Palestine Polytechnic University

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Minimizing the Power Losses in Hebron Electrical Power Grid

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الإهداء

نهدي هذا العمل المتواضع إلى والدينا الكرام اللذان لم يدخرا جهداً في توفير كل الظروف المناسبة لإنجاح عملنا هذا ونهديه ايضاً إلى أعضاء هيئة التدريس وموظفي جامعة البوليتكنك ونخص بالذكر الدكتور فؤاد الزرو

كما نهدي هذا العمل المتواضع لوطننا الغالي وعاصمة بلادنا القدس الشريف وإلى أرواح شهداء الوطن وإلى الأسرى وإلى كل من احب العلم و التعلم

شكر وتقدير

الحمد لله الذي جعل التربية مشتقة من اسمه ،وجعل أشرف الأعمال عمل المربين والصلاة والسلام على سيد المرسلين محمد

وعلى من اهتدى بهديه إلى يوم الدين وبعد :

في نهاية عملنا المتواضع نحمد الله العظيم ونشكره كثيرا بجزيل شكرنا وعظيم امتناننا إلى جامعة

بوليتكنك فلسطين ممثلة في رئيسها **الاستاذ الدكتور عماد الخطيب** .

وإن واجب العرفان يدعونا أن أتقدم بالشكر الوفير والتقدير الكبير لأستاذنا الجليل **الدكتور فؤاد الزرو**

الذي كان له فضل الإشراف على هذه المشروع فكان نعم المرشد والموجه .

ولا ننسى كثير الشكر والاحترام والتقدير الى شركة كهرباء الخليل ممثلة في رئيسها

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وان واجب العرفان يدعونا أن نتقدم بالشكر الوفير و التقدير الكبير الى موظفين شركة كهرباء الخليل

ونخص بالذكر **المهندسان أيمن حسونة وسامر سلطان** الذان أفادونا بآرائهم العلمية القيمة واعطونا

المعلومات الكافية عن شركة كهرباء الخليل لاتمام هذا المشروع . كما نتقدم بجزيل الشكر لعضوي

لجنة المناقشة : **الدكتور سمير حنا والدكتور نسيم أقطيط** .

في الختام نتقدم بخالص شكرنا وتقديرنا وعرفانا لكل من ساهم وأنصح وأرشد من أجل أتمام هذه الدراسة.

Abstract

This project studies the medium voltage electric power network of Hebron city by using Electrical Transient Analyzer Program (ETAP) and it aims to make the critical developments and improvements on the network in order to minimize the power losses.

The core of this project is the use of the ETAP, as simulation tool property that allows us to analyze and study the status of the network more accurately.

Hebron grid suffers from high losses, which about 21%, divided into technical and non-technical losses. In this project, several techniques are presented to reduce the power losses and clarify their impact in improving power efficiency of the distribution system.

After studying the network, we found that the power losses in the medium voltage network is 3.2%, which is an acceptable value according to the standards of The International Electro-Technical Commission (IEC).

In this project, two scenarios were applied to the power flow analysis, in addition, a new sub-station was added to the network.

Moreover, the scenarios studied and estimated the power losses before and after adding the new sub-station and we made a redistribution of loads on the sub-stations in order to connect the loads to the nearest sub-station feeders as much as possible, which helped in decreasing the total power losses.

Finally, after studying the network, we found that the total power losses could be reduced from 3.2% to 2.93% in MV, which makes a difference of 0.274% of the power losses.

الملخص

يدرس هذا المشروع شبكة الطاقة الكهربائية متوسطة الجهد في مدينة الخليل باستخدام برنامج محلل الكهرباء (ETAP), ويهدف الى إجراء التطويرات والتحسينات ذات الأهمية والتأثير الأكبر على الشبكة من أجل تقليل خسائر الطاقة.

يتمثل جوهر هذا المشروع في استخدام (ETAP)، الذي يحتوي على خاصية المحاكاة التي تسمح لنا بتحليل ودراسة حالة الشبكة بشكل أكثر دقة.

تعاني هذه الشبكة من خسائر كبيرة، وهي 21 ٪، مقسمة الى خسائر تقنية وغير تقنية، في هذا المشروع، سيتم عرض العديد من التقنيات لتقليل فقد الطاقة وتوضيح تأثيرها في تحسين كفاءة الطاقة لنظام التوزيع.

بعد دراسة الشبكة، وجدنا أن مقدار الطاقة الضائعة في شبكة الجهد المتوسط هي 3.2 ٪، وهي قيمة مقبولة وفقًا لمعايير اللجنة الكهرو تقنية الدولية (IEC).

في هذا المشروع، تم تطبيق عدة حالات على تحليل تدفق الطاقة، بالإضافة إلى إضافة محطة فرعية جديدة إلى الشبكة. علاوة على ذلك، قامت الحالات بدراسة وتقدير مقدار فقد الطاقة قبل وبعد إضافة المحطة الفرعية الجديدة.

وقمنا بإعادة توزيع الأحمال على المحطات الفرعية من أجل توصيل الأحمال بأقرب مغذيات من المحطات الفرعية قدر الإمكان، مما ساعد في تقليل إجمالي خسائر الطاقة.

في النهاية، بعد دراسة الشبكة ، وجدنا أنه يمكن تخفيض إجمالي خسائر الطاقة من 3.2٪ إلى 2.93٪ ، مما يحدث فرقًا بنسبة 0.274٪ من مقدار فقد الطاقة.

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List of abbreviations

HEPCo: Hebron Electrical Power Company
ETAP: Electrical Transient Analyzer Program
AC: Alternating Current
ACCC: Aluminum Conductor Composite Core
AVR: Automatic Voltage Regulator
DC: Direct Current
FACTS: Flexible Alternating Current Transmission System
HVDS: High Voltage Distribution System
IEC: Israeli Electric Company
IEEE: Institute of Electrical and Electronics Engineers
LTC: Load Tap Changers
LV: Low Voltage
LVDS: Low Voltage Distribution System
MPC: Main power center
MV: Medium Voltage
NIS: New Israeli Shekel
OPF: Optimal Power Flow
SSSC: Static Synchronous Series Compensator
STATCOM: Static Synchronous Compensator
SVS: Synchronous Voltage Source
UPFC: Unified Power Flow Controllers
MV: Medium Voltage
GIs:Geographic Information System
DPS: Distibuted Power System
NR: Newton-Raphson
HVS: High Voltage Substation
PCBS: Palestinian Central Bureau of Statistics
kV: kilo Volt
S/S: Sub-stiation
kVA: Kilovolt-ampere
MVA: Megavolt- Ampere
km: kilometer
kWh : kilowatt hour
MWh : Megawatt hour
NIS: New Israeli Shekel
kW: kilo Watt
PF : Power Factor

Chapter 1

Introduction

1.1 Overview

This project studies the medium voltage electric power network in Hebron Electrical Power Company (HEPCo), determine the power losses in the distribution networks components such as losses in the cables and transformers, and do the simulation for the distribution networks of HEPCo by using ETAP to estimate the real power losses and propose scenarios to reduce it.

1.2 Motivation

The motivation behind this study is to get the best economical solution which help in reducing the money lost that can be used to improve the distribution networks of HEPCo or in another benefits for the company which also may give the customer some advantages, estimate the power losses in the distribution networks for HEPCo in the Medium Voltage (MV) network by using ETAP, and start the essential steps to minimize the power losses.

1.3 Objectives

1. Analyzing the power flow using ETAP to obtain useful and detailed readings and information about the power losses in the distribution network.
2. Proposing and discussing scenarios for loss minimization.
3. Deciding whether it is possible to apply this project practically or not.

1.4 Methodology

The procedures followed to accomplish this project are summarized as follow:

1. Data collection: the collected data involves the single line diagram (SLD) of Hebron electrical network for Hebron city, of the electrical MV network, the electrical

specifications of the wires, cables and transformers used by HEPCo and the transformers loading measurements for both summer and winter seasons.

2. Load flow analysis: the single-line diagram of the seven main substations of Hebron are provided to ETAP software. The electrical specifications of the lines and transformers were entered to customized libraries in ETAP. Then, A simulation process will be performed to evaluate the status of the distribution networks completely.

1.5 Literature review

Nassim A. Iqteit', 'Aysen Basa Arsoy' and 'Bekir Cakir' illustrated a simple approximated formulas which explain the way to estimate the active and reactive power losses in the distribution networks, taking load profiles into account. Also, a detailed simulation and discussion were presented with an applied example, the idea of the formulas is easy to apply and has a small error when using an appropriate number of time intervals [1]. Another paper discusses the types of the losses in the DC and AC generator, the effect of these losses and how may reduce these losses to the minimum magnitude. In addition, he discussed the major electrical transmission line losses and the best solutions to minimize it, this article was made for a specific part of Jordan, the author used ETAP for simulation and presented a detailed comparison before and after each case [2].

The authors in focused on developing and improving the medium voltage electrical network and they presented the modeling approach used to restructure electrical network configuration, reduce drop voltage, reduce power losses and add new distribution transformer to enhance reliability of power systems distribution. Restructure electrical network was aimed to analyze and investigate electric loads of a distribution transformer. Measurement of real voltage and real current were finished two times for each consumer, that were morning period and night period or when peak load. Design and simulation were conduct by using ETAP [3].

The authors in stated that accurate loss minimization is the critical component for efficient electrical distribution power flow. The contribution of their work presents loss minimization in power distribution system through feeder restructuring, incorporating DG and placement of capacitor. The study of this work was conducted on IEEE distribution network and India Electricity Board benchmark distribution system. The executed experimental result of Indian system is recommended to board and implement practically for regulated stable output [4].

The reduction of customer interruption due to failures in the distribution network is one of the leading priorities of power companies, which are working in market driven environment. The faults in the distribution network determine the distribution system reliability level and service quality, and they are the source of complains and customers' dissatisfaction. The reduction of customer interruption is of a significant importance for extremely loaded distribution systems. On the other band, this paper presents how to reduce the service interruption duration and customer outage costs when a failure occurs in the medium voltage network. By using the Geographic Information System (GIs) [5].

In this research paper, a detailed study for load flow analysis in distributed power system (DPS) is presented. A case study of modeling and simulation of the actual power distribution network is implemented with the electrical transient analyzer program (ETAP) software (version no: 12.6). Furthermore, a comparison of common load flow techniques of power distribution is presented. In this assessment, numerical and practical methods including Newton-Raphson (NR), Fast Decoupled (FD), and Accelerated Gauss-Seidel (AGS) are provided and compared. The results (total generation, loading, demand, system losses, and critical report of load flow) are obtained and analyzed. This paper focuses on the detailed assessment and monitoring by using the most modern ETAP software, from high voltage substation (HVS) to the loads [6].

This paper presents the estimation of Technical loss in a distribution system which plays an important role in planning and hence economics of any distribution utility. In a system there are two types of losses: fixed i.e.no load losses and variable i.e. load losses which are a function of load. This paper focuses on how load curve parameters like load factor, loss factor, coefficient of variation and loss coefficient can be useful for the loss estimation process. A simple approach is proposed to estimate technical loss in HT feeder and Distribution Transformer with non-functional energy meters with average demand using data available with local distribution company. Also, the paper discusses the use of average demand and loss coefficient in making economic cable choices and energy losses analysis [7].

CHAPTER 2

Hebron City Network

2.1 Introduction

Hebron is a Palestinian city located in the southern West Bank, 35 km south of Jerusalem, it lies 930 m above the sea level, the largest city in the West Bank and the second largest city in Palestine after Gaza, it has a population of 215,000 Palestinians according to the Palestinian Central Bureau of Statistics (PCBS) in 2016 count.

2.2 Hebron City Network

In the early of 1973, the Municipality started to deliver the Israeli generated power through distribution network owned by the Municipality. The electric power delivered increased from 26MVA in 1994 to 115MVA in 2018 due to the normal modernization and industrialization increase [7].

Electrical power system is divided into three types, generation, transmission and distribution. HEPCo is considered as a distribution company, which is supplied from Israeli Electric Company (IEC).

The areas which are served by HEPCo in terms of electric power is about 91 km^2. HEPCo has a flexibility in controlling the distribution electricity to different areas illustrated in figure (2.1) which are; Hebron city, Halhul, Essa, Loza, Beit Enun Baq'a, Dowara, Oddese, Qilqes, Jalajel. The estimated number of people who are supplied by electricity from HEPCo is around 250,000 inhabitants [7].

HEPCo is supplied from IEC with 161 kV and the transformer convert it to 33 kV, however, each substation has a type of 33/11 kV transformer and most loads are connected by distribution transformers 11/0.4 kV as shown in figure (2.2).

Figure 2. 1: Concession area map .

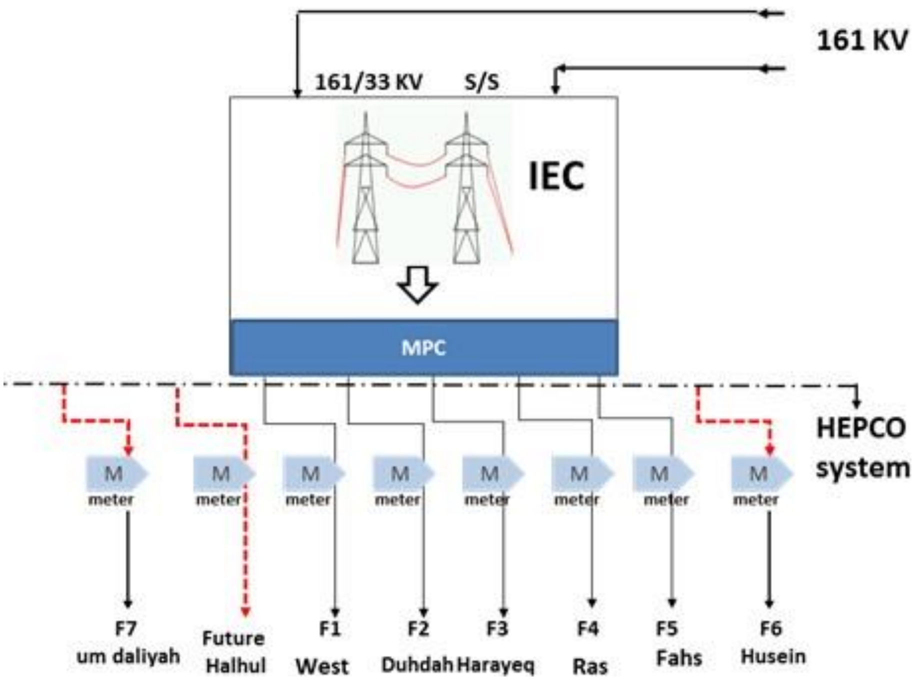

Figure 2. 2: Source of Electricity in the South .

2.3 Background

Main power center (MPC) was established to bridge between main connection points from IEC on 33 kV networks and the 33 kV networks exiting the station and heading towards main transforming substations (33/11 kV). MPC transfer capacity and electric loads from IEC Station to HEPCo seven main substations [7].

HEPCo uses a small substations contain power transformers, these substations receive 33 kV feeder from IEC and by using step down transformers, it convert the voltage to 11 kV, after that, each substation is connected with some distribution transformer of the ratio of (11 - 0.4) kV [7].

HEPCo has five tie points that connect it with IEC, Then, MPC supply the load by seven substations. The system includes some substations that are supplied from another substation as shown in figure (2.4). In addition, a photo of MPC is derived in figure (2.3).

Figure 2. 3: Main Power Center .

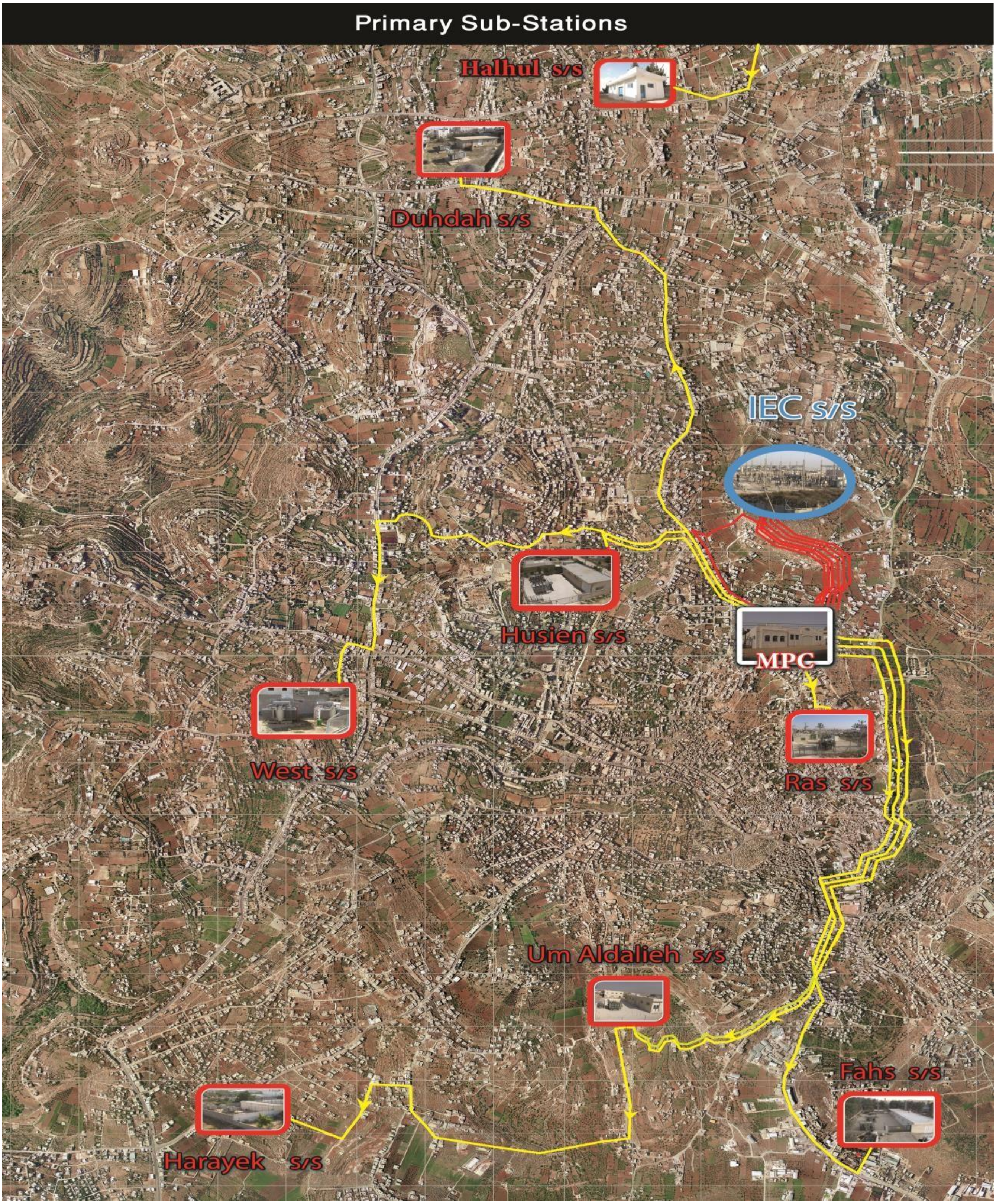

Figure 2. 4: Distribution substation for Hebron city.

