An-Najah National University
Faculty of Graduate Studies

Techno Economic Feasibility of Energy Supply of Tower Communication Systems in Palestine by PV-Hybrid system

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DEDICATION

To the spirit of our leader and teacher Mohammed
Blessings and Peace be upon him

To my mother

To my father

To my wife (Manal)

To my daughter (Toleen), and son (Shaher)

To my brothers, and sister

To my big family

To my teachers

To all friends and colleagues

To all of them,

I dedicate this work

Acknowledgments

Initially, I would like to thank Allah for blessing me with the opportunity to contribute to the research community through this research thesis.

I would like to thank my university supervisor Dr.Imad Ibrik for giving me strong support, encouragement and guidance during the thesis.

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Special thanks to Al-Najah National University my second home.

Finally, I would like to thank everybody who was important to the successful realization of thesis, as well as expressing my apology that I could not mention personally one by one.

الإقرار

إنا الموقع أدناه مقدم الرسالة التي تحمل عنوان

Techno Economic Feasibility of Energy Supply of Tower Communication Systems in Palestine by PV-Hybrid system

الدراسة الفنية والاقتصادية لاستخدام أنظمة الخلايا الشمسية لتزويد أبراج الاتصالات بالكهرباء بدلاً من الديزل

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة كاملة، أو أي جزء منها لم يُقدم من قبل لنيل أي درجة أو لقب علمي أو بحثي 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 other degree or qualification.

Student's Name:	**اسم الطالب:**
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Date:	**التاريخ:**

List of Abbreviations

AC	Alternative current
AW	Annual Worth
DC	Direct current
DF	Depreciation Factor
DG	Diesel generator
DOD	Depth of Discharge
ERC	Energy Research Center
GHG	Green house gasses
KVA	Kilo volt ampere
KWh	Kilo watt hour
LCC	Life Cycle Cost
PA	Palestinian Authority
PSH	Peak sun hour
PV	Photo voltaic
PVG	Photo voltaic generator
PW	Present worth
RE	Renewable Energy
STC	Standard Test Condition
VA	Volt ampere
Wh	Watt hour
Wp	Watt Peak

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Techno Economic Feasibility of Energy Supply of Tower Communication Systems in Palestine by PV-Hybrid system

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Abstract

This thesis investigates the techno-economical analysis of using PV system for electrification of remote communication towers in Jawwal company in the West Bank, design and simulation of Solar hybrid power generation system connected to the tower loads .This hybrid system consists of photovoltaic system, diesel generator , power flow controller, power electronic converter and the tower loads. The main strategy of the system will be if there is enough energy from the sun , the load demands can be supplied from these sources. Whenever there is excess supply from the renewable energy sources, the energy will storage in special batteries. If either the available power from the solar panels cannot satisfy the load demand, the generator can meet the excess power demand.

The main objective is to estimate the economical and environmental impact of using solar PV -hybrid system instead of diesel generators, estimated for both running and fixed costs. A PV system with a capacity of around 8-10 KW peak power has analyzed to implemented in four towers locations in remote areas, where Jawwal still using a diesel generators as a main source for electrification of these communication towers, requires a total investment of about $ (US) 50 thousand and the cost of electricity

comes out as $ (US) 0.63/ kWh with an interest rate of 10% , comparing with average cost around $ (US) 1.15/ kWh from the existing diesel generators.

The related environmental impacts are discussed from the sustainable development point of view, the using of PV solar energy systems in four mentioned locations it can be saved around 53,000 kg co_2, which is emphasize on the future role of renewable energy sources in Palestine.

INTRODUCTION

Introduction:

Electricity and fuel are one of the major problems facing the PA specially as the PA satisfies the majority of its electricity needs through imports, depending mainly on Israel.

Palestine is a developing nation in great need of all types of energy for economic growth and human development. Most Palestinian people have access to electricity. However, there are unusual constraints on energy development in the West Bank and Gaza. Palestine has no developed domestic energy resources, and relies heavily on imports from Israel. Energy insecurity is further reinforced by the fact that Israel controls the quantity and condition of energy imported into Palestine. For example, Israeli control of Palestinian borders prevents open trade in electricity and petroleum products between the Palestinian Authority (PA) and other countries: Israel is therefore able to impose non-competitive energy prices and tariffs on the Palestinian Authority.

In these circumstances, the possibility of using such renewable energy technologies as solar thermal, wind and solar photovoltaic have become an option for the Palestinians, especially as Palestine is gifted with huge solar radiation. This type of renewable energy is already extensively utilised in domestic water heating in Palestine, but the commercial feasibility for producing electricity has been questioned because of the high cost of photovoltaic systems per watt. High oil prices and the desire for national energy sovereignty have recently led to a reconsideration of the potential for renewable energy in at least meeting part of growing Palestinian energy needs.

This thesis highlights the importance and the need of using solar PV systems instead of diesel generators for electrification of communication towers in Jawwal Company in West Bank; it will be as commercial renewable energy applications in Palestine, addressing the potential and possibility of adopting solar energy resources, in particular for sectors with high energy consumption. Such an uptake of solar energy would reduce conventional diesel fuel energy consumption and its imports, potentially releasing money for other public expenditures and also reducing environmental emissions.

The electric power generation system, which consists of solar PV system hybrid with diesel generator, has the ability to provide 24 hours electricity to the load. This system offers a better reliability, efficiency, flexibility of planning and environmental benefits compared to the diesel generator system. Each kilowatt-hour (kWh) generated from solar systems saves the environment from the burning of fossil fuels. The diesel -fired and the natural-gas-fired power generators produce 1.2 Kg and 0. 5307 Kg carbon dioxide, respectively, to generate 1 kWh electricity [1].

Problem Statement

- Lack of conventional electrical sources in Palestine.
- The importance of technical analysis of using renewable energy sources in Palestine (west bank) based on available solar data to

evaluate the visibility of using RE in West Bank for electrification of remote communication towers.

- Performance analysis of the design and operation of solar PV system with hybrid for electrification of communication towers instead of diesel generator.
- Economical and environmental impact of using solar PV systems for electrification communication towers loads.

Thesis Objectives

- Technical Analysis of using photovoltaic sources hybrid with diesel generators for electrification of communication towers.
- Investigate the design layout (connection topology) for all components of PV-hybrid system.
- Study the different configurations of the PV system for different environment conditions.
- Investigate the techno-economical performance analysis of four communication towers in Jawwal company as a case studies for using PV systems as a hybrid with diesel generators.
- Analyze the economical and environmental impact of the hybrid system for communication towers.

The main activities of my thesis to achieve goals

- Theoretical background and literature review.
- Mathematical models for characterizing PV module and diesel generator.
- Design of PV module, the controller, and power electronic inverter.
- Determine the economical impact of using solar hybrid system instead of generators; investigate the variable of radiation effect on the operation of model.
- Apply the design and operation analysis on four towers locations in West Bank.
- Find the economical and environmental impact for the PV hybrid system for electrification four communication towers.

Thesis Structure

The work carried out in this thesis has been summarized in eight chapters.

Chapter 1: Potential of solar energy in Palestine

This chapter describes the potential of solar PV radiations, also analyzing the existing PV system projects in West Bank, Palestine.

Chapter 2: Configuration of PV System

This chapter consist basic information about PV systems, selection of all parameters, maximum power point tracker (MPPT), three-phase AC-DC rectifier, DC-DC converter, storage batteries and also DC-AC inverter.

Chapter 3: Electrification of Telecommunication Towers by Using Solar Energy

This chapter describes the advantages of electrification communication towers by using solar energy instead of diesel generators, analysis the PV system configurations of electrification the telecommunication towers.

Chapter 4: The Existing Situation in Jawwal Company Regarding the Electrification of Telecommunication Towers

Analysis of existing diesel consumption in each locations in Jawwal company, and analyze the yearly running costs of using DG for electrifications of these towers.

Chapter 5: Design of PV System for Electrification of Jawwal Towers in Remote Areas.

Design of PV system for all locations, determine the necessary calculations for selection all elements and suggest the design configurations of PV systems for all locations.

Chapter 6: Economic analysis of using PV solar systems instead of diesel generators.

Calculate the running and fixed costs of PV systems, also the saving money after implemented the PV system for each telecom tower site.

Chapter 7: Environmental Impact of Using Solar PV systems Instead of Diesel Generator for Telecommunication Towers in Jawwal.

Study the environment impact of such PV systems and analyze the Carbon Dioxide Emission from Diesel Generators.

Chapter 8: Conclusions and Recommendations.

Describes the main conclusions about Electrification telecom towers by using PV-hybrid system and Recommendations of the thesis.

Chapter One

Potential of Solar Energy in Palestine

Chapter One
Potential of Solar Energy in Palestine

Introduction

Palestine is located between 34^o:20′ - 35 ^{o}:30′ E and 31^o: 10′ - 32^o:30′ N, it consists of two separated areas from one another. The Gaza Strip is located on the western side of Palestine adjacent to the Mediterranean Sea and the West-Bank which extends from the Jordan River to the center of Palestine [2].

The climate of Palestine for the greater part of the year is pleasant. Winter lasts for three months, from mid-December to mid-March, and can be severe, during the remainder of the year. The area of Arab Palestine is about 27009 square kilometers. [3]

The atmosphere of Palestine is clear and its air is pure. Summer temperatures reach 35° centigrade and in the winter temperature may drop to Zero. The rainy season starts in the second half of autumn. (Mid-October) and continues until the end of April. Heavy rain is, however, limited to fewer than 50 days, with around 70% of the rain falling during November to February. The country is influenced by the Mediterranean Sea breeze that comes around mid-day. However, the country is affected by annual waves of hot, dry, sandy and dust Khamaseen winds which originate from the Arabian Desert during the months of April, May and mid-June [3].

Palestine receives an average of seven hours of sunshine a day during the winter and thirteen hours during the summer [3].

As a consequence, Palestine uses rooftop solar collectors extensively, to capture the solar energy and to replace limited and expensive available energy resource.

The average annual relative humidity is 60% and reaches its highest rates during the months of January and February. In May, however, humidity levels are at their lowest. Night dew may occur in up to 180 days per year [3].

1.1 Potential of Solar Energy in Palestine:

In Palestine area, the lowest solar energy average is in January

it amounts to 2.47 kWh/m²-day, and the highest one is in June, it amounts to 6.93 kWh/m²-day. As shown in table and Figure for the region of Salfeet district. These measures are very suitable for PV system to generate electricity [4].

Note that these data were measured by the ERC of An-Najah University.

- The following table (1.1) shows the average monthly solar energy on horizontal surface for Salfeet district-2011

Table (1.1): Average monthly solar energy on horizontal surface for Salfeet district – 2011.

Month	(kWh/m2-day)
January	2.47
February	2.82
March	4.17
April	4.88
May	5.85
June	6.93
July	6.62
August	6.04
September	5.11
October	4.11
November	3.41
December	3.24

Figure (1.1) shows the average monthly solar energy on horizontal surface plotted from data of table (1.1).

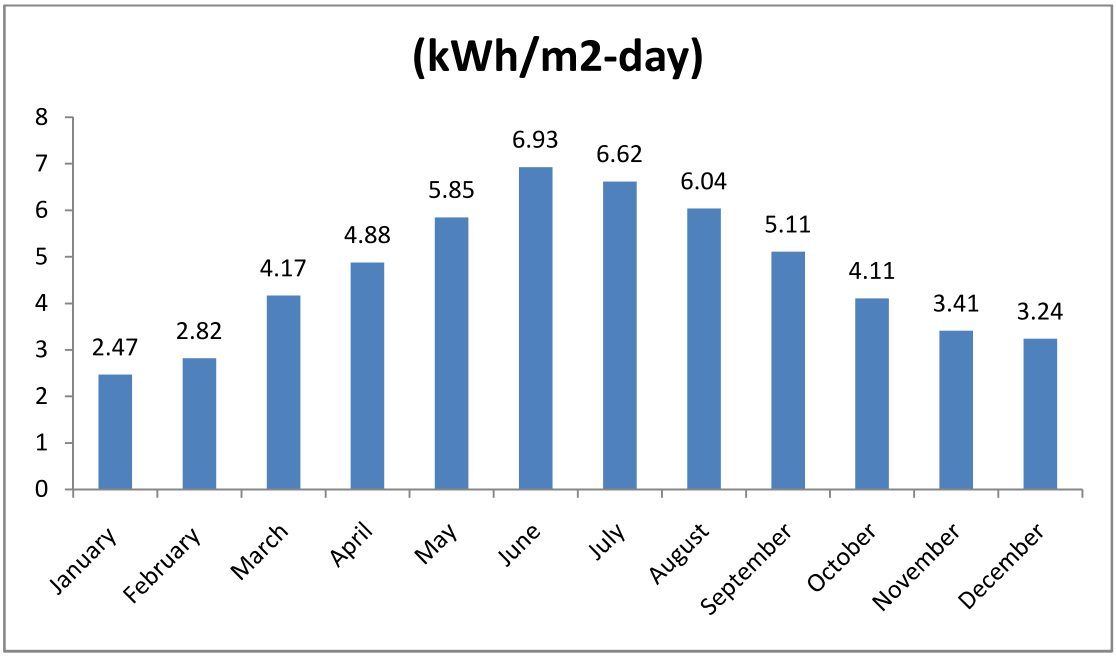

Figure (1.1): Average monthly solar energy on horizontal surface for Salfeet district – 2011.

- In order To Know the Potential of solar energy in Palestine, we must study and measure two elements.

1- SOLAR Radiation (w/m^2)

2- Ambient Temperature (C)

1.1.1 The Potential of Solar Radiation in Palestine:

To calculate the amount of sunlight reaching the ground, both the elliptical orbit of the Earth and the attenuation by the Earth's atmosphere have to be taken into account. The extraterrestrial solar illuminance (E_{ext}), corrected for the elliptical orbit by using the day number of the year (dn), is given by [9]:

$$E_{\mathrm{ext}} = E_{\mathrm{sc}} \cdot \left(1 + 0.033412 \cdot \cos\left(2\pi \frac{\mathrm{dn} - 3}{365}\right)\right), \qquad \textbf{(1.1)}$$

Where:

E_{ext} = the extraterrestrial solar illuminance.

$E_{sc} = 128 \times 10^3$ lx.

dn= the day of the year (Ex. 1^{st} of February would be 32)

Palestine has high solar energy potential. It has about 3000 sunshine hours/year, and high annual average of solar radiation amounting to 5.4 kWh/m^2 - day on horizontal surface, and it reaches 8.4 kWh/m^2 - day in June.

The solar radiation (W/m^2) doesn't change significantly within such short distance, so it will be in Palestine the same since the area of Palestine is relatively small.

The following table (1.2) shows the measurement of the solar radiation on a horizontal surface in the target area (Nablus Area). [4]

Table (1.2) Hourly average solar radiation of typical summer day (23/7/2012)

Hours	Solar Radiation(w/m²)	Hours	Solar Radiation(w/m²)
01:00	0	13:00	1000
02:00	0	14:00	917
03:00	0	15:00	776
04:00	0	16:00	585
05:00	20	17:00	371
06:00	135	18:00	156
07:00	343	19:00	20
08:00	532	20:00	0
09:00	774	21:00	0
10:00	905	22:00	0
11:00	1019	23:00	0
12:00	1062	00:00	0

These measurements are from the ERC. This measurement we've done by horizontally oriented measuring devices, and done on a 5-minute interval basis.

The following Figure (1:2) shows the daily solar radiation plotted from data of table (1.2):

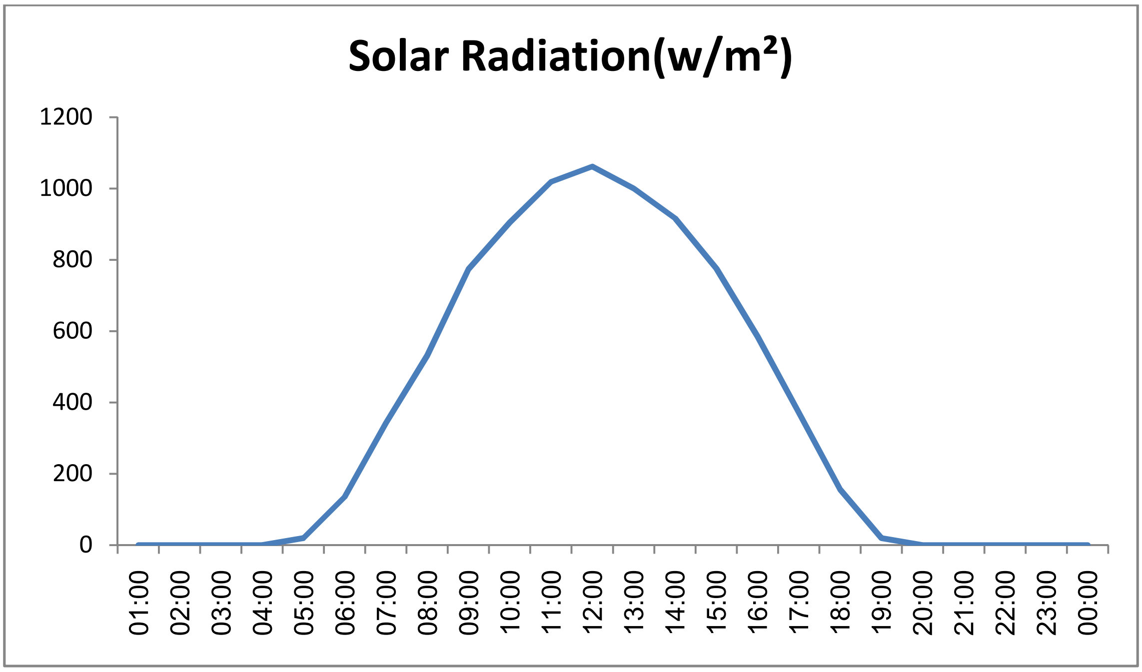

Figure (1.2): Daily solar radiation of typical summer day (23/7/2012)

From table (1.2) and Figure (1.2),

It's obvious that we have enough potential for solar radiation in the interval period from 10 to 14, it's more than 900 W/m² also we can obtain electric energy in morning and evening period because the solar radiation is more than 130 W/m²

1.1.2 Ambient Temperatures

Ambient temperature affects the PV generators efficiency.

The relation between efficiency and ambient temperature is inversed [9].

Table (1.3) shows an example of the ambient temperature of the target area achieved by ERC mentioned before. The shown data is the average of five days measurement in June 2012. The original Measurements are done on a 5-minute interval basis [4].

Table (1.3): The daily ambient temperature 23-7-2012

Hours	Ambient temp.(°C)	Hours	Ambient temp.(°C)
01:00	22	13:00	32
02:00	22	14:00	32
03:00	22	15:00	31
04:00	21	16:00	31
05:00	21	17:00	29
06:00	22	18:00	28
07:00	22	19:00	27
08:00	23	20:00	25
09:00	24	21:00	24
10:00	27	22:00	24
11:00	28	23:00	23
12:00	31	00:00	22

Figure (1.3) shows the daily curve of the ambient temperature drawn from the data table (1.3). It shows that the maximum temperature occurs around noon time (32°C), and the minimum temperature occurs in the early morning (21°C).

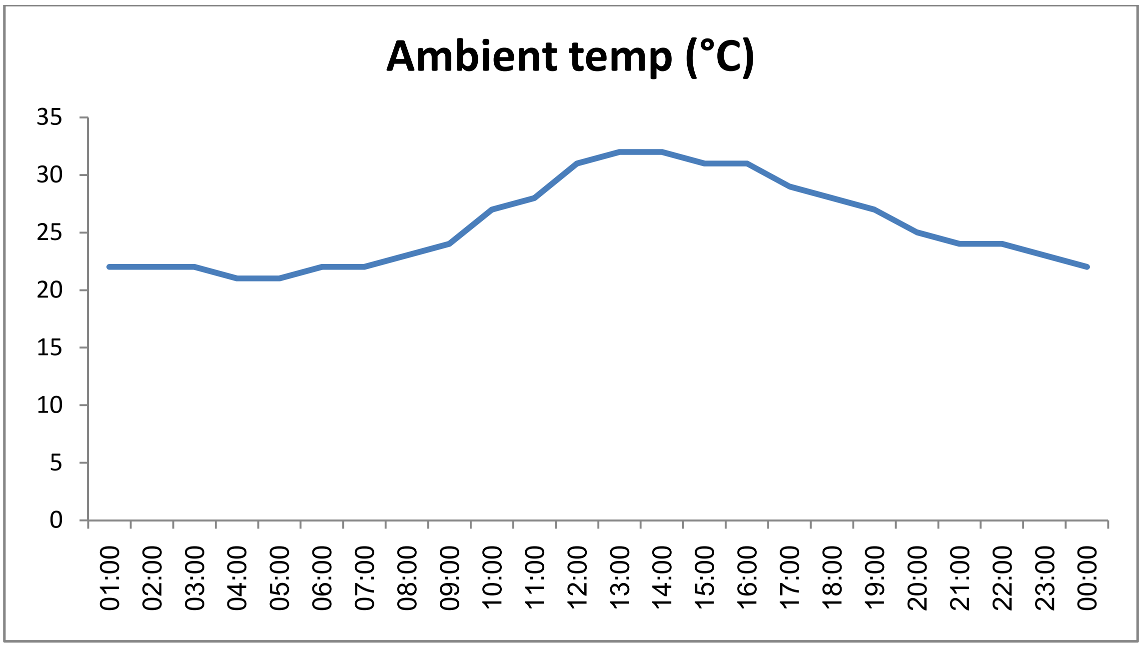

Figure (1.3): The daily ambient temperature 23-7-2012

1.2 Existing Solar Energy Projects in Palestine:

Introduction

Photovoltaic electrification in isolated rural villages and communities in Palestine is considered feasible and effective compared with other alternatives like electrical grid and diesel generators.

The PV electrification could be using the decentralized stand alone and centralized systems, depending to the nature of the load and the distribution of houses.

Photovoltaic electrification is limitedly used in different rural areas in Palestine mainly for schools, clinics, Bedouins communities, agricultural and animal farms, and private homes.

The most recently PV electrification project was implemented by the energy research center at An Najah National University.

The most important solar energy projects in Palestine are:

1. Electrifying a Palestinian village **Atouf** (Tubas) by PV centralized power system; the village includes 25 houses, school, and clinic with power capacity about 12 kWp [4].
2. Electrifying a Palestinian village **Imnezel** (south Hebron) by PV centralized power system [4].
3. Electrifying a Palestinian village **Al-Saed** (Yaebd-Jinin) by PV centralized power system [4].

4. Electrifying a Palestinian village **Al-Mikhal** (Yaebd-Jinin) by PV centralized power system [4].
5. Electrifying a Palestinian village **Yerza** (Tubas) by PV decentralized power system [4].
6. Electrifying a Palestinian village **Ibziq** (Tubas) by PV decentralized power system [4].
7. Electrifying a Palestinian School Rabood (south Hebron) [4].
8. Alisteqlal center for media and development , also use solar PV system to Electrification **Um-Alkher**, **Almajaz** and **Aldaqiqa** villages in south of Hebron [4].
9. The applied research institute-Jerusalem (ARIG), also implemented some PV projects such as:

- Utilization of Solar Energy in lighting **Jub-Altheib** Village in the West Bank (Southeast Bethlehem) [6].
- Utilization of Solar Energy in lighting **Al-Bierh Children Happiness Center** (Albira) [6].
- Utilization of Solar Energy in lighting the emergency entrance of the clinic of Medical Charitable Society (Toque- Bethlehem) [6].

- Installed 500 watt solar panel system at the **Applied Research**

Institute to power the external lighting system of ARIJ and to assist in establishing a research center for renewable energy [6].

10. Palestinian solar and sustainable energy society (Psses), implemented PV project for Streetlights of Wadi El-Nar (the road connects Hebron with Bethlehem) by Solar energy [7].

11. Renewable energy Unit- Hebron University.

Research with a view to the exploitation of wind energy and solar energy for lighting of the University and its facilities by two stages, First stage; lighting the green room at the University, Second stage; street lighting for the University [8].

12. Action Against Hunger Foundation (ACF). They implemented some Projects to supply electricity to the Nomadic areas in Yatta, **Khirbet Altaban** and **Alfkhit** (South of Hebron) using solar energy [4].

13. SATCO Company. They implemented in December 2010, project of Street Lighting using Solar Energy, The project was executed in Jericho city, to light the Amman-AL-Karama Bypass Street in Jericho [10].

14. Palestinian Energy and Natural Resources Authority. They implemented Jericho station to generate solar electricity, this project funded by Japanese Government, with the support of the Japanese development cooperation (JICA). [4]

15. Authority of Water and House of Water and Environment (HWE) and Alnajah National University, implemented Water pumping project in the Palestinian village **Beitillu** (Ramallah) depending on solar energy, this project was funded by UNDP_ GEF\SGP. [12]

16. Palestinian Hydrology Group for water and environmental resources development (PHG) –Gaza, they implemented lighting project the

main idea is to provide electricity for Gaza Valley Bridge by solar energy, this project was funded by Global Environmental Facility - Small Grant Program, and UNDP. [13]

Chapter Two

Configuration of PV System

Chapter Two

Configuration of PV Systems.

Introduction

Photovoltaic's offer consumers the ability to generate electricity in a clean, quiet and reliable way.

Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells.

The word photovoltaic comes from “photo” meaning light and “voltaic” which refers to producing electricity. Photovoltaic's are often referred to as PV.

PV made of at least two layers of semiconductor material. One layer has a positive charge, the other negative.

When light enters the cell, some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell’s negative layer to flow through an external circuit and back into the positive layer. This flow of electrons produces electric current.

The following figure (2.1) shows the main components of PV cell and how it works [11].

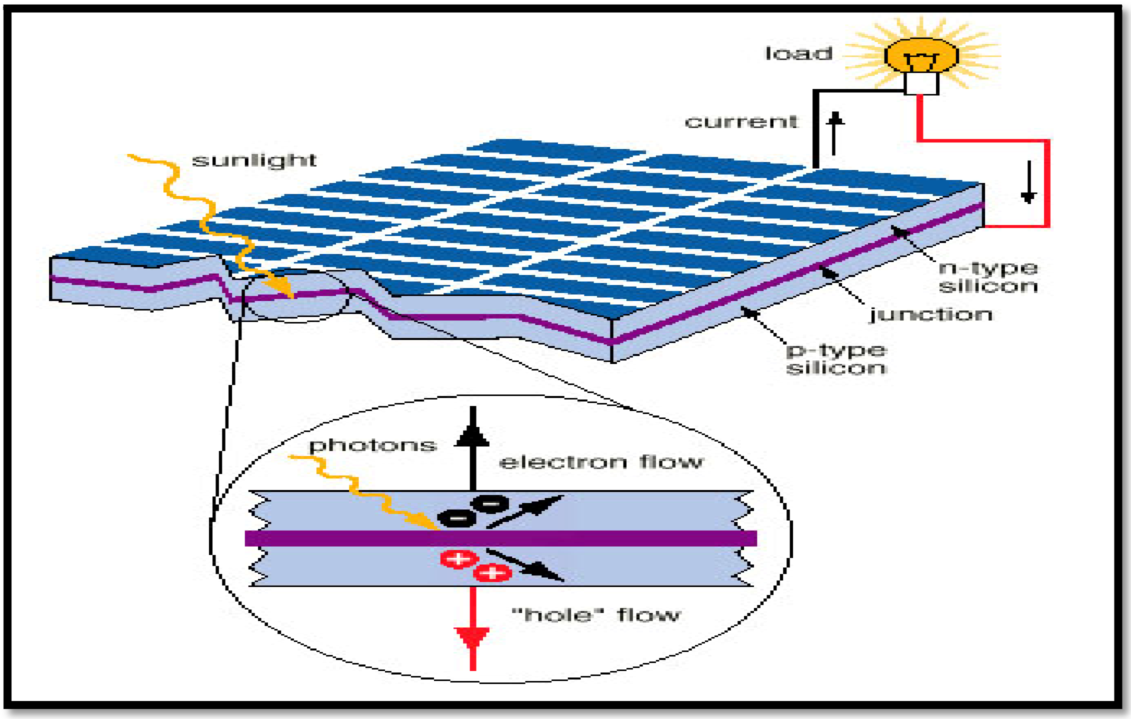

Figure (2.1): Basic solar cell construction

2.1 Types of PV System

There are two major types of PV system, and it depend on the connection of the system if it's connected to the main grid or it stands alone without any connection, these types are [11]:

- Off-grid systems.
- Grid-tied systems.

2.1.1 Off-Grid Systems

They are also called stand-alone systems. Although they are most common in remote locations without utility grid service, off-grid solar-electric systems can work anywhere. These systems operate independently from the grid to provide loads with electricity, and there are many types of this system.

Types of Off-Grid System

1. DC system without storage.

It's the simplest type, where the DC output of a PV module is directly connected to a DC load. The critical part of designing a well performing direct-coupled system is the matching of impedance of the electrical load to the maximum power output of the PV module. It can be used to operate pumping machine where water is pumped in the day to reservoir for used at night. The following figure (2.2) shows the DC system without storage [11].

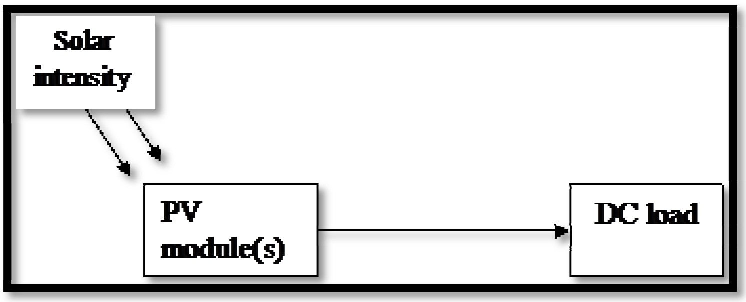

Figure (2.2): DC system without storage.

