Forecasting and Planning for Hebron Electrical Power System

Project Team

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ABSTRACT

Palestinian electrical power distribution companies nowadays are trying to seek to not rely on imported electricity from Israeli generation companies. Due to the importance of the up-mentioned case, studying the power demand load growth for Hebron electrical company became very necessary and important. Furthermore, a planning process should take place to take an accurate decision for the generation unit that must be constructed to fulfill the required demand, under the cooperation with the Palestinian energy and natural resources authority, and under optimal specified conditions and constraints.

The regression model was used to forecast and predict the load growth for HEPCO concession areas from 2016 to 2035 depending on six factors like population, load factor, power system losses, gross domestic product, gross domestic product per capita, and the cost of one kilowatt-Hour. these factors are differing from one country to another and they affect the demand growth in Hebron in general.

Four power plants with different fuel types and with different capacities are represented within Hebron geographical borders as a solution for the separation process from the Israeli control. These plants have been extensively studied and constructed from an economic point of view according to the used fuel type, moreover an estimation process of the output power and fuel consumption of each generating unit is achieved at minimum fuel cost.

Keywords: Load Forecasting, Planning, Regression Method, Optimal Power Flow, Economic Dispatch, Optimal Constraint, Fuel Cost Curve, Power World, MATLAB-Simulink.

الملخص

شركات توزيع الطاقة الكهربائية الفلسطينية تحاول في هذه الأيام أن تتخلص من الإعتماد على إستيراد الطاقة الكهربائية من شركات التوليد القطرية "الإسرائيلية" .نظراً لأهمية هذه العملية , فإن دراسة الزيادة في الأحمال المتوقعة لشركه كهرباء الخليل أصبح من القضايا المهمة والضرورية ,علاوة على ذلك يجب البدء بعملية التخطيط لإتخاذ القرارات التي تتعلق بإنشاء وحدات توليد للطاقة الكهربائية وذلك بالتعاون مع سلطة الطاقة الفلسطينية, والتي سيتم إنشائها لتغطية الإستهلاك المتوقع تحت العديد من المحددات والشروط للحصول على التوزيع والإنتاج الأفضل والأمثل من الناحية الاقتصادية.

في هذا المشروع تم استخدام نموذج الحركة التراجعية "Regression Model" لحساب الحمل المتوقع لمناطق إمتياز شركة كهرباء الخليل لهذا المشروع للفترة الزمنية من ٢٠١٦ لغاية ٢٠٣٥ بالإعتماد على ستة عوامل رئيسية كتعداد السكان ,عامل الأحمال ،الناتج المحلي الاجمالي ,الناتج المحلي الاجمالي لكل فرد ،خسائر الطاقه للنظام وتكلفه كيلو واط/ساعة من الطاقة. هذه العوامل تختلف من دولة لأخرى ومن منطقة جغرافية لأخرى وتؤثر بشكل كبير على كمية الأحمال المتوقعة.

أربع محطات لتوليد الطاقة الكهربائية بأنواع مختلفة من الوقود المستخدم وبقدرات مختلفة سيتم تمثيلها ضمن النطاق الجغرافي لمدينة الخليل كحل نهائي للإنفصال عن السيطرة الاسرائيلية للطاقة الكهربائية، هذه المحطات تمت دراستها بشكل مركز من وجهة نظر اقتصادية نظراً لنوع الوقود المستخدم، علاوة على ذلك، عملية تقدير كمية الطاقه الناتجة وكميه الوقود المطلوب سوف تكون بأقل التكاليف الممكنة.

الإهداء

ها نحن اليوم وبحمد الله نطوي سهر الليالي وتعب السنين التي مضت

ونقدم بين طيات الكتاب خلاصة مشوارنا ... .

إليك حبيبي وسيدي يا منارة العلم وهداية البشر، يا من أنقذتني برسالتك من ظلمات الجهل

وكنت الذي اهتدي به اذا ما اسود ليلي يا سيدي ونبي محمد صلى الله عليه وسلم

إلى اطيب قلب واجمل ابتسامة واعذب حديث، اليك امي يا من كنت شريكتي في سهري وتعبي

وحزني وفرحي أدامك الله تاجاً فوق رؤوسنا يا من كنتي لي أماً وأختاً وصديقة ...

اليك يا من ضحيت بعمرك من أجلي وآثرت راحتي على راحتك وأحرقت شمعة أيامك وشبابك من

أجل ان تضعني على أول الطريق إليك ابي حفظك الله من كل شر وبارك في عمرك ....

اليكم يا من رويتم بدمائكم الطاهرة أرض بلادي يا من ضحيتم بأرواحكم من أجلنا لضمان بقاءنا

على هذه الارض رحمكم الله واحلكم الفردوس الاعلى ....

إلى من حبهم سكن في اعماق قلبي الذين ادعو لهم بالسر والعلن أن يحفظهم الله من كل شر

وأن يبقيهم نوراً لدربي وسنداً لي إليكم اخوتي واخواتي ....

إليكم يا من وهَبْتُكُم لي الحياة وكنتم سنداً لي على طول الطريق يا من كنتم سبباً في زرع الابتسامة

على وجهي حتى في أصعب الظروف..... أصدقائي وأحبابي .....

اليهم جميعاً اهدي هذا العمل ....

والله ولي التوفيق

الشكر

نشكر الله العلي القدير الذي أنعم عليّنا بنعمة العقل والدين. القائل في محكم التنزيل

(وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيم ....) صدق الله العظيم .

وقال رسول الله (صلي الله عليه وسلم)

(من صنع إليكم معروفاً فكافئوه, فإن لم تجدوا ما تكافئونه به فادعوا له حتى تروا أنكم كافأتموه.)

وفاءً وتقديراً وإعترافاً منا بالجميل نتقدم بجزيل الشكر لأولئك المخلصين الذين لم يألوا جهداً في مساعدتنا في مجال البحث العلمي

ونخص بالذكر مشرف المشروع

الدكتور" **فــؤاد الــزرو**"

صاحب الفضل في توجيهنا ومساعدتنا في تجميع المادة البحثية فجزاه الله كل خير.

كما ونتقدم بجزيل الشكر إلى كل من مدوا لنا يد العون والمساعدة في إخراج هذه الدراسة على أكمل وجه وامدادنا بالمعلومات المطلوبة.

ونخص بالذكر :

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والمهندس "**محمد التميمي**" والمهندس "**سامر سلطان**" لما بذلوه من جهد ومساعدة لإتمام هذا المشروع على أكمل وجه

تقديرا لجهودهم في اتمام هذا المشروع.

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	Abbreviation statement
LES	least Error Square
PV	Photovoltaic
HEPCO	Hebron Electric Power Company
MV	Medium Voltage
GDP	The gross domestic product
POP	The population
GDP/CAP	The GDP per capita
EP	The multiplication of electricity consumption by population
LOSS	The power system losses
LF	The load factor
KWH	kilowatt-hour
%E	Percentage error
PENRA	Palestinian Energy and Natural Resources Authority
OPF	Optimal Power Flow
ED	Economic Dispatch
BTU	British thermal unit
LP	Linear programming
GIS	Geographic Information System
TSS	Time Step Simulation

1

Chapter One Introduction

1.1 Overview

1.2 Motivations

1.3 Literature Review

1.4 Objectives

1.5 Challenges

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1.7 Time Schedule

1.1 Overview

This project discusses the load power forecasting and energy growth for Hebron electrical power company load for a time horizon up to 2035,this process will be applied using the regression mathematical model by using the least error square (LES) model, depending on the outcome expected result a planning process will be implemented ,this process includes an expansion or upgrading for the power system under economical dispatching criteria depending on the capacity and the location of some new power stations that will be adopt in Hebron , The MATLAB/Simulink software is used to apply the(LES) model, and power world simulator software is used for modeling Hebron electrical network for some special scenarios .

1.2 Motivation

The motivation behind such an approach is to get a Self-sufficiency in the electrical manner, as a developing and occupied country we must improve and build our Owen electrical generating sources apart from the " Israeli " control, in addition the Israeli electrical company cannot provide Hebron electrical company the expected and needed load in the next decade, the forecasting and predicting methodologies help us to determine the power demand that must be covered, according to this we will start our planning process. In addition to that the collaborate work with HEPCO formalize the future studies in this project.

1.3 Literature Review

Two major goals of our project will be presented; the first one is to forecast the load demand for Hebron electrical company and as ‘Serkan yavasca’ and ‘Celal yasar’ stated in [1], there study was about the peak load demand forecast using many approaches as the least error square and The exponential regression, this process is then applied by ‘Mohammed Hattab’, ‘Mohammed Ma’itah’, ‘Tha’er Sweidan’, ‘Mohammed Rifai’, and ‘Mohammad Momani’ in [2] ,there project was presenting a technique for Medium Term Load Forecasting to forecast the electric loads of the Jordanian grid for year of 2015, The prediction is made either weekly or monthly based on historical peak load data and weather influence.

In another different phase ‘Guguloth Ramesh’ and ‘Dr. T. K. Sunil Kumar’ have worked [3], they focused here on solving the OPF problem by classical methods like Newton method and PLP method. The 26 and IEEE 30 bus systems have been modeled as test bus systems using power world simulator, to minimize the total operation cost of the system. They conclude that the two main approaches can be used to solve the OPF problem effectively. All these projects and conclusions lead us to take an accurate step by choosing the best problem solving technique, and the best software.

1.4 Objectives

- Modeling the (LES) mathematical method to get the predicted load demand for Hebron electrical network.
- Expansion and upgrading for Hebron electrical network in 2025 and 2035 according to the predicted load demand.
- Using the PV system as a generating unit in the future network planning
- Determine the behavior for each generating unit output power under the economic and optimal power flow constraint.
- To estimate the output power, fuel consumption and cost of each generating unit in a power plant while meeting the load demands at a minimum fuel cost.

1.5 Challenges

- 25% of total population of West Bank is not distributed to the official electricity companies and this percentage represents about 750,000 residents of the total population of the West Bank which is equal to 3000000 residents.

- Some Jewish communities are supplied from Jerusalem distribution electrical company, according to this there is no information about the population growth and some information related to Palestinian Central Bureau of Statistics in these areas.

- The required data for the load forecasting algorithm are not available at some of the electrical companies in west bank and Palestinian Energy and Natural Resources Authority.

- Limited knowledge of the MATLAB and Power World Simulator Program due to lack of course education program which has led to the self-learning.

- Limited knowledge of the forecasting and planning process due to lack of education courses.

- Lack of case studies about our project.

1.6 Importance

- The forecasting model that we have built can be used to forecast any power system load by entering the factors that depends on the country itself.
- The Forecasting model gives an accurate indication about the load growth.
- Any expansion process will be economically dispatched that means the cost of electricity generation will be minimum.
- Develop the best approach that will help all the power utility companies to solve the problem of economic load dispatch in power system.

1.7 Time Schedule

Table 1.1: Time schedule for first semester.

Date / **Task**	1st Month				2nd Month				3rd Month				4th Month			
	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$
Task 1	■	■														
Task 2			■	■	■	■	■	■	■	■						
Task 3				■	■	■	■	■	■	■	■	■	■			
Task 4							■	■	■	■	■	■	■	■		
Task 5							■	■	■							
Task 6										■	■	■	■	■	■	
Task 7																■

- **Task 1:** Identification of Project Idea.
- **Task 2:** Literature Review.
- **Task 3:** Data collection.
- **Task 4:** Analysis Data.
- **Task 5:** Building MATLAB/Simulink for forecasting model.
- **Task 6:** Documentation.
- **Task 7:** Prepare the Presentation.

Table 1.2: Time schedule for second semester.

Date / Task	1st Month				2nd Month				3rd Month				4th Month			
	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4
Task 1	■	■														
Task 2			■	■	■	■	■	■								
Task 3				■	■	■	■	■	■	■						
Task 4							■	■	■	■	■	■				
Task 5							■	■	■	■	■					
Task 6										■	■	■	■	■	■	
Task 7																■

- **Task 1:** Identification the Complete Work for the Project.
- **Task 2:** Literature Review.
- **Task 3:** Data collection.
- **Task 4:** Analysis Data.
- **Task 5:** Building power world simulation.
- **Task 6:** Documentation.
- **Task 7:** Prepare the Presentation.

2

Chapter Two — Hebron Electrical Power System

2.1 Introduction

Hebron city is located in the southern of west bank, at 35Km in the south of Jerusalem. The population of Hebron city is about 208,000 residents.

The total area of Hebron city is about $42Km^2$. The areas which are served by the HEPCO in terms of electric power is about 91 km^2. HEPCO has a flexibility in controlling the distribution electricity to different areas as; Hebron city, Halhul, Essa, Loza, Beit Enun Baq'a, Dowara, Oddese, Qilqes, Jalajel. The estimated number of people which are supplied by electricity form HEPCO company is about 250,000 inhabitants [4].

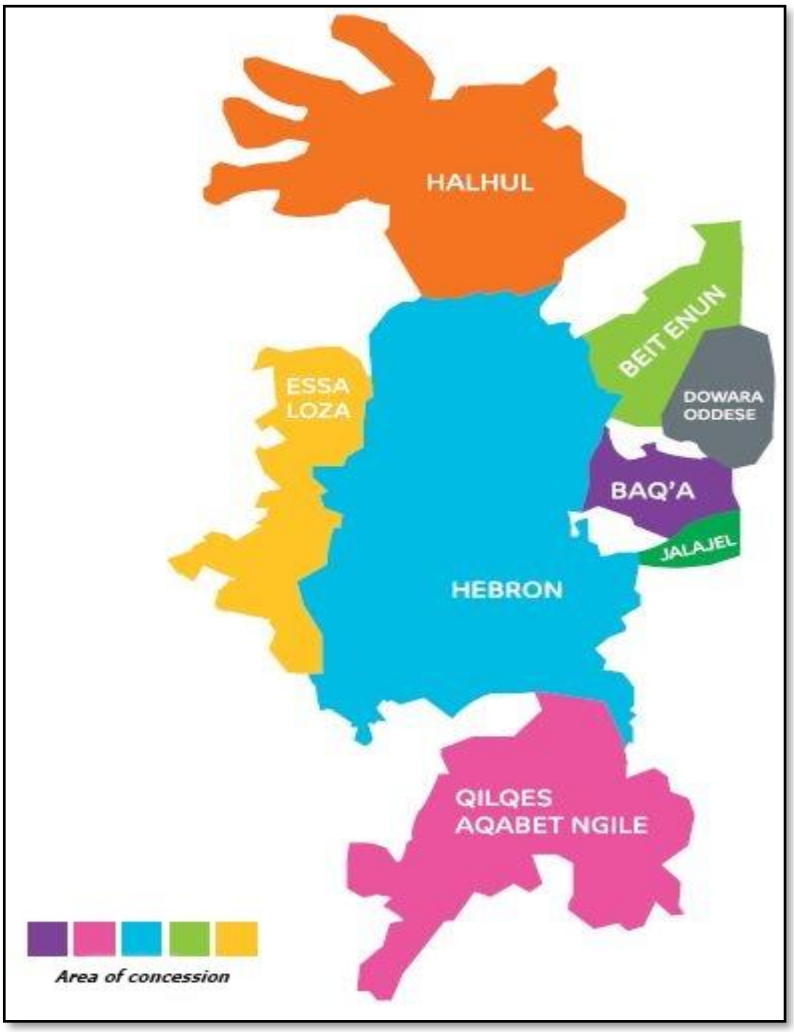

Figure (2.1): Area of concession for HEPCO.

2.2 Description of HEPCO Network

2.2.1 Hebron Electrical Power Company

Electrical power system is divided into three types, generation, transmission and distribution. HEPCO is considered as Distribution Company, which is supplied from "Israel" electrical company (IEC).

HEPCO network is supplied by IEC substation through an overhead transmission lines, with about maximum monthly load of 104.47 MVA according to 2016 records [4].

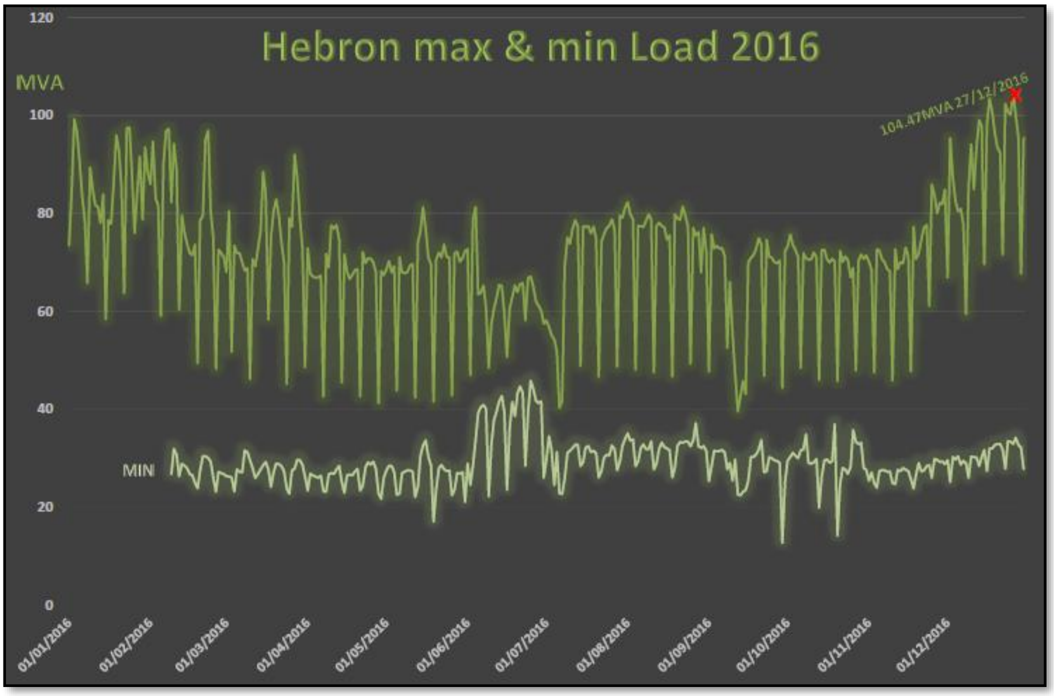

Figure (2.2): Load Profile in 2016.

2.2.2 Electrical Power Supplier for HEPCO

The main transmission lines (161 KV) are passes through Halhul city Bridge, AlRama Suburb, shabeh until Wade Alqota to reach IEC substation after step down process for the voltage level to reach (33 KV) then this transmitted power is received to the main power control (MPC) after that the line which comes out will distributed to seven substations inside the city borders which are step the voltage down to (11 KV) level. See Appendix B

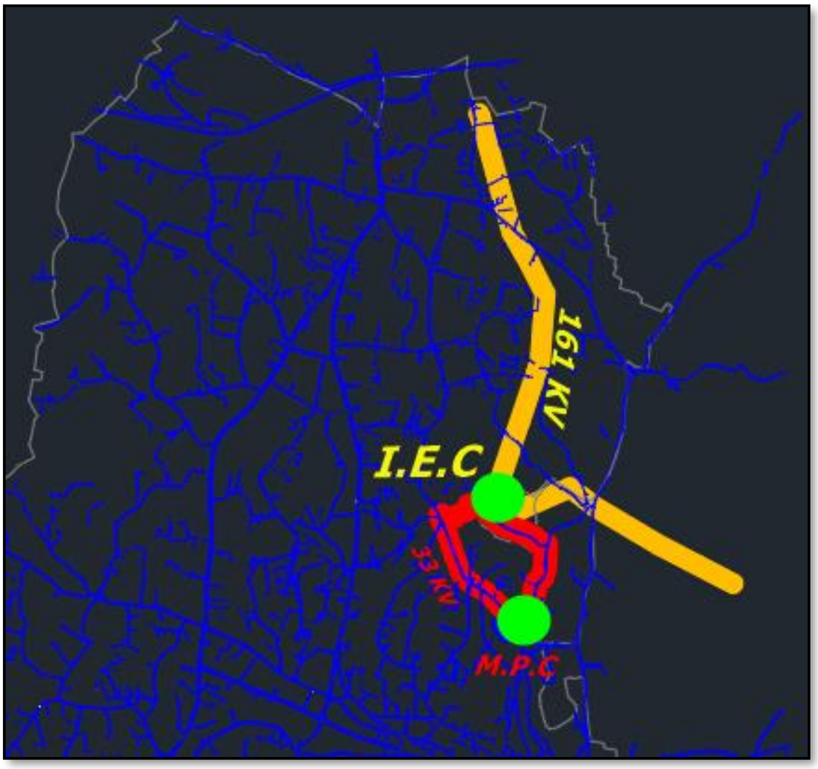

Figure (2.3): Electrical supplier path (161 KV).

2.2.3 Classification of Distribution System

The HEPCO network power connection configuration is radial at medium voltage level of 33 KV, in addition the network with voltage level of 11 KV have a ring connection scheme.

2.2.4 Classification of Transmission Lines

There are two types of transmission lines that are used in Hebron network:

- All the transmission lines in 33 KV level are used to be underground cables only, which use a Single core, medium voltage energy cables (20,3-35 kV) with stranded Aluminum conductor. The capacity of these cables is equal to 40 MVA See Appendix G
- The transmission lines with 11 KV level are using the overhead and the underground cables.

2.3 Medium Voltage Network

Hebron Medium Voltage network is fed from seven main substations (33kv-11kv) which are Alras Substation, Alfahs Substation, Alduhdah Substation, Alharyek Substation, Algarbeah Substation, Emaldaleyah Substation and Alhusen Substation. These Substations have a various range of apparent power (MVA), and these Substations ratings and voltage level are summarized in the following table (2.1).

Table 2.1: Main Substations

Substation Name	MVA rating	Number of transformer	Ratio
Alras Substation	20 MVA	2 Transformers of 10 MVA	33/11 kV
Alfahs Substation	30 MVA	3 Transformers of 10 MVA	33/11 kV
Alduhdah Substation	20 MVA	3 Transformers of 10 MVA	33/11 kV
Alharyek Substation	20 MVA	2 Transformers of 10 MVA	33/11 kV
Alhusen Substation	20 MVA	2 Transformers of 10 MVA	33/11 kV
Algarbeah Substation	20 MVA	2 Transformers of 10 MVA	33/11 kV
Emaldaleyah Substation	20 MVA	2 Transformers of 10 MVA	33/11 kV

HEPCO electrical power network has five tie points which are connected from IEC to MPC, Then the MPC supply the load by seven substations. The system includes some substations that are supplied from another substation because it has just five tie points from MPC as shown in the figure below.