2.4 The existing system

2.4.1 HEPCo substations

There are basically two major types of distribution substations:

Primary substation and distribution substation. The primary substation serves as a load center and the distribution substation interfaces to the Low Voltage (LV) network.

Each one of the seven substations in the grid has two transformers, while AL-Fahs and Al- Dahdah substations have three transformers specified as follow in table (2.1): [7]

Table 2. 1 :Main substations transformers.

Substation	No. Of transformers	capacity	capacity (MVA)
Al-Dahdah	3	10 MVA for each tr.	30
Al-Gharbia (west)	2	13 MVA for each tr.	26
Al-Fahs	3	10 MVA for two trs &13 MVA.	33
Al-Ras	2	10 MVA for each tr.	20
Al-Harayek	2	10 MVA for each tr.	20
Al-Hussein	2	10 MVA for each tr.	20
Um Al-Daliyeh	2	10 MVA tr. & 13 MVA tr.	23
			total = 172 MVA

2.4.2 Distribution transformers

Hebron electrical power company contains 668 transformers, these transformers have a wide range of (kVA), from (100- 1000) kVA represented in the following table(2.2) and figure (2.5) show the percentage range of the distribution transformer in the MV network [7] :

Table 2. 2: Distribution Transformers.

Transformer rating (kVA)	Number of transformers	%	MVA
100	14	2.096	1.4
160	57	8.53	9.12
200	3	0.45	0.6
230	5	0.749	1.15
250	116	17.365	29
315	9	1.347	2.835
400	201	30.09	80.4
500	18	2.695	9
630	163	24.401	102.69
800	46	6.887	36.8
1000	36	5.389	36
Total	**668**	**100**	**308.995**

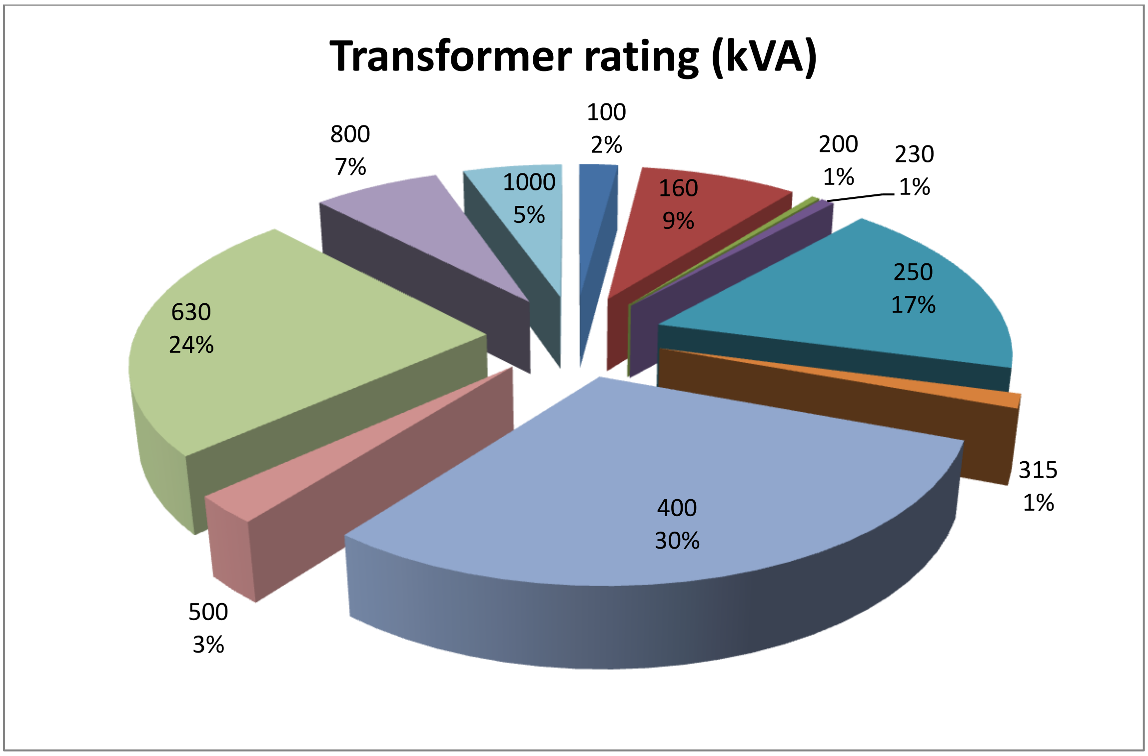

Figure 2. 5: Distribution Transformers.

Recently, several distribution transformers have been installed and operated to serve domestic, commercial and industrial customers, HEPCo has carried out many maintenance works for distribution transformers, including changing insulators, silica gel, oil and welding. In addition, the transformers were replaced and their capacity increased to suit the electrical loads [7].

2.4.3 Overhead lines and underground cables

Hebron electric medium voltage network is divided into 33 kV and 11 kV network, all 33 kV overhead networks have been canceled, and replaced with underground cables**,** HEPCo uses both copper and aluminum cables**.** The 11kV network contains overhead lines and underground cables, Hebron electric power company is working for replacing the overhead networks with underground cables [7].

The data of the cables and overhead lines were collected and it is shown in table (2.3).

Table 2. 3: Conductors data.

Conductor type	Quantity (km)
Underground 11kV Copper Cable 150 mm^2	140.62
Underground 11kV Copper Cable 120 mm^2	7.395
Underground 11kV Aluminum Cable 95 mm^2	0.93
Underground 11kV Copper Cable 50 mm^2	5.96
Overhead Network 11kV	78.094
Total	232.999

2.5 HEPCo power losses

Table (2.4) illustrates the annual energy sales and purchases between 2014 and 2018. It can be seen that the losses (technical & non-technical) have increased from 19% to 21% which equals losses 97,355,235 kWh [7].

Table 2. 4: Sales and purchases between 2014&2018.

	2014	2015	2016	2017	2018
Sales kwh	305,512,904	327,546,410	342,052,257	360,420,934	368,287,005
Sales NIS including fixed amt + VAT	212,005,335	213,261,791	211,084,321	240,735,001	241,779,846
Purchases kwh	379,030,800	411,243,600	421,484,910	468,230,280	465,642,240
Purchases NIS	207,562,455	192,840,853	179,822,949	202,822,684	206,787,790
Losses	19%	20%	19%	23%	21%
Debts till end of the year	445,608,129	451,021,796	484,175,332	511,047,667	550,958,213
Debts annual increase	6,287,195	5,413,667	33,153,536	26,872,335	39,910,546

Electrical losses are the amounts that are not paid by the users.

$$\textbf{Electrical losses} = \frac{\textbf{Purchased energy (kWh)} - \textbf{Sales (kWh)}}{\textbf{Purchased energy (kWh))}} \times \mathbf{100\%} \qquad (2.1)$$

$$\textbf{Electrical losses} = \frac{465{,}642{,}240\ (kWh) - 368{,}287{,}005\ (kWh)}{465{,}642{,}240\ (kWh)} \times 100\% \quad \text{for 2018}$$

$$= 20.9\%$$

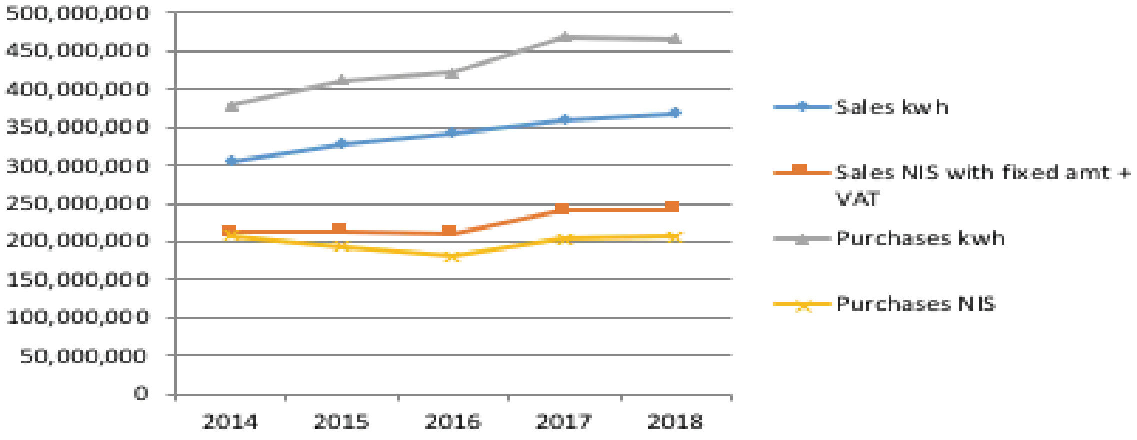

Figure 2. 6: Sales and Purchases .

The figure (2.7) summarize the percentage of power losses in the last 5 years.

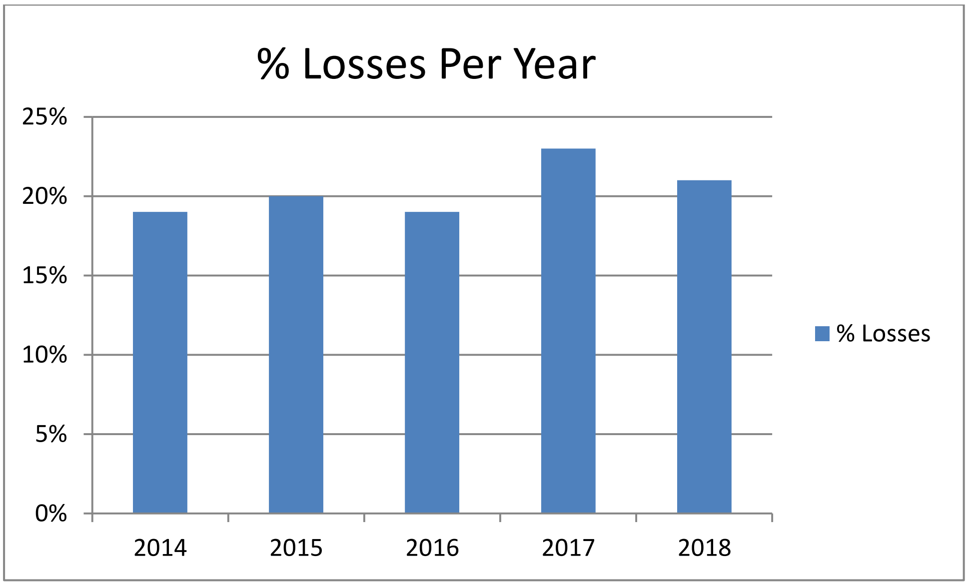

Figure 2. 7:Losses per Year .

2.6 Subscriptions

The number of installed subscriptions in 2018 were estimated by HEPCo to be 51,983 subscription divided into five categories with the following percentage for each category as show in table (2.5) [7]:

Table 2. 5: Subscriptions categories.

Type	NO	%
Domestic	38,200	73.68%
Commercial	11,927	22.80%
Industrial	1,543	2.97%
Street lighting	306	0.59%
Agricultural	7	0.01%
Total	**51,983**	**100%**

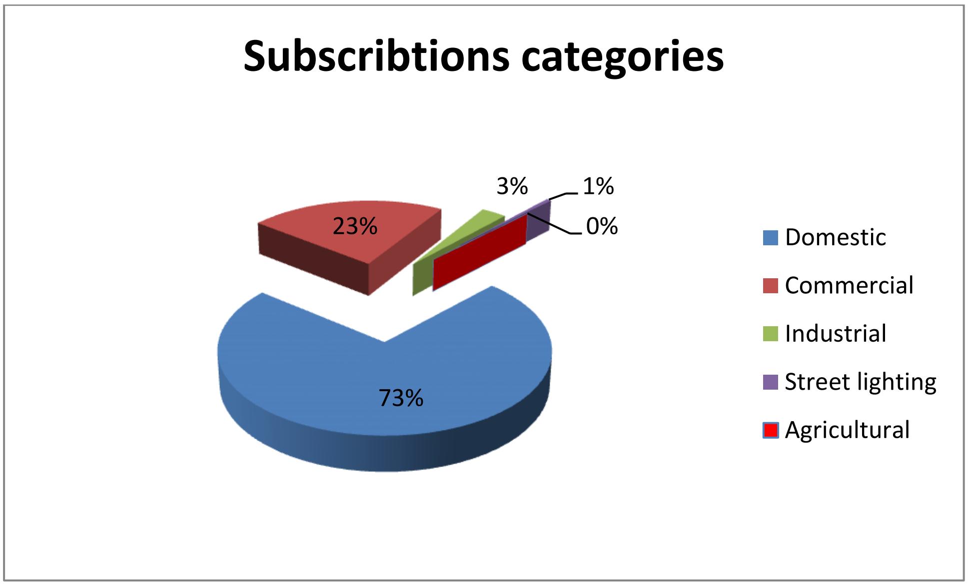

Figure 2. 8: Subscriptions categories .

2.7 Hebron Peak & Maximum and Minimum load

During 2018, the Maintenance , Inspection and Control Department has worked on strengthening electricity networks and stations in HEPCo Concession Area; to increase network reliability and meet customers' needs. The Department has maintained existing distribution networks to ensure continuity of electricity supply around the clock [7].

HEPCo Peak Load was (115) MVA in 2018, compared to (110) MVA in 2017, with an increase of 4.5%, figure (2.9)(2.10) represents the peak load values for 2018.

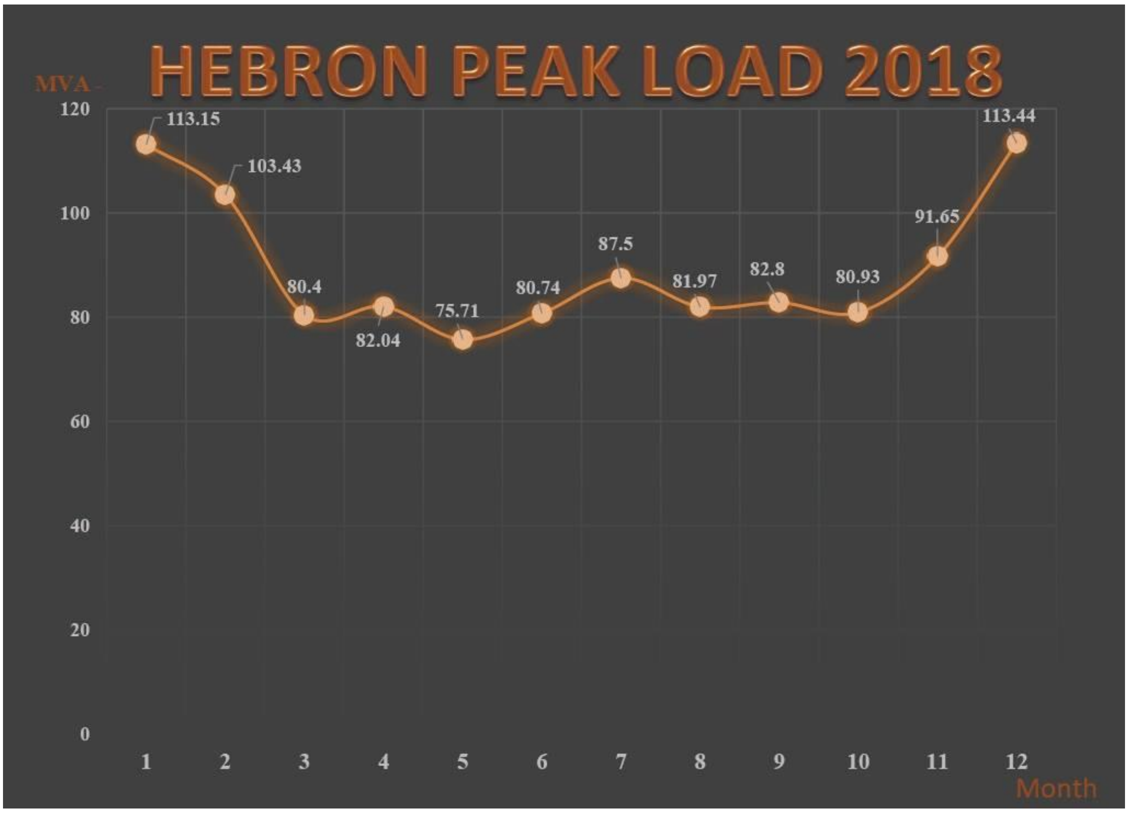

Figure 2. 9: Hebron Peak Load in 2018 .

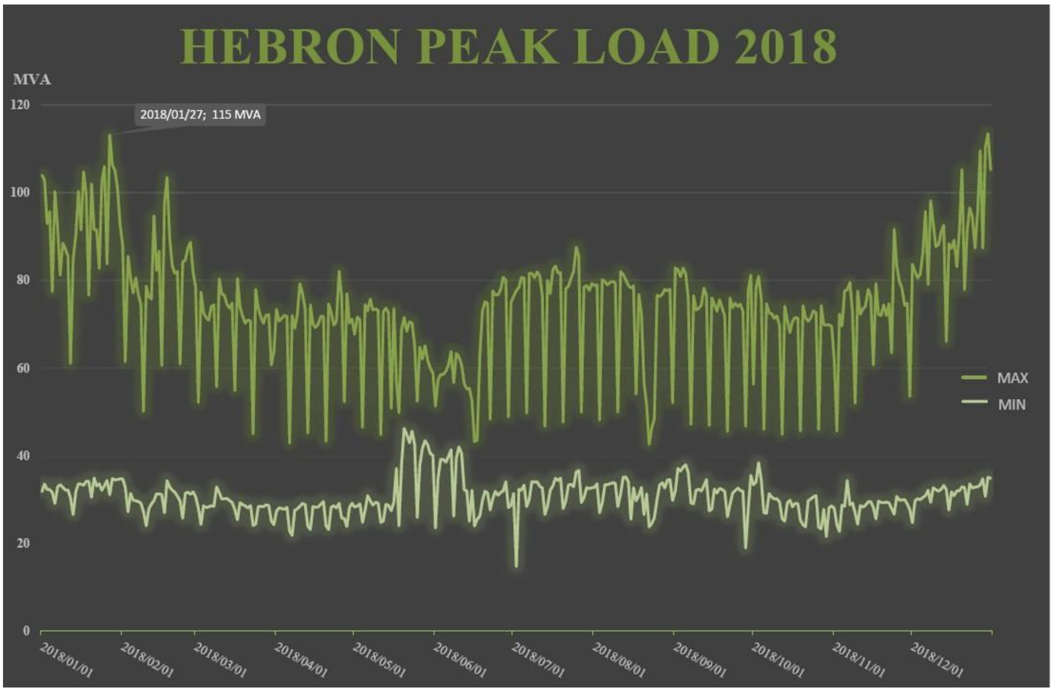

Figure2. 10:Hebron Peak Load Min and Max in 2018.

