Palestine Polytechnic University
Electrical and Computer Engineering Department

Industrial Automation Engineering Program

Bachelor Thesis

Graduation Project

Design and Implement Photovoltaic-Grid System to Feed Office of Deanship of Graduate Studies in Palestine Polytechnic University

Project Team

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Abstract

The idea of this project is to provide design and practically implementation for alternative, environment friendly electrical feeding system by using solar energy. It is used to feed all electrical loads in the **Office of Graduate Studies and Scientific Research in Palestine Polytechnic University** during the day through **"Grid-Tie solar system".** This system is differing from the **"Grid-Off solar system"** that doesn't use batteries to store energy, due to their disadvantages in terms of high cost and higher need for maintenance and replacement.

Advantages of "Grid-Tie solar system" include the low operating cost, low maintenance, easy installation, long life and saving in the bills.

At the binging of the project we use theoretical calculation and we found that the office consumes 2.9MWh/year, after theoretical analysis we find that we need 8 photovoltaic modules and 3KW inverter. Now the system produced 3.5MWh/year that means the system will feed the loads completely during the office work hours. However when the office is not working the energy produced by the system will feed the grid.

ملخص

فكرة المشروع تقوم على تقديم تصميم وتطبيق عملي لنظام تغذية كهربائية بديل وصديق للبيئة باستخدام الطاقة الشمسية، لتغذية مكتب **عمادة الدراسات العليا والبحث العلمي في جامعة بوليتكنك فلسطين** بكامل أحماله الكهربائية، حيث تقوم فكرة المشروع على تغذية المكتب نهارا من خلال **" نظام شمسي مربوط بالشبكة "** . يختلف هذا النظام عن النظام الشمسي الغير مربوط بالشبكة أو القائم بذاته عن أنه لا يستخدم البطاريات لتخزين الطاقة وذلك لما لها من مساوئ من حيث سعرها العالي وحاجتها للصيانة والتبديل.

وتتمثل محاسن هذا النظام في سهولة تركيبه وتكلفة تشغيله قليلة ولا يحتاج لصيانة وعمر التشغيل طويل يصل الى 25 عام ويعمل على تخفيض قيمة الفواتير المدفوعة شهرياً.

في بداية العمل في المشروع قمنا بعمل حسابات نظرية وتبين أن المكتب يستهلك2.9 ميجا واط ساعه كل سنة ، وبعد اجراء عملية الحسابات النظرية للتصميم تبين أننا نحتاج لـ8 ألواح شمسية وانفيرتر قدرته 3كيلو واط حيث ينتج هذا المشروع سنويا 3.5 ميجا واط ساعه وهذا يعني أن النظام سيغطي احمال المكتب بشكل كامل أثناء دوامه، وفي حال كان المكتب مغلقاً سيتم تغذية الشبكة الرئيسية بشكل مباشر.

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CHAPTER ONE

INTRODUCTION

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1.1 Project Overview

Electricity is the most important element at this century, because that, studies are ended to the sources which gives the needs for human from electricity.

Producing electricity at the beginning of the last century were by incinerate the petroleum and the coal and there differentiations. But by very big increasing of the numbers of people in the earth and by increasing the consumption of electricity, different studies shows that these sources will be carry out, because that these studies taking to search of another sources to produce the electricity, also the large negative effect of the environment which caused by incinerate the oil differentiations increase the needs to found another source of electricity.

One of the most important stead is produce the electricity using the sun light, by direct conversion of the light to electricity using solar cells.

The using of solar energy at a long time meaning that there is a very large saving the overall cost of producing electricity, Figure1-1 shows a simplified Idea for the design of our project.

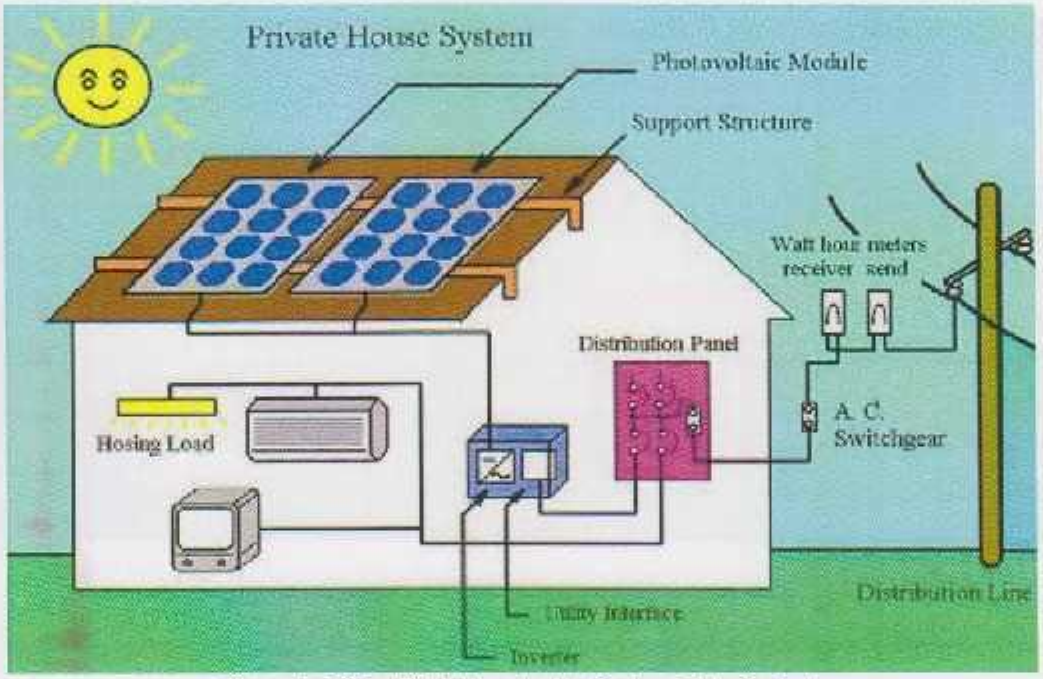


Figure 1-1 Simplified Idea for the Design of the Project

1.2 Project aims

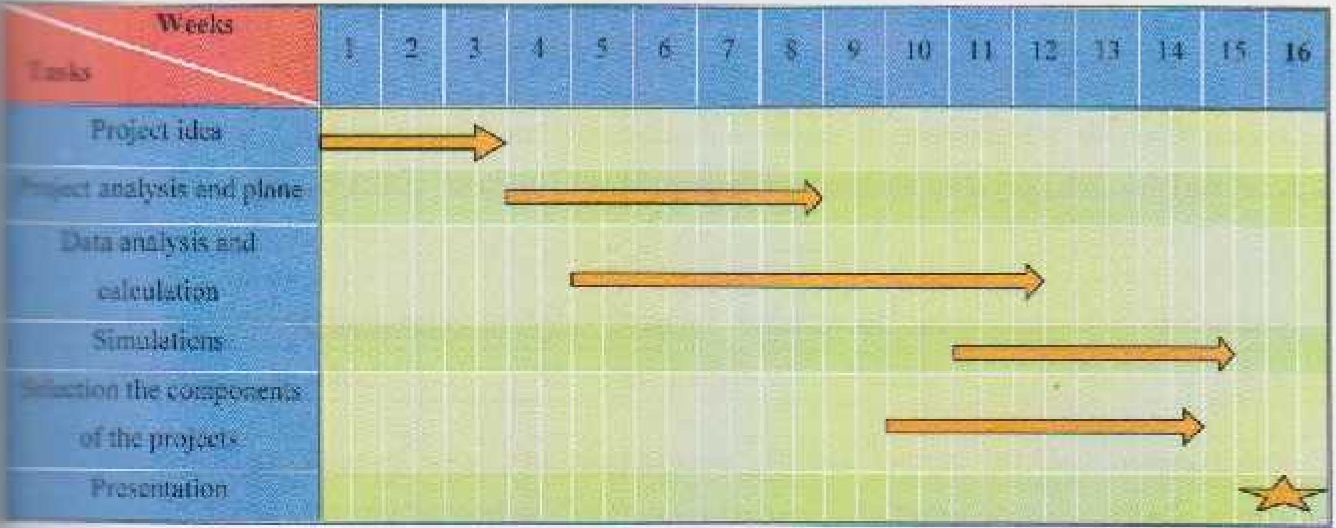
This Project aims at:

- Building of alternative power supply system using solar energy.
- Decrease energy drawn from the grid.
- Development of renewable energy source and environment-friendly.
- Solve the energy problem in Palestine and find alternative solutions for the future.

1.3 Time Table

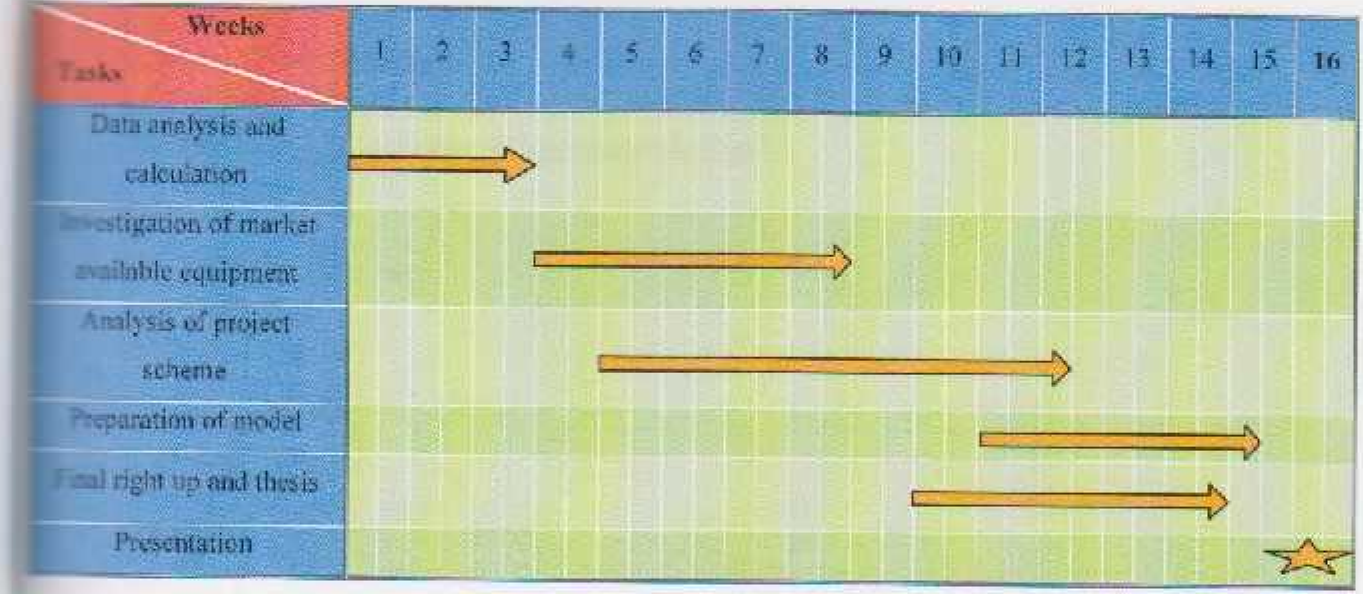
The time schedule shows the stages of developing in our work and the process of project growth that include Project determination, studying, collecting data, designing the entire system. Table 1-1: shows the first semester project growth. All tasks are referred to the theoretical background and the whole system analysis.

Table 1-1 Time Schedule



Weeks / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project idea	→	→	→													
Project analysis and plane				→	→	→	→	→								
Data analysis and calculation					→	→	→	→	→	→	→	→				
Simulations											→	→	→	→	→	
Selection the components of the projects										→	→	→	→	→		
Presentation																★

Table 1-2 Time Schedule for second semester



Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Data analysis and calculation	→	→	→													
Investigation of market available equipment				→	→	→	→	→								
Analysis of project scheme					→	→	→	→	→	→	→	→				
Preparation of model											→	→	→	→	→	
Final right up and thesis										→	→	→	→	→		
Presentation																★

1.4 Project Scope

This project consists of four chapters as follows:

Chapter One **"<u>Introduction</u>"** and you will find inside it, overview for the total project, objectives, time schedule, literature view, estimated coast and the main risks that we have faced in the project.

Chapter Two **"<u>Components of Solar System</u>"** Solar panel, charge controller, the battery, inverter and the load.

Chapter Three **"<u>Type of Solar Electrical System"</u>** Grid-tie system, Off Grid system, Hybrid system and net metering connected.

Chapter Four **"<u>Design & Calculation</u>"**.

Chapter Five **"<u>System implementation</u>"**.

Chapter Six "**Protection**".

Chapter Seven "**Results**".

Chapter Eight "**Conclusion & Recommendations**".

CHAPTER TWO

COMPONENTS OF SOLAR SYSTEM

2.1 Introduction

A basic PV system consists of five main components. The ***solar panel*, *charge controller*, *the battery*, *inverter*,** and ***the load***. The solar panel are collecting the energy of the sun and generating electricity. Charge controller is responsible of regulation of charging the batteries. The inverter responsible of converting DC/AC power, the load refers to any device that requires electrical power and is the sum of the consumption of all electrical equipments connected to the system and it will be discussed in chapter four.

2.2 A solar panel

Photovoltaic conversion is the direct conversion of sunlight into electricity with no intervening heat engine. Photovoltaic devices are solid state; therefore, they are rugged and simple in design and require very little maintenance. Perhaps the biggest advantage of solar photovoltaic devices is that they can be constructed as standalone systems to give outputs from microwatts to megawatts. That is why they have been used as the power sources for calculators, watches, water pumps, remote buildings, communications, satellites and space vehicles, and even megawatt-scale power plants. Photovoltaic panels can be made to form components of building skin, such as roof shingles and wall panels. With such a vast array of applications, the demand for photovoltaics is increasing every year.

The sun fills the requirements of a clean energy-source, but why are people not making use of all the energy that surrounds us in form of sunlight? The answer to this is to be found in the solar cell, the component used to transform the sunlight into electricity.

Solar cells are used in different areas. Solar cell as the gadget that will help to solve the energy problem, through of using the sun as an energy-source is very tempting. The obstacle in the way of the ultimate solution is the solar cell itself.

