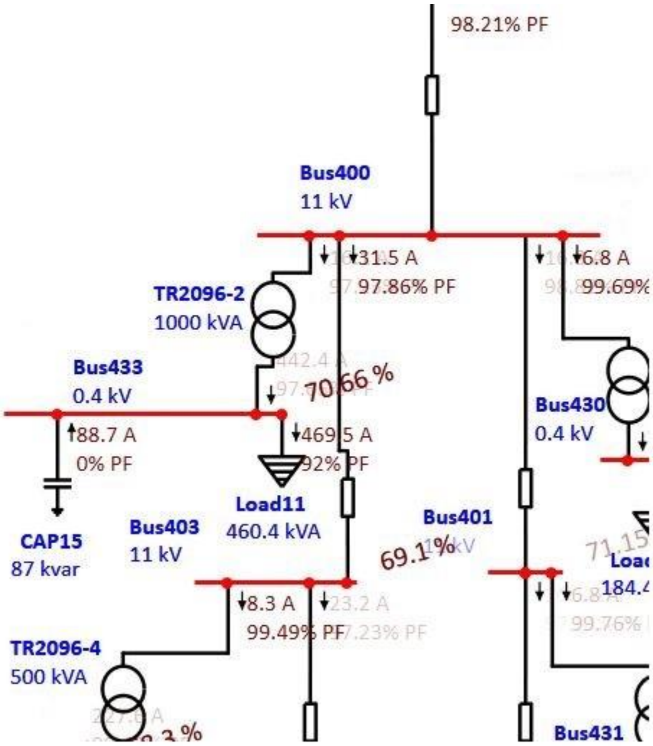


Figure (6.5) Bus 400 after adding the capacitor bank

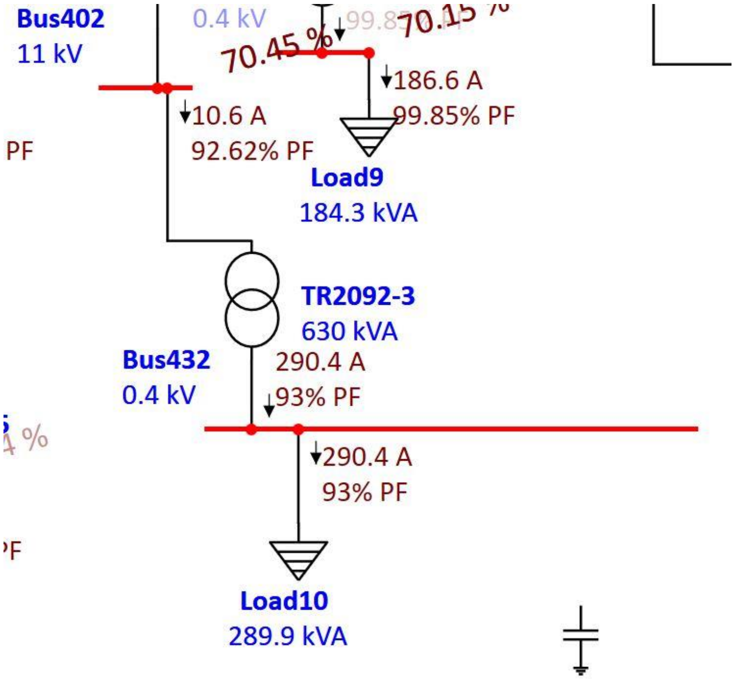


Figure (6.6) Bus 402 before adding the capacitor bank

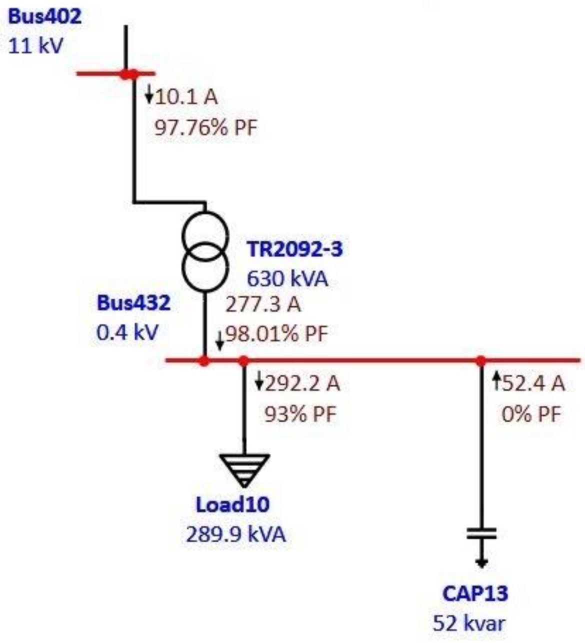


Figure (6.7) Bus 402 after adding the capacitor bank

7

Chapter seven

Conclusion and recommendations

Chapter 7: Conclusion and recommendations

7.1 Conclusion

Power factor correction techniques can be applied in industries, commercial lines and power distribution system to increase stability and efficiency of the system. This project presents a case study for west of Jerusalem grid on power factor correction. A site with poor power factor and high peak demand is selected