The disadvantages for this type of off-grid are:

1. It can only be used in the day to supply load as there is no battery for storing energy.
2. It cannot be used with AC load

2. AC system without storage.

This is another type of off-grid system is the type that incorporate inverter unit for conversion of DC voltage to AC at appropriate voltage level [11].

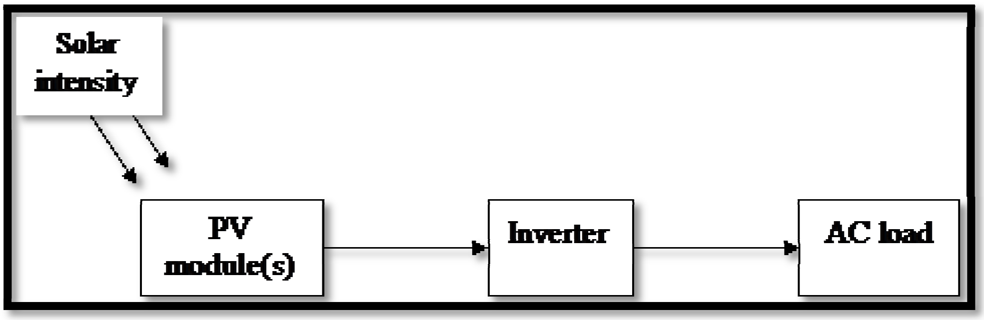

Figure (2.3): AC system without storage

The disadvantage of this system is

- The lack of storage unit, so it will not supply load at night.

3. Off-Grid system with DC output and battery.

Figure (2.4) shows the block diagram of a typical off-grid stand-alone PV system. A solar PV array, battery, and charge controller are the three primary components of the PV system. The solar array generates DC power for the load and charges the battery, which serves as the energy storage device that powers the load when there is no output from the array. The charge controller regulates the output of the PV array and ensures proper charging of the battery, thus protecting it from abuse. A portable gen-set is required to power the telecom equipment in case of no power output from the PV system [11].

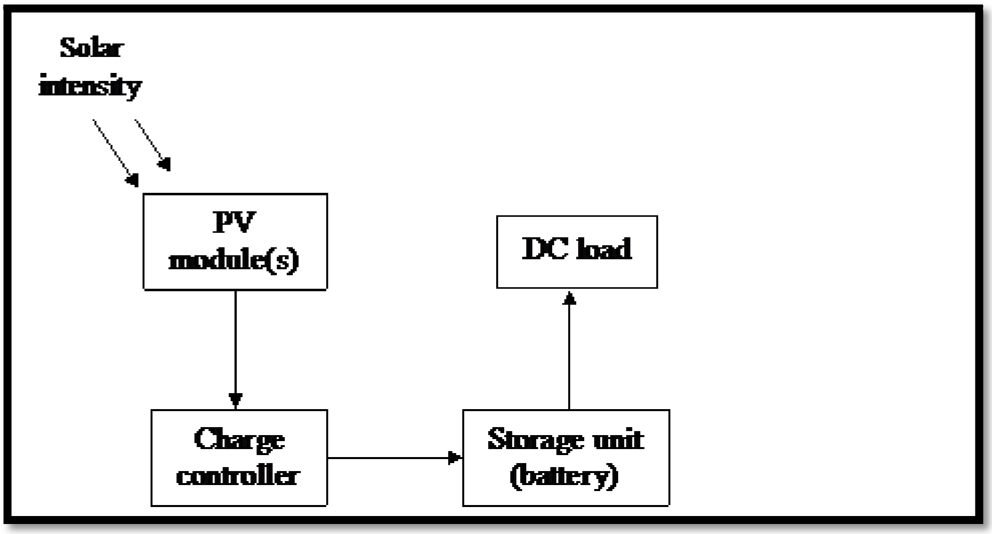

Figure (2.4): Off-Grid system with DC output and battery

4. Off-Grid system with battery and DC and AC output.

The following figure (2.5) shows the Off-Grid system with battery for storage and both types of output loads DC and AC [11].

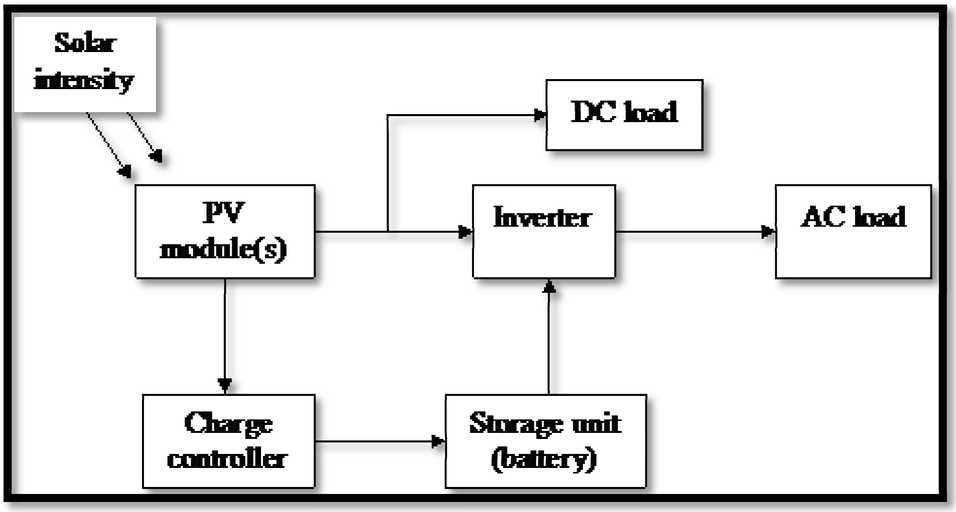

Figure (2.5) Off-Grid system with battery and DC and AC output

5. Off-Grid system with battery and without DC output.

This system is only for AC loads and there is no DC loads. We can use it for one phase and three phases; it depends on the type of the inverter.

The following figure (2.6) shows this type of Off-Grid system

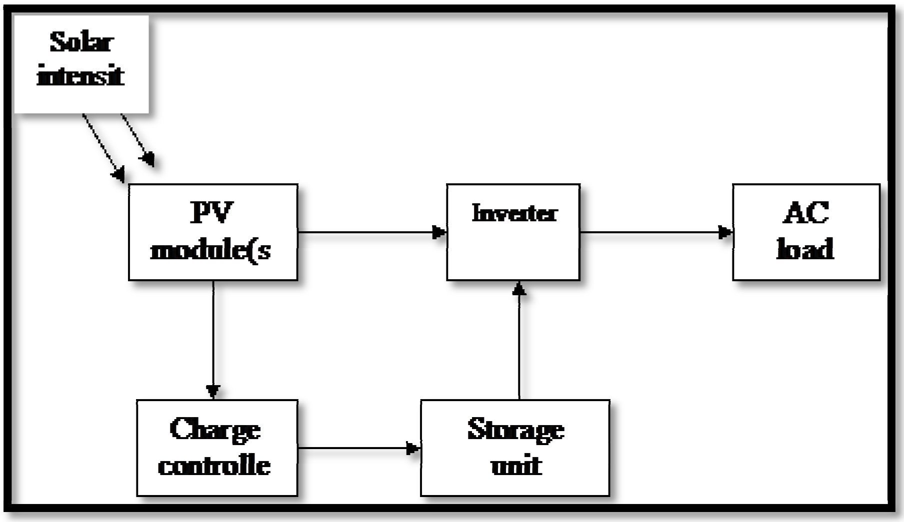

Figure (2.6): Off-grid system with battery and without DC output.

6. Off-grid system with engine generator as back-up (hybrid system)

   In this thesis we use this type of Off- Grid system to provide electricity to the telecom towers sites as will be shown in next chapters.

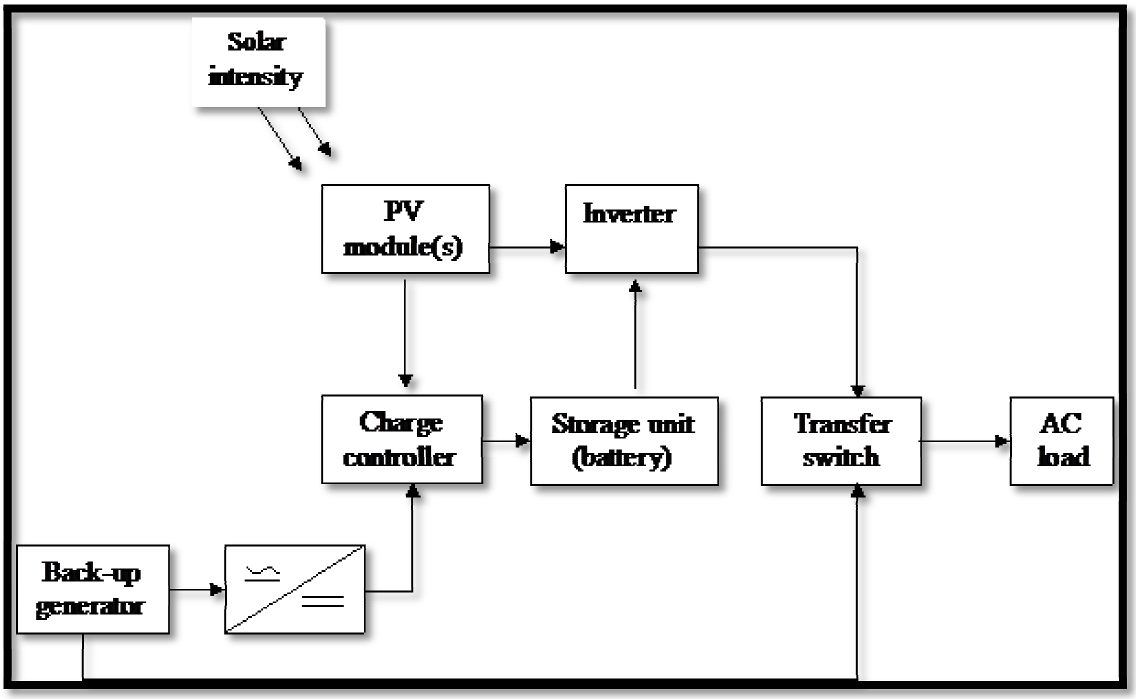

Figure (2.7): Off-grid system with engine generator as back-up

2.1.2 Grid-Tied Systems: (on-Grid System)

They are also called on-grid or utility interactive. Grid-tied systems are designed to operate in parallel with and interconnected with the electric utility grid. Below are the block diagrams of grid-tied systems.

1. Grid-tied system with no battery for storing charges [11].

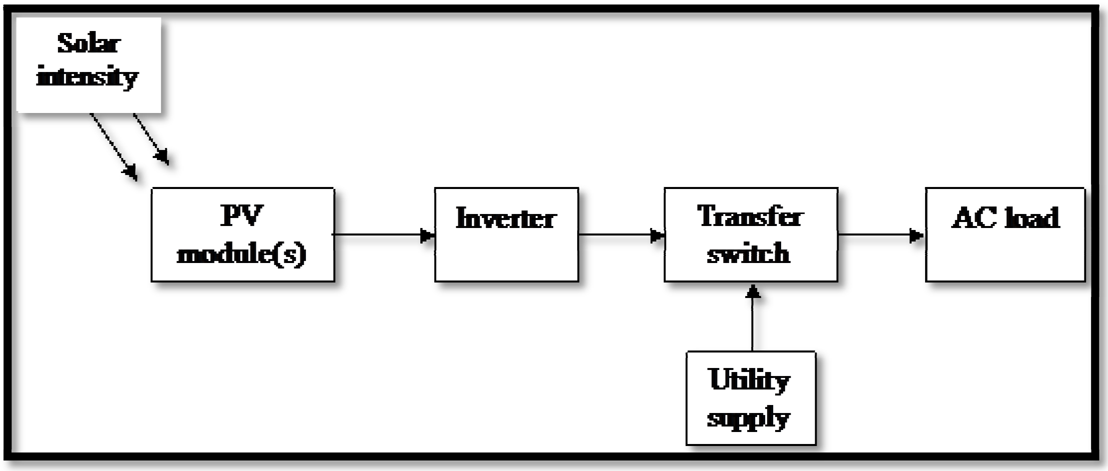

Figure (2:8): Grid-tied system with no battery for storing charges.

2. Grid-tied system with batteries for storing charges [11].

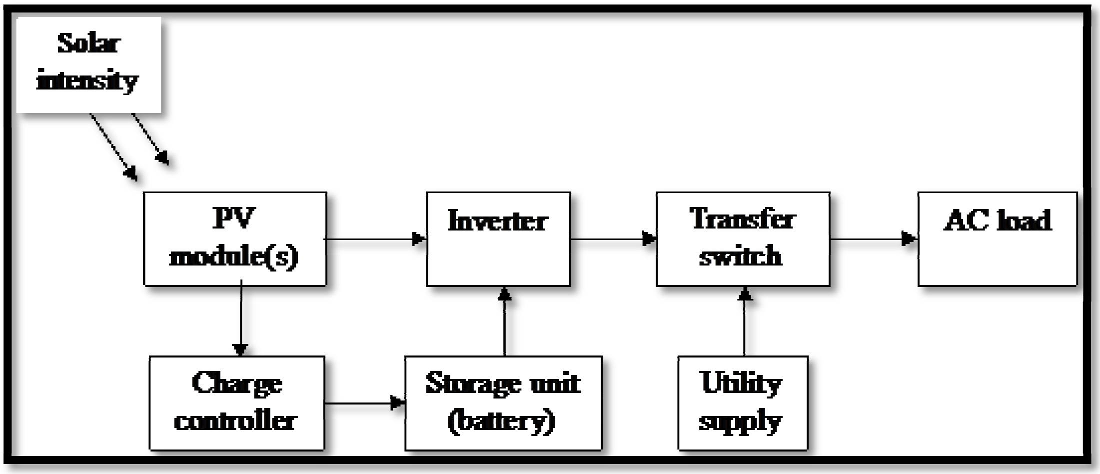

Figure (2.9): Grid-tied system with batteries for storing charges

3. Grid-tied system with utility connected to charge battery [11].

Grid-tied system can also be connected in a way that utility supply will be charging battery in the period of low light intensity. It has the same features as off-grid system with engine generator back-up. In the case of long cloudy days and utility outage, there is likely to be blackout.

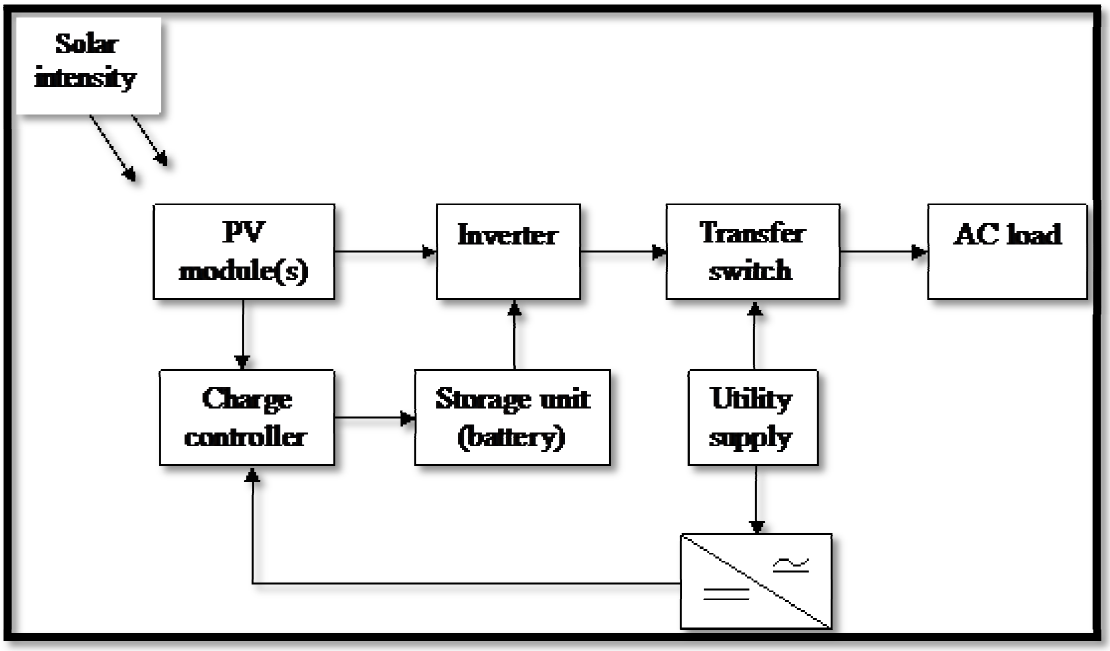

Figure (2.10): Grid-tied system with utility connected to charge battery

2.2 The Selection of Photovoltaic System Elements

A complete system includes different components that should be selected taking into consideration your individual needs, site location, climate and expectations. In this section we review the components' function and several different system types [9].

The functional and operational requirements will determine which components the system will include. It may include major components as; DC-AC power inverter, battery bank, system and battery controller, auxiliary energy sources and sometimes the specified electrical loads (appliances).

Major System Components of PV system [9]:

- Photovoltaic
- Charge controller
- Battery
- Inverter
- Load

2.2.1 Determine PV Sizing

The current produce by a solar cell is proportional to its surface area and the light intensity, whereas the voltage is limited by the forward potential drop across the p-n junction.

In order to get higher voltages and currents, the cells are arranged in series and parallel strings and packed into modules for mechanical protection. The support structure for PV modules should be corrosion resistant (galvanized or stainless steel or aluminum) and electrolytically compatible with materials used in the module frame, fasteners, nuts, and bolts. The design of the support structure should allow for proper orientation of the module and tilt.

Figure (2.11) shows form of PV from cell to array [5].

- Cells: Semiconductor device that converts sunlight into direct current (DC) electricity.

- Modules: PV modules consist of PV cell circuits sealed in an environmentally protective laminate and are the fundamental building block of PV systems.

- Panels: PV panels include one or more PV modules assembled as a pre-wired, field-installable unit.

- Arrays: PV array is the complete power-generating unit, consisting of any number of PV modules and panels.

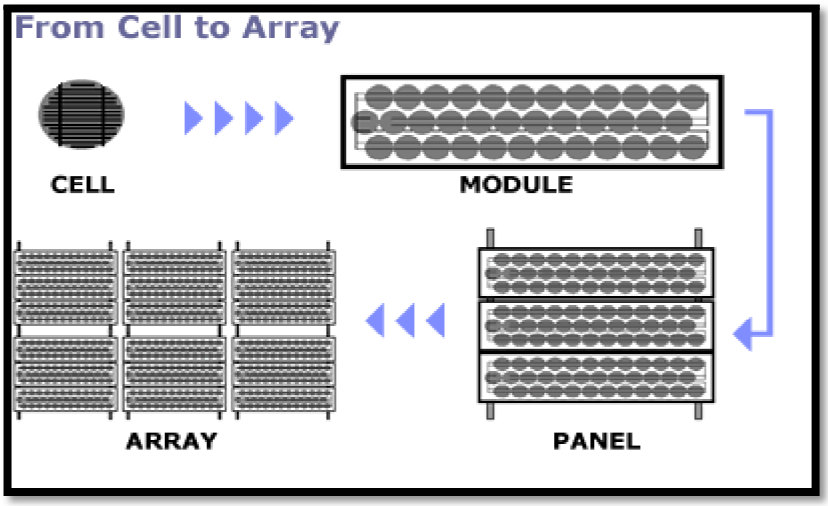

Figure (2.11): Form of PV from cell to Array.

For Selection the right capacity of the PV modules it is necessary to determine the power consumption demands as the following:

1. Calculate total Watt-hours per day for each appliance used which equal the energy consumption per day [14].

2. Calculate total Watt-hours per day needed from the PV module by using the following equation (2.1) [14].

$$\text{PV Energy} = \frac{\text{Energy consumption per day}}{\text{Efficiency inverter} \times \text{Efficiency charge controller}} \quad \mathbf{(2.1)}$$

After that it is necessary to Calculate the total Watt-peak rating needed for PV modules by using the following equation (2.2) [14].

$$\text{Power peak (wp)} = \frac{\text{PV energy/day} \times \text{Safty factor}}{\text{Peak Sun Hours}} \quad \mathbf{(2.2)}$$

To determine the Size of PV modules, it is necessary to calculate the number of PV modules for the system by using the following equation [14].

$$\text{No of modules} = \frac{\text{Power peak}}{\text{power for one module}} \quad \mathbf{(2.3)}$$

$$\text{No of modules in series} = \frac{\text{Voltage of the PV generator}}{\text{Voltage of one module}} \quad \mathbf{(2.4)}$$

$$\text{No of strings} = \frac{\text{No of modules}}{\text{No of modules in series}} \quad \mathbf{(2.5)}$$

$$\text{Total area nedded for PVG} = \text{\#of module} \times \text{area of one modul}e \quad \mathbf{(2.6)}$$

2.2.2 Determine Inverter Sizing

An inverter is a basic component of any independent power system that produces AC power. Inverters convert DC power from PV module or stored in batteries into AC power to run conventional appliances. Another application of inverters is in the case of uninterruptible power supply where the inverter with the aid of 12V DC battery is able to generate up to 220V

AC that can be used to power most of the house and office appliances depending on their power rating.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type, motor or compressor, then inverter size should be minimum three times of the capacity of those appliances and must be added to the inverter capacity to handle high starting current of these appliances. [14].

For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation [14].

Select the right capacity of the Inverter

For selection the inverter, necessary determine the following parameters.

- Vinput , has to be matched with battery block voltage.
- Power of inverter ≥ total required power. **(2.7)**
- The efficiency must be not less than 90 %.

2.2.3 Determine Battery Block Sizing

Since, the storage capacity for this system is considerably large, so we have to select a special lead-acid battery cell (block type) which are of long life (more than 10 years), high cycling stability (more than 1100 times) and standing very deep discharge [15].

The selection of the capacity of batteries in Ah, which are necessary to cover the load demands for a period of two autonomy days, can be calculated as the following [15].

$$\mathrm{Ah} = \frac{\text{autonomy days} \times \text{Energy consumption per day}}{\text{Depth of discharg} \times \eta\ \text{Battary} \times \text{VBattary} \times \eta\ \text{Inverter}} \qquad (\mathbf{2.8})$$

The capacity of batteries in Wh , can be calculated as the following:

$$\mathrm{WA} = \text{Amper hour capacity} \times \text{Voltage of battary} \qquad (\mathbf{2.9})$$

2.2.4 Charge Controller Sizing

It's a DC/DC converter, used to regulate the output current of PV generator going to the inverter, and to protect the battery block against deep discharge and over charge, input/output rating of CR are fixed by the output of the PV array and VB [14].

The selection the charge controller is necessary to determine the following parameters:

- V input , must equal to the V Open Circuit.(PV)
- V output , must equal to V nominal(PV)
- The efficiency must be not less of 92 %.
- The current for charge controller

I = Is.c for one modules × modules in Parallel × K safety factor **(2.10)**

K safety = 1.25 is a safety factor.

- The appropriate rated power of Charge controller , can be calculated by the following equation:

$$PCC = VCC \times ICC \quad \mathbf{(2.11)}$$

Chapter Three

Electrification of Telecommunication Towers by Using Solar Energy

Chapter Three

Electrification of Telecommunication Towers by Using Solar Energy.

Introduction

Telecommunication towers need electricity to power it; some of towers electrified by electricity come from the grid and remaining through burning of fossil fuel like diesel, and by using diesel generator.

Both of these sources contribute to emission of green house gases (GHG) with the attendant negative environmental effects. Reduction of the GHG produced or caused to be produced by the telecom sector is referred to as greening of telecom. Green telecom can be classified broadly in terms of greening of telecom networks, green telecom equipment manufacture, environment friendly design of telecom buildings and safe telecom waste disposal. These aspects are briefly described below:

- Green Telecom Networks: In telecom networks greening would refer to minimizing consumption of energy through use of energy efficient technology, using renewable energy sources and ecofriendly consumables.
- Green Manufacturing: The greening process would involve using eco-friendly components, energy efficient manufacturing equipment, electronic and mechanical waste recycling and disposal, reduction in use of hazardous substances like chromium, lead and mercury and reduction of harmful radio emission.

- Design of green central office buildings: optimization of energy power consumption and thermal emission, minimization of green house gas emission.

- Waste disposal: disposal of mobile phones, network equipment etc., in an environment-friendly manner so that any toxic material used during production does not get channelized into the atmosphere or underground water.

3.1 The Disadvantages of Using Diesel Generator to Electrification of the Telecommunication Towers

1. Many of telecom towers are in remote locations or not easily accessible places maintenance can be expensive and time consuming.

2. The important point is the Cost of fossil fuels is on the increase. This means that as times pass the running costs will keep getting higher with DG generators. The cost of electricity from the DG also is increasing in cost steadily.

3. The high quantity of carbon emissions from diesel generators, which affecting the environment negatively.

3.2 Global Examples of Using PV- Solar Systems for Electrification of Telecom Towers.

❖ The China Mobile has one of the world's largest deployments of green technologies to power its base stations. China Mobile had 2,135 base station powered by alternative energy in 2008. Of these 1,615 were powered by alternative solar energy, 515 by solar and wind energy and 5 by other alternative sources. According to a study low-carbon telecommunications solutions saved China 48.5 million metric tons of direct carbon dioxide emissions in 2008 and 58.2 million metric tons in 2009 and projected to deliver as much as 615 tons in carbon savings by the year 2020 [16].

- Indonesian operator PT Telekomunikasi Selular (Telkomsel) is using latest generation low power consumption RBSs which are powered by Solar technology from Ericsson to provide macro coverage in Sumatra and rural areas of Indonesia [16].

- In India, have around 310,000 telecom towers of which about 70% are in rural areas. Presently 40% power requirements are met by grid electricity and 60% by diesel generators. The diesel generators are of 10-15 KVA capacity and consume about 2 liters of diesel per hour and produce 2.63 kg of CO2 per liter. The total consumption is 2 billion litres of diesel and 5.3 million litres of CO2 is produced. For every KWh of grid electricity consumed 0.84 Kg of CO2 is emitted. Total CO2 emission is around 5 million tones of CO2 due to diesel consumption and around 8 million tons due to power grid per annum. [16].

- Jordan Telecom Implement solar energy project for telecom tower in Karak area is a hybrid system that contains solar panels, wind turbine and diesel engine generator. The study for this site was done by local subcontractor.

Also there are 15 projects for telecom sites with stand alone solar systems are installed and support GSM telecoms equip.

Jordan Telecom are installing solar systems for outdoor sites where there is no need for a/c units and the average load is 300W to 1400W including the consumption of fans [17].

3.3 The Advantages of Electrification Communication Towers by Using Solar Energy Instead of Diesel Generator

There are many advantages that can be achieved by using PV system to electrification telecom towers instead of DG.

- To reduce the cost of operations of the telecom network by reducing energy cost. as solar powered systems have no moving parts in them they are relatively maintenance free delivering a higher reliability
- To expand network into rural areas where power availability is poor.
- Renewable energy technology becoming available at increasingly reducing cost.
- Confluence of socio-political trends towards environmental responsibility, pressure groups against global warming
- To create sustainable businesses and it has become important where the objective is not only to create products and services through ethical

means but also minimize environmental impact and improve communities.

- Also solar power reduces carbon emissions and helps us to be environmentally friendly.

- After the one time investment in solar power, the running costs are almost nil thus protecting the investment from inflation and increasing raw material costs.

3.4 System Configuration for Electrification of the Telecommunication Towers

For electrification of telecommunication towers in west bank – Palestine, we select the following configuration figure (3.1), which consists of the following elements [11]:

1- DG (stand by source).
2- Inverter (to convert DC to AC)
3- PV (for producing electricity)
4- Batteries (storage system)
5- Charge controller.
6- Transfer switch

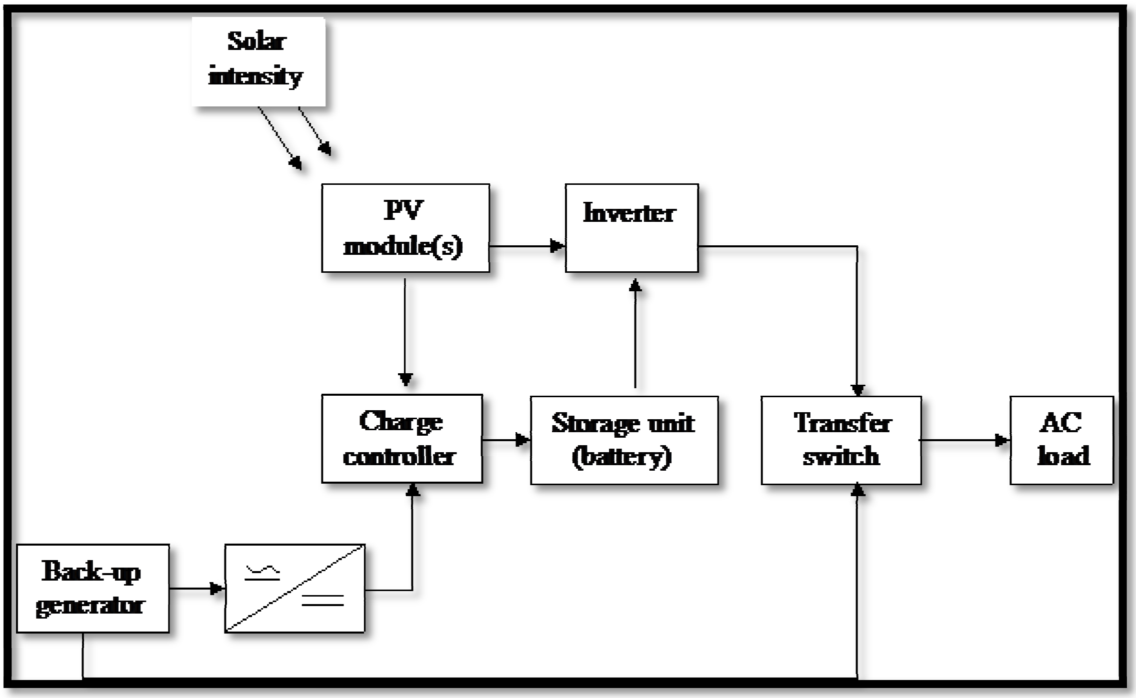

Figure (3.1): Configuration of Off-grid PV system with DG as back-up to produce electricity for telecom towers.