Figure (2.11) shows the power consumption in each month during the last 5 years.

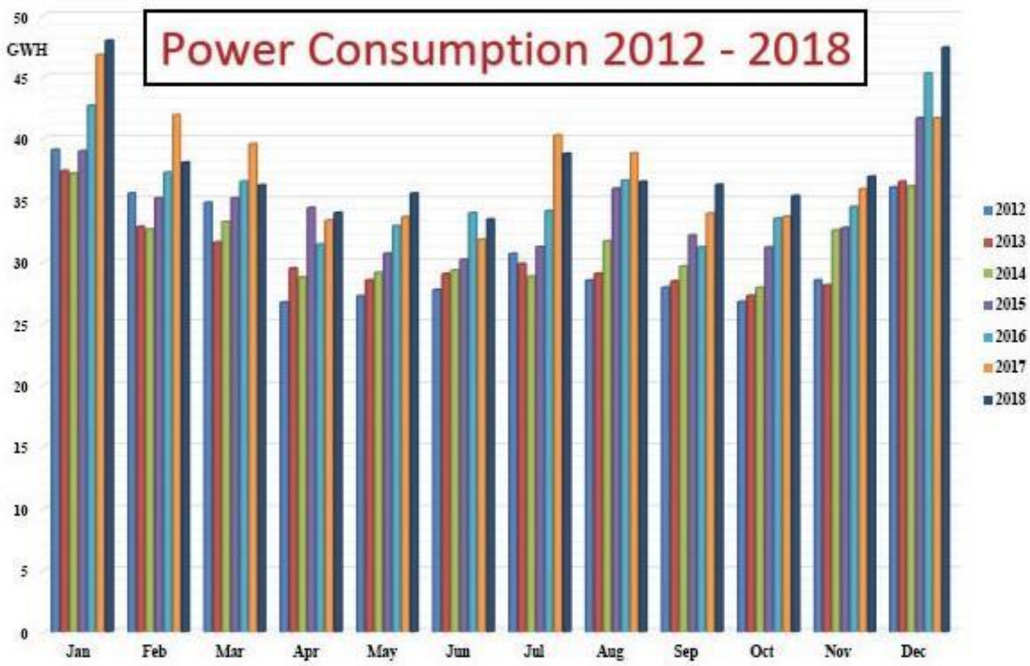

Figure 2. 11: Power Consumption 2012 - 2018 .

2.8 New MV Substation

HEPCo constructed a new substation called (Al- Sala AL- readiyah), which converts the voltage from 33 to 11 kV. This sub-station contains two transformers with 13 MVA each, the main objective of this sub-station is to redistribute the loads on the sub-stations through making a new connection point from the IEC. Figure (2.12) shows a photo of the transformers of the new sub-station. [7] .

Figure 2. 12:New MV Substation .

2.9 Summary

In this chapter, we illustrated some of the medium voltage electrical network main component of HEPCo which is important to be known for the following chapters. The distribution transformers and substations are also have been showed in this chapter according to their power rating.

Also, it is evident that HEPCo grid suffers from high losses according to annual purchases and revenues , our project aims to studs these losses technical & non- technical and minimize the technical losses to be around the value of the international standard losses .

Chapter 3

ETAP

3.1 ETAP

3.1.1 ETAP overview

ETAP “Electrical Transient Analysis Program” is the most comprehensive solution for the design, simulation, and analysis of generation, transmission, distribution, and industrial power systems.

ETAP organizes your work on a project basis. Each project that you create provides all the necessary tools and support for modeling and analyzing an electrical power system. A project consists of an electrical system that requires a unique set of electrical components and interconnections. In ETAP, each project provides a set of users, user access controls, and a separate database in which its elements and connectivity data are stored [8].

The following figure(3.1) shows the numerous options and applications of ETAP.

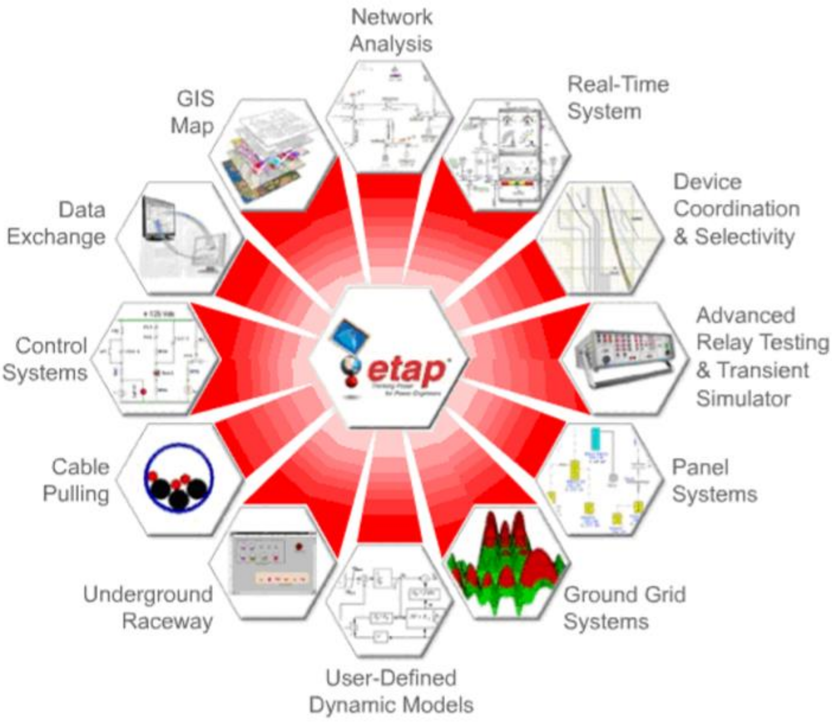

Figure 3. 1: ETAP applications.

3.1.2 Why using ETAP ?

We use ETAP because it is suitable to study power flow losses and it has many Options such as[8] :

1-Virtual reality operation.

2-Total integration of data (electrical, logical, mechanical, and physical attributes).

3- Ring and radial systems.

4- Unlimited isolated subsystems.

5- No system connection limitations.

6- Multiple loading conditions.

7-User access control and data validation.

8- Asynchronous calculations, allow multiple modules to calculate simultaneously.

3.2 ETAP Power Load Flow

3.2.1 Load Flow

The ETAP Load Flow Analysis module calculates the bus voltages, branch power factors, currents, and power flows throughout the electrical system. ETAP allows for swing, voltage regulated, and unregulated power sources with multiple power grids and generator connections. It is capable of performing analysis on both radial and loop systems. ETAP allows you to select from several different methods in order to achieve the best calculation efficiency.

The Load Flow Toolbar section explains how you can launch a load flow calculation, open and view an output report, or select display options. The Load Flow Study Case Editor section explains how can you create a new study case, what parameters are required to specify a study case, and how to set them. The Display Options section explains what options are available for displaying some key system parameters and the output results on the one-line diagram, and how to set them. The Load Flow Calculation Methods section shows formulations of different load flow calculation methods. Comparisons on their rate of convergence, improving convergence based on different system parameters and configurations, and some tips on selecting an appropriate calculation method are also found in this section. The Required Data for Calculations section describes what data is necessary to perform load flow calculations and where to enter them. The Load Flow Study Output Report section illustrates and explains output reports and their format. Finally, the Load Flow Result Analyzer allows you to view the results of various studies in one screen so you can analyze and compare the different results.

3.2.2 Mode toolbar

When you click the One-Line Diagram (Network Systems) button on the System toolbar, the Mode toolbar becomes available that contains all the study modules related to the one-line diagram.

In general, ETAP has three modes of operation under Network Systems; Edit, AC Study, and DC Study. The AC Study mode consists of analyses such as Load Flow, Short-Circuit, Motor Acceleration, Transient Stability, and Protective Device Coordination.

Mode Toolbar

Figure 3. 2:Mode Toolbar .

Load Flow Toolbar

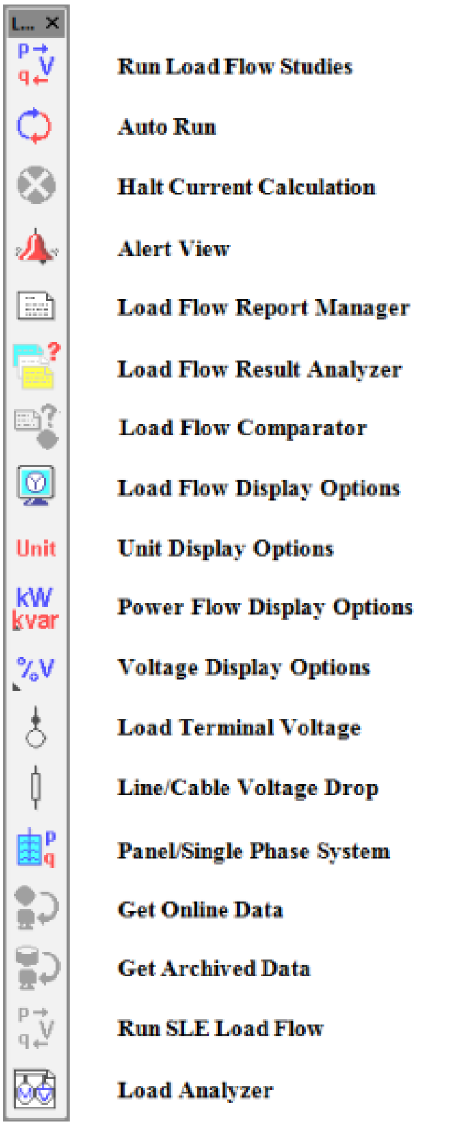

Figure 3. 3:Load Flow Toolbar .

3.2.3 Load Flow Calculation Methods

ETAP provides four load flow calculation methods: Adaptive Newton-Raphson, Newton-Raphson, Fast-Decoupled, and Accelerated Gauss-Seidel. They possess different convergent characteristics, and sometimes one is more favorable in terms of achieving the best performance.

You can select any one of them depending on your system configuration, generation, loading condition, and the initial bus voltages.

3.3 Filling Data

In order to start the power flow and run the program, the data and specifications of the transformers, cables, overhead lines and loads are needed to be filled accurately in the filling areas.

3.3.1 Transformers Data

The information inserted in the transformer's editor were the voltage rating, power rating and the type of the transformer. All these data were important to power flow simulation and calculations. Those data and specifications were collected from HEPCo.

3.3.2 Transmission Lines Data

In this part, we inserted the type of the transmission lines based on the data from HEPCo, moreover, we added the length of each line and the type of connection whether it was single phase or three phase.

3.3.3 Load data

Regarding to the data of the load. The value of the percentage of loading in the figure attached in appendix A reflects on the power rating for the load, which is also related to the transformer loading connected to the load.

3.4 ETAP simulation

In the following figures, we illustrate some sketches of the simulation project on ETAP, while the full single line diagram simulation of HEPCo will be found in the CD drive attached. In addition, the full single line diagram drawing is attached in appendix A.

CHAPTER 4

POWER LOSSES

4.1 Introduction

We know that there are certain losses which affect the economy of the power system. It is a well-known fact that all energy supplied to a distribution utility does not reach the end users. A substantial amount of energy is lost in the distribution system by way of technical and non-technical losses. The distribution system accounts for highest technical and non-technical losses in the power sector [9].

The term "distribution losses" refers to the difference between the amount of energy delivered to the distribution system and the amount of energy customers are billed. Distribution line losses are comprised into two types: Technical losses and non-technical losses as shown in figure (4.1) [9].

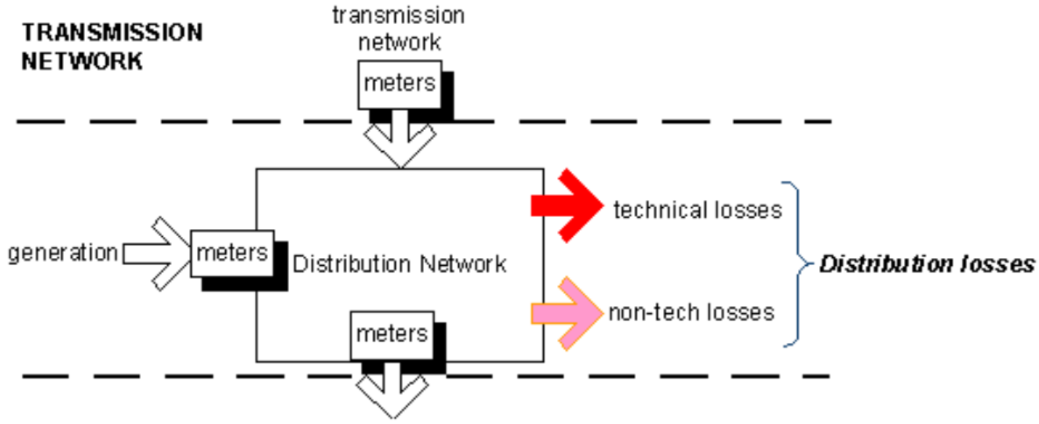

Figure 4. 1: losses type in distribution network .

4.2 Technical losses and non-technical losses

4.2.1 Non-technical losses

Non-technical losses, on the other hand, are caused by actions external to the power system or are caused by loads and condition that the technical losses computation failed to take into account. Non- technical losses are more difficult to measure because these losses are often unaccounted for by the system operators and thus have no recorded information. Non-technical losses, on the other hand, occur as a result of theft, metering inaccuracies and unmetered energy. It is relate mainly to power theft in one form or another. Theft of power is energy delivered to customers that is not measured by the energy meter for the customer. This can happen as a result of meter tampering or by bypassing the meter. Losses due to metering inaccuracies are defined as the difference between the amount of energy actually delivered through the meters and the amount registered by the meters [9].

The three main types of non-technical losses are[10]:

1. Energy theft.
2. Errors in Unmetered Supplies
3. Conveyance errors

4.2.1.1 Energy theft

This is not energy that has been accurately billed but not paid, it is energy that has been illegally taken from the network through tampering with meters or other network assets. This is taken without the knowledge of an energy company and leads to differences between estimated and actual electricity consumption. Energy theft increases everybody’s energy bills and creates serious electrical hazards for both those stealing the power and those working on the network [10].

4.2.1.2 Unmetered supplies

Unmetered supplies are commonly used for the communal areas, street lamps, bus stops and advertising boards. Unmetered supply customers provide inventories of their connected electrical equipment and estimated consumption. Although we audit these inventories and request accurate updates they are not always provided and may change frequently. The difference between unmetered supplies estimates and actual consumption creates a non-technical loss [10].

4.2.1.3 Conveyance errors

These are losses that arise when electricity is consumed but not correctly recorded. Situations arise where energy is legally consumed but is not properly recorded in the national electricity settlement system. This can occur due to inaccuracies in meter readings, unregistered meter points, errors in registration or faulty meters. These errors result in a discrepancy between actual and measured consumption, meaning energy is lost in the system [10].

4.2.2 Technical losses

Technical losses in power system are caused by the physical properties of the components of the power system. Technical losses are possible to compute and control, provided the power system which consists of known quantities of loads. Technical losses occur during transmission and distribution and involve substation, transformer, and line related losses. These include resistive losses of the primary feeders, the distribution transformer losses (resistive loses in windings and the core losses), resistive losses in secondary network, resistive losses in service drops and losses in kWh meter [9].

4.2.2.1 Transformer losses

Classified into two components, namely, no-load and load losses:

1- No-load losses: occur from the energy required to retain the continuously varying magnetic flux in the core and its invariant with load on the transformer.
2- Load loss: mainly arises from resistance losses in the conducting material of the windings and it vary with loading.

The cost of losses is the most important factor in selecting a transformer because it is quite possible for the estimated value of future losses to exceed the first cost of a transformer. Therefore, the right balance between the initial expenses and the upcoming loss expenses should be considered when buying a transformer [8].

For transformers, this table illustrating the value of the power losses estimated on each transformer in case of no load and full load. This information are based on the data sheet of the transformers, which is also very close to the value of results in chapter 6.

Table 4.1:Losses at no load &full load transformer .

transformer rating (kVA)	power losses at no load (kW)	power losses at full load (kW)
13,000	11.376	72.933
10,000	8.751	56.102
1,000	1.55	9
800	1.3	8
630	1.1	7.1
500	0.523	4.91
400	0.419	3.928
315	0.33	3.093
250	0.261	2.455
160	0.167	1.571
100	0.104	0.982

4.2.2.2 Losses in power overhead lines and cables:

One of the main sources of losses in the distribution system is the copper losses in power overhead lines and cables. Since these losses are a function of current flow through the line [11].

The length of cables between a power plant and a step-up substation is short since they are usually installed in the same place, so the energy losses there are quite low. The situation is not the same between the step down substation and users where kilometers of medium and low voltage cables must be erected or buried to reach them. In order to reduce the cost and power losses in the power converter, different configurations of 1ph-to-3ph converter with a reduced number of power device [11].

4.3 Drawbacks of losses

Technical and non-technical power losses may cause:

1. Poor quality of service offered to customers.
2. High cost due to useless or premature investments.
3. Reduction in revenue resulting in cash difficulties with all ensuing economic consequences .

4.4 Advantages of minimizing losses

Technical advantages cover a wide variety of issues such as:

1. Peak load saving.
2. Good voltage profile.
3. Improve continuity.
4. Improve reliability.
5. Removal of some power quality problems.
6. Financial and economical benefits.

4.5 Power flow analysis

Load flow (power flow) analysis is a basic analysis for the study of power systems. It is used for normal, steady-state operation. It provides you with the info of what is happening in a system. Load flow analysis is an important requirement for whatever you do in power systems, whether you do fault studies, stability studies, economic operation etc. [12].

The objective of load flow calculations is to determine the steady-state operating characteristics of the power system for a given load and generator real power and voltage conditions. Once we have this information, we can calculate easily real and reactive power flow in all branches together with power losses [12].

The principles of a power flow analysis are direct, an accurate study relating to a power system can be passed out only with the digital computer. Two of the frequently used mathematical methods are the Gauss Seidel method and the Newton Raphson method, in addition to Fast-decoupled method [12].

