An-Najah National University

Faculty of Graduate Studies

Electric Energy Consumption of West-Bank: Past, Present and Forecast until 2025 Considering a Partial Coverage by PV-Solar

By

Ola Yousef Ahmad Antari

Supervisor

Prof. Marwan Mahmoud

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This Thesis was Successfully Defended on 2/ 11/ 2020 and approved by:

Defense Committee Members		Signature
1. Prof. Marwan Mahmoud	/ Supervisor	....
2. Dr. Basim Alsayed	/ External Examiner	....
3. Dr. Moien Omar	/ Internal Examiner	....

Dedication

إلى التي علمتني كيف امسك القلم وكيف اكتب الحرف وكيف اقرأ الكلمة ...إلى روح أمي الغالية رحمها الله...

إلى من علَّمني كيف أقف بكل ثبات فوق الأرض.. الى السند والأمان على هذه الأرض.. الى أبي الغالي اطال الله في عمره...

إلى اخواتي الرائعات.. اللواتي وقفن الى جانبي بكل الحب والدعم والاسناد.. منى وهبة.

إلى اخوتي.. ضلعي الثابت في هذه الحياة.. الغاليين كثيراً على قلبي.. أحمد ومحمد ووسيم..

إلى الصديقة بمثابة الأخت.. اليكِ أسيل كرزون، اليكِ بيسان حسن، اليكِ بلسم الجندي..

اليكم جميعا اهدي هذه الاطروحة...

Acknowledgement

"يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ"

(سورة المجادلة: 11)

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الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Electric Energy Consumption of West-Bank: Past, Present and Forecast until 2025 Considering a Partial Coverage by PV-Solar

أقر بأن ما اشتملت عليه هذه الرسالة انما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة اليه حيثما ورد، وان هذا الرسالة ككل أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any degree or qualification.

Student's Name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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List of Abbreviations

WB	West Bank
IEC	Israel Electric Company
RE	Renewable Energy
PV	Photovoltaic
PENRA	Palestinian Energy & Natural Resources Authority
PNA	Palestinian National Authority
PETL	Palestinian Electricity Transmission L.t.d
PERC	Palestinian Electricity Regulatory Council
GWH	Giga watt hour
KWH	Kilo watt hour
GDP	Gross Domestic Product
PCBS	Palestinian Central Bureau of Statistics
DISCOs	Distribution companies

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Abstract

The Electrical Energy sector in the West Bank suffers from different problems, the biggest one is the fully control of the Israeli occupation on the electricity source, this makes the energy sector ineffective to meet the needs of consumers.

This research aims to study the whole energy system in the West Bank by lighting on the obstacles that the energy sector has, then to predict the percentage of increasing in the load demand either the peak load or the energy consumption, these numbers could be used to know how much of energy do we need in the future.

The load forecasted (peak demand and energy consumption) had indicated an average growth rate of 4.67% and 4.97% respectively till the year of 2025.

An important solution which helps to cover parts of the electrical energy consumption is the renewable energy particularly the solar energy which has a real potential in Palestine. In this study A 30 MWp PV power plant is mentioned as one of the expected planning for the near future energy coverage.

Chapter One
Introduction

1. Introduction

1.1 General Background

Palestine is a country which has no electrical generation to supply and meets its demand. It depends mainly on the Israel's electrical network that called Israel Electric Company (IEC). On the other hand, there is one electrical generation station that is located in Gaza strip, but this station doesn't fulfill all demands of Gaza Strip, so that the Israel's electricity supply along with Egyptian electrical supply is still the basic source of electricity in Gaza.

Nowadays, fossil fuel is considered as the main energy supplier of the worldwide economy, but the high use of it reflects badly on the environment caused accordantly a climate changes, smog, and other human health problems, along with the increasing of energy demands, furthermore the oil and other fossil fuel sources will be drained and end up in the next centuries, which makes the world to look for another alternative clean and renewable resources in power generation [1].

The load forecasting is an important way for the electric industry in the deregulated economy. Since it has many applications including energy purchasing and generation, contract evaluation, load switching and infrastructure development. Load forecasting have a large variety of mathematical methods that were developed [2].

In this thesis load forecasting was done to predict the total demand (power and energy) in West Bank in the upcoming years specifically until the year of 2025, this analyzing way helps basically to find the effective solution to meet up the increasing in the consumption for the future.

The renewable energies are encouraging to give flexibility to the system power supply, also reducing the external dependence of electricity and reduce problems that caused basically by the environmental impact of using fossil fuels and the shortage of its resources. In addition, RE can play an important role in energy supply in remote and isolated areas of Palestine where no electricity is available during 24 h a day [3] .

One of the most important and efficient renewable sources is the solar energy, where the sun is considered as the biggest energy source of life and at the same time it is the unlimited source of most of renewable energy sources. Solar energy can be used to produce electricity directly from using photovoltaic modules, or by using solar thermal or concentrating solar power to heat a media or water and generate steam then electricity. See figure 1.1. [1].

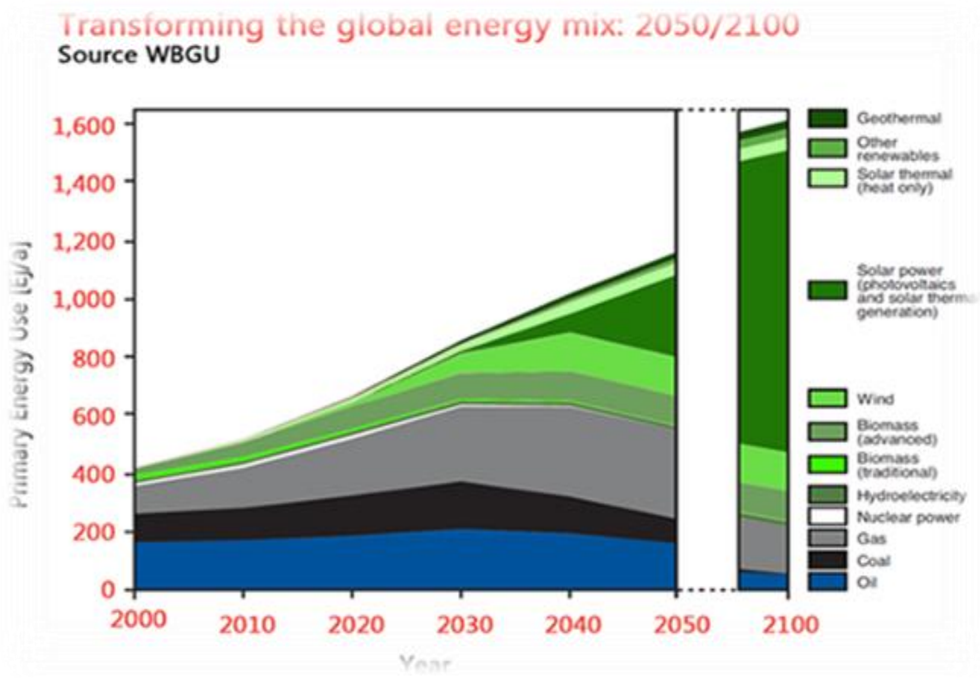

Figure (1-1): Transforming the Global Energy.

1.2 Research Objectives

The objectives of this thesis are referred to the followings:

- Analyze the current electric energy sector situation in Palestine (practically West-Bank): production, consumption, the electric power transmission grid and the role of political issues on electric energy sector.

- Forecasting the energy consumption development in West-Bank till 2025.

- Highlight the status of the potential of renewable energy (especially solar PV energy) as future energy source in the West-Bank.

- Design future PV solar power plants to cover a particular partial percentage of West-Bank consumption of electricity: technical and economic feasibility of PV power plants.

1.3 Activities and Methodology

The main activities that done to achieve the goals of this thesis are summarized in the following work packages (WP):

WP-1: Literature survey.

WP-2: Study the electricity consumption during the past seven years, how it changes, the factors that affected the consumption in the West-Bank..etc.

WP-3: Collecting data from different load institutions (As PENRA, the Palestinian department for Statistics, etc..), and develop the required algorithms to achieve the forecast estimated for the energy consumption in the West-Bank till 2025.

WP-4: Study and analyze the challenges and obstacles by Israel against developing the energy sector in West-Bank.

WP-5: Determining the capacity of PV distribution generators necessary for covering an economically feasible portion of future electric energy consumption in West-Bank.

WP-6: Building several distribution PV solar power plants-by simulation-to cover a part of electricity needs of West-Bank, and to define the areas which could be suitable to install the PV plants.

WP-7: Evaluate the economic feasibility of installing these distribution PV plants.

WP-8: Determining the main advantages and disadvantages of installing the solar PV plants.

WP-9: Preparing the final report of this research project which includes all research results and represents the Master Thesis.

Chapter Two

Energy Sector Situation in Palestine

2. Introduction

The energy sector in Palestine is considered as one of the highly different issues compared to other countries in the Middle East. This is mainly due these reasons: (i) non-availability of natural resources, (ii) unstable political conditions, (iii) financial crisis and high density population.

Moreover, Palestine is highly dependent on several countries for 100% of its fossil fuel imports and for 87% of its electricity imports. Recently energy demand in Palestine have increased rapidly due to high growth of population, increasing living standards and rapid growth of industry [3].

Both of contracted power and the available power resources are insufficient to meet the growth in power demand. Moreover, the electric power supplied by Israel is not fully controlled by a purchase agreement between the PNA and Israel; it is controlled by bilateral contracts between IEC and each one of the Palestinian municipalities, rural councils, or distribution utilities, and newly by a temporary agreement between PETL (Palestinian Electricity Transmission L.t.d) and IEC, this agreement is for Al-Jalama substation only. About 63 localities in the PT are not connected to the public electricity network. Therefore, electrical sector will be unreliable and unsecure.

In general, the electrical energy sector is characterized by a relatively low level of electrical energy consumption; in 2018 the Palestine electrical energy consumption was estimated by 5915.758 GWh/year, which is considered to be the lowest consumption rate in the region [4].