Chapter Four

The Existing Situation in Jawwal Company Regarding the Electrification of Telecommunication Towers

Chapter Four

The Existing Situation in Jawwal Company Regarding the Electrification of Telecommunication Towers

4.1 Introduction

Jawwal is the first Palestinian Provider for communication services; it helps all people to communicate through the latest technology**,** Jawwal has more than 1300 towers in all Palestinian area [18], in West Bank and Gaza, and also it have 4 main switches, outside the country, in London, Jordan, and Israel [18]

All Jawwal towers are connected to these main switches by international, National and local networks, each telecom tower provide communication services to the customer in the surrounding area.

Telecom towers are usually very similar in terms of design, equipments, and principle of work, and also electrical loads. In each site there is a small room $4m^2$ area containing telecom equipments, electrical AC distribution boards, racks, DC power system …else

Approximately the electrical loads are the same at all telecom towers, but there is some difference because there are many types of air conditioner.

Telecom equipments are very sensitive, it needs a stable source of electricity, so all telecom equipments in Jawwal towers working on 24V DC source, each site has stable power system, counting AC to DC inverter, 2 battery systems, each battery system contains 4 batteries in series with 6V for each battery , rectifier.

The largest electrical loads is air conditioner, because the telecom equipments must be under low temperature between 17C-20C, so it must working for a long time during a day in winter and summer.

Note that all telecom towers rooms are isolated very well from all sides as shown in figure (4.1),

This maybe reduces the working hour for the Air conditioners, because the losses of thermal energy are very little.

Also there is new project in Jawwal to remove all low efficient air conditioners and install new high efficient air conditioners in all telecom towers room.

Figure (4.1): Telecom tower and room for Jawwal Company

4.2 Electrification of Existing Towers in Jawwal Company.

Most of all microwave links (telecommunication towers) for Jawwal including the telecom equipments needs DC power (24V) to operate it, and this mean the sites need an AC/DC inverter to invert the power from AC to DC power.

There are three cases to supply the towers by electricity in Jawwal sites:

- **Main Towers:**

There are about 70 main and important towers in Jawwal [18], supplying of the electricity as follows:

1- Main Source is AC power from Grid networks

2-First Backup System is Diesel Generators.

3- Second Backup system is Battery Systems.

- **Towers that serve small areas:**

There are about 1300 towers [18], supplying electricity as follows:

1- Main source is AC power from Grid networks

2- Backup system is Battery Systems.

- **Towers in remote Rural Areas:**

There are 4 towers in remote rural areas [18], supplying electricity as follow:

1- Main source is Diesel Generators.

2- Backup system is Battery Systems.

4.3 Existing Situation of Towers for Jawwal in Remote Areas.

There are four sites of telecommunication towers in West Bank, supplied with electricity from Diesel Generators for 24 hours daily throughout the year, and there is DC Battery system for Backup, these sites are:

- Za'tara between Nablus and Ramallah
- Raba in Jenin

- Selit Harithia in Jenin
- Frosh Beat Dajan in Nablus

The main problem facing company in these locations is:

- High running cost, due to the high cost of diesel.
- Emission from diesel, dirty place.
- Using non sustainable supply, if any fault happens usually, the generator stops working.
- Maintenance problems, each year it is necessary to replace filters, oil….etc for the diesel generator.
- Diesel transportation. It is very difficult to transport diesel for this locations because it's very far and the roads are bad.

4.3.1The Yearly Diesel Consumption of Jawwal Towers.

The yearly Diesel consumption for each site, from July 2011 till June-2012, can be summarized in table (4.1).

Table (4.1): Yearly and average daily Diesel consumption for each site.

Site	Total Diesel consumption per one year 7/2011 till 6-2012	Daily diesel consumption
Za'tara	6030 Litter	16.52 Litter
Raba	7330 Litter	20.1 Litter
Selit Harithia	5300 Litter	14.52 Litter
Frosh Beat Dajan	6000 Litter	16.44 Litter

And it can be illustrated in figure (4.2)

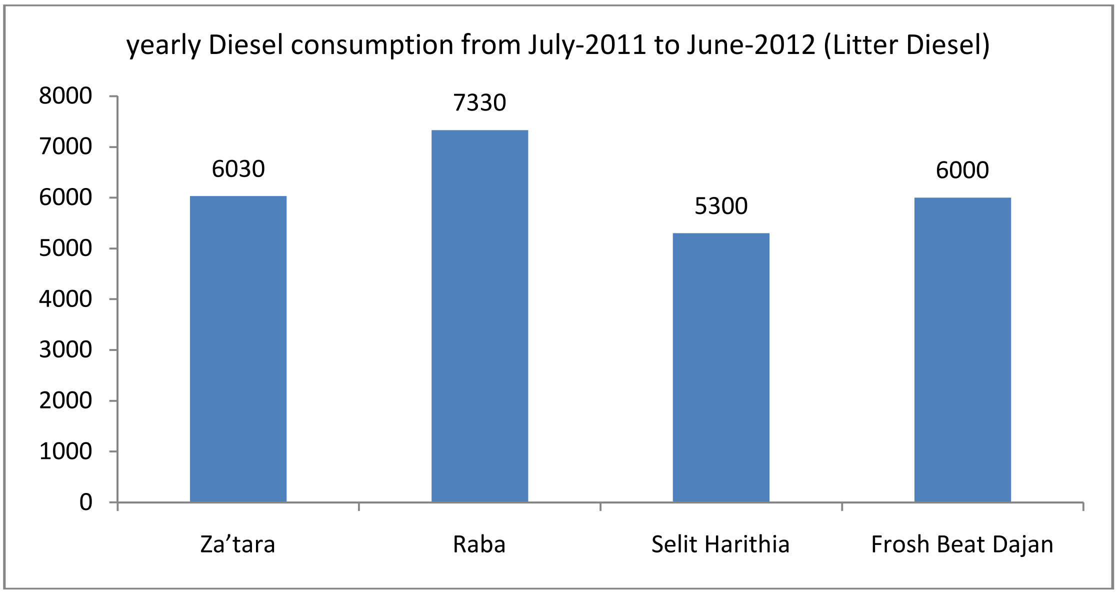

Figure (4.2): Yearly Diesel consumption for each site

4.3.2 The Electrical Consumption of Jawwal Towers:

By using Energy analyzer from ERC, we measured the energy consumption and all electrical parameters for each location as mentioned in (Appendix A).

The Yearly Energy consumption for each site can be summarized in table (4.2), and figure (4.3).

Table (4.2): Yearly Energy consumption (KWh) for each site.

Site	Yearly Energy consumption July/2011 till June-2012
Za'tara	13176 KWh/Year
Raba	14830 KWh/Year
Selit Harithia	11785 KWh/year
Frosh Beat Dajan	12638 KWh/year

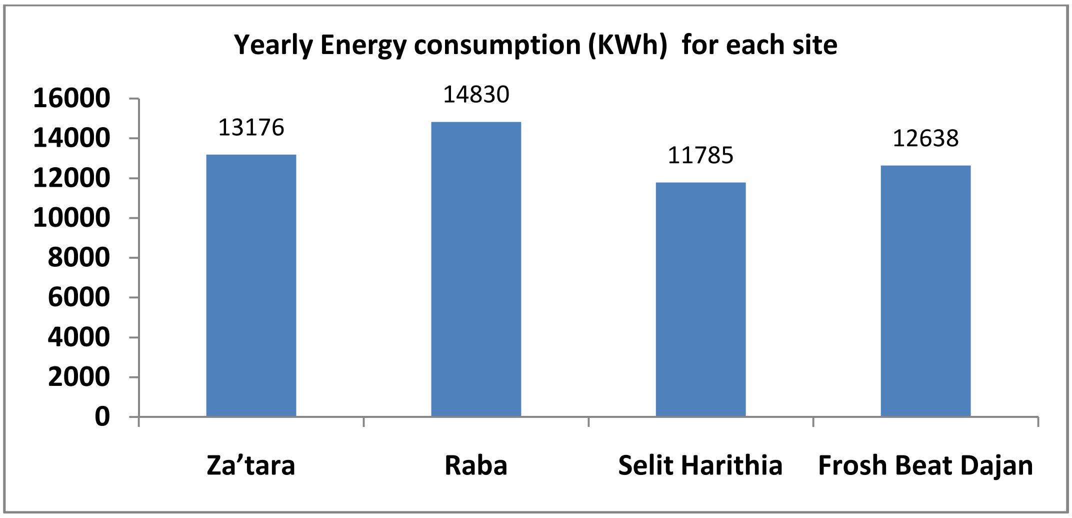

Figure (4.3): Yearly Energy consumption for each site.

From these measurements in (appendix A) the average daily Energy consumption for each location, can be illustrated in table (4.3) and figure (4.4)

Table (4.3): Daily Energy consumption (KWh) for each site.

Site	Daily Energy consumption
Za'tara	36 KWH
Raba	40.52 KWH
Selit Harithia	32.25 KWH
Frosh Beat Dajan	34.53 KWH

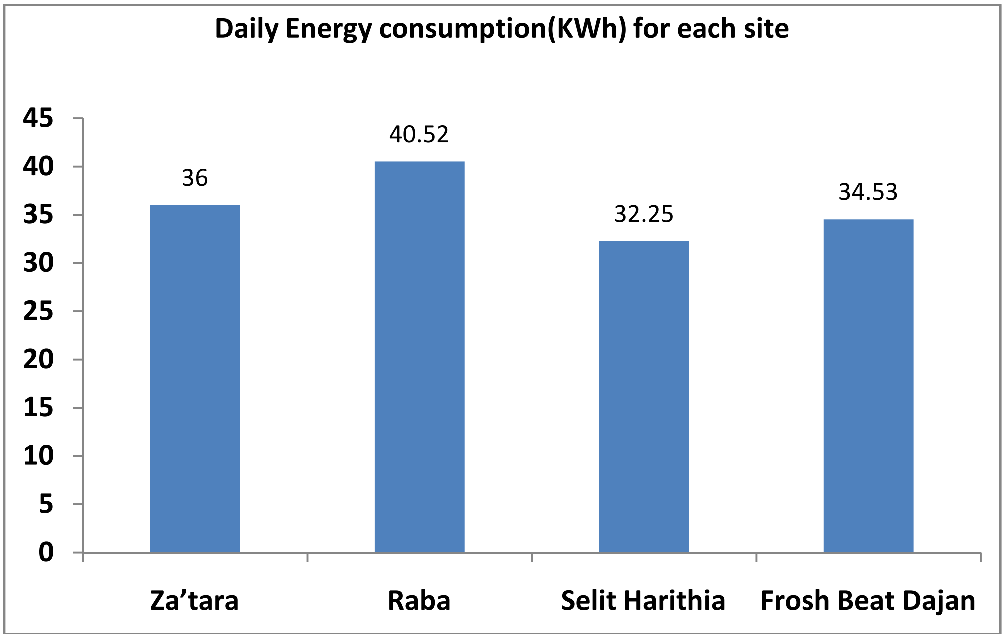

Figure (4.4): Daily Energy consumption (KWh) for each site.

The average monthly energy consumption for each site is shown in the following table (4.4).

Table (4.4): Average monthly Energy consumption (KWh) for each site.

Month	Za'tara	Raba	Selit Harithia	Frosh Beat Dajan
January	1116	1256	1000	1070
February	1044	1174	913	1004
March	1116	1256	1000	1070
April	1080	1216	968	1036
May	1116	1256	1000	1070
June	1080	1216	968	1036
July	1116	1256	1000	1070
August	1116	1256	1000	1070
September	1080	1216	968	1036
October	1116	1256	1000	1070
November	1080	1216	968	1036
December	1116	1256	1000	1070
Total	13176	14830	11785	12638

Chapter Five

Design of PV System for Electrification of Jawwal Towers in Remote Areas

Chapter Five

Design of PV System for Electrification of Jawwal Towers in Remote Areas.

5.1 Analysis of Electrical Loads in Each Site

Actually, the electrical load in each of the mentioned telecom tower site is mainly concentrated Air conditioner system , since the telecom equipment must be under low temperature to protect it from possible damage. Also there is constant load (telecom equipments) works for 24 hours in a day. As a result of my visit to these telecom sites, I've noticed that all of sites are similar to each other, the same shelter, have the same design, the same area, and approximately the same loads.

5.1.1 The Electrical Loads of Telecom Tower shelter at Selit Alharithaya Site

The electrical loads inside 4m² shelter at this site are shown in table (5.1)

Table (5.1): The electrical load for Selit Alharithaya telecom tower site

Appliance	Power (W)	Quantity	Time working (h)	Energy consumption (Wh/day)
CFL lamp	13W	2	1	26
Modem	15W	1	24	360
Fan unit	180W	1	24	4320
Microwave cell equipment (RBS2206)	230 W	1	24	5520
Microwave cell equipment (RBS2206)	230 W	1	24	5520
Microwave cell equipment (RBS2206)	230 W	1	24	5520
Air conditioner	1690W	1	6.5	10985
Total	**2288 W**			**32.25 KWh**

So the total average Energy consumption per one day is =32.25 KWh/day and the total max demand is 2.288 KW

5.1.2 The Electrical Loads of Telecom Tower Shelter at Raba Site

The electrical loads inside 4m² shelter, in Raba site are shown in table (5.2),

Table (5.2): The electrical load for Raba telecom tower site

Appliance	Power (W)	Quantity	Time working (h)	Energy consumption (Wh/day)
CFL lamp	13W	2	1	26
Modem	15W	1	24	360
Fan Unit	180W	1	24	4320
Microwave cell equipment (RBS2202)	280W	1	24	6720
Microwave cell equipment (RBS2202)	280W	1	24	6720
Microwave cell equipment (RBS2202)	280W	1	24	6720
Air conditioner #1	1575W	1	9.94	15655
Total	**2623 W**			**40.52 KWh**

So the total average Energy consumption per one day is = 40.52KWh/day**,** and the total max required power is 2.623 KW**.**

5.1.3 The Electrical Loads of Telecom Tower Shelter at Za’tara Site

The electrical loads inside 4m² shelter at Za'tara site are shown table in (5.3)

Table (5.3): The electrical load for Za'tara telecom tower site

Appliance	Power (W)	Quantity	Time working (h)	Energy consumption (Wh/day)
CFL lamp	13W	2	1	26
Modem	15W	1	24	360
Fan Unit	180 W	1	24	4320
Microwave cell equipment (RBS2202)	280W	1	24	6720
Microwave cell equipment (RBS2202)	280W	1	24	6720
Microwave cell equipment (RBS2202)	280W	1	24	6720
Air conditioner #1	1690	1	6.6	11150
Total	**2738 W**			**36 KWh**

So the total average Energy consumption per one day is =36 KWh/day, and the total max required power is 2.738 KW

5.1.4The Electrical Loads of Telecom Tower Shelter at Frosh Beat Dajan Site

The electrical loads inside $4m^2$ shelter at this site are shown in table (5.4)

Table (5.4): The electrical load for Frosh Beat Dajan telecom tower site

Appliance	Power (W)	Quantity	Time working (h)	Energy consumption (Wh/day)
CFL lamp	13W	2	1	26
Modem	15W	1	24	360
Fan unit	180W	1	24	4320
Microwave cell equipment (RBS2206)	230W	1	24	5520
Microwave cell equipment (RBS2206)	230W	1	24	5520
Microwave cell equipment (RBS2206)	230W	1	24	5520
Air conditioner #1	1575W	1	8.4	13264
Total	**2473W**			**34.53 KWH**

So the total average Energy consumption per one day is =34.53KWh/day, and the total max required power is 2.473 KW

5.2 The Design of PV System For Electrification of Telecom Towers in Remote Areas.

The main reasons for using PV system for electrification of remote Telecom towers can be summarized as the following:

- The fuel is free, it depends on the sun.
- Technology is mature and almost worldwide available and it has modularity, now in Palestine we have some experience with these technologies.
- Low maintenance requirements, clean modules once time in a month.
- Area to install the PV system is available, especially in rural and remote areas.

- In Palestine we have lack of energy supply resources therefore the power generation from solar PV systems will increase our energy resources to be independent at Israel and increasing our security of supply.

All these mentioned advantages are encouraging us to implement the PV system instead of diesel generator.

5.2.1 Design of PV System for Selit Alharithaya Telecom Tower Site

Selection of PV Generator Sizing

To determine the PV sizing, we should calculate the necessary output energy from the PV modules, and its can be calculated by using equation (2.1) [14].

$$E_{\text{PV output}} = \frac{\text{E consumption per day}}{\eta_{\text{In}} \times \eta_{\text{cont}}}$$

Where Energy consumption from table (5.1) equal 32.25 KWh,

η_{In} =0.90, η_{cont} = 0.92.

$$E_{\text{PV output}} = \frac{32.25}{0.9 \times 0.92} = 38.95 \text{ KWh}$$

The peak power (Wp) of the PV generator can be calculated by using equation (2.2) [14].

$$\text{Power peak (Wp)} = \frac{(\text{PV Energy/day}) \times \text{Safty factor}}{\text{Peak Sun Hours}}$$

PSH (average peak sun hours in Palestine) = 5.4, the safety factor for compensation of resistive and PV-cell temperature losses = 1.15.

The power peak necessary for Silet Alharithaya tower

$$\mathrm{Wp} = \frac{38.95 \times 1.15}{5.4} = 8.3\ \mathrm{KW}$$

To obtain this peak value, we select to install 135W high efficiency multicrystal photovoltaic modules for example Kyocera-135,

Rectangular cells module type 135 W of a 1.002 m^2 area, rated at 12 VDC, and P_{mpp} = 135 W the specific of this module shown in (Appendix B.1).

We selected the module of Kyocera-135W for our analysis, because it has a good performance and suitable for our environmental conditions.

The number of necessary PV modules (No_{PV}) can be calculated by using equation (2.3)

$$\text{No of PV modules} = \frac{\mathrm{Wp}}{\text{power for one module}}$$

$$\text{No of PV modules} = \frac{8.3 \times 1000}{135} = 61.5\ \text{PVmodule}$$

and, we take 63 modules for this site, in order to install it in symmetric arrays, each array will include 21 modules, also to be sure we will get the needed Wp value.

We can select the voltage of the DC equal 48 V, so the number of modules in series can be obtained by using equation (2.4).

$$\text{Number of modules in series} = \frac{\text{Voltage of the DC PV generator}}{\text{Voltage of one module}}$$

$$\text{Number of modules in series} = \frac{48\text{V}}{17.7\text{V}} = 2.771 \approx 3 \text{ modules}$$

We can calculate the number of strings by using equation (2.5).

$$\text{Number of strings} = \frac{\text{Number of modules}}{\text{Number of modules in series}}$$

$$\text{No of strings} = \frac{63}{3} = 21 \text{ string}$$

We can select No of arrays to be three arrays with seven strings in each array.

By using equation (2.6) we can calculate the total area needed for PV generator at Silet Alharithya site.

Total minimum area needed for PV generator = # of modules × area for one module.

Total minimum area needed to install PV generator = 63 × 1.002 = 63.126 m^2 which is available in this place.

The configuration of distribution PV modules will be shown in Figure (5.1)

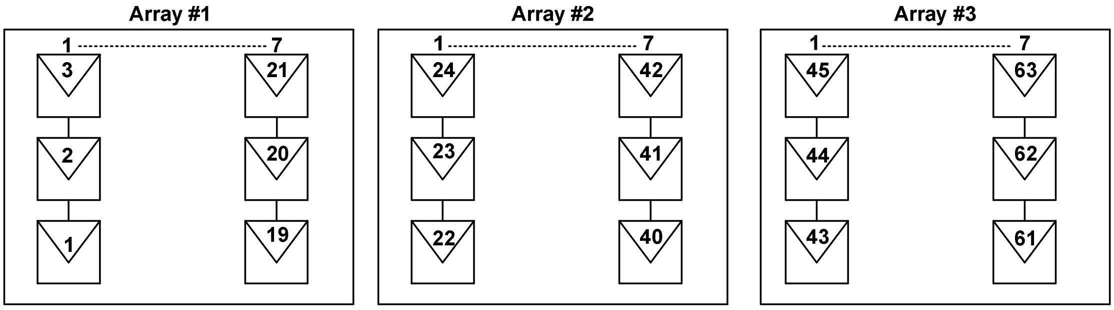

Figure (5.1): The configuration of the PV generator for Silet Harithaya site

For these arrays, the actual maximum open circuit voltage is

$V_{oc} = 3\times22.1 = 66.3$ VDC

The actual maximum short circuit current is

$I_{.sc} = 21\times8.37 = 175.77$ A

Accordingly, the maximum power point of this array will be in the I-V curve at the coordinates of 53.1 V DC and Impp of 160.23 A .

The actual maximum power obtained from PV = 53.1×160.23 = 8.508 kWp, which is enough to supply the tower energy.

5.2.2 Selection of Battery Block Sizing for Selit Alharithya tower

Since the necessary storage capacity for this system is considerably large, so we have to select a special lead-acid battery cell (block type) which are of long life (more than 8 years), high cycling stability (more than 1100 times) and standing very deep discharge [3].

The Ampere hour capacity (C Ah) of the block battery that is necessary to cover the load demands for a period of 2 days autonomy, is obtained by using equation (2.8) [15].

$$\text{Ampere hour capacity} = \frac{2 \times \text{ELoad}}{\text{DOD} \times \eta_{\text{Battary}} \times V_{\text{Battary}} \times \eta_{\text{Invertor}}}$$

where DOD is the depth of Discharge = 0.75

$$C_{Ah} = \frac{2 \times 32250}{0.75 \times 0.85 \times 48 \times 0.9} = 2342 \text{ AH}$$

And the Watt hour capacity (C_{wh}) is obtained from equation (2.9)

$C_{Wh} = C_{Ah} V_{Battary}$

$C_{Wh} = 2342 \times 48 = 112.42$ KWh

To install this capacity, we need 24 batteries in series, (each battery rated at 2 V / 2500 Ah) as shown in Figure (5.2) to build a battery block of an output rated at 48 V DC /2500 Ah (2V/2500Ah block battery has been selected as shown in appendix B.2).

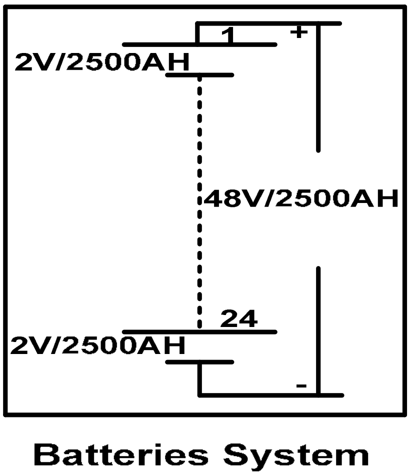

Figure (5.2): The configuration of battery blocks of the PV system for Silet Harithay site

5.2.3 Selection of Charge Controller Sizing for Silet Alharithyia Site

It's a DC/DC converter, used to regulate the output current of PV generator going to the inverter, and to protect the battery block against deep discharge and over charge, the input/output rating of CR are fixed by the output of the PV array and the voltage of batteries (VB) [14]

- The range of the V input equal: $V_{o.c.}(PV) = (3\times12) \div (3\times22.1)$

  $= (36 \div 66.3)$ VDC

- The range of the V output equal: $V_{nominal}(PV) = (48\times0.875) \div (48\times1.2)$

  $= (42 \div 57.6)$ V DC

  The efficiency must not be less than 92 % .

- The current for the selection of charge controller can be calculated by using equation (2.10), and it should be equal $I_{s.c}$ of the module multiplied by No of modules in Parallel and multiplied by safety factor

Where the safety factor =1.25

$I_{C.C} = 8.37\times21\times1.25 \cong 210$ Ampere.

- The power of C.C ,

  P=48V×210A=10080 Watt, we choose the rated power =10 KW

  It's recommended that the CC should have a maximum power control unit.

We select three (70A ÷ 48V) charge controller for Selit Harithya site, as shown in (Appendix B.7).

5.2.4 Selection of Inverter Sizing for Silet Alharithyia Site

For the selection of the suitable inverter, we should determine the following data.

- Vinput , has to be matched with battery block voltage, =
  VCC output = (42÷57.6) V DC
- Voutput , should fulfill the specification of the Diesel generator of the site specified as: 230V AC ± 5%,single phase 50 HZ, (sinusoidal wave voltage) [15].
- Power of inverter :
  By using equation (2.8) we can calculate P nominal for the inverter

P nominal ≥ P max load

P load =2288 Watt

So P nominal = 3 KW

- The efficiency must not be less than 90 %
- (3 KW inverters have been selected for Silet Harthiya site , as shown in appendix B.8)

5.3 Design of PV System for all Remote telecom tower sites

5.3.1 Selection of PV Generator Sizing for All Sites

We make all the calculation for determining the PV generator sizing for all sites, Za'atara,Raba,Frosh bet dajan, and Silet Harthiya table (5.5) summarizes all PV sizing for all sites and the suggestion design for each one.

Table (5.5): The selection of PV sizing for all sites.

Item	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Energy consumption per day (KWH)	36	40.52	34.53	32.25
PV Energy (KWH)	43.48	48.94	41.7	38.95
Power Peak (KW)	9.26	10.42	8.88	8.3
No of PV modules needed	68.6	77.18	65.77	61.48
Actual No of PV modules needed	72	81	72	63
No of PV modules in series	3	3	3	3
No of strings	24	27	24	21
No of Arrays	3 (8 Strings in 1 array)	3 (9 Strings in 1 array)	3 (8 Strings in 1 array)	3 (7 Strings in 1 array)
Total Area of PV generator (m^2)	72.144	81.162	72.144	63.126
$V_{\mathbf{mpp\ (volts)}}$	53.1	53.1	53.1	53.1
$I_{\mathbf{mpp\ (amperes)}}$	183.1	206	183.1	160.23
Actual maximum power peak obtained from PV (KW)	9.72	10.94	9.72	8.5

To obtain this peak value for each site, we select to install 135W high efficiency multicrystal photovoltaic Kyocera modules.

Rectangular cells module type 135 W of a 1.002 m² area, rated at 12 VDC, and P_{mpp} = 135 W, V_{mpp} =17.7 Volt, I_{mpp} =7.63 Ampere as shown in (Appendix B.1)

5.3.2 Selection of Battery Block Sizing for All Sites:

Since the storage capacity for this system is considerably large, we have to select a special lead-acid battery cell (block type) which is of long life (more than 10 years), high cycling stability (more than 1100 times) and standing very deep discharge [15].

The Ampere hour capacity (*C Ah)* of the block battery that is necessary to cover the load demands for a period of 2 days autonomy, is obtained as recommended in [15]

Table (5.6) shows all details to choose right capacity for Batteries Note that to obtain the C_{Ah} and C_{wh} we used in calculation the following:

- Battery system Voltage = 48V
- Efficiency of Battery = 85%
- Efficiency of Inverter =90%
- Depth of Discharge =75 %
- Autonomy days =2

Table (5.6): The selection of Battery Block sizing for all sites

Item	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Ampere hour capacity (C_{AH})	2615	2943	2508	2342
Watt hour capacity (C_{WH}) (KWH)	125.52	141.26	120.38	112.42
No of Battery in series in each string	24	24	24	24
Type of the selected Battery	2V/2700 AH	2V/3000 AH	2V/2700 AH	2V/2500 AH

- For Za'tara to build a battery block of an output rated at 48VDC/2700Ah (2V/2700Ah block battery has been selected as shown in appendix B.3)
- For Raba to build a battery block of an output rated at 48VDC/3000Ah (2V/3000Ah block battery has been selected as shown in appendix B.4)
- For Frosh beat Dajan to build a battery block of an output rated at 48VDC/2700Ah (2V/2700Ah block battery has been selected as shown in appendix B.3)
- For Selit Harithia to build a battery block of an output rated at 48VDC/2500Ah (2V/2500Ah block battery has been selected as shown in appendix B.2)

5.3.3 Selection of Charge Controller Sizing for All Sites

The table (5.7) shows the selection of charge controller for all selected locations:

Table (5.7): The selection of Charge Controller sizing for all sites

Item	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
V input (volt)	36 – 66.3	36 – 66.3	36 – 66.3	36 – 66.3
Voutput (Volt)	42 – 57.6	42 – 57.6	42 – 57.6	42 – 57.6
Efficiency	No less 92%	No less 92%	No less 92%	No less 92%
Approximated rated power for CC (KW)	12	14	12	10
I for CC □ Impp	240	270	240	210
No of CC controller needed	3	3	3	3
Type of CC or Size of CC	80A-48V	90A-48V	80A-48V	70A-48V

- 80 A – 48V charge controller have been selected for Za'tara, and Frosh Beat Dajan as shown in appendix B.5
- 70A – 48V charge controller have been selected for Selit Harithia as shown in appendix B.7
- 90A – 48V charge controller have been selected for Raba as shown in appendix B.6

5.3.4 Selection of Inverter Sizing for All Sites

The Selection of inverter for all remote telecom sites is shown in table (5.8)

Table (5.8): The selection of Inverter sizing for all sites

Item	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
V input (Volt)	42 –57.6	42 –57.6	42 –57.6	42 –57.6
V output (Volt)	230V AC ±5%	230V AC ±5%	230V AC ±5%	230V AC ±5%
Power of inverter (KW)	3KW	3KW	3KW	3 KW
Efficiency	No less 90%	No less 90%	No less 90%	No less 90%
Type of selected inverter	3KW inverter	3KW inverter	3KW inverter	3KW inverter

3 kW inverter have been selected for all sites, as shown in appendix B.8

5.4 The Configuration of PV system for All Remote Locations

The configuration of PV system for all locations can be presented in the following figures (5.3÷5.6). In each configuration illustrated the connections of all elements with cables and protective devices.