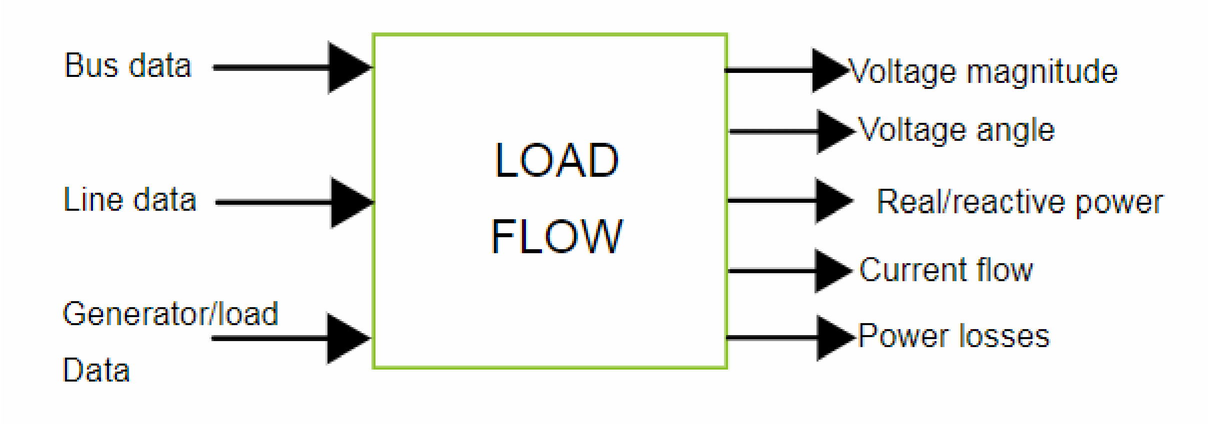

Figure 4. 2: Load Flow .

4.6 Efficient Electrical Energy Transmission and Distribution

Growing populations and industrializing countries create huge needs for electrical energy. Unfortunately, electricity is not always used in the same place that it is produced, meaning long-distance transmission lines and distribution systems are necessary. But transmitting electricity over distance and via networks involves energy loss

So, with growing demand comes the need to minimize this loss to achieve two main goals: reduce resource consumption while delivering more power to users. Reducing consumption can be done in at least two ways: deliver electrical energy more efficiently and change consumer habits.

Transmission and distribution of electrical energy require cables and power transformers, which create three types of energy loss [15].

1. The Joule effect, where energy is lost as heat in the conductor (a copper wire, for example).
2. Magnetic losses, where energy dissipates into a magnetic field.
3. The dielectric effect, where energy is absorbed in the insulating material.

The Joule effect in transmission cables accounts for losses of about 2.5 % while the losses in transformers range between 1 % and 2 % (depending on the type and ratings of the transformer). So, saving just 1 % on the electrical energy produced by a power plant of 1000 megawatts means transmitting 10 MW more to consumers, which is far from negligible, with the same energy we can supply 1000 - 2000 more homes.

We can estimate the power losses on the conductors by applying the following equation :

$P_{losses} = I^2 \times R$, multiplying the result by the length of the conductor.

For transformers, this table illustrating the value of the power losses estimated on each transformer in case of no load and full load. This information are based on the data sheet of the transformers.

Considering the main parts of a typical Transmission & Distribution network, here are the average values of power losses at the different steps [15]:

- **1-2%** - Step-up transformer from generator to Transmission line
- **2-4%** - Transmission line
- **1-2%** - Step-down transformer from Transmission line to Distribution network.
- **4-6%** - Distribution network transformers and cables

The overall losses between the power plant and consumers is then in the range between 8 and 15%.

Chapter 5

Power loss minimization methods

5.1 Introduction

In general, there are many ways to reduce the power losses in the distribution network. In this chapter we introduce the effective methods and techniques to minimize the power losses that will be used and applied in the graduation project, Moreover, it will be discussed with a detailed comparison between the several scenarios of loss reduction.

We can summarize the methods of reducing power losses as follow:

1. Network reconfiguration.
2. Network reconductoring.
3. Distribution transformer locating and resizing.
4. High voltage distribution system.
5. Flexible Alternating Current Transmission System (FACTS).
6. Adding a New Sub-Station

5.2 Network reconfiguration

Network reconfiguration is the one of the possible methods in distribution system for reducing losses in which the power flow is altered by the formation of new links within a feeder to form tree structure or by opening or closing the appropriate switches on the feeders. And by forming new links to the change area of feed from one substation to another, balance the load among the substation. Network reconfiguration is the process of operating switches to change the circuit topology so that operating costs are reduced while satisfying the specified constraints [9].

Distribution lines or line sections show different characteristics as each has a different mixture of residential, commercial and industrial type loads and their corresponding peak times are not coincident. This is due to the fact that some parts of the distribution system becomes more heavily loaded at certain times of the day and less heavily loaded at other times. Therefore, by shifting the loads in the system, the radial structure of the distribution feeders can be modified from time to time in order to reschedule the load currents more efficiently for loss minimization.

This technique helps in minimizing the system real power losses in the network and also it releases the overloads in the feeders.

5.3 Network reconductoring

Network reconductoring is the technique in which replaces the existing conductor on the feeder by a conductor of optimal size for optimal length of the feeder. This technique is used when the existing conductor is no more optimal because of rapid growth of load. This technique is good for the developing countries, where annual growth rates are high and the conductor are chosen to minimize the initial capital investment [9].

Resizing of the conductors to match the carried load, or using new low-loss conductors like Aluminum Conductor Composite Core (ACCC), it can transport two to three times as much power as conventional conductors over the same rights-of-way and with no tower modifications. In addition, the conductor's core has 25% lower electrical resistances than steel, enabling higher transmission efficiencies according to the specifications of the ACCC conductor.

This technique increases the feeder's capacity to handle load growth. However, the maximum load that can be transferred by the cables in AL Fahs substation is 24 MVA while the capacity of the transformers in the substation is 33 MVA according to the data of the cables from HEPCo for this substation [7].

It is very successful for minimizing the losses and developing the voltage profile. But it leads to an extra investment that increases the original investment of the feeders.

5.4 Distribution transformer locating and sizing

Generally, distribution transformers are not located centrally with respect to customers. The farthest customers take an extremely low voltage even though a reasonably good voltage level is maintained at the secondary of transformer. This leads to more losses in distribution system. In this technique, distribution transformers should be located close to the load center as possible and replace large transformers by the transformers of small rating so that it serves small number of customers so that optimum voltage level is maintained [9].

However, after collecting the transformers data for the customers of HEPCo, we found that there are a lot of transformers work at less than the half of the rated KVA of the transformer, and also there is a lot of overloaded transformers, while the maximum efficiency of the transformer happens when it is on its rated KVA value.

This technique calls for less investment than reconductoring the network. It helps in reducing the peak load and electrical losses in the distribution system. In addition, it improves the voltage that customers take. Moreover, it avoids overloading on conductors and transformers.

5.5 High Voltage Distribution System (HVDS)

This technique is most effective and efficient in reducing the technical losses and improving the power quality in distribution system. In this method, conversion of the existing Low Voltage Distribution System (LVDS) to HVDS is done. This technique aims at extending high voltage lines as closer to the load as possible and replacing large transformers with various small rating transformers. By using this method, we can reduce the losses as current is low in high voltage systems [9].

Transmission losses depend on the voltage level with the current passing in the conductor and the distance between feed-in location and consumer, so when converting the LVDS into HVDS, the current will be reduced, which affects the network positively by reducing the power losses [9].

This method decreases power losses, increases energy saving and improves voltage profile. It also reduces the theft of electricity and decreases illegal connections as the transmission lines are decreased and replaced with cables. In addition it helps in avoiding unnecessary iron losses in overrated distribution transformers and hence reduces technical losses. Moreover, it makes the distribution system more reliable. However, it requires additional investment and needs regular maintenance.

5.6 FACTS

5.6.1 FACTS definition, necessity and types

Before we apply this technology, we have to understand and explain the definition and the importance of it, after that we can introduce its types and show more details about the type that could be more effective than the others in our project for minimizing power losses.

A flexible alternating current transmission system is a collection of controllers, which can be applied individually, or in coordination with others to control one or more of the interrelated system parameters, such as series impedance, shunt impedance, current, voltage, and damping of oscillations [13].

In other words, FACTS is a system collected of static equipment used for the Alternating

Current (AC) transmission of electrical energy. It is meant to improve controllability and increase power transfer capability of the network. It is generally a power electronics-based system [13].

FACTS is defined by the Institute of Electrical and Electronics Engineers (IEEE) as “a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability” [14].

FACTS controllers can be categorized as follow:

1. Shunt connected controllers.
2. Series connected controllers.
3. Combined series-series controllers.
4. Combined shunt-series controllers.

5.6.1.1Shunt connected controllers

Shunt controllers consist of variable impedance devices like capacitors or reactors which introduce current in series with the line. Their major task is to reduce the capacitivity of the transmission line. The injected current is in phase with the line voltage [13].

5.6.1.2 Series connected controllers

Series Controllers consists of capacitors or reactors which introduce voltage in series with the line. They are basically variable impedance devices. Their major task is to reduce the inductivity of the transmission line. They supply or consume variable reactive power [13].

5.6.1.3 Combined series-series controllers

These controllers consist of a combination of series controllers with each controller providing series compensation and also the transfer real power along the line [13] .

5.6.1.4 Combined shunt-series controllers

These controllers introduce current in series using the series controllers and voltage in shunt using the shunt controllers [13].

5.6.3 FACTS benefits

In general, we can summarize the advantages and merits of FACTS technology in these points:

1. Facts is economical technology.
2. All the FACTS controllers can be uses with an existing AC transmission system.
3. Facts technology allows greater throughput over existing routes.
4. Facts can be uses on an existing transmission routes without construction of new transmission lines.
5. Reducing power loss and increasing power transfer capability.
6. Increase the security by raising transient stability limit.
7. Limit short circuit current and overloads.
8. Provide secure tie line connections to neighboring utilities.
9. Voltage regulating speed is fast.
10. Reduce reactive power flow with increasing active power flow.

5.6.2 Unified Power Flow Controller (UPFC)

The unified power flow controller is an example of the combined shunt-series controllers, and this controller has many merits that could make it one of the best techniques to use in our project, we can explain this controller with a few points:

- UPFC can control both of active and reactive power flows in transmission system.
- UPFC uses solid-state devices.
- UPFC is a combination of Static Synchronous Compensator (STATCOM) and Static Synchronous Series Compensator (SSSC) coupled common voltage Direct Current (DC) link.

- It was invented for real time control and dynamic compensation of AC transmission system.
- UPFC can control simultaneously or selectively voltage impedance phase angle in transmission line and hence it is called unified.
- UPFC is a generalized Synchronous Voltage Source (SVS).

5.7 Adding a new sub-station

Adding a new sub-station to the medium voltage network is highly effective way to decrease the power losses and improving the voltage drop, if the distance between the sub-station and the load was far away, the power losses will be increased through the cables in addition to the distribution transformers. As a result, when the sub-station feeders are close enough or at least not far away from the loads, the power losses will be less compared to a far sub-station or a feeder.

Chapter 6

Simulation analysis

6.1 Case study

In order to run the simulation in the MV network

We asumed that the Power Factor (PF) 92 % acordin to HEPCo , and two cases were applied:

1. In the first case, we assumed the transformers loading to be 40% of the rated kVA for each transformer in order to reach the total peak value for HEPCo network which is 115 MWh.

2. In the second case, we set the input data for loading distribution transformers depending on the instantaneous readings in deffirent days and times for each transformer in the network from the company.

6.2 Case 1 results

ETAP has many different solution methods, Newton- Raphson (NR) has been chosen to run the load flow, because it is most reliable and powerful technique for solving load flow problems at very accurate solution, fast in convergence, independent size of system and not effected by choosing of slack bus.

The data used in this analysis is obtained from HEPCo, the simulation was made taking into consideration the transformers, cables and overhead transmission lines values as mentioned and explained in chapter two, after that we assumed the transformers to be loaded with 40% of its capacities, the results for the substations were as follows:

6.2.1 Sub-Stations Results

In the following table(6.1), the results of the power demand in (MW), the power percentage of each sub-station, and the power factor are explained as follow:

Table 6. 1: Loading on each sub-station .

ID	Rated kV	kW	A	% PF
AL-DAHDAH	33	17926.6	344	91.16
AL-FAHS	33	20434.5	374.9	95.36
AL-GHARBIA	33	20479.6	397.7	90.09
AL-HARAYEK	33	10390.8	203.4	89.37
AL-HUSSEIN	33	14525.1	285.4	89.03
AL-RAS	33	12658.5	247.5	89.46
UM AL-DALIYEH	33	16503.7	316.4	91.26
Total		**112918.8**		

Number of loads = 668 load .

Number of buses = 1523 bus .

Power imported from Power Grid = 112.9188 MW .

Total power losses = 3.618 MW = 3.204%.

$$P_{Total} = P_{Demand} + P_{Losses} \quad (6.1)$$

$$P_{Total} = 109.301 MW + 3.618\ MW$$

$$= 112.9188\ MW$$

The following figure (6.1) represents the contribution of each sub-station in loading.

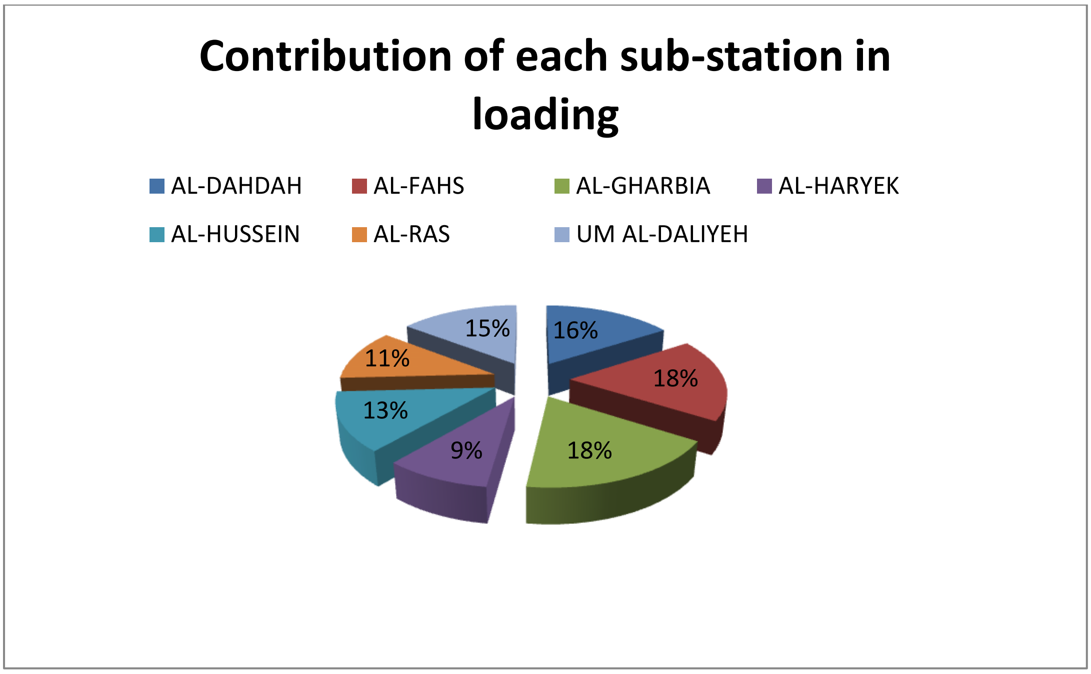

Figure 6.1: the percentage of loading in substation .

Table (6.2) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 6.2 : loading and power losses on sub-stations transformers .

ID	Rating kVA	kW Flow	A	% Loading	kW Losses	% Losses
T1 AL-DAHDAH	10000 kVA	6001.4	122.8	70.2	31.53	0.52
T2 AL-DAHDAH	10000 kVA	5923.8	104.6	59.8	22.9	0.38
T3 AL-DAHDAH	10000 kVA	6001.4	122.8	70.2	31.53	0.52
T1 AL-FAHS	10000 kVA	6674	118.3	67.6	29.29	0.43
T2 AL-FAHS	10000 kVA	6674	118.3	67.6	29.29	0.43
T3 AL-FAHS	10000 kVA	7086.6	144.7	82.7	41.64	0.58
T1 AL-GHARBIA	13000 kVA	10239.8	198.9	87.4	49.62	0.48
T2 AL-GHARBIA	13000 kVA	10239.8	198.9	87.4	49.62	0.48
T1 AL-HAARYEK	10000 kVA	5243.5	115.6	66	27.94	0.53
T2 AL-HARAYEK	10000 kVA	5147.3	92.48	52.9	17.89	0.34
T1 AL-HUSSEIN	10000 kVA	7262.5	142.7	81.6	40.51	0.55
T2 AL-HUSSEIN	10000 kVA	7262.5	142.7	81.6	40.51	0.55
T1 UM AL-DALIYEH	10000 kVA	7963	151.7	86.7	45.79	0.57
T2 UM AL-DALIYEH	13000 kVA	8540.7	164.7	72.4	32.36	0.37
T1 AL-RAS	10000 kVA	6091.7	106.6	60.9	23.77	0.39
T2 AL-RAS	10000 kVA	6566.8	158.3	90.5	49.84	0.75
Total		**112918.8**			**564.03**	

6.2.2 Transmission Lines and Transformers

The transmission lines and cables gathered with the step down transformers (11-0.4) kV resulted in 2121.2509 kW of the total power losses contributed as shown in figure (6.2):

The follwing table (6.3) show the value & percentage of the total losses in distribution & substation transformer , and cables with transmission line

Table 6. 3: losses in distribution & Substation Tr-r, cable with transmission line.

Type	kW Losses	% losses
LV Tr-r losses	981.88	27.14
cable% line losses	2071.89	57.26
Substation Tr-r losses	564.03	15.59
total	**3618**	**100**

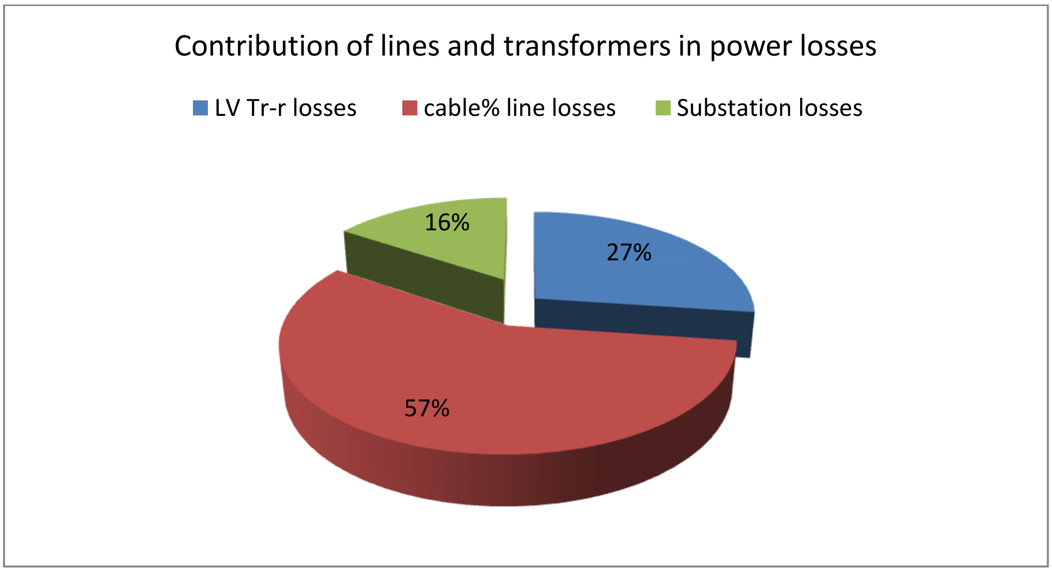

Figure 6. 2 : losses in distribution & Substation Tr-r, cable with transmission line.