As noted, the Palestinian electricity sector suffers from many problems, such as high distribution technical and non-technical losses, it was estimated to be 21% at the year 2018 [5], this loss reflects economically, which in turn leads to a high price for kWh.

2.1 Electric Energy Production Situation in Palestine

In Palestine, there is only one power plant for electrical energy production which is located in GS, with 140 MW of production total capacity which covers Gaza city and other surrounding areas. The Palestine Electric Company was established in 1999, with 33% of its assets for public shareholders and 67% for private shareholders and with cost of $150 million, Figure (2-1) [6].

Figure (2-1): Gaza power plant

The IEC is considered as the main source of electricity production in WB with a production capacity of 2590 MW. The main production power plants are constructed in Ashkilon and Khadera. In reality, Palestine is completely dependent on the IEC for its electricity needs. Electricity distribution companies in WB are performed by Municipalities [7]. Palestine also has two other electrical energy sources, Jordan and Egypt.

In 2018, the total electrical energy that had been distributed came from IEC as 5360 GWh, Gaza power plant as 254 GWh, Jordan as 87.7 GWh, renewable energy as 51 GWh and Egypt as 36 GWh [8].

2.2 Electrical Grid System in the WB

The electrical energy sector in Palestine has undergone several institutional reforms, which still require further consolidation. In 1995, the sector was reorganized to cluster most of the former municipal service providers into six local distribution utilities. The Electricity Law of 2009 created the Palestinian Electricity Regulatory Council (PERC), with responsibility for tariff setting and monitoring, as well as the Palestinian Electricity Transmission Company Ltd (PETL), a new transmission operator and wholesale single buyer. While there is no Palestinian transmission infrastructure at present, PETL will take charge of four high-voltage substations, three of which have been built, to manage the flow of high voltage power from Israel into the West Bank, which previously took place through a myriad of low voltage connection points [9].

In WB there is no high voltage transmission lines and all the lines are medium and low voltage type, electricity is supplied to the WB via 33kV, 22kV and 11kV distribution lines at several connection points with the IEC and recently by ALJALAMAH S.S that is owned by PETL in addition to another three substations that is still under construction.

ALJALAMAH S.S is one of three other 161/33KV substations with a capacity of 135 MW scalable to become 180 MW, just 80 MW are used right now regarding the purchasing agreement between IEC and PETL, this substation supplies electrical energy to the area of Jenin and its environs, the other three substations distribute across WB as follows [Figure (2-2)]:

- SARRA S.S with a capacity of 135 MW, it is supposed to supply electrical energy to the area of Nablus and its environs.

- BEIT ULA S.S with a capacity of 90 MW scalable to become 180MW, it is supposed to supply electrical energy to its surrounding area.

- RAMALLAH (QALANDYA) S.S is the biggest S.S with a capacity of 180 MW, it is supposed to supply electrical energy to the area of Ramallah and its environs. [7]

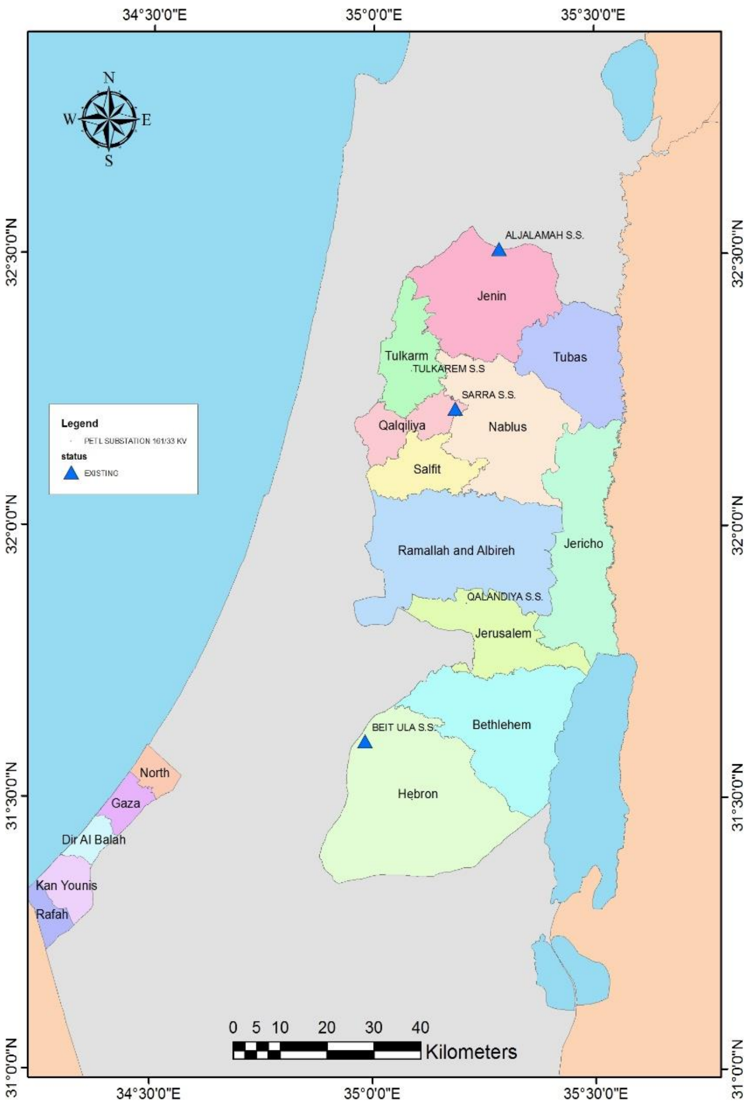

Figure (2-2): The sites of the substations of PETL

2.3 Electric Energy Distribution Situation in WB

The Distribution of electrical power is considered as one of the responsibilities of municipalities, councils and distribution companies. See Table 2-1[10].

Table 2-1: Palestinian electric distribution companies

#	Abbreviation	Name	Location
1	NEDCO	Northern Electricity Distribution Company	Northern West Bank
2	JDECO	Jerusalem District Electric Company	Ramallah and around area
3	HEPCO	Hebron Electric Power Company	Hebron Municipality
4	SELCO	Southern Electric Company	Southern Municipalities Yatta, AlThaherya
5	GEDCO	Gaza Electricity Distribution Company	Gaza
6	TDECO	Tubas District Electricity Company	Tubas city and region

The maximum peak load for the DISCOs reached 805 MVA in January 2018 [5].

2.4 The Electrical Energy Consumption Situation in WB

The electrical energy consumption of Palestine especially the WB is the lowest compared with the surrounding countries.

The total number of consumers for all DISCOs in WB reached 502,310 consumers in the year of 2018 divided into the following category:

- Household

- Commercial
- Industrial
- Others

Table (2-2) and Figure (2-3) shows the number of consumers in the year of 2018 divided according to the category for all DISCOs in WB.

Table 2-2: Number of consumers for all DISCOs in WB.

Consumer category	JEDCO	NDECO	TEDCO	HEPCO	SELCO	Total
Household	236,781	81,685	16,694	38,055	28,236	401,451
Commercial	43,366	19,424	1,859	11,875	3,787	80,311
Industrial	1,541	651	75	1,538	137	3,942
Others	9,625	3,327	654	1,941	1,059	16,606
#of consumers in the year 2018	291,313	105,087	19,282	53,409	33,219	502,310

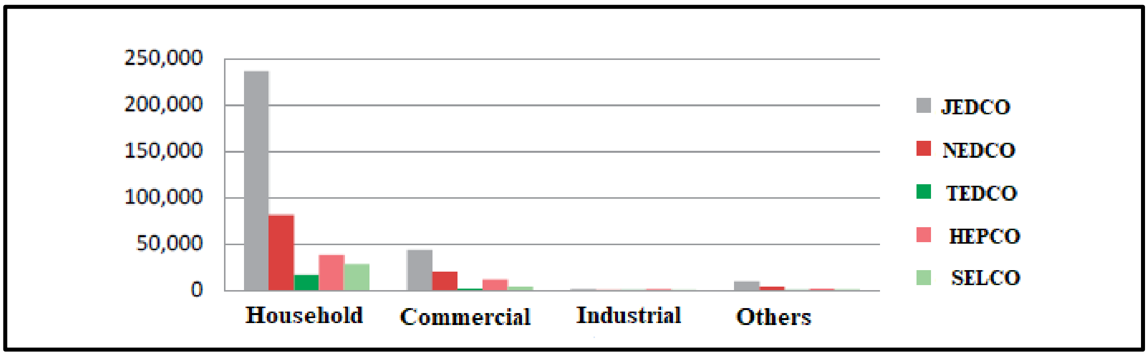

Figure (2-3): Number of consumers for all DISCOs in WB.

The total consumption and the loss percentage of the years 2015-2018 for all consumers of all DISCOs in WB are divided as shown in Table (2-3) [5].

Table 2-3: Total consumption and the loss percentage of the years 2015-2018 for all DISCOs in WB.

Year	2015	2016	2017	2018
Consumption (GWh)	3182.3	2739	3732	3775
Loss Percentage(%)	22	22	23	21

The total sales for all consumers of all DISCOs in WB reached 2937 GWh and the total purchases reached 3775 GWh in the year of 2018 divided as shown in Table (2-4) [5].

Table 2-4: The total sales purchases for all DISCOs in WB.

	JEDCO	NDECO	TEDCO	HEPCO	SELCO	Total
Total sales	1,776	532	113	369	148	2,937
Total purchases	2,334	650	137	466	188	3,775

2.5 The Electrical Energy Problems in WB

The electrical energy in Palestine in general suffers from many problems, the biggest one is that the main source of electricity in the WB comes from the IEC, and some of these problems are:

2.5.1 Distribution Losses

Distribution losses are considered as one of the main challenges for the electric rehabilitation plan, with highest value in the region. Although the IEC is the main supplier of electricity, which uses the electric transmission and distribution network, no rehabilitation was made to this network. The minimum distribution losses in Israel is about (6-7) %, while the electricity distribution loss in Palestine is about 10% to 20% of the total energy injected [11].