for demonstration. With 12-months of the data collection and analysis, three capacitor banks where selected to achieve the optimal outcome. As a result the data shows there was a significant inductive load reduction and the power factor was able to be improved from 0.92 to 0.98 on average.

7.2 Recommendations

- Connect smart meters to all distribution transformers in order to monitor and manage loads.
- The importance and necessity of connecting the ring system for the network.
- There is a need for development studies using network analysis programs.
- Use GIS to collect and archive network contents.

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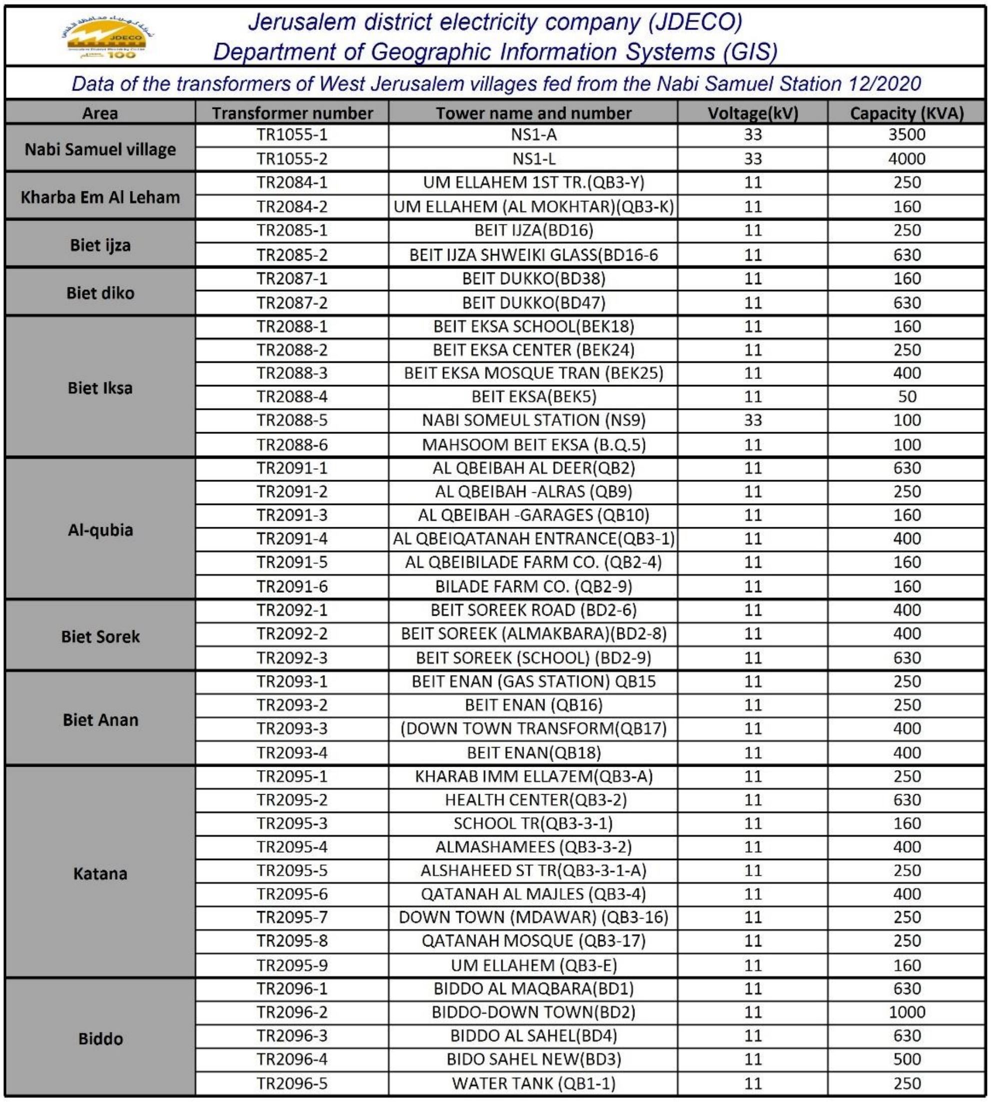
Appendices