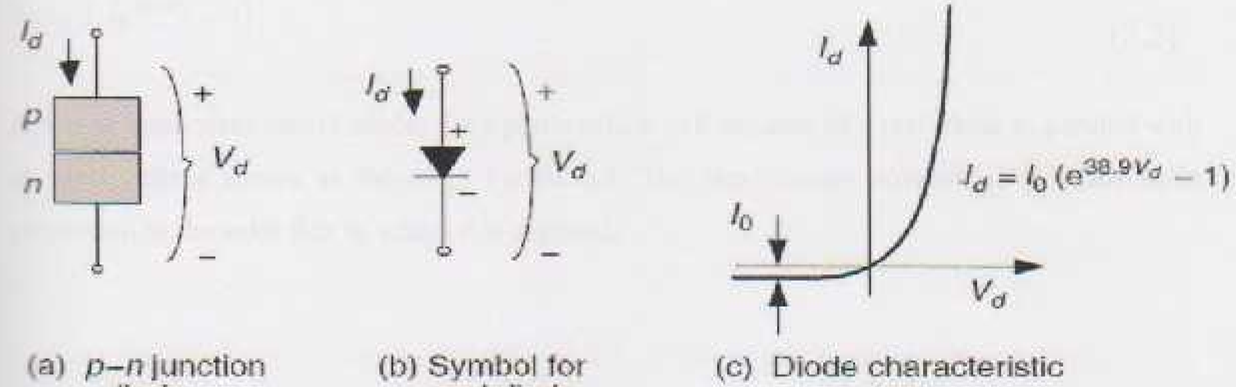
2.2.1 Photovoltaic cell

2.2.1.1 Physical characteristics of the solar cell

The P-N Junction Diode

Anyone familiar with semiconductors will immediately recognize that what has been described thus far is just common, conventional p–n junction diode, the characteristics of which are presented in Figure 2-1. If we were to apply a voltage V_d across the diode terminals, forward current would flow easily through the diode from the p-side to the n-side; but if we try to send current in the reverse direction, only a very small $\left(\approx 10^{-12}\ A/m^2\right)$ reverse saturation current I_o will flow. This reverse saturation current is the result of thermally generated carriers with the holes being swept into the p-side and the electrons into the n-side. In the forward direction, the voltage drop across the diode is only a few tenths of a volt.

The symbol for a real diode is shown here as a blackened triangle with a bar; the triangle suggests an arrow, which is a convenient reminder of the direction in which current flows easily. The triangle is blackened to distinguish it from an "ideal" diode. Ideal diodes have no voltage drop across them in the forward direction, and no current at all flows in the reverse direction. The voltage–current characteristic curve for the p–n junction diode is described by the following Shockley diode equation. [1]



(a) p–n junction diode (b) Symbol for real diode (c) Diode characteristic curve

Figure 2-1 A p–n junction diode allows current to flow easily from the p-side to the n-side

$$I_d = I_0\left(e^{\frac{qV_d}{kT}} - 1\right) \tag{2.1}$$

Where:

I_d: Is the diode current in the direction of the arrow.

V_d: Is the voltage across the diode terminals from the p-side to the n-side (V).

I_0: Is the reverse saturation current (A).

q: Is the electron charge (1.602×10^{-19} C).

K: Is Boltzmann's constant (1.381×10^{-23} J/K).

T: Is the junction temperature (K).

At T= 25°C:

$$\frac{qV_d}{kT} = \frac{1.602\times10^{-19}C}{1.381\times10^{-23}J/K}\cdot\frac{V_d}{298K} = 38.9V_d$$

$$I_d = I_0\left(e^{38.9V_d} - 1\right) \tag{2.2}$$

A simple equivalent circuit model for a photovoltaic cell consists of a real diode in parallel with an ideal current source as shown in Figure 2-2. The ideal current source delivers current in proportion to the solar flux to which it is exposed.

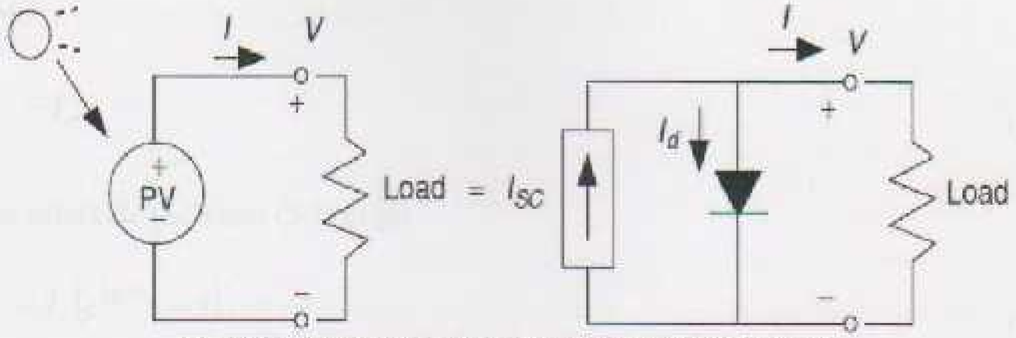
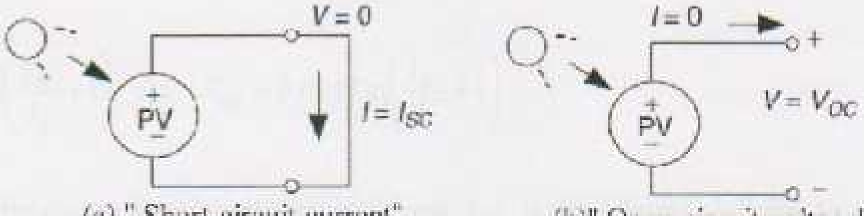


Figure 2-2 A simple equivalent circuit for a photovoltaic cell



(a) " Short-circuit current" (b)" Open-circuit voltage"

Figure 2-3 Two parameters for photovoltaic's the short-circuit current I_{SC} and the open-circuit voltage V_{OC}

There are two conditions of particular interest for the actual PV and for its equivalent circuit. As shown in Figure2-3, they are:

1. The current that flows when the terminals are shorted together (the short-circuit current, I_{SC})
2. The voltage across the terminals when the leads are left open (the open-circuit voltage, VOC)

When the leads of the equivalent circuit for the PV cell are shorted together, no current flows in the (real) diode since $V_d = 0$, so all of the current from the ideal source flows through the shorted leads. Since that short-circuit current must equal I_{SC}, the magnitude of the ideal current source itself must be equal to I_{SC}. Now we can write a voltage and current equation for the equivalent circuit of the PV cell shown in Figure 2-3.

Start with:

$$I = I_{SC} - I_d \tag{2.3}$$

And then substitute (2-2) into (2-3) to get

$$I = I_{SC} - I_0\left(e^{38.9V_d} - 1\right) \tag{2.4}$$

When the leads from the PV cell are left open, I = 0 and we can solve (2.4) for the open-circuit voltage V_{OC}

$$V_{OC} = \frac{kT}{q}\ln\left(\frac{I_{SC}}{I_0}+1\right) \;\Rightarrow\; V_{OC} = 0.0257\ln\left(\frac{I_{SC}}{I_0}+1\right) \tag{2.5}$$

In both of these equations, short-circuit current, I_{SC}, is directly proportional to solar insulation, which means that we can now quite easily plot sets of PV current–voltage curves for varying sunlight. Also, quite often laboratory specifications for the performance of photovoltaic's are given per cm^2 of junction.

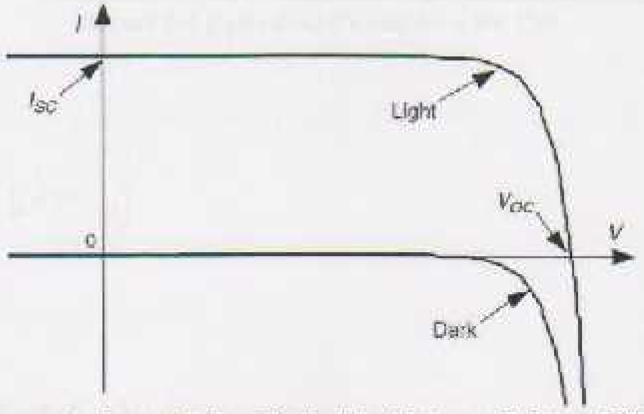


Figure 2-4 Photovoltaic current–voltage relationship for "dark" (no sunlight) and "light" (an illuminated cell)

2.2.1.2 A More Accurate Equivalent Circuit for a PV Cell

There are times when a more complex PV equivalent circuit than the one shown in Figure 2-5 is needed In our simplified equivalent circuit for the shaded cell, the current through that cell's current source is zero and its diode is back biased so it doesn't pass any current either (other than a tiny amount of reverse saturation current). This means that the simple equivalent circuit suggests that no power will be delivered to a load if any of its cells are shaded. While it is true that PV modules are very sensitive to shading, the situation is not quite as bad as that. So, we need a more complex model if we are going to be able to deal with realities such as the shading problem. Figure 2-5 shows a PV equivalent circuit that includes some parallel leakage resistance R_P. The ideal current source I_{SC} in this case delivers current to the diode, the parallel resistance, and the load. **[1]**

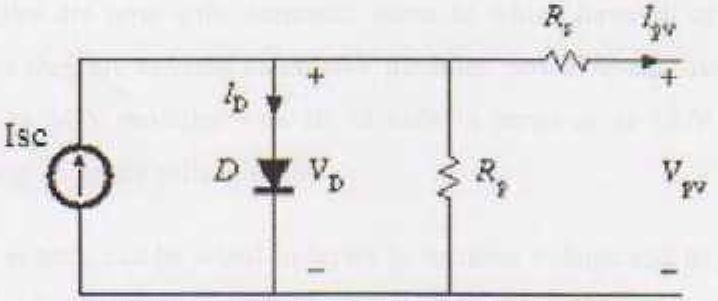


Figure 2-5 Equivalent Circuit for a PV Cell

$$I_{SC} = I_d + I_p + I_{pv} \tag{2.6}$$

$$I = I_{SC} - I_d = I_{SC} - I_{pv}\left(e^{qV/kT} - 1\right) \tag{2.7}$$

$$V_d = V + R_S I_p \tag{2.8}$$

$$I = I_{SC} - I_{pv}\left(\exp\left[q\left(\frac{V + I_p R_S}{kT}\right)\right] - 1\right)$$

(2.9)

$$I = I_{SC} - I_S\left[e^{38.9(V+IR_S)} - 1\right] - \frac{1}{R_P}(V + IR_S) \tag{2.10}$$

$$R_P > \frac{100V_{OC}}{I_{SC}} \qquad R_S < \frac{0.01V_{OC}}{I_{SC}}$$

2.2.2 Photovoltaic Module

Since an individual cell produces only about 0.5 V, it is a rare application for which just a single cell is of any use. Instead, the basic building block for PV applications is a module consisting of a number of pre-wired cells in series, all encased in tough, weather-resistant packages. A typical module has 36 cells in series and is often designated as a "12-V module" even though it is capable of delivering much higher voltages than that. Some 12-V modules have only 33 cells. Large 72-cell modules are now quite common, some of which have all of the cells wired in series, in which case they are referred to as 24-V modules. Some 72-cell modules can be field-wired to act either as 24-V modules with all 72 cells in series or as 12-V modules with two parallel strings having 36 series cells in each.

Multiple modules, in turn, can be wired in series to increase voltage and in parallel to increase current, the product of which is power. An important element in PV system design is deciding how many modules should be connected in series and how many in parallel to deliver whatever energy is needed. Such combinations of modules are referred to as an array. Figure2-6 show this distinction between cell, module.

When photovoltaics are wired in series, they all carry the same current, and at any given current their voltages add as shown in Figure 2-7. **[2]**

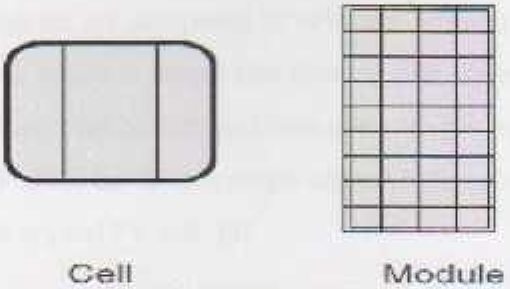


Figure 2-6 Photovoltaic cell, modules

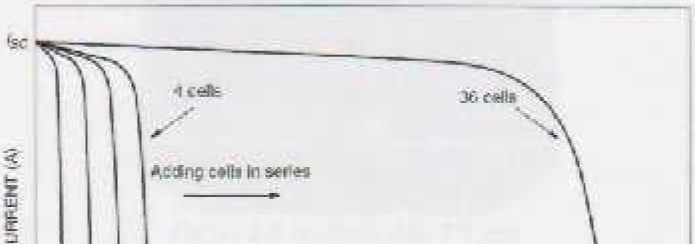


Figure 2-7 Current-voltage varying depending on number of cell

To find value of the module voltage (V):

$$V_{module} = n(V_d - IR_S) \tag{2.11}$$

To find power of module (W):

$$P = V_{module} * I_{module} \tag{2.12}$$

2.2.2.1 Photovoltaic construction types

- Single crystal (Monocrystalline)

Monocrystalline, or Single Crystal, is the original PV technology invented in 1955, and never known to wear out. Polycrystalline entered the market in 1981. It is similar in performance and reliability. Single crystal modules are composed of cells cut from a piece of continuous crystal. The material forms a cylinder which is sliced into thin circular wafers. To minimize waste, the cells may be fully round or they may be trimmed into other shapes, retaining more or less of the original circle. Because each cell is cut from a single crystal, it has a uniform color which is dark blue. Figure 2-8 shows single crystal PV cell. **[3]**

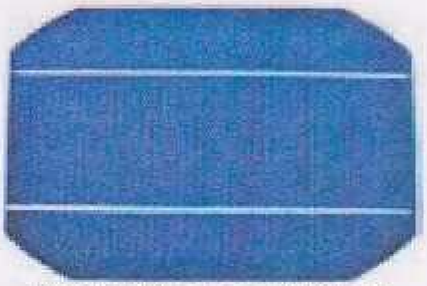


Figure 2-8 Single crystal PV cell

- Multicrystalline

Polycrystalline cells are made from similar silicon material except that instead of being grown into a single crystal, they are melted and poured into a mold. This forms a square block that can be cut into square wafers with less waste of space or material than round single-crystal wafers. As the material cools, it crystallizes in an imperfect manner, forming random crystal boundaries. The efficiency of energy conversion is slightly lower. This merely means that the size of the finished module is slightly greater per watt than most single crystal modules. The cells look different from single crystal cells. The surface has a jumbled look with many variations of blue color. In fact, they are quite beautiful like sheets of gemstone Figure2-9 shows multicrystaline PV cell.

Figure 2-9 Multicrystaline PV cell

- Thin Film Technology

Thin film panels can be made flexible and light weight by using plastic glazing. Some flexible panels can tolerate a bullet hole without failing. Some of them perform slightly better than crystalline modules under low light conditions. They are also less. Susceptible to power loss are from Partial shading of a module.

The disadvantages of thin film technology are lower efficiency and uncertain durability. Lower efficiency means that more space and mounting hardware is required to produce the same power output. Thin film materials tend to be less stable than crystalline, causing degradation over time. The technology is being greatly improved, however, so I do not wish to generalize in this article. We will be seeing many new thin film products introduced in the coming years, with efficiency and warranties that may approach those of crystalline silicon.

PV experts generally agree that crystalline silicon will remain the "premium" technology for critical applications in remote areas. Thin film will be strong in the "consumer" market where price is a critical factor. As usual, you get what you pay for Figure2-10 shows thin film PV cell.**[3]**

Figure 2-10 Thin film PV cell

2.2.3 Modules Array

Modules can be wired in series to increase voltage, and in parallel to increase current. Arrays are made up of some combination of series and parallel modules to increase power.

For modules in series, the I-V curves are simply added along the voltage axis. That is, at any given current (which flows through each of the modules), the total voltage is just the sum of the individual module voltages as is suggested in Figure 2-11.