2.5.2 High Cost of Electrical Energy

Palestine is mainly depending on import of oil and petroleum products. Electrical energy in Palestine is characterized by the lowest total energy consumption with relatively high cost compared with other countries in the region. The residential sector represents the majority of this consumption. The largest source of different types of imported fossil fuels consumed in Palestine originates from Israel, while the remainder comes from Jordan and Egypt [12].

Palestinian Electricity Regulatory Council (PERC) set a new uniform pricing regime which divided residential consumers into five groups (from NIS 0.465 up to NIS 0.69 per kWh). The tariff for the commercial sector is NIS 0.63. The industry sector has two tariffs: NIS 0.5 for low voltage and NIS 0.45 for medium voltage, while the tariff for the agricultural sector is NIS 0.46 and NIS 0.5 for water pumps. The highest price is in the services sector (NIS 0.8). Obviously, these are very expensive prices [13].

2.5.3 Lack of Electrical Energy Supply

Large number of remote villages and existing settlements make difficult for connecting them in order to improve the electricity services, although the area of Palestine is relatively small comparing to other countries [14].

However, about 63 localities in the WB are not connected to a public electricity network, including 29 in the Hebron district and the probability of connecting them with high voltage grid in the near future is very poor due to financial and political situation, as shown in figure (2-4) [15].

Figure (2-4): Percentage of households that are not connected to electricity network in the PT, July 2006

Chapter Three

Forecasting the Energy Consumption Development in West-Bank till 2025

3.1 General Background

Load demand growth is one of the key forecast parameters that are subject to uncertainty. Load growth is affected by many factors as: (i) the demographic growth, (ii) the local economy, (iii) energy prices and energy conservation.

Power and energy load demand forecasting are the starting point for the energy and power utility industry planning process. Load demand forecasting is an important issue that gives the utilities an indication of the demand for electrical power and energy that leads the utilities to make the decision of adding or retire generation, transmission, or distribution capacity.

Typically, the load-forecast task is performed in two steps. First, an economic and demographic forecast is prepared and the electricity usage forecast is developed. An accurate forecast requires both an accurate economic forecast and an accurate demographic forecast. If the economic forecast or the demographic projections are in error, then probably the load forecast will be in error [16].

Over the last decade, the load forecasting has become highly important for the planning operation of energy systems due to reasons as:(i) the increase in market competition, (ii) the aging infrastructure and renewable integration requirements, therefor the load forecasting can be used for stochastic unit commitment, power supply planning, probabilistic price forecasting, the prediction of equipment failure, and the integration of renewable energy sources [17].

There are a three categories that Load forecasts are divided to: (i) short-term forecasts which are usually from one hour to one week, (ii) medium forecasts which are usually from a week to a year, and long-term forecasts which are longer than year. The forecasts for different time periods are important for different operations within a utility company, the natures of these forecasts are different as well [2].

Load forecasting is considered as a critical point in electrical power production, due to it is used to determine the future prices of the electricity in the market and which units should be committed for economic dispatch. An electric grid may include hundreds of power plants and provide the electricity service for millions of people, so accurate forecasting is crucial so that reliable and economical electric power can be produced and delivered. On another smaller scale, load forecasting is also an important issue for the regulation of micro grids to make sure that the demand is always met [18].

3.2 Load Forecasting Methods

3.2.1 Econometric Method

The Econometric method dependence on doing the forecasts of a time series that is using one or more related time series and sometimes past values of the time series.

This process includes improving a regression model that the time series is forecasted as the dependent variable (in our case the peak power demand or the electrical energy consumption); in addition, the independent variables like (the total population & GDP/capita) are the related time series and the past values of the time series.

Accordingly, the peak power demand and total energy forecast is achieved by connecting the past series values of total population and total national economy (GDP/capita).

3.2.2 Appliance Saturation Model

This method is an engineering type methodology. The load forecasting dependence on determining the number of the customers which use a particular appliance like the central air conditioning, together with the typical annual energy used by this appliance.

After that forecasting done by the number of appliances that expected to use in the future along with a forecast of how the total annual energy usage per appliance will change, in the result an energy load forecast is made.

3.2.3 End-Use Energy Model

This method is the same as the appliance saturation method but it examines the end use process as commercial, residential, industrial etc.

The benefit of using any method depends on data availability. About the appliance saturation and the end use methods, it is difficult to analyze due to the lack of data.

To use the End- Use method in the West Bank (as in other developing countries) is generally unreliable because the data about end uses mainly the industrial end uses and that data are unavailable or not enough. Furthermore, the future is not clear about the industrial zones in the West Bank.

The econometric method is used in this study as it will be the most practical method to predict the electricity demand (peak power and energy) up to year 2025 based on a macroeconomic forecast.

This macroeconomic forecast depends on variables or drivers that include :(i) total population, (ii) the gross domestic product (GDP), (iii) industrial production and electricity price.

The two main uncertainty variables will be used to forecast are the load growth and the demographic variable that include the total population, natural growth rate, migration rate and the economic variable (GDP per capita).

Noting that the industrial index won't be used as a driving variable because the industrial sector in the West Bank is not active, as well as there is a lack in the data and statistics about this sector.

3.3 Analytical Method

First of all, the two main driving variables that are used to forecast the maximum demand (peak power and energy) are total population and GDP per capita.

Note that one of the driving variables may not have the same effect like the other driving variables, but it may have the same effect or even more in the future.

Some equations were made in a previous study to obtain the best one that will give the most accurate result for the forecasting.

In that study two equations were used to obtain the forecasting represented as follows:

- The first equation that had been used to represent the relation between the dependent variable (Peak demand) and independent variables (population and GDP) is a quadratic function as in equation 3.1. [16].

$$\hat{Y} = A+B*X+C*Z+D*X^2 +E*Z^2 \quad (3.1)$$

$\hat{Y}$ = Predicted Peak demand in MW

A, B, C, D, E are equation coefficients

X= total population

Z= GDP per capita

Where A= 840.7268, B= 0.001737, C= -2.783115, D = -4.94303E-10, E= 0.000903263.

So the equation (3.1) will be as follows:

$\hat{Y}$ = 840.7268+0.001737*X - 2.783115*Z - 4.94303E-10*X^2+9.033E-4*Z^2

- The second equation that had been used represent the relation between the dependent variable (energy consumption) and independent variables (population and GDP) is a quadratic function as in equation 3.2.

$$En=A1+B1*X+C1*Z+D1*X^2+E1*Z^2 \qquad (3.\ 2)$$

En= total forecasted energy consumption (GWH)

A1, B1, C1, D1, E1 are equation coefficients

X = total population

Z= GDP/ capita

Where A1 = 0.00001, B1 = 0.00001, C1= -207.287, D1 = 7.47E-07,

E1= - 0.1105298.

Secondly, to get the load forecast done as specified in the above equations, a data for the variables (total population, GDP/capita, peak load and energy consumption) should be obtained.

The growth of the total population and the GDP/capita, are received from Palestinian Central Bureau of Statistics(PCBS), and the actual peak load and energy consumption are received from PENRA, so the forecasting till the year of 2025 is shown in the tables 3.1 and 3.2.

Table 3.1: The annual growth in the peak load in the West Bank up to the year of 2025.

Year	**Total Population**	**GDP/capita ($)**	**Actual Peak (MW)**	**Forecasted Peak (MW)**	**Peak Growth rate (%)**
2000	1,943,658	1858	315.7	296.66	
2001	1,992,577	1900	340.5	312.13	5.2
2002	2,042,306	1940	365.4	326.75	4.68
2003	2,093,381	1982	397.5	342.95	4.9
2004	2,146,400	2024	417.3	359.01	4.7
2005	2,203,738	2065	437.8	372.64	3.8
2006	2,262,735	2106	458.8	385.23	3.4
2007	2,323,469	2147	480.3	396.44	2.9
2008	2,376,893	2188	502.5	411.5	3.8
2009	2,430,170	2230	525.2	428.20	4
2010	2,483,446	2271	548.5	443.93	3.6
2011	2,536,725	2316	569.5	465.47	4.8
2012	2,590,152	2362	588.1	489.22	5.1
2013	2,643,435	2410	607.0	517.24	5.7
2014	2,696,714	2458	626.4	546.62	5.7
2015	2,749,990	2507	646.1	579.10	5.9
2016	2,803,411	2557	675.8	614.80	6.1
2017	2,856,691	2608	706.9	654.28	6.4
2018	2,921,170	2661	739.4	686.86	4.9
2019	2,986,714	2714	773.4	719.12	4.5
2020	3,053,183	2768		753.23	4.7
2021	3,120,448	2820		782.54	3.8
2022	3,189,097	2875		817.54	4.5
2023	3,259,257	2928		846.08	3.5
2024	3,324,442	2985		892.97	5.5
2025	3,390,931	3041		936.71	4.9

As shown in the table 3.1 the forecasted peak demand increases by an average growth rate of 4.67% over the years.

Moreover, the actual peak demand numbers are so close to the forecasted one with an error of 7% in the year of 2019 and that's proof that the equation which had been used is accurate and efficient. See Figure (3-1).