Jerusalem district electricity company (JDECO)
Department of Geographic Information Systems (GIS)

Data of the transformers of West Jerusalem villages fed from the Nabi Samuel Station 12/2020

Area	Transformer number	Tower name and number	Voltage(kV)	Capacity (KVA)
Nabi Samuel village	TR1055-1	NS1-A	33	3500
	TR1055-2	NS1-L	33	4000
Kharba Em Al Leham	TR2084-1	UM ELLAHEM 1ST TR.(QB3-Y)	11	250
	TR2084-2	UM ELLAHEM (AL MOKHTAR)(QB3-K)	11	160
Biet ijza	TR2085-1	BEIT IJZA(BD16)	11	250
	TR2085-2	BEIT IJZA SHWEIKI GLASS(BD16-6	11	630
Biet diko	TR2087-1	BEIT DUKKO(BD38)	11	160
	TR2087-2	BEIT DUKKO(BD47)	11	630
Biet Iksa	TR2088-1	BEIT EKSA SCHOOL(BEK18)	11	160
	TR2088-2	BEIT EKSA CENTER (BEK24)	11	250
	TR2088-3	BEIT EKSA MOSQUE TRAN (BEK25)	11	400
	TR2088-4	BEIT EKSA(BEK5)	11	50
	TR2088-5	NABI SOMEUL STATION (NS9)	33	100
	TR2088-6	MAHSOOM BEIT EKSA (B.Q.5)	11	100
Al-qubia	TR2091-1	AL QBEIBAH AL DEER(QB2)	11	630
	TR2091-2	AL QBEIBAH -ALRAS (QB9)	11	250
	TR2091-3	AL QBEIBAH -GARAGES (QB10)	11	160
	TR2091-4	AL QBEIQATANAH ENTRANCE(QB3-1)	11	400
	TR2091-5	AL QBEIBILADE FARM CO. (QB2-4)	11	160
	TR2091-6	BILADE FARM CO. (QB2-9)	11	160
Biet Sorek	TR2092-1	BEIT SOREEK ROAD (BD2-6)	11	400
	TR2092-2	BEIT SOREEK (ALMAKBARA)(BD2-8)	11	400
	TR2092-3	BEIT SOREEK (SCHOOL) (BD2-9)	11	630
Biet Anan	TR2093-1	BEIT ENAN (GAS STATION) QB15	11	250
	TR2093-2	BEIT ENAN (QB16)	11	250
	TR2093-3	(DOWN TOWN TRANSFORM(QB17)	11	400
	TR2093-4	BEIT ENAN(QB18)	11	400
Katana	TR2095-1	KHARAB IMM ELLA7EM(QB3-A)	11	250
	TR2095-2	HEALTH CENTER(QB3-2)	11	630
	TR2095-3	SCHOOL TR(QB3-3-1)	11	160
	TR2095-4	ALMASHAMEES (QB3-3-2)	11	400
	TR2095-5	ALSHAHEED ST TR(QB3-3-1-A)	11	250
	TR2095-6	QATANAH AL MAJLES (QB3-4)	11	400
	TR2095-7	DOWN TOWN (MDAWAR) (QB3-16)	11	250
	TR2095-8	QATANAH MOSQUE (QB3-17)	11	250
	TR2095-9	UM ELLAHEM (QB3-E)	11	160
Biddo	TR2096-1	BIDDO AL MAQBARA(BD1)	11	630
	TR2096-2	BIDDO-DOWN TOWN(BD2)	11	1000
	TR2096-3	BIDDO AL SAHEL(BD4)	11	630
	TR2096-4	BIDO SAHEL NEW(BD3)	11	500
	TR2096-5	WATER TANK (QB1-1)	11	250