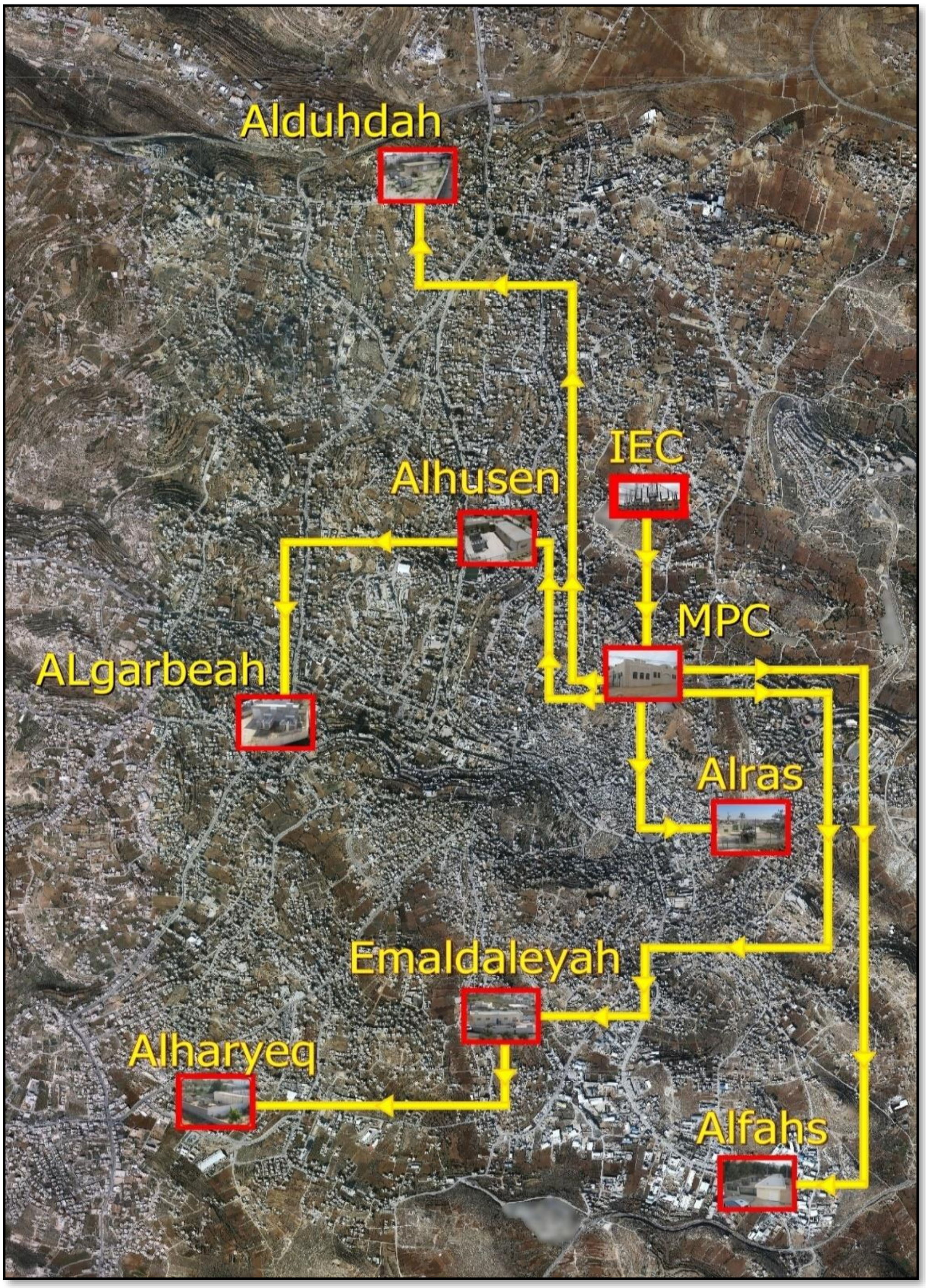

Figure (2.4): HEPCO Distribution Substation.

2.4 Summary

In this chapter, we present some of the medium voltage electrical network main component of Hebron electrical company which will be used in the next chapters to analyze the electrical system. The distribution lines and substation are also showed in this chapter according to their power rating and voltage level.

3

Chapter Three Forecasting and Planning Overview

3.1 Power System Forecasting

3.1.1 Introduction for power system forecasting

One of the important tools of planning is to try to predict or foresee the future. The term forecast represents predictions of future events, conditions, and qualifications. This process is called forecasting. Forecasting has developed over the years into a science. Models and tools are presently available commercially. The process of predicting the future include many business and economic activities such as: following up technological evolutions, estimating the sales process, knowing the economic cost and the competition, maintenance requirements, and replacement of a plant or equipment to fit the forecasting process [5].

The main purpose of forecasting is to meet future requirements, present a possible input to take a specific decision and reduce the unexpected cost. It is also essential to use accurate methodologies for predicting the future load to meet future supply. It's very important to be sure that exploration and development efforts in the energy process are not wasted. Moreover, the knowledge of future energy load will help countries to plan their development activities correctly, thus, avoiding under-or over-planning of future supply [5].

Load forecasting is being used in a different field of the electric power industry, including generation, transmission, and distribution.

Applications of load forecasts expanded to cover power supply planning, transmission and distribution systems planning, demand side management, power systems maintenance, financial planning and rate design. Inaccurate load forecasts may result a problem in the financial side or bankruptcy of a utility company, and can lead to equipment failures or even system blackout [5] [6].

3.1.2 Classification Electrical Load Forecasting

Electricity load forecasting is divided into four main categories:

1) **Long-term for a period of one year up to 20 years**: This category is used for power system expansion planning, long-term economic planning, and load flow studies for economic dispatch.

2) **Medium-term for a period of one to 12 months**: making a plan for the maintenance process, making test on the outcome result.

3) **Short-term**: covers a period of one day to several days. It is applicable for some operation planning, unit commitment of generating plants.

4) **Very short-term**: it is used for forecasting for one hour to a few hours and is used for power exchange and purchase contracts, and tie-line operation. In many power companies the last two forecasts are combined in one under the title short-term forecasting [7].

3.1.3 Forecasting Methodology

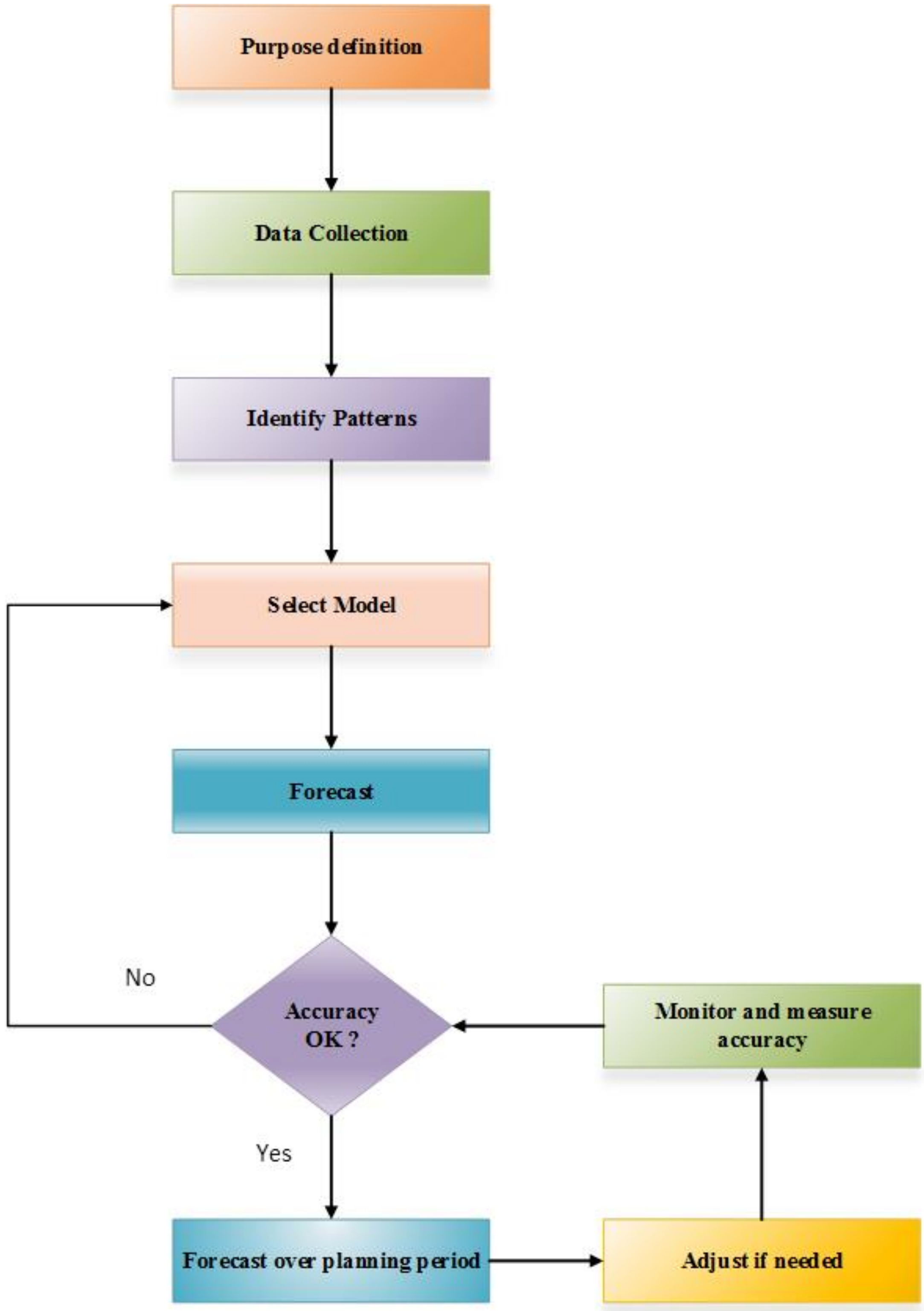

Figure (3.1) :forecasting methodology [5].

3.1.4 Characteristics of Load Forecasting Model

Data availability, purpose of forecasting, computational capabilities, skills available, budget availability, and time are important Characteristics, Moreover. The forecasting model must have these critical Characteristics:

- **Forecasting variables must have a reason to be calculated**: it means that we must choose variables which have major effect on load.
- **Be reproducible:** Its means that any person using the same algorithm will get similar predicting results.
- **Be functional:** This means we must put our objective before choosing the appropriate model ex. long, medium, short.
- **Simplicity.** There is no need in making complicated. The simpler the model, the easier it is to satisfy all above characteristics.
- **Using scenarios:** scenarios means test the outcome results as changes in the independent variables due to changes in the assumptions [5].

3.1.5 Forecasting Factors

- Time factor.
- Weather conditions (temperature and humidity).
- Class of customers (residential, commercial, industrial, agricultural, public, etc.).
- Special events (TV programmers, public holidays, etc.).
- Population.
- Economic indicators (per capita income, Gross National Product (GNP), Gross Domestic Product (GDP), etc.).
- Trends in using new technologies.
- Electricity price.
- State of the Economy.
- Type of Economy.
- Status of the Electric Power System.
- Technology changes.
- Customer behavior [7] [5].

3.1.6 Load Forecasting Mathematical Methods

We will present some major mathematical methods of forecasting. We can collect these methods into 5 different groups that are mentioned bellow.

♦ Subjective or Intuitive Models

The basic idea is that information is collected from a set of people/ a set of experts on what the demand forecast is likely to be and this could be done through either opinion poll or a personal interview or DELPHI procedure. The following are an explanation for each one:

- **An opinion poll**: is a research survey of public opinion from a particular sample. Opinion polls are usually designed to represent the opinions of a people by conducting a series of questions [6].
- **The Delphi method**: is a forecasting method based on the results of questionnaires sent to the experts. Comparing process will take place of the expert opinion and then the Delphi method seeks to reach the correct response through consensus [6].

The advantage of subjective or intuitive methods are depends on the wide knowledge and experience of individuals and experts [6].

♦ Averaging of Past Data Models

If the data available on demand for the past few years, it can be used to predict the future demand, the two most commonly used methods in this category are moving averages and exponential smoothing. They are both weighted averaging methods and we can use this method to determine what is going to happen to the demand if the previous history is what it is.

The moving average method: The basic idea in this method is that past data serve a calculation for a long-term trend. Average moving is used because it is obtained by summing and averaging the value from a given number of periods, each time deleting the oldest value and adding a new value.

For Example: Five-year moving average

- First average:

$$X_5 = \frac{x_1+x_2+x_3+x_4+x_5}{5} \tag{3.1}$$

- Second average:

$$X_6 = \frac{x_2+x_3+x_4+x_5+x_6}{5} \tag{3.2}$$

Where: x_1, x_2, x_3, x_4, x_5 and x_6 are the past power demand data.

- **Exponential smoothing method**: A sophisticated weighted moving average method that calculates the average of a time series by giving recent demands more weight than earlier demands. This equation represents the Exponential smoothing method:

$$F_{t+1} = \mathbf{a}\ (\text{Demand this period}) + \mathbf{(1 - a)}\ (\text{Forecast calculated last period})$$

$$= a\,D_t + (1 - a)\,F_t \qquad (3.3)$$

Or an equivalent equation: $F_{t+1} = F_t + a\,(D_t - F_t)$ (3.4)

Where: F_t = exponentially smoothed forecast of the data series in period *t*.

D_t = actual demand in period *t*.

a = smoothing constant for the average (weight).

Where alpha (a) is a smoothing parameter with a value between 0 and 1.0

Exponential smoothing is the most frequently used formal forecasting method because of its simplicity and the small amount of data needed to support it [5].

♦ Regression Models

This model is depending on historical data. If you have access to information of demand for the last 5 years plotted as a graph, then you can do some trend extrapolation and based on this trend extrapolation you can project what is going to be the forecast for the next year or the year after that based on the trend that exist in the historical data. But this method has limitations, the major limitations of these methods is that they essentially assume that whatever was happening in the past will continue to happen in the future as well without any changing. If that assumption is true these are good models. If this assumption is false these need not be good models. The alternative in that case is casual or econometric models [5].

♦ Casual or Econometric Models

Casual or econometric models are also regression models but the basic advantage of this models is that you can answer what if questions. As an example, what would happen if the government policy changes to such and such thing? So, the regression models, and trend and extrapolation model will not be able to answer this [5].

- ## **Time Series Analysis Models**

In a time-series analysis model, a time series is constructed that takes into account the effect of load for the previous years on the load for the year in question. The order of this time difference series depends on the accuracy of the prediction needed as well as the data available from the past history. The general form for this time series can be formulated as:

$$\mathrm{PL(k)} = a_1 PL(k-1) + a_2 PL(k-2) - a_3 PL(k-3) + \ldots + \ldots + a_n PL(k-n) \qquad (3.5)$$

Where: k=K, K-1, K-2, . . . ,1, K is the year in equation, and n is the degree of the Time series.

The major advantage of this model is that they are pretty accurate for short term forecasts [8].

3.2 Power System Planning

3.2.1 Introduction for power system planning

Power system planning represent a very important process to take into account in these days because it is a part of more general problem, that of energy and economic affect each other significantly. Our goals are therefore to determine a minimum cost strategy for long-term expansion of the generation, transmission and distribution systems appropriate to supply the load forecast within a set of constraints, the process starts with an estimation or calculation for the electricity load demand forecasting [9], which is followed by reliability determination to determine if and when additional generation is needed and how to construct them effectively. Finally, optimal capacity expansions are selected based on economic considerations.

3.2.2 Planning process

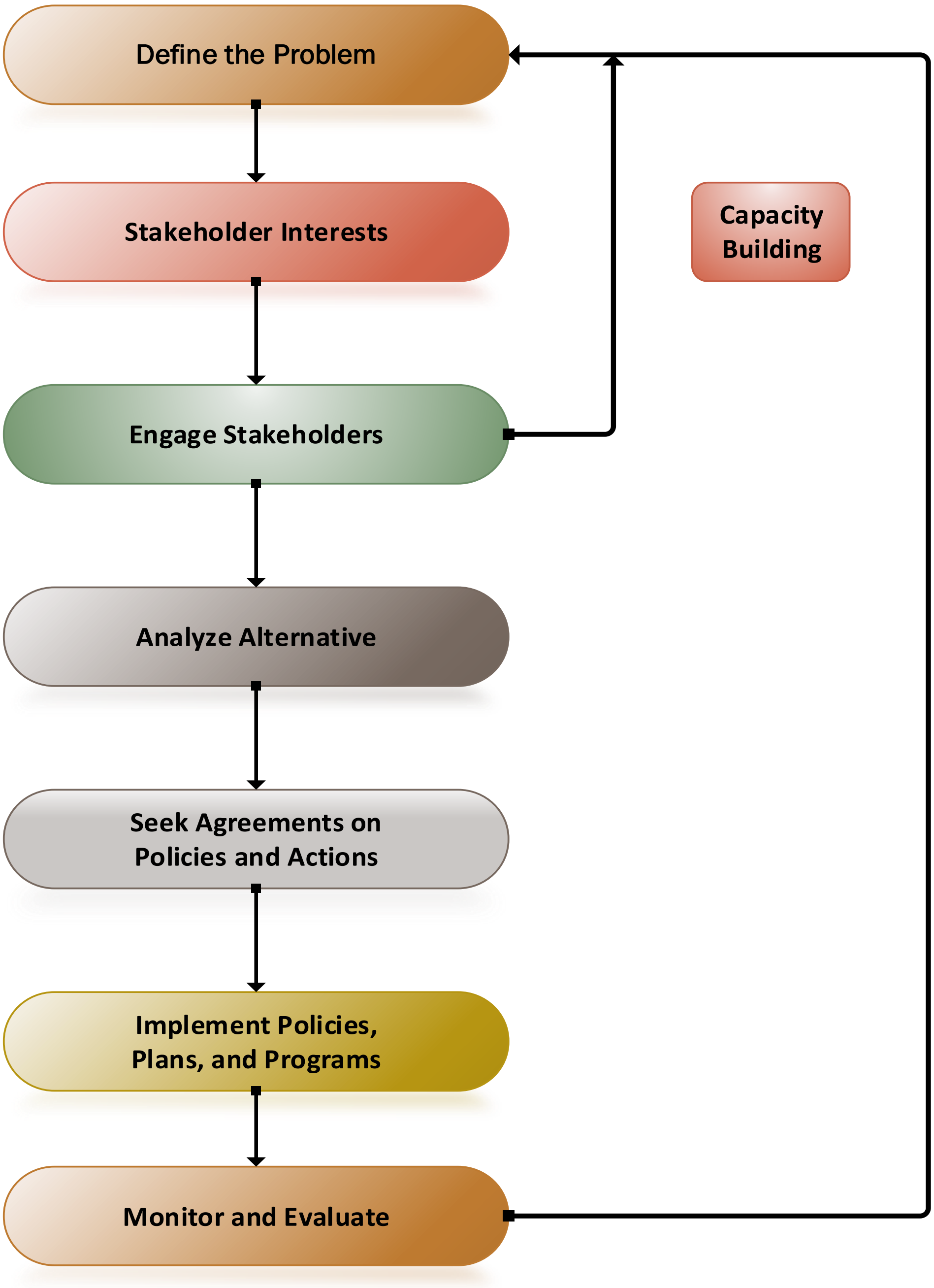

Figure (3.2): The planning process [10].

There are six main steps that summarize the planning process

1. Estimation and forecasting of the electric load 5 to 20 years for the future, according to specific data.
2. Knowing the energy resources and its capacity that will be available in the future for electricity generation and the expected trends in economic and technical developments based on scientific studies.
3. Evaluation of the characteristic that affect the planning process like capital investment cost, the fuel cost, operation and maintenance costs, efficiencies, construction times, ability for expansion when needed.
4. Determination of the economic and technical parameters affecting decisions such as discount rate, level or reliability and security required from the generating system, etc.
5. Locating a strategy that will be choosing to determine the optimal expansion process within some important constraints.
6. Estimation of the performance of the proposed solution [11].

3.2.3 Long, Medium, Short Planning

Table 3.1: Planning classification [12].

Time ahead	Planning	Activity
5-20 years	Long-term planning	Vision, values, mission, load forecasting regional system and National grid expansions scheme
2-5 years	Medium-term	Medium-term utility generation schemes such as coal, thermal, gas turbines, hydro etc. Renovation and modernization of existing generating plants
1-2 years	Short-term planning	System improvement of transmission and distribution systems, Small generation schemes, small hydro, gas turbines diesel power projects, non-conventional sources of generation
15days-l year	Operational planning	Maintenance scheduling of units and fuel requirements
1-1 days	Operational planning	Generation scheduling and network switching
2-12 hours	Operational planning	Economic dispatching instruction and power purchases Selling
0-2 hours	Operational planning	Network switching Economic Dispatch Control

3.2.4 Planning Tools

3.2.4.1. Planning tools criteria

- Planning engineer main objective is to give power continuity to consumers in a reliable way at a minimum cost with due flexibility for future expansion.
- The constraints in planning an energy system are reliability, environmental economics, electricity pricing, financial constraints, society impacts.
- The system must be optimal.
- Many computer and simulation programs are available and are used before doing any tangible action for fast alternative solution.

3.2.4.2. Available planning tools

The available tools for power system planning can be split into:

- **Simulation tools**: these simulate the behavior of the system under certain conditions and calculate relevant indices. Examples are load flow models, short circuit models, stability models, etc.

- **Optimization tools:** these minimize or maximize an objective function by choosing adequate values for decision variables. Examples are optimum power, least cost expansion planning, generation expansion planning, etc.

- **Scenario tools**: this is a method of viewing the future in a quantitative fashion. All possible outcomes are investigated. The sort of decision or assumptions which might be made by a utility developing such a scenario might be: should we computerize automate the management of power system after certain date [12].

3.3 Summary

Forecasting is one of the most important tools in the planning process for any business. With forecasting an accurate management can foresee and predict the future actions. Electricity load forecasting is one of the complicated concerns. This is because the electricity is a critical and important process for all societies. Different models are used in load forecasting were discussed in short. The discussion showed that no technique can Preference over others. In spite of that, it is possible to pull more than one techniques together in order to produce better and accurate forecasting process. the regression model has been applied because it is the appropriate model for the proposed work which needs to be long-term forecasting, a minimum cost strategy for long-term expansion of the generation are appropriate to supply the load forecast within a set of constraints, this process will be done by using the economic and optimal power dispatching as shown in chapter five.

4

Chapter Four Hebron Electrical Power System Forecasting

4.1 Load Forecasting For HEPCO

4.1.1 Introduction

In this chapter, a long-term electricity load forecasting will be studied. Load forecasting methodology adopted by Regression models which is an accurate model that takes into account the factors that affect the growth of the load over a number of years. Furthermore, an accurate algorithm is used to estimate the parameters of this model. The mathematical model has been built by using MATLAB / Simulink, to get accurate results.

All the information that required in the forecasting process was brought from HEPCO Company and The Palestinian Central Bureau of Statistics and these information has been shown in Appendix A and B.

4.1.2 Forecasting Factors

- **The gross domestic product (GDP):** It is the broadest quantitative measure of a nation's total economic activity. More specifically, GDP represents the monetary value of all goods and services produced within a nation's geographic borders over a specified period of time.