The following figure(6.3) show the percentage terminal voltage in 11 kV buses and the buses that less than 95 % of the nominal voltage at 11 kV in table (6.3)

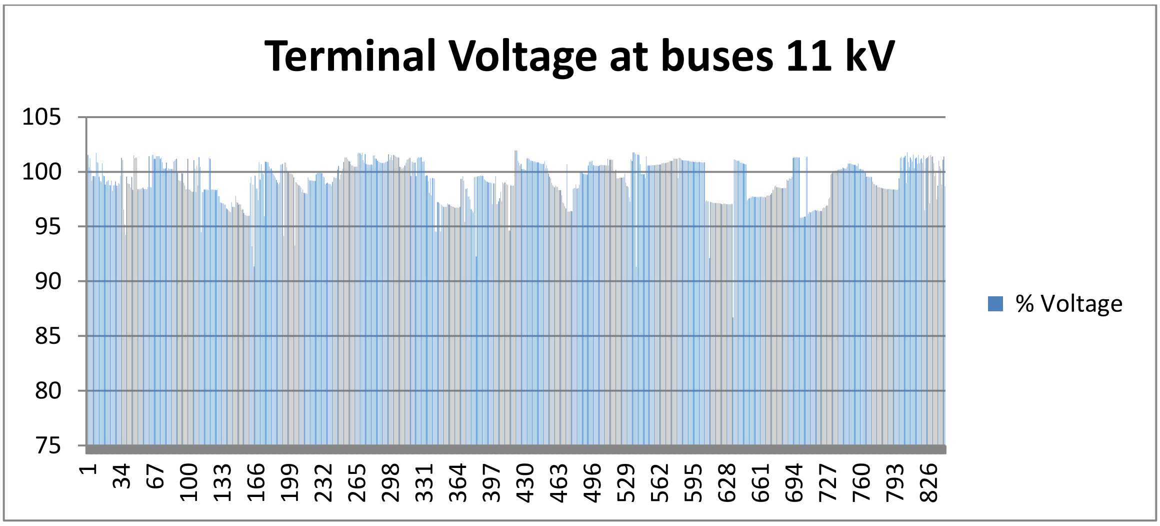

Figure 6. 3:The percentage terminal voltage in 11 kV buses .

Table 6. 4: The buses that less than 95 % of the nominal voltage at 11 kV.

NO	Bus ID	Nominal kV	% Voltage
1	Bus4130	11	86.71
2	Bus3947	11	91.34
3	Bus350	11	91.37
4	Bus4087	11	92.12
5	Bus966	11	92.27
6	Bus345	11	93.2
7	Bus545	11	93.27
8	Bus524	11	94.15
9	Bus73	11	94.26
10	Bus220	11	94.5
11	Bus862	11	94.51
12	Bus871	11	94.54
13	Bus861	11	94.55
14	Bus1029	11	94.63
15	Bus1030	11	94.63

The following figure(6.4) show the percentage terminal voltage in 0.4 KV buses and the buses that less than 90 % of the nominal voltage at 0.4 KV in table (6.4)

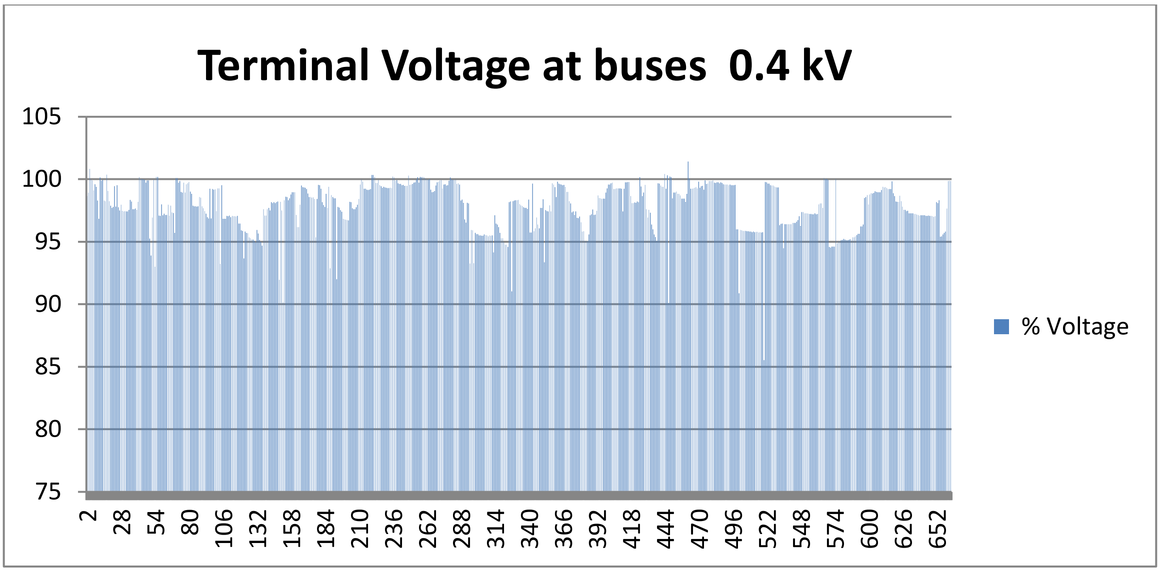

Figure 6. 4 :the percentage terminal voltage in 0.4 KV buses .

Table 6. 5:The bus that less than 90 % of the nominal voltage at 0.4 KV.

Bus ID	Nominal kV	% Voltage
Bus4131	0.4	85.52

6.2.3 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{124.61}{309} = 0.403$$

Total technical of losses in MW = 3.618 MW

Cost for losses during 1 hour = 3618*0.378 = 1,370.5 NIS / h

Annual cost for losses = 3618 kW*0.378 * 8760 h * 0.403 = 4,828,025 NIS /Y

6.3 Case 2 results

In this case, we set the input data for transformers depending on the instantaneous readings for each transformer in the network from the company, noticing that the values of transformers loading were taken in a different times, the transformers loading information is attahed in appendix C.

6.3.1 Sub-Stations Results

In the following table, the results of the power demand in (MW), the power percentage of each sub-station, and the power factor are explained as follow:

Table 6. 6: Loading on each sub-station.

ID	Rated kV	kW	A	% PF
AL-DAHDAH	33	18801.9	364.8	90.16
AL-FAHS	33	22341.5	416.4	93.87
AL-GHARBIA	33	21541.8	428.7	87.91
AL-HARAYEK	33	12651.2	255.9	86.49
AL-HUSSEIN	33	12999.6	255.9	88.89
AL-RAS	33	15964.6	321.1	86.99
UM AL-DALIYEH	33	20883.8	418.9	87.21
Total		**125184.4**		

Number of loads = 668 load.

Number of buses = 1523 bus.

Power imported from Power Grid = 125.1844 MW.

Total power losses = 5.073 MW = 4.052%.

$$P_{Total} = P_{Demand} + P_{Losses}$$

$$P_{Total} = 120.1114\ MW + 5.073\ MW$$

$$= 125.1844\ MW$$

The following figure(6.5) represents the contribution of each sub-station in loading.

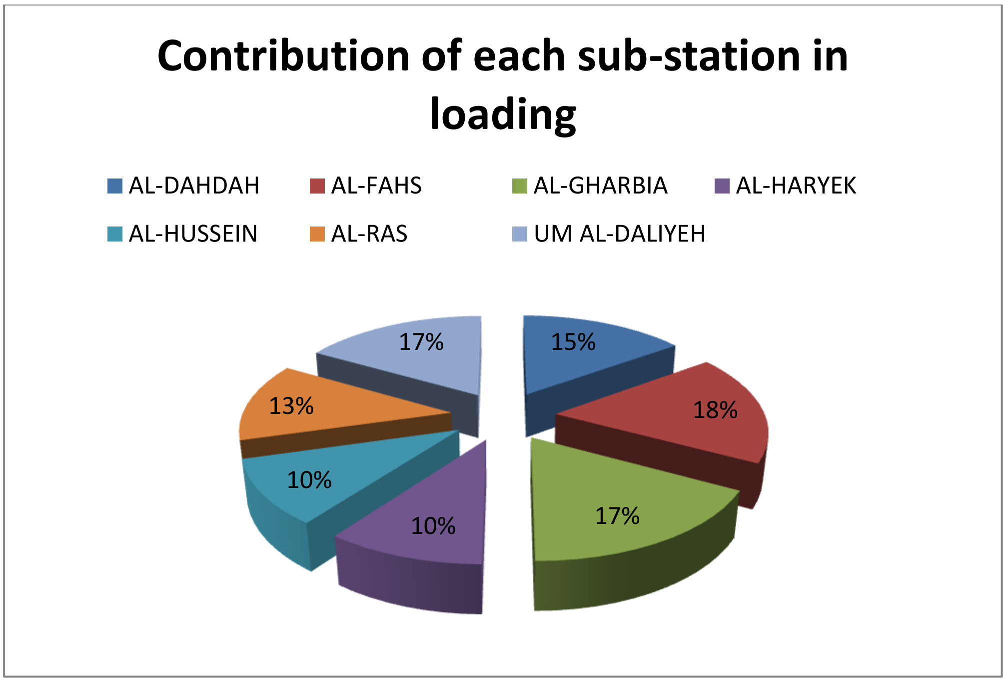

Figure 6. 5: The percentage of loading in substation .

Table(6.7) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them .

Table 6. 7: loading and power losses & power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	A	% PF	kW Losses
T1 AL-DAHDAH	10000 kVA	6220.3	110.6	98.39	25.6
T2 AL-DAHDAH	10000 kVA	6290.8	129.9	84.72	35.31
T3 AL-DAHDAH	10000 kVA	6290.8	129.9	84.72	35.31
T1 AL-GHARBIA	13000 kVA	10770.9	214.4	87.91	57.67
T2 AL-GHARBIA	13000 kVA	10770.9	214.4	87.91	57.67
T1 AL-FAHS	10000 kVA	7717.8	151.3	89.25	45.52
T2 AL-FAHS	10000 kVA	7289.3	128.2	99.49	34.38
T3 AL-FAHS	10000 kVA	7334.5	142.7	89.94	42.59
T1 AL-RAS	10000 kVA	7982.3	160.5	86.99	53.92
T2 AL-RAS	10000 kVA	7982.3	160.5	86.99	53.92
T1 AL-HARAYEK	10000 kVA	6325.6	128	86.49	34.25
T2 AL-HARAYEK	10000 kVA	6325.6	128	86.49	34.25
T1 AL-HUSSEIN	10000 kVA	6499.8	127.9	88.89	34.24
T2 AL-HUSSEIN	10000 kVA	6499.8	127.9	88.89	34.24
T1 UM AL-DALIYEH	10000 kVA	9633.6	168.7	99.88	59.57
T2 UM AL-DALIYEH	13000 kVA	11250.2	278.4	70.71	87.77
Total		**125184.5**			**726.21**

6.3.2 Transmission Lines and Transformers

The transmission lines and cables gathered with the step down transformers (11-0.4) kV resulted in 2121.2509 kW of the total power losses contributed as shown in figure (6.6):

The following table (6.8) show the value & percentage of the total losses in distribution & substation transformer , and cables with transmission line

Table6. 8: losses in distribution & Substation Tr-r, cable with transmission line.

Type	kW Losses	% losses
LV Tr-r losses	1571.8744	30.98
cable% line losses	2774.5542	54.69
Substation Tr-r losses	726.21	14.31
total	5072.6386	100

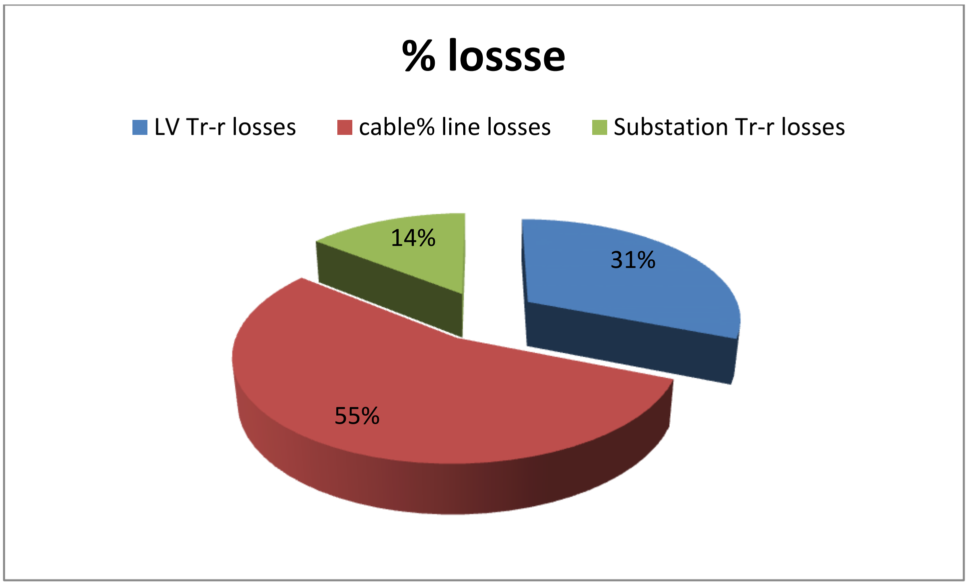

Figure 6. 6 : Losses in distribution & Substation Tr-r, cable with transmission line.

The following figure (6.7) show the percentage terminal voltage in 11 kV buses and the buses that less than 95 % of the nominal voltage at 11 kV in table (6.9)

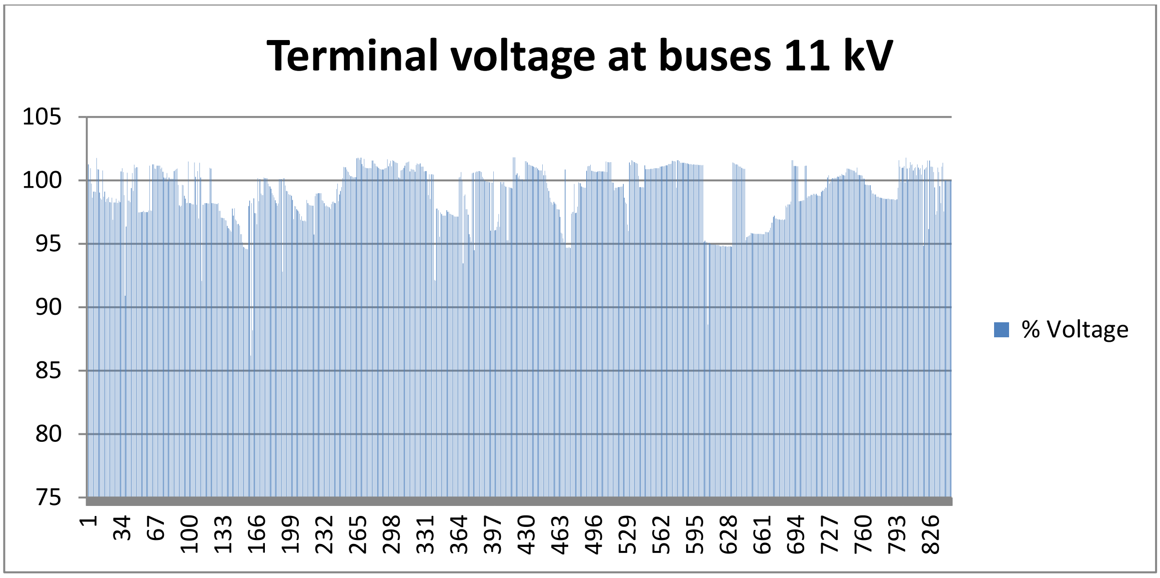

Figure 6. 7: The percentage terminal voltage in 11 kV buses .

Table 6. 9:The buses that less than 95 % of the nominal voltage at 11 kV. .

NO	Bus ID	Nominal kV	% Voltage
1	Bus345	11	86.17
2	Bus350	11	88.18
3	Bus4087	11	88.63
4	Bus72	11	90.91
5	Bus220	11	92.07
6	Bus862	11	92.09
7	Bus861	11	92.15
8	Bus524	11	92.8
9	Bus921	11	93.45
10	Bus966	11	94.48
11	Bus328	11	94.56
12	Bus326	11	94.58
13	Bus325	11	94.59
14	Bus1146	11	94.67
15	Bus1150	11	94.67
16	Bus1143	11	94.68
17	Bus324	11	94.69
18	Bus1142	11	94.69
19	Bus1148	11	94.74
20	Bus323	11	94.75
21	Bus4122	11	94.77
22	Bus4130	11	94.77
23	Bus4121	11	94.78
24	Bus4124	11	94.78
25	Bus4126	11	94.78
26	Bus4128	11	94.78
27	Bus4110	11	94.79

28	Bus4120	11	94.79
29	Bus4111	11	94.8
30	Bus4119	11	94.8
31	Bus4117	11	94.83
32	Bus4115	11	94.85
33	دوار ابو رمان	11	94.85
34	Bus4108	11	94.87
35	Bus4106	11	94.88
36	Bus4104	11	94.89
37	Bus4101	11	94.9
38	Bus4100	11	94.92
39	Bus4094	11	94.93
40	Bus4095	11	94.93
41	Bus4096	11	94.93
42	Bus4093	11	94.96

The following figure (6.8) show the percentage terminal voltage in 0.4 kV buses and the buses that less than 90 % of the nominal voltage at 0.4 kV in table (6.10).