Table (A.1) West of Jerusalem grid transformers data

11kv BIDDO

From	To	Type designation	Length km
TS288-1(NABI SOMEUL)	B.Q.1	TSLE 3X1X150 CU	0.011
B.Q.1	B.Q.2	FEAL 1X95	0.116
B.Q.2	B.Q.3	FEAL 1X95	0.143
B.Q.3	B.Q.4	FEAL 1X95	0.12
B.Q.4	B.Q.5	FEAL 1X95	0.123
B.Q.5	B.Q.6	FEAL 1X95	0.094
B.Q.6	B.Q.7	FEAL 1X95	0.101
B.Q.7	B.Q.8	FEAL 1X95	0.115
B.Q.8	B.Q.9	FEAL 1X95	0.076
B.Q.9	BD1	TSLE 3X1X150 CU	0.677
BD1	BD2	TSLE 3X1X150 CU	0.517
BD2	BD2-1	TSLE 3X1X150 CU	0.296
BD2-1	BD2-2	FEAL 1X50	0.099
BD2-2	BD2-3	FEAL 1X50	0.094
BD2-3	BD2-4	FEAL 1X50	0.054
BD2-4	BD2-5	FEAL 1X50	0.083
BD2-5	BD2-6	FEAL 1X50	0.094
BD2-6	BD2-7	FEAL 1X50	0.12
BD2-7	BD2-8	DKBA 1X3X120 CU	0.309
BD2-8	BD2-9	DKBA 1X3X120 CU	0.313
BD2	BD2-A	TSLE 3X1X240 AL	0.295
BD2	BD3	TSLE 3X1X150 CU	0.809
BD3	BD4	TSLE 3X1X240 AL	0.351
BD4	BD5	FEAL 1X120	0.118
BD5	BD6	FEAL 1X120	0.084
BD6	BD7	FEAL 1X120	0.105
BD7	BD8	FEAL 1X120	0.122
BD8	BD9	FEAL 1X120	0.169
BD9	BD10	FEAL 1X95	0.136
BD10	BD11	FEAL 1X95	0.055
BD11	BD12	FEAL 1X95	0.104
BD12	BD13	FEAL 1X95	0.118
BD13	BD14	FEAL 1X95	0.063
BD14	BD15	FEAL 1X95	0.067
BD15	BD16	FEAL 1X50	0.121
BD16	BD16-1	FEAL 1X95	0.069
BD16	BD17	FEAL 1X50	0.063
BD16-1	BD16-2	FEAL 1X95	0.041
BD16-2	BD16-3	FEAL 1X95	0.071
BD16-3	BD16-4	FEAL 1X95	0.067
BD16-4	BD16-5	FEAL 1X95	0.039
BD16-5	BD16-6	FEAL 1X95	0.047
BD17	BD18	FEAL 1X50	0.105
BD18	BD19	FEAL 1X50	0.111
BD19	BD20	FEAL 1X50	0.076
BD20	BD21	FEAL 1X50	0.064
BD21	BD22	FEAL 1X50	0.062
BD22	BD23	FEAL 1X50	0.091
BD23	BD24	FEAL 1X50	0.08
BD24	BD25	FEAL 1X50	0.104
BD25	BD26	FEAL 1X50	0.137
BD26	BD27	FEAL 1X50	0.112
BD27	BD28	FEAL 1X50	0.09
BD28	BD29	FEAL 1X50	0.126
BD29	BD30	FEAL 1X50	0.165
BD30	BD31	FEAL 1X50	0.105
BD31	BD32	FEAL 1X50	0.07
BD32	BD33	FEAL 1X50	0.073
BD33	BD34	FEAL 1X50	0.136
BD34	BD35	FEAL 1X50	0.096
BD35	BD36	FEAL 1X50	0.098
BD36	BD37	FEAL 1X50	0.114
BD37	BD38	FEAL 1X50	0.116
BD38	BD39	FEAL 1X50	0.125
BD39	BD40	FEAL 1X50	0.078
BD40	BD41	FEAL 1X50	0.062
BD41	BD42	FEAL 1X50	0.086
BD42	BD43	FEAL 1X50	0.063
BD43	BD44	FEAL 1X50	0.055
BD44	BD45	FEAL 1X50	0.072
BD45	BD46	FEAL 1X50	0.06
BD46	BD47	DKBA 1X3X120 CU	0.203