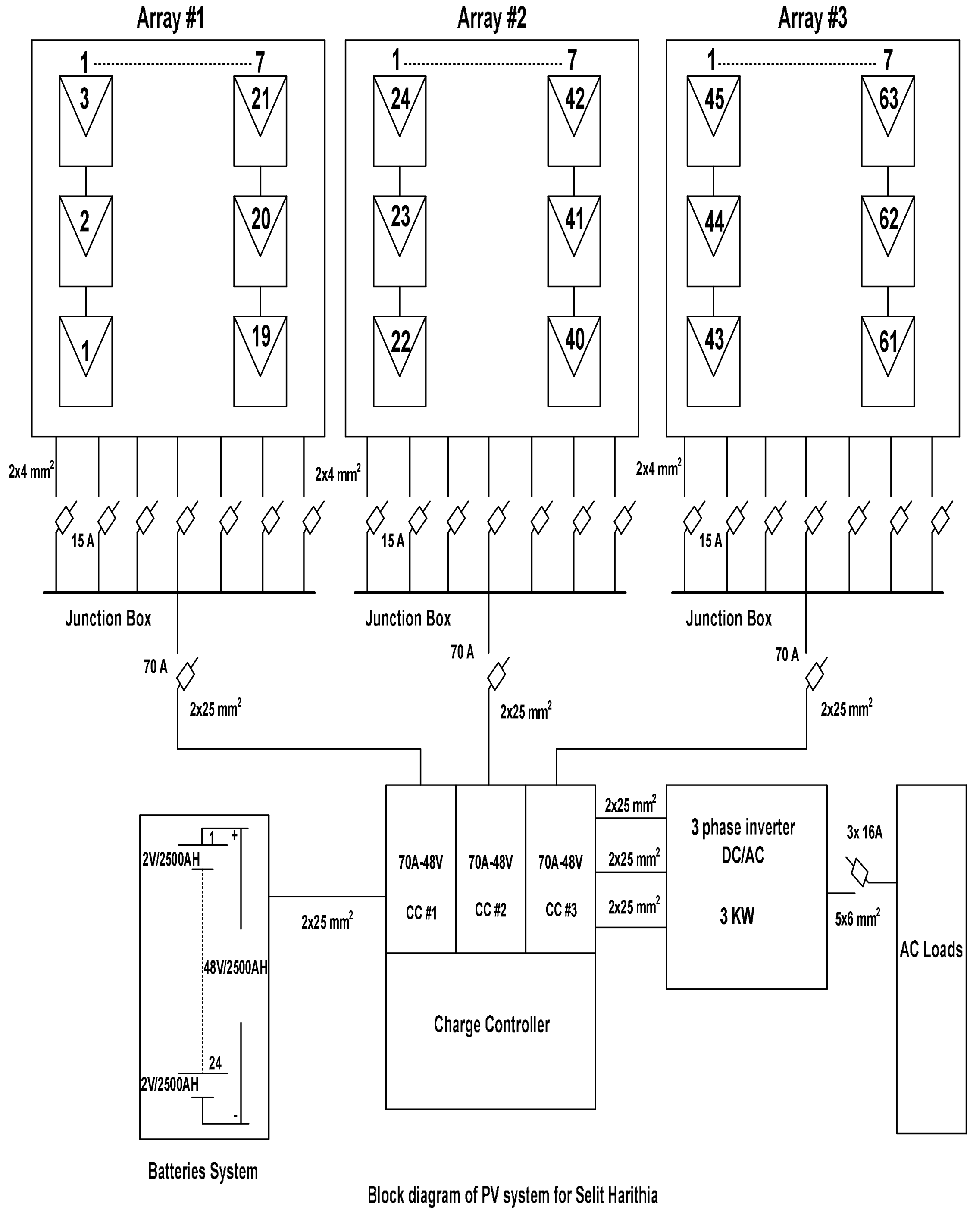

Figure (5.3) PV system with all components for Selit Harithia site

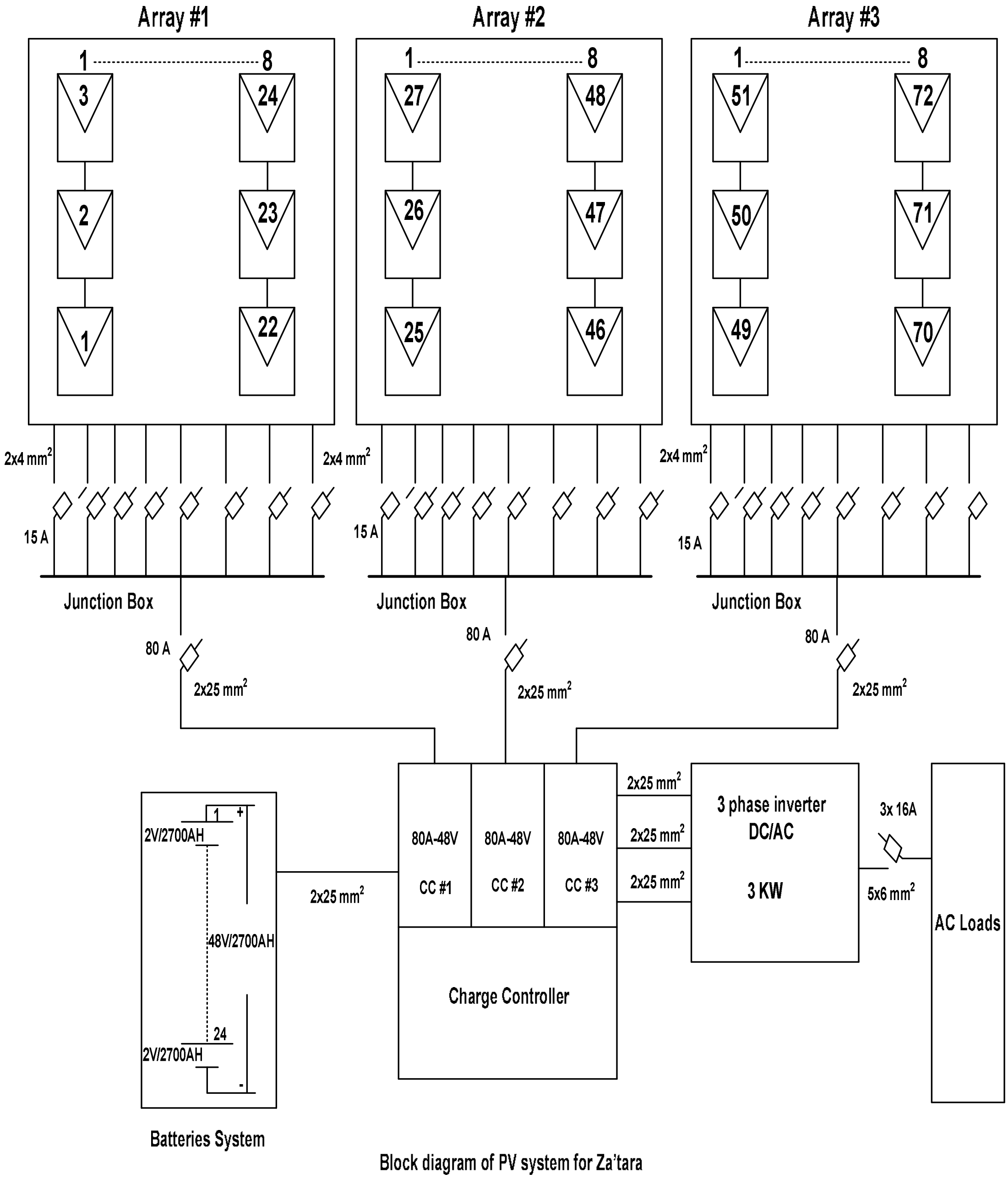

Figure (5.4) PV system with all components for Za'tara site

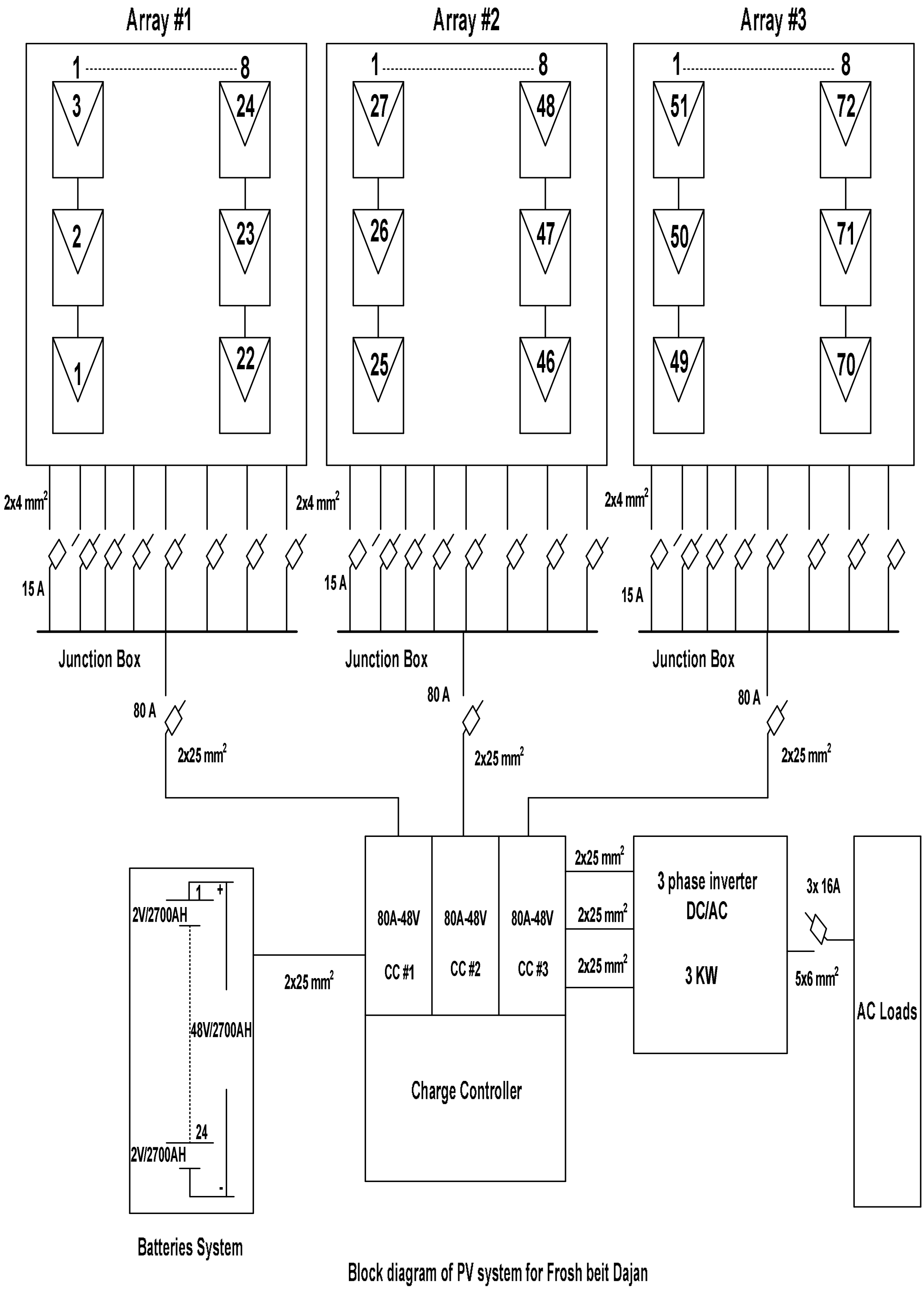

Figure (5.5) PV system with all components for Frosh beit Dajan site

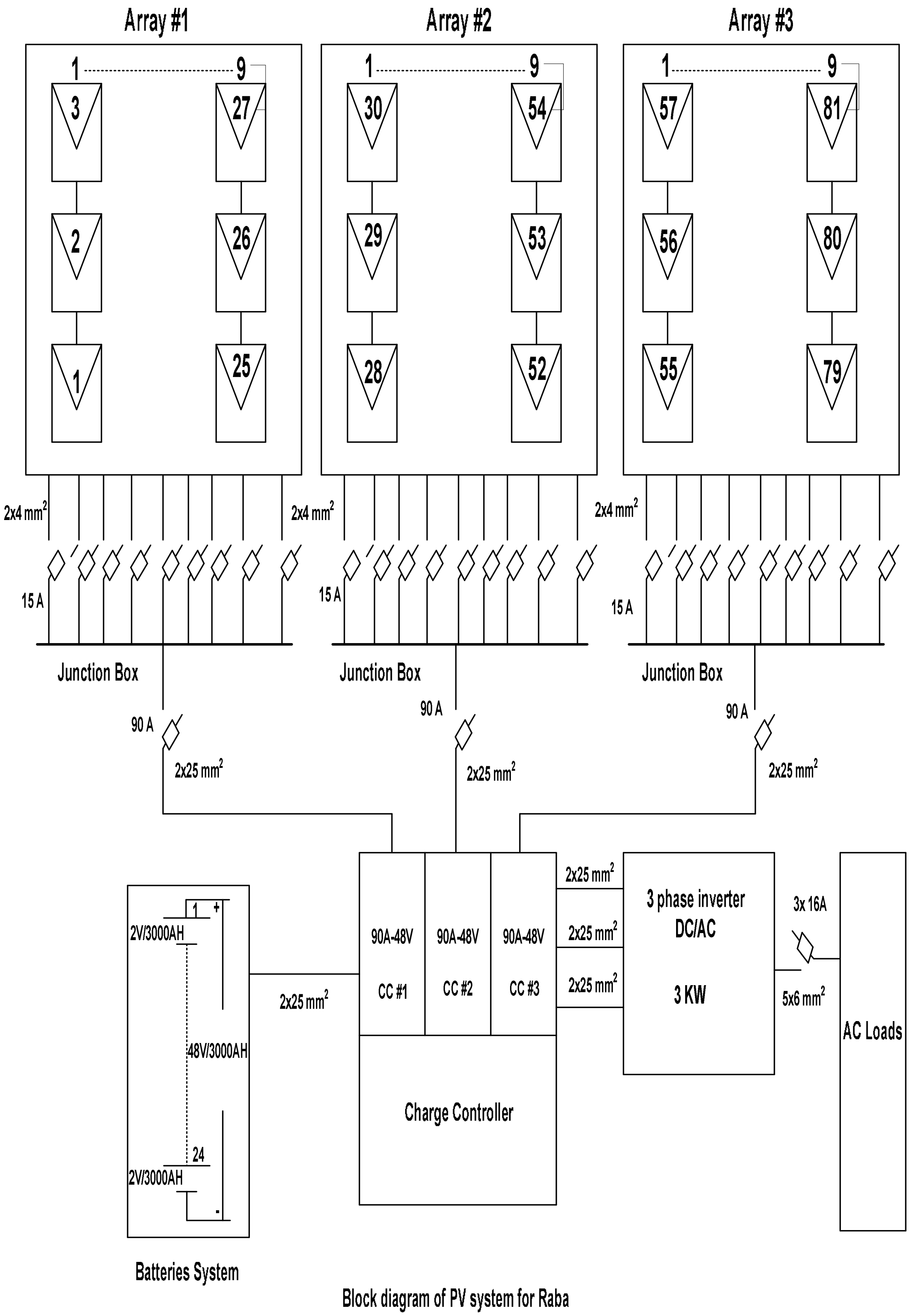

Figure (5.6) PV system with all components for Frosh Raba site

Chapter Six

Economic analysis of using PV solar systems instead of diesel generators

Chapter Six

Economic analysis of using PV solar systems instead of diesel generators

Introduction

The basis of most engineering decisions is economics, beside other significant scientific and environmental factors. Designing and building a device or system that functions properly is only a part of the engineer's task.

The economic model is based on the use of conventional life cycle cost. This includes yearly cash flows, the present value of system costs, incomes and levelized annual costs. In addition, the analysis has been designed to allow economical comparison of using PV system instead of diesel generators.

6.1 Running and Fixed Cost of Existing Diesel Generator, in Jawwal locations

In each Telecom tower site of these above four sites which we are studying in our analysis in each location, there are two diesel generators working 24 hours all day throughout the year, each one works for 12 hours a day, so they require very high operating costs , which can be summarized in the following points

- High maintenance cost
- High diesel consumption
- Prices of oils and filters for the diesel generators

- Cost of transporting diesel to these sites

I noticed that the diesel generators consume high amounts of diesel, despite the load is small compared with fuel consumption, maybe it is because the high capacity of the diesel generator, and the load factor is very small in these generators less than 30%.

Table (6.1) shows the capacity and type of generators for each telecom tower sites.

Table (6.1): capacity and type of generators for each site

Location	No of generator	Type of generator	Capacity
Za'tara	2	LISTER- LPW4	15 KVA
Raba	2	OLYMPIAN-22-2	18 KVA
Frosh Beat Dajan	2	LISTER- LPW4	15 KVA
Selit Harithia	2	LISTER- LPW4	15 KVA

The following table (6.2) shows total fixed cost for the two generators in each telecom tower site. [18]

Table (6.2): total investment cost for each telecom tower site.

Location	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Total investment cost US $	12000	16000	12000	12000

The following table (6.3) explains the yearly running costs for each site of the four sites in U.S $ currency [18].

Table (6.3): Yearly running cost for each telecom tower site.

Location	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Diesel consumption for the two generators ($)/year	10100	12278	8878	10050
Maintenance cost and Prices of oils and filters for the two diesel generators ($)/year	3048	3360	3048	3048
Urgent maintenance cost ($)/year	300	300	300	300
Cost of transporting diesel ($)/year	400	500	500	300
Total ($)/year	13848	16438	12726	13698

Jawwal company are contracted with a private company for maintenance and change the filters and oil for all generators in all telecom towers site.

The price of the diesel consumption in US $ for each telecom site is equal the quantity of diesel in litter multiplied by price of one litter diesel in US $ as shown in the following equation (6.1)

$$\text{price of the diesel conusmption U.S \$} = \text{Quantity of diesel (litter)} \times \text{price of 1 litter in US \$} \qquad (6.1)$$

Note that the average price per one litter of diesel = 6.7NIS, and each U.S $ = 4 NIS

So each litter of diesel= 6.7/4= 1.675 $

6.2 Analysis of Unit Energy Cost from Diesel Generators

To calculate the cost per one KWh electricity produced by diesel generator, we must know running cost table (6.3), and total investment cost table (6.2) for the diesel generators.

Also we need to know the average of energy output from for each generator; this is in table (4.3)

The running cost per one KWh for Selit Harithia site can be calculated as the following.

$$\text{Running cost per KWh} = \frac{\text{Total running cost}}{\text{Total annual Energy consumption}} \qquad \mathbf{(6.2)}$$

$$\text{Running cost per KWh} = \frac{13698}{11785} = 1.15\,\frac{\$}{\text{KWh}}\text{, which is very huge}$$

For the four sites the results are shown in the following table (6.4)

Table (6.4): Running cost per one KWh produced by diesel generators

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Running cost per one KWh produced by diesel generator	1.05$	1.11$	1.01$	1.15$

The fixed cost per one KWh for Selit Harithia site can be calculated as the following:

$$\text{Fixed cost per KWh} = \frac{\text{Total investment cost} \times \text{D.F}}{\text{Total annual Energy consumption}} \qquad \mathbf{(6.3)}$$

Where D.F is depreciation factor and its equal =0.1

$$\text{Fixed cost per KWh} = \frac{12000 \times 0.1}{11785} = 0.1\ \$/\text{KWh}$$

For the four sites the results shown in the following table (6.5)

Table (6.5): Fixed cost per one KWh produced by diesel generators

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Fixed cost per one KWh produced by diesel generator	0.09$	0.11$	0.1$	0.1 $

The total cost per one KWh electricity from diesel generator for each telecom towers site from diesel generators

It will be the summation of fixed cost per one KWh plus the running cost per one KWh as shown in table (6.6).

Table (6.6): Total cost per one KWh produced by diesel generators

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Total cost per one KWh produced by diesel generator	1.14$	1.22$	1.11$	1.25 $

6.3 Fixed and Running Cost of PV System for Remote Locations.

6.3.1 Fixed and Running Costs of PV System for Selit Harithia Site

The associated costs of the components, materials and erections of the PV power system are shown in table (6.7):

Table (6.7): The fixed and running costs of the PV system for Selit Harithia site.

Component	Quantity	Unit price US $	Total price US $	Life time year
PV module (135W)	8500 WP	1.1/Wp	9350	25
Batteries (2V/2500Ah)	24	800	19200	10
Charge Controller 10 kW	1	0,8/W	8000	25
Inverter 3 kW	1	1.2/W	3600	25
Others *		1/WP	8500	25
Total Capital System Cost	**48650 $**			
O&M System Cost /year**			800	
Electrical Losses /year***			300	
Salvage Value ****			4900	

- Suppose, the land of project is free of money, because Jawwal has free space in the land, where the towers are installed.
- All above prices from previous projects implemented by ERC [4]

* This cost included all installation costs, cables, poles, joints, installation materials, support structure…else

** O&M System Cost means operating and maintenance system cost, and it's suggested generally to be (1-2) % of total investment cost .

*** Electrical losses is suggested generally to be 5% of total electricity generated.

**** Salvage value suggested to be 10% of total capital cost

6.3.2 Fixed and Running Cost of PV System for Raba Site,

The associated costs of the components, materials and erections of the PV power system are shown in table (6.8):

Table (6.8): The fixed and running costs of the PV system for Raba site

Component	Quantity	Unit price US $	Total price US $	Life time year
PV module (135W)	10840 WP	1.1/Wp	11924	25
Batteries (2V/3000Ah)	24	1000	24000	10
Charge Controller 14 kW	1	0,8/W	11200	25
Inverter 3 kW	1	1.2/W	3600	25
Others *		1/WP	10840	25
Total Capital System Cost	**61564 $**			
O&M System Cost /year**			900	
Electrical Losses /year***			300	
Salvage Value			6200	

6.3.3 Fixed and Running Cost of PV System for Za'tara Site

The associated costs of the components, materials and erections of the PV power system are shown in table (6.9):

Table (6.9): The fixed and running costs of the PV system for Za'tara site

Component	Quantity	Unit price US $	Total price US $	Life time year
PV module (135W)	9720 WP	1.1/Wp	10692	25
Batteries (2V/2700Ah)	24	860	20640	10
Charge Controller 12 kW	1	0,8/W	9600	25
Inverter 3 kW	1	1.2/W	3600	25
Others *		1/WP	9720	25
Total Capital System Cost	**54252 $**			
O&M System Cost /year**			800	
Electrical Losses /year***			300	
Salvage Value			5400	

6.3.4 Fixed and Running Cost of PV System for Frosh Beat Dajan site,

The associated costs of the components, materials and erections of the PV power system are shown in table (6.10):

Table (6.10): Fixed and running costs of the PV system for Frosh Beat Dajan site

Component	Quantity	Unit price US $	Total price US $	Life time year
PV module (135W)	9720WP	1.1/Wp	10692	25
Batteries (2V/2700Ah)	24	860	20640	10
Charge Controller 12 kW	1	0,8/W	9600	25
Inverter 3 kW	1	1.2/W	3600	25
Others *		1/WP	9720	25
Total Capital System Cost	**54252 $**			
O&M System Cost /year**			800	
Electrical Losses /year***			300	
Salvage Value			5400	

6.4 Annual Saving Money after Implementing the PV System for Each Telecom Tower Site.

The annual saving in money for each site can be calculated by using the following formula.

$$\text{Monthly Saving US \$} = E_{PVoutput/month} \times Z$$

Where $E_{PVoutput/month}$ is the monthly PV energy output, and Z is the total cost of 1KWh in US $ produced from diesel generator.

The monthly output energy from PV system can be calculated by using the following equation (6.4).

$$E_{PVoutput/month} = Wp \times PSH \times No.\,days\ per\ month \times \eta_{overall} \qquad (6.4)$$

The $\eta_{overall} = \eta_{inverter} \times \eta_{converter} \times \eta_{battary}$

The $\eta_{overall} = 0.9 \times 0.92 \times 0.85 = 0.7$

The following tables (6.11÷6.14) show the $E_{PVoutput/month}$ and the monthly saving for each telecom site after using PV system.

Also it can be illustrated by the following figures (6.1÷6.4).**For Za'tara site,** the average monthly energy produced from PV system can be calculated by the obtained Wp value from table (5.5), and the average PSH from table (1.1).

Also the monthly saving in money can be calculated by the obtained total cost of 1KWh produced by diesel generator from table (6.6).

Note that in some months of the year there is excess energy, and we don't need it. So in our calculation we take $E_{PVoutput/month}$ equal to $E_{consumption}$ from table (4.5)

Table (6.11): The Monthly energy produced from PV system and the monthly saving in US \$ for Zatara site

Month	$E_{PVoutput/month}$ KWh	Saving US \$
January	522	595
February	556	634
March	880	1003
April	996	1135
May	1116	1272
June	1080	1231
July	1116	1272
August	1116	1272
September	1043	1189
October	867	988
November	696	793
December	683	779
Total	10671KWh	12165 \$

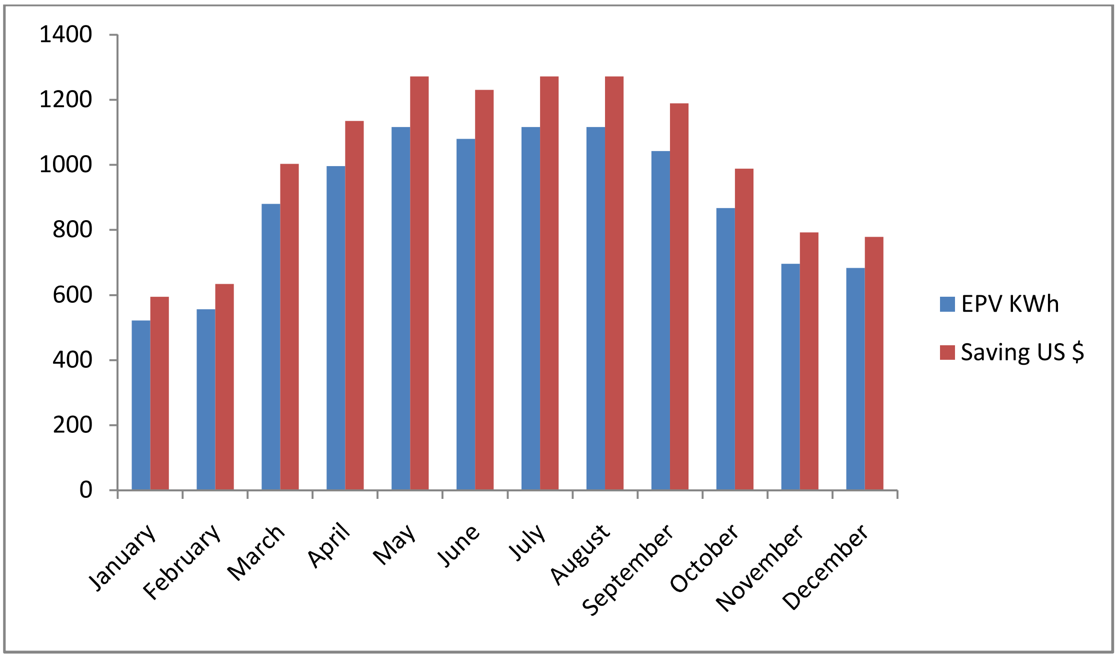

Figure (6.1): The Monthly energy produced from PV system and the monthly saving in US $ for Zatara site.

For Raba Site, the following table (6.12) and Figure (6.2) shows the average monthly Energy output from PV system and the monthly saving in Money US $.

Table (6.12): The Monthly energy produced from PV system and the monthly saving in US $ for Raba site.

Month	$E_{PVoutput/month}$ KWh	Saving US $
January	587	716
February	626	764
March	990	1208
April	1121	1368
May	1256	1532
June	1216	1484
July	1256	1532
August	1256	1532
September	1174	1432
October	976	1191
November	783	955
December	769	938
Total	12010 KWh	14652 $

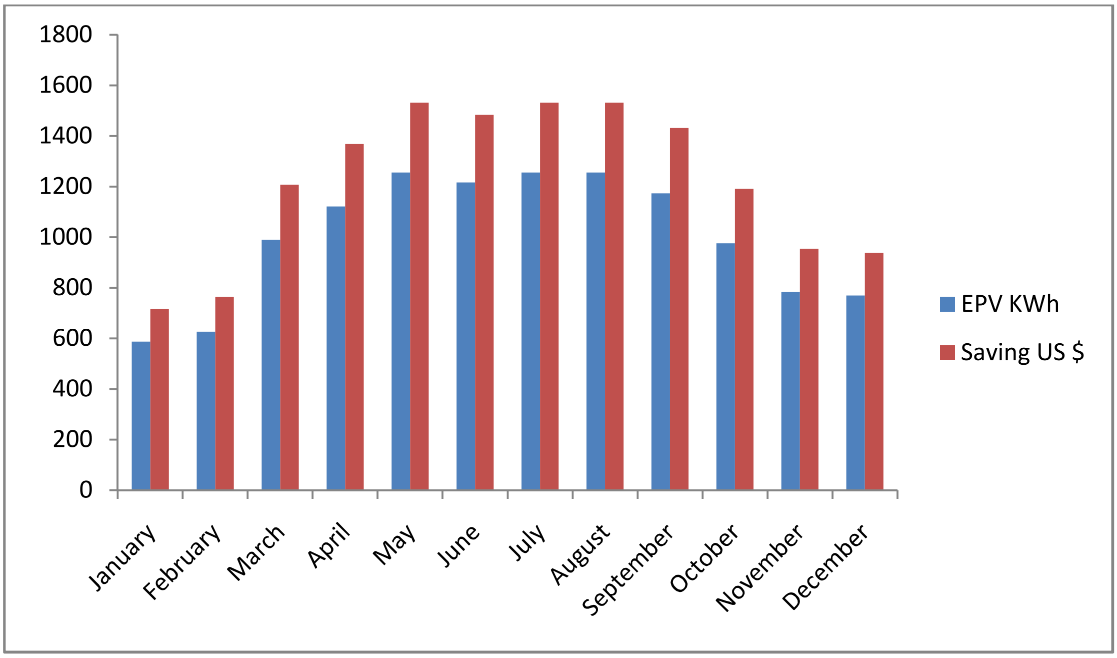

Figure (6.2): The Monthly energy produced from PV system and the monthly saving in US $ for Raba site.