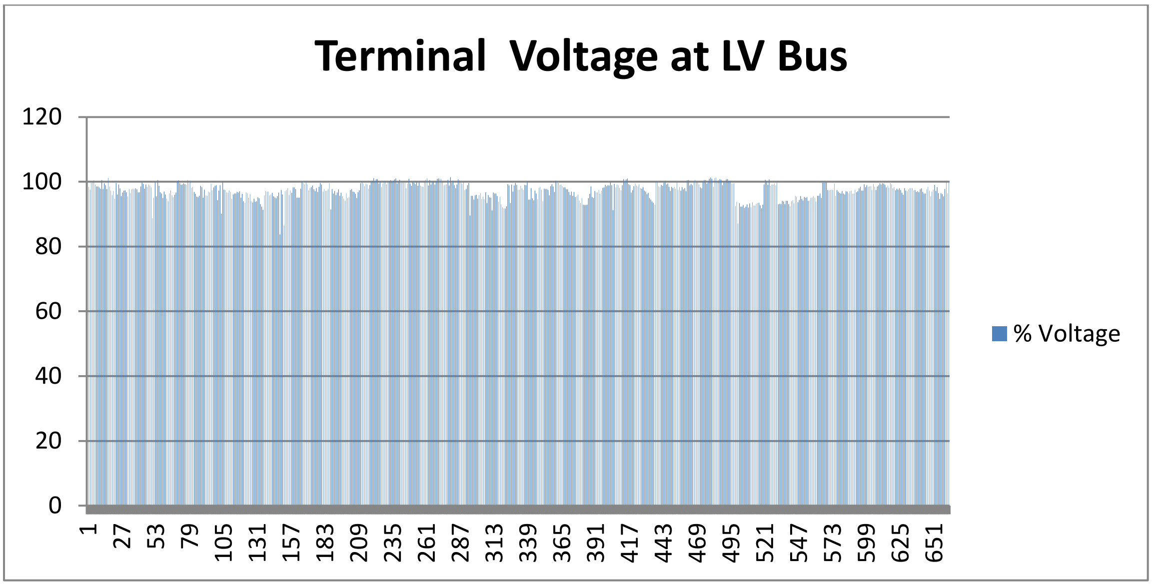

Figure 6. 8: Terminal Voltage at LV Bus.

Table 6. 10: The buses that less than 90 % of the nominal voltage at 0.4 KV.

NO	Bus ID	Nominal kV	% Voltage
1	Bus346	0.4	83.73
2	Bus351	0.4	86.52
3	Bus4088	0.4	87.06
4	Bus98	0.4	88.79
5	Bus863	0.4	89.56

6.3.3 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{140.46}{309} = 0.454$$

Total technical of losses in MW = 3.618 MW

Cost for losses during 1 hour = 5075*0.378 = 1,918.4 NIS / h

Annual cost for losses = 5075 kW*0.378 * 8760 h * 0.454 = 6,772,312.6 NIS /Y

6.2 Comparison between two cases

Table 6. 11 : Comparison between two cases.

		Al-Gharbia	Al-Hussein	Um Al-Daliyeh	Al-Dahdah	Al-Fahs	Al-Ras	Al-Harayek	Total
Case 1	**Power MW**	20.48	14.525	16.503	17.927	20.434	12.659	10.39	112.92
	P.losses in Subtation Tr-r kW	99.24	81.02	78.15	85.96	100.22	73.61	45.83	564.03
	Cable and line losses kW	2071.88							
	distribution transformer losses kW	981.881							
	Total losses kW	3618							
Case 2	**Power MW**	21.542	12.999	20.883	18.801	22.34	15.97	12.651	125.19
	P.losses kW	115.34	68.48	147.34	96.22	124.5	108.8	68.5	726.21
	Cable and line losses KW	2774.5542							
	distribution transformer losses kW	1571.8744							
	Total losses kW	5072.6383							

Table (6.11) represents the comparision between the two cases, and the difference between the values of the total power losses and the losses on both of cables and transformers.

The following figure(6.9) illustrates the valuse of power losses of the overall power delivered.

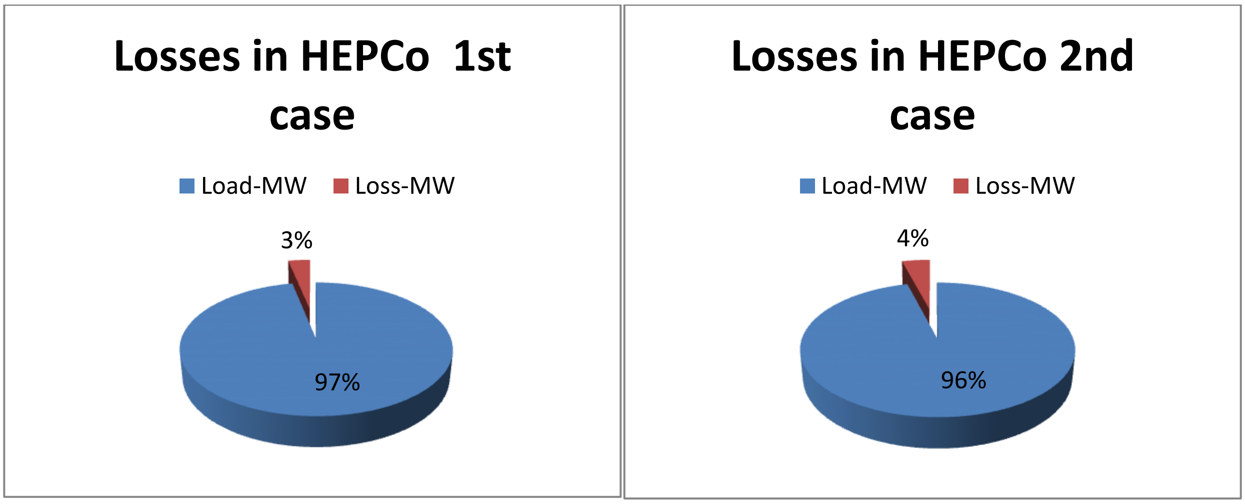

Figure 6. 9: The percentage of losses in two cases.

6.3 Conclusion

In this chapter we applied load flow test on HEPCo MV network with balance load, then, we recorded the result of our two simulation by ETAP, and the percentage of the losses in each case was acceptable according to the standard IEEE and the opinion of HEPCo and the result show that HEPCo has suffering from high non-technical losses , and according to this result the UPFC technology is very expensive and does not effective in MV network .

And after discussing the results with HEPCo we decide to study the effect of the new substation that HEPCo work on it, and the effects on losses in MV network and redistributed loads.

Chapter 7

New Substation

7.1 Introduction

HEPCo planned to construct a new sub-station, consists of 6 feeders, the main goal of this move is to redistribute the loads which help in the improvement of the power grid.

In this chapter, the new sub-station was added to the single line diagram on the ETAP, we will introduce the result of adding this sub-station by dividing it into 6 cases explained in the following table (7.1):

Table 7. 1: Cases explanation.

No cases	Adding feeder
case 1	Adding 2 feeders to the new sub-station with redistribution of loads on sub-stations.
case 2	Adding 3 feeders to the new sub-station with redistribution of loads on sub-stations.
case 3	Adding 4 feeders to the new sub-station with redistribution of loads on sub-stations.
case 4	Adding 5 feeders to the new sub-station with redistribution of loads on sub-stations.
case 5	The same in case 4 + more redistribution of loads on sub-stations.
case 6	Adding 6 feeders to the new sub-station with redistribution of loads on sub-stations.

This system will make a difference by replacing a feeder from a sub-station and connecting it to the new sub-stations which decrease the load on the first sub-station, as a result, the power losses will be decreased

In order to redistribute the loads in the network, we must take into account the geographical location of the sub-station and the feeders, on the other hand, the opinion of HEPCo was that there are four sutiable substation for redistribution, which are: (Al-Gharbia ,Al-Hussein, Al-Dahdah and Al-Ras) .

7.2 Case 1 Results

In this case, two feeders were added to the new substation (Alsala-Alriyadia), as a feeding unit (Diwan al-Mohatasab) was divided and separated from the substation (Al-Hussein), and they were connected to the new substation (Alsala-Alriyadia) in two feeders.

In addition, the loads were redistributed between the three substations (Al-Hussein, Al-Dahdah and Al-Ras) to divide the loads between the stations based on distances close to the station to reduce the percentage of electrical loss and drop voltage.

In the following table (7.2) , the results of the power demand in (MW), and the power factor are explained as follow :

Table 7. 2: Loading on each sub-station.

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	16.049	306.6	91.57
AL-FAHS	33	20.182	370.2	95.39
AL-GHARBIA	33	14.971	293.6	89.22
AL-HARAYEK	33	10.199	199.1	89.6
AL-HUSSEIN	33	13.179	254.1	90.75
AL-RAS	33	14.992	290.6	90.26
Alsala-Alriyadia	33	2.309	44.77	90.24
UM AL-DALIYEH	33	19.239	372.1	90.46
Total		111.12		

Power imported from Power Grid = 111.119 MW .

Total power losses = 3.443 MW

$P_{Total} = P_{Demand} + P_{Losses}$

$P_{Total} = 107.676\ MW + 3.443\ MW$

$= 111.119\ MW$

Table (7.3) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 7.3: loading and power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	% Loading	kW Losses
T1 AL-DAHDAH	10000 kVA	5349.6	58.4	21.86
T2 AL-DAHDAH	10000 kVA	5349.6	58.4	21.86
T3 AL-DAHDAH	10000 kVA	5349.6	58.4	21.86
T1 AL-FAHS	10000 kVA	6727.2	70.5	31.85
T2 AL-FAHS	10000 kVA	6727.2	70.5	31.85
T3 AL-FAHS	10000 kVA	6727.2	70.5	31.85
T1 AL-GHARBIA	13000 kVA	7485.6	64.5	27.04
T2 AL-GHARABIA	13000 kVA	7485.6	64.5	27.04
T1 AL-HARAYEK	10000 kVA	5099.3	56.9	20.74
T2 AL-HARAYEK	10000 kVA	5099.3	56.9	20.74
T1 AL-RAS	10000 kVA	7496.1	83	44.17
T2 AL-RAS	10000 kVA	7496.1	83	44.17
T1Alsala-Alriyadia	13000 kVA	1220.5	19	2.34
T2 Alsala-Alriyadia	13000 kVA	1087.8	11.7	0.875
T1 AL-HUSSEIN	10000 kVA	6589.6	72.6	33.77
T2 AL-HUSSEIN	10000 kVA	6589.6	72.6	33.77
T1 UM AL-DALIYEH	10000 kVA	9060.4	94.1	56.72
T2 UM AL-DALIYEH	13000 kVA	10178.3	93	53.35
Total				525.855

7.2.1 Cost of the technical power losses

$$\text{utilization factor} = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{121.626}{309} = 0.393$$

Total technical of losses in MW = 3.433 MW

Cost for losses during 1 hour = 3433*0.378 = 1,297.7 NIS / h

Annual cost for losses = 3433 kW*0.378 * 8760 h * 0.393 = 4,474,427.3 NIS /Y

7.3 Case 2 Results

In this case, the same changes were made in the first case, in addition to adding a new feed unit to the new station(Alsala-Alriyadia) and connecting it to a bus (Gabriel Zalloum) and it was separated from the feeder (Wad Al Tuffah) connected to the substation (AL-Gharbia).

In addition, the loads were redistributed between the two substations (Al-Gharbia and Al Ras), which combined them with two feeders (Al-Adl and Al-Shallala) the same electrical loads, so the loads were fed from the feeders (Al-Adl) connected to the sub-station (Al-Gharbia) and separated from the disturber (Al-Shallala) connected from the sub-station (Al-Ras).

In the following table (7.4), the results of the power demand in (MW), and the power factor are explained as follow:

Table 7. 4: Loading on each sub-station .

ID	Rated kV	MW	Amp	% PF
AL-DAHDAH	33	16.049	306.6	91.57
AL-FAHS	33	20.182	370.2	95.39
AL-GHARBIA	33	15.309	292.2	91.67
AL-HARAYEK	33	10.199	199.1	89.6
AL-HUSSEIN	33	13.423	263.2	89.23
AL-RAS	33	9.495	184.2	90.17
Alsala Alriyadia	33	7.573	146.7	90.3
UM AL-DALIYEH	33	19.239	372.1	90.46
Total		111.469		

Power imported from Power Grid = 111.468 MW .

Total power losses = 3.397 MW

$$P_{Total} = P_{Demand} + P_{Losses}$$

$$P_{Total} = 108.071\ MW + 3.397\ MW$$
$$= 111.468\ MW\ .$$

Table (7.5) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 7. 5: loading and power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	% Loading	kW Losses
T1 AL-DAHDAH	10000 kVA	5349.6	58.4	21.86
T2 AL-DAHDAH	10000 kVA	5349.6	58.4	21.86
T3 AL-DAHDAH	10000 kVA	5349.6	58.4	21.86
T1 AL-FAHS	10000 kVA	6727.2	70.5	31.85
T2 AL-FAHS	10000 kVA	6727.2	70.5	31.85
T3 AL-FAHS	10000 kVA	6727.2	70.5	31.85
T1 AL-GHARBIA	13000 kVA	7654.5	64.2	26.79
T2 AL-GHARBIA	13000 kVA	7654.5	64.2	26.79
T1 AL-HARAYEK	10000 kVA	5099.3	56.9	20.74
T2 AL-HARAYEK	10000 kVA	5099.3	56.9	20.74
T1 AL-HUSSEIN	10000 kVA	6711.5	75.2	36.23
T2 AL-HUSSEIN	10000 kVA	6711.5	75.2	36.23
T1 AL-RAS	10000 kVA	4747.5	52.7	17.75
T2 AL-RAS	10000 kVA	4747.5	52.7	17.75
T1 UM AL-DALIYEH	10000 kVA	9060.4	94.1	56.72
T2 UM AL-DALIYEH	13000 kVA	10178.3	93	53.35
T1 Alsala-Alriyadia	13000 kVA	3786.5	32.3	6.75
T2 Alsala-Alriyadia	13000 kVA	3786.5	32.3	6.75
Total				487.72

7.3.1 Cost of the technical power losses

$$\text{utilization factor} = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{121.817}{309} = 0.394$$

Total technical of losses in MW = 3.397 MW

Cost for losses during 1 hour = 3397*0.378 = 1,284.06 NIS / h

Annual cost for losses = 3397 kW*0.378 * 8760 h * 0.394 = 4,431,876.8 NIS /Y

7.4 Case 3 Results

In this case, the same modifications were made in the second case, in addition to adding a new feed unit to the new sub-station (Alsala-Alriyadia) and connecting it to a bus (Chamber of Commerce) that was fed from the (Hussein) sub-station.

In the following table (7.6), the results of the power demand in (MW), and the power factor are explained as follow:

Table 7. 6: Loading on each sub-station .

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	16.049	306.6	91.57
AL-FAHS	33	20.182	370.2	95.39
AL-GHARBIA	33	15.309	292.2	91.67
AL-HARAYEK	33	10.199	199.1	89.6
AL-HUSSEIN	33	10.401	204.2	89.13
AL-RAS	33	9.495	184.2	90.17
Alsala-Alriyadia	33	10.703	207.1	90.44
UM AL-DALIYEH	33	19.239	372.1	90.46
Total		111.577		

Power imported from Power Grid = 111.576 MW .

Total power losses = 3.365 MW

$$P_{Total} = P_{Demand} + P_{Losses}$$

$$P_{Total} = 108.211\ MW + 3.365\ MW$$
$$= 111.576\ MW$$

Table (7.7) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 7. 7: loading and power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	A	% Loading	kW Losses
T1 AL-DAHDAH	10000 kVA	5349.6	102.2	58.4	21.86
T2 AL-DAHDAH	10000 kVA	5349.6	102.2	58.4	21.86
T3 AL-DAHDAH	10000 kVA	5349.6	102.2	58.4	21.86
T1 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T2 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T3 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T1 AL-GHARBIA	13000 kVA	7654.5	146.1	64.2	26.79
T2 AL-GHARBIA	13000 kVA	7654.5	146.1	64.2	26.79
T1 AL-HARAYEK	10000 kVA	5099.3	99.57	56.9	20.74
T2 AL-HARAYEK	10000 kVA	5099.3	99.57	56.9	20.74
T1 AL-HUSSEIN	10000 kVA	5200.4	102.1	58.3	21.8
T2 AL-HUSSEIN	10000 kVA	5200.4	102.1	58.3	21.8
T1 AL-RAS	10000 kVA	4747.5	92.12	52.7	17.75
T2 AL-RAS	10000 kVA	4747.5	92.12	52.7	17.75
T1 UM AL-DALIYEH	10000 kVA	9060.4	164.7	94.1	56.72
T2 UM AL-DALIYEH	13000 kVA	10178.3	211.5	93	53.35
T1Alsala Alriyadia	13000 kVA	5351.7	103.5	45.5	13.45

T2 Alsala Alriyadia	13000 kVA	5351.7	103.5	45.5	13.45
Total					472.26

7.4.1 Cost of technical the power losses

$$\text{utilization factor} = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{121.893}{309} = 0.394$$

Total technical of losses in MW = 3.365 MW

Cost for losses during 1 hour = 3365*0.378 = 1,271.97 NIS / h

Annual cost for losses = 3365 kW*0.378 * 8760 h * 0.394 = 4,390,128.1 NIS /Y

7.5 Case 4 Results

In this case, the same modifications were made in the third case, in addition to adding a new feed unit to the (Alsala-Alriyadia) new substation and connecting it to the bus being fed from the (AL-Gharbia)substation.

In addition to the redistribution of loads between two stations (AL-Gharbia ,Al Ras) shared in two feeders (Al-Shallala and Al-adl) taking into account the reduction of electrical losses and voltage drop.

In the following table (7.8), the results of the power demand in (MW), and the power factor are explained as follow:

Table 7. 8: Loading on each sub-station.

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	16.049	306.6	91.57
AL-FAHS	33	20.182	370.2	95.39
AL-GHARBIA	33	12.137	228.7	92.84
AL-HARAYEK	33	10.199	199.1	89.6
AL-HUSSEIN	33	12.077	236.1	89.5
AL-RAS	33	11.731	228.7	89.76
Alsala Alriyadia	33	10.027	195.1	89.9

UM AL-DALIYEH	33	19.239	372.1	90.46
Total		111.641		

Power imported from Power Grid = 111.641 MW .