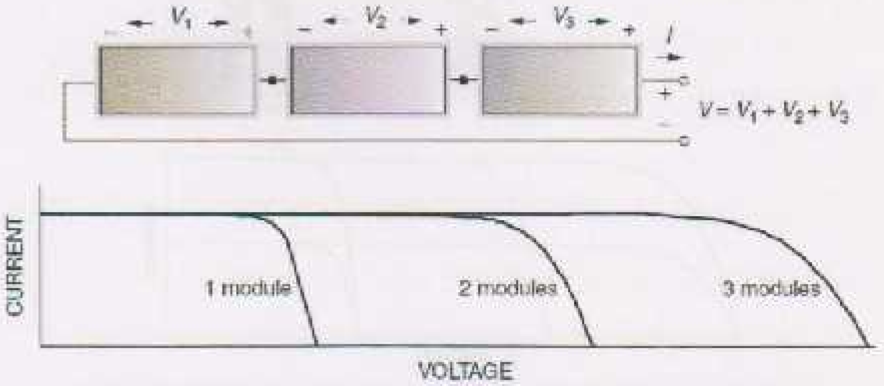


Figure 2-11 modules in series, at any given current the voltages add

For modules in parallel, the same voltage is across each module and the total current is the sum of the currents. That is, at any given voltage, the I-V curve of the parallel combination is just the sum of the individual module currents at that voltage. Figure2-12 shows the I-V curve for three modules in parallel. When high power is needed, the array will usually consist of a combination of series and parallel modules for which the total I-V curve is the sum of the individual module I-V curves. There are two ways to imagine wiring a series/parallel combination of modules: The series modules may be wired as strings, and the strings wired in parallel as in Figure 2-13(a), or the parallel modules may be wired together first and those units combined in series as in Figure2-13(b) **[2]**.

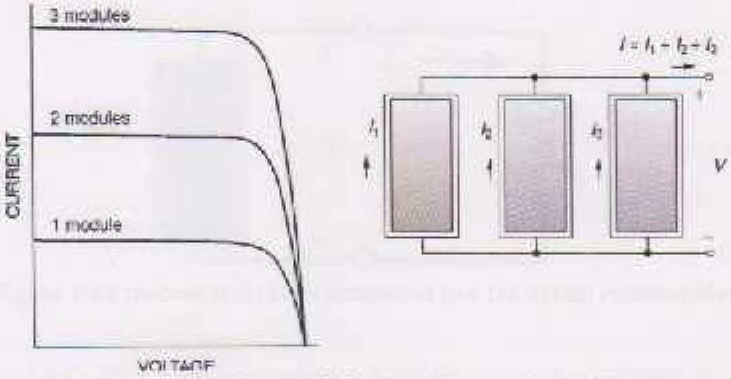


Figure 2-12 For modules in parallel, at any given voltage the currents add

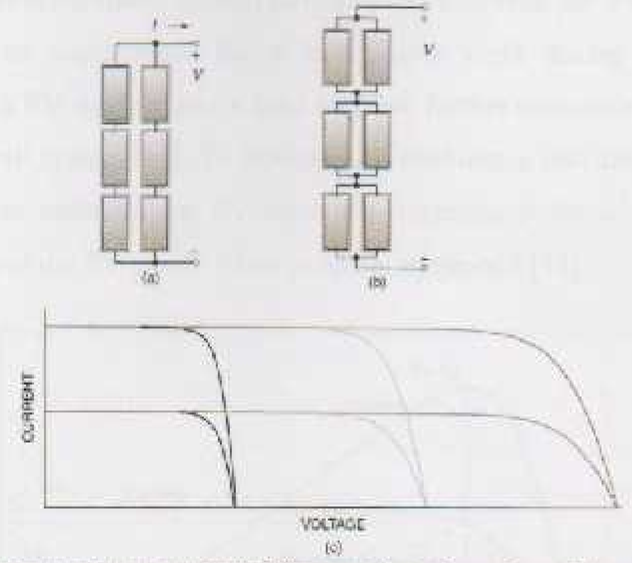


Figure 2-13 Two ways to wire an array with three modules in series and two modules in parallel

2.2.4 Maximum Power Point Tracking

When a PV module is directly coupled to a load, the PV module's operating point will be at the intersection of its I–V curve and the load line which is the I-V relationship of load. For example in Figure 2-14, a resistive load has a straight line with a slope of $1/R_L$ as shown in Figure2-15. In other words, the impedance of load dictates the operating condition of the PV module. In general, this operating point is seldom at the PV module's MPP. Thus it is not producing the maximum power.

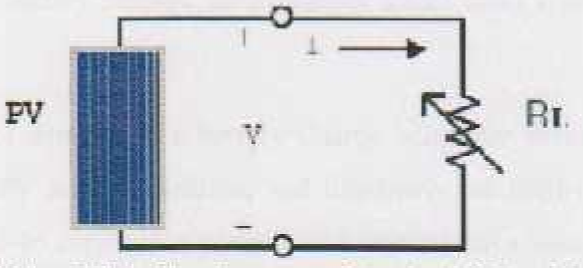


Figure 2-14 module is directly connected to a (variable) resistive load

A study shows that a direct-coupled system utilizes a more 31% of the PV capacity. A PV array is usually oversized to compensate for a low power yield during winter months. This mismatching between a PV module and a load requires further over-sizing of the PV array and thus increases the overall system cost. To mitigate this problem, a maximum power point tracker (MPPT) can be used to maintain the PV module's operating point at the MPP. MPPTs can extract more than 97% of the PV power when properly optimized **[11].**

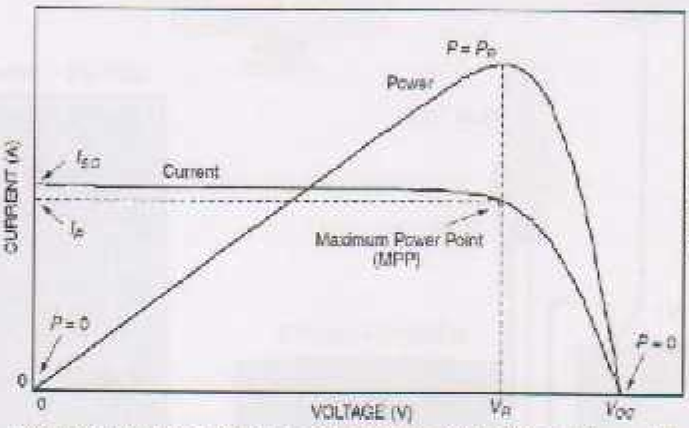


Figure 2-15 The I-V curve and power output for a PV module

2.3 Charge controller

The primary function of a charge controller in a stand-alone PV system is to maintain the battery at highest possible state of charge while protecting it from overcharge by the array and from over discharge by the loads. Although some PV systems can be effectively designed without the use of charge control, any System that has unpredictable loads, user intervention, optimized or undersized battery storage (to minimize initial cost) typically requires a battery charge controller.

The algorithm or control strategy of a battery Charge controller determines the effectiveness of battery charging and PV array utilization, and ultimately the ability of the system to meet the load demands;Figure2-16 explain the connect of a regulator in a solar system .

Additional features such as temperature compensation, alarms, meters, remote voltage sense leads and special algorithms can enhance the ability of a charge controller to maintain the health and extend the lifetime of a battery, as well as providing an indication of operational status to the system caretaker. [4]

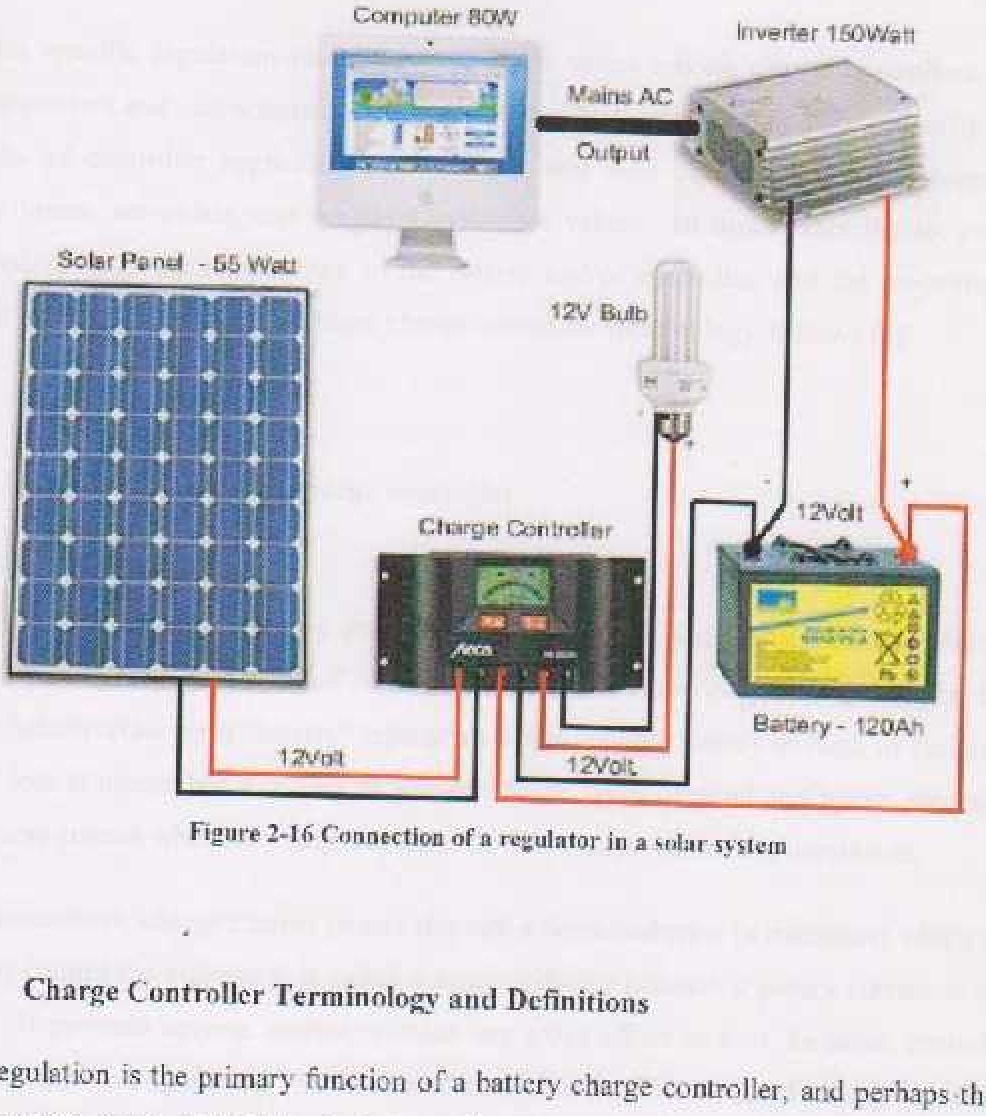


Figure 2-16 Connection of a regulator in a solar system

2.3.1 Charge Controller Terminology and Definitions

Charge regulation is the primary function of a battery charge controller, and perhaps the single most important issue related to battery performance and life. The purpose of a charge controller is to supply power to the battery in a manner to fully recharge the battery without overcharging. Regulation or limiting the PV array current to a battery in a PV system may be accomplished by several methods. The most popular method is battery voltage sensing, however other methods such as amp hour integration are also employed. Generally, voltage regulation is accomplished by limiting the PV array current at a predefined charge regulation voltage. Depending on the regulation algorithm, the current may be limited while maintaining the regulation voltage, or remain disconnected until the battery voltage drops to the array reconnect set point.

While the specific regulation method or algorithm varies among charge controllers, all have basic parameters and characteristics. Charge controller manufacturer's data generally provides the limits of controller application such as PV and load currents, operating temperatures, parasitic losses, set points, and set point hysteresis values. In some cases the set points may be dependent upon the temperature of the battery and/or controller, and the magnitude of the battery current. A discussion of basic charge controller terminology follows [4].

2.3.2 The function of the charge controller

- Blocking Reverse Current

Photovoltaic (PV) panels work by pumping current through your battery in one direction. At night, the panels may pass a bit of current in the reverse direction, causing a slight discharge from the battery. (Our term "battery" represents either a single battery or bank of batteries.) The potential loss is minor, but it is easy to prevent. Some types of wind and hydro generators also draw reverse current when they stop, but most do not, except under fault conditions.

In most controllers, charge current passes through a semiconductor (a transistor) which acts like a valve to control the current. It is called a semiconductor because it passes current in only one direction. It prevents reverse current without any extra effort or cost. In some controllers, an electromagnetic coil opens and closes a mechanical switch. This is called a relay. It switches off at night, to block reverse current. As it turns on and off, there is an audible clicking sound. If you are using a very small array relative to the size of the battery, then you may not need a charge controller. This is a rare application. An example is a tiny maintenance PV module that trickle-charges a battery and compensates for battery discharge in a parked vehicle but will not support significant loads. In this situation, you can install a simple diode to block reverse current. A diode used for this purpose is called a blocking diode.

- Preventing Overcharge

When a battery reaches full charge, it can no longer store incoming energy. If energy continues to be applied at the full rate, the battery voltage gets too high. Water separates into hydrogen and oxygen and bubbles out rapidly. It looks like it's boiling so we sometimes call it that, although it's not actually hot. There is an excessive loss of water, and a chance that the gasses can ignite and cause a small explosion. The battery will also degrade rapidly and may possibly overheat. Excessive voltage can also stress your loads (lights, appliances, etc.) or cause your inverter to shut off. Preventing overcharge is simply a matter of reducing the flow of energy to the battery when the battery reaches a specific voltage.

When the voltage drops due to lower sun intensity or an increase in electrical usage, the controller again allows the maximum possible charge. This is called voltage regulating. It is the most essential function of all charge controllers. The controller "looks at" the voltage, and regulates the battery charging in response. This can be illustrated by an analogy:

The Energy Chef is watching a pot of water on a gas burner, which is fed by a tube coming from the sun. He has one hand on the gas valve. He's thinking, "I need to get this water as close to a boil as possible before the sun goes down, but I must never boil the water."

In this analogy, the temperature of the water represents battery voltage; the flow of gas represents charging current; boiling represents overcharge; and the energy chef manipulating the valve is like the charge controller. Some controllers regulate the flow of energy to the battery by switching the current fully on or fully off. This is called on/off control. Others reduce the current gradually, called pulse width modulation (PWM). Both methods work well when the voltage set points are properly selected for your type of battery.

A PWM controller holds the voltage more constant. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then it will drop the voltage lower to sustain a "finish" or "trickle" charge. Two- stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress.

The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated pattern of use, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. Some controllers have adjustable set points, while others do not.

- Control Set Points vs. Temperature

The ideal set points for charge control vary with battery Temperature. Some controllers have a feature called temperature compensation. When the controller senses a low battery temperature, it will raise the set points. Otherwise when the battery is cold, it reduces the charge too soon. If your batteries are exposed to temperature swings greater than about 30°F (17°C), compensation is essential.

Some controllers have a temperature sensor built in. This type of controller must be mounted in a place where the temperature is close to that of the batteries. Better controllers have a remote temperature sensor on a small cable. The probe should be attached directly to a battery in order to report its temperature to the controller. An alternative to automatic temperature compensation is to manually adjust the set points (if possible) according to the seasons. It may be sufficient to do this only twice a year, in spring and fall.