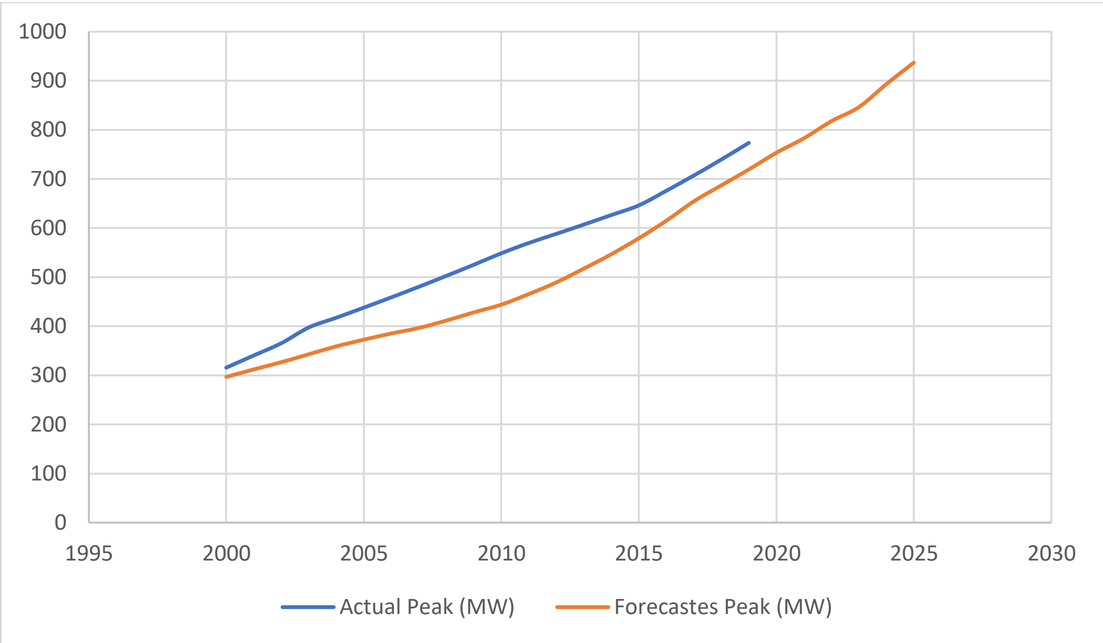

Figure (3-1): The relationship between the actual peak load and the forecasted peak load**.**

Table 3.2: The annual growth in the energy consumption in the West Bank up to the year of 2025

Year	Total Population	GDP/ Capita ($)	Actual Energy (GWH)	Forecasted Energy (GWH)	Growth rate of energy Consumption %
2000	1,943,658	1858	1573.453	2060	
2001	1,992,577	1900	1710.104	2170	5.3
2002	2,042,306	1940	1,741.8	2300	5.9
2003	2,093,381	1982	1,858.3	2430	5.65
2004	2,146,400	2024	1873.10	2570	5.7
2005	2,203,738	2065	1,981.31	2730	6.2
2006	2,262,735	2106	2,109.8	2900	6.2
2007	2,323,469	2147	2,244.08	3080	6.2
2008	2,376,893	2188	2,384.1	3240	5.1
2009	2,430,170	2230	2,530.3	3400	4.9
2010	2,483,446	2271	2,682.7	3570	5
2011	2,536,725	2316	2,827.1	3730	4.5
2012	2,590,152	2362	2,962.2	3910	4.8
2013	2,643,435	2410	3,101.9	4080	4.3
2014	2,696,714	2458	3,246.4	4260	4.4
2015	2,749,990	2507	3,395.7	4430	4
2016	2,803,411	2557	3,551.9	4620	4.3
2017	2,856,691	2608	3,715.3	4800	3.9
2018	2,921,170	2661	3,886.21	5040	5
2019	2,986,714	2714	4,064.9	5290	4.9
2020	3,053,183	2768		5540	4.9
2021	3,120,448	2820		5810	4.9
2022	3,189,097	2875		6090	4.8
2023	3,259,257	2928		6380	4.8
2024	3,324,442	2985		6650	4.2
2025	3,390,931	3041		6940	4.4

As shown in the table 3.2 the forecasted energy consumption increases by an average growth rate of 4.97% over the years.

Moreover, the actual energy consumption numbers are close to the forecasted one with an error of 23% in the year of 2020, the percentage of error increased here because of the actual data collection. See Figure (3-2).

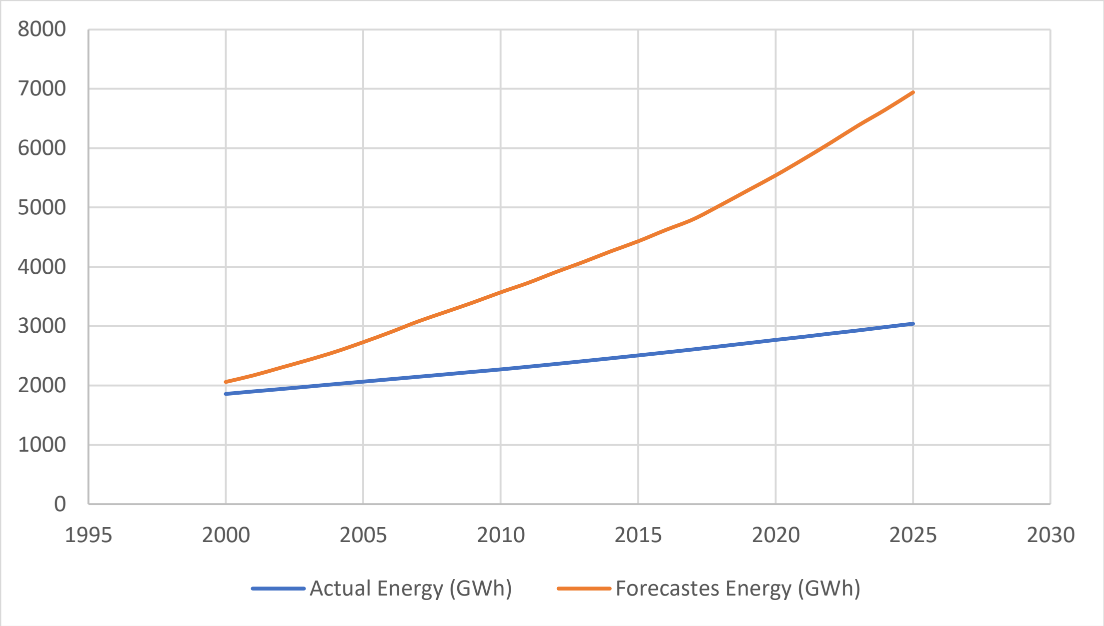

Figure (3-2): The relationship between the actual energy consumption and the forecasted energy consumption**.**

Chapter Four

Potential of Renewable Energy in Palestine

4.1 Overview of the Renewable Energy

Renewable energy is an energy that is derived from natural processes that are replenished constantly. In its various forms, it is deriving directly or indirectly from the sun, or from heat generated deep within the earth. Included in the definition is the energy generated from solar, wind, biomass, geothermal, hydropower, ocean energy, bio-fuels and hydrogen derived from renewable resource.

The perfect solution to fulfill the huge increase in energy demand is Renewable Energy (RE), as well as to save the environment by reducing CO_2 emissions, which increases in 2018 by more than 4%, thus avoiding 215 Mt of emissions. The generated electricity from the sources of RE has increased by more than 7% in 2018. And about 45% of the growth in the generated electricity around the world is now fulfilled by RE, and it is also accounted for more than 25% of the world's power output. Apart from this, the generated electricity from wind has grown by about 12% in 2018, and the generated electricity from solar PV has risen by about 31% [19, 20].

4.2 The Renewable Energy in Palestine

Renewable energy is the optimum solution of energy security problem in Palestine, which will improve living and the economic conditions [21, 22], it will also create energy security by using RE for electricity production. This will reduce the imported electricity and thus creating more energy sustainability with less cost, as well as it will reduce CO2 emissions. In fact, the carbon emissions in 2016 amounted to 4,645.5 tons according to PCBS [4].

The renewable energy production contributed only by 1.9% of the total energy, the percent of solar energy used is just 8%, despite its high potential. However, this percentage has declined over the last years, and most of this energy is used for heating water. According to the Palestinian Central Bureau of Statistics, approximately 66% of households in the Palestinian Territories use renewable energy (solar and Biomass) to heat water in residential buildings [23]. In addition, the potential of wind power in Palestine has been mentioned in many studies but this is not applied at all [23]. RE development needs research on RE sources, establishing national laboratories internationally accredited for RE technologies, and increasing the professional skills related to the RE sector [8].

The Palestinian energy sector consists of three main sources, which are fossil fuels and gas, electricity and renewable energy (thermal). Figure (4.1) shows the percentage of using each source. The main renewable energy sources considered to have potential in Palestine are wind energy, biogas and solar energy [4].

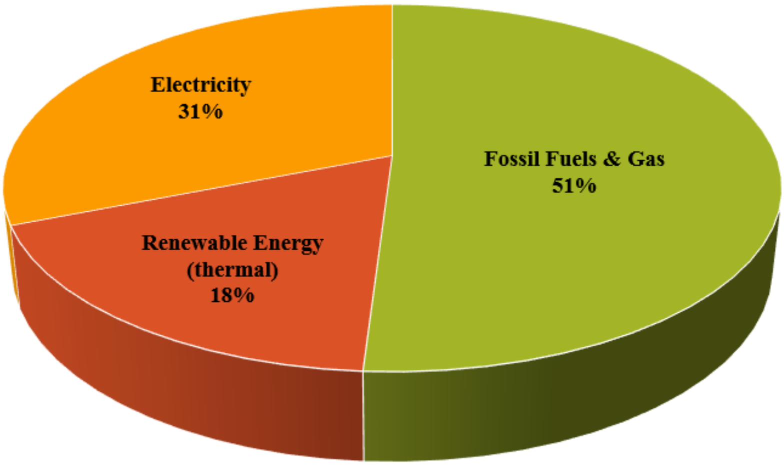

Figure (4.1): The Palestinian Energy sector sources according to PCBS [7]

4.2.1 The Wind Energy Potential in Different Areas in Palestine

Presently, wind energy in Palestine is not exploited, as there is no project based on the exploitation of wind energy. There are studies that confirmed the potential of wind energy and stressed that wind energy has a promising future. However, only few studies related to wind energy potential were performed in the past, and these studies mainly depended on historical data and data from automated meteorological stations which cannot be considered for making a reliable decision [23].

The location of Palestine classified it as low wind speed area in the Middle East. Small wind turbines can be used to generate energy from wind in some areas of Palestine [24], these small wind turbines are especially attractive for supplying energy in the areas located far from the electrical grid [25].

Despite of the small potential of wind energy in Palestine, it has a future outlook on mountains (elevation of about 1000 m); regions of Nablus, Ramallah and Hebron where the speed exceeds 5 m/s have a potential of about 600 kWh/m^2. Some hilly regions in West Bank, such as Nablus, Ramallah, Jerusalem and Hebron, have an average annual wind speed varied in the range of 4–8 m/s [23]. The highest wind potential areas in West Bank are in Hebron and northern Ramallah [25]. Depending on daily wind speed data from the Palestinian Metrological Authority in year 2006 [26], the average wind speed in Nablus and Ramallah cities were 4.346 m/s and 5.521 m/s, respectively.