For Selit Harithia site, the following table (6.13) and Figure (6.3) shows the average monthly Energy output from PV system and the monthly saving in Money US $.

Table (6.13): The Monthly energy produced from PV system and the monthly saving in US $ for Selit Harithia site.

Month	**$E_{PVoutput/month}$ KWh**	**Saving US $**
January	521	651
February	537	671
March	880	1100
April	968	1210
May	1000	1250
June	968	1210
July	1000	1250
August	1000	1250
September	968	1210
October	867	1084
November	696	870
December	683	854
Total	10088 KWh	12610 $

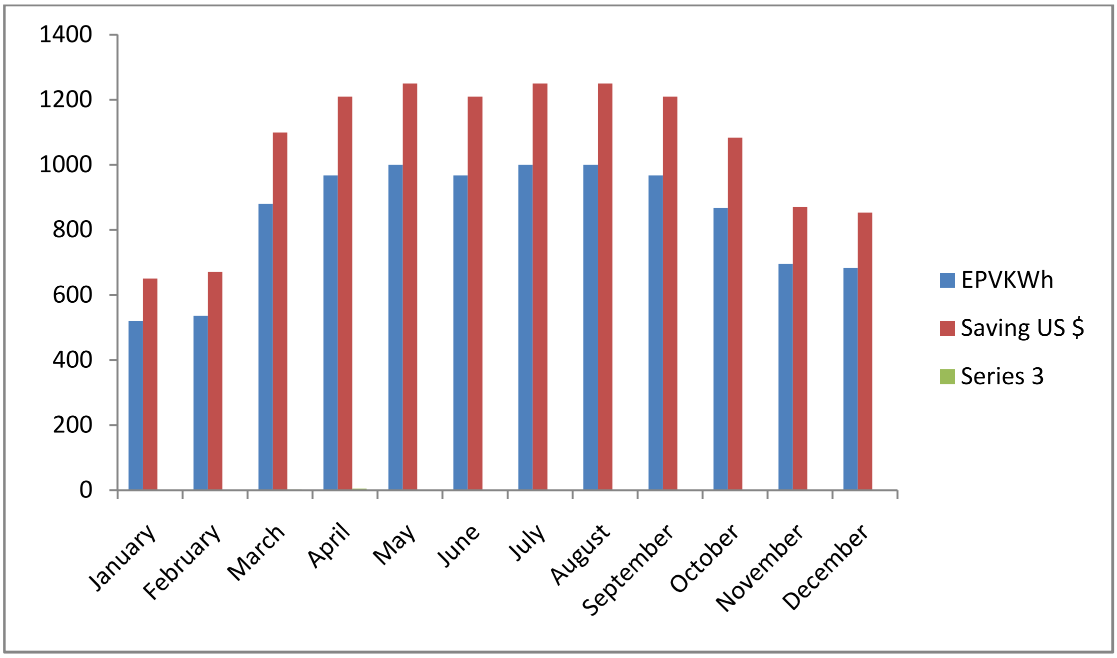

Figure (6.3): The Monthly energy produced from PV system and the monthly saving in US $ for Selit Harithia site.

For Frosh Beat Dajan site the following table (6.14) and Figure (6.4) shows the average monthly Energy output from PV system and the monthly saving in Money US $.

Table (6.14): The Monthly energy produced from PV system and the monthly saving in US $ for Frosh Beat Dajan site.

Month	$E_{PVoutput/month}$ KWh	Saving US $
January	456	506
February	470	522
March	769	854
April	871	967
May	1070	1188
June	1036	1150
July	1070	1188
August	1070	1188
September	912	1012
October	758	841
November	609	676
December	598	664
Total	9689	10755

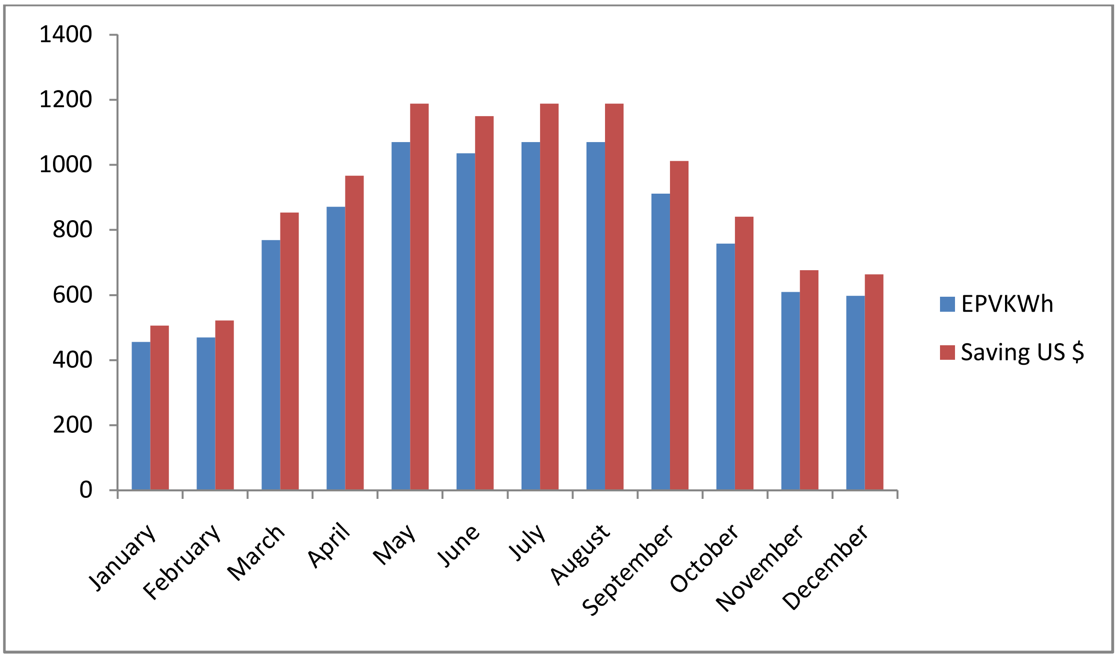

Figure (6.4): The Monthly energy produced from PV system and the monthly saving in US $ for Frosh Beat Dajan site.

6.5 Cash Flow Analysis for All Sites

A cash flow statement is one of the most important financial statements for a project or business. The statement can be as simple as a one page analysis or may involve several schedules that feed information into a central statement. Cash flow statement is a listing of the flows of cash into and out of the business or project, cash flow statement is not only concerned with the amount of the cash flows but also the timing of the flows [19].

In this section the cash flow charts will show the income money and outcome money for the new project which is replacement of the existing diesel generators by PV system for each telecom tower site in this study.

The all parameters of cash flow for each telecom site after using PV system instead of diesel generator, shown in the following table (6.15)

Table (6.15): All Parameters of cash flow for each telecom site, after using PV system instead of DG.

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Capital cost (US $)	54252	61564	54252	48650
Electrical losses (US $)	300	300	300	300
O&M (US $)	800	900	800	800
Battery replacement (US $)	20640	24000	20640	19200
Annual saving (US $)	12165	14652	10755	11198
Salvage value	5400	6200	5400	4900

- ❖ The Cash flow chart for Za'tara telecom tower site is shown in Figure (6.5)

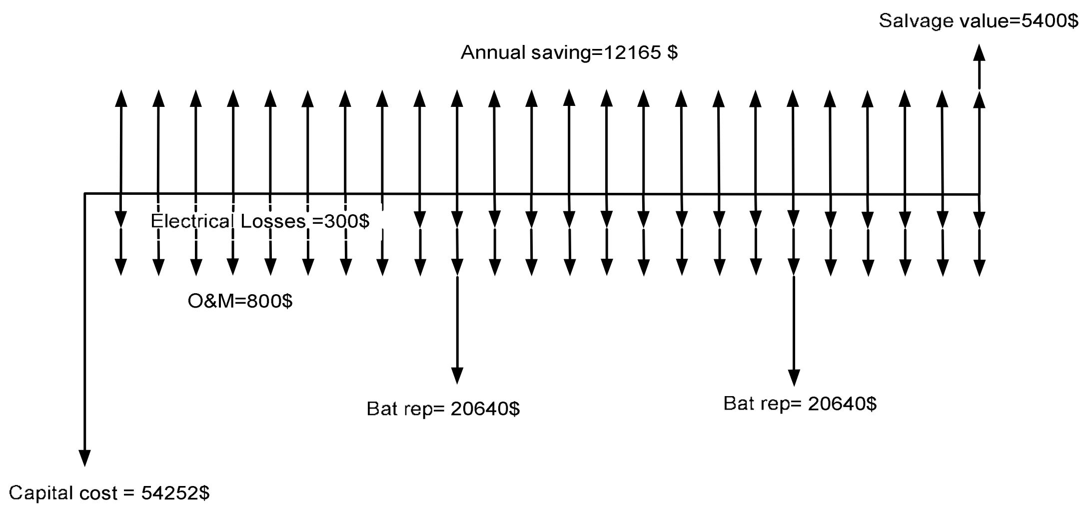

Figure (6.5): The cash flow chart for Za'tara site

- ❖ The Cash flow chart for Raba telecom tower site is shown in Figure (6.6)

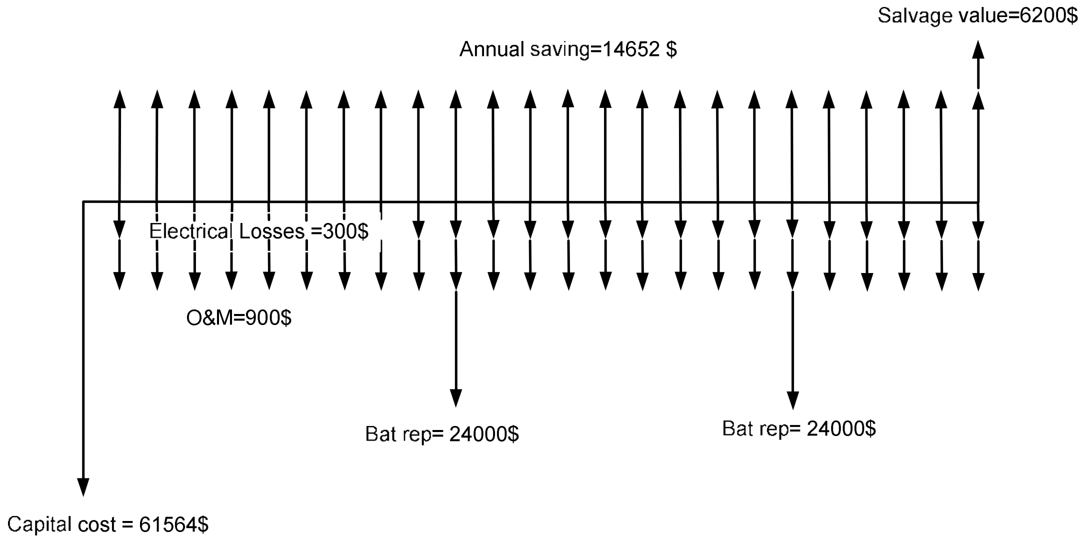

Figure (6.6): The cash flow chart for Raba site.

- ❖ The Cash flow chart for Frosh Beat Dajan telecom tower site is shown in Figure (6.7)

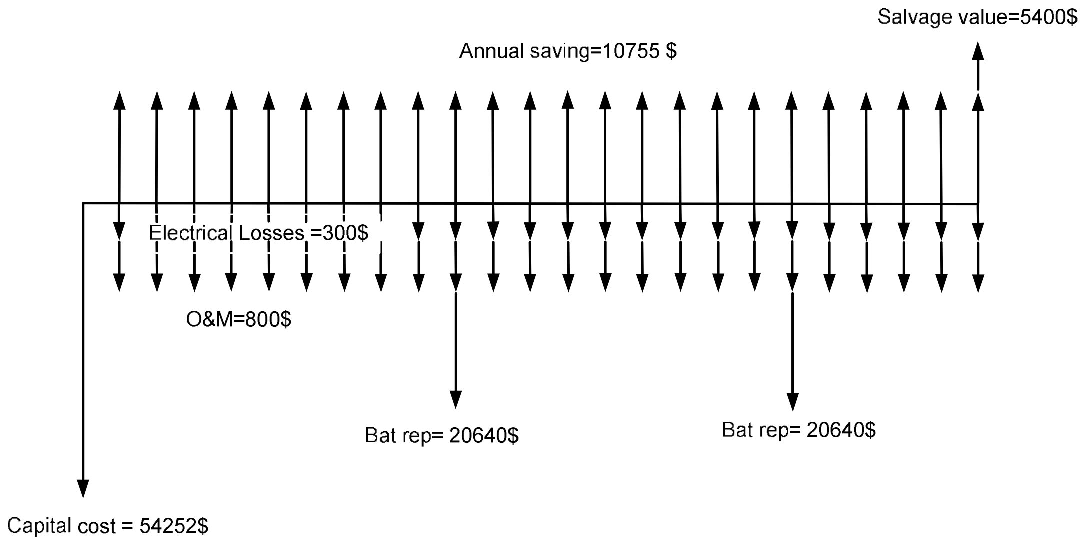

Figure (6.7): The cash flow chart for Frosh Beat Dajan site

- ❖ The Cash flow chart for Selit Harithia telecom tower site is shown in Figure (6.8)

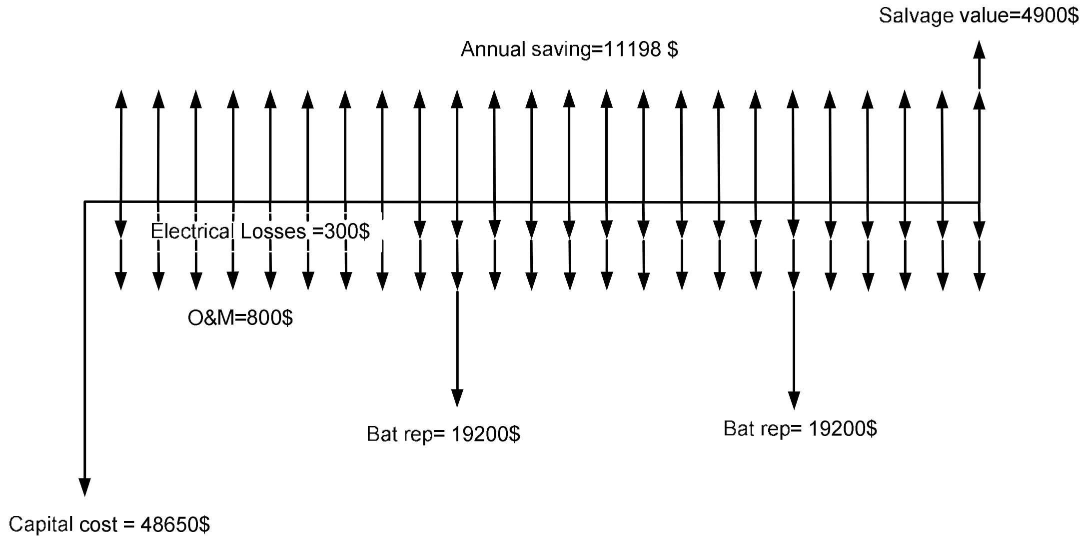

Figure (6.8): The cash flow chart for Selit Harithia site

6.6 Economical Analysis of Using PV System Instead of DG

6.6.1Economical Analysis Using Rate of Return method (ROR)

It is the effective annual interest rate earned on an investment and It's one of the important economic methods to justify whether or not the project feasible.

We can find rate of return by use the following formula [24].

PWincome – PWoutcome=0 **(6.5)**

Where

- PWincome its mean present worth income (positive Value in cash flow) and the formula for it is [24].

PWincome = annual saving (P/A,i,25)+Salvage value(P/F,i,25) **(6.6)**

- PWoutcome it mean present worth outcome (negative value in cash flow) ,the formula for it [24].

PWoutcome = annual cost (P/A,i,25)+capital investment **(6.7)**

- 25 it's the life years of the project

- **For Za'tara** site, we use equation (6.5) to find ROR, and we obtained the values from "Za'tara cash flow chart" as shown above in figure (6.5).

To find PWincome and PWoutcome, we use equations (6.6) and (6.7) as follow:

PWincome = 12165 (P/A,i,25)+5400(P/F,i,25)

PWoutcome = 300(P/A,i,25) + 800(P/A,i,25) + 20640(P/F,i,10) + 20640 (P/F,i,20) + 54252

12165 (P/A,i,25)+5400(P/F,i,25) -{300(P/A,i,25)+800(P/A,i,25)+ 20640(P/F,i,10)+ 20640(P/F,i,20)+54252 }=0

After solving this equation, the ROR of Za'tara site equal **i =19.5%**

- **For Raba** site, we used equation (6.5) to find ROR, and we obtained the values from "Raba cash flow chart" as shown above in figure (6.6)

14652(P/A,i,25)+6200(P/F,i,25) -{300(P/A,i,25)+900(P/A,i,25)+ 24000(P/F,i,10)+ 24000(P/F,i,20)+61564 }=0

After solving this equation, the ROR of Raba site equal **i =20.4 %**

- **For Frosh Beat Dajan** site, we used equation (6.5) to find ROR, and we got the values from " Frosh Beat Dajan cash flow chart" as shown in figure (6.7)

  10755(P/A,i,25)+5400(P/F,i,25) -{300(P/A,i,25)+800(P/A,i,25)+ 20640(P/F,i,10)+ 20640(P/F,i,20)+54252 }=0

  After solving this equation, the ROR of Raba site equal **i = 16.2%.**

- **For Selit Harithia** site, we used equation (6.5) to find ROR, and we got the values from " Selit Harithia cash flow chart" as shown in figure (6.8)

  11198 (P/A,i,25)+4900(P/F,i,25) -{300(P/A,i,25)+800(P/A,i,25)+ 19200(P/F,i,10)+ 19200(P/F,i,20)+48650 }=0

  After solving this equation, the ROR of Raba site equal **i =22.1 %**

The following table (6.16) summarizes the Rate of return (ROR) of PV system for the four telecom towers site:

Table (6.16): Rate of Return of PV system for all telecom towers sites.

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Rate of Return	19.5%	20.4%	16.2%	22.1%

It's clear that these ROR percentages are high; it will justify and encourage the investment in this project (replacement diesel generators by PV system)

So this Project is feasible, and there is high annual saving from this project.

6.6.2 Analysis of Energy Unit cost From PV Systems

To find energy unit cost we must know the annuity cost which is bases on Life Cycle Cost for annual production of electricity [25].

Life Cycle Cost in Annual worth = Investment Cost in annual worth + annual cost+ battery replacement in annual worth - Salvage Value in annual worth [24].

$$LCC(AW) = C_{investment.AW} + C_{annual} + C_{bat\ rep.AW} - C_{salvage.AW} \qquad \textbf{(6.8)}$$

$$\text{Unit energy cost\$/KWh} = \frac{\text{Life Cycle Cost (AW)}}{\text{Yearly energy consumption}} \qquad (\mathbf{6.9})$$

I use 10% interest rate (as shown in appendix C) to find AW of the LCC for each site,

- Yearly energy consumption for each site from table (4.3)
- Other Values of C investment, C annual, C battery replacement, C salvage we obtain it from Cash flow diagrams for each site.
- Number of year project= 25 years.

❖ **For Za'tara** site, we used equation (6.8) to find LCC, and we got the values from "Za'tara cash flow chart" as shown in figure (6.5)

LCC (AW) = 300+800+20640(P/F,10%,10)(A/P,10%,25)+ 20640 (P/F,i,20) (A/P,10%,25)+54252(A/P,10%,25) - 5400(A/F,i,25)

LCC (AW) = 8237 $

By using equation (6.9) the unit energy cost $/KWh is equal

Unit energy cost $/KWh = 8237/13176 =**0.63 $/KWh.**

- **For Raba** site, we used equation (6.8) to find LCC (AW), and we got the values from "Raba cash flow chart" as shown in figure (6.6) LCC (AW) = 300+900+24000(P/F,10%,10) (A/P,10%,25) + 24000 (P/F,i,20) (A/P,10%,25)+61564(A/P,10%,25) - 6200(A/F,i,25)

  LCC (AW)=9332 $

  By using equation (6.9) the unit energy cost $/KWh is equal

  Unit energy cost $/KWh = 9332/14830 =**0.63 $/KWh.**

- **For Frosh Beat Dajan** site, we used equation (6.8) to find LCC (AW), and we got the values from " Frosh Beat Dajan cash flow chart" as shown in figure (6.7) LCC(AW) =300+800+20640 (P/F,10%,10) (A/P,10%,25)+ 20640(P/F,i,20) (A/P,10%,25)+ 54252(A/P,10%,25) - 5400(A/F,i,25)

  LCC (AW) =8237 $

  By using equation (6.9) the unity cost $/KWh is equal

  Unit energy cost $/KWh = 8237/12638 =**0.65 $/KWh**

- **For Selit Harithia** site, we used equation (6.8) to find LCC (AW), and we got the values from " Selit Harithia cash flow chart" as shown in figure (6.8) LCC (AW)=300+800+19200(P/F,10%,10) (A/P,10%,25)+ 19200(P/F,i,20) (A/P,10%,25)+48650(A/P,10%,25) - 4900(A/F,i,25) LCC (AW) = 7540$

  By using equation (6.9) the unit energy cost $/KWh is equal

  Unit energy cost $/KWh = 7540/11785 =**0.64 $/KWh**

The following table (6.17) summarizes the unit energy cost per one KWh produced from PV system for each telecom tower site.

Table (6.17): Unit energy cost per one KWh produced from PV system for each telecom tower site

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Unit energy cost ($/KWh)	0.63	0.63	0.65	0.64

6.6.3 Comparison Analysis of Unit Energy Cost Values of PV Systems and DG's.

Table (6.18) summarizes the unity cost per one KWh produced from PV system and the unity cost per one KWh produced from diesel generator for each telecom tower site,

Table (6.18): unity cost per KWh produced from PV system and from diesel generator for each telecom tower site.

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Unity cost per KWh from PV system ($/KWh)	0.63	0.63	0.65	0.64
Unity cost per KWh from diesel generator ($/KWh)	1.14	1.22	1.11	1.25

The following figure (6.9) shows the difference of the cost per one KWh produced from PV system and from diesel generators.

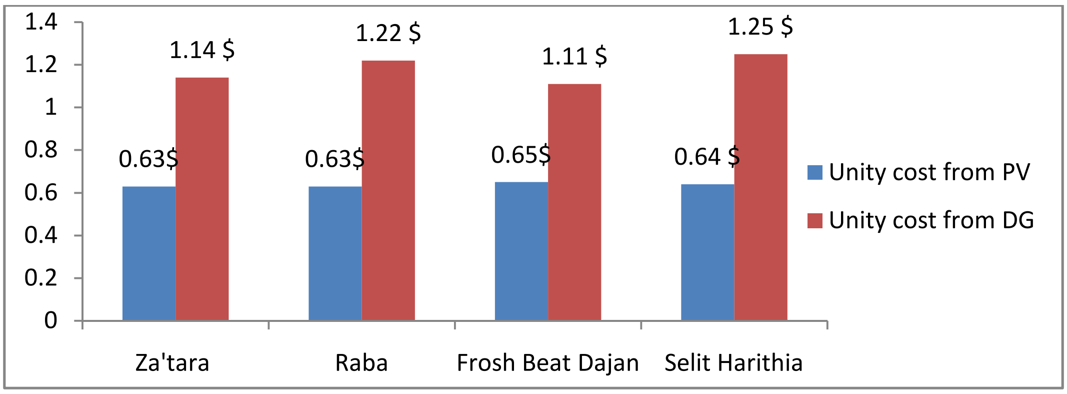

Figure (6.9): the difference of the cost per one KWh produced from PV system and from diesel generators

It's obvious that unity cost per one KWh from PV system is the lowest one. So it's the best alternative to choose and to adopt for electrification of these remote and isolated telecom towers sites.

6.7 Economical Analyses of Electrification Remote Towers in Jawwal Company Before and After Implementing PV Systems.

6.7.1 The Total Cost of Electrification Telecom Towers by using Diesel Generators

To calculate the total cost of electrification telecom towers in remote area by using D.G and before implementing PV systems, we use the following equation (6.10).

$$\text{Total cost of } E_{DG} = E_{DG} \times \text{unity cost of 1 KWh from DG} \qquad \mathbf{(6.10)}$$

Where E generator = E consumption, because all energy produced from DG's only.

From Table (4.3) we obtained the average yearly energy consumption for each site, and from table (6.6) we obtained the unity cost of 1KWh produced from DG.

The following tables (6.19) summarize the yearly total cost of energy consumption for each telecom site from DG.

Table (6.19): The Total Cost of Electrification Telecom Towers by using Diesel Generators

Site	$E_{out\,DG}$ (KWh)	Total yearly Energy cost (US $)
Zatara	13176	15021
Raba	14830	18093
Selit Harithia	11785	14731
Froosh Beat Dajan	12638	14028
Total	52429 KWh	61873 $

6.7.2 The Total Cost of Electrification Telecom Towers by using Hybrid System (PV and DG).

When we use hybrid systems (PV and DG) to electrification the telecom towers, we need to calculate the total cost of energy produced from PV system and the total cost of energy produced from DG when it's working as backup system.

To calculate the total cost of electrification telecom towers in remote area by using PV systems, we use the following equation [25] (6.11)

$$\text{Total cost } E_{PV} = E_{PV} \times \text{unity cost of 1 KWh from PV system} \qquad \textbf{(6.11)}$$

From tables (6.11÷ 6.14) we obtained the value of Energy output from PV systems for all sites, and from table (6.17) we obtained the unity cost of 1KWh energy produced from PV system.

To calculate the total cost of energy produced from DG, when it's working as back system we use equation (6.10).

The yearly energy produced from DG after using PV system equal yearly energy produced from PV subtract from yearly energy consumption system, as the following equation (6.12) [25].

$$E_{DG} = E_{consumption} - E_{PV} \qquad (6.12)$$

Where $E_{consumption}$ for all sites obtained from table (4.4), and yearly E_{PV} for all sites obtained from tables (6.11÷ 6.14).

The following tables (6.20) summarize the yearly total cost of energy consumption for each telecom site from hybrid systems.

Table (6.20): The Total Cost of Electrification Telecom Towers by using hybrid system (PV+DG)

Site	**E_{out} PV (KWh)**	**E_{out} DG (KWh)**	**Cost of E_{out} PV($)**	**Cost of E_{out} DG($)**	**Total cost ($)**
Zatara	10671	2505	6723	2856	9579
Raba	12010	2820	7566	3440	11006
Selit Harithia	10088	1697	6456	2121	8577
Froosh Beat Dajan	9689	2949	6298	3273	9571
Total	42458 KWh	9971KWh	27043$	11690 $	38733 $

$$\text{The total saving } \$ = \text{ Energy cost befor PV} - \text{Energy cost after PV}$$

Total Saving = 61873 $ – 38733 $ = 23140 $

Chapter Seven

Environmental Impact of Using Solar PV systems Instead of Diesel Generator for Telecommunication Towers in Jawwal

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Environmental Impact of Using Solar PV systems Instead of Diesel Generator for Telecommunication Towers in Jawwal.

Introduction

The considerable problems deriving from the growth of energetic consumptions and from the relevant environmental “emergency” due to the emissions of green house gases push people to find out new solutions and new technologies for the production of primary energy fit for fulfilling the urging and growing energetic demands.

The global climate change, which is due to increased CO_2 and other green house gases concentration levels in atmosphere, is considered one of the most important global emergencies that require immediate and effective policies. The CO_2 emissions are mostly due to the use of fossil fuels as energy source. This can be obtained by improving energy efficiency and by using large scale renewable energy sources.

This is also true in the telecommunication applications, which has seen, in the last years, a remarkable increase in the number of telecommunications towers and the relevant growth of energetic consumptions, because of growing interest about new and reliable services in mobility calls with an increase of the BTS operation hours and traffic management, in order to guarantee the quality of the service anywhere and anytime.

7.1 Environmental Impact of PV Systems

Photovoltaic (PV) technology has distinct environmental advantages for generating electricity over conventional technologies. PV technology does not produce any noise, toxic-gas emissions, or green house gases. It's a zero-emission process. [20]

Also there is some negative environmental impact of solar systems, especially during PV manufacturing

7.1.1 The Positive Environmental Impact of Solar Systems

- Climate Change

The burning of fossil fuels for energy remains the world's No. 1 source of carbon dioxide emissions [21]. Solar power is sometimes described as a zero-emission or emissions-free form of energy and it is true that green house gas emissions from solar are negligible. [21]

- Water

Creating energy is a water intensive process. In the U.S. electricity production accounts for more than 40 percent of all daily freshwater withdrawals. [22] Solar photovoltaic systems do not require any water to generate electricity [21]. Some solar thermal systems use water, but this water can be reused.

- Land

When placed on existing structured, such as the rooftop of a home or office building, solar energy systems require negligible amount of land space [21], on the other hand, it requires large amounts of land to produce electricity on a commercial scale .

7.1.2 The Negative Environmental Impact of Solar System

- PV manufacture

Materials used in some solar systems can create health and safety hazards for workers and anyone else coming into contact with them**.**

The main concerns about occupational and health risks from a life cycle perspective of a PV system are related with the emission of toxic or risky substances used to manufacture PV cells. The potential risk can occur during the manufacturing process, from the leaching of substances or from the combustion of modules. [23]

Among the most dangerous substances related with PV systems from a life cycle approach, we can find (not all the substances are present in all the PV technologies :

- Silica (SiO_2). The mining of metallurgical grade silica can produce silica dust that has been associated with silicosis, a severe lung disease.

- Cadmium (Cd). Known carcinogenic. Extremely toxic Potential to cause kidney, liver, bone, and blood damage from ingestion. Lung cancer from inhalation. Workers may be exposed to cadmium compounds during manufacturing.