- Control Set Points vs. Battery Type

The ideal set points for charge controlling depend on the battery design. The vast majority of RE (Rechargeable) systems use deep cycle lead-acid batteries of either the flooded type or the sealed type. Flooded batteries are filled with liquid. These are the standard, economical deep cycle batteries. Sealed batteries use saturated pads between the plates. They are also called "valve-regulated," "absorbed glass mat," or simply "maintenance-free." They need to be regulated to a slightly lower voltage than flooded batteries or they will dry out and be ruined. Some controllers have a means to select the type of battery. Never use a controller that is not intended for your type of battery.

- Low Voltage Disconnect(LVD)

The deep cycle batteries used in renewable energy systems are designed to be discharged a maximum of 80 percent (20% state of charge). If they are discharged 100 percent, they are immediately damaged. Imagine a pot of water boiling on your kitchen stove. The moment it runs dry, the pot overheats. If you wait until the steaming stops, it is already too late! Similarly, if you wait until your lights look dim, some battery damage will have already occurred. Every time this happens, both the capacity and the life of the battery will be reduced by a small amount. If the battery sits in this over discharged state for days or weeks at a time, it can be ruined quickly. The only way to prevent over discharge when all else fails is to disconnect loads (appliances, lights, etc.), and then reconnect them only when the voltage has recovered due to some substantial charging. When over discharge is approaching, a 12 volt battery will drop below 11 volts (a 24 V battery will drop below 22 V). A low voltage disconnects (LVD) circuit will disconnect loads at that set point. It will reconnect the loads only when the battery voltage has substantially recovered due to the accumulation of some charge. A typical LVD reset point is 13 volts (26 V on a 24 V system).

All modern inverters have LVD built in, even cheap pocket- sized ones. The inverter will turn off to protect itself, your loads, and your battery. Normally, an inverter is connected directly to the batteries, not through the charge controller, because its current draw can be very high, and because it does not require external LVD. If you have any DC loads, you should have an LVD. Some charge controllers have one built in. You can also obtain a separate LVD device. Some LVD systems have a "mercy switch" to let you draw a minimal amount of energy, at least Long enough to find the candles and matches! DC Refrigerators have LVD built in. If you purchase a charge controller with built-in LVD, make sure that it has enough capacity to handle your DC loads. For example, let's say you need a charge controller to handle less than 10 amps of charge current, but you have a DC water pressurizing pump that draws 20 amps (for short periods) plus a 6 amp DC lighting load. A charge controller with a 30 amp LVD would be appropriate. Don't buy a 10 amp charge controller that has only a 10 or 15 amp load capacity!

- Overload Protection

A circuit is overloaded when the current flowing in it is higher than it can safely handle. This can cause overheating and can even be a fire hazard. Overload can be caused by a fault (short circuit) in the wiring, or by a faulty appliance (like a frozen water pump). Some charge controllers have overload protection built in, usually with a push-button reset [5].

2.3.3 Types of charge Controller

There are essentially two types of controllers: shunt and series. A shunt controller bypasses current around fully charged batteries and through a power transistor or resistance heater where excess power is converted into heat. Shunt controllers are simple and inexpensive, but are only designed for very small systems. Series controllers stop the flow of current by opening the circuit between the battery and the PV array.

Series controllers may be single-stage or pulse type. Single-stage controllers are small and inexpensive and have a greater load-handling capacity than shunt-type controllers. Pulse controllers and a type of shunt controller referred to as a multi-stage controller (e.g., three-stage controller) has routines that optimize battery charging rates to extend battery life. Most charge controllers are now three-stage controllers. These chargers have dramatically improved battery life.

- Interaction with Inverter

Since the majority of charge controllers have been installed in off-grid systems, their default settings may not be appropriate for a grid-connected system. The charge controller must be set up such that it does not interfere with the proper operation of the inverter. In particular, the controller must be set up such that charging the batteries from the PV array takes precedence over charging from the grid. For more information, contact the manufacturer.

- Interaction with Batteries

The charge controller must be selected to deliver the charging current appropriate for the type of batteries used in the system. For example, on a 12V system, flooded lead-acid batteries have a voltage of 14.6V to 15.0V when fully charged, while sealed lead-acid batteries are fully charged at 14.1 V. Refer to the battery manufacturer for the charging requirements of particular batteries [6].

Selection Charge controllers are selected based on

- ✓ PV array voltage – The controller's DC voltage input must match the nominal voltage of the solar array.
- ✓ PV array current – The controller must be sized to handle the maximum current produced by the PV array.

Figure 2-17 commercial charge controller

2.4 Batteries

2.4.1 Introduction

The function of the batteries is to store the energy when the PV is supplying energy and to provide it to the system when the coming energy from the PV is under the needed amount of the energy and this function need a special kind of batteries according to the nature of the system from the daily repeated charging and discharging of the batteries.

In the natural systems one battery can it hold with the needed power of the system so we can connect two or more electrochemical cells enclosed in a container and electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels.

Under common usage, the term battery also applies to a single cell if it constitutes the entire electrochemical storage system. The battery bank consists of one or more solar deep-cycle type batteries. Depending on the current and voltage for certain application the batteries are wired in series and/or parallel.Figure2-18 shows a battery model.

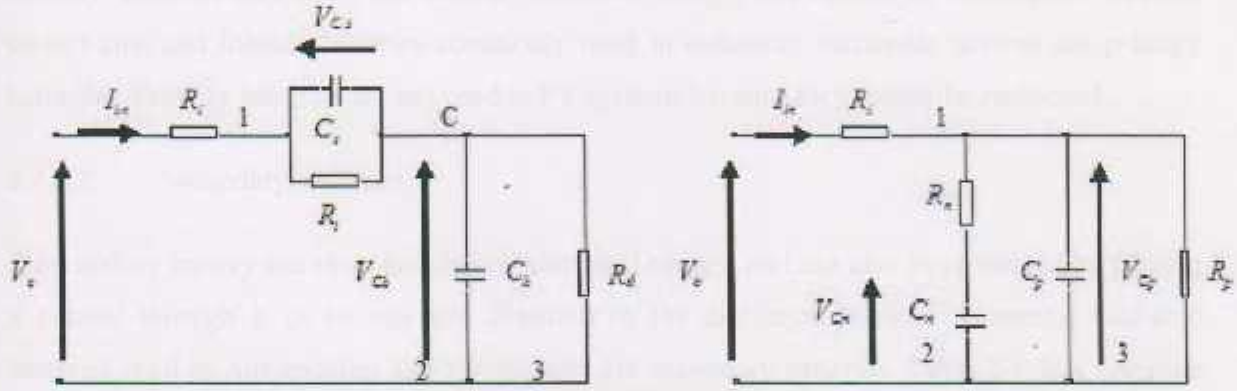


Figure 2-18 Battery model

2.4.2 Types of batteries

Many types and classifications of batteries are manufactured today, each with specific design and performance characteristics suited for particular applications. Each battery type or design has its individual strengths and weaknesses.

In PV systems, lead-acid batteries are most common due to their wide availability in many sizes, low cost and well understood performance characteristics. In a few critical, low temperature applications nickel-cadmium cells are used, but their high initial cost limits their use in most PV systems. There is no "perfect battery" and it is the task of the PV system designer to decide which battery type is most appropriate for each application.

In general, electrical storage batteries can be divided into two major categories, primary and secondary batteries. [4]

2.4.2.1 Primary Batteries

Primary batteries can store and deliver electrical energy, but cannot be recharged. Typical carbon-zinc and lithium batteries commonly used in consumer electronic devices are primary batteries. Primary batteries are not used in PV systems because they cannot be recharged.

2.4.2.2 Secondary Batteries

A secondary battery can store and deliver electrical energy, and can also be recharged by passing a current through it in an opposite direction to the discharge current. Common lead-acid batteries used in Automobiles and PV systems are secondary batteries. Table 2-1 lists common secondary battery types and their characteristics which are of importance to PV system designers. A detailed discussion of each battery type follows.

Table 2-1 Secondary battery type characteristics

Battery Type	Cost	Deep Cycle Performance	Maintenance
Flooded Lead-Acid			
Lead-Antimony	low	good	high
Lead-Calcium Open Vent	low	poor	medium
Lead-Calcium Sealed Vent	low	poor	low
Lead Antimony/Calcium Hybrid	medium	good	medium
Captive Electrolyte Lead-Acid (VRLA)			
Gelled	medium	fair	low
Absorbed Glass Mat	medium	fair	low
Nickel-Cadmium			
Sintered-Plate	high	good	none
Pocket-Plate	high	good	medium

➢ Type Secondary Batteries

1. Lead Acid

When a lead acid battery is fully or partially discharged, lead sulphate forms at the electrodes. If the battery is allowed to remain for a prolonged period in a discharged state or with a very low state of charge the lead sulphate may form into large crystals which are very difficult to convert back into lead and sulphuric acid by the charging process. The formation of these crystals is called sulphation and causes a permanent loss of capacity of the battery. To avoid this problem lead acid batteries should therefore only be stored in a fully charged condition and the charge should be topped up from time to time during storage to compensate for the self discharge of the cells.

To prolong shelf life without charging, the batteries should be stored at 10°C or less but the electrolyte should not be allowed to freeze. When the battery is fully charged the electrolyte is sulphuric acid solution and the freezing point is -36°C but it rises to 0°C in the fully discharged state when the electrolyte is simply water.

2. Nickel Cadmium

Nickel Cadmium batteries can be stored in either a charged or discharged state. Long term storage can accelerate battery self-discharge, and lead to the deactivation of reactants. Although the cells can be stored at temperatures between -20°C and +45°C, as with almost all batteries heat can cause deterioration of the active chemicals and it is better to keep the cells in a cool, clean, dry, non-corrosive environment. After prolonged storage, two or three deep discharge cycles may be needed to restore full capacity.

3. Nickel Metal Hydride

Nickel Metal Hydride batteries have similar characteristics to Nickel Cadmium cells. They can be stored in a charged or discharged state and have similar storage requirements. Because NiMH cells have a higher self discharge rate than NiCad cells, they will lose more charge during storage and will most likely need charging before they can be used.

4. Lithium-Ion

The possible storage temperature range for Lithium-Ion batteries is -20°C to 60°C but for prolonged storage period -20°C to 25°C is recommended and 15°C is ideal. Cells should be stored with a partial charge of between 30% and 50%. Although the cells can be stored fully discharged the cell voltage should not drop below 2.0 Volts per cell and cells should be topped up to prevent over-discharge. The maximum voltage should not exceed 4.1 Volts **[4]**.

2.4.3 Temperature effects

The ambient temperature has several important affects on the characteristics of a battery:

The nominal capacity of a battery (that the manufacturer usually gives for 25°C) increases with temperature at the rate of about 1%/°C. But if the temperature is too high, the chemical reaction that takes place in the battery accelerates, which can cause the same type of oxidation that takes places during overcharging. This will obviously reduce the life expectancy of battery. This problem can be compensated partially in car batteries by using a low density of dissolution (a specific gravity of 1.25 when the battery is totally charged).

As the temperature is reduced, the useful life of the battery increases. But if the temperature is too low, you run the risk of freezing the electrolyte. The freezing temperature depends on the density of the solution, which is also related to the state of charge of the battery. The lower the density, is the greater the risk of freezing. In areas of low temperatures, you should avoid deeply discharging the batteries (that is, DOD max is effectively reduced) Figure2-19 shows depth of discharge of a lead-acid battery at freezing temperature.

The temperature also changes the relation between voltage and charge. It is preferable to use a regulator which adjusts the low voltage disconnect and reconnect parameters according to temperature. The temperature sensor of the regulator should be fixed to the battery using tape or some other simple method.

In hot areas it is important to keep the batteries as cool as possible. The batteries must be stored in a shaded area and never get direct sunlight. It's also desirable to place the batteries on a small support to allow air to flow under them, thus increase the cooling. [4]

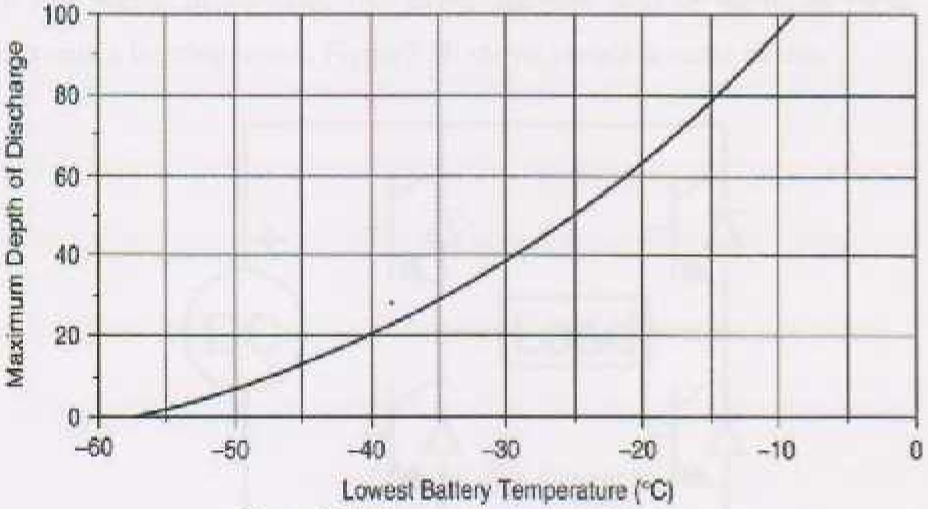


Figure 2-19 Concern for battery freezing

2.5 Inverter

2.5.1 Introduction

Inverters are used when your equipment requires AC power. Inverters chop and invert the DC current to generate a square wave that is later filtered to approximate a sine wave and eliminate undesired harmonics. Very few inverters actually supply a pure sine wave as output. Most models available on the market produce what is known as "modified sine wave", as their voltage output is not a pure sinusoid. When it comes to efficiency, modified sine wave inverters perform better than pure sinusoidal inverters. Be aware that not all the equipment will accept a modified sine wave as voltage input. Most commonly, some laser printers will not work with a modified sine wave inverter. Motors will work, but they may consume more power than if they are fed with a pure sine wave. In addition, DC power supplies tend to warm up more, and audio amplifiers can emit a buzzing sound, Figure2-20 shows simple inverter circuit.

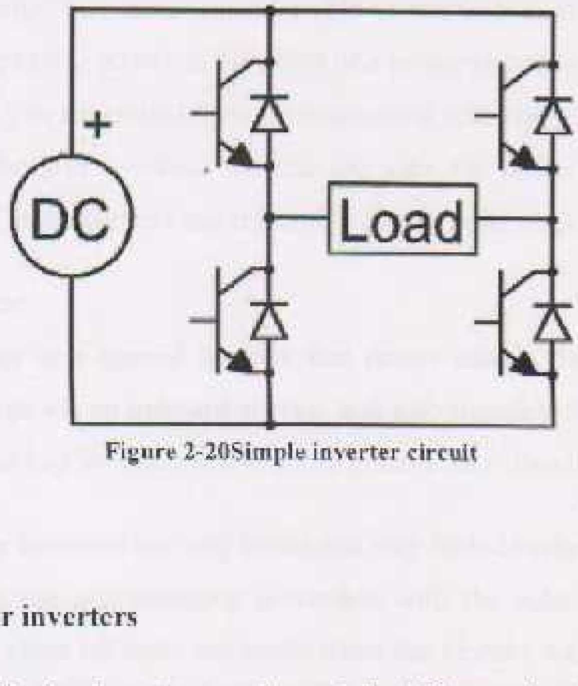


Figure 2-20Simple inverter circuit

2.5.2 Types of solar inverters

There are three types of solar inverters, each used in different situations. A solar inverter is integral to the usage of solar panels because it converts the direct current (DC) from the sun into the usable alternating current (AC) power that is used for household appliances.