According to the data of wind speed and direction, which Energy Research Centre (ERC) had been measured in cities like Ramallah, Tubas, Jericho, Hebron, and Salfeet in 2013, the wind speed in these cities was found to be higher in summer months except for Salfeet which found that wind speed is higher in winter months. The wind speed averages for these cities are ranging from 4.97 m/s in Tubas to 1.32 m/s in Jericho which are very low speeds that are not encouraging to exploit wind in that areas.

As a result of these wind speed values, small wind turbines are recommended to use to generate electricity in the areas that suffer from power shortages, and in the areas located far from the electrical grid.

Adding to that, it can be used as an alternative choice to diesel engines in water pumping [23].

Gaza strip is also characterized as a very low wind speed area with an average of approximately 2.5–3.5 m/s and this speed of wind is considered as not enough to generate energy in Gaza [23].

There are some obstacles that prevent the wind power in Palestine to be exploited as follows:

- The main and major one is the Israeli occupation, which prevents any Palestinian efforts to generate electricity by using RE, particularly in areas C, which forms 62% of the Palestinian territories. Also, by controlling the movements of importing and exporting that leads to a costly tax system which accordingly increase the cost of clean, reliable, efficient technologies.

- The Lack of technical and human capabilities, and the absence of professional training on the modern applications and designs.

- The high investment in Palestine, and the low income of the Palestinian people.

- The Lack of awareness of the importance of energy conservation and green technology.

- The political situation in Palestine, and the Israeli occupation does not allow any foreign investment.

4.2.2 The Solar Energy Potential in Different Areas in Palestine

on the other hand, Palestine has a high solar energy potential of about 3000 sunshine hours per year with a solar radiation (kWh/m^2/day) for the year 2013 of 7.51 in Hebron, 8.27 in Ramallah, 6.15 in Tubas and 6.86 in Salfeet. These values are encouraging to utilize the solar energy for different applications [27].

Palestine has a high solar energy potential, where average solar energy is between 2.63 kWh/m^2 / day in December to 8.5 kWh/m^2 /day in June, and the daily average of solar radiation intensity on horizontal surface (5.46 kWh/m^2 /day) while the total annual sunshine hours amounts to about 3000. These figures are very encouraging to use PV generators to produce electricity as it has been worldwide successfully used. The amount of radiation that reaches Palestine differs from place to another. The amount of radiation decreases toward the West. This reduction is because the cloud cover between the hills and the coastal plain. Solar radiation in the West Bank performs a highest value in Jericho [11].

The solar energy utilization is very popular to the Palestinian population and is used mainly for water heating. The available information from PCBS shows that around 67% of Palestinians are using solar system in their own residences, see figure (4.2).

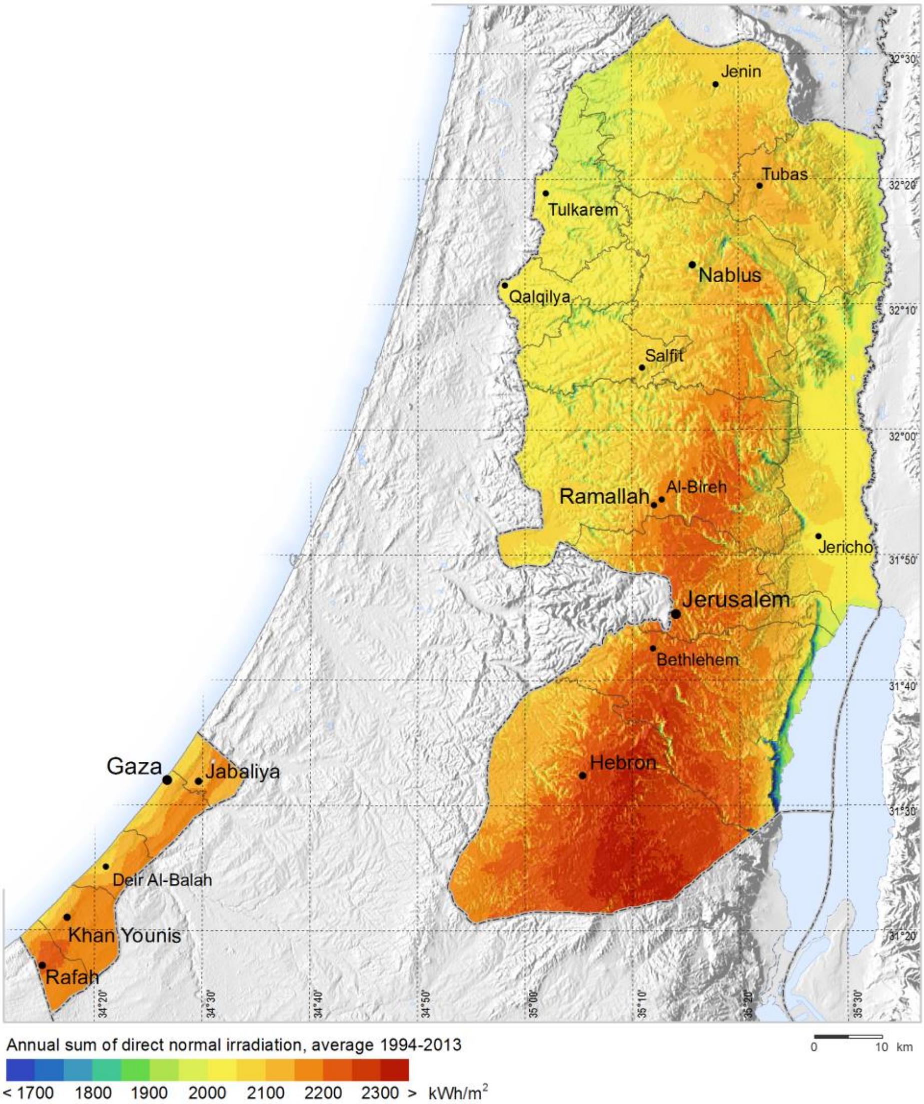

Figure (4.2): Direct Normal Irradiation (DNI) - long-term yearly average.

Otherwise, the total installed PV capacity until the end of the year 2019 was about 80 MW, as these systems produce the equivalent of about 136 GWh annually, which is equivalent to 2% of the total energy consumed in Palestine, and this percentage is expected to increase significantly after the completion of building the licensed stations during the coming year, the government will provide incentives to encourage investment in this sector [8].

4.2.3 The Potential of Biogas Production in Palestine

The West Bank has four geographic areas divided into: (i) the coastal plain which includes Tulkarem and Jenin. These areas are rich agricultural areas producing vegetables, fruits, olive oil and melons. (ii) The uplands start north of Jenin and comprise the mountains of Nablus, Jerusalem and Hebron. (iii)The eastern foothills areas that is located between the central uplands and the Jordan Valley. (iv)The Jordan Valley which is characterized by a tropical climate and is a very rich agricultural area.

The northern and southern areas are good for cultivation with an average annual rainfall of 450-600 mm, the Jordan Valley area does not receive enough rainfall (150 mm) and so the cultivation is irrigated. The rainfall in the Gaza Strip changes between the north 350 mm and the south (only 150 mm).

The agricultural sector suffered badly as a result of the Israeli Occupation through direct control and hegemony or through immigration to the Israeli markets. Even though, agriculture still makes up to 24% of the gross domestic product of the West Bank and 19% of that of Gaza Strip. The agricultural sector employs 31% of the workers and 18% of the workers in Gaza.

In some locations in Palestine biogas technologies were applied for the purpose of gas production for cooking but not for electricity generation, only one project is designed for electricity generation "Al-Jabreeni" dairy production plant in the West Bank was able to meet its needs of electrical energy, by using the manure of the cows owned by the factory. This cow farm is one of the biggest farms in the West Bank. The factory management was able to take advantage of the huge quantities of "waste" produced by the cows on the farm, in order to find a solution to the problem of poor electricity networks in the area that surrounds the farm, which is located near the city of Yatta, in the southern area of the West Bank. The current capacity of the project produces about 380 kWh, of which about 20kWh are utilized is the farm only, and the remainder is pumped into the southern electricity grid.

On the other hand, and according to the results and surveys from (Palestinian Centre for Statistics) the animal property can be presented as follows: an average of 60% of the families in rural areas own animals and an average of 46% of them owns one animal, 26 % of them own between 2-5 animals and 26% of them own more than 6 animals [28].

The expansion of digesters in West Bank and Gaza Strip is extremely little, but some experiments were done as follows:

- Jericho digester: This digester was built in the spring of 1998 with $5m^3$ volume; it could produce about $1m^3$ biogas and 200 L fertilizer daily, and it was used for educational purposes but now it is not working anymore [28].

- Jenin digester plant: This experiment was utilized over ground at the most agricultural governorate (Jenin) of Palestine. Furthermore; the biogas production for 20 samples of mixed organic wastes (food residues animal dung, and wheat straw) were tested in the same time but now it is not working anymore.

- Khadoury digester/ Tulkarem: This digester was constructed in the middle of 2000 with $14m^3$ digester volume and $3m^3$ holder volume that could store 60% from daily biogas production [28].

4.3 Photovoltaic Systems Configuration

4.3.1 The Concept of Photovoltaic Module

The PV module is a group of PV cells that are connected in parallel or and in series, this group of cells is the main element in the PV systems (On-grid or the Off-grid PV systems) which can produce useful power. See figure (4.3).