- **The population (POP):** The whole number of people or inhabitants in a country or region.

- **The GDP per capita (GDP/CAP**): GDP per capita is a measure of a country's economic output per person. It divides the country's Gross Domestic Product by its total population. That makes it the best measurement of a country's standard of living.

- **The power system losses (LOSS)**: Are the losses in all parts of the power system, such as transmission lines, distribution system and addition robbed.

- **The load factor (LF)**: The ratio between Average load and the Maximum demand in a given period of time.

- **The cost of one kilowatt-hour (KWh):** Kilowatt-hour is an energy unit; one kilowatt-hour is defined as the energy consumed by power consumption of 1kW during 1 hour [13].

4.1.3 Regression Model

Definition: The Regression Analysis is a technique of studying the dependence of one variable (called dependent variable), on one or more variables (called explanatory variable), with a view to estimate or predict the average value of the dependent variables in terms of the known or fixed values of the independent variables [14].

The regression technique is primarily used to estimate the relationship that exists, on the average, between the dependent variable and the explanatory variable; determine the effect of each of the explanatory variables on the dependent variable, controlling the effects of all other explanatory variables, and Predict the value of dependent variable for a given value of the explanatory variable [14].

This technique has been used to estimate the annual peak load, and the least error squares (LES) which it is a type of regression that is static state estimation algorithms are used to estimate the parameters of the load model that will be explained in this section.

The first three factors that were mentioned in section (4.1.2) depend on the behavior of the people; due to this, these factors will vary from one country to another, while the last three factors depend on the load and the electrical power system in that country, as well as the demand of the energy. part A and B will explain modeling this method.

PART A: the starting point will be with the first three factors which called the (country dependency factors), The peak-load demand according to Regression Technique can be written as:

$$PL = a_0 + a_1 GDP + a_2 POP + a_3 (GDP/CAP) \qquad (4.1)$$

Where:

- PL: peak-load demand.
- a_0,a_1,a_2 and a_3: are the regression parameters to be determined using the LES algorithms.

By using the past data, the parameter can be determined as:

$$PL_i = \begin{bmatrix} 1 & GDP & POP & \frac{GDP}{CAP} \end{bmatrix}_i \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix} \quad i = 1, m \qquad (4.2)$$

for i = 1, . . ., m; where m is the number of year observations available from past data history; $m \geq 4$. In vector form, equation (4.2) can be rewritten as

$$Z = HX + \xi \qquad (4.3)$$

Where:

- Z: is the $m \times 1$ measurement vector of peak-load demand.
- H: is an $m \times n$ observation matrix containing the factors that affect the peak load.
- X: is the $n \times 1$ column vector of the load parameters to be estimated.
- ξ: is the $m \times 1$ error vector to be minimized.

At least the past four years' data should be given to determine the peak load-Demand parameter X. The solution for equation (4.3) based on the least error squares algorithm (LES) is:

$$X^* = [H^T H]^{-1} H^T Z \quad (4.4)$$

The model was mentioned in the last section is implemented using the data for HEPCO Company; the data are given for the years 2009 to 2015 and listed in Table 4.1.

The load model parameters are estimated using only the data of the year 2009 to 2015 (m = 7 observations). Table 4.2 gives these parameters using the LES algorithms. Table 4.7 gives the predicted peak-load demand for the years 2016 to 2035, and Table 4.3 shows the percentage error after using this model estimation algorithms. The absolute error for LES techniques (residual vector) resulting from these parameters for the seven years is given by:

$$\xi = Z - HX^* \quad (4.5)$$

Table 4.1: Data for HEPCO.

year	Peak Load (MW)	GDP (M$)	POP	GDP/ CAP	System Losses (KW)	Load Factor (%)	Cost of Energy (ILS/ kWh)
2009	64.329	451.04	200059	2254.5	7595	76.50	0.5870
2010	74.880	545.38	206742	2637.97	7074	77.04	0.5870
2011	76.800	655.62	213648	3068.68	9087	78.09	0.59175
2012	85.615	716.53	220794	3245.25	7898	78.77	0.6878
2013	85.581	787.30	228124	3451.19	8468	82.03	0.7291
2014	83.317	827.85	235628	3513.3	8392	84.61	0.7291
2015	89.825	927.33	243294	3811.56	9554	81.39	0.6426

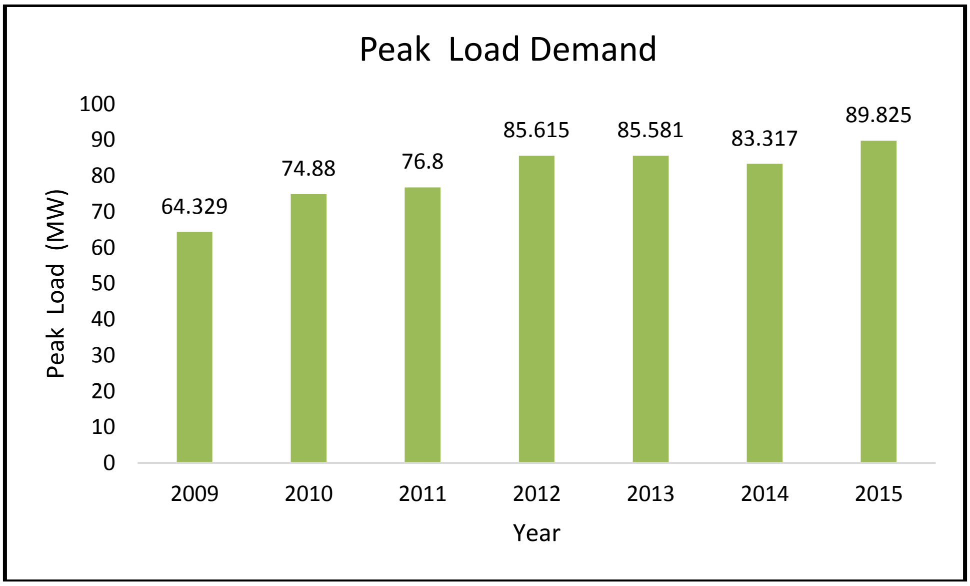

Figure (4.1): The growth of peak load demand between 2009 to 2015.

Table 4.2: Estimated Parameters for the Peak-Load-Demand Model.

Parameters	LES Algorithm
$\boldsymbol{a_0}$	-0.1605
$\boldsymbol{a_1}$	-0.0765
$\boldsymbol{a_2}$	$9.05e^{-5}$
$\boldsymbol{a_3}$	0.0363

The predicted loads as well as the errors in this prediction using LES techniques are given in Table 4.3. Examining this table shows the technique produce fairly good estimates for such type of forecast and such type of peak-load model.

Table 4.3: Predicted Peak Load and the Percentage Error.

Actual Load		**LES Estimates**	
Year	**MW**	**Peak Load Power (MW)**	**% Error**
2009	64.320	65.20	1.352
2010	74.880	72.50	-3.288
2011	76.800	80.30	4.535
2012	85.615	82.68	-3.553
2013	85.581	85.38	-0.232
2014	83.317	85.20	2.210
2015	89.825	89.08	-0.833

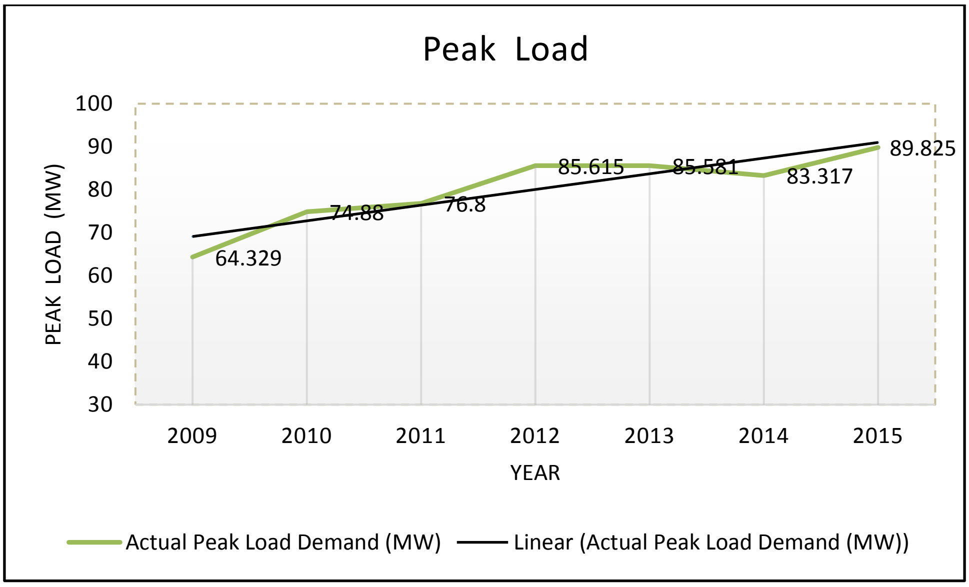

Figure (4.2): The growth of peak load demand between 2009 to 2015 with representation of linear regression.

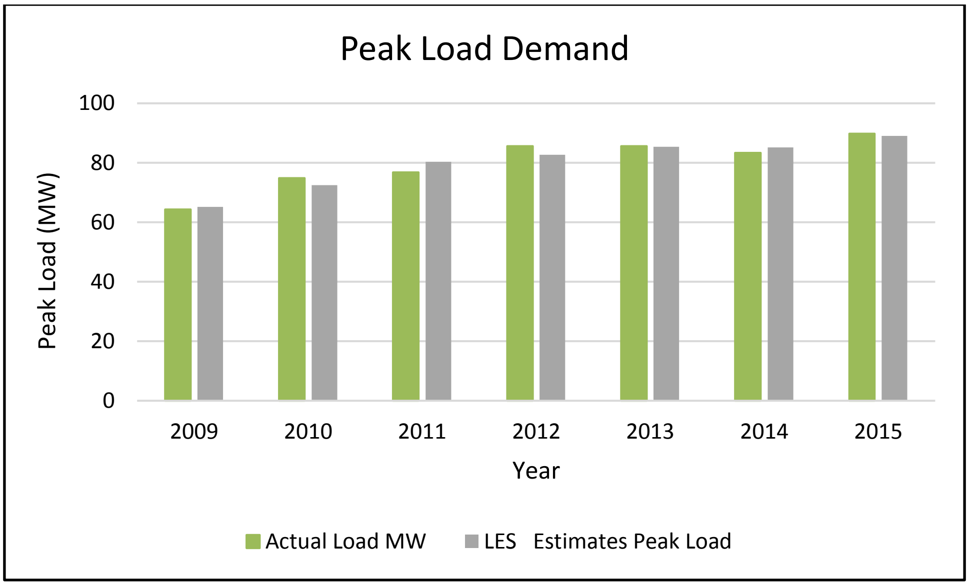

Figure (4.3): The actual and the estimation of peak load demand between 2009 to 2015.

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PART B: More Detailed Model

Using three variables in the first model may not be adequate; thus, we need an accurate model that takes into account all the factors stated previously. We may assume that the model will be:

$$\mathrm{PL} = \mathrm{a_0} + \mathrm{a_1 GDP} + \mathrm{a_2 POP} + \mathrm{a_3}\left(\frac{\mathrm{GDP}}{\mathrm{CAP}}\right) + \mathrm{a_4(system\ losses)} + \mathrm{a_5(LF)} + \mathrm{a_6(cost\ of\ kWh)} \qquad (4.6)$$

Table 4.4: Estimated Parameters for a Detailed Peak-Load-Demand Model.

Parameters	LES Algorithm
a_0	303.3
a_1	0.2086
a_2	-0.001091
a_3	-0.009341
a_4	-0.004291
a_5	-0.8837
a_6	10.98

Equation (4.6) is a linear equation for the parameters to be estimated, a_0 to a_6. Thus, equation (4.6) can be rewritten in the form of equation (4.3) as

$$Z = HX + \xi. \qquad (4.7)$$

In equation (4.6), the following vectors and matrices are defined as follows:

- Z: is an m × 1 measurement vector of the past history of the peak-load demand;
- H is an m × 7 measurement matrix of which the elements contain the seven factors stated in equation (4.6).
- X: is the 7 × 1 load parameters a_0 to a_6.
- ξ: is an m × 1 error vector associated with each measurement to be minimized.

Therefore, we have six parameters to be estimated, and at least six measurements should be available to estimate these parameters. Using only six measurements we may produce a poor estimation because we need to force the errors vector to be zero (because the number of equations equals the number of unknowns). Here, the solution to equation (4.7) is similar to that given in equation (4.3). Table 4.4 gives the estimated parameters using LES. The validity of the proposed model and the accuracy of the estimated parameters are checked by implementing the model to predict the peak-load power for the years 2009 to 2015, using the factors given in Table 4.1 for the same years. Table 4.5 gives the estimated peak load and the percentage error in these estimates.

Table 4.5: Predicted Peak-Load Power with the Percentage Errors.

Actual Load		**LES Estimates**	
Year	**MW**	**Peak Load Power (MW)**	**% Error**
2009	64.320	64.32	-4.55e^{-8}
2010	74.880	74.88	-3.943e^{-8}
2011	76.800	76.8	0.001302
2012	85.615	85.61	-3.452e^{-8}
2013	85.581	85.58	-3.438e^{-8}
2014	83.317	83.32	-3.486e^{-8}
2015	89.825	89.82	-3.22 e^{-8}

4.1.4 Peak Load Demand Forecasting For HEPCO.

After we prove LES method for the past data we had estimate the peak load, and calculate the least errors, we made a forecasting on the peak load of the concession areas of HEPCO for the years between 2016 to 2035 using the parameter that we have got from the previous section.

Forecasting the factor for the years between 2016-2035 was found by LES method as shown in Appendix C.

Table 4.6: forecasting data for HEPCO.

year	Peak Load (MW)	GDP (M$)	POP	GDP/ CAP	System Losses (KW)	Load Factor (%)	Cost of Energy (ILS/ kWh)
2016	100.19	1005.22	250035	4112.40	9423	67.50	0.5870
2017	103.87	1081.13	257247	4391.13	9705	77.04	0.5870
2018	107.15	1157.04	264460	4669.85	9987	78.09	0.59175
2019	111.75	1232.95	271672	4948.58	10269	78.77	0.6878
2020	113.49	1308.86	278885	5227.31	10551	82.03	0.7299
2021	115.35	1384.77	286098	5506.03	10833	84.61	0.7291
2022	121.40	1460.68	293310	5784.76	11115	81.39	0.6426
2023	124.62	1536.59	300523	6063.49	11397	82.50	0.6469
2024	127.82	1612.50	307735	6342.21	11679	83.61	0.6501
2025	134.14	1688.41	314948	6620.94	11960	81.22	0.6545
2026	139.5222	1764.32	322161	6899.67	12242	80.02	0.67
2027	145.3972	1840.23	329373	7178.39	12524	77.04	0.587
2028	148.6733	1916.14	336586	7457.12	12806	78.09	0.59175
2029	153.2798	1992.05	343798	7735.85	13088	78.77	0.6878
2030	156.563	2067.97	351011	8014.57	13370	80.03	0.7099
2031	156.6586	2143.88	358224	8293.3	13652	84.61	0.7091
2032	161.1594	2219.79	365436	8572.03	13934	83.39	0.6426
2033	168.9058	2295.7	372649	8850.76	14216	79.5	0.6569
2034	173.6597	2371.61	379862	9129.48	14498	78.61	0.6401
2035	175.6642	2447.52	387074	9408.21	14780	81.22	0.6545

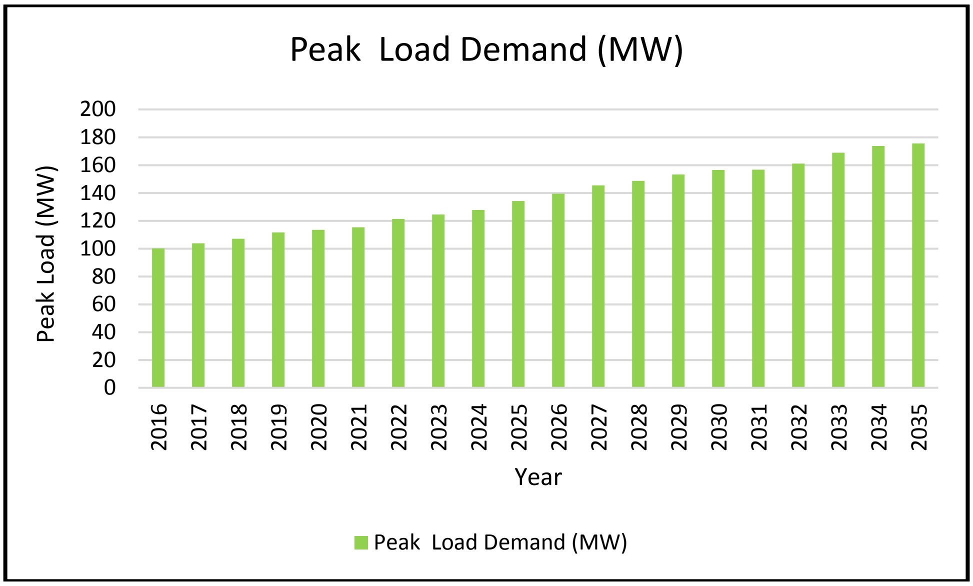

Figure (4.4): The growth of forecasted peak load demand between 2016 to 2035.

4.2 Regression Simulation By MATLAB

4.2.1 Parameters of the load model

The Parameters of the load model which has the symbol a_x which can be calculated by the equation (4.8) and shown in the figure 4.1.

$$X^* = [H^T H]^{-1} H^T Z = \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \end{bmatrix} \qquad (4.8)$$

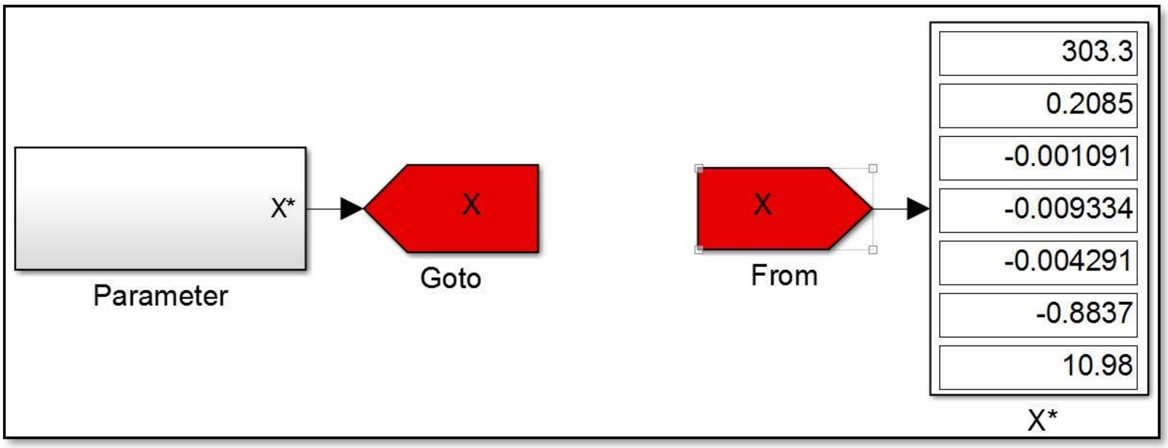

Figure (4.5): Parameters measurement subsystem.

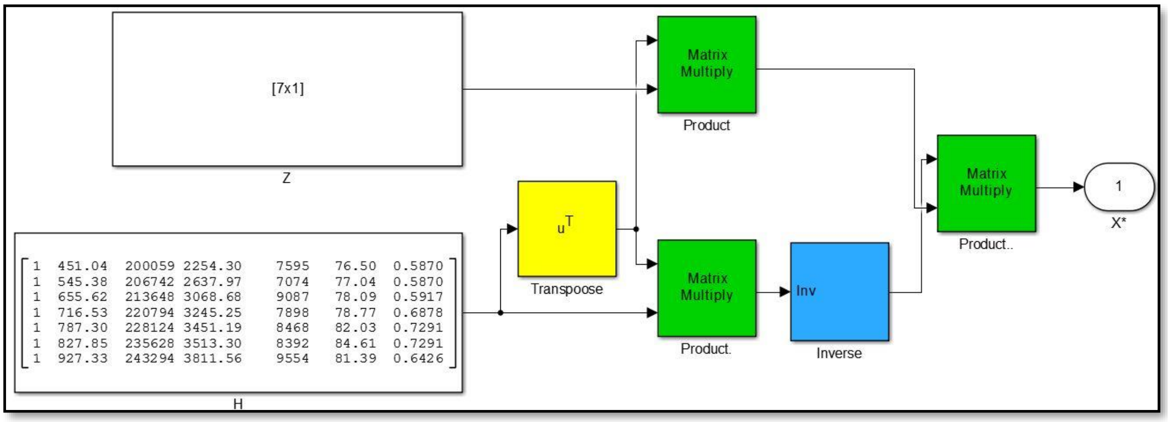

Figure (4.6): Inside (figure 4.5) Parameters blocks.

4.2.2 Least error squares (LES)

Least error squares which has the symbol ξ can be calculated by the equation:

$$\xi = Z - HX^{*} \tag{4.9}$$

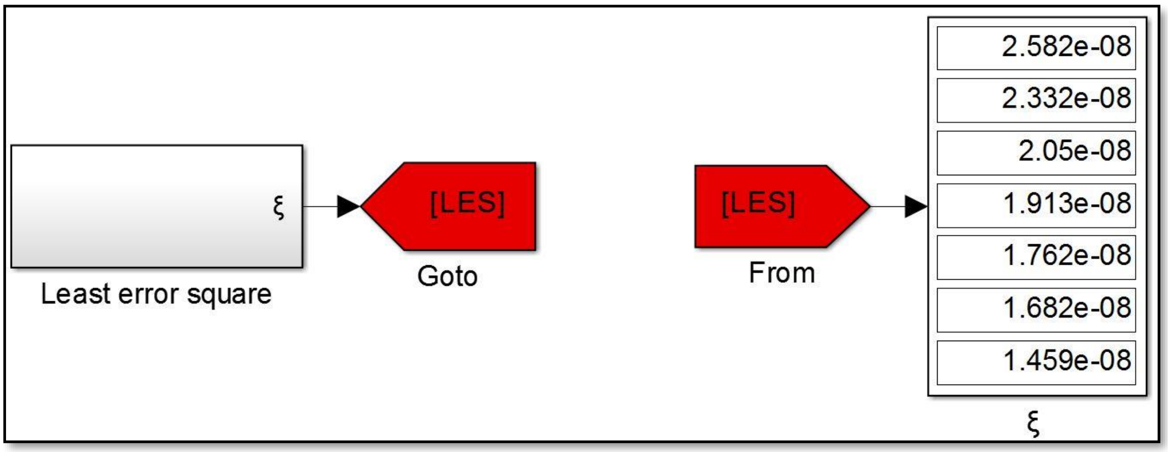

Figure (4.7): Least error squares measurement (subsystem).