1. Stand-Alone Inverter

Stand alone inverters are used in isolated systems such as cabins, cottages, water heaters, pumps, and monitoring stations. They are also used for mobile energy such as boats. The stand-alone inverter draws the DC energy taken from solar rays, from batteries and other sources such as wind turbines, hydro turbines, and engine generators. Many stand-alone inverters also incorporate battery charges to help replenish the battery from the AC source. These stand-alone inverters do not usually work with utility grids and are not required to have anti-islanding protection.

2. Grid-Tie Inverter

A grid-tie inverter is an electrical device that allows users to complement their grid power with solar energy. The grid-tie inverter regulates the amount of voltage and the current that is received from the DC solar panels and then converts it into an alternating current. Grid-tie inverters make sure that the power will be in phase with the grid-power. This allows for selling excess power back to the power company. The meter must be able to run in both directions because of this. Grid-tie inverters do not provide power in the event of a power shortage. On the AC side, grid-tie inverters supply electricity in sinusoidal form (synchronized with the grid), and also limit feed in voltage no higher than the grid's voltage. On the DC side, the power outlet varies to find the maximum power point. These inverters use maximum power point tracking.

3. Battery Backup Inverter

A battery backup inverter is a special inverter that draws energy from a battery, as well as manages the battery charge via an onboard charge, and also transfers the excess energy back to the utility grid. Battery backup inverters are required to have anti-islanding protection.

These three types of solar inverters are very broad and may include other subsections within their types. It is important to use anti-islanding protection with the solar inverters for protection. When a utility company shuts off there are times when the circuits within resonate an electrical current that resembles an alternating current. The solar inverters may detect this current and continue to work even though the utility company is shut down. This is called islanding. It is very dangerous for utility workers who believe there are no currents because the power is off. An anti-islanding device injects impulses into the currents that offset the resonations, which causes the solar inverter to turn off completely, which eliminates danger to those working with the solar inverter.

Each inverter is used in a different situation and they are easily interchangeable. If users decide to go off-grid or back on-grid, or even if they want to make a minor adjustment, it is easy to do so with the help of a different solar inverter.Figure2-21 shows connection an inverter in solar system. **[8]**

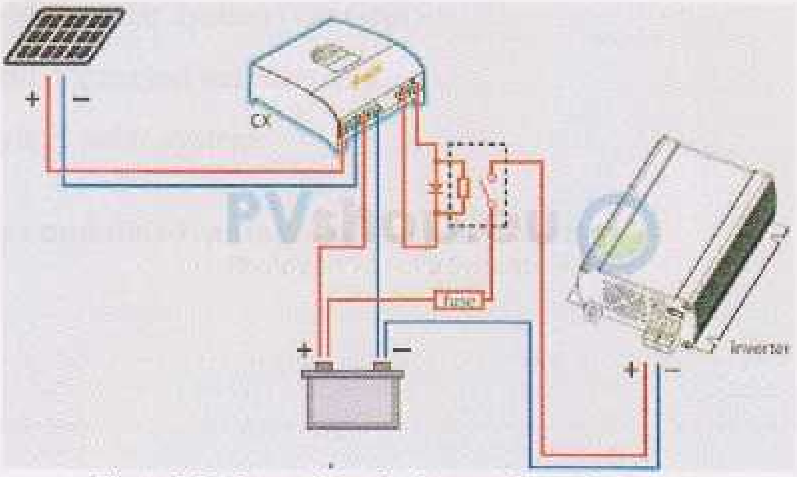


Figure 2-21 Connection of an inverter in a solar system

2.5.3 Conversion efficiency

Inverters are most efficient when providing 50% to 90% of their continuous power rating. You should select an inverter that most closely matches your load requirements. The manufacturer usually provides the performance of the inverter at 70% of its nominal power.

CHAPTER THREE

TYPES OF SOLAR ELECTRICAL SYSTEMS

3.1 Introduction

3.1.1 Small "Stand-Alone "system (off grid)

3.1.2 Grid-tie solar system (On Grid).

3.1.3 Grid connected net metering.

3.1.4 Hybrid solar system.

3.2 Advantages and disadvantages of the solar energy

3.1 Introduction

Solar cell produce a DC voltage, but the load voltage is DC or AC, high voltage or low voltage, because that we need the devices which give us the voltage which we need.

The following is the deferent forms of solar systems:

3.1.1 Small "Stand-Alone" Systems (off grid)

A free standing or Stand Alone PV System is made up of a number of individual photovoltaic modules (or panels) usually of 12 volts with power outputs of between 50 and 100+ watts each. These PV modules are then combined into a single array to give the desired power output. A simple *stand-alone PV system* is an automatic solar system that produces electrical power to charge banks of batteries during the day for use at night when the suns energy is unavailable. A stand alone small scale PV system employs rechargeable batteries to store the electrical energy supplied by a PV panels or array. Stand alone PV systems are ideal for remote rural areas and applications where other power sources are either impractical or are unavailable to provide power for lighting, appliances and other uses. In these cases, it is more cost effective to install a single stand alone PV system than pay the costs of having the local electricity company extend their power lines and cables directly to the home:Figure3-1 shows the block diagram of a simple *Stand-Alone PV system.*

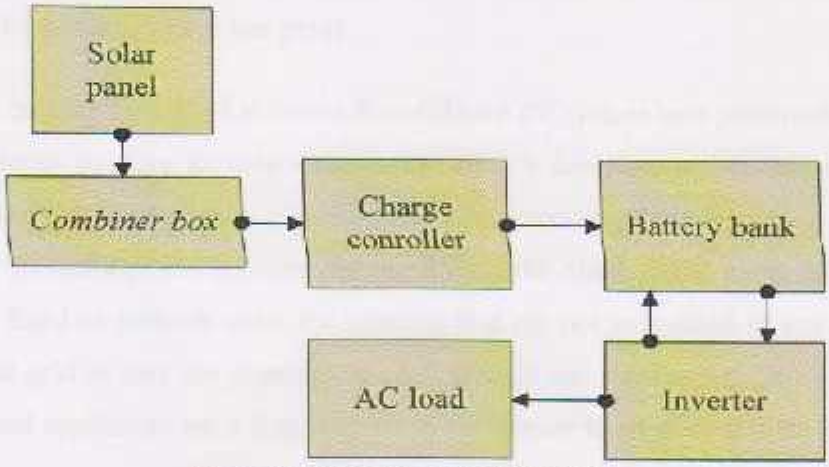


Figure 3-1 Block diagram of Stand-Alone

A stand alone photovoltaic (PV) system is an electrical system consisting of array of one or more PV modules, conductors, electrical components, and one or more loads. But a small-scale PV system does not have to be attached to a roof top or building structures for domestic applications, they can be used for camper vans, RV's (Recreational vehicle), boats, tents, camping and any other remote location. Many companies now offer portable solar kits that allow you to provide your own reliable and free solar electricity anywhere you go even in hard to reach locations; Figure3-2 shows the simplified stand-alone system. [9]

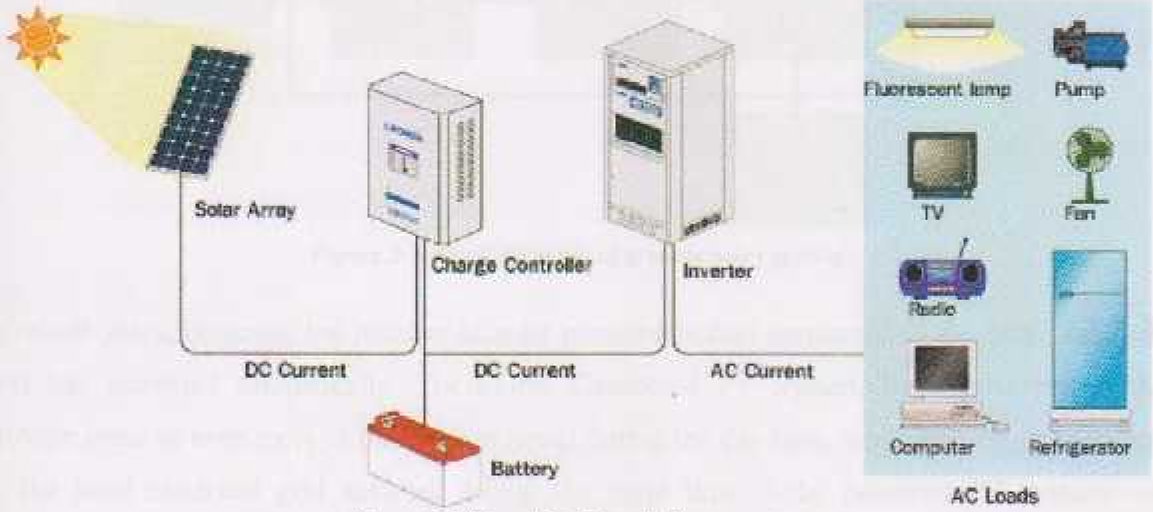


Figure 3-2 Simplified Stand-Alone system

3.1.2 Grid-tie solar system (on grid)

In the previous tutorial we looked at how a ***Stand-Alone PV system*** uses photovoltaic panels and deep cycle batteries to store its solar energy providing a complete self-contained solar power system. However, this type of solar system works fine providing there is enough solar radiation during the day to recharge the batteries for use during the night. Stand alone solar systems are self contained fixed or portable solar PV systems that are not connected to any local utility or mains electrical grid as they are generally used in remote and rural areas. This generally means that the electrical appliances are a long way from the nearest fixed electrical supply, or were the cost of extending a power line from the local grid may be very expensive,Figure3-3 shows the block diagram of a Grid-tie solar system.

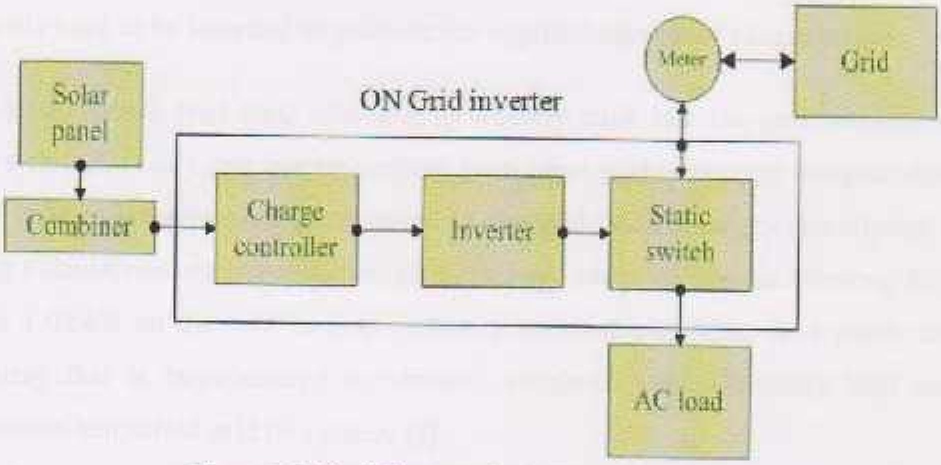


Figure 3-3 Block diagram of grid-tie solar system

In recent years, however, the number of solar powered homes connected to the local electricity grid has increased dramatically. These Grid Connected PV Systems have solar panels that provide some or even most of their power needs during the day time, while still being connected to the local electrical grid network during the night time. Solar powered PV systems can sometimes produce more electricity than is actually needed or consumed, especially during the long hot summer months. This extra or surplus electricity is either stored in batteries or as in most grid connected PV systems, fed directly back into the electrical grid network. In other words, homes and buildings that use a grid connected PV system can use a portion or all of their energy needs with solar energy, and still use power from the normal electrical mains grid during the night or on cloudy dull and rainy days, giving the best of both worlds. Then in grid is connected PV systems, are electricity flows back-and-forth to and from the mains grid according to sunlight conditions and the actual electrical demand at that time.

In a grid connected PV system, also known as a "grid-tied", or "on-grid" solar system, the PV solar panels or array are electrically connected or "tied" to the local mains electricity grid which feeds electrical energy back into the grid. The main advantage of a grid connected PV system is its simplicity, relatively low operating and maintenance

Costs as well as reduced electricity bills. The disadvantage however is that a sufficient number of solar panels need to be installed to generate the required amount of excess power.

Since grid tied systems feed their solar energy directly back into the grid, expensive back-up batteries are not necessary and can be omitted from most grid connected designs. Also, as this type of PV system is permanently connected to the grid, solar energy consumption and solar panel sizing calculations are not required, giving a large range of options allowing for a system as small as 1.0kWh on the roof to help reduce your electricity bills, or a much larger floor mounted array that is large enough to virtually eliminate your electricity bills completely: Figure3-4 shows simplified grid tie system. [9]

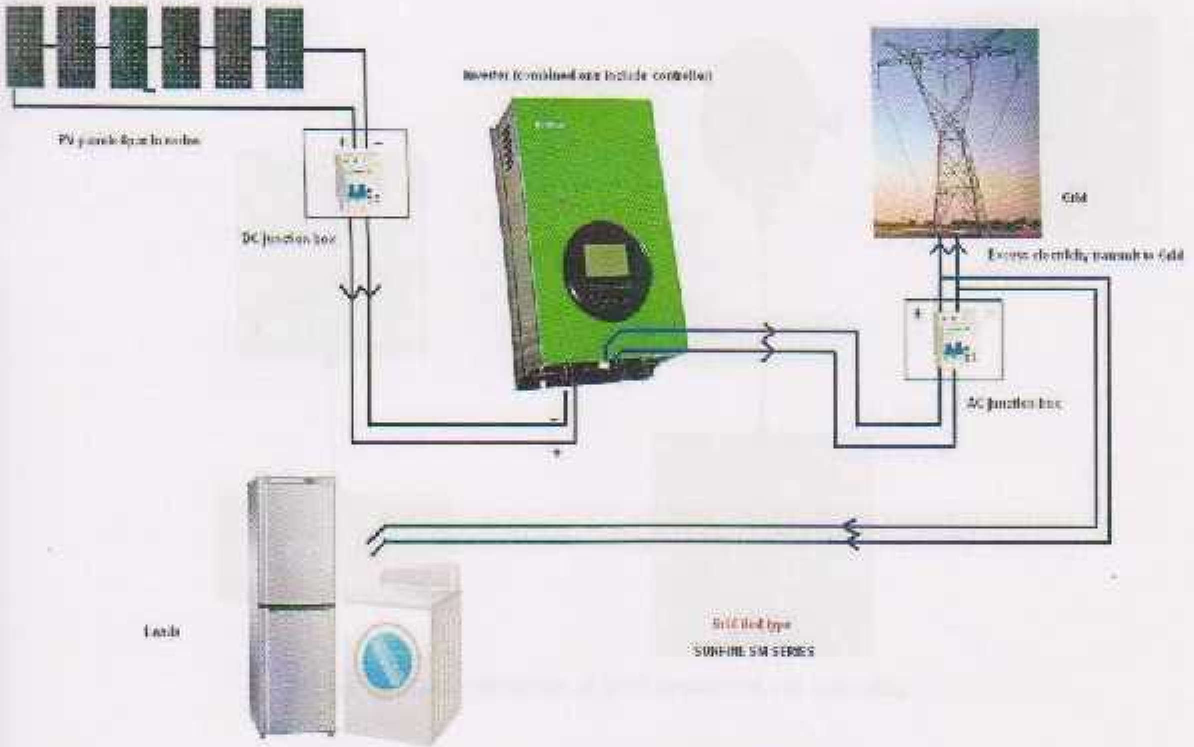


Figure 3-4 Simplified grid tie connected PV system

3.1.3 Grid connected net metering

Connecting your home solar energy array to the local power grid enables you to engage in one of the most advantageous parts of generating your own electricity: *Net Metering or Net Billing*. If more electricity is produced by your solar PV system then is used or consumed, this excess solar power is delivered back to the grid with the effect of rotating the electric meter backwards.