Under ground cable

Table (A.2) Biddo transmission lines and cables types

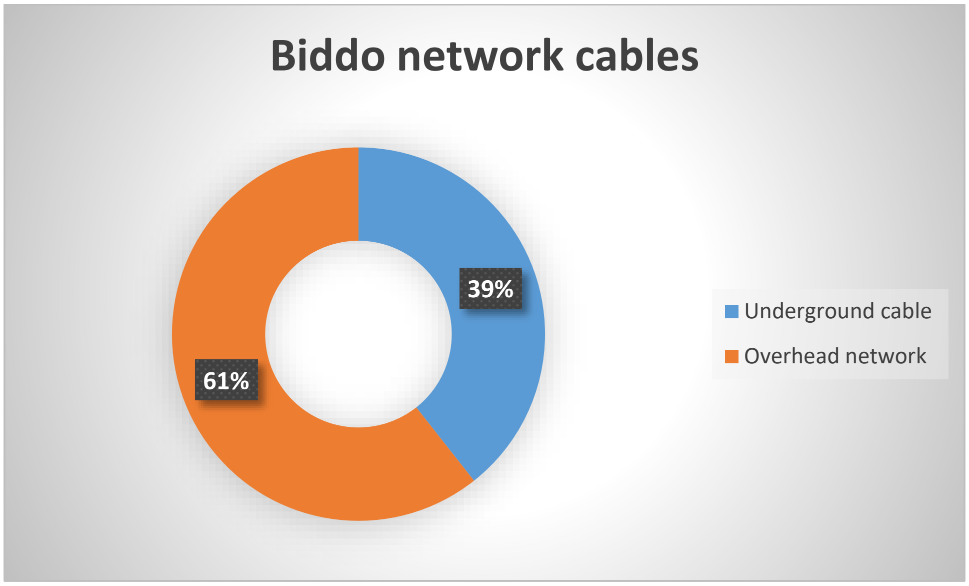
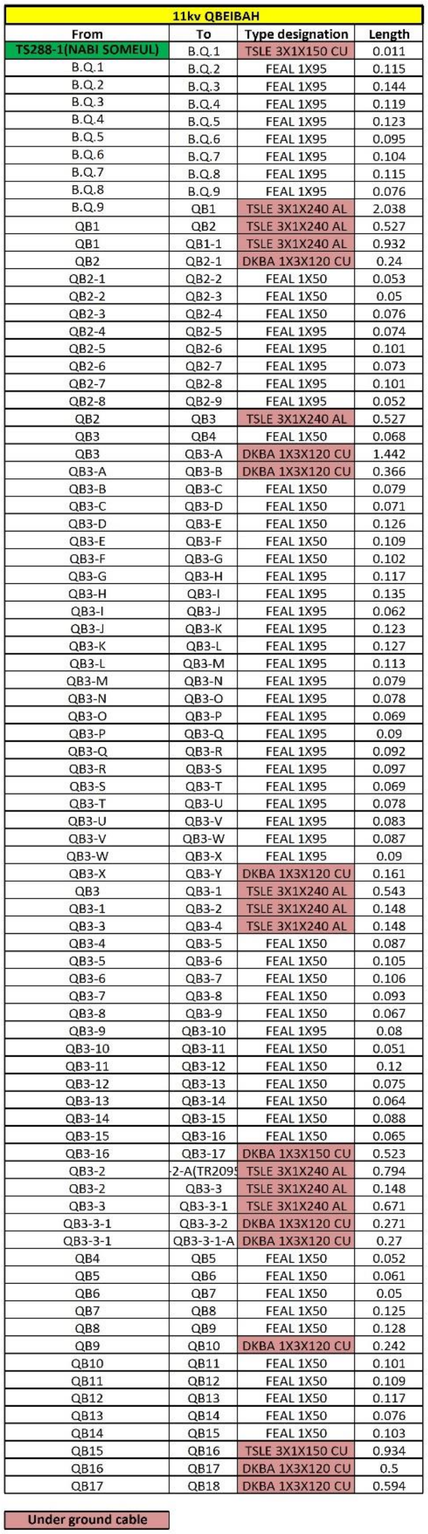