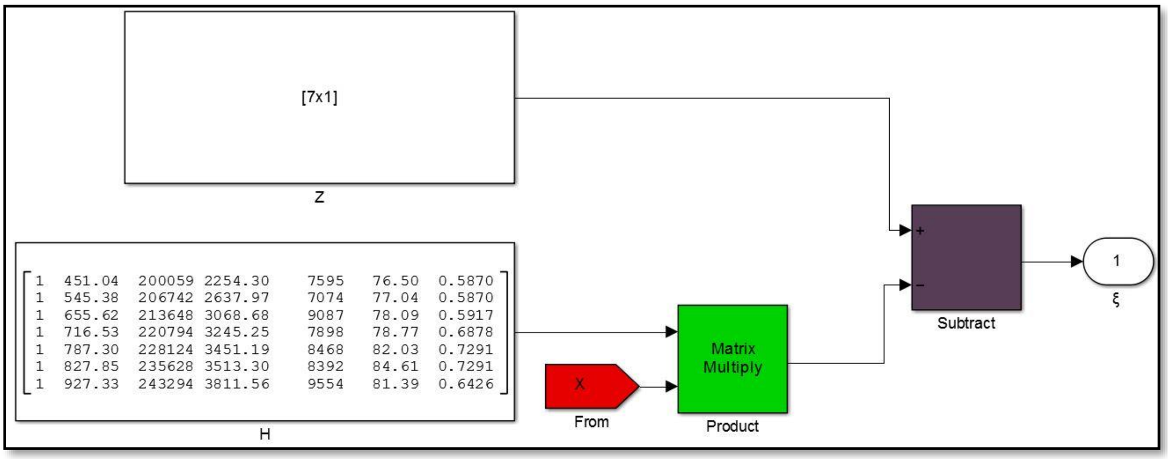

Figure (4.8): Inside subsystem of (figure 4.7) Least error squares blocks.

4.2.3 Peak-load demand

Peak load demand which has the symbol Z which can be calculated by the equation:

$$Z = HX + \xi \qquad (4.10)$$

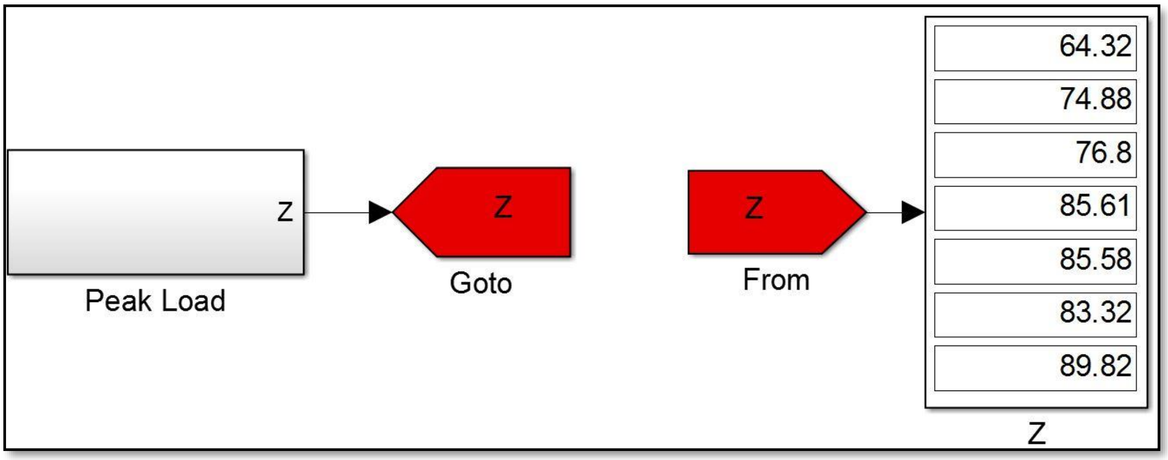

Figure (4.9): Peak load demand measurement subsystem.

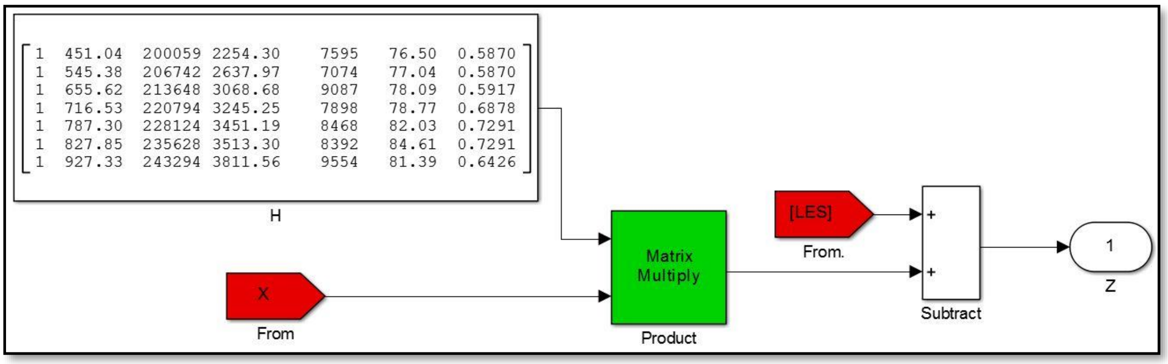

Figure (4.10): Inside subsystem of (figure 4.9) Peak load demand blocks.

4.2.4 Percentage error

Percentage error which has the symbol %E which can be calculated by the equation:

$$\%E = \frac{\text{Estmation} - \text{Actual}}{\text{Estmation}} * 100\% \qquad (4.11)$$

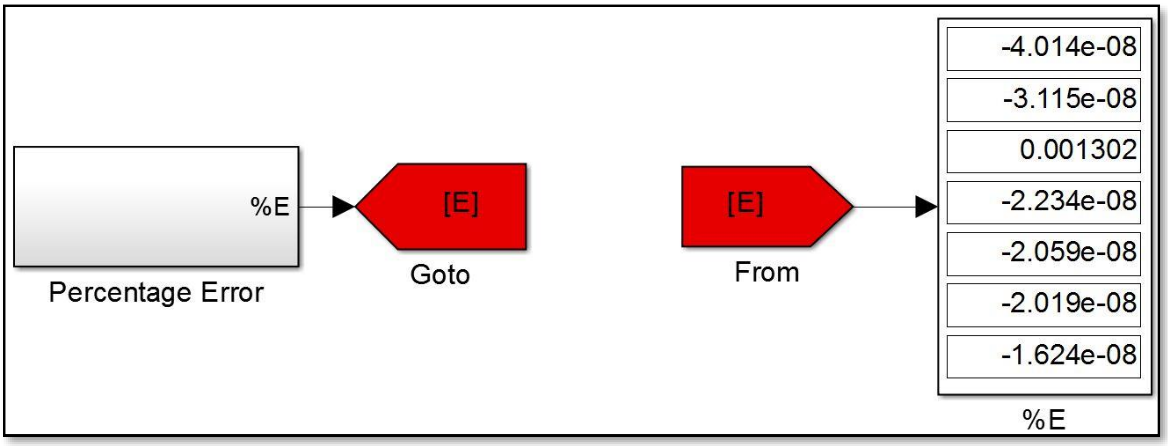

Figure (4.11): Percentage error measurement subsystem.

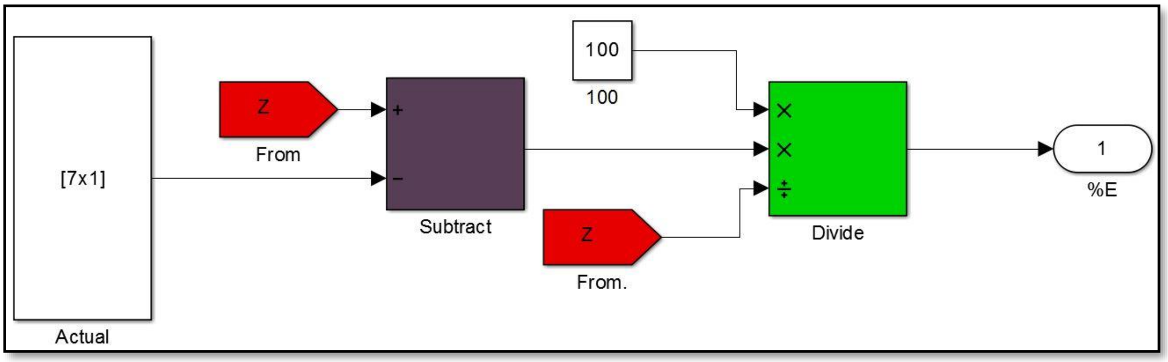

Figure (4.12): Inside subsystem of (figure 4.11) Percentage error blocks.

4.3 Summary

• The predicted load using LES technique is accurate enough for such long-term forecasting.

• The predicted load for this estimation period using six parameters.

• The maximum predicted error for LES is about 4.535% in Table (4.3), for the year 2011. These are fairly good estimates for such long-term forecasting.

5

Chapter Five Hebron Electrical Power System Planning

5.1 Overview

5.1.1 Electrical Network Future Planning Methodology
5.1.2 Economic Dispatching and Optimal Power Flow
5.1.3 OPF Equality and Inequality Constraint
5.1.4 Input – Output Curve for Generating Unit
5.1.5 Power World Simulator Optimal Power Flow Overview

5.2 Hebron Electrical Power System in 2016

5.2.1 Power World Modeling
5.2.2 Geographic Information System (GIS)

5.3 Hebron Electrical Power System in 2025

5.3.1 Power World Modeling
5.3.2 Power System Temporary Upgrading
5.3.3 Geographic Information System (GIS)

5.4 Hebron Electrical Power System in 2035

5.4.1 Generators Characteristic
5.4.2 Power World Modeling Final Upgrading -Economic Perspective

5.4.2.1. Generators Behavior Under Peak Load

5.4.2.2. Simulation Results

5.4.3 Geographic Information System (GIS)

5.1 Overview

5.1.1 Electrical Network Future Planning Methodology

Future planning work flow of Hebron Electrical Network will be based on two main stages:

- **First stage (construction)**: During the period between 2017 and 2025, four power plants will be built to cover the expected load demand until 2035. These plants will start operating in 2026; the construction process was estimated to be eight years.

- **Second stage (upgrading)**: The upgrading process of electricity distribution substations of HEPCO between 2017 and 2025 must be start, this process will include increasing the total capacity of each distribution substation by increasing the number of transformers. Moreover, adding a new substation will effectively enhance the upgrading process to satisfy the expected load until 2035.

5.1.2 Economic Dispatching and Optimal Power Flow

A power system has many power plants, with many generating units. The load should be satisfied at any time by the generating units in different power plants. Generation and distribution of power must be accomplished at minimum cost but with maximum efficiency [15]. This includes the real and reactive power allocation for each power plant in such way as to minimize the total operating cost of the entire system.

This process will be done by using the Economic dispatch and optimal power flow control which determines the power output of each power plant, which causes to minimize the overall cost of fuel needed to serve the system total load [16]. In other words, the generator's real and reactive power is allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost [15]. This is called the Optimal Power Flow (OPF) or sometimes known as the Economic Dispatch (ED) problem [17].

Different optimization techniques are used such as lambda iteration method, gradient method, lagrangian relaxation algorithm, Newton's method and linear programming for solving OPF. LP approach provides optimal results in less computational time. this will be represented by using the power world simulator which uses this approach as an optimal solution [18] [15].

5.1.3 OPF Equality and Inequality Constraint

While solving any constrained optimization problem, such as the OPF problem, there are two general types of constraints, equality and inequality. Equality constraints define as the constraints that always have to be enforced. Because of that, they are always binding. For example, in the OPF, real and reactive power balance at system buses must always be satisfied; On the other hand, the inequality constraints may or may not be binding. For example, a line MVA flow may or may not be at its limit, likewise, generators real power output may or may not be at its maximum limit.

The following classes of inequality constraints are enforced during the OPF solution.

- **Generator real power limits:** Generator real power limits are enforced during the LP solution.
- **Generator reactive power limits**: Generator reactive power limits are enforced during the power flow solution.
- **Transmission Line and Transformer (Branch) MVA Limits**: Transmission line and transformer (branch) MVA limits are enforced during the LP solution. During the LP, the branch line flow is constrained to be less than or equal to a user specified percentage of its limit, provided the branch is active for enforcement.

5.1.4 Input – Output Curve of Generating Unit

Generating units are consuming huge amount of money, Fuel cost, interest and staff salary, depreciation charges and maintenance cost which are the components of the operating cost. Fuel cost is consider as the major part of the operating cost and it can be controlled[16][18].

The fuel cost function describes the electric power generation and cost relationship in the thermal plants. In other words, it specifies the relationship between how much heat must be input to the generator and its MW output. Different models have been proposed to explain the relation between the cost of production and the output power from the generating unit's as the quadratic cost function which considers being the most popular one. Parameters of second order fuel cost function can be estimated using cuckoo search algorithm [19]. Figure (5.1) shows a typical input-output curve of a generator, also commonly known as the heat-rate curve.

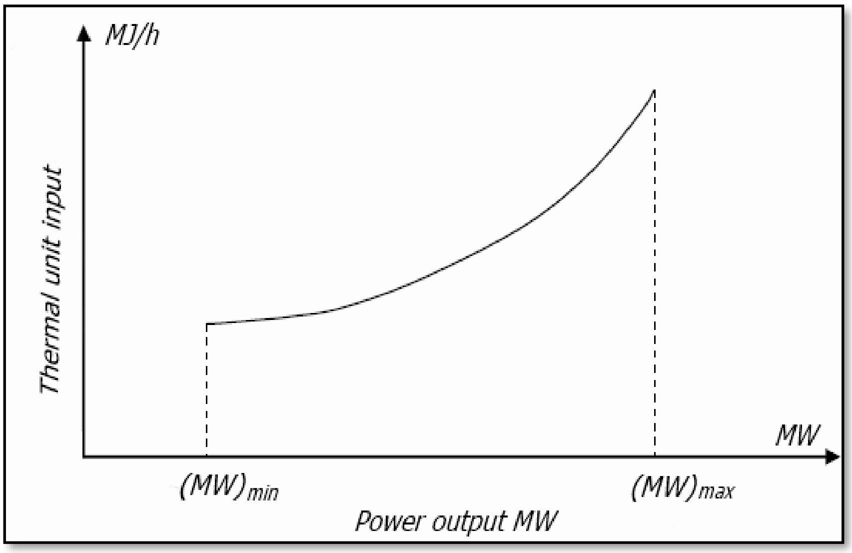

Figure (5.1): Input-Output Curve of a Generating Unit.

In the solution of optimal power flow, the main goal is to minimize the total operating costs of the system. Therefore, when the load is light, the cheapest generators must always be chosen to run firstly. And when the load increases; the more expensive generators will then be operating [15], this process will be done in section 5.4. Thus, the operating cost plays a very important role in the solution of OPF. The amount of fuel or input to a generator is usually expressed in Btu/hr (British thermal units per hour) and its output in MW (Mega Watts).

In all practical cases the cost of generator i can be represented as function of real power generation expressed in $/h as shown:

$$Ci = (\alpha i + \beta iPi + \gamma iPi^2) * \text{fuel cost} \qquad (5.1)$$

- Where: Pi is the real power output of generator i.
- αi, βi, γi, are the cost coefficients as shown in figure (5.2):

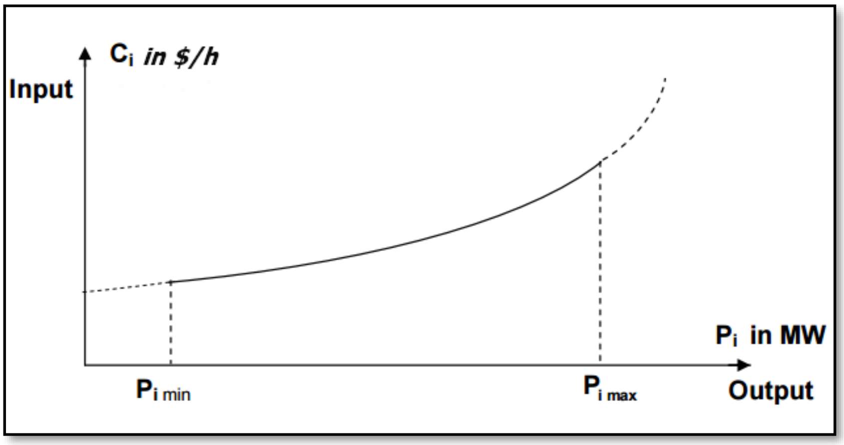

Figure (5.2): Fuel Cost Function Curve.

The distribution of the load between any two units is based on whether increasing the generation of one unit, and decreasing the generation of the other unit by the same amount results in an increase or decrease in total cost. This can be obtained by calculating the change in input cost ΔCi for a small change in power ΔPi and this is called as the incremental cost which can be obtained from the derivative of Ci (5.1) with respect to Pi which is expressed in $/MWhr.

$$dCi = (\beta i + 2\gamma Pi) * \text{fuel cost} \quad (5.2)$$

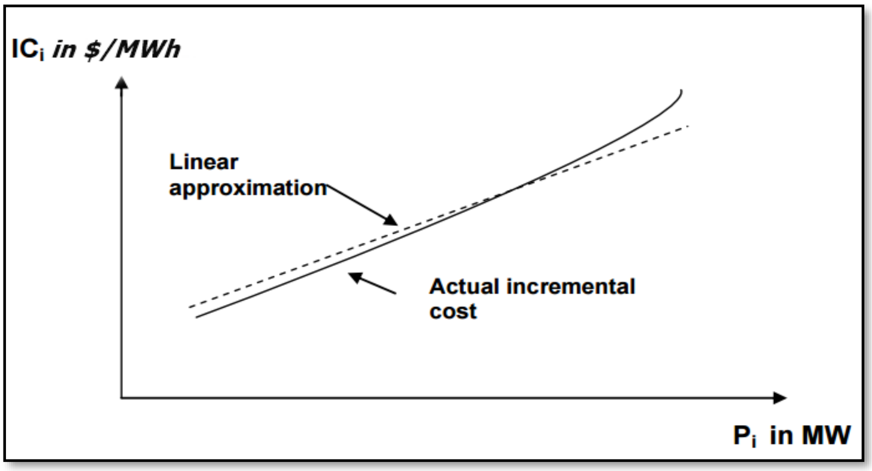

Figure (5.3): Incremental Cost Curve.

5.1.5 Power World Simulator Optimal Power Flow Overview

The Power World Simulator is an interactive power system simulation package designed to simulate high voltage power system operation. In the standard mode, Simulator solves the power flow equations using a Newton-Raphson power flow algorithm. However, with the optimal power flow (OPF) enhancement, Simulator OPF can also solve these equations using an OPF. In particular, Simulator OPF uses a linear programming (LP) OPF implementation.

In Simulator OPF the LP determines the optimal solution by iterating between solving a standard power and then solving a linear program to change the system controls to remove any limit violations.

5.2 Hebron Electrical Power System in 2016

5.2.1 Power World Modeling

For modeling the power network for Hebron electrical company, we collected the desired data and information, the following figure (5.4) shows the percentage MVA from the total peak load demand for each substation, these percentages are collected at 2016. The main purpose from this is to know how the system will behave under certain load values and to find the overloaded substation to determine the best solutions scenario.

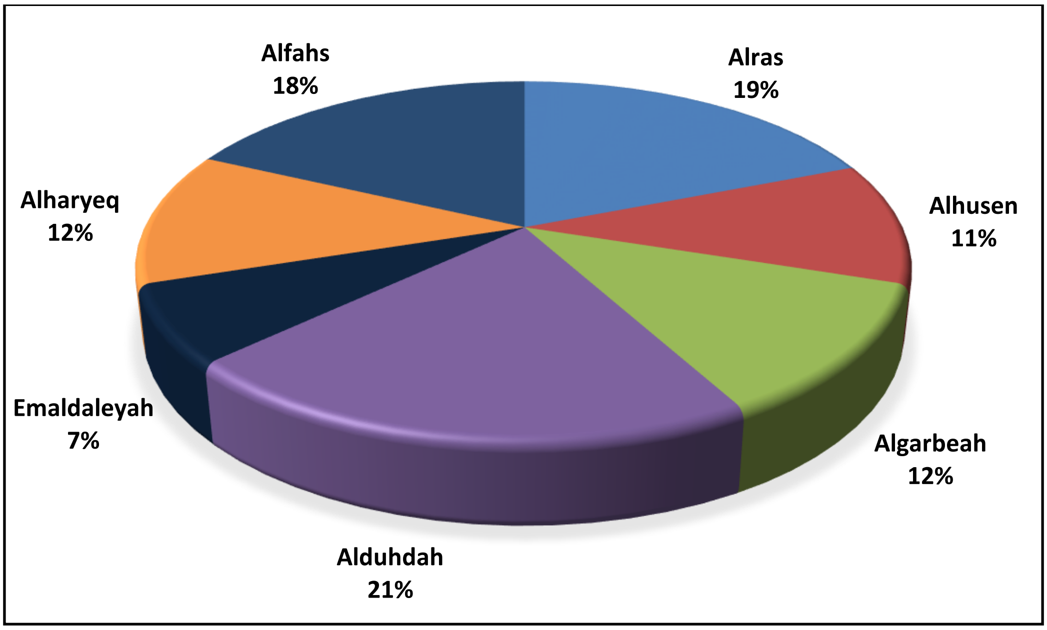

Figure (5.4): Loading MVA Percentage in 2016.

The following table 5.1 represents the peak load for each substation depending on the load percentage at 2016.

Table (5.1): Peak Load for Each Substation at 2016.