When this happens you will be given credits by their local power companies for the amounts of PV power electricity produced. If during the billing period you consume more energy than you generate, you are billed for the "net amount" of electricity consumed as normal. If, however, you generate more solar energy than you consume, you are credited for the "net amount" of electricity generated which may be either a reduction in your monthly electricity bill or a positive payment, Figure 3-5 explain the block diagram of grid connected net metering.

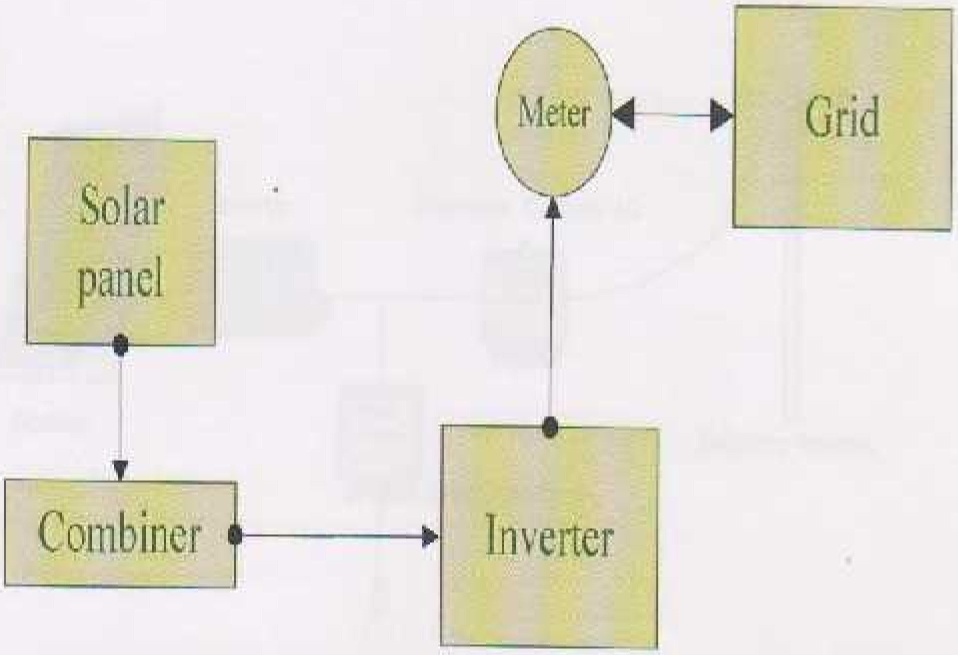


Figure 3-5 Block diagram of grid connected net metering

When installing a PV system, if net metering is available by your local electricity company, you may be required to install a new second electrical meter instead of using a single electricity meter that spins in both directions.

This new meter allows for a measurement of net energy consumption, both entering and leaving the system and would be used to reduce your electricity bill. However, each electrical utility company has its own policy regarding the buying back of energy generated by your own small solar power station. While net metering is the ideal way to resell your solar generated excess power, some companies buy-back energy at a lower wholesale rate than the electricity you consume from the same power company. This means that you may need to generate more solar power than you would normally consume just to break even. Figure3-6 shows the simplified of grid connecting net metering. [9]

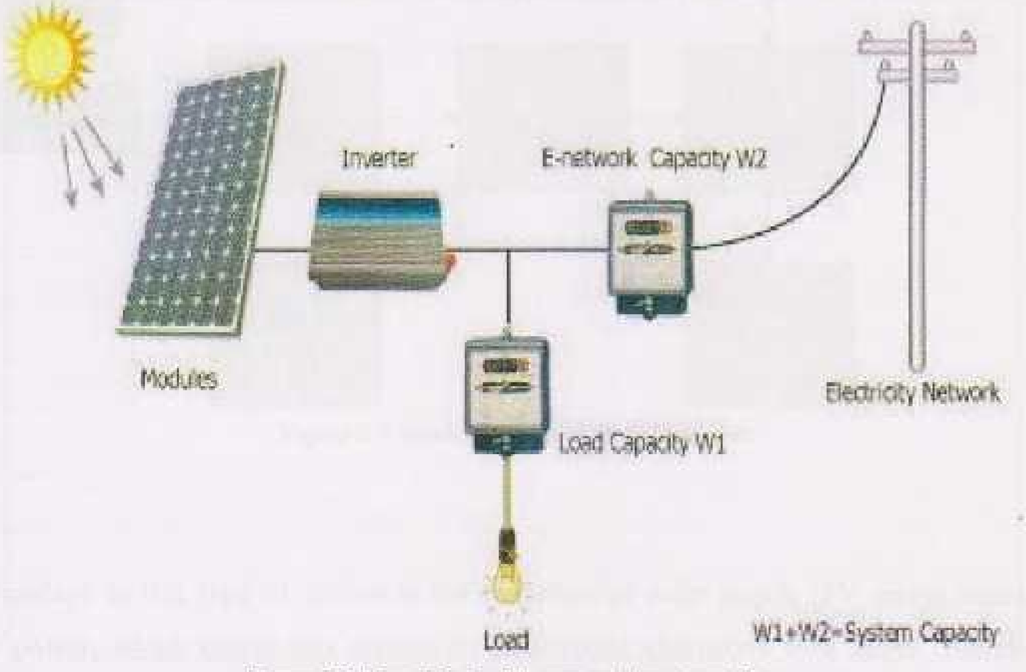


Figure 3-6 Simplified grid connected net metering

3.1.4 Hybrid solar system

The "Hybrid" - Solar Electric and Generator Combination provides a reliable power source, and produces electricity even when the sun is not providing solar power. These "hybrid" systems have the ability to charge the battery bank and provide electricity when weather conditions are unfavorable for solar power production,Figure3-7 explain block diagram of a Hybrid solar system.

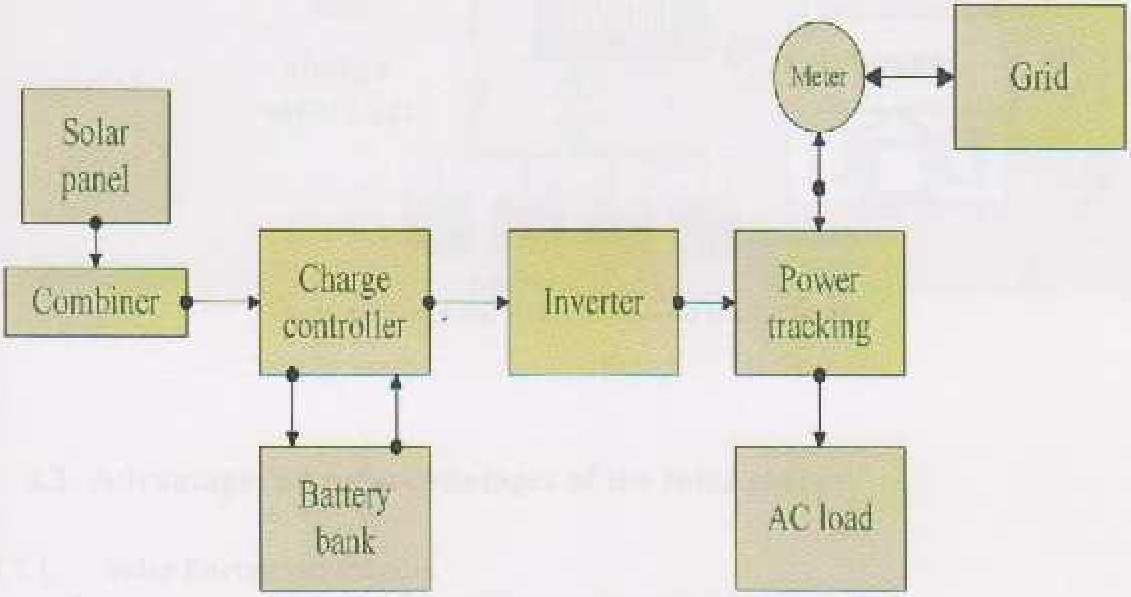


Figure 3-7 Block diagram of Hybrid system

An advantage to this type of system is the reduction of solar panels (PV array) necessary to supply power, which makes this system an economical alternative to a larger "Stand-Alone" system. When more power is needed than the solar panels are producing, a gasoline, propane or diesel generator is activated. The generator will provide enough power to overcome the difference between solar power available and the electricity you require. This type of system is used for cabins, remote homes and is a common system used to provide power for small medical facilities in third world countries Figure3-8 shows the simplified hybrid solar system. **[10]**

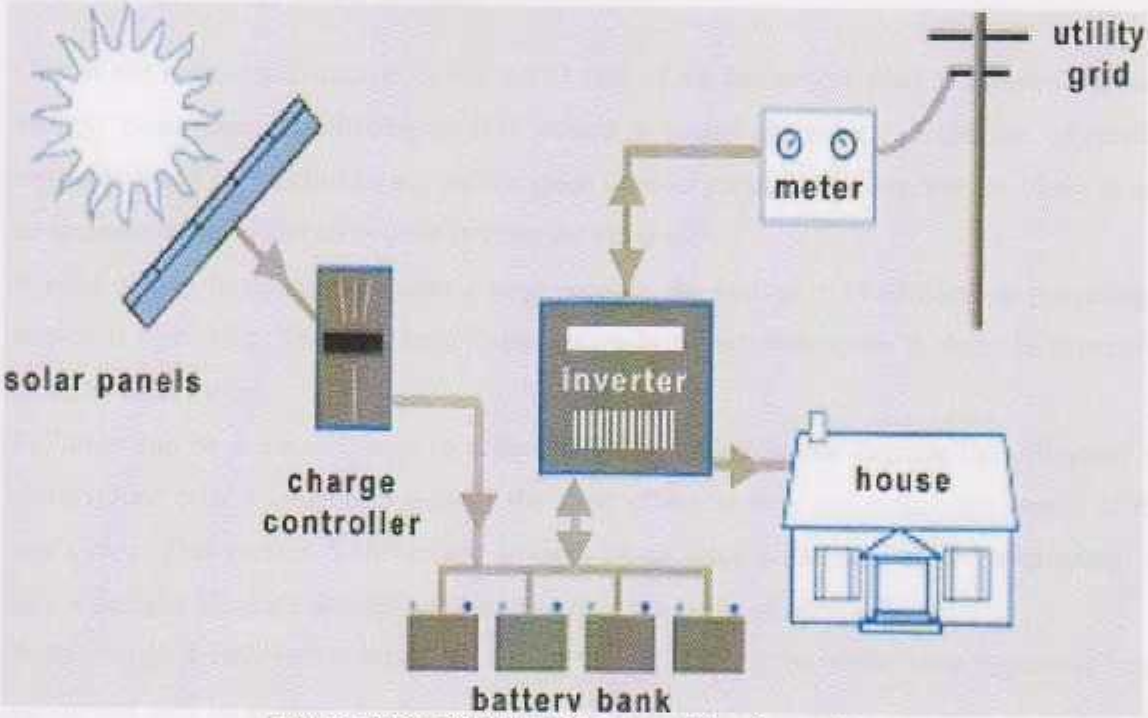


Figure 3-8 Simplified Hybrid connected in solar system

3.2 Advantages and disadvantages of the solar energy

3.2.1 Solar Energy advantages

- ✓ The power source of the sun is absolutely free.
- ✓ The production of solar energy produces no pollution.
- ✓ The technological advancements in solar energy systems have made them extremely cost effective.
- ✓ Most systems do not require any maintenance during their lifespan, which means you never have to put money into them.
- ✓ Most systems have a life span of 30 to 40 years.

✓ Most systems carry a full warranty for 20 to 30 years or more.

3.2.2 Solar Energy Disadvantages

× One of the main disadvantages is the initial cost of the equipment used to harness the suns energy. Solar energy technologies still remain a costly alternative to the use of readily available fossil fuel technologies. As the price of solar panels decreases, we are likely to see an increase in the use of solar cells to generate electricity.

× A solar energy installation requires a large area for the system to be efficient in providing a source of electricity. This may be a disadvantage in areas where space is short, or expensive (such as inner cities).

× Pollution can be a disadvantage to solar panels, as pollution can degrade the efficiency of photovoltaic cells. Clouds also provide the same effect, as they can reduce the energy of the sun's rays. This certain disadvantage is more of an issue with older solar components, as newer designs integrate technologies to overcome the worst of these effects.

× Solar energy is only useful when the sun is shining. During the night, your expensive solar equipment will be useless; however the use of solar battery chargers can help to reduce the effects of this disadvantage.

CHAPTER FOUR

DESIGN & CALCULATION

4.1 Grid-tie solar system (On Grid)

Later on chapter three, we explain the idea of grid-tie (On-Grid) solar system, and the block diagram shown in Figure 3-3 explain all system equipments, now we want to show our considerations in design and installation to apply this system properly.

First, we collect information's about daily energy consumption, which it very important to make accurate calculations to design this system.

4.1.1 Environmental data

The site information (environmental data) where the data of solar intensity, ambient temperature, relative humidity and cloudiness must be available shown the all information in appendix A.

4.1.2 Energy consumption for Office of DGSSR

The energy consumption in the office is mainly concentrated at day, so electricity consumption in office is not high; in Figure 4-1 simple design of office and Table4-1 explain energy consumption in four seasons and Figure 4-2 shows energy consumption in four seasons.