Figure (A.1) Biddo Percentages for overhead and underground networks



11kv QBEIBAH			
From	To	Type designation	Length
TS288-1(NABI SOMEUL)	B.Q.1	TSLE 3X1X150 CU	0.011
B.Q.1	B.Q.2	FEAL 1X95	0.115
B.Q.2	B.Q.3	FEAL 1X95	0.144
B.Q.3	B.Q.4	FEAL 1X95	0.119
B.Q.4	B.Q.5	FEAL 1X95	0.123
B.Q.5	B.Q.6	FEAL 1X95	0.095
B.Q.6	B.Q.7	FEAL 1X95	0.104
B.Q.7	B.Q.8	FEAL 1X95	0.115
B.Q.8	B.Q.9	FEAL 1X95	0.076
B.Q.9	QB1	TSLE 3X1X240 AL	2.038
QB1	QB2	TSLE 3X1X240 AL	0.527
QB1	QB1-1	TSLE 3X1X240 AL	0.932
QB2	QB2-1	DKBA 1X3X120 CU	0.24
QB2-1	QB2-2	FEAL 1X50	0.053
QB2-2	QB2-3	FEAL 1X50	0.05
QB2-3	QB2-4	FEAL 1X50	0.076
QB2-4	QB2-5	FEAL 1X95	0.074
QB2-5	QB2-6	FEAL 1X95	0.101
QB2-6	QB2-7	FEAL 1X95	0.073
QB2-7	QB2-8	FEAL 1X95	0.101
QB2-8	QB2-9	FEAL 1X95	0.052
QB2	QB3	TSLE 3X1X240 AL	0.527
QB3	QB4	FEAL 1X50	0.068
QB3	QB3-A	DKBA 1X3X120 CU	1.442
QB3-A	QB3-B	DKBA 1X3X120 CU	0.366
QB3-B	QB3-C	FEAL 1X50	0.079
QB3-C	QB3-D	FEAL 1X50	0.071
QB3-D	QB3-E	FEAL 1X50	0.126
QB3-E	QB3-F	FEAL 1X50	0.109
QB3-F	QB3-G	FEAL 1X50	0.102
QB3-G	QB3-H	FEAL 1X95	0.117
QB3-H	QB3-I	FEAL 1X95	0.135
QB3-I	QB3-J	FEAL 1X95	0.062
QB3-J	QB3-K	FEAL 1X95	0.123
QB3-K	QB3-L	FEAL 1X95	0.127
QB3-L	QB3-M	FEAL 1X95	0.113
QB3-M	QB3-N	FEAL 1X95	0.079
QB3-N	QB3-O	FEAL 1X95	0.078
QB3-O	QB3-P	FEAL 1X95	0.069
QB3-P	QB3-Q	FEAL 1X95	0.09
QB3-Q	QB3-R	FEAL 1X95	0.092
QB3-R	QB3-S	FEAL 1X95	0.097
QB3-S	QB3-T	FEAL 1X95	0.069
QB3-T	QB3-U	FEAL 1X95	0.078
QB3-U	QB3-V	FEAL 1X95	0.083
QB3-V	QB3-W	FEAL 1X95	0.087
QB3-W	QB3-X	FEAL 1X95	0.09
QB3-X	QB3-Y	DKBA 1X3X120 CU	0.161
QB3	QB3-1	TSLE 3X1X240 AL	0.543
QB3-1	QB3-2	TSLE 3X1X240 AL	0.148
QB3-3	QB3-4	TSLE 3X1X240 AL	0.148
QB3-4	QB3-5	FEAL 1X50	0.087
QB3-5	QB3-6	FEAL 1X50	0.105
QB3-6	QB3-7	FEAL 1X50	0.106
QB3-7	QB3-8	FEAL 1X50	0.093
QB3-8	QB3-9	FEAL 1X50	0.067
QB3-9	QB3-10	FEAL 1X95	0.08
QB3-10	QB3-11	FEAL 1X50	0.051
QB3-11	QB3-12	FEAL 1X50	0.12
QB3-12	QB3-13	FEAL 1X50	0.075
QB3-13	QB3-14	FEAL 1X50	0.064
QB3-14	QB3-15	FEAL 1X50	0.088
QB3-15	QB3-16	FEAL 1X50	0.065
QB3-16	QB3-17	DKBA 1X3X150 CU	0.523
QB3-2	-2-A(TR2095	TSLE 3X1X240 AL	0.794
QB3-2	QB3-3	TSLE 3X1X240 AL	0.148
QB3-3	QB3-3-1	TSLE 3X1X240 AL	0.671
QB3-3-1	QB3-3-2	DKBA 1X3X120 CU	0.271
QB3-3-1	QB3-3-1-A	DKBA 1X3X120 CU	0.27
QB4	QB5	FEAL 1X50	0.052
QB5	QB6	FEAL 1X50	0.061
QB6	QB7	FEAL 1X50	0.05
QB7	QB8	FEAL 1X50	0.125
QB8	QB9	FEAL 1X50	0.128
QB9	QB10	DKBA 1X3X120 CU	0.242
QB10	QB11	FEAL 1X50	0.101
QB11	QB12	FEAL 1X50	0.109
QB12	QB13	FEAL 1X50	0.117
QB13	QB14	FEAL 1X50	0.076
QB14	QB15	FEAL 1X50	0.103
QB15	QB16	TSLE 3X1X150 CU	0.934
QB16	QB17	DKBA 1X3X120 CU	0.5
QB17	QB18	DKBA 1X3X120 CU	0.594