- Silane (SiH_4). Most significant hazard. It is extremely explosive. Dangerous for workers and communities. The semiconductor industry reports several silane incidents every year, although some companies use an alternative that in turn could be used in the PV industry.

- Chlorosilane ($HSiCl_3$). Very toxic and highly flammable

- Silicon Tetrachloride ($SiCl_4$) (waste). Extremely toxic substance. Causes skin burns, and is a respiratory, skin and eye irritant.

- Hydrogen selenide (H_2Se). Highly toxic and dangerous at concentrations as low as 1 part per million in the air. It Will present occupational health and safety issues.

- Sulfur hexafluoride (SF_6). Extremely potent green house gas. Accidental or fugitive emissions will greatly undermine reductions gained by using solar power.

- Selenium dioxide (SeO_2). Potential formation at high temperatures. It is a tissue poison like arsenic. The recovery of selenium is very high but not 100 percent.

- Sodium hydroxide (NaOH), hydrochloric acid (HCL), sulfuric acid (H_2SO_4), nitric acid (HNO_3), hydrogen fluoride (HF), phosphine (PH_3) or arsine (AsH_3), Isopropyl alcohol (C_3H_8O). These components require special handling and disposal procedures because of possible chemical burns and risks from inhalation of fumes.

- Kerf (waste silicon dust from sawing c-Si wafers). May generate silicon particulate matter that will pose inhalation problems for production workers and those who clean and maintain equipment.

- Lead (Pb). Highly toxic to the central nervous system, endocrine system, cardiovascular system, and kidneys.

- Brominated flame retardants (BFRs), Polybrominated biphenyls (PBBs) and Polybrominated dephenylethers (PBDEs). Hexavalent chromium (Cr(VI)). They are considered carcinogenic.

- Hazardous Waste

Solar photovoltaic panels may contain hazardous materials that could be released when a panel is damaged or disposed of improperly [23] Concentrating solar energy systems may also use potentially hazardous materials like oils and molten salts, creating the potential for spills.

- Visual

One person's beauty is another person's eyesore. For some, solar panels evoke positive feelings, even when set in a natural landscape. For others, the sight of a solar panel invading a pristine desert environment is gut wrenching.[23]

7.2 Carbon Dioxide Emission from Diesel Generators.

Regarding environmental impact, we will focus on carbon dioxide emissions resulting from electricity generation to supply the required energy for telecom towers.

One liter of diesel typically weighs 0.83kg (the density range is 820-845kg/m3), about 87% of this is carbon [23], so one liter of diesel contains

0.83 x 87% = 0.722kg of carbon, each atom of carbon weighs 12 atomic units.

When it combines with two atoms of oxygen in the combustion process it becomes CO_2, which weighs 44 atomic units.

The 0.722kg of carbon in the original fuel then becomes 0.722 x 44/12 = 2.65kg of CO_2, so one liter of diesel fuel produces about 2.65kg of CO2

7.2.1 The Environmental Impact of Using Diesel generators for each telecom towers site.

As shown in the previous section 7.2 one litter of diesel produces around 2.65 kg CO_2, and the total quantity of yearly diesel consumption from each telecom tower sites are mentioned in table (4.1)

And to calculate the yearly CO_2 emission from each site we use the following equation.

$$\text{Yearly emission (CO2)} = \text{Yearly quantity of diesel} \times \text{emission of CO2 Kg/L} \quad \mathbf{(7.1)}$$

The results shown in the following table (7.1)

Table (7.1):CO_2 emission from diesel generator for each telecom tower site

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
CO_2 emission (kg)	15980	19425	15900	14045

7.3 The Environmental Impact of Using PV Systems Instead of DG for each Telecom Tower Site

After using solar system for each site to produce electricity, there is a lot of saving in diesel consumption as shown in pervious chapter (6), so this mean there is a lot of saving in CO_2 emissions.

To calculate the annual saving in CO_2 emission for each site after using solar system, we use equation (7.2).

$$CO_2 \text{ Saving} = E_{Pv\ output} \times \text{emissions of } CO_2 \text{ Kg/KWh} \quad \mathbf{(7.2)}$$

To calculate the emissions of CO_2 Kg/KWh, we use the following equation (7.3)

$$\text{Emissions of CO2 Kg/KWh} = \frac{\text{Emission of CO2 in (Kg)}}{\text{Energy consumption(KWh)}} \quad \mathbf{(7.3)}$$

The Emission of CO_2 in Kg/KWh for all telecom sites are shown in the following table (7.2)

Table (7.2):CO_2 emission in Kg/KWh for all telecom towers site.

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
CO_2 emission (kg)	1.21	1.3	1.25	1.2

The saving in $CO_{2\ \text{emission}}$ for each telecom after using PV systems instead of DG site are shown in the following table (7.3)

Table (7.3): Environmental impact of using PV system instead of DG in (Kg)

Site	Za'tara	Raba	Frosh Beat Dajan	Selit Harithia
Energy PV output (KWh)	10671	12010	9689	10088
Environmental impact (saving Kg CO_2)	12912	15613	12111	12106

The Total Saving in CO_2 emission from all sites equal 52742 Kg.

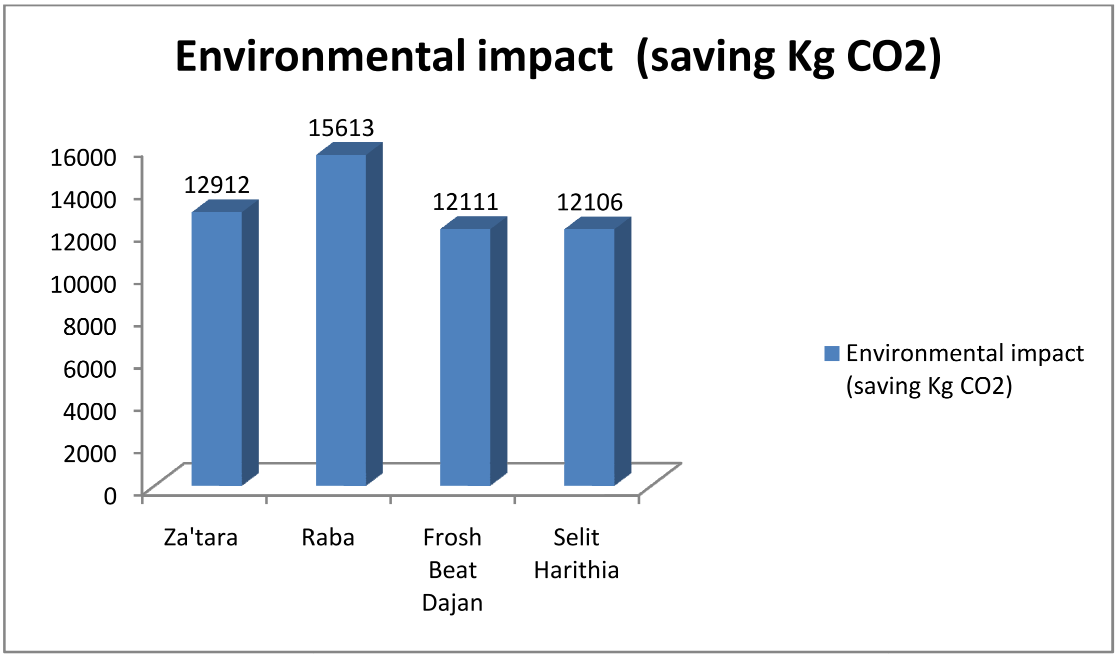

Figure (7.1): Environmental impact of using PV system instead of DG in (Kg)

Chapter Eight

Conclusion and Recommendations

Chapter Eight

Conclusion and Recommendations

8.1 Conclusions

From this research it was shown that it is possible to supply the communication towers in remote areas by using PV systems as a hybrid with existing diesel generators. Furthermore, it was shown that it is possible to design and select the size of PV models which are applicable to supply the tower loads during 24 hours/day.

Upon achieving this, techno-economical analysis for specific locations was performed. The analysis was justified by looking at different measured values over the collection period, such as: variation of solar radiation in west Bank, variation of electrical loads, and output energy VS. Solar radiations. This analysis gave an appropriate justification for the PV sizes as the optimum design for electrification of these towers by using solar energy.

In addition to all these, the PV solar hybrid systems like the one analyzed for specific towers and specific locations mentioned in this research, can be used very effectively and efficiently as well during all days in a year, specially in these rural areas, where the connection from the grid is not possible for the next five years, it is show that the installation of these PV systems usually are an economically and cost saving viable idea.

Also, it is highly recommended to implement the design suggested in this thesis in PALTEL company to achieve these economical and environmental savings mentioned in this research.

8.2 Recommendations

1- To expand such studies to include the techno-economical analysis of using PV systems on-Grid, this will help increase the penetration factor of using solar energy to achieve our Palestinian targets from R-E. by 2020.

2- We suggest and advice that similar research studies must be conducted in other sectors, that's because the suffering of high cost of energy as we have shown through this study.

3- Establishment of a campaign program to raise awareness of the benefits of using solar PV systems in Public Buildings and in other sectors, and to encourage companies to investment in this technology.

4- Study the ability and feasibility of using different types of renewable energy as a hybrid system with solar PV technology.

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APPENDICES

Appendix A: Energy Analyzer data from all sites

Appendix B: Specifications of all PV system elements

Appendix C: Table of interest at i = 10%

APPENDIX (A): Energy Analyzer Data from all Sites.

(A.1): Energy analyzer Data from Selit Harthiya Site (17-18/3/2012).

Time	V1 avg	V2 avg	V3 avg	A1 avg	A2 avg	A3 avg	PF1 avg	Pf 2 avg	PF3 avg	WT Total avg	VAR Total avg	VA Total avg	PF Total avg	KWh Total
11:00	234	233	234	2.01	4.63	2	0.77	0.77	0.75	1548	1295	2019	0.77	1.55
12:00	237	233	236	2	2.84	2	0.77	0.77	0.77	1228	1041	1611	0.76	2.78
13:00	236	235	232	2.02	3.79	1.99	0.77	0.77	0.78	1409	1168	1830	0.77	4.19
14:00	235	237	235	2.02	2.96	1.96	0.77	0.77	0.77	1260	1042	1636	0.77	5.45
15:00	237	237	233	2.03	3.73	1.97	0.77	0.77	0.77	1408	1158	1824	0.77	6.85
16:00	233	236	234	2.04	4.24	2.02	0.76	0.77	0.77	1497	1242	1946	0.77	8.35
17:00	234	237	235	2.1	1.93	2.9	0.77	0.76	0.77	1254	1036	1627	0.77	9.6
18:00	234	236	235	2.08	1.97	3.79	0.77	0.77	0.77	1425	1170	1844	0.77	11.03
19:00	235	236	234	2.04	2	3.81	0.77	0.77	0.77	1413	1181	1842	0.77	12.44
20:00	234	236	235	2.03	1.98	3.36	0.77	0.78	0.76	1329	1106	1729	0.77	13.77
21:00	233	237	237	2.03	1.97	3.96	0.77	0.77	0.76	1444	1204	1881	0.77	15.22
22:00	237	237	238	2	2.02	3.27	0.77	0.77	0.76	1326	1112	1731	0.76	16.54
23:00	237	236	237	1.99	3.29	2.01	0.77	0.77	0.73	1304	1122	1722	0.76	17.84
00:00	237	237	236	1.98	2.94	2	0.77	0.77	0.74	1247	1054	1635	0.76	19.09
01:00	236	236	237	1.97	3.79	2.02	0.75	0.73	0.77	1373	1219	1839	0.75	20.46
02:00	238	236	236	1.94	3.33	2.02	0.77	0.74	0.77	1294	1133	1724	0.75	21.76
03:00	237	236	238	1.95	3.65	2.03	0.74	0.74	0.77	1344	1202	1807	0.75	23.1
04:00	237	236	237	1.96	2.88	2.04	0.73	0.76	0.77	1228	1062	1625	0.75	24.33
05:00	239	234	236	1.93	2	3.31	0.74	0.77	0.77	1307	1099	1710	0.76	25.64
06:00	236	235	237	1.97	2	3.96	0.73	0.77	0.76	1415	1224	1873	0.76	27.05
07:00	237	235	236	2	1.99	3.56	0.74	0.76	0.77	1355	1157	1783	0.76	28.41
08:00	237	234	236	1.98	1.96	3.55	0.77	0.77	0.73	1334	1152	1765	0.76	29.74
09:00	236	236	236	1.97	1.97	3.18	0.77	0.77	0.74	1278	1092	1683	0.76	31.02
10:00	237	237	236	2.05	2.07	2.85	0.77	0.72	0.73	1226	1097	1650	0.74	32.25

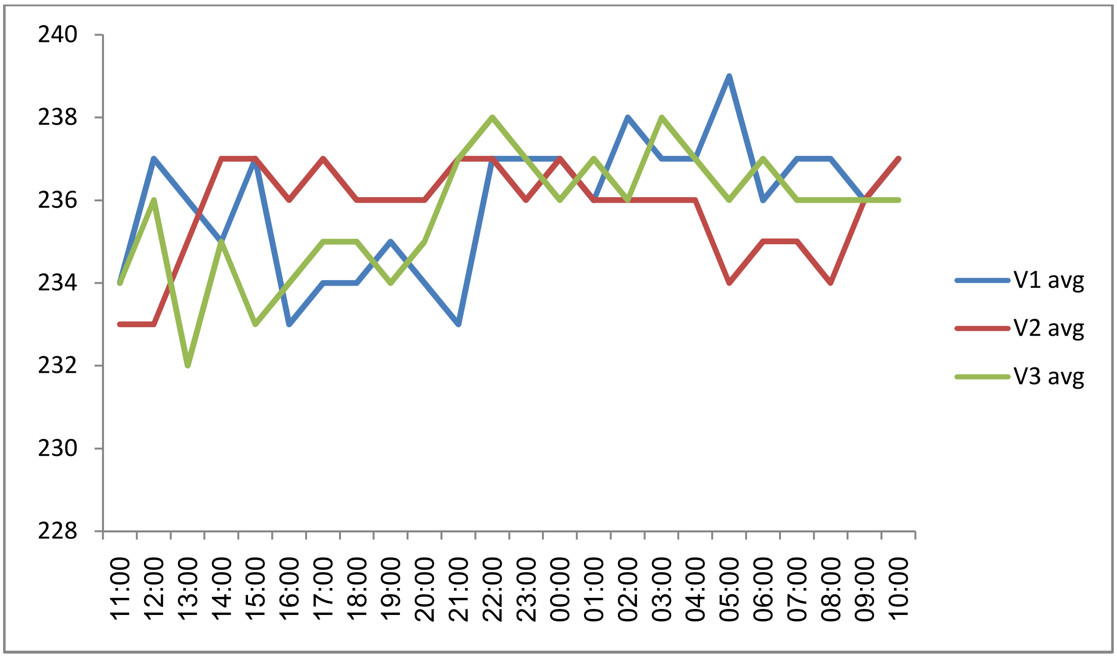


Figure (A.1): three phase voltage from DG at Selit Harithya site

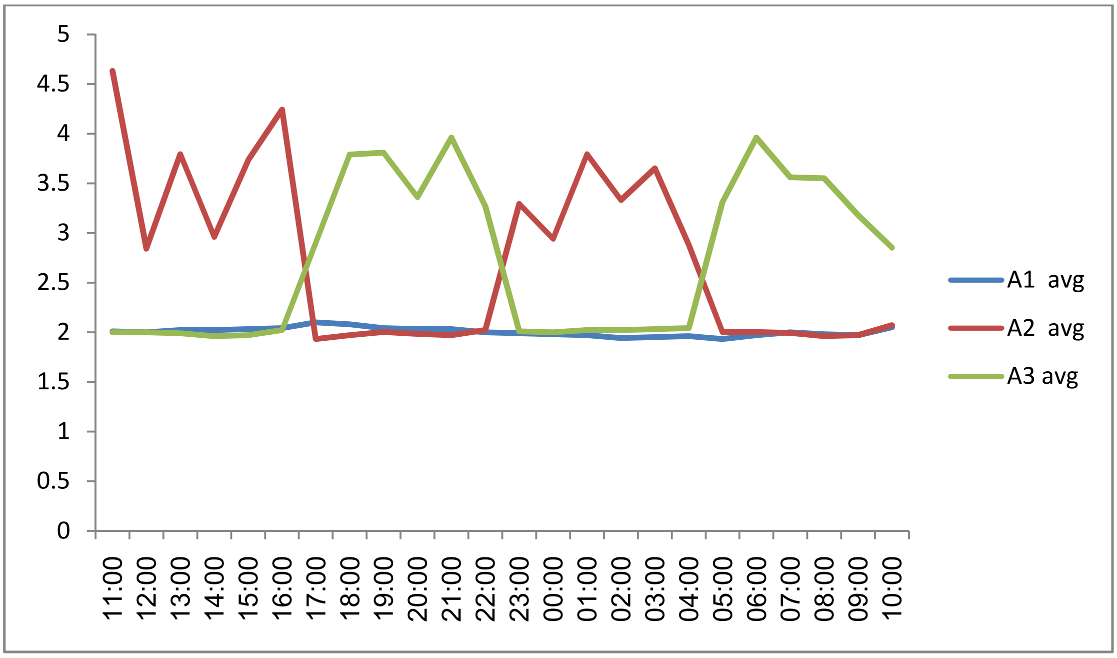


Figure (A.2): three phase current from D.G at Selit Harthia site.

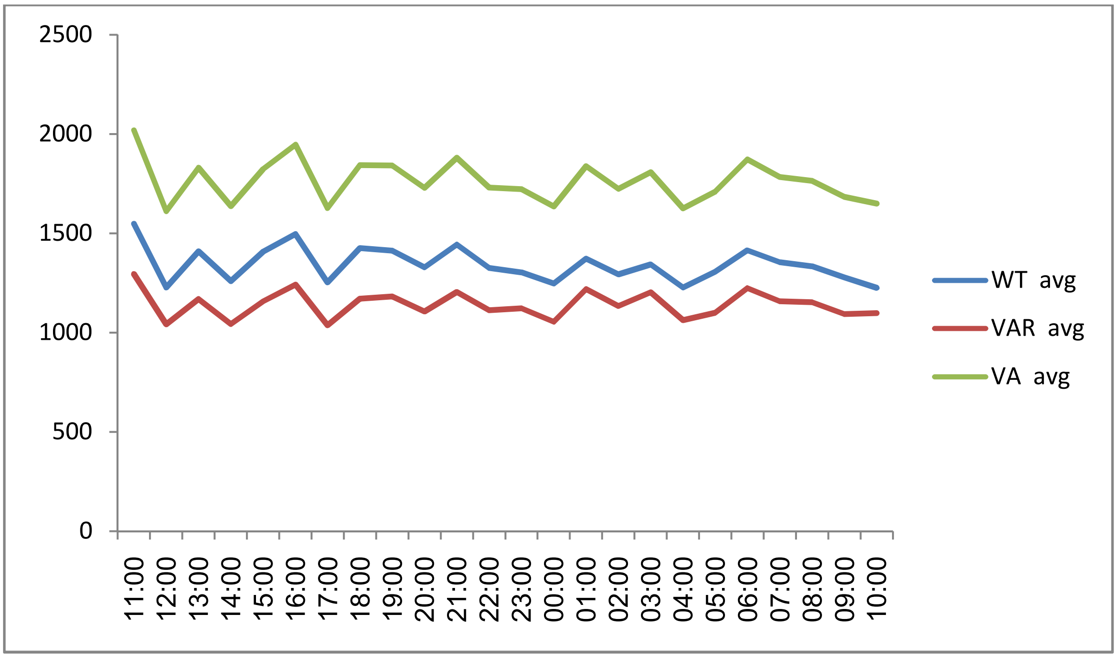


Figure (A.3): Total average three phase P, Q, and S from DG at Selit Harithya site.

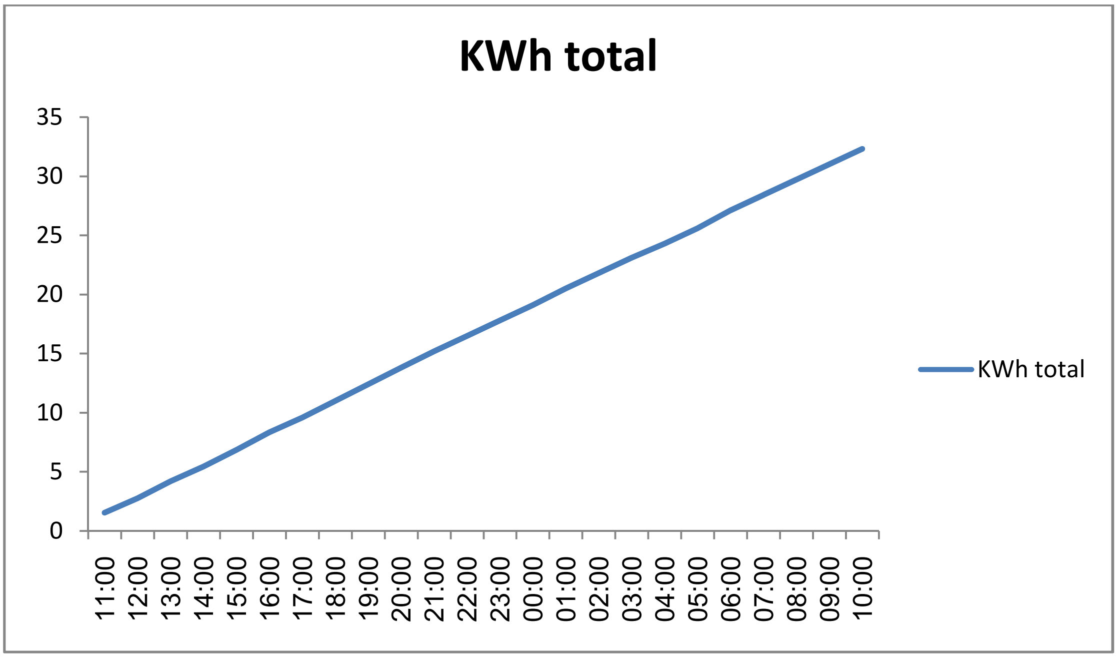


Figure (A.4): Total Energy consumption by the loads at Selit Harithya site.

(A.2):Energy analyzer Data at Raba Site (22-23/4/2012).

Time	V1 avg	V2 avg	V3 avg	A1 avg	A2 avg	A3 avg	PF1 avg	Pf 2 avg	PF3 avg	WT Total avg	VAR Total avg	VA Total avg	PF Total avg	KWh Total
13:00	230	232	229	2.01	6.02	2	0.74	0.64	0.75	1577	1692	2320	0.68	1.577
14:00	227	229	232	2.33	6.2	2.2	0.73	0.66	0.76	1722	1746	2458	0.7	3.299
15:00	228	227	230	2.37	6.4	2.13	0.73	0.66	0.76	1739	1769	2486	0.7	5.038
16:00	224	232	226	2.19	6.52	2.04	0.75	0.67	0.76	1736	1740	2463	0.7	6.774
17:00	228	230	222	2.01	2.28	6.32	0.76	0.51	0.64	1516	1819	2382	0.64	8.29
18:00	226	234	222	2.34	2.4	6.19	0.74	0.65	0.76	1811	1662	2463	0.74	10.1
19:00	228	229	222	2.02	2.26	6.33	0.75	0.5	0.64	1508	1826	2382	0.63	11.61
20:00	225	234	223	2.01	2.25	6.23	0.75	0.66	0.76	1748	1589	2367	0.74	13.36
21:00	227	231	225	2.21	2.28	6.15	0.74	0.67	0.75	1774	1626	2409	0.74	15.13
22:00	228	232	223	2.02	2.26	6.02	0.73	0.67	0.76	1708	1575	2327	0.73	16.84
23:00	231	233	229	2.43	6.72	2.07	0.73	0.63	0.73	1747	1913	2598	0.67	18.59
00:00	230	229	227	2.24	6.12	2.32	0.75	0.53	0.65	1474	1924	2442	0.6	20.06
01:00	232	228	227	2.11	6.61	2.4	0.72	0.65	0.73	1730	1858	2543	0.68	21.79
02:00	230	228	228	1.99	6.08	2.1	0.75	0.54	0.65	1407	1829	2324	0.61	23.2
03:00	228	233	232	2.09	6.23	2.02	0.75	0.65	0.77	1659	1720	2398	0.69	24.86
04:00	232	228	227	2.02	6.41	2.22	0.72	0.65	0.74	1663	1771	2434	0.68	26.52
05:00	227	227	232	1.96	2.29	6.33	0.73	0.67	0.77	1804	1623	2431	0.74	28.32
06:00	233	231	228	2.41	2.27	6.46	0.73	0.63	0.73	1826	1780	2555	0.71	30.15
07:00	232	230	227	2.4	2.25	6.19	0.73	0.64	0.73	1778	1727	2483	0.72	31.93
08:00	228	232	233	2.34	2.7	6.22	0.75	0.66	0.77	1931	1744	2608	0.74	33.86
09:00	234	223	229	2.22	2.25	6.14	0.74	0.56	0.66	1594	1817	2425	0.66	35.45
10:00	231	233	229	2.26	2.4	6.26	0.74	0.63	0.74	1807	1739	2513	0.72	37.26
11:00	231	228	227	2.23	6.34	2.24	0.75	0.52	0.64	1474	1960	2471	0.6	38.73
12:00	228	227	230	2.11	6.2	2.85	0.73	0.66	0.76	1783	1804	2543	0.7	40.52

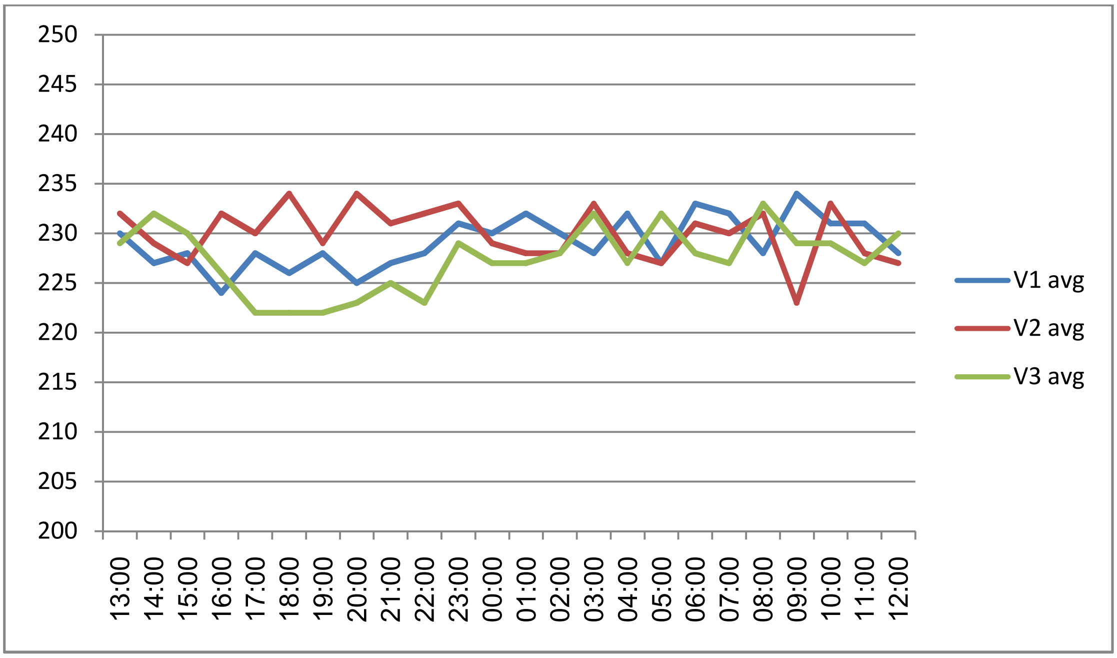


Figure (A.5): three phase voltage from DG at Raba site

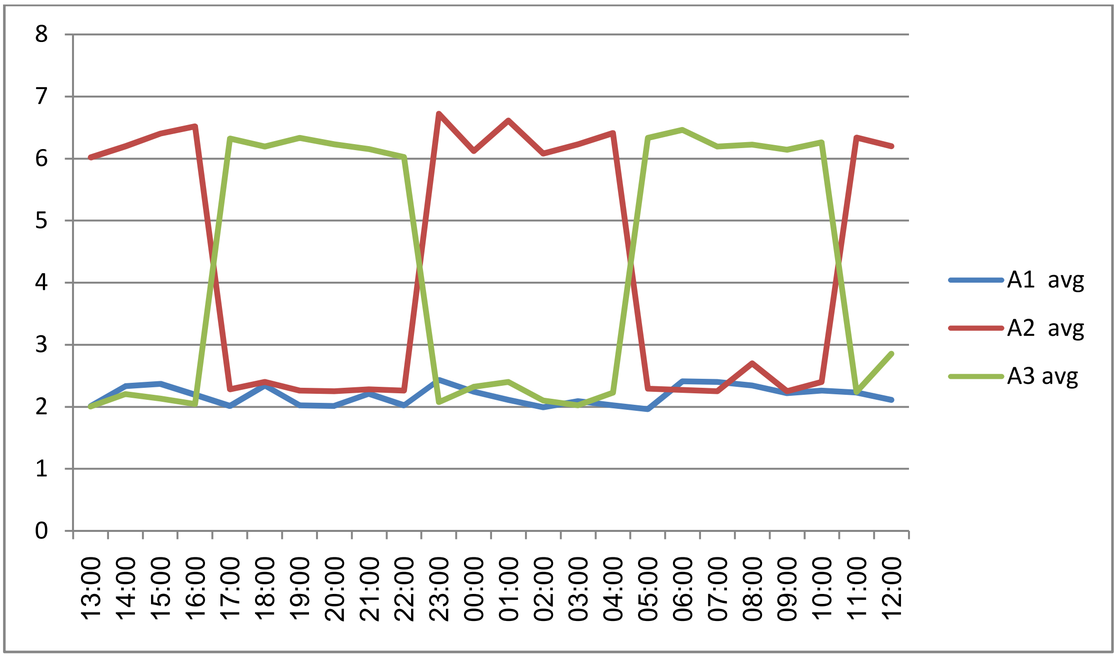


Figure (A.6): three phase current from D.G at Raba site.