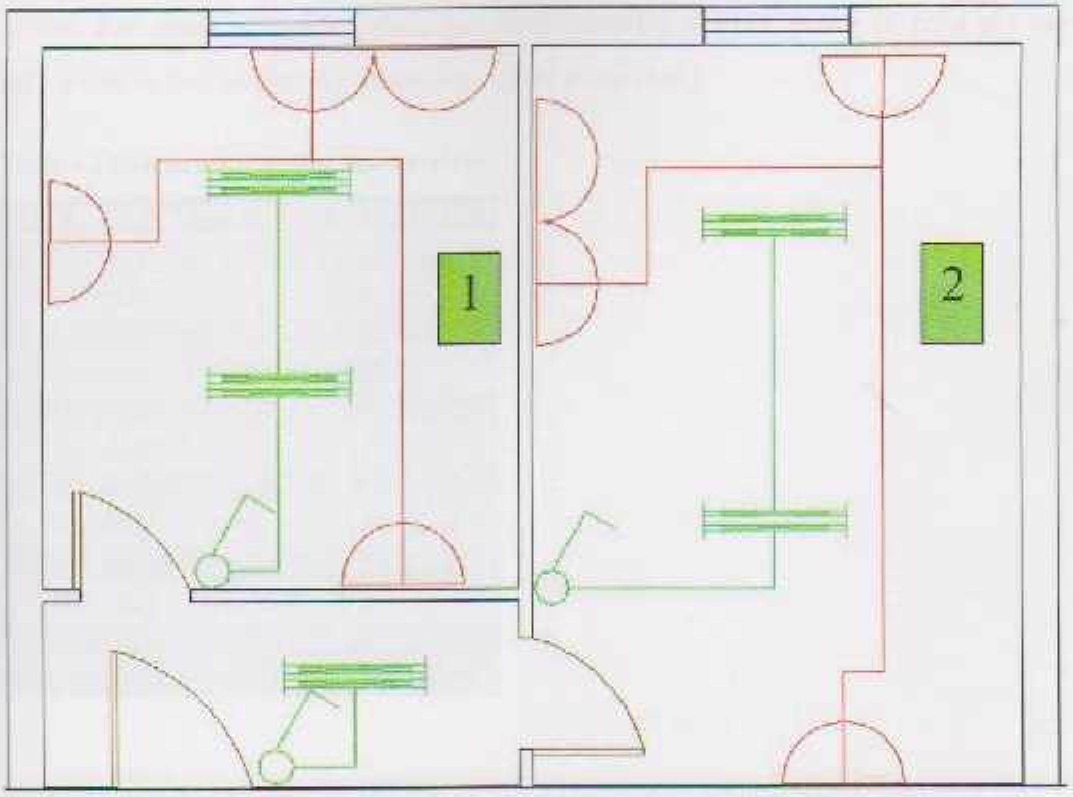


Figure 4-1 Simple design of office (Power and lighting lines)

Table 4-1 Approximate energy consumption in four seasons

Load Type	No.	Load Power (Watt)	Operating Period/day (h) in winter	Operating Period/day (h) in Spring	Operating Period/day (h) in Summer	Operating Period/day (h) in Autumn
Lighting	10	36	8	8	8	7
Laptop	1	200	1	1	0.3	1
Computer & Screen	1	550	8	8	8	8
Heater	1	1500	2	0	0	0.5
water heater	1	2200	0.25	0.25	0	0.25
fan	2	70	0	0	3	0
printer	1	680	0.25	0.25	0.25	0.25
E (KWh/day) in Season			12.58	7.68	6.63	5.54
Avg. Energy (KWh/day)			8.1			
Annual Energy (KWh/Yr)			2956			

(Hint: For more accurate values we have installed a KWh meter to read the consumption office within two weeks, the following tables show that.)

Table 4-2 Energy consumption in winter/day

Day in winter	Energy (KWh/day)
Sunday	16.6
Monday	10
Tuesday	16.1
Wednesday	14
Thursday	12
Sunday	11
Monday	8
Tuesday	14
Wednesday	9
Thursday	9.5
Saturday	10
Average energy	12.5834678

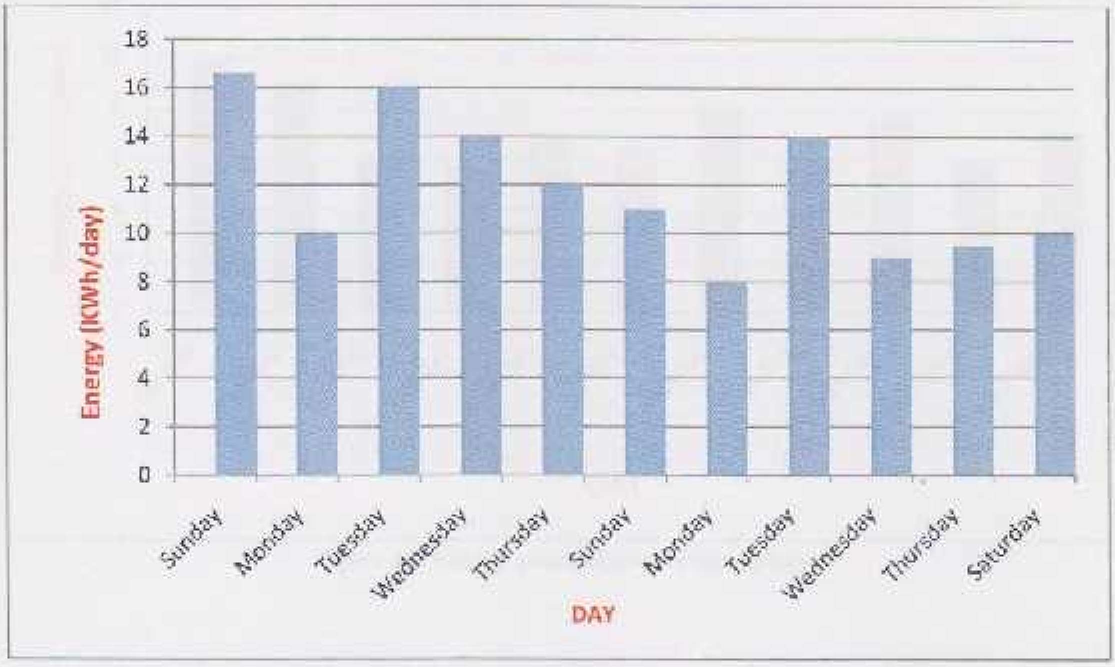


Figure 4-2 Energy consumption in winter/day

Table 4-3 Energy consumption in spring/day

Day in Spring	Energy (KWh/day)
Sunday	10
Monday	8.98
Tuesday	6.02
Wednesday	5.7
Thursday	7
Sunday	6.48
Monday	8.1
Tuesday	5.7
Wednesday	7.68
Thursday	6
Saturday	7.08
Average energy	**7.687123**

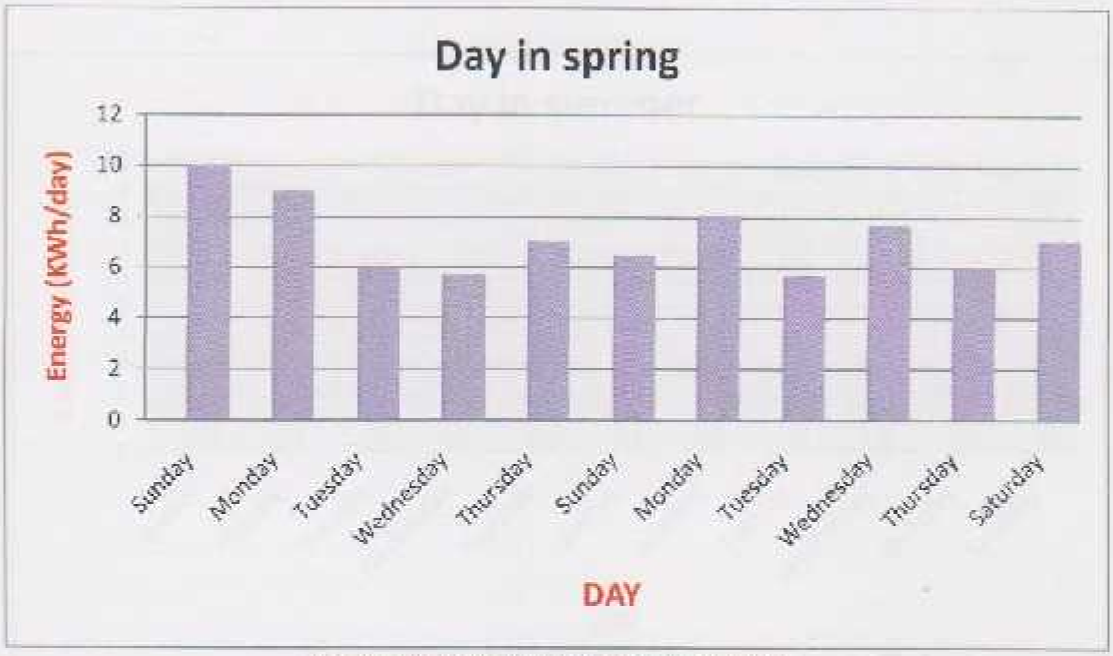


Figure 4-3 Energy consumption in spring/day

Table 4-4 Energy consumption in summer/day

Day in Summer	Energy (KWh/day)
Sunday	8.6
Monday	6.3
Tuesday	6.9
Wednesday	5.4
Thursday	6.01
Sunday	5.4
Monday	6.8
Tuesday	7.7
Wednesday	6
Thursday	5
Saturday	4.1
Average energy	**6.634578**

Figure 4-4 Energy consumption in summer/day

Table 4-5 Energy consumption in summer/day

Day in Autumn	Energy (KWh/day)
Sunday	7.48
Monday	5.76
Tuesday	6.72
Wednesday	4
Thursday	4.8
Sunday	5.18
Monday	4.4
Tuesday	8
Wednesday	5.9
Thursday	4
Saturday	2.5
Average energy	**5.5456780**

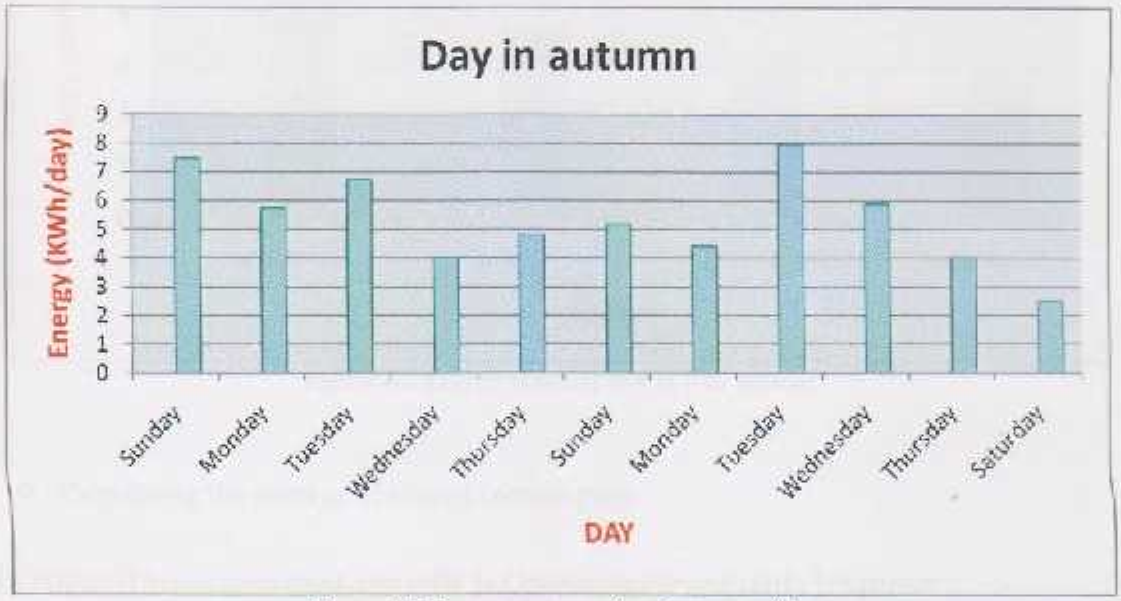


Figure 4-5 Energy consumption in summer/day

- Average consumption in four seasons

Table 4-6 Average energy consumption in four seasons

Season	Average energy(day/season)
winter	12.58
Spring	7.68
Summer	6.63
Autumn	5.54
Average energy	8.1075

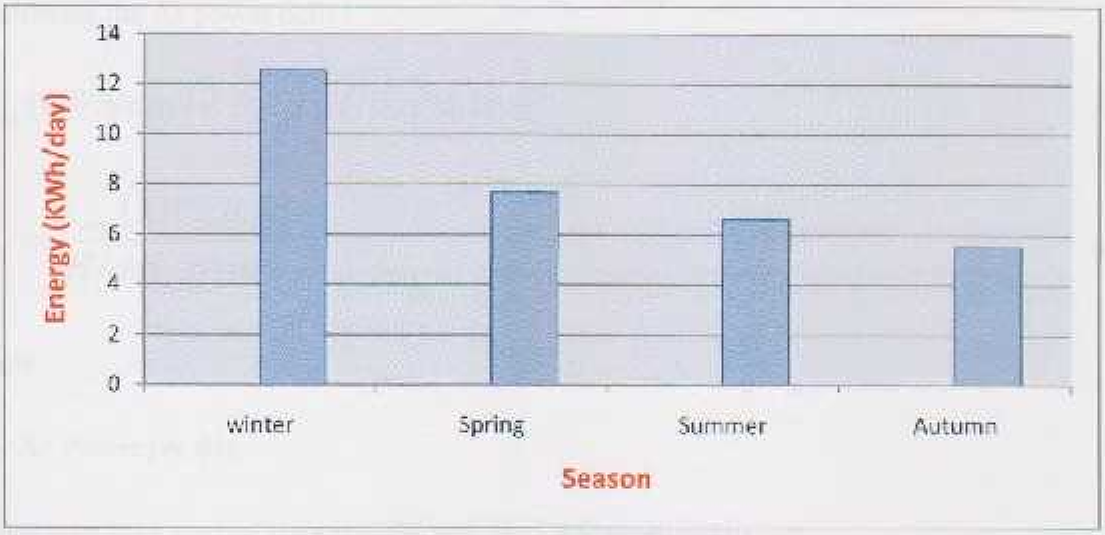


Figure 4-6 Energy consumption in four seasons

- Calculating the average of energy consumption

$$E(KWh/day)\,in\,season = load\,power(W) \times OperatingPeriod/day(y)\,in\,winter \tag{4.1}$$

$$E(KWh/day) = 10 \times 36W \times 8 + 200W \times 1 + 550W \times 8 + 1500W \times 3 + 2200W \times 0.25 + 680W \times 0.25$$
$$E(KWh/day) = 12.734(KWh/day)$$

$$Avg.\ E(KWh/day)\ in\ season = \frac{Total\ E(KWh/day)}{4} \tag{4.2}$$

$$Avg.\ E(KWh/day) = \frac{12.58(KWh/day) + 7.68(KWh/day) + 6.63(KWh/day) + 5.54(KWh/day)}{4day/season}$$

$$Avg.\ E(KWh/day) = 8.1\ KWh/day$$

$$Annual\ Energy(KWh/Yr) = Avg.\ E(KWh/day) \times 365(day/Yr) \tag{4.3}$$

$$Annual\ Energy(KWh/Yr) = 8.1(KWh/day) \times 365(day/Yr) = 2956(KWh)$$

4.1.3 PV array sizing

Calculating the Ac power daily:

$$E_{avg}(KWh/day) = P_{AC} \times (H/day\ @1sun) \tag{4.4}$$

$$P_{AC} = \frac{E_{avg.}(KWh/day)}{H/day\ @1sun} \tag{4.5}$$

Where:

P_{AC}: Ac Power per day.

H: Average solar energy input/day (h/day). H=5.4 from appendix.