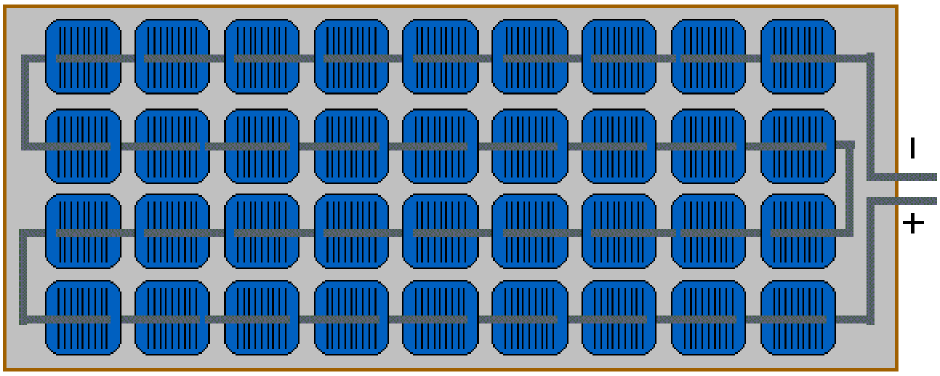

Figure 4.3: PV Module Diagram .

The Photovoltaic module constructed of Semi-Conductors particularly the Silicon element (Si), which is extracted from an intensive purification processes of the sand that contains silicon dioxide (SiO_2) and that's done by heating the sand in the oven with high temperature up to 2000°C for complete melting of the sand. The second process is crystallization of the pure silicon. Then, the P-type and N-type are doping, and finally the PV cells are ready to use after installing the grid connections on it. actually, the PV cell has no commercial or applicable use, but the combination of PV cells that make the PV Module is the most commercial and applicable part in PV systems.

There are three types of the PV cell as follows:

- Poly Crystalline Silicon Cell
- Mono Crystalline Silicon Cell
- Thin Film (Amorphous) Silicon Cell

Every type has its configurations; the output voltage and current, the response to the temperature rising and falling also the ability to absorb the solar radiation.

Some configurations at standard conditions (STC : $T_{cell} = 25°\text{C}, G = 1000\, W/m^2, Airmass = 1.5\ and V_w \leq 2\, m/s$) for the three types shown below[29]:

- Poly Crystalline Silicon Cell

- Open Circuit Voltage $V_{oc} = 0.55 - 0.57\, V$

- Short Circuit Current $I_{sc} = 2.6 - 3.6\ A/100cm^2$

- Mono Crystalline Silicon Cell

- Open Circuit Voltage $V_{oc} = 0.6 - 0.62\ V$

- Short Circuit Current $I_{sc} = 3.4 - 4.0 A/100cm^2$

- Thin Film Silicon Cell

- Open Circuit Voltage $V_{oc} = 0.65 - 0.78\ V$

- Short Circuit Current $I_{sc} = 1 - 2\ \ A/100cm^2$

The main part in the PV system's design is the PV module (Solar Panel), which consists of cells connecting with each other [29].

4.3.2 PV Module Operation

Photovoltaic (PV) solar modules consist of cells that connected with each other and convert sun light into electricity. The output of the PV cells is direct-current (DC) electricity.

Since the electricity provided by the electric utilities and used by most residential end-users is AC electricity, then the electricity generated from solar panels cannot be used until it is converted from DC to AC using an inverter. In some cases, additional power conditioning equipment may be required if the solar panel is connected to the electric grid [30].

4.3.3 PV Module Equivalent Circuit

The operating characteristics of a PV panel is an important element to understand how a PV panel operate. In order to achieve a well understanding the fundamental electrical circuit components of the PV equivalent circuit model must be analyzed, as shown in Figure (4.4) shows the equivalent circuit model.

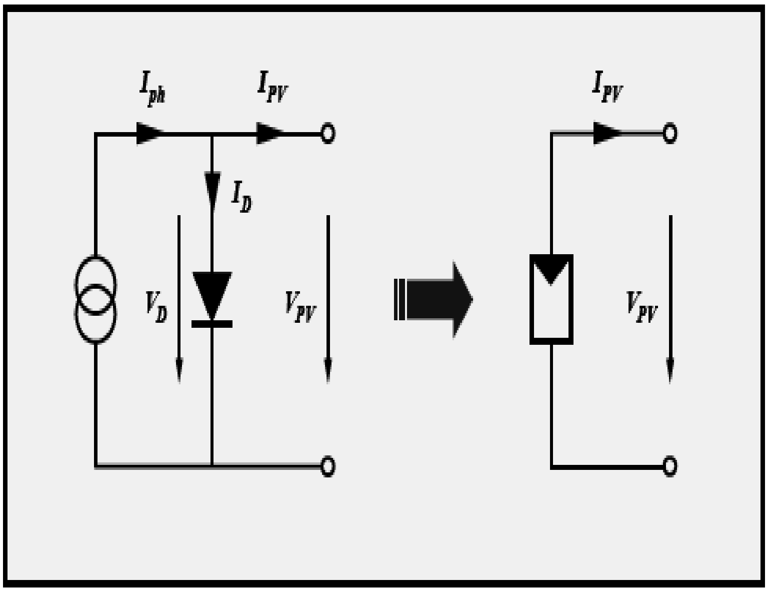

Figure 4.4: Equivalent circuit of PV module [16].

The following equations indicate the mathematical function of an ideal solar cell:

$$I_{PV} = I_{ph} - I_0(e^{\frac{qV}{KT}} - 1)$$

Where:

I_{PV}: Load current [A]

I_{ph}: Photocurrent [A]

I_0: Dark current [A] or saturation current

q: Elementary charge [e =$1.6x10^{-19}As$]

V: Voltage [V]

T: Diode temperature [°K] [34]

K: Boltzmann constant [$8.65x10^{-5}\, {eV}/{{}^{\circ}K}$]

The PV module equivalent circuit parameters are:

- Short Circuit Current (I_{sc}): the maximum current provided by the module when the connectors are short circuited.

- Open Circuit Voltage (V_{oc}): the maximum voltage that the module provides when the terminals are not connected to any load.

- Maximum Power Point (P_{mpp}): the point where the power supplied by the module is at maximum. The maximum power point of a module is measured in Watts (W) or peak Watts (W_p). It is important not to forget that in normal conditions the module will not work at peak conditions, as the voltage of operation is fixed by the load or the regulator. Typical values of V_{max} and I_{max} should be a bit smaller than I_{sc}andV_{oc} [29]

The IV-Characteristics curve is the key element that the operation of PV depends on., and it is the most important requirement to design. See the figures below [Figure (4.5), Figure (4.6) and Figure (4.7)] that describe the IV curve with some relations with solar radiation and temperature.

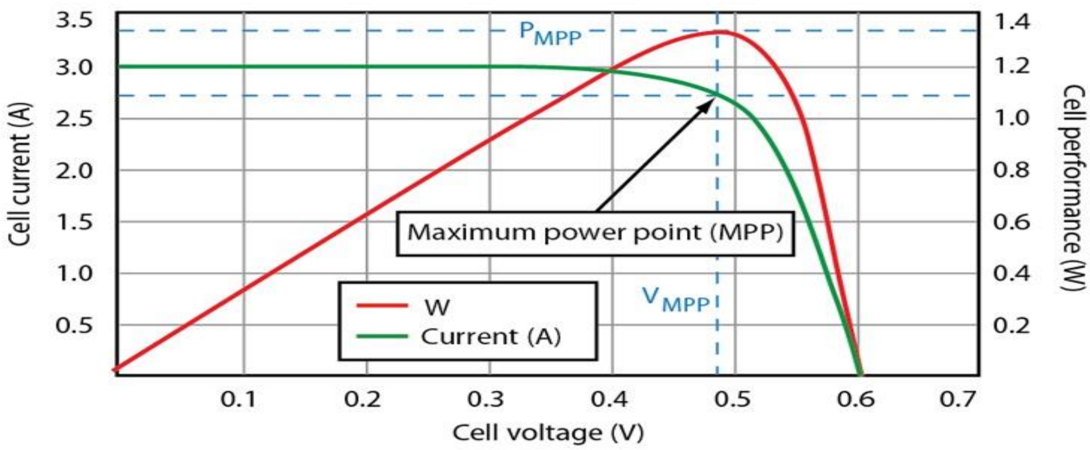

Figure 4.5: Current VS voltage [29].

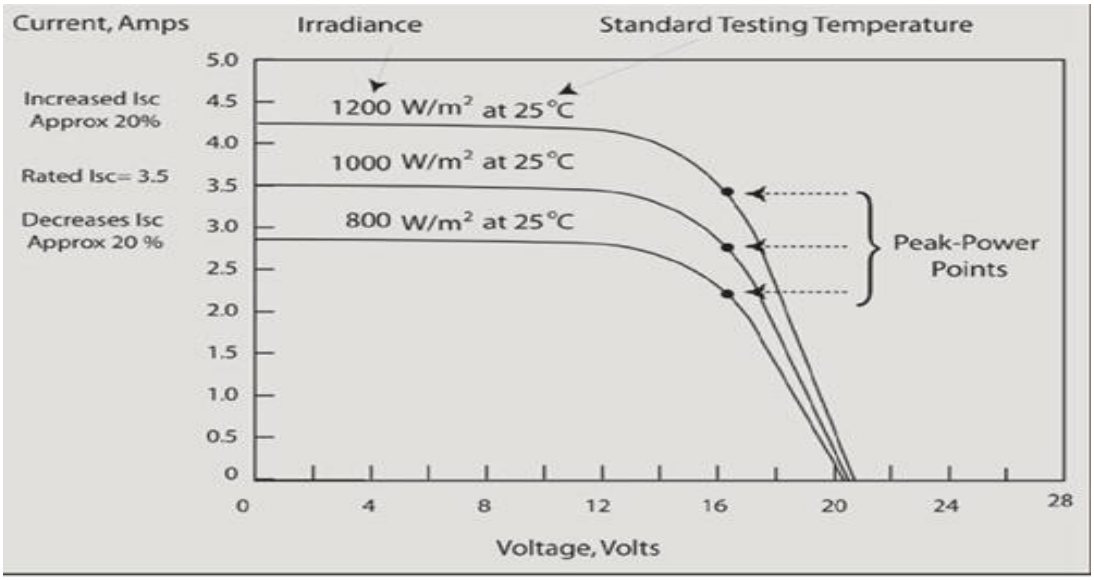

Figure 4.6: Current’s variation with temperature [31].