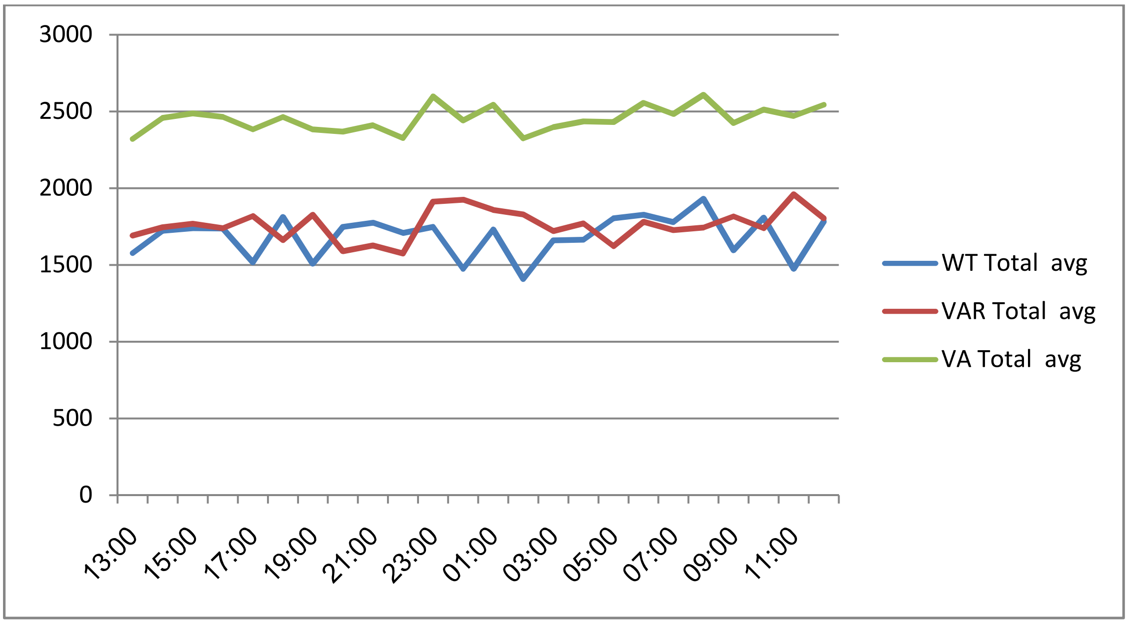


Figure (A.7): Total average three phase P, Q, and S from DG at Raba site.

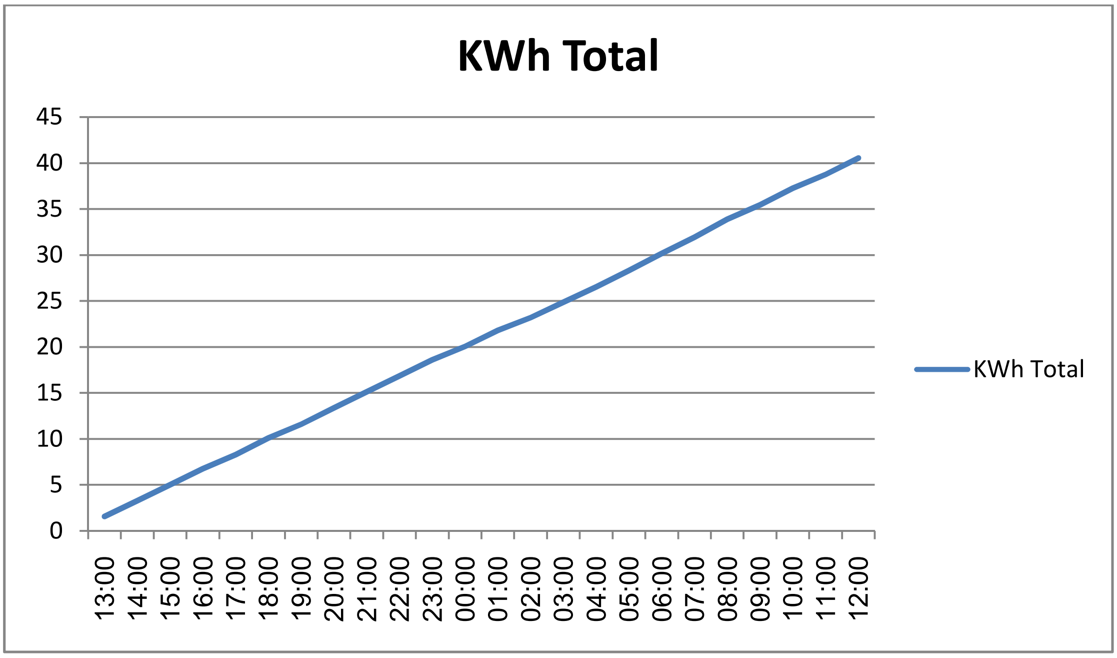


Figure (A.8): Total Energy consumption by the loads at Raba site.

(A.3): Energy analyzer Data at Za'atra Site (14-15/5/2012).

Time	V1 avg	V2 avg	V3 avg	A1 avg	A2 avg	A3 avg	PF1 avg	Pf 2 avg	PF3 avg	WT Total avg	VAR Total avg	VA Total avg	PF Total avg	KWh Total
09:00	227	231	222	1.52	1.8	4.1	0.83	0.86	0.84	1418	888	1674	0.85	1.418
10:00	230	227	227	1.33	4.2	2.2	0.83	0.86	0.85	1499	921	1760	0.85	2.917
11:00	229	226	228	1.37	4.32	2.14	0.84	0.86	0.84	1514	931	1777	0.85	4.431
12:00	231	227	227	1.22	4.13	2.04	0.83	0.86	0.97	1492	741	1683	0.89	5.923
13:00	228	232	232	1.41	4.02	2.16	0.83	0.86	0.97	1558	767	1756	0.89	7.481
14:00	229	231	224	1.37	4.2	2.27	0.83	0.86	0.85	1522	943	1790	0.85	9.003
15:00	232	229	227	1.21	4.1	2.44	0.82	0.86	0.85	1509	929	1772	0.85	10.51
16:00	229	233	223	1.52	1.94	4.11	0.83	0.87	0.97	1576	614	1715	0.92	12.09
17:00	227	231	233	1.42	1.88	4.08	0.82	0.85	0.85	1452	896	1707	0.85	13.54
18:00	230	227	229	1.32	1.78	4.02	0.83	0.85	0.85	1377	866	1627	0.85	14.92
19:00	229	233	231	1.54	1.78	4.21	0.83	0.87	0.97	1599	632	1740	0.92	16.52
20:00	227	233	223	1.27	1.67	4.42	0.83	0.86	0.86	1421	864	1664	0.85	17.94
21:00	224	234	219	1.22	1.52	4.01	0.83	0.86	0.84	1273	808	1508	0.84	19.21
22:00	224	234	220	1.48	4.08	2.2	0.84	0.86	0.97	1571	768	1770	0.89	20.78
23:00	223	234	215	1.51	4.24	1.99	0.93	0.87	0.97	1590	715	1758	0.9	22.37
00:00	226	229	226	1.43	4.41	2.21	0.87	0.86	0.97	1632	795	1832	0.89	24
01:00	229	229	224	1.74	4.12	2.24	0.86	0.86	0.86	1582	945	1843	0.86	25.59
02:00	225	233	219	1.98	4.11	2.41	0.86	0.86	0.85	1659	983	1929	0.86	27.25
03:00	224	234	218	1.72	4.06	2.31	0.87	0.86	0.98	1649	772	1840	0.9	28.9
04:00	223	234	218	1.37	1.93	4.32	0.84	0.86	0.97	1572	583	1701	0.92	30.47
05:00	225	234	218	1.52	1.65	4.19	0.83	0.86	0.97	1508	586	1641	0.92	31.98
06:00	224	232	220	1.46	1.89	4.01	0.83	0.86	0.84	1396	873	1647	0.85	33.37
07:00	222	233	214	1.43	1.45	3.99	0.83	0.86	0.85	1281	796	1508	0.85	34.65
08:00	225	231	219	1.41	1.49	4.11	0.86	0.86	0.86	1343	797	1562	0.86	36

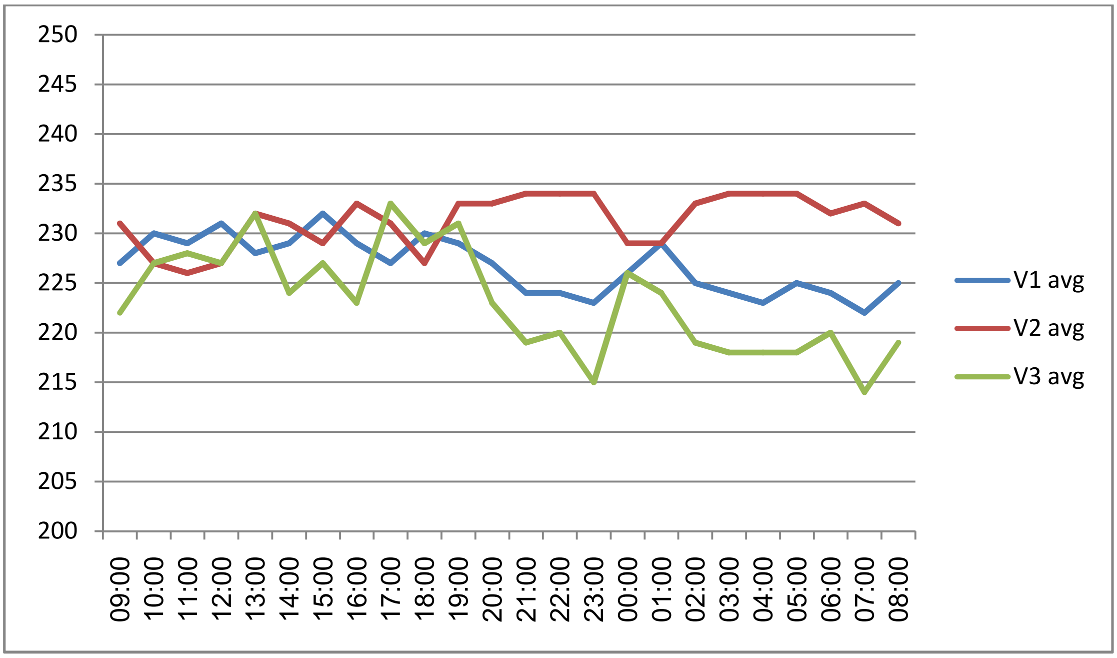


Figure (A.9): three phase voltage from DG at Za'tara site

Figure (A.10): three phase current from D.G at Za'tara site.

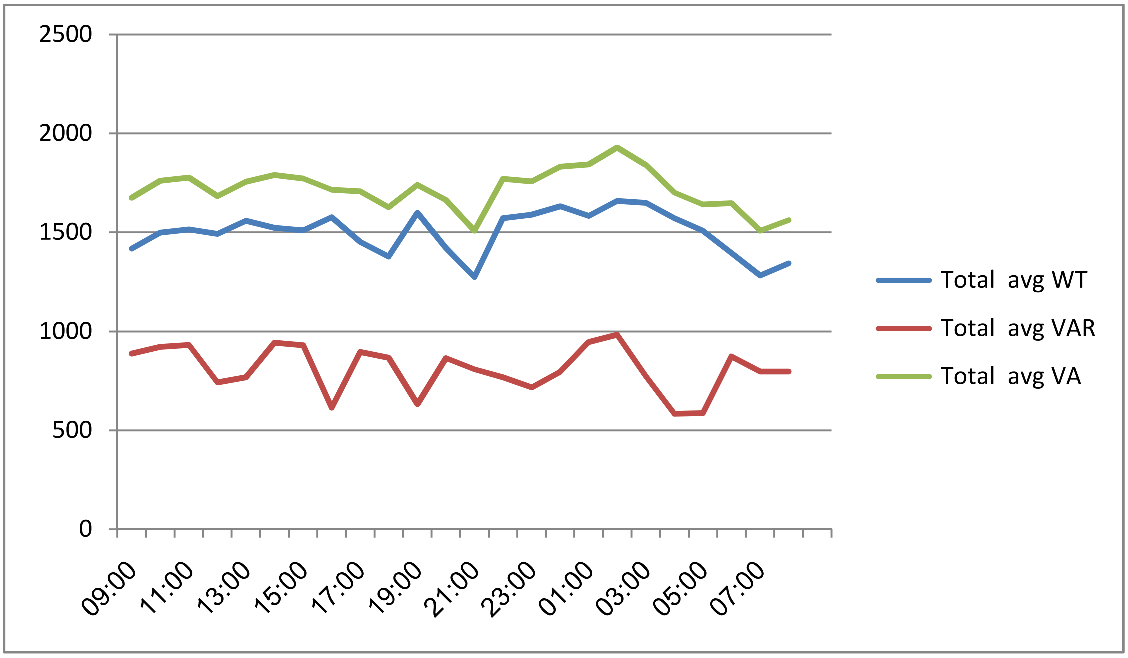


Figure (A.11): Total average three phase P, Q, and S from DG at Za'tara site.

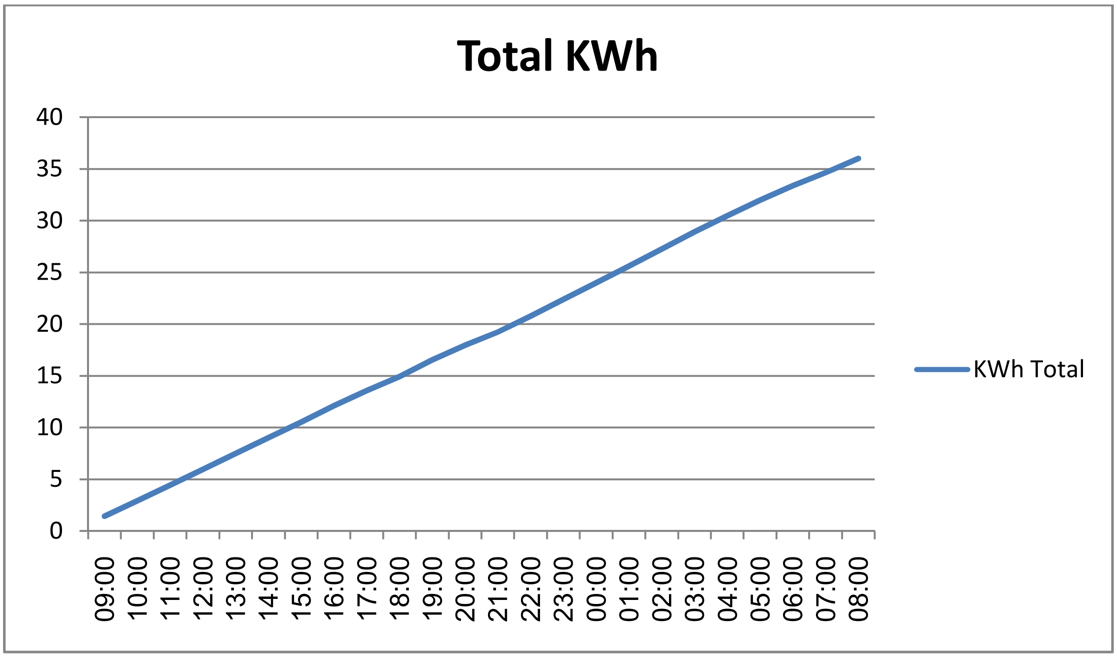


Figure (A.12): Total Energy consumption by the loads at Za'tara site.

(A.4):Energy analyzer Data at Froosh beat Dajan Site (19-20/5/2012).

Time	V1 avg	V2 avg	V3 avg	A1 avg	A2 avg	A3 avg	PF1 avg	Pf 2 avg	PF3 avg	WT Total avg	VAR Total avg	VA Total avg	PF Total avg	KWh Total
15:00	239	244	243	1.78	1.6	3.89	0.83	0.85	0.85	1493	933	1761	0.85	1.493
16:00	239	242	241	1.59	3.79	1.99	0.84	0.85	0.97	1565	801	1775	0.88	3.059
17:00	239	242	241	1.63	3.91	1.93	0.87	0.85	0.79	1509	976	1800	0.84	4.567
18:00	240	243	241	1.48	3.72	1.83	0.86	0.86	0.8	1432	912	1700	0.84	6
19:00	240	243	241	1.46	3.61	1.85	0.86	0.87	0.8	1415	886	1671	0.85	7.415
20:00	241	243	242	1.42	3.79	1.96	0.86	0.85	0.82	1463	934	1736	0.84	8.877
21:00	241	243	242	1.31	3.9	1.92	0.86	0.86	0.82	1464	917	1728	0.85	10.34
22:00	240	245	244	1.62	1.74	3.59	0.85	0.84	0.81	1400	948	1692	0.83	11.74
23:00	242	244	243	1.52	1.68	3.56	0.85	0.87	0.82	1378	890	1642	0.84	13.12
00:00	240	243	241	1.42	1.58	3.5	0.85	0.86	0.81	1304	870	1569	0.83	14.42
01:00	240	243	242	1.64	1.58	3.69	0.86	0.86	0.82	1398	910	1670	0.84	15.82
02:00	241	244	239	1.37	1.47	3.9	0.86	0.86	0.83	1360	881	1621	0.84	17.18
03:00	239	242	241	1.32	1.5	3.49	0.86	0.86	0.82	1271	827	1518	0.84	18.45
04:00	241	244	239	1.58	3.62	1.89	0.98	0.85	0.8	1476	825	1714	0.86	19.93
05:00	239	242	240	1.51	3.83	1.78	0.86	0.86	0.81	1445	916	1712	0.84	21.37
06:00	239	242	241	1.64	3.99	2	0.85	0.86	0.8	1548	994	1841	0.84	22.92
07:00	239	242	241	1.95	3.71	2.03	0.85	0.86	0.81	1563	987	1851	0.84	24.49
08:00	239	242	241	2.19	3.7	2.2	0.85	0.86	0.79	1630	1062	1948	0.84	26.12
09:00	240	242	241	1.93	3.65	2.1	0.86	0.85	0.81	1558	999	1852	0.84	27.67
10:00	239	244	243	1.58	1.73	3.9	0.85	0.86	0.81	1450	973	1747	0.83	29.12
11:00	239	242	241	1.73	1.45	3.77	0.85	0.86	0.8	1381	938	1671	0.83	30.5
12:00	239	242	241	1.67	1.69	3.59	0.85	0.86	0.81	1388	928	1671	0.83	31.89
13:00	240	243	241	1.64	1.51	3.57	0.85	0.86	0.79	1329	924	1622	0.82	33.22
14:00	240	243	241	1.62	1.29	3.69	0.86	0.85	0.81	1317	888	1591	0.83	34.53

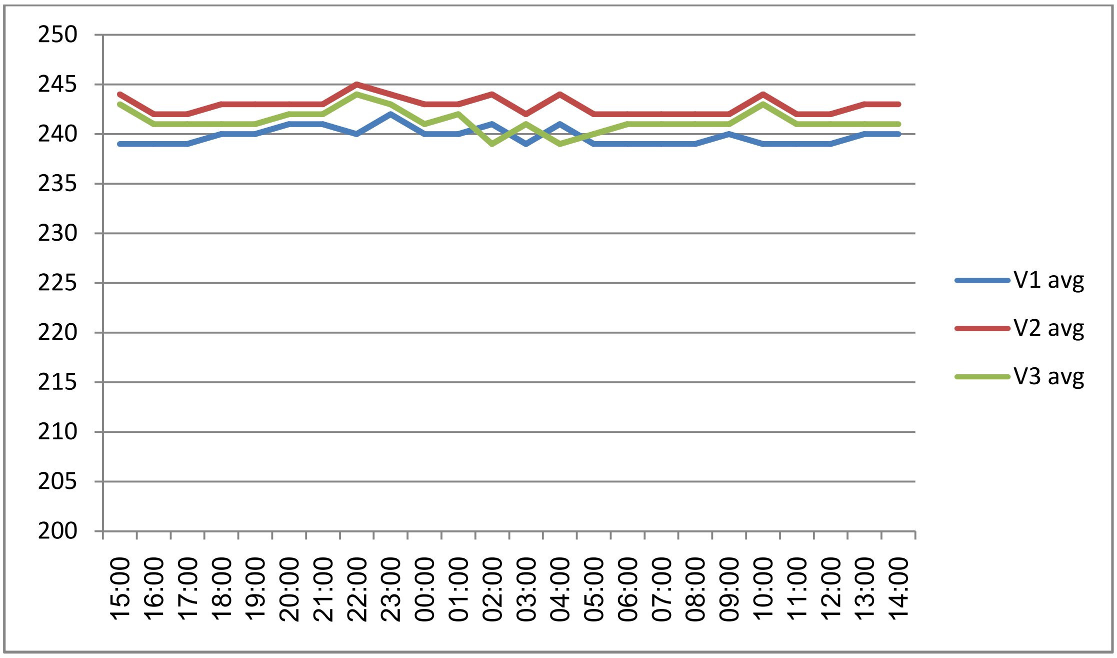


Figure (A.13): three phase voltage from DG at Froosh beat Dajan site.

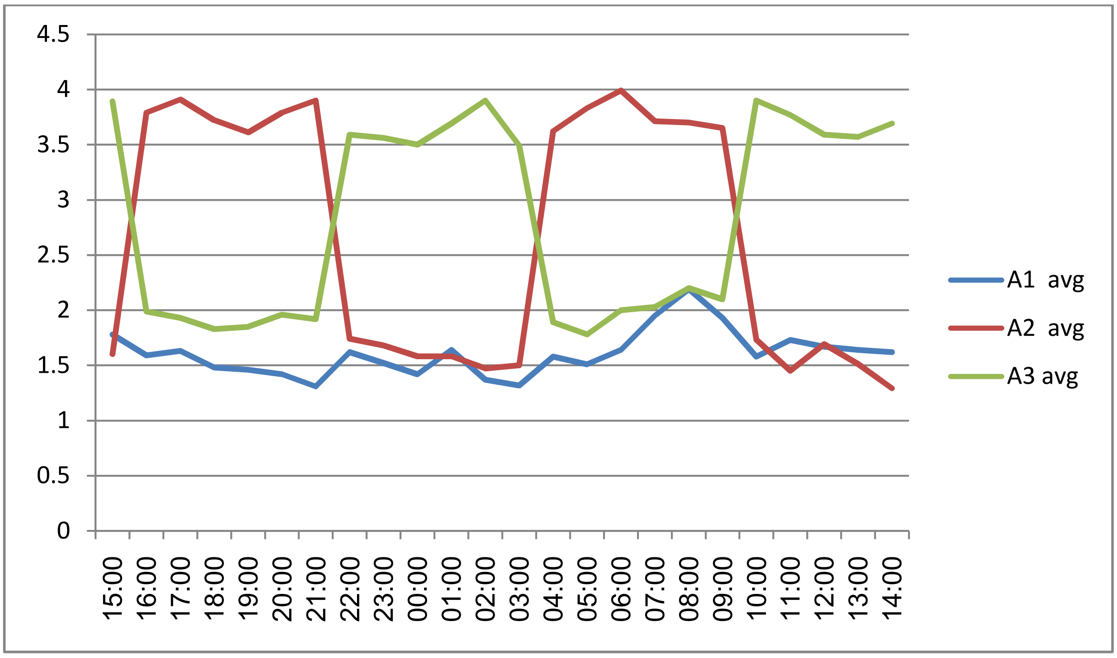


Figure (A.14): three phase current from D.G at Frosh beat Dajan site.

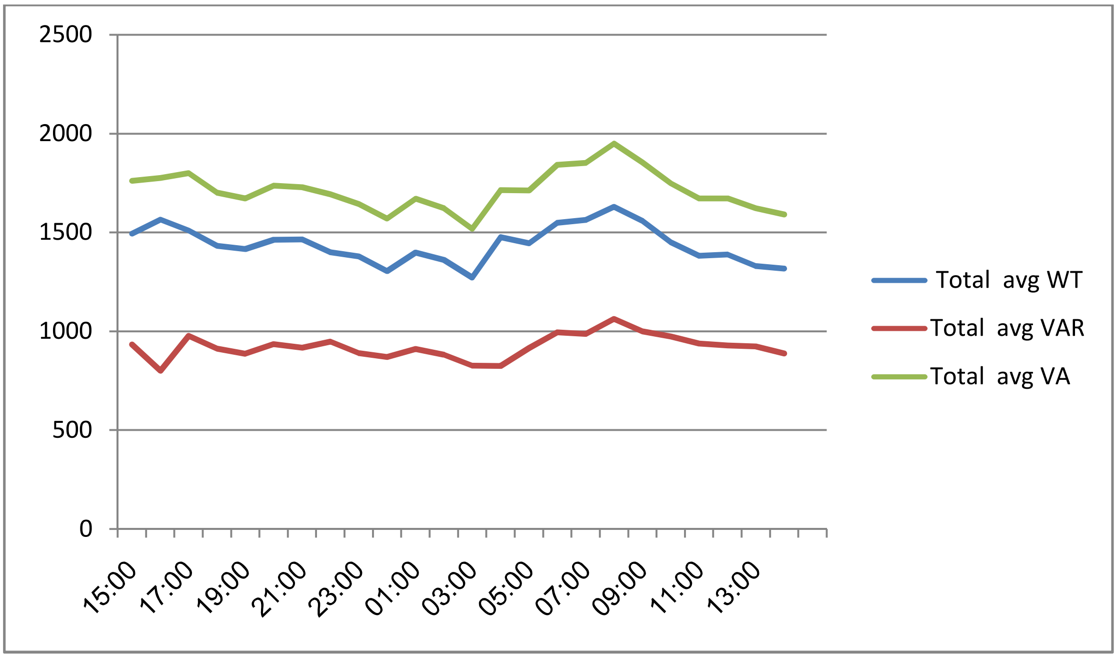


Figure (A.15): Total average three phase P, Q, and S from DG at Froosh beat Dajan site.

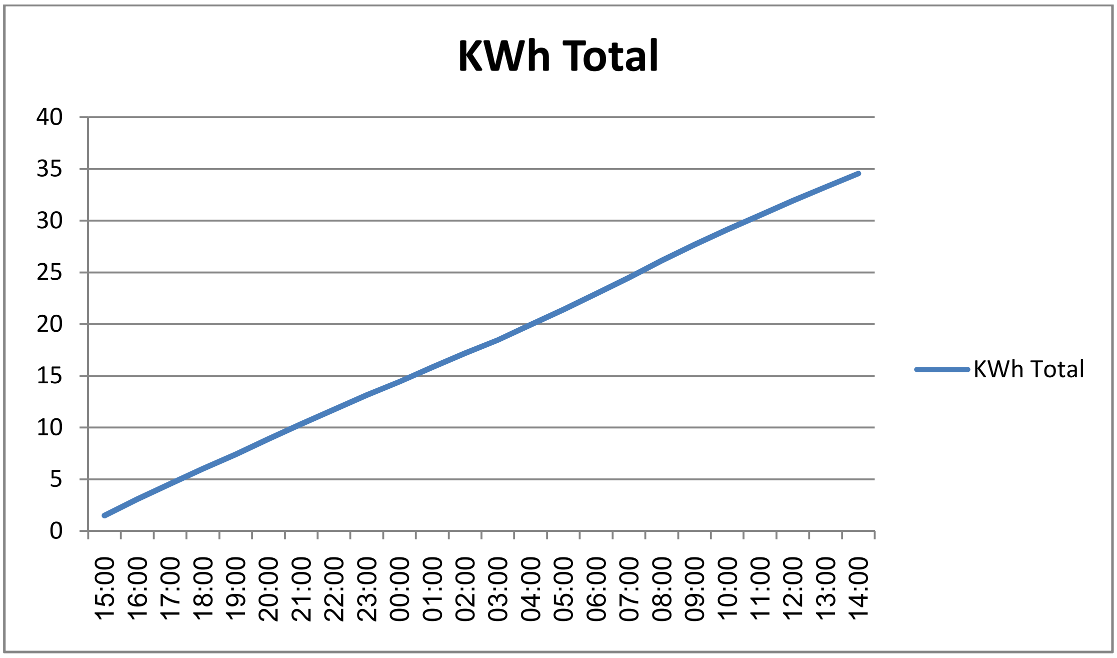


Figure (A.16): Total Energy consumption by the loads at Froosh beat Dajan site.

APPENDIX B: Specifications of all PV System Elements.

(B.1): Solar PV module technical specifications:

New Release
Greater Field Performance

KYOCERA

135 WATT

HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE

KD135SX-UPU

NEC 2008 Compliant
UL1703, Class C

c UL us

CUTTING EDGE TECHNOLOGY

As a pioneer with 35 years in solar, Kyocera demonstrates leadership in the development of solar energy products. Kyocera's *Kaizen* Philosophy, commitment to continuous improvement, is shown by repeatedly achieving world record cell efficiencies.

Kyocera Quality Built In:

- New frame technology allows for end mounting under 2400 Pa (50 psf) or wind speeds of 130 mph (ASTM E1830) and traditional mounting under 5400 Pa (113 psf) to support increased snow load
- UV stabilized, aesthetically pleasing black anodized frame
- Supported by all major mounting structure manufacturers
- Easily accessible grounding points on all four corners for fast installation
- Proven junction box technology

Kyocera manufactures and assembles solar cells and modules at its own worldwide production sites using a true vertical integration process. This superior approach gives Kyocera complete control over every step of the manufacturing process, producing modules with the industry's tightest power tolerance, promising high quality and efficiency.