Under ground cable

Table (A.3) Qbeibah transmission lines and cables types

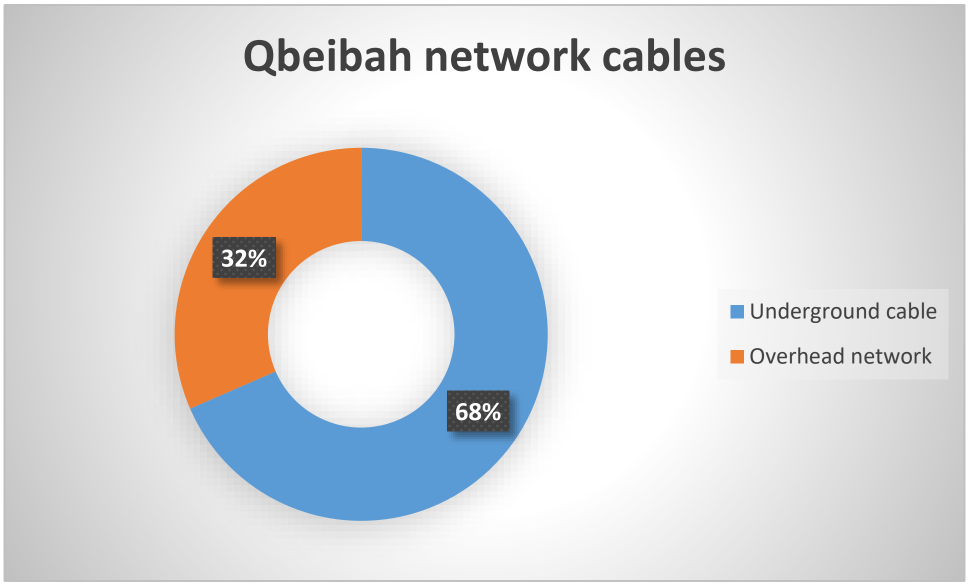
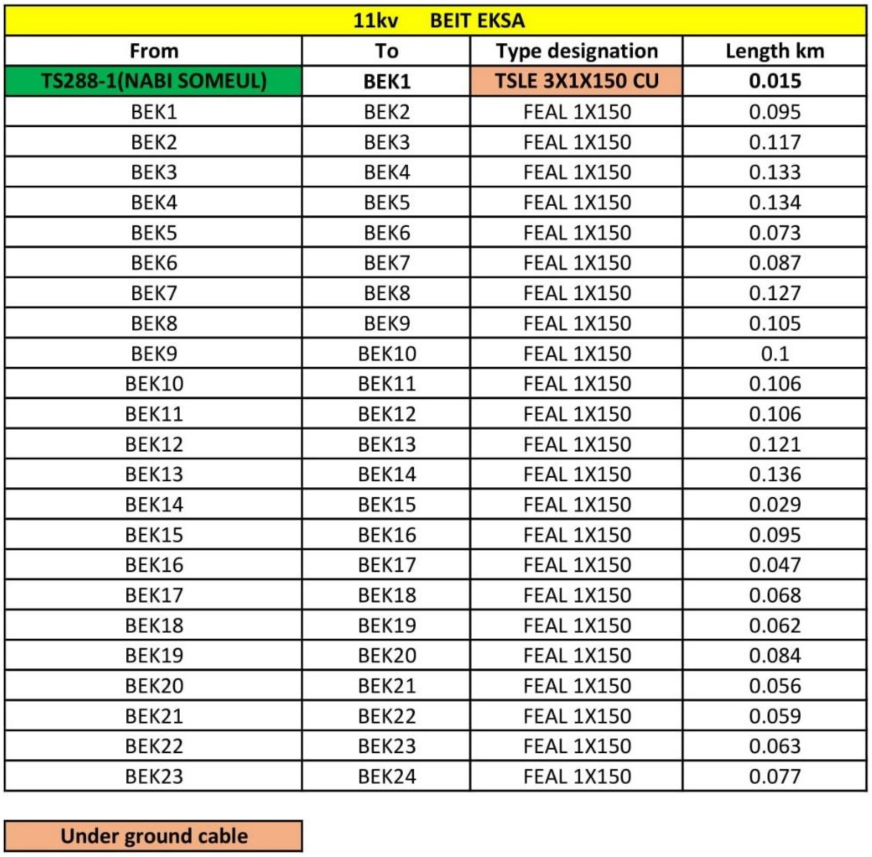