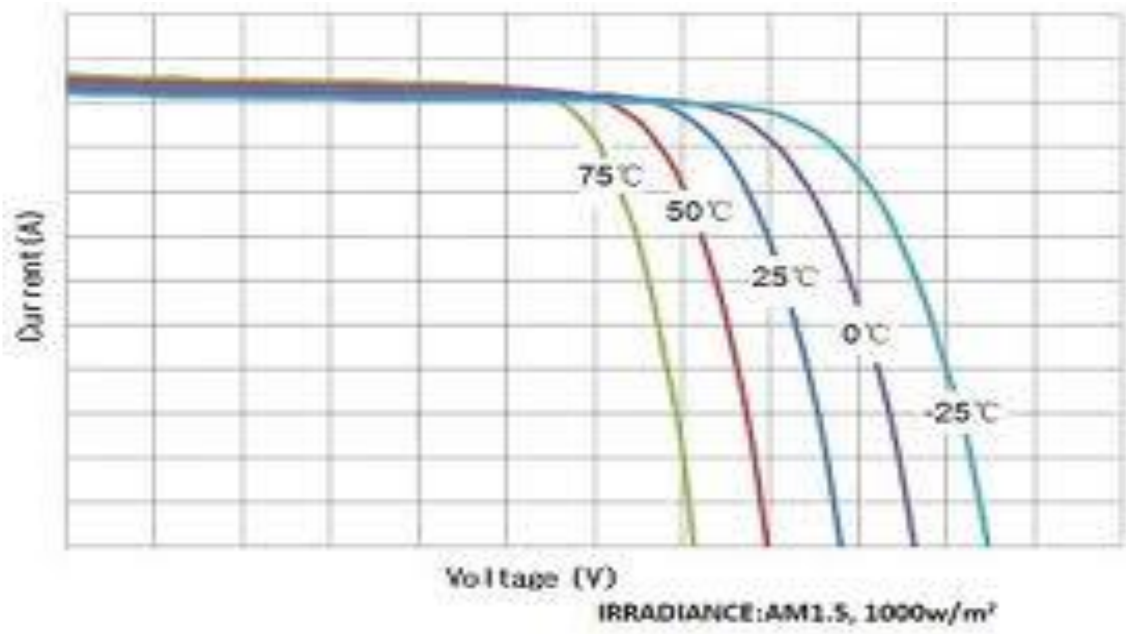

Figure 4.7: Voltage's variation with solar radiation [29].

The rated power of a module is mainly expressed in "peak watts" [Wp] and measured under internationally specified test conditions, named as Standard Test Conditions (STC), which refers to solar radiation 1000 W/m^2 incident perpendicularly on the cell or the module, cell temperature 25 °C and 1.5 air mass, PV have a current voltage relationship that represented in I-V curve [29].

Figure (4.8) shows a single PV cell of 100 cm^2 connected to a variable electrical resistance R, and an ammeter to measure the current (I) in the circuit and a voltmeter to measure the voltage (V) developed across the cell terminals.

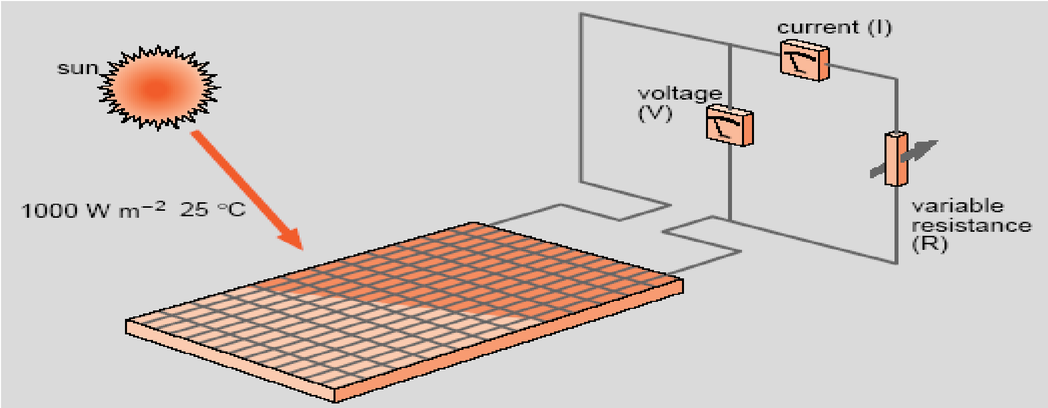

Figure 4.8: Test of PV under STC.

When the resistance is infinite (i.e. open circuited) the current in the circuits at its minimum (zero) and the voltage across the cell is at its maximum, known as the 'open circuit voltage' (Voc). On the other extreme, when the resistance is zero, the cell is in effect of 'short circuited' and the current in the circuit then reaches its maximum, known as the 'short circuit current (Isc).

4.4 Power Generation of Solar PV Systems in Palestine

The climatic conditions are the main elements to identify the availability and magnitude of solar energy at a particular site. For better utilization of the solar energy resource, an analysis of the characteristic of solar radiation at a potential site should be made at the stage of inception.

Palestine is known as region that is rich in the solar resource with an annual average of 5.4 peak sun hours and about 5.5 kW h/m^2 /day, furthermore it lacks for oil and gas resources.

The Palestinian government has noticed the high importance of exhausting the opportunities in renewable energy for the sufficient supply of clean energy for residential, commercial and industrial needs. Recently, a national strategy for expanding the use of renewable energy has been launched, that calls for the production of 120 MW of electricity using different alternative energy sources [32].

4.5 Renewable Energy Regulations and laws in West Bank

Renewable energy regulations are issued in the form of laws or decisions by the Council of Ministers, or legislation by the Energy and Natural Resources Authority(PENRA) or by the Palestinian Electricity Sector Regulatory Council (PERC).

The law number 14 in the year of 2015 for the renewable energy and the energy efficiency, this law consists of 23 items that has the following objectives:

- Encouraging the exploitation and development of renewable energy sources, and utilizing their applications to increase the percentage of their contribution in the total balanced energy, also achieving a safe increase in it along with the strategy of the renewable energy.
- Conservation of energy through an optimal use of it in various sectors and contributing to the requirements for sustainable development, environmental protection and preservation.

- Encouraging local manufacturing and the use of energy-efficient, energy-consuming equipment and renewable energy application systems.

According to the law number 14 there is three mechanisms to implement renewable energy projects as follows:

1. The Palestinian Solar Energy Initiative for the household sector for capacity (5) kilowatt or less for a single system, which is subject to the distinct tariff recommended by Palestinian Electricity Sector Regulatory Council (PERC) and periodically reviews it.

2. Net metering systems for projects with capacities higher than (5) kilowatt in all sectors, at that it does not exceed a certain percentage determined by the renewable energy strategy.

3. Offering bids or inviting bids on competitive grounds in accordance with the applicable related laws related to establish power plants for sale [5].

The net metering system is the system used for renewable energy projects that connected to the electrical grid, the net metering is calculated and counting as follows:

1. The distributor issues a monthly bill showing the amount of energy exported to the network, and the amount of energy consumed by the customer.

2. The distributor deducts 10% from the amount of energy exported to the electrical network.

3. In case the amount of energy consumed is greater than the amount of energy exported after the deduction, the consumer shall pay (on a monthly basis) the value of the net amount of implicated electrical energy.

4. In case the amount of energy consumed is less than the exported amount after deduction, the distributor recycles the net balance of electrical energy to the account of the following month.

5. Financial settlement is made at the end of the productive year of the project (April 1 - March 31) so that the balance of the exported energy is recycled in favor of the customer within one production year only [5].

As long as it does not conflict with the terms of the net metering instructions, any customer within the distributor's connection area has the right to establish a project to produce renewable energy and connect it to the distributor network and consume the energy produced from that project in a different place from another place the project so that the place of consumption is within the privilege of the distributor only, the computation for this is the same of the household but with 12% deduction[5].

Chapter Five

Expected Planning for the Near Future Energy Coverage by PV Power Plant of 30MW in Bani-Naeem

5.1 General Background

The Project name is China-aid PV Solar Power Project in Palestine, the competent authority for this project in Palestine is Palestine Energy & Natural Resources(PENRA).

The main purpose of the project: a new PV solar power station is to be built in Bani-Naeem of Hebron Province, the West Bank of Jordan River (31°29'19.62"N, 35°13'58.69" E). For Phase I Project, a 30MWp station will be built to provide power supply for schools, hospitals and residential areas in Hebron and its surroundings. The China-aid PV Solar Power Project would relieve the tension of power supply in the aided area of Palestine.

5.2 Project Implementation Scheme

5.2.1 General Scheme Design and Power Generation Calculation for the PV Power System

This project adopts the scheme of power generation by pieces and centralized grid connection. Through the comprehensive technical and economical comparison, all together 96,320 pieces of 315Wp polycrystalline silicon PV modules are adopted.

This project has a total installed capacity of 30.34MWp; it is consisting of 28 PV power generation units and each unit has an installed capacity of 1.08MWp. Each power generation unit is connected with one set of 33/0.315-0.315kV 1,000kVA double-split box-type transformer. The transformer is further connected to two sets of 500kW grid-connected inverters. Each inverter is connected to six DC lightning-protection combiner boxes so that each power generation unit is provided with a total of 12 sets of combiner boxes. There are 12 to 16 input circuits for each combiner box and each DC circuit consists of 20 pieces of 315Wp polycrystalline silicon PV modules connected in series.

The AC power output from the inverter is connected to the box-type transformer on its low-voltage side so that the voltage is stepped up from 315V to 33kV. The power of the PV power station can be collected to the 33kV switching station by 2 circuits of 33kV power collecting lines.

According to calculation, it is estimated that the energy of the PV power station in its first year of operation is 52958MWh, the equivalent full-load utilization hours of the first year are 1745h, the mean annual on-grid energy during the 25 years of operation period will be 48395MWh and the annual equivalent full-load utilization hours are 1595h.