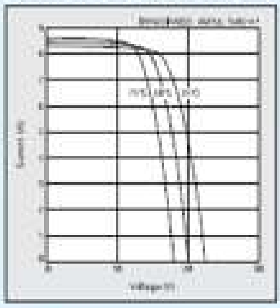
- Built-In Quality for Off-Grid Applications
- Proven Superior Field Performance
- Tight Power Tolerance
- 20 Year Warranty
- 5 Year Workmanship Warranty

SOLAR by KYOCERA

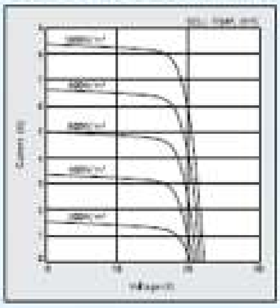
KD135SX-UPU

ELECTRICAL CHARACTERISTICS

Current-Voltage characteristics of Photovoltaic Module KD135SX-UPU at various cell temperatures

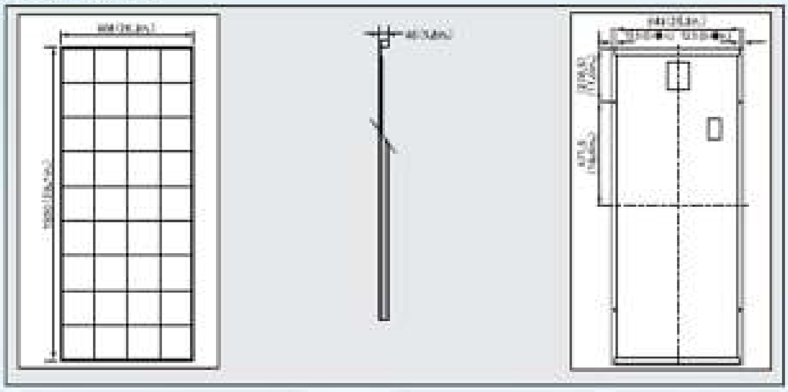


Current-Voltage characteristics of Photovoltaic Module KD135SX-UPU at various irradiance levels



SPECIFICATIONS

■ Physical Specifications



■ Specifications

■ Electrical Performance under Standard Test Conditions (*STC)

Maximum Power (Pmax)	135W (+5%/-5%)
Maximum Power Voltage (Vmpp)	17.7V
Maximum Power Current (Impp)	7.63A
Open Circuit Voltage (Voc)	22.1V
Short Circuit Current (Isc)	8.37A
Max System Voltage	600V
Temperature Coefficient of Voc	−8.0x10[illegible] V/°C
Temperature Coefficient of Isc	5.02x10[illegible] A/°C

■ Electrical Performance at 800W/m², *NOCT, AM1.5

Maximum Power (Pmax)	95W
Maximum Power Voltage (Vmpp)	15.7V
Maximum Power Current (Impp)	6.10A
Open Circuit Voltage (Voc)	20.0V
Short Circuit Current (Isc)	6.79A

■ Cells

Number per Module	36

■ Module Characteristics

Length x Width x Depth	[illegible]
Weight	12.5kg(27.5lbs.)

■ Junction Box Characteristics

Length x Width x Depth	[illegible]
IP Code	IP65

■ Others

*Operating Temperature	−40°~90°C
Maximum Fuse	15A

*This temperature is based on cell temperature.

ISO 9001 and ISO 14001 Certified and Registered

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800-223-9580 toll free 800-523-2329 fax

KYOCERA

(B.2): 2V/2500 Ah Solar Battery Technical Specifications:

Solar Battery 2V 2500AH

Hi-performance batteries designed to meet the demands of solar power generation applications

Highlights of Solar Panel Battery 2V 2500AH

- Flame retardant cell container and cover material.
- Proprietary process technology ideal for tropical conditions.
- Robust and aesthetically attractive modular design.
- Leak resistant double seal terminal design.
- High performance operation with no maintenance (doesn't require routine water additions or specific gravity checks).
- Efficient Vent Valve Assembly.
- Reliable performance under float and cyclic usage.
- Balanced active material design.

- Excellent charge acceptance.
- Good deep discharge recovery.
- Uniformly useful capacity during its expected service life.
- Long Cycle Life of 1200 cycles at 50% DOD.
- Long Float Life at 27°C.
- Usage of highest purity material results Low self discharge Long Shelf life.
- Heavy-duty plates.
- High conductivity lead coated copper connectors.
- Better usage of foot print area due to stackable modular design.

Applications of Solar Batteries 2V 2500AH

- Diesel Generator Alternative Using Solar Power Plants
- Lower Your Electric Bill Using Solar Power Stations

Our Solar Applications Engineer starts with the Proposal for Solar Energy Projects including a detailed site survey, shading study and requirements assessment to provide you with indicative financial estimates.

Besides Solar Panel Battery 2V 2500AH our solar power system design includes key considerations on Solar Module Panels that will maximize generation, Solar Panel Mounting Systems that optimize roof space, array configuration to boost Photovoltaic Combiner Box output, suitable Solar Inverter for Indian Conditions for your load profile and ideal location for the installation of Automatic Weather Stations.

Specifications of Solar Panels Battery 2V 2500AH

Nominal Voltage		2V
Capacity (10 hr, 25°C)		2500Ah
Dimension	Length	710 mm
	Width	352 mm
	Height	342 mm
	Total Height	369 mm
Approx. Weight		165 Kg

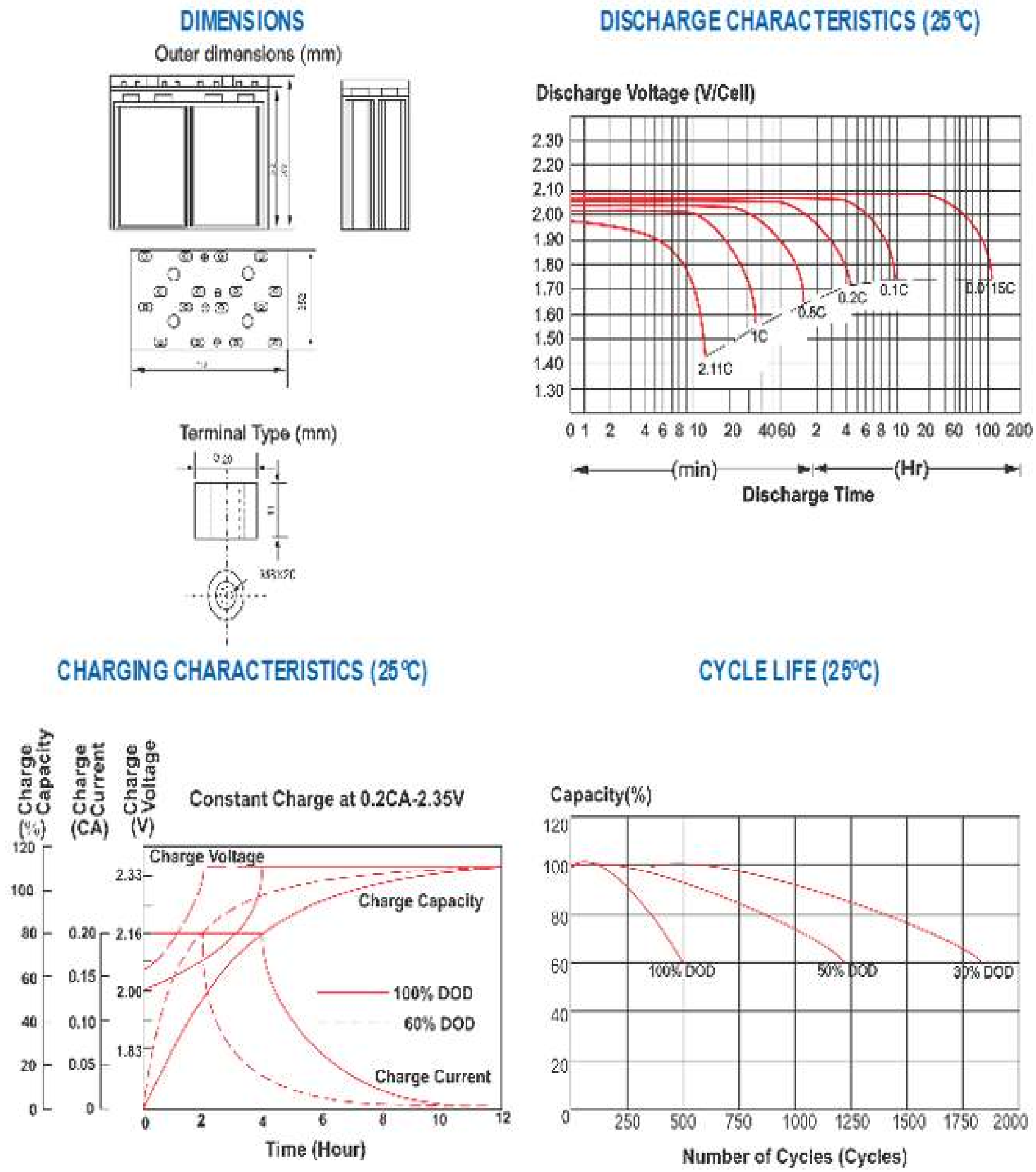
CHARACTERISTICS

Capacity (25°C)	10 hour rate	2500Ah
	5 hour rate	2000Ah
	1 hour rate	1500Ah
	1.5 hour discharge to 1.75V	1000A

CHARACTERISTICS cont.

Capacity affected by temperature (10 hr)	40°C	102%
	25°C	100%
	0°C	85%
	-15°C	65%
Self-discharge (25°C)	3 month	Remaining Capacity: 91%
	6 month	Remaining Capacity: 82%
	12 month	Remaining Capacity: 64%
Nominal operating temperature		25°C±3°C
Operating temperature range		-15°C to 50°C
Float charging voltage (25°C)		2.25 to 2.30V
Cyclic charging voltage (25°C)		2.35 to 2.40V
Internal Resistance (Fully charged, 25°C)		Approx. 0.08 mΩ

Characteristics of Solar Cell Battery 2V 2500AH



(B.3): 2V/2700 Ah Solar Battery Technical Specifications:

	**Battery MVSV (gel) 2V/2700 Ah** **Part 68002700**	
	Ah capacity/C10 (capacity at 10 hours of discharge time at a surrounding temperature of 20°C)	2700 Ah
	Dimensions excluding poles (LxWxH)	214 x 488 x 774 mm
	Dimensions including poles (LxWxH)	214 x 488 x 819 mm
	Weight	196 kg
	Installation length	222 mm
	Number of poles	4
	Guarantee period	7 year pro rata (ask comprehensive term

Product Description

Specifications

Nominal voltage	2V
Ah capacity/C10 (capacity at 10 hours of discharge time at a surrounding temperature of 20°C)	2700 Ah

Capacity for larger installations

Very intense deep cycle use

Extremely durable

Entirely maintenance-free and safe

Can be linked in series for 12 or 24V

Suitable for 3-step Plus© charging method

The right voltage at all times

Horizontal & vertical installation possible

First-rate condition even after winter storage

No gas production

Safe & easy to install

Support for heavy AC power appliances

Use a Mass Combi for all-in-one charging and DC-AC conversion

(B.4): 2V/3000 Ah Solar Battery Technical Specifications:

Solar Battery 2V 3000AH

Hi-performance batteries designed to meet the demands of solar power generation applications

Highlights of Solar Panel Battery 2V 3000AH

- Flame retardant cell container and cover material.
- Proprietary process technology ideal for tropical conditions.
- Robust and aesthetically attractive modular design.
- Leak resistant double seal terminal design.
- High performance operation with no maintenance (doesn't require routine water additions or specific gravity checks).

- Efficient Vent Valve Assembly.
- Reliable performance under float and cyclic usage.
- Balanced active material design.
- Excellent charge acceptance.
- Good deep discharge recovery.
- Uniformly useful capacity during its expected service life.
- Long Cycle Life of 1200 cycles at 50% DOD.
- Long Float Life at 27°C.
- Usage of highest purity material results Low self discharge Long Shelf life.
- Heavy-duty plates.
- High conductivity lead coated copper connectors.
- Better usage of foot print area due to stackable modular design.

Applications of Solar Batteries 2V 3000AH

- Diesel Generator Alternative Using Solar Power Plants
- Lower Your Electric Bill Using Solar Power Stations

Our Solar Applications Engineer starts with the Proposal for Solar Energy Projects including a detailed site survey, shading study and requirements assessment to provide you with indicative financial estimates.

Besides Solar Panel Battery 2V 3000AH our solar power system design includes key considerations on Solar Modules that will maximize generation, Solar Panel Mounting Systems that optimize roof space, array configuration to boost Solar Combiner Box output, suitable Solar Powered Inverters for your load profile and ideal location for the installation of Automatic Weather Stations.

Specifications of Solar Panels Battery 2V 3000AH

Nominal Voltage		2V
Capacity (10 hr, 25˚C)		3000Ah
Dimension	Length	710 mm
	Width	352 mm
	Height	342 mm
	Total Height	369 mm
Approx. Weight		195 Kg

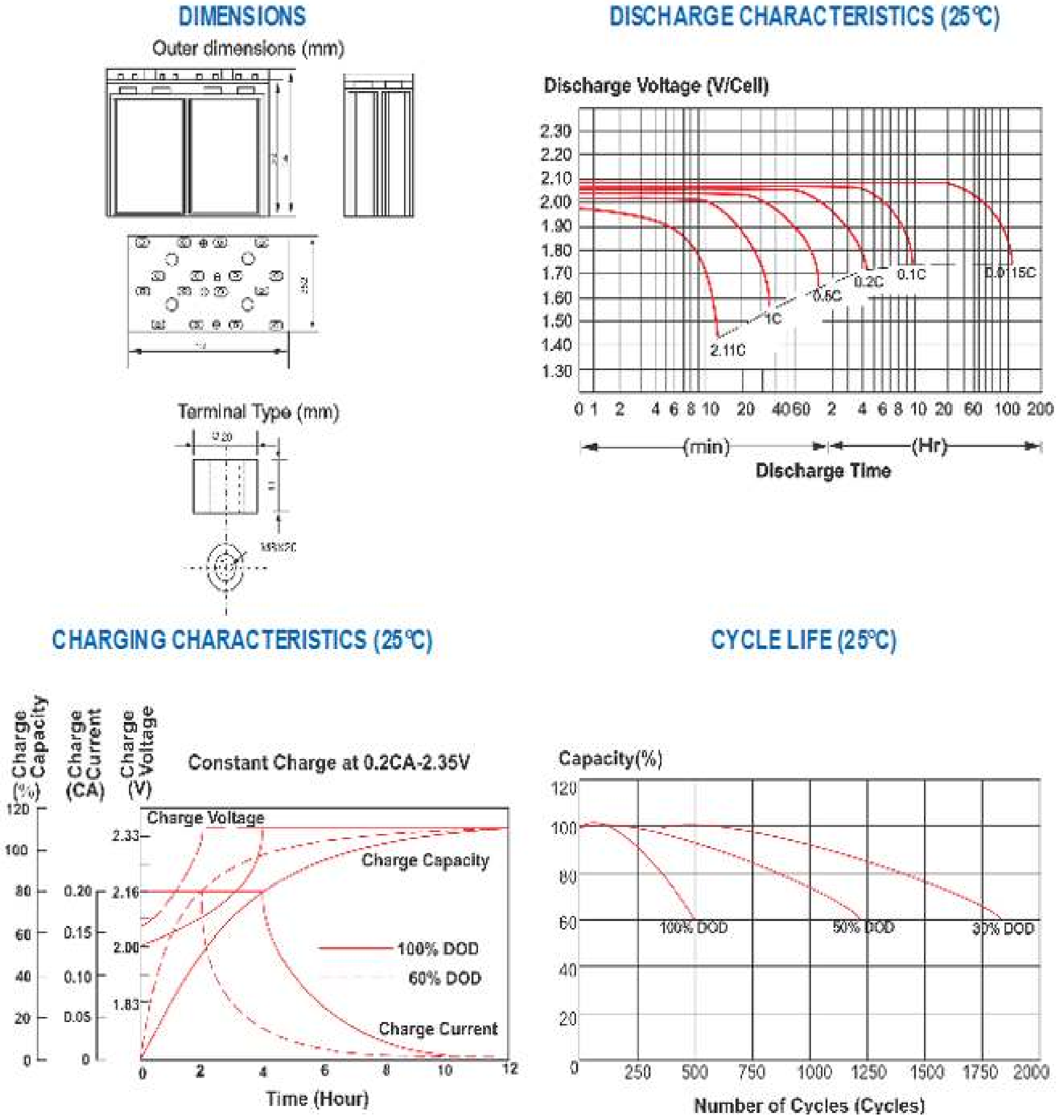
CHARACTERISTICS

Capacity (25˚C)	10 hour rate	3000Ah
	5 hour rate	2400Ah
	1 hour rate	1800Ah
	1.5 hour discharge to 1.75V	1200A

CHARACTERISTICS cont.

Capacity affected by temperature (10 hr)	40˚C	102%
	25˚C	100%
	0˚C	85%
	-15˚C	65%
Self-discharge (25˚C)	3 month	Remaining Capacity: 91%
	6 month	Remaining Capacity: 82%
	12 month	Remaining Capacity: 64%
Nominal operating temperature		25˚C±3˚C
Operating temperature range		-15˚C to 50˚C
Float charging voltage (25˚C)		2.25 to 2.30V
Cyclic charging voltage (25˚C)		2.35 to 2.40V
Internal Resistance (Fully charged, 25˚C)		Approx. 0.08 mΩ

Characteristics of Solar Cell Battery 2V 3000AH



(B.5): 80A-48V Charge Controller Technical Specifications:

80A -48V MPPT solar charge controller.

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Product Details:

Place of Origin	Taiwan
Brand Name	MPP SOLAR
Model Number	PCM8048
Application	Solar System Controller
Rated Voltage	12v 24v 36v 48v
Maximum Current	80A
MPPT solar charge controller	12v 24v 48v
Max charging current 80A	Max voltage 140V
Max PV power 5400w	LCD monitor
Data logger 90 days	with BTS
voltage programmable	Made in Taiwan

(B.6): 90A-48V Charge Controller Technical Specifications:

larger image

WRND has a wide range of MPPT type solar charge controllers to best fit your needs. We manufacture in-house and support directly in South Africa. No need to pay the importers and expensive oversees shipping cost or waiting for stock. We offer a 2 year warranty as standard on our ProSeries products , but also have a 5 year and 10 year optional extension available.

MPPT solar charge controllers have been proven to offer far better performance compared to standard PWM type solar regulators. On average one can expect up to 30% better yields. This is because of the dynamic and intelligent way in which these controllers find and track the maximum power delivery point of the connected solar panels, hens the abbreviation MPPT (Maximum Power Point Tracking).

Given 30% better power yield translates to a significant cost saving when buying solar panels – one simple need less total panel watts to yield the same average power output compared to a PWM type solar regulator. In addition, the MPPT also log statistics, intelligently charges and conditions the batteries and can be user configured for optimum system performance.

Our units are all solid state and have no moving parts or fans that could malfunction with time. We also offer an optional conformal coating to prevent moisture from influencing or damaging the unit. This option is ideal for maritime applications, harsh environments, preventing damage due to insects and damp conditions.

Nominal battery voltage: 12V, 24V, 36V or 48V (auto selects) Handles panels up to: 4500W (48V system), 3375W (36V system), 2250W (24V system), 1125W (12V system)

Max panel voltage: 125V (system shutdown), 150V (absolute max)

Max continues battery charging current: 91 A (electronically limited)
Charging (3-stages): Bulk, Absorb & Equalize

Log history: last 31 days (saves: kWh, run time and max pv watts) Totals counter: days & kWh

Protection:

Over current protection in hardware and software

Over voltage limiting in hardware and software

Over temperature

(B.7): 70A-48V Charge Controller Technical Specifications:

48-70ASolar Charge Controller,

Product Details:

Place of Origin	Beijing, China (Mainland)
Brand Name	Fangpusun
Model Number	Power Tarom
Application	Solar System Controller
Rated Voltage	DC12V,DC24V,DC48V
Maximum Current	140A
Charging current	70A,140A,55A,110A,140A
Discharging current	55A,70A
Interfaces	RJ45 interface
Options	External temperature sensor,Alarm contact
Text LCD Display	operating parameters,fault message,self test

(B.8): 3KW three phase off gird Solar Inverter Technical Specifications:

3-phase inverter 3000w-5000w(solar inverter 3-phase)

Specifications

3-phase inverter 3000w-5000w

1.CE Cert. solar inverter 3 phase

2.3-phase inverter are used for compressor, big industry

3-phase inverter 3000w-5000w(solar inverter 3-phase)

Power capacity(W)	300	500	800	1K	1.5K	2K	3K	5K	6K	10K
dc voltage (V)	12/24	24/48					48/96		192	
input voltage (V)	160-265VAC									
output frequency	45—65Hz									

output voltage (V)	220VAC±5%/50Hz±1%	
output waveform	pure sine wave	
automatic switch time	<1ms	
charge current	Max15A	Max20A
Preotection	over-voltage and low voltage protection; Low battery protection; Surge and spindle current protection; Overload protection 100%-120%; 30 SEC > 120% 100 ms; > 150%, 50 ms output short circuit < 150 ms	
effeciency	≥90%	
noise	<45db	
Working environment temperature	0-40°C	
storage temperature	-15 - +50°C	
size(L*W*H)	388*145*210	
net weight	16.0kg	

APPENDIX C:Table of interest i=10%

10%								10%
	Single Payments		Uniform-Series Payments				Uniform Gradient	
n	Compound Amount F/P	Present Worth P/F	Sinking Fund A/F	Compound Amount F/A	Capital Recovery A/P	Present Worth P/A	Gradient Present Worth P/G	Gradient Annual Series A/G
1	1.1000	0.9091	1.00000	1.0000	1.10000	0.9091		
2	1.2100	0.8264	0.47619	2.1000	0.57619	1.7355	0.8264	0.4762
3	1.3310	0.7513	0.30211	3.3100	0.40211	2.4869	2.3291	0.9366
4	1.4641	0.6830	0.21547	4.6410	0.31547	3.1699	4.3781	1.3812
5	1.6105	0.6209	0.16380	6.1051	0.26380	3.7908	6.8618	1.8101
6	1.7716	0.5645	0.12961	7.7156	0.22961	4.3553	9.6842	2.2236
7	1.9487	0.5132	0.10541	9.4872	0.20541	4.8684	12.7631	2.6216
8	2.1436	0.4665	0.08744	11.4359	0.18744	5.3349	16.0287	3.0045
9	2.3579	0.4241	0.07364	13.5795	0.17364	5.7590	19.4215	3.3724
10	2.5937	0.3855	0.06275	15.9374	0.16275	6.1446	22.8913	3.7255
11	2.8531	0.3505	0.05396	18.5312	0.15396	6.4951	26.3963	4.0641
12	3.1384	0.3186	0.04676	21.3843	0.14676	6.8137	29.9012	4.3884
13	3.4523	0.2897	0.04078	24.5227	0.14078	7.1034	33.3772	4.6988
14	3.7975	0.2633	0.03575	27.9750	0.13575	7.3667	36.8005	4.9955
15	4.1772	0.2394	0.03147	31.7725	0.13147	7.6061	40.1520	5.2789
16	4.5950	0.2176	0.02782	35.9497	0.12782	7.8237	43.4164	5.5493
17	5.0545	0.1978	0.02466	40.5447	0.12466	8.0216	46.5819	5.8071
18	5.5599	0.1799	0.02193	45.5992	0.12193	8.2014	49.6395	6.0526
19	6.1159	0.1635	0.01955	51.1591	0.11955	8.3649	52.5827	6.2861
20	6.7275	0.1486	0.01746	57.2750	0.11746	8.5136	55.4069	6.5081
21	7.4002	0.1351	0.01562	64.0025	0.11562	8.6487	58.1095	6.7189
22	8.1403	0.1228	0.01401	71.4027	0.11401	8.7715	60.6893	6.9189
23	8.9543	0.1117	0.01257	79.5430	0.11257	8.8832	63.1462	7.1085
24	9.8497	0.1015	0.01130	88.4973	0.11130	8.9847	65.4813	7.2881
25	10.8347	0.0923	0.01017	98.3471	0.11017	9.0770	67.6964	7.4580
26	11.9182	0.0839	0.00916	109.1818	0.10916	9.1609	69.7940	7.6186
27	13.1100	0.0763	0.00826	121.0999	0.10826	9.2372	71.7773	7.7704
28	14.4210	0.0693	0.00745	134.2099	0.10745	9.3066	73.6495	7.9137
29	15.8631	0.0630	0.00673	148.6309	0.10673	9.3696	75.4146	8.0489
30	17.4494	0.0573	0.00608	164.4940	0.10608	9.4269	77.0766	8.1762
31	19.1943	0.0521	0.00550	181.9434	0.10550	9.4790	78.6395	8.2962
32	21.1138	0.0474	0.00497	201.1378	0.10497	9.5264	80.1078	8.4091
33	23.2252	0.0431	0.00450	222.2515	0.10450	9.5694	81.4856	8.5152
34	25.5477	0.0391	0.00407	245.4767	0.10407	9.6086	82.7773	8.6149
35	28.1024	0.0356	0.00369	271.0244	0.10369	9.6442	83.9872	8.7086
40	45.2593	0.0221	0.00226	442.5926	0.10226	9.7791	88.9525	9.0962
45	72.8905	0.0137	0.00139	718.9048	0.10139	9.8628	92.4544	9.3740
50	117.3909	0.0085	0.00086	1163.91	0.10086	9.9148	94.8889	9.5704
55	189.0591	0.0053	0.00053	1880.59	0.10053	9.9471	96.5619	9.7073
60	304.4816	0.0033	0.00033	3034.82	0.10033	9.9672	97.7010	9.8023
65	490.3707	0.0020	0.00020	4893.71	0.10020	9.9796	98.4705	9.8672
70	789.7470	0.0013	0.00013	7887.47	0.10013	9.9873	98.9870	9.9113
75	1271.90	0.0008	0.00008	12709	0.10008	9.9921	99.3317	9.9410
80	2048.40	0.0005	0.00005	20474	0.10005	9.9951	99.5606	9.9609
85	3298.97	0.0003	0.00003	32980	0.10003	9.9970	99.7120	9.9742
90	5313.02	0.0002	0.00002	53120	0.10002	9.9981	99.8118	9.9831
95	8556.68	0.0001	0.00001	85557	0.10001	9.9988	99.8773	9.9889
96	9412.34	0.0001	0.00001	94113	0.10001	9.9989	99.8874	9.9898
98	11389	0.0001	0.00001		0.10001	9.9991	99.9052	9.9914
100	13781	0.0001	0.00001		0.10001	9.9993	99.9202	9.9927

جامعة النجاح الوطنية
كلية الدراسات العليا

الدراسة الفنية والاقتصادية لاستخدام أنظمة الخلايا الشمسية لتزويد أبراج الاتصالات بالكهرباء بدلاً من الديزل

إعداد
فراس شاهر حسن صنوبر

إشراف
د . عماد بريك

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وإستراتيجية الترشيد بكلية الدراسات العليا في جامعة النجاح الوطنية نابلس فلسطين.

2013م

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الملخص

حيث أن الطاقة المتجددة أصبحت أكثر انتشارا، ومع ازدياد الحاجة لمعرفة المزيد من المعلومات حول كيفية عمل الأنواع المختلفة من هذه التكنولوجيا. سوف يقوم هذا البحث بعمل دراسة وتحليل فني واقتصادي لتزويد أبراج الاتصالات في المناطق النائية بالكهرباء بواسطة نظام الخلايا الشمسية الهجين بدلا من الاعتماد على مولدات الديزل كمصدر وحيد لتزويد الأبراج بالكهرباء بشكل مستمر طوال العام. حيث أن هذا النظام الهجين يتكون من الخلايا شمسية كمصدر رئيسي ومولدات الديزل كمصدر احتياط لتوليد الكهرباء، وكذلك يتكون من نظام تخزين للطاقة داخل بطاريات شمسية، ومحولات تحويل من تيار ثابت إلى تيار متناوب، بالإضافة إلى منظم شحن والأحمال الكهربائية للأبراج.

الإستراتيجية الرئيسية لعمل النظام ,إذا كان هناك ما يكفي من الطاقة الناتجة من أشعة الشمس بما يتلاءم مع توفير متطلبات أحمال الأبراج، فأن نظام الخلايا الشمسية وحده يعمل لإنتاج الكهرباء وبالتالي إذا كان هناك فائض عن الحاجة من الطاقة الشمسية، فأنه سيتم تخزين هذه الطاقة في بطاريات خاصة، أما إذا كانت الطاقة المنتجة من الخلايا الشمسية لا تكفي لتلبية احتياجات الأحمال فأنه يتم الاستعانة بمولدات الديزل لتغطية النقص في الطاقة.

أحد الأهداف الرئيسية من البحث هو تقدير الأثر الاقتصادي والبيئي لاستخدام نظام الطاقة الشمسية الهجين بدلا من مولدات الديزل، وذلك بتحليل ودراسة كل التكاليف التشغيلية والثابتة للنظامين.

حيث تم دراسة وتصميم أنظمة خلايا شمسية للمواقع الأربعة النائية بقدرات تتراوح ما بين (8KW-10KW)، حيث يتطلب ذلك استثمار ما مجموعه حوالي (50000$) للموقع الواحد، وبالتالي فأن تكلفة الكهرباء المنتجة من نظام الخلايا الشمسية تكون بمعدل 0.63$/KWh، وذلك باستخدام معدل فائدة بنسبة 10% مقارنة مع متوسط التكلفة من مولدات الديزل الموجودة حيث تساوي 1.15$/KWh.

وكذلك يناقش هذا البحث الآثار البيئية الناتجة عند استخدام الخلايا الشمسية بدلا من مولدات الديزل في توليد الكهرباء، وكمية التوفير من انبعاثات غاز ثاني أكسيد الكربون حيث تقدر كمية التوفير للمواقع الأربعة عند تطبيق استخدام أنظمة الخلايا الشمسية (53000Kg)، وهذا يؤكد على الدور المستقبلي لمصادر الطاقة المتجددة في فلسطين.