Figure (A.2) Qbeibah Percentages for overhead and underground networks



11kv BEIT EKSA			
From	**To**	**Type designation**	**Length km**
TS288-1(NABI SOMEUL)	**BEK1**	**TSLE 3X1X150 CU**	**0.015**
BEK1	BEK2	FEAL 1X150	0.095
BEK2	BEK3	FEAL 1X150	0.117
BEK3	BEK4	FEAL 1X150	0.133
BEK4	BEK5	FEAL 1X150	0.134
BEK5	BEK6	FEAL 1X150	0.073
BEK6	BEK7	FEAL 1X150	0.087
BEK7	BEK8	FEAL 1X150	0.127
BEK8	BEK9	FEAL 1X150	0.105
BEK9	BEK10	FEAL 1X150	0.1
BEK10	BEK11	FEAL 1X150	0.106
BEK11	BEK12	FEAL 1X150	0.106
BEK12	BEK13	FEAL 1X150	0.121
BEK13	BEK14	FEAL 1X150	0.136
BEK14	BEK15	FEAL 1X150	0.029
BEK15	BEK16	FEAL 1X150	0.095
BEK16	BEK17	FEAL 1X150	0.047
BEK17	BEK18	FEAL 1X150	0.068
BEK18	BEK19	FEAL 1X150	0.062
BEK19	BEK20	FEAL 1X150	0.084
BEK20	BEK21	FEAL 1X150	0.056
BEK21	BEK22	FEAL 1X150	0.059
BEK22	BEK23	FEAL 1X150	0.063
BEK23	BEK24	FEAL 1X150	0.077

Under ground cable

Table (A.4) Beit Iksa transmission lines and cables types

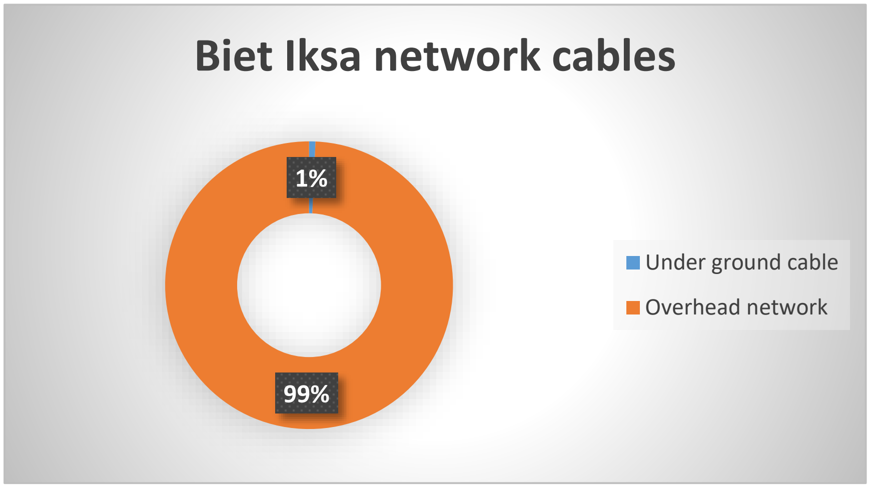


Figure (A.3) Beit Iksa Percentages for overhead and underground networks

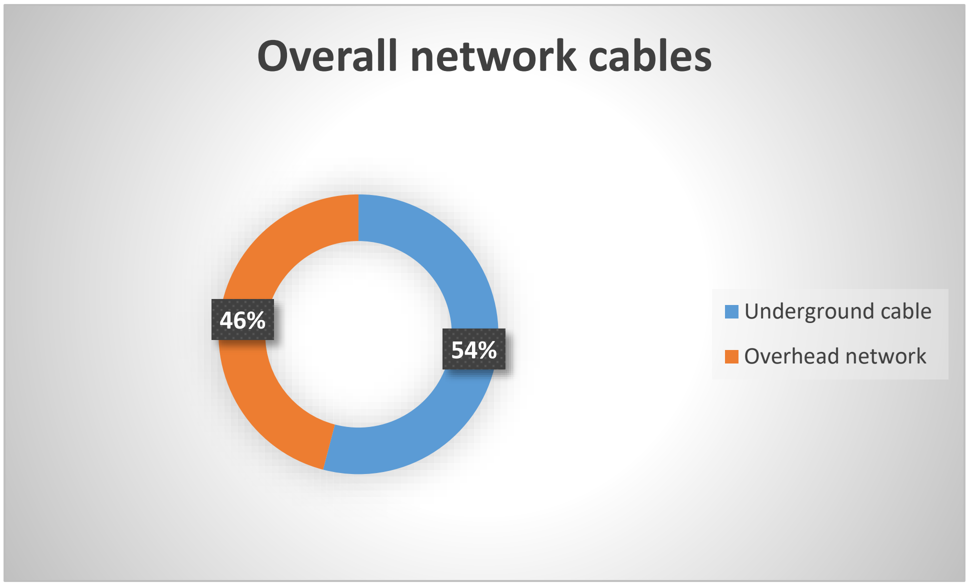


Figure (A.4) west of Jerusalem overall Percentages for overhead and underground networks