5.2.2 Main Electrical Equipment and Connection

The project has a total installed capacity of 30.34MWp. It is proposed that a new 33kV switching station is to be built and the voltage level is 33kV; the power from the PV power station is proposed to be transmitted to the 33kV national grid of Palestine via two circuits of 33kV lines yet the final grid connection scheme is still subject to the demonstration by departments concerned of Palestine.

The 33kV high-voltage part in the switching station adopts single bus bar connection mode and the 33kV switchgear is proposed to use KYN61-40.5 metal armoring enclosed indoor high-voltage switchgear. There are all together 8 sets of 33kV HV switchgears installed on the 33kV bus bar, among them there are 2 sets of 33kV outgoing bus bar switchgears, 3 sets of 33kV power collecting line switchgears (including one set of backup

feeder switchgear), one set of 33kV grounding and station service switchgear, one set of SVG reactive compensation switchgear and one set of bus bar voltage transformer. The PV plant area of this project is provided with a total of 2 circuits of 33kV power collecting lines to collect the power from each PV power generation unit of the plant area to the switching station; the 33kV system adopts arc suppression coils as its way of grounding.

The station service power system of this project is a 380/220V 3-phase 4-line grounding system; it adopts a single bus bar connection and 2 circuits of low-voltage AC incoming lines; the two circuits of station service power supply use ATS for automatic switching, which is realized by the AC/DC integrated power supply system; the station service power system is equipped with two circuits of station service LV AC incoming line power source, with one of the circuits led from the 33kV grounding and station service transformer (the grounding transformer has 1000kVA capacity and the station service transformer has 250kVA capacity) and the other one using the construction power supply as the backup power supply.

Voltage regulation of the power grid by the PV power station includes such modes as adjusting the reactive power of the grid-connected inverter of the PV power station, the input of the reactive compensation equipment and the transformation ratio of the step-up transformer at the PV station. As the output power factor of the inverter is higher than 0.99, to make full use of the reactive capacity of the grid-connected inverter and its adjustment ability, it is not necessary to make reactive compensation for the PV modules and the inverter of the PV power station. In this project, an SVG reactive compensator is installed for the 33kV bus bar in the switching station, with the capacitive reactive power compensation capacity being +8.0MVAr and the emotional-capacitive reactive power compensation capacity being -2.0MVAr, to compensate the reactive loss from the step-up transformer system, the power collecting lines and the outgoing lines. As the grid connecting scheme of the PV power project has not determined yet, the mode and capacity of the reactive compensation needs to be finalized through the review according to the analysis report on the grid-connection system of this project at last.

5.2.3 Control, Protection and Instrumentation

The computer supervisory control system at the switching station is designed as per the mode of "No-man on duty (or few-man on duty)"; the supervisory control system adopts a layered and distributed system structure and is consisted of a bay floor and a station control floor.

In the switching station, the relay protection and automatic devices for the main electrical equipment are configured according to related standards and specifications as well as the actual situation of the local grid and the relay protection can use microcomputer protection device.

5.2.4 Communication

The relation between the PV power station and the power dispatching management system is proposed to be managed by the local grid. The system communication is proposed to use optical fiber communication and the communication information mainly includes relay protection information, tele control information, metrical information, administration and dispatcher telephone information. The dispatching relation and the communication mode of the system need to be finalized through the demonstration of departments concerned in Palestine.

5.2.5 Fire-Prevention Design

The fire-prevention design of this project follows the principle of "prevention first, combined with extinguishing". The design actively adopts some advanced fire-prevention technologies to ensure safety, easy application and economical rationality. The fire hazard ratings and fire resistance ratings of the structures in the switching station of this project are as follows: the living building is of Class V fire hazard rating and Level II fire resistance rating; the 33kV distribution room is of Class V fire hazard rating and Level II fire resistance rating; the living and fire-fighting water pump house is of Class V fire hazard rating and Level II fire resistance rating. The fire-fighting access at the switching station should be no less than 4m wide and the turning radius no less than 9m.

The access is arranged in a circular way so that the fire-fighting truck can reach any part of the station.

5.2.6 Civil Works

Giving overall consideration to the technical scheme and site conditions of the project, the civil works of this project is a regular one and is similar to those for the international PV power projects that have already been built or are still under construction.

The PV modules of this project are installed on fixed mountings and the modules of each single mountings are arranged in 2 rows×10 lines, with an inclined angle of 28°. The foundation of the fixed PV mounting adopts punched-borehole cast-in-situ piles. The equipment foundations at the plant area of this project are the foundations for the inverters and box-type transformers, both of which are 28 in quantities. The foundations for both inverters and box-type transformers are natural foundations of reinforced concrete slab foundation.

A new 33kV switching station is proposed to be built and will be arranged in a rectangle. At the station, a 33kV distribution room, a living building, a spare part warehouse and a water pump house etc. will be mainly arranged.

5.3 Calculation of Annual On-Grid Energy from PV Power Project

5.3.1 Calculation Condition

a) It is designed to install 96,320 polycrystalline PV modules each with a peak power of 315Wp.

The total capacity is 30.34MWp. Based on average annual radiation for Solar GIS in recent 20 years, an annual energy of PV power station during the operation period (25 years) is estimated. The optimum inclination angle of PV modules is 28°, with the corresponding annual total radiation being 2295.1kWh/m^2. When efficiency attenuation caused by aging of components of power station equipment is not considered, the system efficiency of the project is 78.0%.

The operation period of the project is considered as per 25 years. With the increase in the operation period, the system efficiency decreases due to aging of components, and the power loss increases accordingly. As a result, the power generation reduces. The power of polycrystalline PV modules of the Project is attenuated 2.5% for the first year and 19.3% by the end of 25 years, with attenuation rate of 0.7% per year [8].

5.3.2 Calculation Results

Based on calculations, the estimated on-grid energy of the PV power station for the first year: 52,958MWh, equivalent full-load utilization hours for the first year: 1,745h; average annual on-grid energy during the operation period (25 years) ： 48 ， 395MWh; average annual equivalent full-load utilization hours: 1,595h.

5.4 Grid Interconnection Scheme for the Project

It is proposed that a new 33kV switching station is to be built for the project and the voltage level is 33kV; based on preliminary investigation, there are two possible 33kV grid connection schemes for the project:

1) The power from the PV power station is transmitted to the 161kV substation of Palestine via two circuits of 33kV lines and then connected to the national grid of Israel via 161kV lines, with the length of each circuit of power transmission lines being 8km.
2) The power from the PV power station is transmitted to the 33kV national grid of Palestine via two circuits of 33kV lines and is supplied directly to users, with the length of each circuit of 33 kV power transmission lines being 11km.

The above two connection schemes are both feasible in terms of power acceptance by the grid, yet the finalization is subject to the demonstration by departments concerned of Palestine.

5.5 Cost Estimate

In this project, the Chinese government will grant Palestine an amount of aid fund to cover the obligations of China's part, yet for the part of Palestine, they shall find ways to raise the fund by themselves to cover their obligations. According to calculation, the per kW static cost for the project is RMB 11,537.51 Yuan/kW which is equivalent to 1670.17 $ /kW and it is suggested that the min. project cost should be RMB 385.0528 million thus 3.62 million $ [8].

Chapter Six

Conclusions and Recommendations

6. Conclusions and Recommendations

6.1 Conclusions

The following are the main conclusions:

1) Palestine (West Bank and Gaza) has a serious problem in providing the electricity due to the full dependence on importing the electrical energy form the IEC.

2) The load forecasting is done as a first step to find out how electricity consumption increases over the years, as a result of that, solutions can be obtained to reduce the dependence on the electricity imported.

3) The forecasted peak demand increases by an average growth rate of 4.67% over the years and the energy consumption increases by an average growth rate of 4.97% over the years.

4) The renewable energy is the best and effective solution which can be considered as the reliable power source that can help to meet the needs from electricity in the present and future.

5) Bani-Naeem PV power plant is one of the examples of a PV plants which can be built around the WB area to cover the electrical requirement of that area.

6.2 Recommendations

The following are the recommendations:

1. More studies on the energy consumption and peak demand over the upcoming years makes the vision clearer.

2. New strategies should be done and supported by the government to encourage the consumers to use the renewable energy sources which is the first step toward lesser electrical consumption from the grid.

3. The focus shall be either on the PV power plants to feed bigger areas which leads also to cover the needs of that areas and to reduce the electrical power demand from the grid.

4. Studying the potential of transfer the electrical energy from the PV power plants from the closer areas to farther regions.

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كلية الدراسات العليا

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إعداد

علا يوسف أحمد عنتري

إشراف

أ. د. مروان محمود

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك، بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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إعداد

علا يوسف أحمد عنتري

إشراف

أ. د. مروان محمود

الملخص

يعاني قطاع الطاقة الكهربائية في الضفة الغربية من مشاكل مختلفة، أكبرها سيطرة الاحتلال الإسرائيلي بشكل كامل على مصدر الكهرباء، مما يجعل قطاع الطاقة غير فعال لتلبية احتياجات المستهلكين.

يهدف هذا البحث إلى دراسة نظام الطاقة بالكامل في الضفة الغربية من خلال الإضاءة على معوقات قطاع الطاقة، ثم التنبؤ بنسبة الزيادة في الطلب على الحمل إما ذروة الحمل أو استهلاك الطاقة، ويمكن استخدام هذه الأرقام في معرفة مقدار الطاقة التي نحتاجها في المستقبل.

تمت الإشارة إلى الحمل المتوقع (ذروة الطلب واستهلاك الطاقة) بمتوسط معدل نمو قدره 4.67٪ و4.97٪ على التوالي حتى عام 2025.

تعد الطاقة المتجددة من الحلول المهمة والتي تساعد على تغطية أجزاء من استهلاك الطاقة الكهربائية خاصة الطاقة الشمسية التي لها إمكانات حقيقية هنا في فلسطين، أدرجت في بحثي محطة طاقة كهروضوئية بقوة 30 ميجاوات كأحد التخطيطات المتوقعة للمستقبل القريب لتغطية الطاقة.