Substation	MW	MVA	Mvar	PF	%
Alras	19.70	19.76	4.78	0.97	19
Alhusen	11.00	11.44	2.96	0.97	11
Algarbeah	12.10	12.48	3.00	0.97	12
Alduhdah	20.50	21.84	7.43	0.94	21
Emaldaleyah	6.50	7.28	3.17	0.90	7
Alharyeq	11.78	12.48	3.87	0.95	12
Alfahs	16.60	18.72	8.53	0.89	18

In this section, a present case of network is simulated using power world simulator to analyze power flow, and transformer loading. After determining each substation loading, Hebron electrical network has been built by using power world simulator as shown below. See Appendix D1

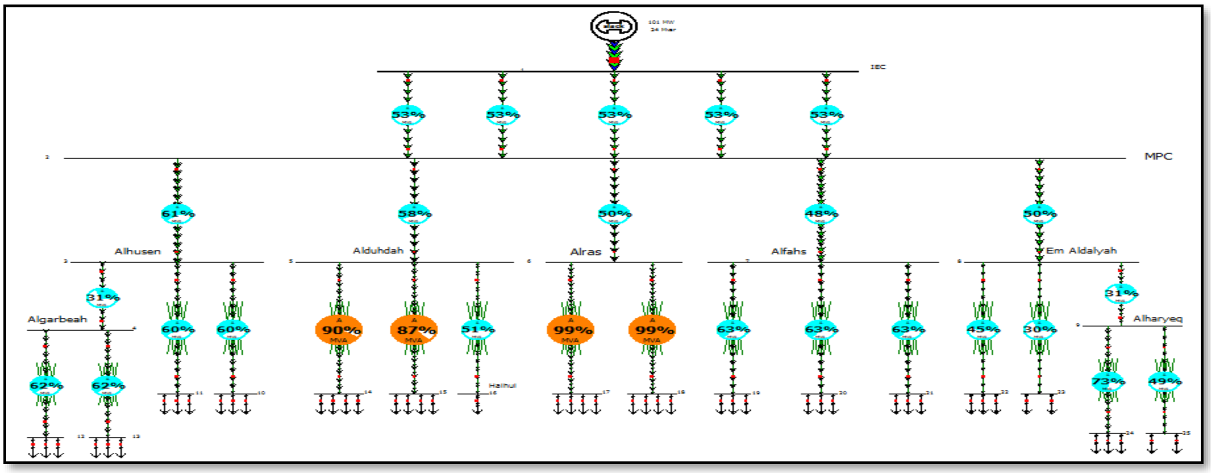

Figure (5.5): Single Line Diagram for Hebron in 2016.

The diagram shows that Alras substation will be loaded 19.76MVA while the total MVA rating for both of the transformers is 20MVA which will give an indication that these power transformers are overloaded by 99% of their rated output power, so any increasing in the load in the future will negatively affect the loading process for the customers.

This problem is also appearing in Alduhdah substation which is loaded up to 21.89MVA from the total 30 MVA rating power.

5.2.2 Geographic Information System (GIS)

Hebron electrical network is represented geographically by using the GIS system, which represents the seven substations, the IEC substation and MPC location. This diagram will show the tie lines between MPC and the substations, and also shows the Coordination for each substation, that's will be done to know exactly the distances for the tie lines between each substation in the next sections. see Appendix E1

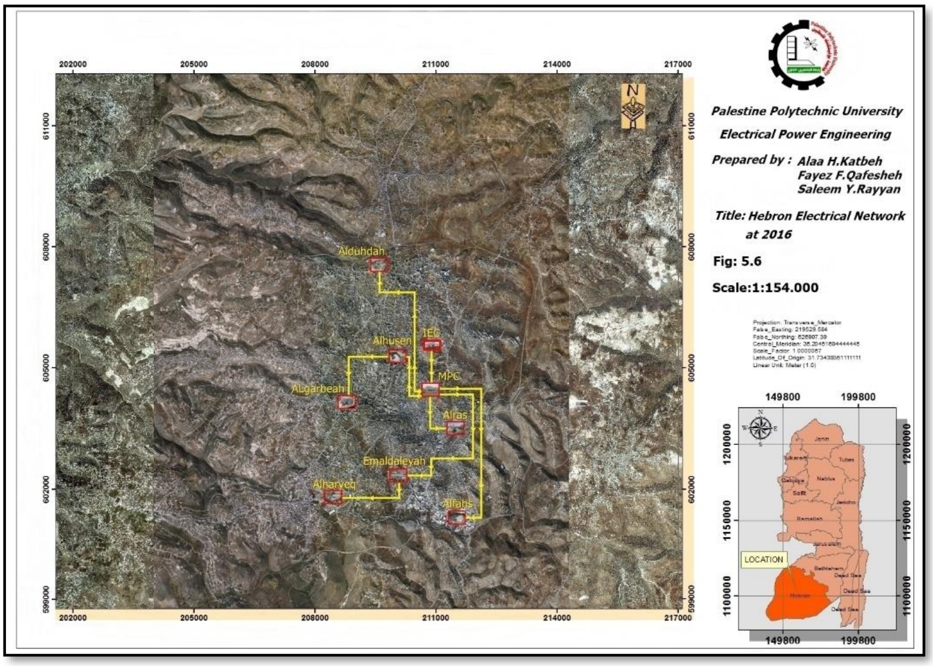

Figure (5.6): Hebron Electrical Network at 2016.

The following table 5.2 shows the coordination for each substation:

Table (5.2): Substation Coordination 2016.

Name	X - coordinate	Y - coordinate
Alras	604441	210702
Alhusen	607447	209487
Algarbeah	605248	209962
Alduhdah	602377	209894
Emaldaleyah	603836	211352
Alharyeq	603535	211288
Alfahs	601922	208415
MPC	605524	210757
IEC	604121	208603

5.3 Hebron Electrical Network In 2025

In this section, we will clarify the problems that will occur in the system at 2025 and develop proposed solutions for them.

5.3.1 Power World Modeling

The following table represents the peak load for each substation according to the forecasted load values for 2025; the total MW consumption is 134.14MW and Total MVA is 140.20 MVA.

Table (5.3): Peak Load For Each Substation at 2025.

Substation	MW	MVA	Mvar	PF	%
Alras	25.48	27.01	6.65	0.97	19
Alhusen	14.75	15.64	3.80	0.97	11
Algarbeah	16.09	17.06	4.14	0.97	12
Alduhdah	28.16	29.86	10.18	0.94	21
Emaldaleyah	9.38	9.95	4.33	0.90	7
Alharyeq	16.09	17.06	5.32	0.95	12
Alfahs	24.145	25.59	11.67	0.89	18

In this section, an expected case of network at 2025 is simulated using power world simulator to analyze power flow, and transformer loading. After determining each substation loading, Hebron electrical network has been built by using power world simulator as shown in figure (5.7). See Appendix D2

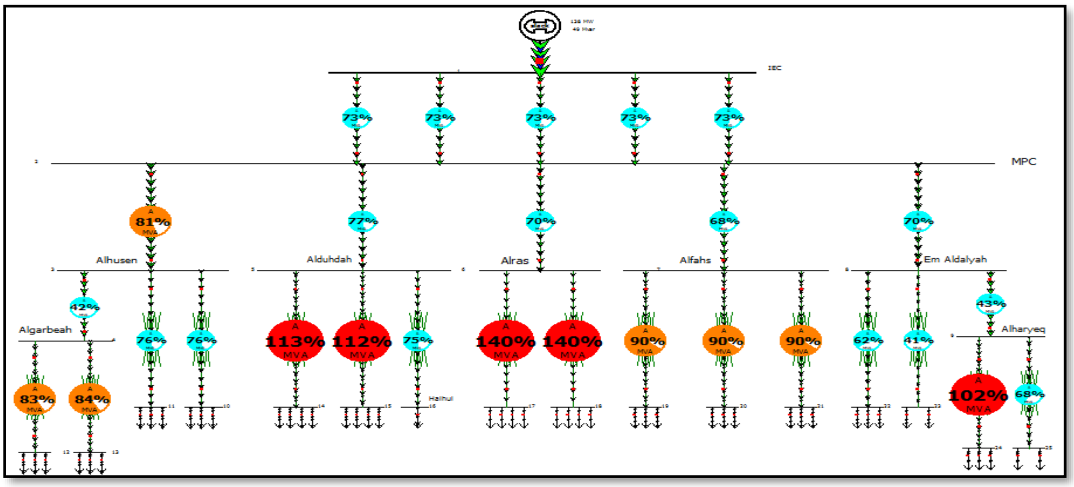

Figure (5.7): Single Line Diagram for Hebron before Upgrading in 2025.

5.3.2 Power System Temporary Upgrading

From the simulated diagram (5.5) at section 5.3.1 we can conclude that:

- Alras substation will be loaded 27.01 MVA at 2025 while the total MVA rating for both of the transformers is 20 MVA, both of the transformers are overloaded respectively by 140% and 139%.
- Alduhdah substation will be loaded 29.86 MVA at 2025 while the total MVA rating for the three transformers is 30 MVA. Two of three transformers are overloaded respectively by 113% and 114%.
- One of the transformers at Alharayeq substation is overloaded by 102%, while this substation will be loaded 17.06 MVA at 2025 with total rating is 20MVA.

These results give an indication that these power transformers should be upgraded to satisfy the forecasted load, a temporary solution will be provided to deal with these problems are listed below:

- Halhoul area is served from Alduhdah substation by a single transformer so it should be disconnected and start to operate separately by using a new substation which is located at Halhoul city, this substation includes single transformer of 10 MVA rating to serve Halhoul city.
- Alduhdah and Alras substation must increase their capability by adding new 20 MVA transformers to serve the excepted load; the feeders also will be redistributed.
- Alharayeq substation must increase its capability by adding new 10 MVA transformer to serve the excepted load, the feeders also will be redistributed.

The percentage of loading are redistributed after implement the temporary solution on the substation as shown in figure (5.8).

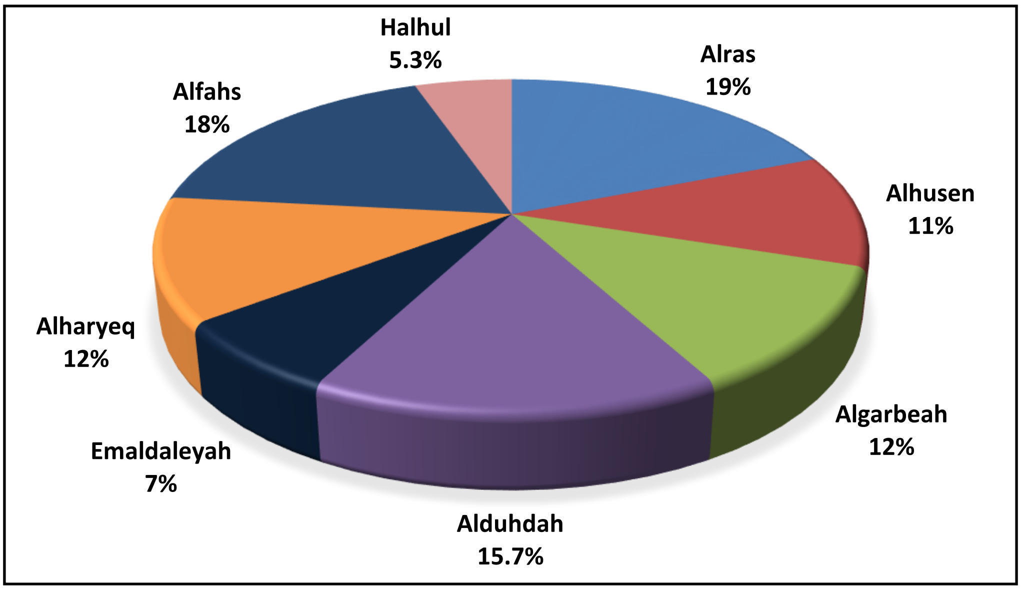

Figure (5.8): Loading MVA Percentage in 2025.

The following table 5.4 represents the peak load for each substation after upgrading the substation capability according to the forecasted load values for 2025; the total MW consumption is 134.14MW and Total MVA is 140.20 MVA.

Table (5.4): Peak Load For Each Substation at 2025.

Substation	MW	MVA	Mvar	PF	%
Alras	25.48	27.01	6.65	0.97	19
Alhusen	14.75	15.64	3.80	0.97	11
Algarbeah	16.09	17.06	4.14	0.97	12
Alduhdah	21.12	22.60	7.641	0.94	15.7
Emaldaleyah	9.38	9.95	4.33	0.90	7
Alharyeq	16.09	17.06	5.32	0.95	12
Alfahs	24.145	25.59	11.67	0.89	18
Halhul	7.04	7.26	2.55	0.97	5.3

After upgrading the network the new system at 2025 is simulated using power world simulator to analyze power flow, and transformer loading. After determining each substation loading, Hebron electrical network has been built by using power world simulator as shown. See Appendix D3

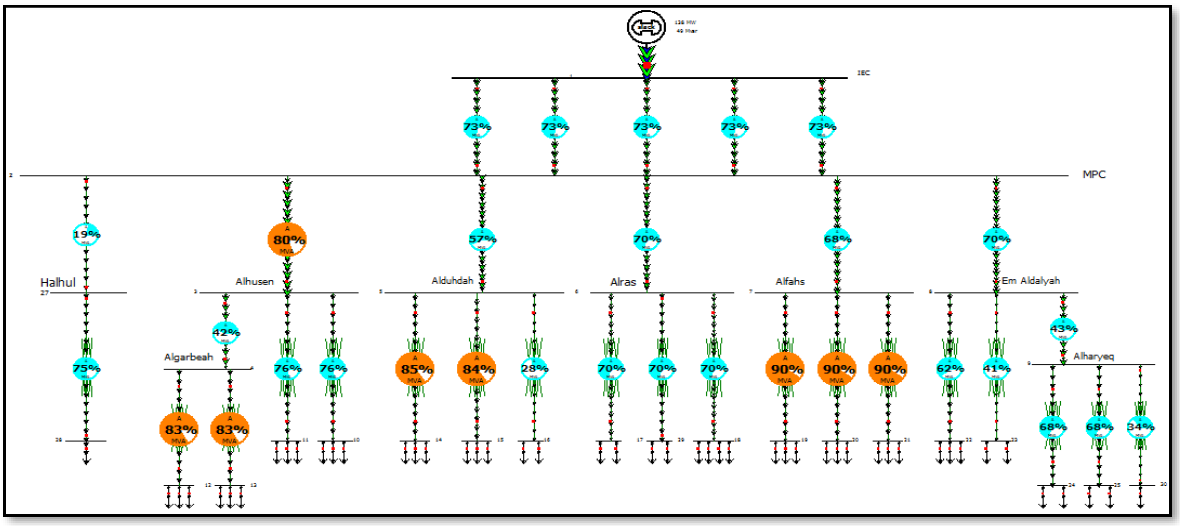

Figure (5.9): Single Line Diagram for Hebron After Upgrading in 2025.

5.3.3 Geographic information system (GIS)

A Representation of the eight substations, the IEC substation, MPC and their locations is implemented. This diagram shows the tie lines between MPC and the substations at 2025 after considering all the solutions that was represented in the previous section, this diagram also shows the Coordination for each substation as shown. see Appendix E2

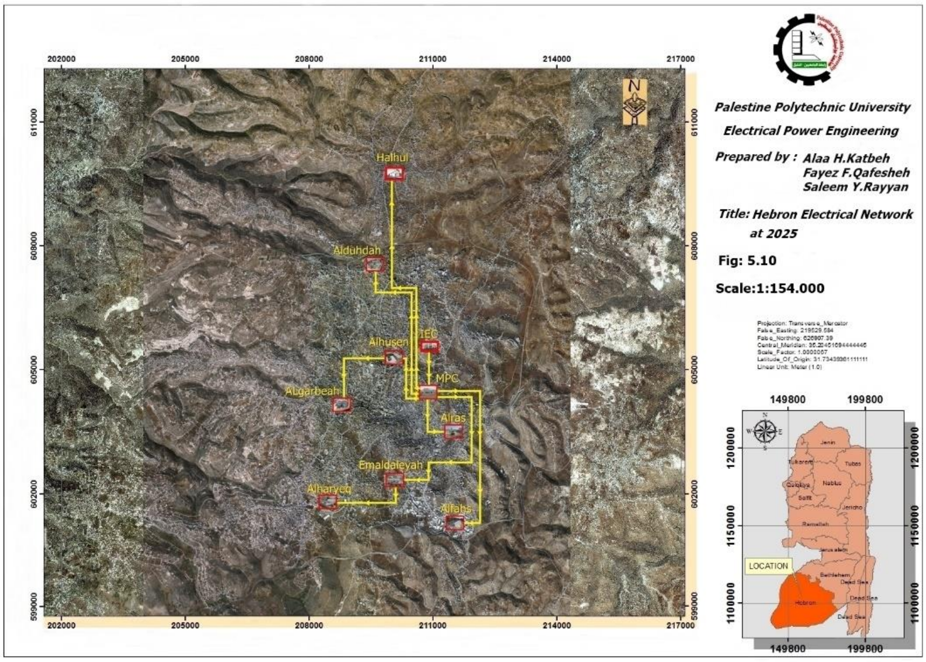

Figure (5.10): Hebron Electrical Network at 2025.

The following table is representing the coordination of Halhul new substation:

Table (5.5): Substation Coordination 2025.

	X - coordinate	Y - coordinate
Halhul	609157	213377

5.4 Hebron Electrical Power System in 2035

In This section, we will present the process of how to operate the power plants, the characteristics for each generating unit type, and their behavior until 2035, depending on the economic dispatching and optimal power flow analysis by using power world simulator, these plants must be ready to operate normally at 2026.

5.4.1 Generators characteristic

For the execution process of the future planning, and to get self-sufficiency in the electrical manner for Hebron electrical system; a four-power plants is suggested to be built in different sites inside Hebron Governorate geographical borders, these plants are classified according to their fuel type:

- Gas power plant.
- Diesel power plant.
- Crude oil power plant.
- Photovoltaic power station.

The following table shows the fuel cost curve parameter for each power plant and their MW ratings:

Table (5.6): Fuel Cost Coefficients for Plants.

Unit type	Unit size(MW)	α	β	γ
Diesel	100	49.92	10.06	0.0103
Crude oil	50	52.87	10.47	0.01160
Gas	30	53.62	10.66	0.01170

Where: α , β, γ are the fuel cost coefficients?

5.4.2 Power World Modeling Final Upgrading -Economic Perspective

Step1: After determining the expected future load of Hebron at 2035 the total MW consumption is 175.5 MW and Total MVA is 181.0 MVA, which is represented in table 5.7 for each substation below.

Table (5.7): peak load for each substation in 2035.

Substation	MW	MVA	Mvar	PF	%
Alras	33.34	34.39	8.36	0.97	19
Alhusen	19.30	19.91	4.84	0.97	11
Algarbeah	21.06	21.72	5.28	0.97	12
Alduhdah	27.55	28.41	9.69	0.94	15.7
Emaldaleyah	12.28	12.67	5.52	0.90	7
Alharyeq	21.06	21.72	6.78	0.95	12
Alfahs	31.59	32.58	14.97	0.89	18
Halhul	9.30	9.59	3.33	0.97	5.3

From the previous table, we can conclude that Alfahs, Alhusen, and Algarbeah substations will be overloaded, so the system must increase its capability to satisfy the forecasted load by adding 10 MVA transformers for each one of the substations respectively.

In this section, a future case of network is simulated using power world simulator to analyze power flow and transformer loading, in addition to that the generation plants will be analyzed under optimal power flow condition. The substations will be connected at the 33 KV level as a ring connection scheme for optimal power flow purposes, and to increase the level of security in the system. After determining each substation loading, and adding four power plants to feed the load, new and final upgraded Hebron electrical network has been built by using power world simulator as shown in figure (5.11). see Appendix D4

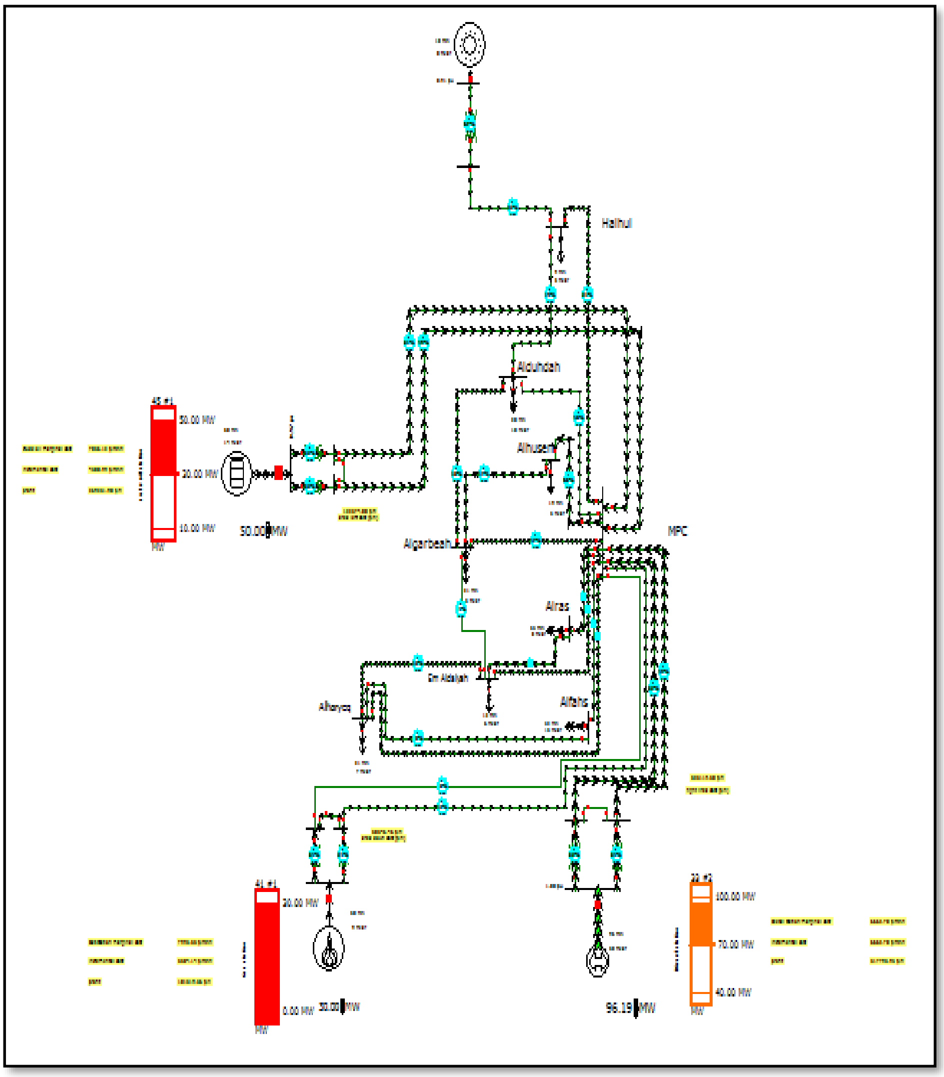

Figure (5.11): Single Line Diagram for Hebron in 2035.

5.4.2.1. Generators Behavior under Peak Load

For any power generation system, the fuel cost plays a major rule in the operation of electric power plants to cover the load demand, so any operation for the different generating unit should be under the cost of production constraint.

In this project, the idea of economic dispatch and how the generating units should be optimally dispatched, will be simulated by using the time step tools in the power world simulator. This tool is often useful to assess how power system quantities vary hour by hour due to changes in load, the Time Step Simulation (TSS) allows obtaining power flow, OPF solutions for a list of time points for which input (scenario) data has been specified. It also gives a model actions that occur at specific times, as well as periodic actions.