Total power losses = 3.329 MW

$P_{Total} = P_{Demand} + P_{Losses}$

$P_{Total} = 108.312\ MW + 3.329\ MW$

$= 111.641\ MW$

Table (7.9) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 7. 9: loading and power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	A	% Loading	kW Losses
T1 AL-DAHDAH	10000 kVA	5349.6	102.2	58.4	21.86
T2 AL-DAHDAH	10000 kVA	5349.6	102.2	58.4	21.86
T3 AL-DAHDAH	10000 kVA	5349.6	102.2	58.4	21.86
T1 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T2 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T3 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T1 AL-GHARBIA	13000 kVA	6068.7	114.4	50.3	16.41
T2 AL-GHARBIA	13000 kVA	6068.7	114.4	50.3	16.41

T1 AL-HARAYEK	10000 kVA	5099.3	99.57	56.9	20.74
T2 AL-HARAYEK	10000 kVA	5099.3	99.57	56.9	20.74
T1 AL-HUSSEIN	10000 kVA	6038.6	118	67.5	29.16
T2 AL-HUSSEIN	10000 kVA	6038.6	118	67.5	29.16
T1 AL-RAS	10000 kVA	5865.7	114.3	65.3	27.35
T2 AL-RAS	10000 kVA	5865.7	114.3	65.3	27.35
T1 UM AL-DALIYEH	10000 kVA	9060.4	164.7	94.1	56.72
T2 UM AL-DALIYEH	13000 kVA	10178.3	211.5	93	53.35
T1Alsala Alriyadia	13000 kVA	5013.6	97.56	42.9	11.95
T2 Alsala Alriyadia	13000 kVA	5013.6	97.56	42.9	11.95
Total					482.42

7.5.1 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{121.934}{309} = 0.395$$

Total technical of losses in MM = 3.329 MW

Cost for losses during 1 hour = 3329*0.378 = 1,258.4 NIS / h

Annual cost for losses = 3329 kW*0.378 * 8760 h * 0.395 = 4,354,184.2 NIS /Y

7.6 Case 5 Results

In this case, we performed a large number of redistributions on the electrical loads between the seven substations (Al-Dahdah, Alsala-Alriyadia, Western, AL-Harayek, Al-Ras, UM AL-Daliyeh and Al-Hussein), while maintaining the same five feed units in the previous case, in order to see the effect of the redistribution Distribute loads evenly among all stations while maintaining reduced electrical losses and voltage drop .

However, the loads can be distributed between approximately six stations equally between them, with the exception of the two stations (Al-Fahs and Al-Dahdah), due to insatiable in the outskirts of the country.

In the following table (7.10), the results of the power demand in (MW), and the power factor are explained as follow :

Table 7. 10: Loading on each sub-station.

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	16.161	308.8	91.56
AL-FAHS	33	20.182	370.2	95.39
AL-GHARBIA	33	13.78	261.6	92.17
AL-HARAYEK	33	10.774	210.1	89.71
AL-HUSSEIN	33	12.734	249.3	89.35
AL-RAS	33	12.919	251.4	89.9
Alsala Alriyadia	33	12.086	236.1	89.57
UM AL-DALIYEH	33	13.182	250.3	92.13
Total		111.818		

Power imported from Power Grid = 111.818 MW .

Total power losses = 3.145 MW

$P_{Total} = P_{Demand} + P_{Losses}$

$P_{Total} = 108.673\ MW + 3.145\ MW$

$= 111.818\ MW$

Table (7.11) shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 7. 11: loading and power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	A	% Loading	kW Losses
T1 AL-DAHDAH	10000 kVA	5387	102.9	58.8	22.17
T2 AL-DAHDAH	10000 kVA	5387	102.9	58.8	22.17
T3 AL-DAHDAH	10000 kVA	5387	102.9	58.8	22.17
T1 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T2 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T3 AL-FAHS	10000 kVA	6727.2	123.4	70.5	31.85
T1 AL-GHARBIA	13000 kVA	6890.2	130.8	57.5	21.47
T2 AL-GHARBIA	13000 kVA	6890.2	130.8	57.5	21.47
T1 AL-HARAYEK	10000 kVA	5387	105.1	60.1	23.09
T2 AL-HARAYEK	10000 kVA	5387	105.1	60.1	23.09
T1 AL-HUSSEIN	10000 kVA	6367.1	124.7	71.3	32.52
T2 AL-HUSSEIN	10000 kVA	6367.1	124.7	71.3	32.52
T1 AL-RAS	10000 kVA	6459.3	125.7	71.8	33.06
T2 AL-RAS	10000 kVA	6459.3	125.7	71.8	33.06
T1 UM AL-DALIYEH	10000 kVA	6170.9	109.2	62.4	24.94
T2 UM AL-DALIYEH	13000 kVA	7010.7	147	64.6	25.79
T1Alsala Alriyadia	13000 kVA	6043.1	118	51.9	17.48
T2 Alsala Alriyadia	13000 kVA	6043.1	118	51.9	17.48
Total					468.03

7.6.1 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{122}{309} = 0.395$$

Total technical of losses in MM = 3.145 MW

Cost for losses during 1 hour = 3145*0.378 = 1,188.8NIS / h

Annual cost for losses = 3145 kW*0.378 * 8760 h * 0.395 = 4,113,520.4 NIS /Y

7.7 Case 6 Result

In this case, we made the same adjustments in the fifth case, in addition to adding a new feed unit to the new substation and connecting it to a bus that was fed from a substation (AL-Gharbia).

However, we redistributed loads the of all eight substations ,in

Medium voltage network taking into account the occurrence of a reduction in the percentage of electrical losses and voltage drop .

In the following table (7.12), the results of the power demand in (MW), and the power factor are explained as follow:

Table 7. 12: Loading on each sub-station.

ID	Rated kV	kW	A	% PF
AL-DAHDAH	33	16183.8	309.2	91.58
AL-FAHS	33	17925.7	331.7	94.54
AL-GHARBIA	33	12474.9	235.7	92.61
AL-HARAYEK	33	10123.3	197.3	89.78
AL-HUSSEIN	33	11743	229.4	89.55
AL-RAS	33	13089.7	254.7	89.93
Alsala Alriyadia	33	15407.8	302.5	89.1
UM AL-DALIYEH	33	15386.9	287.7	93.58
Total		112335.1		

Power imported from Power Grid = 112.335 MW .

Total power losses = 2.93 MW

$P_{Total} = P_{Demand} + P_{Losses}$

$P_{Total} = 109.405\ MW + 2.93\ MW$

$= 112.335\ MW$

Table 7.13 shows the result of every transformer in the seven sub-stations, results contains the loading power on transformers and power losses on each one of them.

Table 7. 13: loading and power losses on sub-stations transformers.

ID	Rating kVA	kW Flow	A	% Loading	kW Losses
T1 AL-DAHDAH	10000 kVA	5394.6	103.1	58.9	22.22
T2 AL-DAHDAH	10000 kVA	5394.6	103.1	58.9	22.22
T3 AL-DAHDAH	10000 kVA	5394.6	103.1	58.9	22.22
T1 AL-FAHS	10000 kVA	5975.2	110.6	63.2	25.58
T2 AL-FAHS	10000 kVA	5975.2	110.6	63.2	25.58
T3 AL-FAHS	10000 kVA	5975.2	110.6	63.2	25.58
T1 AL-GHARBIA	13000 kVA	6237.4	117.8	51.8	17.43
T2 AL-GHARBIA	13000 kVA	6237.4	117.8	51.8	17.43
T1 AL-HARAYEK	10000 kVA	5061.7	98.64	56.4	20.36
T2 AL-HARAYEK	10000 kVA	5061.7	98.64	56.4	20.36
T1 AL-HUSSEIN	10000 kVA	5871.5	114.7	65.6	27.53
T2 AL-HUSSEIN	10000 kVA	5871.5	114.7	65.6	27.53
T1 AL-RAS	10000 kVA	6544.8	127.3	72.8	33.92
T2 AL-RAS	10000 kVA	6544.8	127.3	72.8	33.92
T1 UM AL-DALIYEH	10000 kVA	7215.9	127.5	72.9	34.02
T2 UM AL-DALIYEH	13000 kVA	8171	165.5	72.8	32.69
T1Alsala Alriyadia	13000 kVA	7703.9	151.3	66.5	28.72
T2 Alsala Alriyadia	13000 kVA	7703.9	151.3	66.5	28.72
Total					466.03

7.7.1 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{122.626}{309} = 0.397$$

Total technical of losses in MM = 2.93 MW

Cost for losses during 1 hour = 2930*0.378 = 1,107.5 NIS / h

Annual cost for losses = 2930 kW*0.378 * 8760 h * 0.397 = 3,851,714 NIS /Y

7.8 Comparison between cases

Table (7.14) & figure (7.1) below describes the differences between the 6 cases done on the network, the comparisons are mainly focused on total power losses happened in the network and the division of this value on the transformers and transmission lines, in addition to the total power delivered in the network.

Table 7.14: Comparison between the 6 cases.

No	Total Power Losses MW	Power Delivered MW	Sub-station tr-r losses kW	Line &cable losses kW
CASE 1	3.443	111.119	525.855	1947.2027
CASE 2	3.397	111.468	487.72	1936.3343
CASE 3	3.365	111.576	472.26	1919.1023
CASE 4	3.329	111.641	482.42	1872.095
CASE 5	3.145	111.818	468.03	1698.907
CASE 6	2.93	112.335	466.03	1480.336

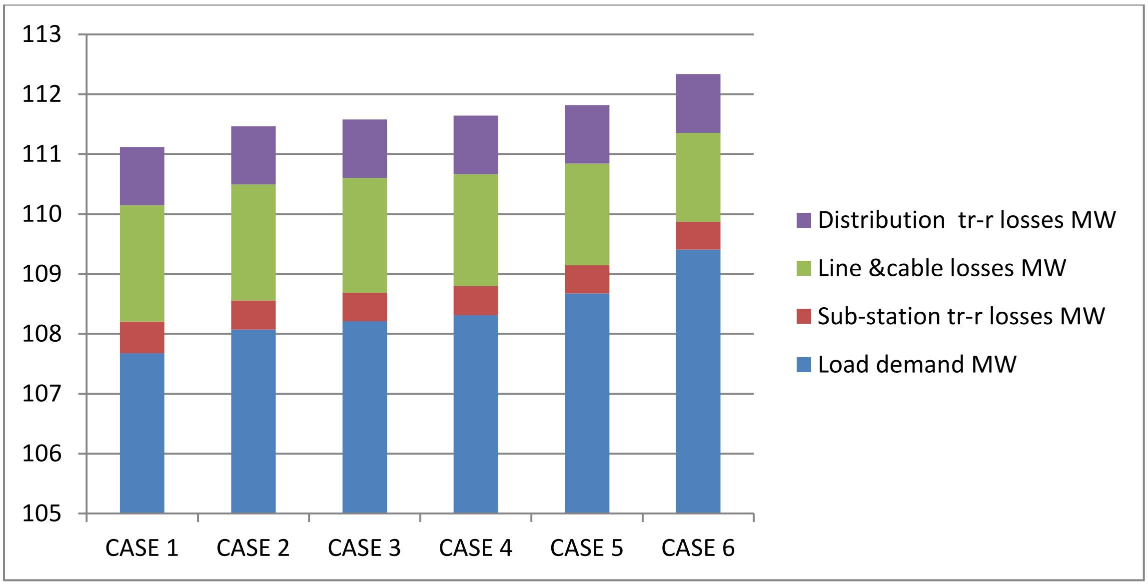

Figure 7. 1:Comparison between cases .

7.9 Network Comparison

Table(7.15) below shows the results of the analysis of the existing network done in the first case in chapter 6, and it also compares these results with the results after adding the new sub-station taking into account all new redistribution on the loads in the network.

Table 7. 15: Comparison before and after adding the new sub-station with all new redistributions of loads.

	Before	After
Total Power Losses	3.618	2.93
Power Demand	112.92	112.335
sub-stations tr-r losses	564.03	466.03
Line losses	2071.88	1480.336

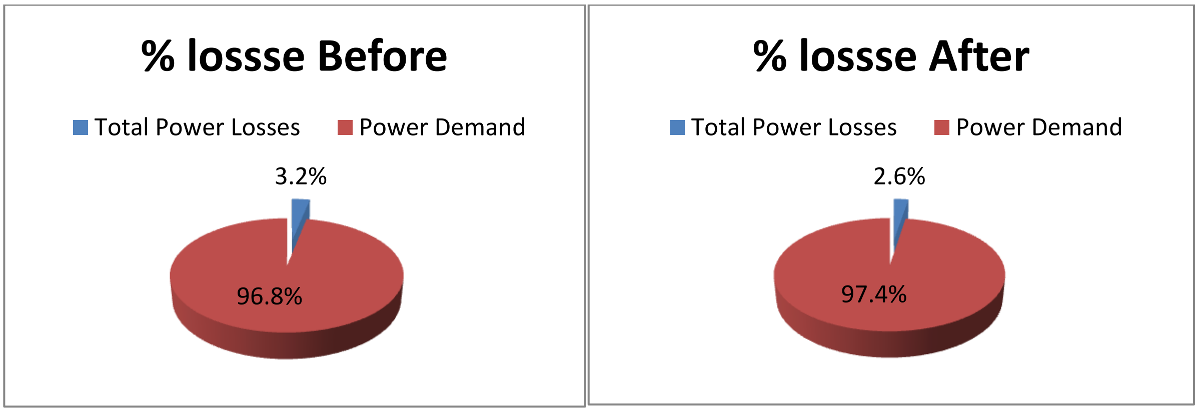

Figure 7. 2: percentage for losses before & after the new sub-station .

7.10 Conclusion

In this chapter, the new sub-station was placed in six feeders on a simulation program using ETAP, redistributing electrical loads between the MV grid in HEPCo.

Electricity losses and voltage drops have been reduced in substations transformers and cables, because of the effect of reducing the length of the lines to the loads, so that when the length of the lines reduce, the power losses also reduce. However, there is no change in the distribution transformers.

the power losses remain constant on the distribution transformers because it loaded by 40% of constant loads.

Chapter 8

Solutions to reduce electrical losses

8.1 Introduction

In this chapter, we suggested and applied adding a new two sub-stations for this reasons:

1. Reduce the power losses.
2. Reduce the overloads in Halhul region.
3. Reduce the voltage drop.

The suggested solution can be categorized as follow:

1. Adding a new sub-station in Halhul region.
2. Adding a new sub-station in Al-Fahs region.

8.2 Adding a new sub-station in Halhul region

We proposed adding a new sub-station in Halhul region in order to reduce power losses, voltage drop and overloads at Halhul feeder. Figure (8.1) shows the overloads on the feeder which feeds Halhul with electricity.

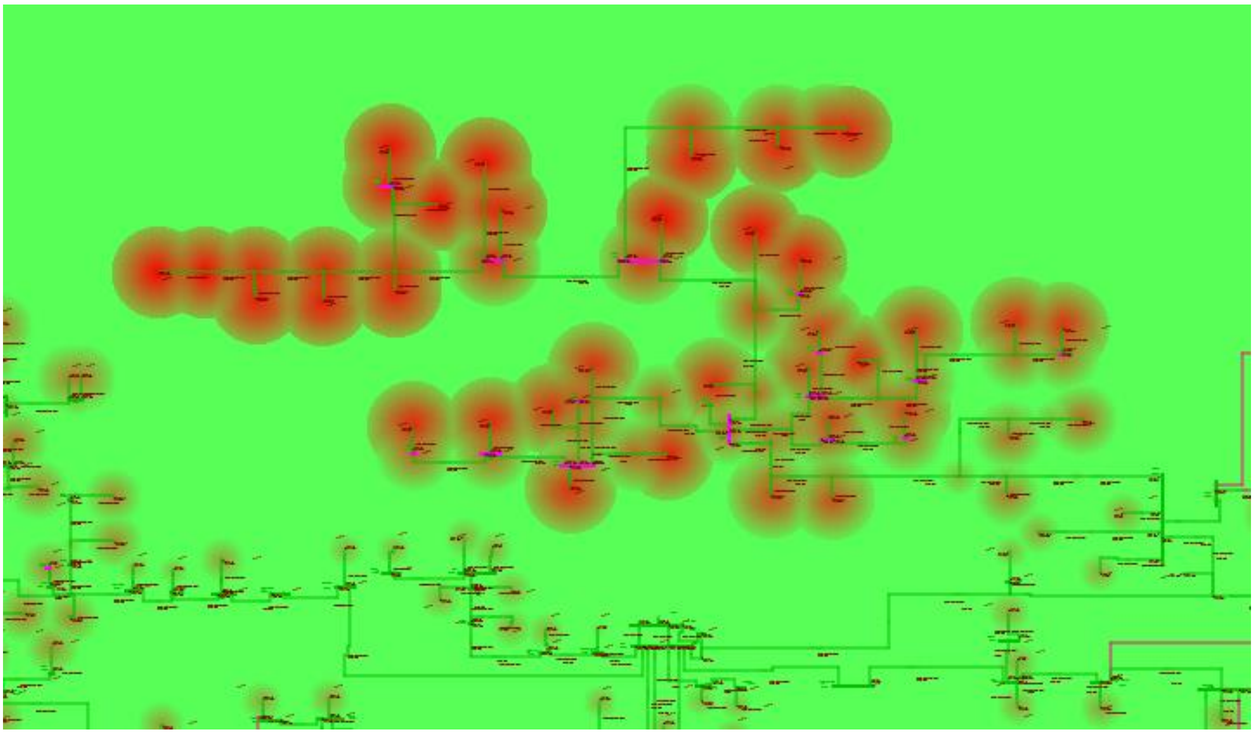

Figure 8. 1: The overload of Halhul feeder.

Both of the two designs were build in the ETAP simulator with taking case 6 of the previous chapter as a base.

8.2.1 Sub-Station information

We assumed the capacity of the transformer of this sub-station to be 10 MVA, which covers 40% of the distribution transformers in Halhul region that is being fed from AL-DAHDAH sub-station. We disconnected the feeder from AL-DAHDAH sub-station and chose a new site of the sub-station in Halhul region to feed the distribution transformers.

Halhul feeder has 41 distribution transformer with 14.37 MVA total power, our choice of the sub-station transformer capacity 10 MVA taking into account the increment of the demand in that region.

8.2.2 ETAP Simulation

The following table (8.1) presents the loading on the sub-stations including Halhul sub-station with the other 8 sub-stations.

Table 8. 1: Loading on each sub-station.

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	11.11	212.6	91.42
AL-FAHS	33	17.926	331.7	94.54
AL-GHARBIA	33	12.475	235.7	92.61
AL-HARAYEK	33	10.123	197.3	89.78
AL-HUSSEIN	33	11.743	229.4	89.55
AL-RAS	33	13.09	254.7	89.93
Alsala Alriyadia	33	15.622	306.9	89.06
Halhul	33	5.004	94.74	92.41
UM AL-DALIYEH	33	15.387	287.7	93.59
Total		112.48		

Power imported from Power Grid = 112.48 MW .

Total power losses = 2.799 MW , 2.488%

$$P_{Total} = P_{Demand} + P_{Losses}$$

$$P_{Total} = 109.681\ MW + 2.799\ MW$$

$$= 112.48 \text{ MW}$$

The following figure (8.2) shows the result after adding the new sub-station of Halhul, which illustrates that the over load in Halhul feeder decresaed Compared with figure (8.1) before adding Halhul sub-station.