The process of running the lowest production cost generator firstly under MW limits for each plant should be implemented in a specified time period, this period is chosen to be the peak case for power load demand at 27-december-2016 for 24 hour, so this load profile is implemented for 2035 peak load demand values, according to the peak load demand for Hebron electrical system as shown in figure (5.12) below. see Appendix F

Date	Time	Num Loads ▲	Total MW Load	Alfahs MW	Alras MW	Alhusen MW	Alharye MW	Emaldal MW	Algarbe MW	Alduhd MW	Halhul MW
12/27/2035	12:00:00 AM	8	80.7	13.33	15.34	11.03	9.49	5.24	9.69	12.28	4.28
12/27/2035	1:00:00 AM	8	65.9	11.19	12.88	7.45	7.96	4.40	8.13	10.31	3.59
12/27/2035	2:00:00 AM	8	56.4	9.58	11.03	6.38	6.82	3.77	6.96	8.83	3.07
12/27/2035	3:00:00 AM	8	54.7	9.29	10.69	6.19	6.61	3.65	6.75	8.56	2.98
12/27/2035	4:00:00 AM	8	55.1	9.35	10.76	6.23	6.65	3.67	6.79	8.61	3.00
12/27/2035	5:00:00 AM	8	61.4	10.42	11.98	6.94	7.41	4.09	7.57	9.60	3.34
12/27/2035	6:00:00 AM	8	71.2	12.09	13.92	8.05	8.61	4.75	8.79	11.14	3.88
12/27/2035	7:00:00 AM	8	95.8	16.27	18.72	10.83	11.58	6.40	11.82	14.99	5.22
12/27/2035	8:00:00 AM	8	117.3	20.38	23.45	13.57	11.78	8.01	14.81	18.77	6.54
12/27/2035	9:00:00 AM	8	128.6	21.84	25.12	14.54	15.54	8.58	15.86	20.12	7.00
12/27/2035	10:00:00 AM	8	160.8	27.31	31.42	18.19	19.43	10.74	19.84	25.16	8.76
12/27/2035	11:00:00 AM	8	170.8	28.99	33.35	19.31	20.63	11.40	21.06	26.71	9.30
12/27/2035	12:00:00 PM	8	162.2	27.54	31.69	18.34	19.60	10.83	20.01	25.37	8.83
12/27/2035	1:00:00 PM	8	161.1	27.36	31.48	18.22	19.44	10.76	19.88	25.21	8.78
12/27/2035	2:00:00 PM	8	164.0	27.84	32.03	18.54	19.81	10.94	20.23	25.64	8.93
12/27/2035	3:00:00 PM	8	148.6	25.24	29.03	16.81	17.96	9.92	18.33	23.25	8.10
12/27/2035	4:00:00 PM	8	150.3	25.51	29.35	16.99	18.15	10.03	18.54	23.50	8.18
12/27/2035	5:00:00 PM	8	156.9	26.64	30.64	17.74	18.95	10.47	19.35	24.54	8.54
12/27/2035	6:00:00 PM	8	146.3	24.84	28.58	16.55	17.68	9.77	18.05	22.89	7.97
12/27/2035	6:00:00 PM	8	146.3	24.84	28.58	16.55	17.68	9.77	18.05	22.89	7.97
12/27/2035	7:00:00 PM	8	141.0	23.94	27.55	15.95	17.04	9.41	17.40	22.06	7.68
12/27/2035	8:00:00 PM	8	137.9	23.41	26.94	15.57	16.66	9.20	17.01	21.57	7.51
12/27/2035	9:00:00 PM	8	127.5	21.65	24.90	14.42	15.40	8.51	15.73	19.94	6.94
12/27/2035	10:00:00 PM	8	113.3	19.24	22.13	12.81	13.69	7.56	13.98	17.72	6.17
12/27/2035	11:00:00 PM	8	74.7	16.56	19.06	0.00	0.00	6.51	12.03	15.26	5.31

Figure (5.12): Peak Load Demand Using TSS Tool.

The generation behavior under the previous allocation of the load values is presented in this section. In any power plant, the generating unit with the cheapest Fuel Cost and the best optimum economic operation will be selected to dispatch first. Diesel Generating Unit is the cheapest while the gas Generating Unit is the most expensive in terms of fuel cost and economic efficiency. Hence, the diesel Generating Unit would be dispatched first and the gas Generating Unit last, in addition to that the gas plant is categorized as a fast start generator, so it will operate at the peak periods in the load profile only. The solar panel is assumed to operate under specific periods at its maximum capacity. The figures below show how the generators should act under the dispatching conditions and the max MW load demand.

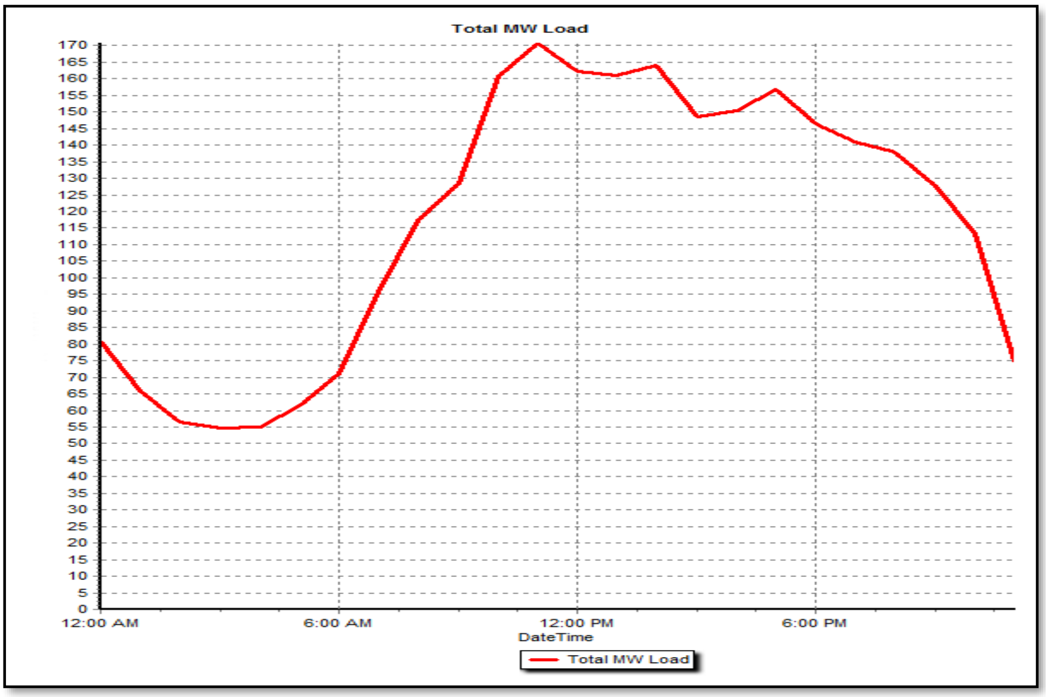

Figure (5.13): Total Maximum MW Load Demand.

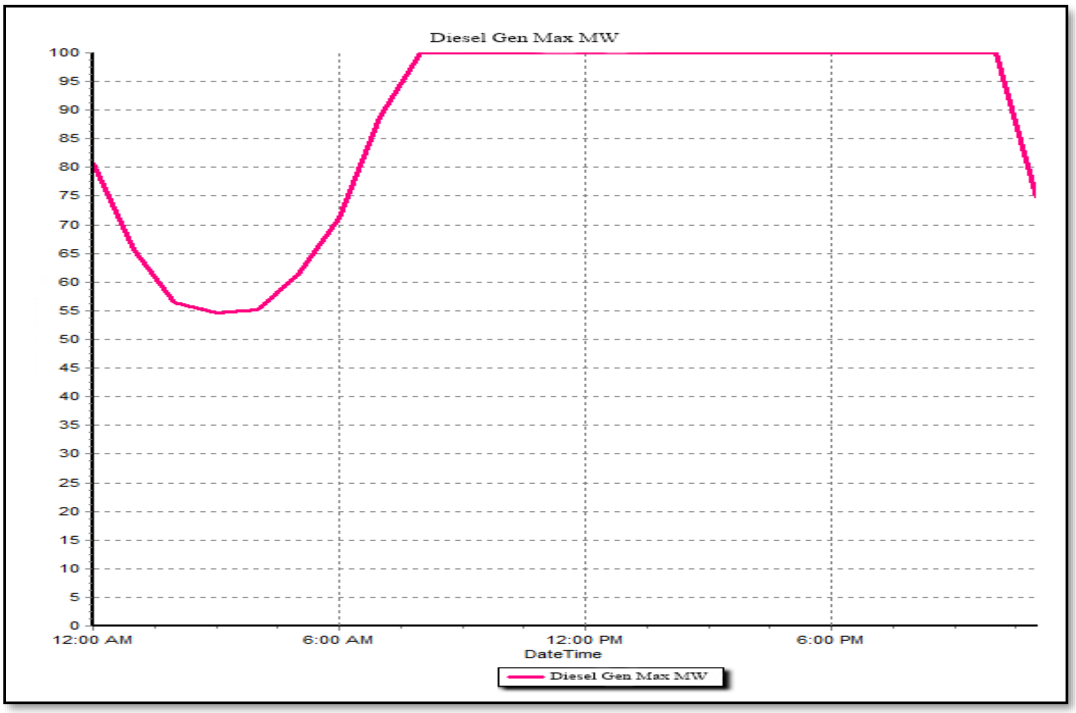

Figure (5.14): Diesel Power Plant.

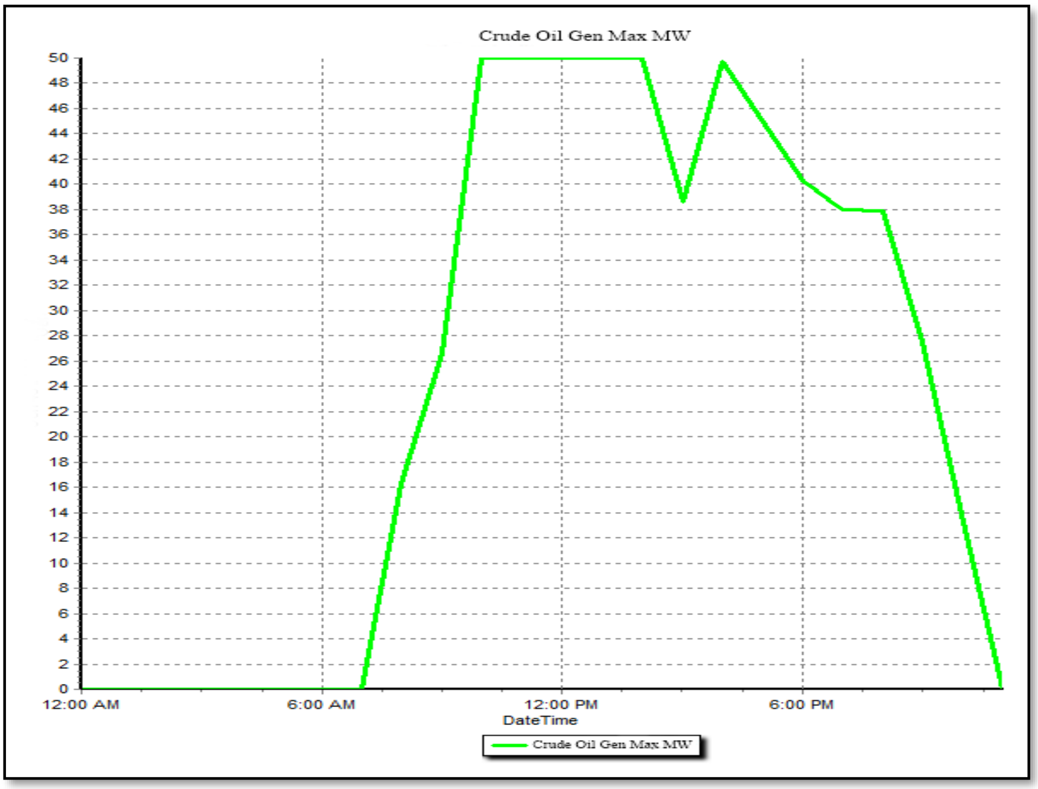

Figure (5.15): Crude Oil Power Plant.

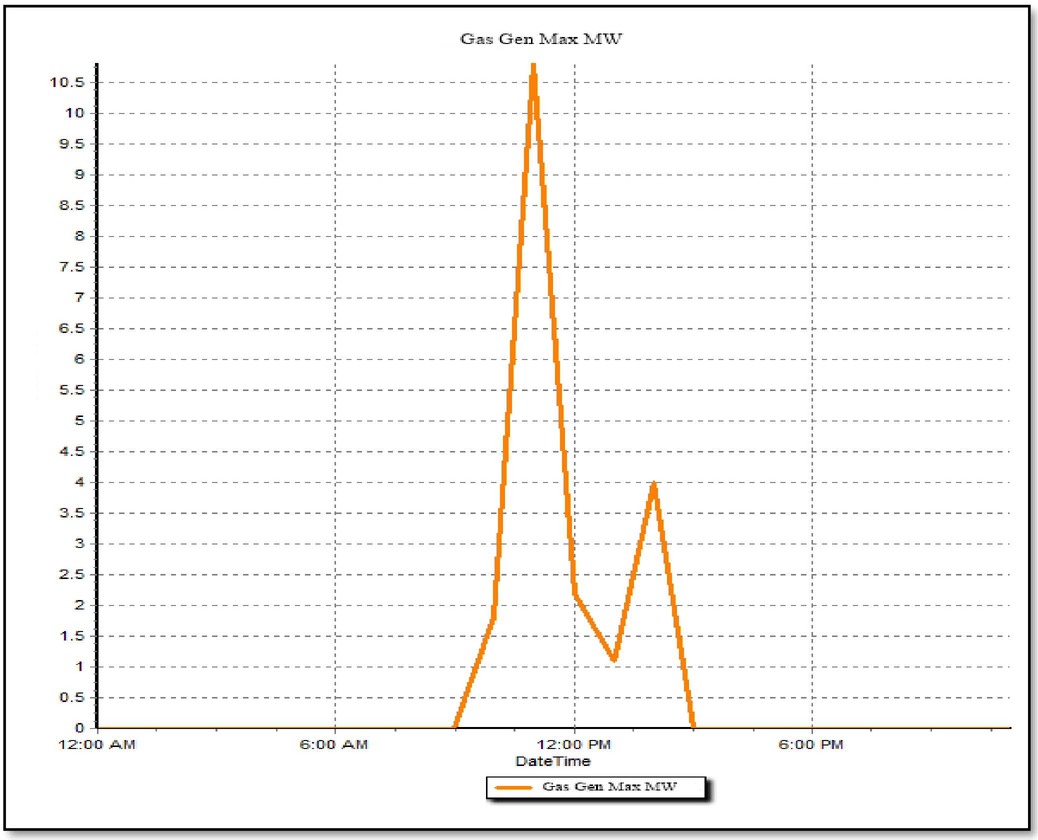

Figure (5.16): Gas Power Plant.

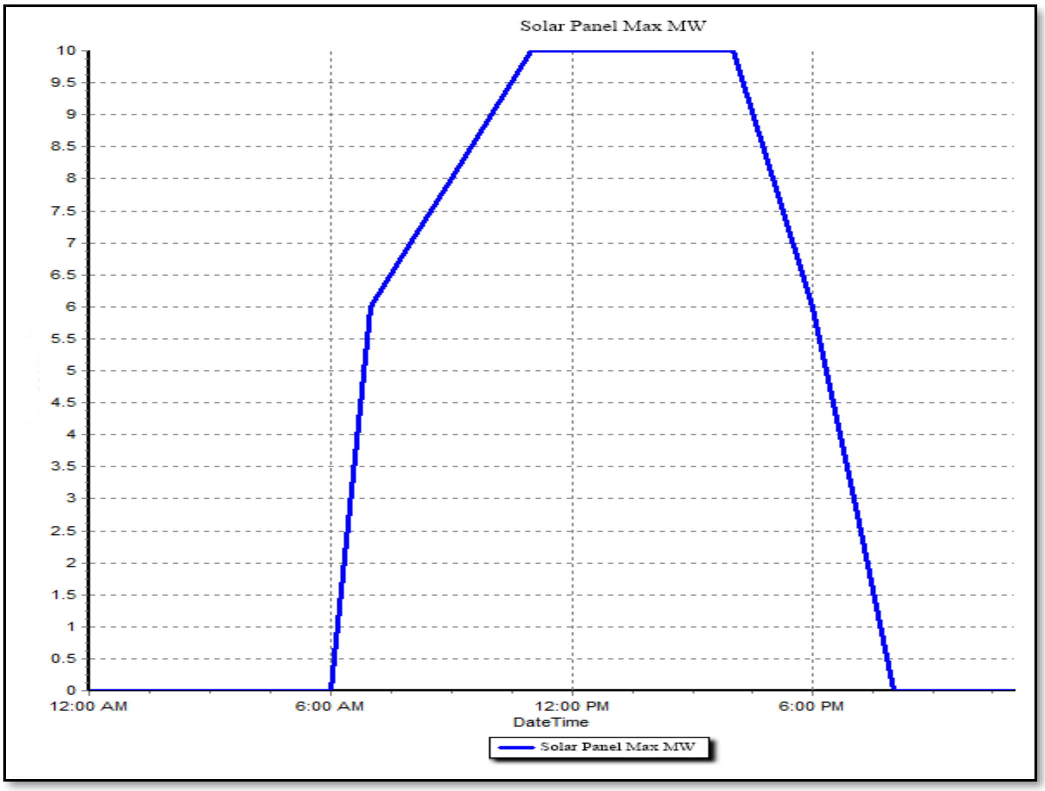

Figure (5.17): Solar Panel Power Station.

5.4.2.2. **Simulation Results**

The following figures show the input data in the power world simulator for each of the power plant including the fuel cubic cost coefficient.

- Diesel power plant:

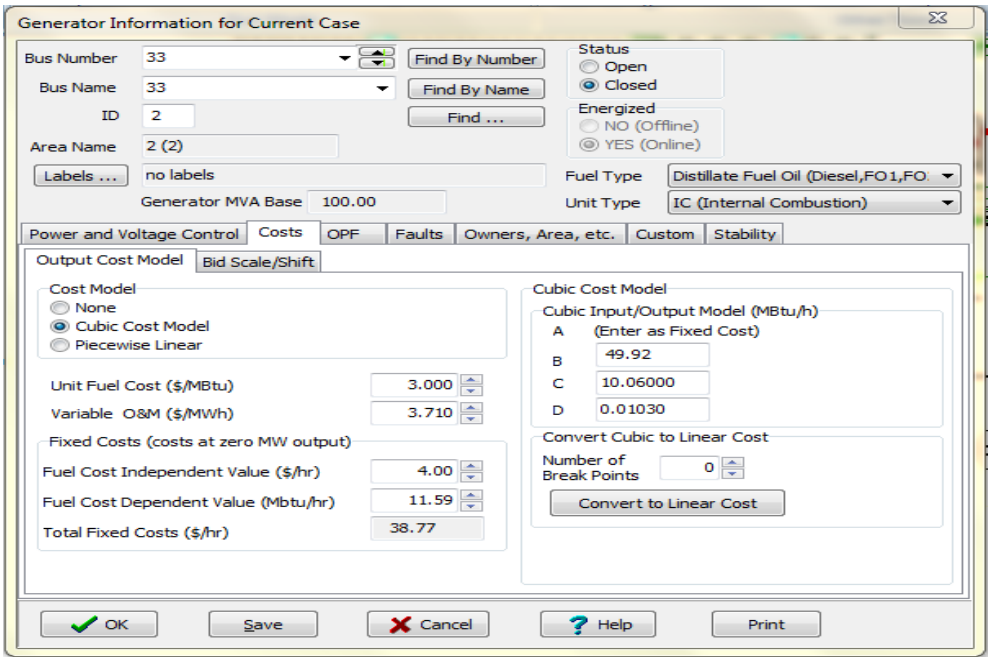

Figure (5.18): Input Data (Diesel Plant).

- Crude oil plant:

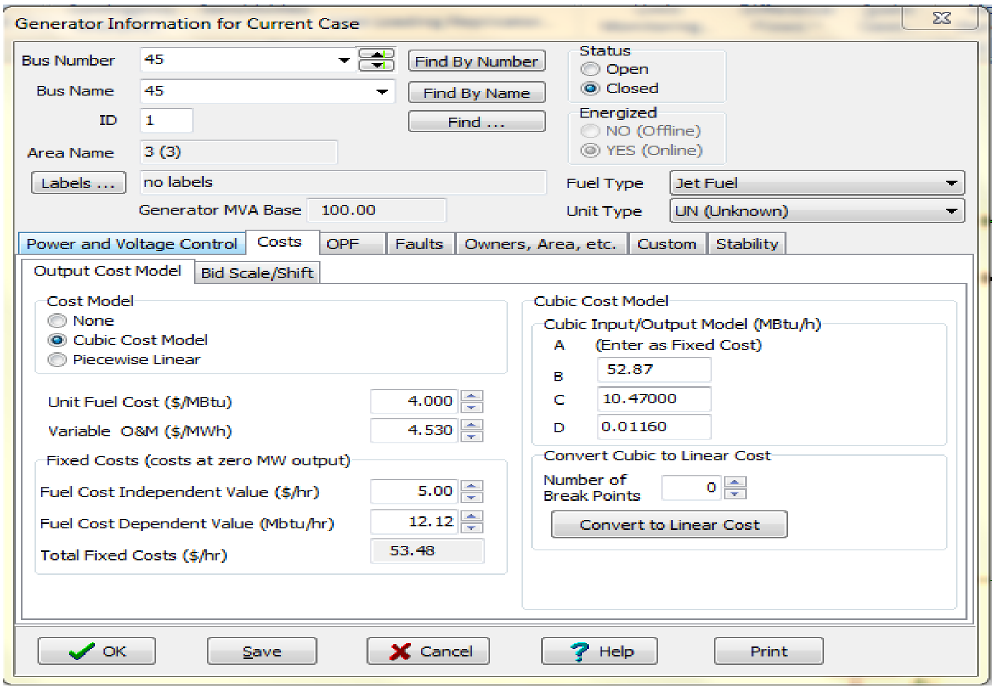

Figure (5.19): Input Data (Crude Oil Plant).

- Gas power plant:

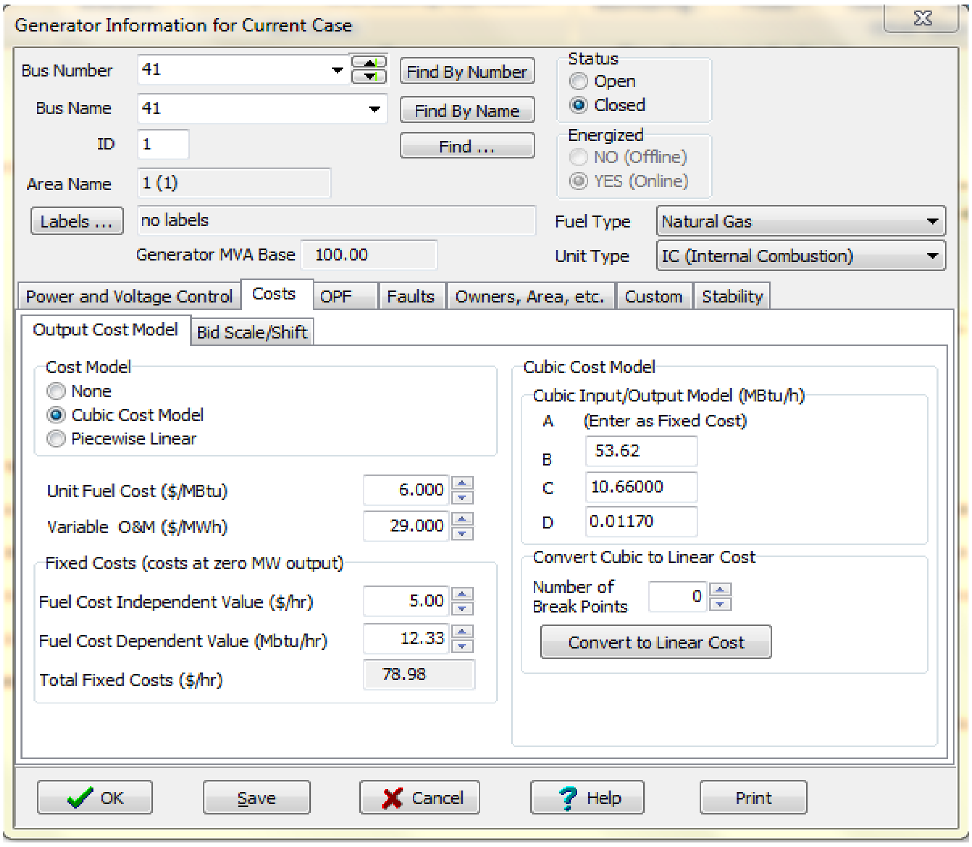

Figure (5.20): Input Data (Gas Plant).

The following figures illustrate the input output curve and fuel cost curve for each type of the power plant, these estimations are made to determine the amount of fuel needed by each generating station.

- **Diesel power plant:**

Table (5.8): MW Related to MIBtu/hr for Diesel Plant.

MW output	MBtu/hr
96	112000

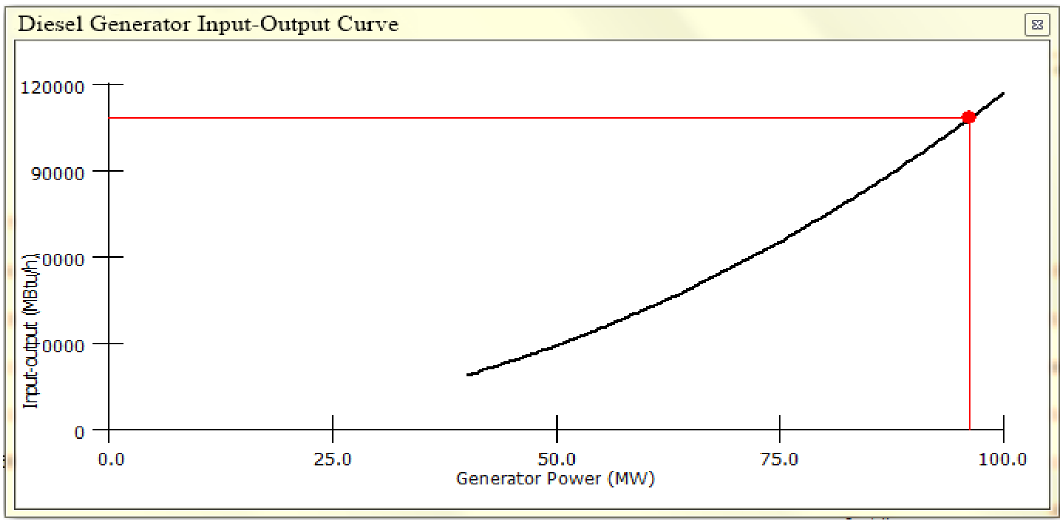

Figure (5.21): Diesel Power Plant Input Output Curve.

Table (5.9): MW Related to Fuel Cost $/hr for Diesel Plant.

MW output	Fuel cost $/hr
96	330000

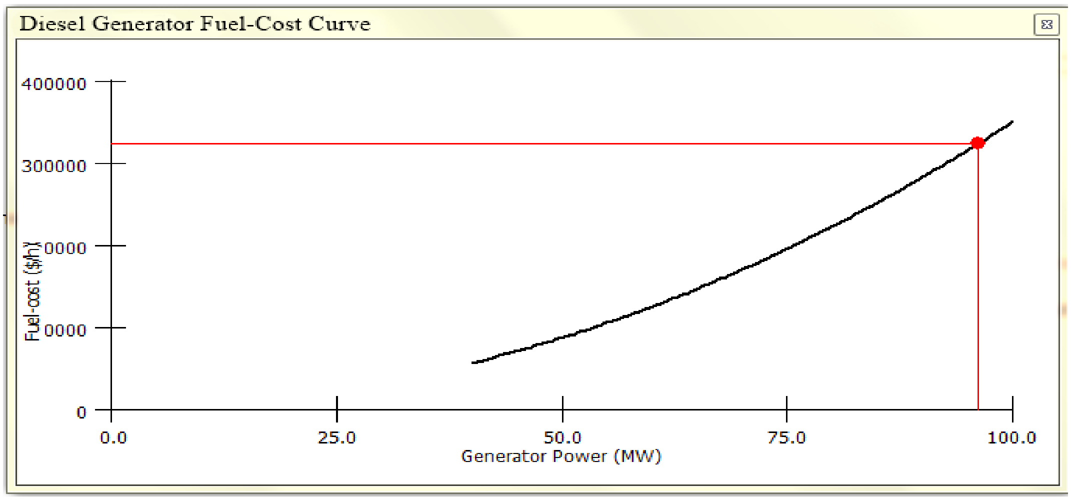

Figure (5.22): Diesel Power Plant Fuel Cost Curve.

- **Crude Oil power plant:**

Table (5.10): MW Related to MIBtu/hr for Crude Oil Plant.

MW output	MBtu/hr
50	31000

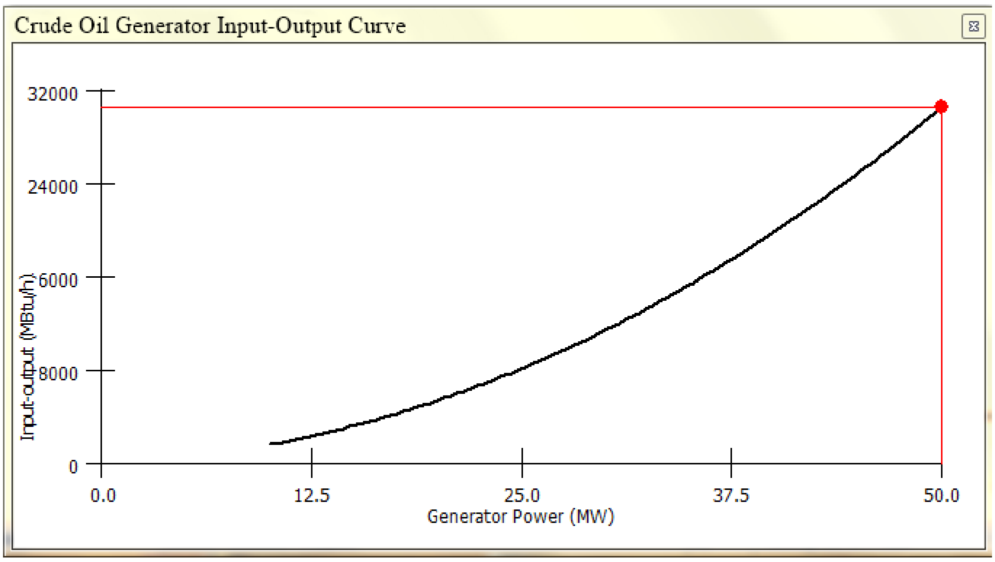

Figure (5.23): Oil Power Plant Input Output Curve.

Table (5.11): MW Related to Fuel Cost $/hr for Crude Oil Plant.

MW output	Fuel cost $/hr
50	125000

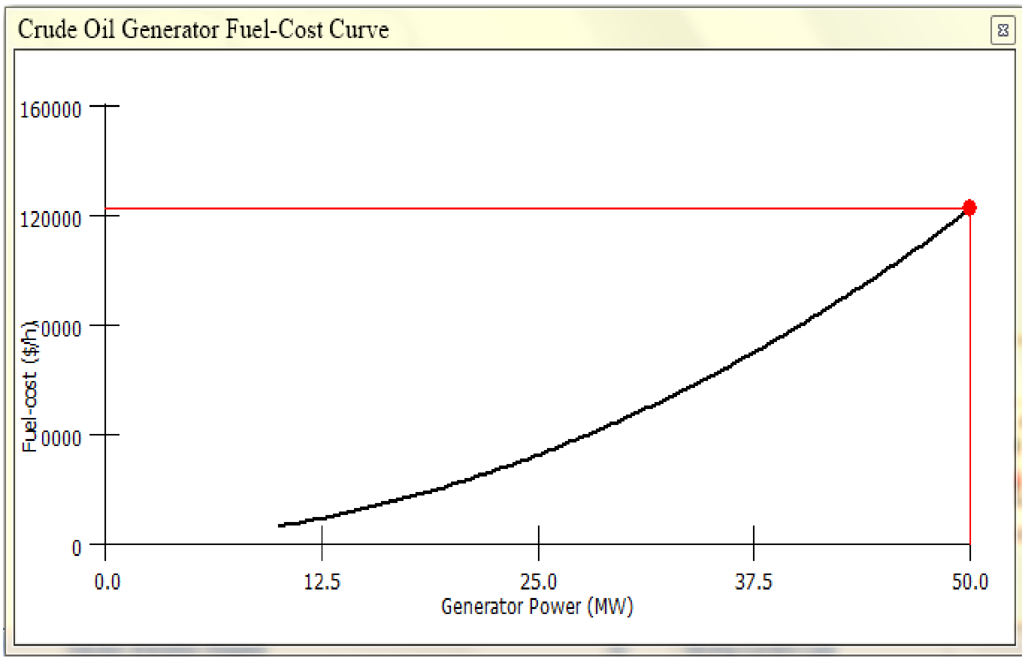

Figure (5.24): Oil Power Plant Fuel Cost Curve.

- **Gas power plant:**

Table (5.12): MW Related to MIBtu/hr for Gas Plant.

MW output	MBtu/hr
30	11850

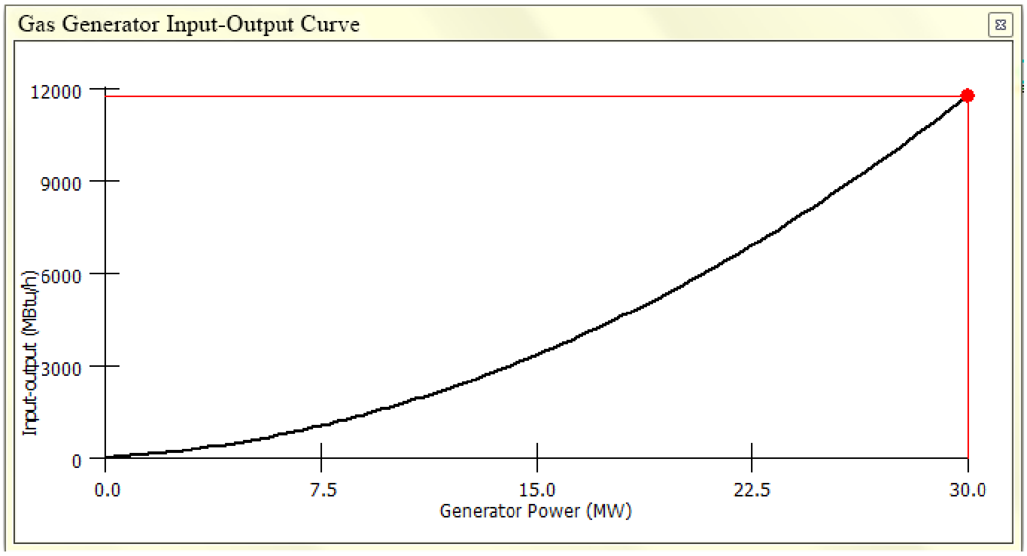

Figure (5.25): Gas Power Plant Input Output Curve.

Table (5.13): MW Related to Fuel Cost $/hr for Gas Plant.

MW output	Fuel cost $/hr
30	70050

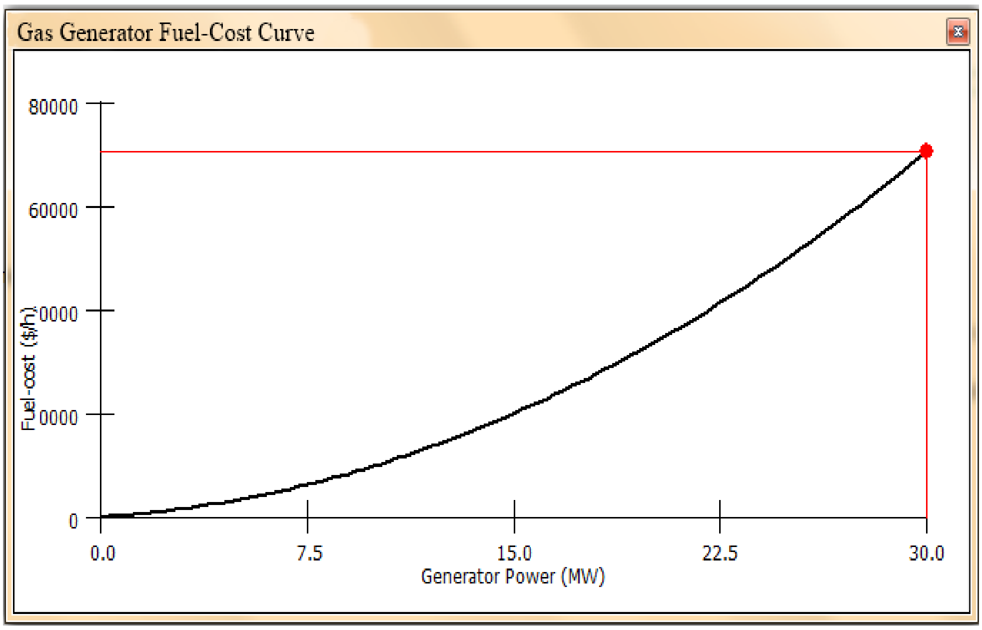

Figure (5.26): Gas Power Plant Fuel Cost Curve.

Some of the important terms and values that are used in the optimal and economic dispatch power flow are listed below.

- **Cubic Cost Coefficients α, β, γ**: specify the cost curve's coefficients. The **α** coefficient is historically the fuel cost dependent fixed cost value, which is combined separately now with the fuel cost independent value. These coefficients can be specified only when you have chosen to use a cubic cost model.
- **Marginal Cost:** During any constrained minimization, there is a cost associated with enforcing the equality constraints and the binding inequality constraints. These costs are known as the marginal costs, in $ / MWhr, to supply one additional MW of load at this bus. If a generator is available as a control and is not at either its minimum or maximum limit or a cost model breakpoint, then the MW Marginal Cost field will be identical to the generator's current marginal cost. However, the usual case is for the generator to be at either a limit or a cost model breakpoint so the usual situation is that the MW Marg. Cost field values is not equal to the generator's marginal cost.
- **Unit Fuel Cost:** The cost of fuel in $/MBtu. This value can be specified only when you have chosen to use a cubic cost model.
- **Incremental cost:** measure of how costly it will be to produce the next increment of power.
- **Profit $/hr**: Shows the profit of the generator. Profit is calculated using this equation:

$$\text{Profit} = (\text{GenMW} * \text{MW Marg Cost}) - (\text{Evaluation of the Generator Cost Function}). \qquad (5.1)$$

These results are obtained for all of the generation plant as shown in figure (5.27). see Appendix F

Name of Gen	AGC	Fast Start	OPF MW Control	Gen MW	Cost $/Hr (generation only)	MW Marg. Cost of Bus	IC for OPF	Initial MW	Initial Cost	Min MW	Max MW	Cost Model	Fuel Type	Profit $/hr
Solar Panel	YES	NO	Yes	10.0	0.00	8198.87	10.00	10.0	0.00	0.0	10.0	None	Solar	81988.68
Gas	YES	YES	Yes	30.0	58546.46	7995.53	3304.14	30.0	58546.46	0.0	30.0	Cubic	Natural Gas	181319.56
Crude Oil	YES	NO	Yes	50.0	122574.00	7836.12	4380.99	50.0	122574.00	10.0	50.0	Cubic	Jet Fuel	269231.98
Diesel	YES	NO	Yes	96.2	323119.50	6662.70	6662.70	96.2	323119.56	40.0	100.0	Cubic	Distillate Fuel Oil	317795.93

Figure (5.27): Generation Economic Values.

The following table illustrates the relation between the incremental cost and any deviation in the output power from the generator; this table gives an indication of how costly it will be to produce the next increment of power, for various ranges of the output power we notice that any increase in the output power will causing the increment cost to increase.

Table (5.14): Output Power and Increment Cost Relation.

Gas Plant		Crude Oil Plant	
MW Range	**Increment Cost(ϒ) ($/MWhr)**	**MW Range**	**Increment Cost(ϒ) ($/MWhr)**
1-5	619.36	10-17	1433.4
6-11	1271.62	18-25	2143.57
12-17	1936.49	26-33	2871.56
18-22	2614	34-41	3617.36
23-30	3304.14	42-50	4380.99

The total profit for each power plant will change according to the output power by implementing equation (5.1), the results in the following table shows the profit values while changing the output power for gas and crude oil power plant, these variations depends on the previous table 5.14 MW ranges.

Table (5.15): Variation in Profits.

Gas Plant		Crude Oil Plant	
MW	**Profit ($/h)**	**MW**	**Profit ($/h)**
30	18139.56	50	269231.98
23	148078.88	42	24159.89
22	142868.71	41	23710.05
18	120888.3	34	207852.83
17	115110.02	33	203212.39
12	84537.16	26	168142.35
11	78688.76	25	162766.12
6	44196.82	18	122607.91
5	37090.91	17	116513.71
1	29876.56	10	71392.12

5.4.3 Geographic Information System (GIS)

A Representation of the eight substations, four power plant and MPC locations is shown in the following figure. Moreover, this diagram will show the tie lines between the power plants and MPC, between the MPC and substations, and between each one of the eight substations at 2035 and after considering all the solutions that was represented, and also shows the Coordination for each substation as shown in figure (5.28). see Appendix E3

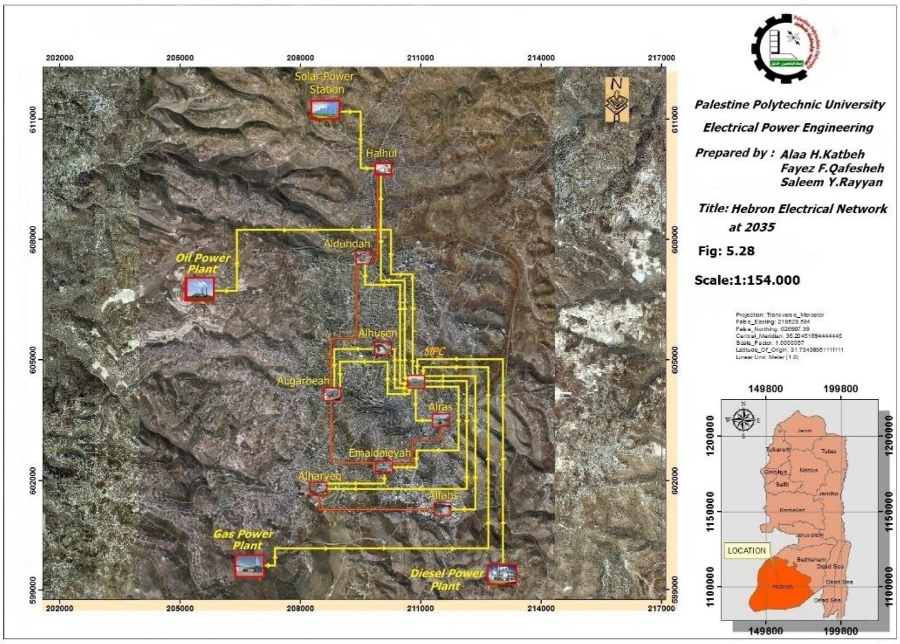

Figure (5.28): Hebron Electrical Network at 2035.

The following table 5.16 is representing the coordination of each power generation.

Table (5.16): Plants Coordination.

Name	X - coordinate	Y - coordinate
Solar Power Station	611776	208389
Oil Power Plant	606390	206679
Gas Power Plant	599760	207181
Diesel Power Plant	599655	213252

6

Chapter Six Conclusion and Recommendations

6.1 Conclusion

6.2 Recommendations

6.1 Conclusion

This project illustrates that under the variation and increasing of the load values over the years, it was recognized that we must construct new substations and extend the available substations; this process is needed for continuing the planning strategy for building four new generation plants under economic constraint, this strategy must be accomplished for every power system planning to identify how much fuel the system need to operate. The input output curve for each fuel type depends on the operating cost for each country. These steps help the planner to determine the needed values before starting the operating conditions for the power plant and causing of increasing in flexibility of reducing the total cost of power production. Furthermore, by Appling the last planning mythology which is presented by construct the new generation plants; the network will achieve continuity of service, reliability, dependability and efficiently until 2035 under economic dispatching control.

6.2 Recommendations

For HEPCO

- To build an accurate scheme for the electrical network by using any power flow program.
- Upgrade the network to satisfy the expected load forecasting.
- Activate the supplying of electricity from Halhul substation.

For the Future Studies

- Build the forecasting model by using another forecasting method which are presented in chapter three and compare the results to choose the more accurate approach for the forecasted system.
- Make a projection for this project to another electrical distribution companies and for west bank in general.
- Start the design procedure for the construction of the power plants including all the details.

For Palestinian Energy and Natural Resources Authority (PENRA)

- Working on organizing all the residents of the West Bank within the official distribution companies to ensure the availability of information which are necessary for any future planning process.
- Build power generation plants in the mentioned sites and study their behavior economically.

For Palestine Polytechnic University

- Add new courses for teaching the students how to use power simulation software's.
- Add new courses for learning the mythology and process of planning the electrical network.
- To make relationship with electrical companies to provide any required facilities for the students researches and projects.

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Appendices

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Appendix F

Appendix G

Appendix A

Data that was collected from the Palestinian Central Bureau of Statistics.