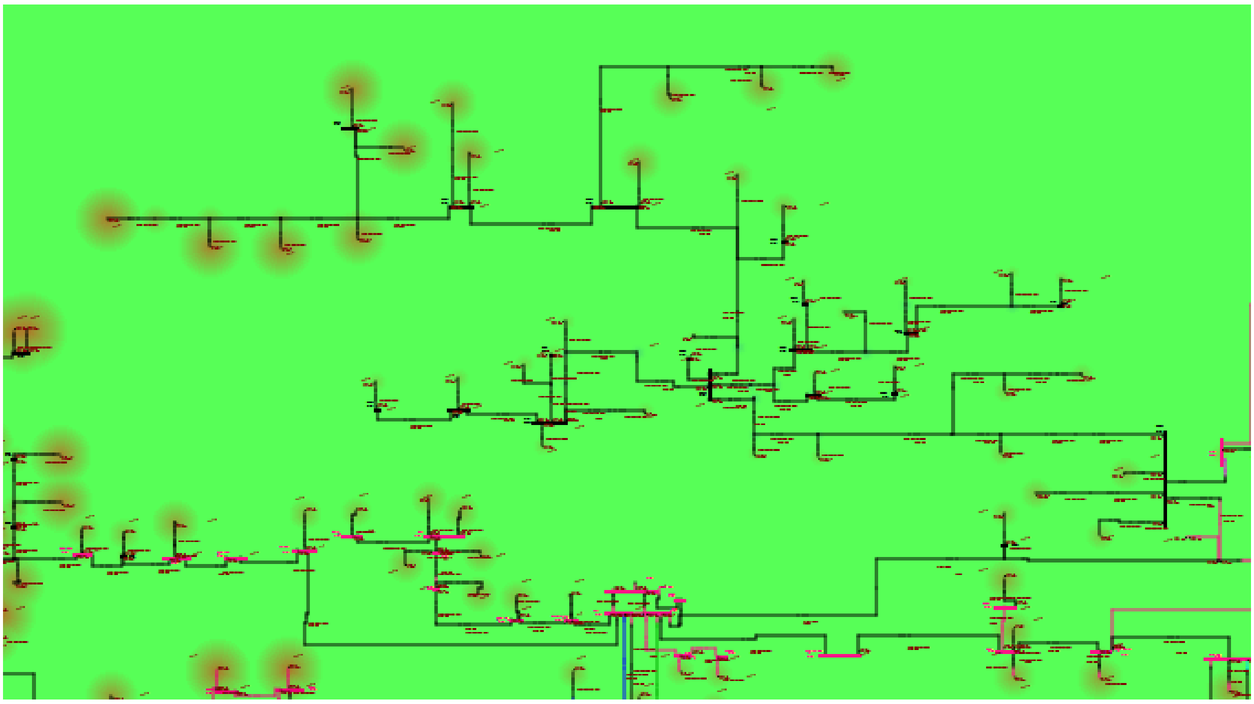

Figure 8. 2: The overload decrement on Halhul feeder.

The following table (8.2) shows the difference between adding the sub-station and without adding it. It is clear that the power losses have decreased from 2.6% to 2.48% with a value of 131 kW.

Table 8. 2 : Comparison before and after adding Halhul sub-station

	Before	After
Power Demand MW	112.335	112.48
Total Power Losses MW	2.93	2.799
Load Demand MW	109.405	109.681
sub-stations tr-r losses kW	466.03	459.58
distribution transformer losses kW	984	981
Line & cable losses kW	1480.336	1358.5

This figure (8.3) shows the difference between adding the sub-station and without adding it.

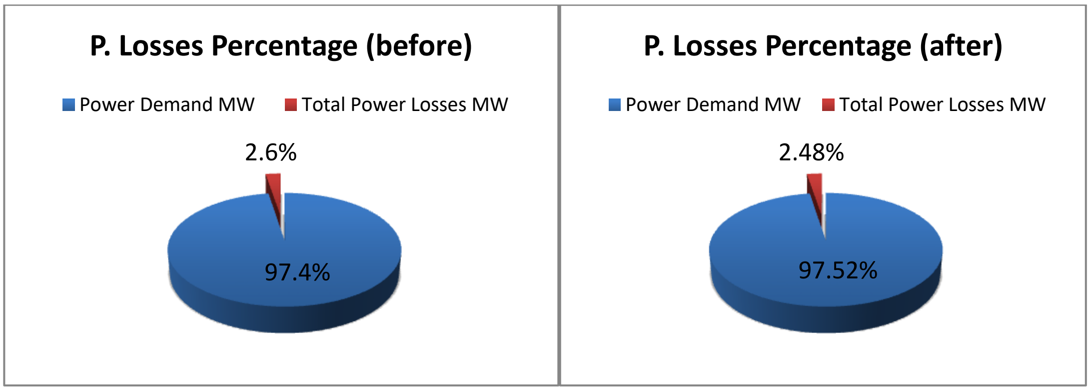

Figure 8. 3: The percentage of losses before & after adding Halhul sub-station.

8.2.3 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{123}{309} = 0.4$$

Total technical of losses in MM = 2.799 MW

Cost for losses during 1 hour = 2799*0.378 = 1,058 NIS / h

Annual cost for losses = 2799 kW*0.378 * 8760 h * 0.4 = 3,707,309 NIS /Y

8.3 Adding a new sub-station in Al-Fahs region

In this case we added a new sub-station in Al-Fahs region in order to solve the problems of losses and overload, the site has been chosen by checking the load demand in the region that have overload and voltage drop. Figure (8.4) shows the overloads in Al-Fahs region.

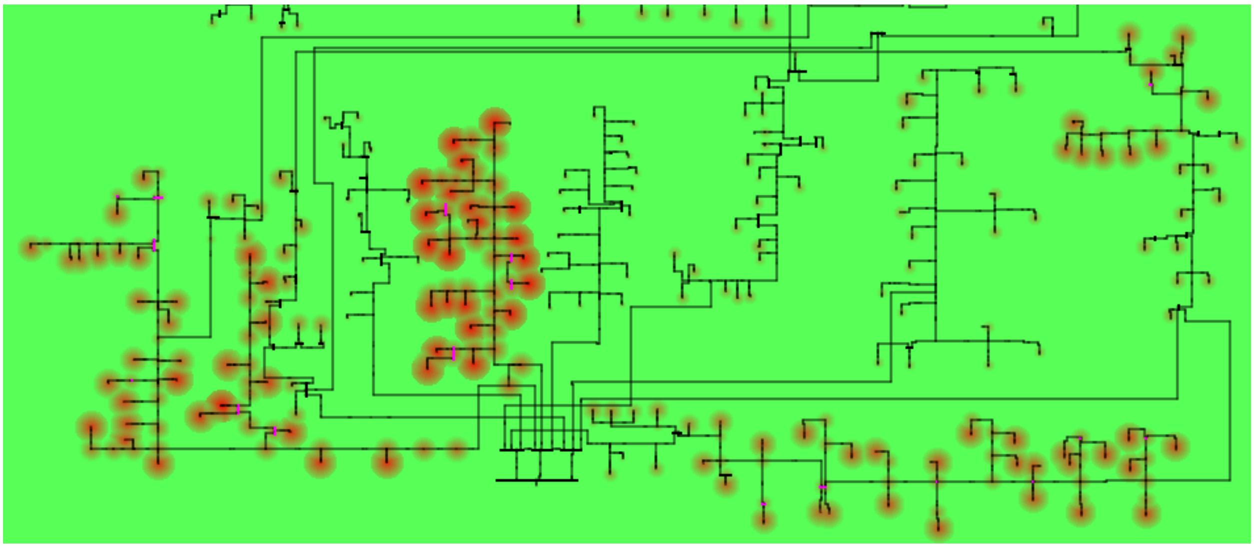

Figure 8. 4: The overload in Al-Fahs region.

After measuring the load demand at Tariq School bus by ETAP, it has been shown that the region has 11 MW when it is at 40% loading, so we assumed the sub-station transformer capacity to be 20 MVA in order to make it suitable for the increment of load demand for the next years.

8.3.1 ETAP Simulation

Table (8.3) shows the loading on the sub-stations including Tariq School sub-station with the other 8 sub-stations.

Table 8. 3: Loading on each sub-station.

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	16.017	305.6	91.71
AL-FAHS	33	13.867	251.8	96.34
AL-GHARBIA	33	10.725	200.9	93.39
AL-HARAYEK	33	10.348	201.8	89.7
AL-HUSSEIN	33	11.743	229.4	89.55
AL-RAS	33	13.092	254.7	89.94
Alsala Alriyadia	33	15.622	306.9	89.06

Tariq School	33	11.08	207.7	93.33
UM AL-DALIYEH	33	9.755	185.3	92.11
Total		112.249		

Power imported from Power Grid = 112.249 MW .

Total power losses = 2.493 MW , 2.22%

$P_{Total} = P_{Demand} + P_{Losses}$

$P_{Total} = 109.756\ MW + 2.493\ MW$

$= 112.249\ \text{MW}$

The following figure (8.5) shows the result after adding the new sub-station of Tariq School, which illustrates that the over load in Halhul feeder decresaed Compared with figure (8.4) before adding Tariq School sub-station.

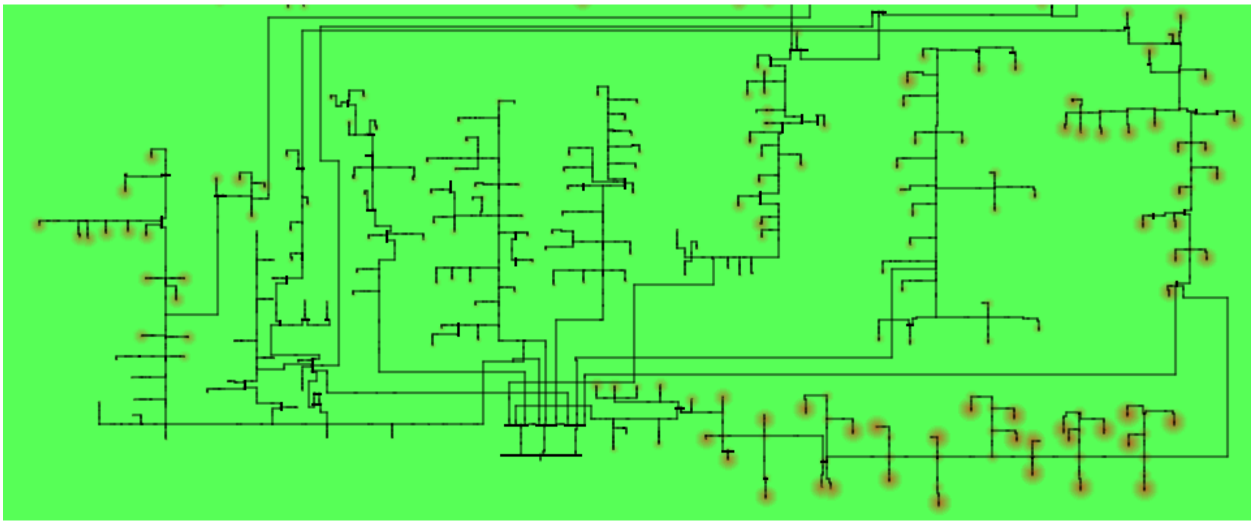

Figure 8. 5 : The overload decreasing in Tariq School region .

The following table (8.4) shows the difference between adding the sub-station and without adding it. It is clear that the power losses have decreased from 2.6% to 2.22% with a value of 437 kW.

Table 8. 4: Comparison before and after adding Tariq School sub-station.

	Before	After
Power Demand MW	112.335	112.249
Total Power Losses MW	2.93	2.493
Load Demand MW	109.405	109.756
sub-stations tr-r losses kW	466.03	436.6

distribution transformer losses KW	984	972
Line & cable losses kW	1480.336	1084.3

This figure (8.6) shows the difference between adding the sub-station and without adding it.

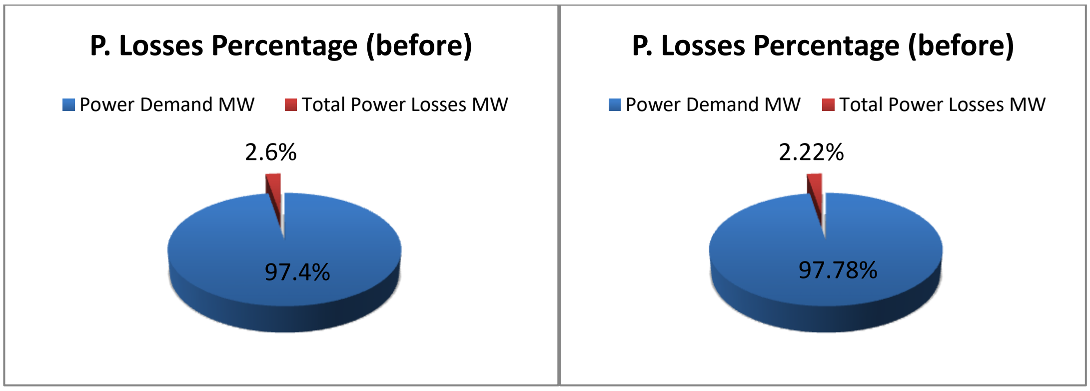

Figure 8. 6: The percentage of losses before & after adding Tariq School sub-station.

8.3.2 Cost of the technical power losses

$$\text{utilization factor } = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{122.3}{309} = 0.396$$

Total technical of losses in MM = 2.493 MW

Cost for losses during 1 hour = 2493*0.378 = 942.4 NIS / h

Annual cost for losses = 2493 kW*0.378 * 8760 h * 0.396 = 3,268,988.4 NIS /Y

8.4 Adding two sub-stations (Halhul & Tariq School)

In this case, we study the effect of adding two sub-stations (Tariq School & Halhul), and table (8.5) shows the loading sub-stations including Tariq School & Halhul sub-stations.

Table 8. 5: Loading on each sub-station.

ID	Rated kV	MW	A	% PF
AL-DAHDAH	33	11.11	212.6	91.42
AL-FAHS	33	13.867	251.8	96.34
AL-GHARBIA	33	10.725	200.9	93.39
AL-HARAYEK	33	10.348	201.8	89.7
AL-HUSSEIN	33	11.743	229.4	89.55
AL-RAS	33	13.092	254.7	89.94
Alsala-Alriyadia	33	15.625	306.9	89.06
Halhul	33	5.004	94.74	92.41
Tariq School	33	11.08	207.7	93.33
UM AL-DALIYEH	33	9.755	185.3	92.11
Total		112.349		

Power imported from Power Grid = 112.349 MW .

Total power losses = 2.371 MW , 2.11%

$$P_{Total} = P_{Demand} + P_{Losses}$$

$$P_{Total} = 109.978\, MW + 2.371\, MW$$

$$= 112.349 \text{ MW}$$

The following table (8.6) shows the difference between adding the new two sub-stations and without adding them. It is clear that the power losses have decreased from 2.6% to 2.11% with a value of 559 kW.

Table 8. 6: Comparison before and after adding Halhul & Tariq School sub-stations.

	Before	After
Power Demand MW	112.335	112.349
Total Power Losses MW	2.93	2.371
Load Demand MW	109.405	109.978
Sub-stations tr-r losses kW	466.03	430.16
Distribution transformer losses KW	984	974.5
Line & cable losses kW	1480.336	966

8.4.1 Cost of the technical power losses

$$\text{utilization factor} = \frac{Maximum\ MVA\ \ Demand}{Transformer\ MVA\ Rating} = \frac{122.41}{309} = 0.396$$

Total technical of losses in MM = 2.371MW

Cost for losses during 1 hour = 2371*0.378 = 896.3 NIS / h

Annual cost for losses = 2371 kW*0.378 * 8760 h * 0.396 = 3,109,013.8 NIS /Y

8.5 Network Comparison

In this section, we made a comparison between 3 cases:

1. Case 1 in chapter 6, which is the basic network existing.
2. Case 6 in chapter 7, which is after adding the first sub-station of Alsala-Alriyadia with all feeders and redistributions.
3. Case 3 in chapter 8, which represents adding the 3 new sub-stations.

The following table (8.7) summarizes the difference between adding the new three sub-stations and before adding them, those are: (Tariq School, Halhul and Alsala-Alriyadia). It is clear that the power losses have decreased from 3.2% to 2.11% with a total of 1.247 MW.

Table 8. 7: comparison between 3 cases .

	case 1 in chapter 6	case 6 in chapter 7	case 3 in chapter 8
Power Demand MW	112.918	112.335	112.349
Total Power Losses MW	3.618	2.93	2.371
Load Demand MW	109.3	109.4	109.978
Sub-stations tr-r losses kW	564	466	430.16
Distribution transformer losses KW	981.88	983.6	974.5
Line & cable losses kW	2071.9	1480.4	966

8.6 Conclusion

In this chapter, two new sub-stations in two regions (alfahs and halhul) were added indivdually first, and then both of them were added at the same time to the ETAP simulation program.

Firstly, a new sub-station was added in Halhul region, due to the difference in the voltage drop and its distance from Al-Dahdah sub-station

Secondly, another new sub-station was added in the Tareq School District, due to the difference in voltage and its distance from (Al-Fahs) sub-station. after adding two new sub-stations in two regions (Al-Fahs & Halhul) with redistributing the loads between all the medium voltage network, the percentage of electrical losses and voltage drop has been reduced, However, both of two sub-stations were chosen to be as close as possible to the loads because of the far distance noticed between loads and the feeders.

Chapter 9

Conclusions & Recommendations

9.1 Conclusions

The project conclusions are as follow:

1. After studying the medium voltage network of HEPCo we noticed that the percentage of the power losses is an acceptable and a normal value while the overall power losses percentage that was taken from HEPCo annual reports show a high overall power losses. As a result, it can be noticed that the rest of the power losses are occurred on the low voltage network components in addition to theft.

2. The result of the analysis show that the redistribution of loads on the feeders of the existing sub-stations is an effective way to reduce the power losses noticeably.

3. The addition of the new sub-stations is also an effective way to reduce the power losses and voltage drop. However, adding the new sub-stations with redistribution of loads improved the network in a noticeable way.

4. Improving the medium voltage network and reducing the power losses on it reflects also on the low voltage network positively.

9.2 Recommendations

Recommendations for Hebron Municipality:

1. Use the ETAP to study and develop the network to get a clear vision of the network, which helps in controlling it better.
2. Add new sub-stations with studies about the best place for it.
3. Redistribute the loads and make more studies about redistribution of loads in each sub-station.
4. Replace aluminum conductor to copper conductor for its high efficiency.

Recommendations for our university:

1. There is a need to do Simulation software courses for students in order to understand more about the electrical network and how it works, depending on our studies in our college.
2. Make more Scientific visits in order to understand more about the parts of electrical network and sub-stations.

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