Gross domestic product (GDP)

Value in USA Dollar (Million)

	West Bank					
Final Use	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Final consumption	5,232.40	5,446.40	5,739.70	6,280.10	6,179.20	6,347.60
Household final consumption	3,840.60	4,068.70	4,326.30	4,874.40	4,812.20	4,949.70
Government final consumption	1,207.30	1,252.20	1,298.60	1,259.00	1,206.10	1,250.80
NPISH final consumption	184.5	125.5	114.8	146.7	160.9	147.1
Gross Capital Formation	1,346.70	1,142.80	1,193.10	1,443.60	1,543.10	1,624.90
Gross fixed capital formation	1,301.30	1,093.40	1,146.30	1,318.70	1,418.10	1,488.60
Buildings	946.8	728.4	777.7	938	1,028.30	1,076.90
Non buildings	354.5	365	368.6	380.7	389.8	411.7
Changes in inventories	45.4	49.4	46.8	124.9	125	136.3
Net Exports of Goods and Services	-2,277.7	-1,959.6	-1,846.0	-2,287.8	-2,245.9	-2,199.0
Exports	979.2	1,012.80	1,200.70	1,215.80	1,236.00	1,373.30
Goods	783.7	860.1	1,046.30	1,050.00	1,094.70	1,233.50
Services	195.5	152.7	154.4	165.8	141.3	139.8
Imports	3,256.90	2,972.40	3,046.70	3,503.60	3,481.90	3,572.30
Goods	2,915.30	2,663.70	2,692.90	3,122.70	3,126.70	3,247.90
Services	341.6	308.7	353.8	380.9	355.2	324.4
Net errors and omissions	3.2	-20.6	14.4	-26.9	-12.1	-19.2
Gross Domestic Product	4,304.60	4,609.00	5,101.20	5,409.00	5,464.30	5,754.30

The Population (POP)

Locality Name	Years							
	2009	2010	2011	2012	2013	2014	2015	2016
Halhul	23,282	24,060	24,863	25,695	26,548	27,421	28,313	29,222
Beit 'Einun	1,903	1,967	2,033	2,101	2,170	2,242	2,315	2,389
Al Baqa	1,282	1,324	1,369	1,414	1,461	1,509	1,558	1,609
Hebron (Al Khalil)	171,653	177,387	183,312	189,444	195,733	202,172	208,750	215,452
Al Bowereh (Aqabat Injeleh)	730	755	780	806	833	860	888	917
Qalqas	1,209	1,249	1,291	1,334	1,379	1,424	1,470	1,517
Urban Total	495,728	512,290	529,401	547,110	565,271	583,867	602,864	622,220
Rural Total	69,986	72,325	74,740	77,240	79,804	82,430	85,112	87,844
Camps Total	15,240	15,749	16,275	16,820	17,378	17,950	18,534	19,129
Total Hebron Gov.	580,955	600,364	620,417	641,170	662,454	684,246	706,509	729,193

Appendix B

Information collected from HEPCO

Concession Area For HEPCO

2009 to 2015 forecasting data factors

Factor / Years	Peak Load MW	Power Loss KW	Load Factor %	Cost ILS/ KWh
2009	64.320	7595	76.50	0.5870
2010	74.880	7074	77.04	0.5870
2011	76.800	9087	78.04	0.5917
2012	85.615	7898	78.77	0.6878
2013	85.581	8468	82.03	0.7291
2014	83.317	8392	84.61	0.7291
2015	89.825	9554	81.39	0.6426

Electrical supplier path

Appendix C

Information Calculated using Excel Program by Regression

Method (2016-2035).

Gross domestic product

Value in M$

GDP = Intercept + (slope * year)

GDP = -152030.06 + (75.91 * year)

year	GDP (M$)
2016	1005.22
2017	1081.13
2018	1157.04
2019	1232.95
2020	1308.86
2021	1384.77
2022	1460.68
2023	1536.59
2024	1612.50
2025	1688.41
2026	1764.32
2027	1840.23
2028	1916.14
2029	1992.05
2030	2067.97
2031	2143.88
2032	2219.79
2033	2295.7
2034	2371.61
2035	2447.52

The Population (POP)

POP = Intercept + (slope * year)

POP = -1.4E+07 + (7212.60 * year)

year	POP
2016	250035
2017	257247
2018	264460
2019	271672
2020	278885
2021	286098
2022	293310
2023	300523
2024	307735
2025	314948
2026	322161
2027	329373
2028	336586
2029	343798
2030	351011
2031	358224
2032	365436
2033	372649
2034	379862
2035	387074

The GDP per capita (GDP/CAP)

(GDP/CAP) = Intercept + (slope * year)

GDP/ CAP = -557800.8 + (278.72 * year)

year	GDP/ CAP
2016	4112.40
2017	4391.13
2018	4669.85
2019	4948.58
2020	5227.31
2021	5506.03
2022	5784.76
2023	6063.49
2024	6342.21
2025	6620.94
2026	6899.67
2027	7178.39
2028	7457.12
2029	7735.85
2030	8014.57
2031	8293.3
2032	8572.03
2033	8850.76
2034	9129.48
2035	9408.21

System Losses (KW)

System Losses (KW) = Intercept + (slope * year)

System Losses (KW) = -558944.85 + (281.92 * year)

year	System Losses (KW)
2016	9423
2017	9705
2018	9987
2019	10269
2020	10551
2021	10833
2022	11115
2023	11397
2024	11679
2025	11960
2026	12242
2027	12524
2028	12806
2029	13088
2030	13370
2031	13652
2032	13934
2033	14216
2034	14498
2035	14780

Load Factor (%)

Due to the dependability of these factors on the Israeli control and because these factors are not available in HEPCO company we make an assumption for the load factor

year	Load Factor (%)
2016	67.50
2017	77.04
2018	78.09
2019	78.77
2020	82.03
2021	84.61
2022	81.39
2023	82.50
2024	83.61
2025	81.22
2026	80.02
2027	77.04
2028	78.09
2029	78.77
2030	80.03
2031	84.61
2032	83.39
2033	79.5
2034	78.61
2035	81.22

Cost of Energy (ILS/ kWh)

Due to the dependability of these factors on the Israeli control and because these factors are not available in HEPCO company we make an assumption for the cost for energy

year	Cost of Energy (ILS/ kWh)
2016	0.5870
2017	0.5870
2018	0.59175
2019	0.6878
2020	0.7299
2021	0.7291
2022	0.6426
2023	0.6469
2024	0.6501
2025	0.6545
2026	0.67
2027	0.587
2028	0.59175
2029	0.6878
2030	0.7099
2031	0.7091
2032	0.6426
2033	0.6569
2034	0.6401
2035	0.6545

Appendix D

Power World Simulator for Hebron Electrical Network

Appendix D1

Appendix D2

Appendix D3

Appendix D4

Appendix E

Geographic information system for Hebron Electrical Network

Appendix E1

Appendix E2

Appendix E3

Appendix F

Simulation Summary

Peak Load Demand Using TSS Tool

Timepoint Load MW

Date	Time	Num Loads	Total MW Load	Alfahs MW	Alras MW	Alhusen MW
12/27/2035	12:00:00 AM	8	80.7	13.33	15.34	11.03
12/27/2035	1:00:00 AM	8	65.9	11.19	12.88	7.45
12/27/2035	2:00:00 AM	8	56.4	9.58	11.03	6.38
12/27/2035	3:00:00 AM	8	54.7	9.29	10.69	6.19
12/27/2035	4:00:00 AM	8	55.1	9.35	10.76	6.23
12/27/2035	5:00:00 AM	8	61.4	10.42	11.98	6.94
12/27/2035	6:00:00 AM	8	71.2	12.09	13.92	8.05
12/27/2035	7:00:00 AM	8	95.8	16.27	18.72	10.83
12/27/2035	8:00:00 AM	8	117.3	20.38	23.45	13.57
12/27/2035	9:00:00 AM	8	128.6	21.84	25.12	14.54
12/27/2035	10:00:00 AM	8	160.8	27.31	31.42	18.19
12/27/2035	11:00:00 AM	8	170.8	28.99	33.35	19.31
12/27/2035	12:00:00 PM	8	162.2	27.54	31.69	18.34
12/27/2035	1:00:00 PM	8	161.1	27.36	31.48	18.22
12/27/2035	2:00:00 PM	8	164	27.84	32.03	18.54
12/27/2035	3:00:00 PM	8	148.6	25.24	29.03	16.81
12/27/2035	4:00:00 PM	8	150.3	25.51	29.35	16.99
12/27/2035	5:00:00 PM	8	156.9	26.64	30.64	17.74
12/27/2035	6:00:00 PM	8	146.3	24.84	28.58	16.55
12/27/2035	7:00:00 PM	8	141	23.94	27.55	15.95
12/27/2035	8:00:00 PM	8	137.9	23.41	26.94	15.57
12/27/2035	9:00:00 PM	8	127.5	21.65	24.9	14.42
12/27/2035	10:00:00 PM	8	113.3	19.24	22.13	12.81
12/27/2035	11:00:00 PM	8	74.7	16.56	19.06	11.03

Timepoint Load MW

Date	Time	Alharyeq MW	Emaldalyah MW	Algarbeah MW	Alduhdah MW	Halhul MW
12/27/2035	12:00:00 AM	9.49	5.24	9.69	12.28	4.28
12/27/2035	1:00:00 AM	7.96	4.4	8.13	10.31	3.59
12/27/2035	2:00:00 AM	6.82	3.77	6.96	8.83	3.07
12/27/2035	3:00:00 AM	6.61	3.65	6.75	8.56	2.98
12/27/2035	4:00:00 AM	6.65	3.67	6.79	8.61	3
12/27/2035	5:00:00 AM	7.41	4.09	7.57	9.6	3.34
12/27/2035	6:00:00 AM	8.61	4.75	8.79	11.14	3.88
12/27/2035	7:00:00 AM	11.58	6.4	11.82	14.99	5.22
12/27/2035	8:00:00 AM	11.78	8.01	14.81	18.77	6.54
12/27/2035	9:00:00 AM	15.54	8.58	15.86	20.12	7
12/27/2035	10:00:00 AM	19.43	10.74	19.84	25.16	8.76
12/27/2035	11:00:00 AM	20.63	11.4	21.06	26.71	9.3
12/27/2035	12:00:00 PM	19.6	10.83	20.01	25.37	8.83
12/27/2035	1:00:00 PM	19.44	10.76	19.88	25.21	8.78
12/27/2035	2:00:00 PM	19.81	10.94	20.23	25.64	8.93
12/27/2035	3:00:00 PM	17.96	9.92	18.33	23.25	8.1
12/27/2035	4:00:00 PM	18.15	10.03	18.54	23.5	8.18
12/27/2035	5:00:00 PM	18.95	10.47	19.35	24.54	8.54
12/27/2035	6:00:00 PM	17.68	9.77	18.05	22.89	7.97
12/27/2035	7:00:00 PM	17.04	9.41	17.4	22.06	7.68
12/27/2035	8:00:00 PM	16.66	9.2	17.01	21.57	7.51
12/27/2035	9:00:00 PM	15.4	8.51	15.73	19.94	6.94
12/27/2035	10:00:00 PM	13.69	7.56	13.98	17.72	6.17
12/27/2035	11:00:00 PM	11.78	6.51	12.03	15.26	5.31

Generation Economic Values

Gen Records

Name of Gen	AGC	Fast Start	OPF MW Control	Gen MW	Cost $/hr (generation only)	MW Marg. Cost of Bus	IC for OPF
Solar Panel	YES	NO	Yes	10	0.00	8198.87	10.00
Gas	YES	YES	Yes	30	58546.46	7995.53	3304.14
Crude Oil	YES	NO	Yes	50	122574.00	7836.12	4380.99
Diesel	YES	NO	Yes	96.3	323119.50	6662.70	6662.70

Gen Records

Name of Gen	Initial MW	Initial Cost	Min MW	Max MW	Cost Model	Fuel Type	Profit $/hr
Solar Panel	10	0.00	0	10	None	Solar	81988.68
Gas	30	58546.46	0	30	Cubic	Natural Gas	181319.56
Crude Oil	50	122574.00	10	50	Cubic	Jet Fuel	269231.98
Diesel	96.3	323119	40	100	Cubic	Distillate Fuel Oil	317795.93

Appendix G

Data Collection for Power System

Distances Between Tie Points

These distances are representing the actual path for the tie lines.

From	To	Distance (m)
MPC	Alduhdah	4017
MPC	Alhusen	1280
MPC	Alras	475
MPC	Alfahs	3883
MPC	Emaldaleyah	3883
MPC	Algarbeah	2670
MPC	Alharyeq	4260
MPC	Halhul	5160
IEC	MPC	1067
Diesel Power Plant	MPC	7000
Gas Power Plant	MPC	11865
Oil Power Plant	MPC	13686
Solar Power Station	Halhul	2350
Alhusen	Algarbeah	2351
Emaldaleyah	Alharyeq	2654
Emaldaleyah	Algarbeah	812
Emaldaleyah	Alras	701
Alduhdah	Halhul	787
Alduhdah	Algarbeah	1031
Alfahs	Alharyeq	903

Estimated Area for Power Plants

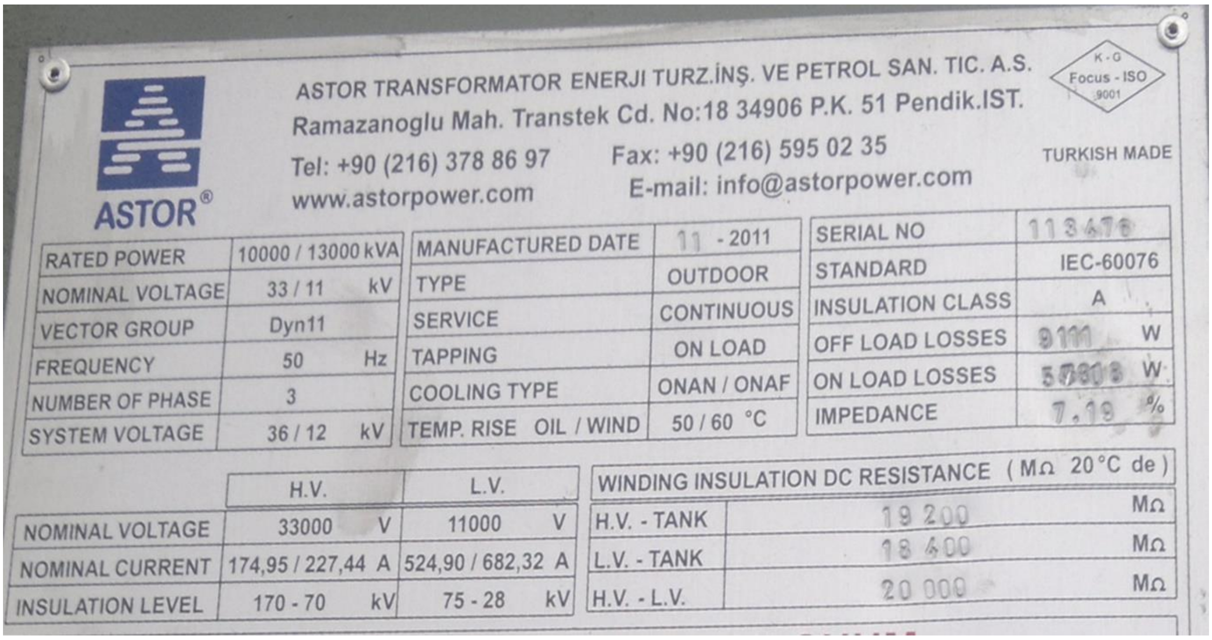
These estimated areas are chosen to be sufficient to build these plants.

*Note: 1 donum = 1000 m^2

Name of Station	Area in donum
Diesel Power Plant	4890
Gas Power Plant	1620
Oil Power Plant	4540
Solar Power Station	2740

*These data Are collected from GIS

Transformer Characteristic



Resistance and reactance values for the transformer.

	R	X
Transformer	0.00539	0.00475

*These data Are collected from HEPCO

Transmission Line Characteristic

20,3/35 kV XLPE Yalıtkanlı, Aluminyum İletkenli, Orta Gerilim Enerji Kabloları

20,3/35 kV XLPE Insulated, Aluminum Conductor, Medium Voltage Power Cables

YAPISI
1 Aluminyum iletken
2 İç yarı iletken tabaka
3 XLPE yalıtkan
4 Dış yarı iletken tabaka
5 Yarı iletken bant
6 Bakır siper
7 Koruma Bandı
8 PVC dış kılıf

CONSTRUCTION
Aluminum conductor
Inner semi conductive layer
XLPE insulation
Outer semi conductive layer
Semi conductive tape
Copper wire screen
Protecting tape
PVC outer sheath

Tip : YAXC7V-R

Code *: (N)A2XSY*

Standartlar : TEDAŞ

Standards *: IEC 60502-2*

Kullanıldığı yerler
Bu kablolar bina içi ve dışı uygulamalarda, kablo kanallarında, borularda veya mekanik darbe riski olmayan yerlerde toprağa doğrudan serilerek kullanılabilir.

Application
This design of cable is used for indoor and outdoor applications. Cable will be installed inside a duct, cable tray, or direct burial where there is no mechanical damage risk.

Gerilim Değerleri
Anma gerilimi : Uo/U= 20,3/35 kV

Voltages
Rated voltage : Uo/U= 20,3/35 kV

Teknik Bilgiler
Maksimum işletme sıcaklığı 90°C
Maksimum kısa devre sıcaklığı 250°C

Technical Data
Maximum operating temperature 90°C
Short - circuit temperature 250°C

Nominal Kesit Alanı	Yalıtkan Et Kalınlığı	Dış Çap Yaklaşık	Net Ağırlık Yaklaşık	20°C'de İletken DC Direnci (Maks.)	Çalışma İndüktansı Yaklaşık		Çalışma Kapasitesi Yaklaşık	Akım Taşıma Kapasitesi*					
								Toprakta		Havada		Boruda	
Nominal Cross Section	*Insulation Thickness*	*Overall Diameter Approx.*	*Net Weight Approx.*	*Conductor DC Resistance At 20°C (Maks.)*	*Operating Inductance Approx.*		*Operating Capacity Approx.*	*Current Carrying Capacity In**					
								Earth		*Air*		*Duct*	
mm²	mm	mm	kg/km	Ω/km	Flat mH/km	Trefoil mH/km	µF/km	A	A	A	A	A	A
1x35/16rm	9,0	35	1370	0,868	0,77	0,51	0,11	134	129	157	154	123	122
1x50/16rm	9,0	36	1535	0,641	0,75	0,48	0,12	157	152	189	184	146	144
1x70/16rm	9,0	38	1800	0,443	0,71	0,46	0,14	192	186	236	230	178	176
1x95/16rm	9,0	40	2100	0,320	0,68	0,44	0,15	129	221	287	280	213	210
1x120/16rm	9,0	42	2400	0,253	0,66	0,42	0,16	260	252	332	324	242	240
1x150/25rm	9,0	43	2810	0,206	0,64	0,40	0,17	288	281	376	368	271	267
1x185/25rm	9,0	45	3220	0,164	0,62	0,39	0,18	324	317	432	424	307	303
1x240/25rm	9,0	48	3830	0,125	0,60	0,37	0,20	373	367	511	502	356	351
1x300/25rm	9,0	50	4450	0,100	0,58	0,36	0,23	419	414	586	577	402	397
1x400/35rm	9,0	53	5550	0,0778	0,55	0,35	0,25	466	470	676	673	457	451

Resistance and reactance values for the transmission line.

	R	X
Transmission Line	0.100	0.138

*These data Are collected from HEPCO

Cost and Performance Projection for A Gas Turbine Power Plant

Year	Capital cost($/KW)	Variable O&M ($/MWhr)	Fixed O&M ($/KWhr-yr)	Hate Rate (Btu/KWhr)	Construction Schedule(month)
2008	671	-	-	-	-
2010	651	29.9	5.26	10,390	30
2015	651	29.9	5.26	10,390	30
2020	651	29.9	5.26	10390	30
2025	651	29.9	5.26	10,390	30
2030	651	29.9	5.26	10,390	30
2035	651	29.9	5.26	10,390	30
2040	651	29.9	5.26	10,390	30
2045	651	29.9	5.26	10,390	30
2050	651	29.9	5.26	10,390	30

Cost and Performance Projection for A Diesel Power Plant

Year	Capital cost($/KW)	Variable O&M ($/MWhr)	Fixed O&M ($/KWhryr)	Hate Rate (Btu/KWhr)	Construction Schedule(month)
2008	3040	-	-	-	-
2010	2890	3.71	23	9,370	55
2015	2890	3.71	23	9,370	55
2020	2890	3.71	23	9,370	55
2025	2890	3.71	23	9000	55
2030	2890	3.71	23	9000	55
2035	2890	3.71	23	9000	55
2040	2890	3.71	23	9000	55
2045	2890	3.71	23	9000	55
2050	2890	3.71	23	9000	55

* This information is collected from cost and performance data for power generation technologies, Prepared for the National Renewable Energy Laboratory, February 2012.

Fuel cost curve coefficient

Unit Size (MW)	Diesel			Crude Oil			Gas		
	α	β	γ	α	β	γ	α	β	γ
50	49.92	10.06	0.0103	52.87	10.47	0.0116	53.62	10.66	0.0117
200	173.61	8.67	0.0023	180.68	9.039	0.00238	182.62	9.19	0.00235
400	300.84	8.14	0.0015	312.35	8.52	0.00150	316.45	8.61	0.00150
600	462.28	8.28	0.00053	483.44	8.65	0.00056	490.02	8.73	0.00059
800	751.39	7.48	0.00099	793.22	7.74	0.00107	824.40	7.73	0.00117
1200	1130.8	7.74	0.00067	1194.6	7.72	0.00072	1240.32	7.72	0.00078

* These values are collected from optimal economic operation of electric power systems, Christensen

Fossil Fuel Heat Characteristic

Fossil fuel	Unit rating	Output (MJ/KW.hr)				
		100%	**80%**	**60%**	**40%**	**25%**
Diesel	50	11.59	11.69	12.05	12.82	14.13
Oil	50	12.12	12.22	12.59	13.41	14.78
Gas	50	12.33	12.43	12.81	13.64	15.03
Diesel	200	10.01	10.09	10.41	11.07	12.21
Oil	200	10.43	10.52	10.84	11.54	12.72
Gas	200	10.59	10.68	11.01	11.72	12.91
Diesel	400	9.49	9.53	9.75	10.31	11.25
Oil	400	9.91	9.96	10.18	10.77	11.75
Gas	400	10.01	10.06	10.29	10.88	11.88
Diesel	600	9.38	9.47	9.77	10.37	11.40
Oil	600	9.80	9.90	10.20	10.84	11.91
Gas	600	9.91	10.01	10.31	10.96	12.04
Diesel	800/1200	9.22	9.28	9.54	10.14	-
Oil	800/1200	9.59	9.65	9.92	10.55	-
Gas	800/1200	9.70	9.75	10.03	10.67	-

*****These data are collected from optimal economic operation of electric power systems, Christensen.