$E_{avg.}$: The average daily load energy (KWh/day).

$$P_{AC} = \frac{8.1(KWh/day)}{5.4(h/day)} = 1.5KW$$

$$P_{DC} = \frac{P_{AC}}{\eta_{con}} \tag{4.6}$$

Where:

P_{DC}: DC Power per Day.

η: Conversion Efficiency is equal 0.75. [2]

$$P_{DC} = \frac{1.5KW}{0.75} = 2KW$$

$$PV(area) = \frac{P_{DC}}{(H/day@1sun)\cdot\eta_{PV}} \tag{4.7}$$

$$PV(area) = \frac{2000W}{1000\times0.149} = 13m^2$$

The PV chosen (AYAVA SoLAR AY Series Monocrystalline 250W) is given in Appendix B.

$$No.\,of\ \text{module} = \frac{P_{DC}}{PV\ module(watt)} \tag{4.8}$$

$$No.\,of\ \text{module} = \frac{2000W}{250W} = 8\ \text{modules}$$

$V_{mp} = 48.5v$ $V_{OC} = 58.1v$ $\eta_{PV} = 14.95\%$

$I_{mp} = 5.15A$ $I_{SC} = 5.58A$

4.1.4 Inverter Sizing

Maximum Power load = 2kWp.

We choose inverter sizing, 3000W because this research project.

- V_{input} Should be located in the inverter MPPT voltage range (260-500V) and Max input voltage is equal 250V.
- The efficiency > 92%

No. module in series * max power voltage in PV is equal 8 * 48.5 – 388v the MPPT range of 260-500 V for the inverter, so we chosen inverter "Danfoss Solar Inverter ULX3000W" From Appendix C.

4.1.5 Verification from previous calculations:

$$PV(area) = No.of\ modules\ \times dimentions \tag{4.9}$$

$$PV(area) = 8 \times 1.58m \times 1.052m = 13.4m^2 > 13m^2 \checkmark$$

$$P_{DC} = Power\ of\ module\ \times No.of\ module \tag{4.10}$$

$$P_{DC} = 250W \times 8 = 2000W > (P_{AC} = 1500W) \checkmark$$

$$\text{Energy} = \text{P}_{\text{DC}} \times \eta_{sol} \times \text{H(h/day)} \tag{4.11}$$

$$\text{Energy} = 2(\text{KW}) \times 0.75 \times 5.4(\text{KWh/m}^2\text{.day}) = 8.1(\text{KWh}) = 8.1(\text{KWh}) \checkmark$$

It is important to estimate the maximum open-circuit voltage of the array to be sure that it doesn't violate the highest dc voltage that the inverter can accept, which in this case is 250 V. With 8 modules in series, each having a VOC at STC of 58.1 V, the string voltage could reach 1× 58.1 = 58.1 V. This is well below the 250-V limit. But, remember that VOC increases when cell temperature is below the STC assumption of 25^{O}C. We could imagine that on a cold morning, with a strong, cold wind and low sunlight, cell temperature might be close to ambient, and that might be well below 25^{O}C. With VOC increasing by 0.38%/°C below 25^{O}C (for crystalline silicon), the open-circuit voltage could then be well above its STC value. Suppose that it is -2^{O}C on the coldest morning in Fresno, and assume that cell temperature and ambient temperature are the same. The three-module string V_{OC} would now be:

$$V_{OC} = 1 \times 58.1 \times [1 + 0.0038 \times (25 + 2)] = 64.06 < (V_{MAX\ INV} = 250v) \checkmark$$

4.1.6 Solar system costs

Grid-tic solar system cost

Table 4-7Grid-tie solar system cost

Item	Quantity	Price/Qty ($/Qty)	Total Price ($)
AYAVA SALAR AY Series Monocrystalline 250W	8	322	2577
Danfoss Solar Inverter ULX3000W	1	1250	1250
Conductor	50m	1.7	85
Earth set	40m	1	59
Inverter box	1	85	85
PV structure	1	1000	1000
Elements, … etc	…	100	100
Total			5156

- **Estimated cost**

- Life span of the system 25 year.

- Cost of the system 5156$ ≈ 18560NIS.

- Annual maintenance cost ≈ 0.

After installation of the project the inverter give us output power of approximately 1.6 KW and the average daily sun insulations 5.4 hr.

- ✓ **Average output from system per year**

$$Average\,annual\,energy = 1.6KW \times 5.4hr \times 365 = 3154KWh$$

The KWh tariff = 0.68 NIS

$$\text{Produced}\,cost = 3154KW \times 0.68 = 2145NIS$$

$$No.\ of\ years\ to\ back\ installation\ cost = \frac{cost\ of\ system}{saving\ per\ year}$$

$$No.\ of\ years\ to\ back\ installation\ cost = \frac{18560}{2145} = 8\ year$$

After recovery of the cost of electric power system is considered a profit for the University for 15 years, the value of profit during the 15 years is:

$$profit\ per\ year = 2145NIS$$

$$profit\ after\ 15\ year = 2145 \times 15 = 32175NIS$$

4.1.7 The system design

The final design in solar system we must connect 8 modules in series (1 string) as shown in Figure 4-7.

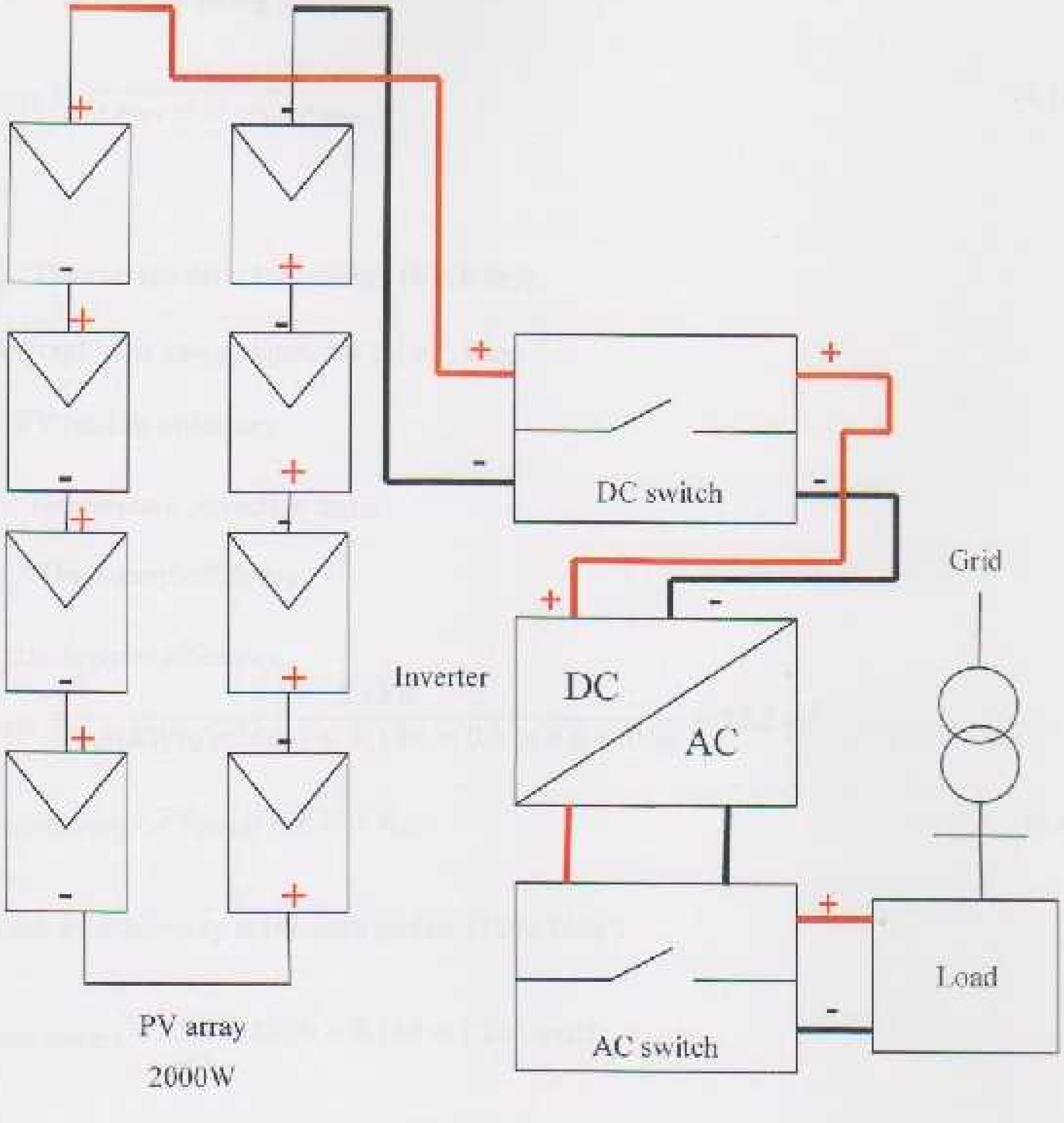


Figure 4-7 The final design of the solar system

4.2 Small "Stand-Alone" Systems (off grid)

Later on chapter three, we explain the idea of small "Stand-Alone" solar system (Off Grid), and the block diagram shown in Figure 3-1 explain all system equipments, now we want to show our considerations in design and installation to apply this system properly.

4.2.1 PV array sizing

$$PV_{(area)} = \frac{E_{avg}}{H\times \mu\eta_{PV}\times TCF\times\eta_{batt}\times\eta_{inv}} \qquad (4.12)$$

Where:

E_{avg}: The average daily load energy (KWh/day).

H: Average solar energy input/day (h/ m^2. Day).

η_{PV}: PV module efficiency.

TCF: Temperature correction factor.

η_{batt}: The battery efficiency.

η_{inv}:the inverter efficiency.

$$PV_{(area)} = \frac{8.1Kw}{5.4(KWh/m^2day)\times\ 0.149\ \times 0.8\ \times 0.9\times\ 0.92} = 15.2\ m^2$$

$$PV_{(peake\ power)} = PV_{(area)}\times PSI\times\eta_{PV} \qquad (4.13)$$

Where:

PSI: Peak solar intensity at the earth surface (1000 W/m²).

$$PV_{(peake\ power)} = 15.2\times 1000\times 0.149 = 2265\ watt$$

$$No.of\ module = \frac{PV_{(peake\ power)}}{PV\ module(watt)}$$

$$No.of\ module = \frac{2265(watt)}{250(watt)} = 9module$$

The PV chosen (AYAVA SALAR AY Series Monocrystalline 250W) is given from Appendix B.

4.2.2 Design of the Storage system

The storage capacity can be calculated according to the following relation

$$Battery\ storage = \frac{N_c \times E_{avg}}{DOD \times \eta_{batt} \times \eta_{inv}} \tag{4.14}$$

N_c: Number of continuous cloudy day =1day (presumptive).

DOD: The allowable depth of discharge for the batteries =0.8.

$$Battery\ storage = \frac{1 \times 8100}{0.8 \times 0.9 \times 0.92} = 12228Wh$$

From the Figure 4-8we chose the Ratio is based on a rated capacity at C/100and 25^{0}C. And we chose the type of battery from Table 4-9(Surette 12SC11PS).

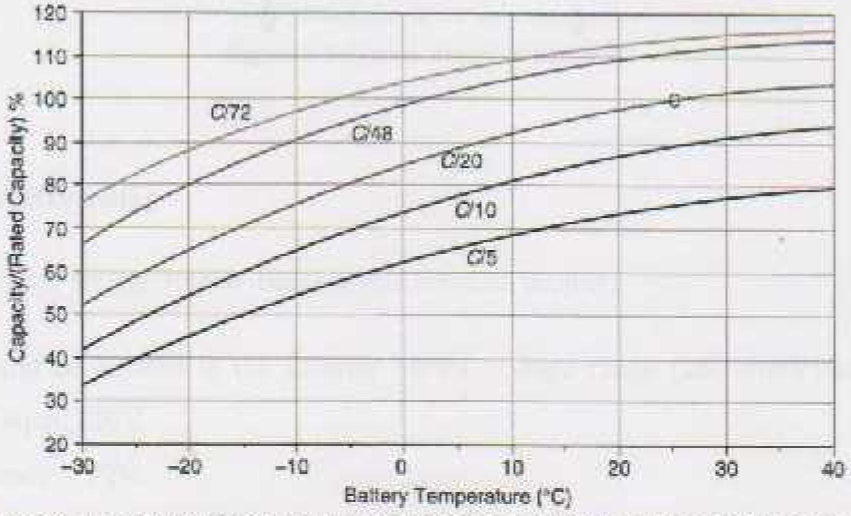


Figure 4-8 Lead-acid battery capacity depends on discharge rate and temperature

Table 4-7 Characteristics of batteries

BATTERY	Voltage	Weight (lbs)	Ah @ *C*/20	Ah @ *C*/100
Concorde PVX 5040T	2	57	495	580
Trojan T-105	6	62	225	250
Trojan L16	6	121	360	400
Concorde PVX 1080	12	70	105	124
Surette 12CS11PS	12	272	357	503

If a 12 V system is chosen, the required amp. Hours of batteries=12228/12=1019 AH. If 12 V blocks with 503AH each are chosen, 2 batteries (12 V, 1019 AH) connected in parallel are needed, Figure 4-9 shown the system design of batteries.

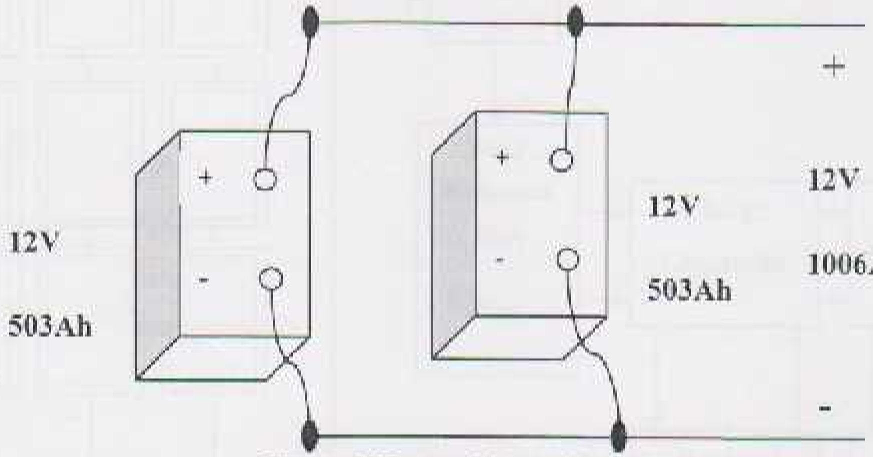


Figure 4-9 System design of batteries

4.2.3 Inverter Sizing

We choice inverter sizing, 3000W because this research project.

- V_{input} Should be located in the inverter MPPT voltage range (260-500V) and Max input voltage is equal 250V.
- The efficiency > 92%

NO of module in sires * max power voltage in PV is equal 8 * 48.5 = 388v the MPPT range of 260-500 V for the inverter, so we chosen inverter "Danfoss Solar Inverter ULX3000W" From Appendix C.

4.2.4 System design

The final design in solar system we must connect 9 modules in series (1 string) and connect 9 as shown in Figure 4-10.

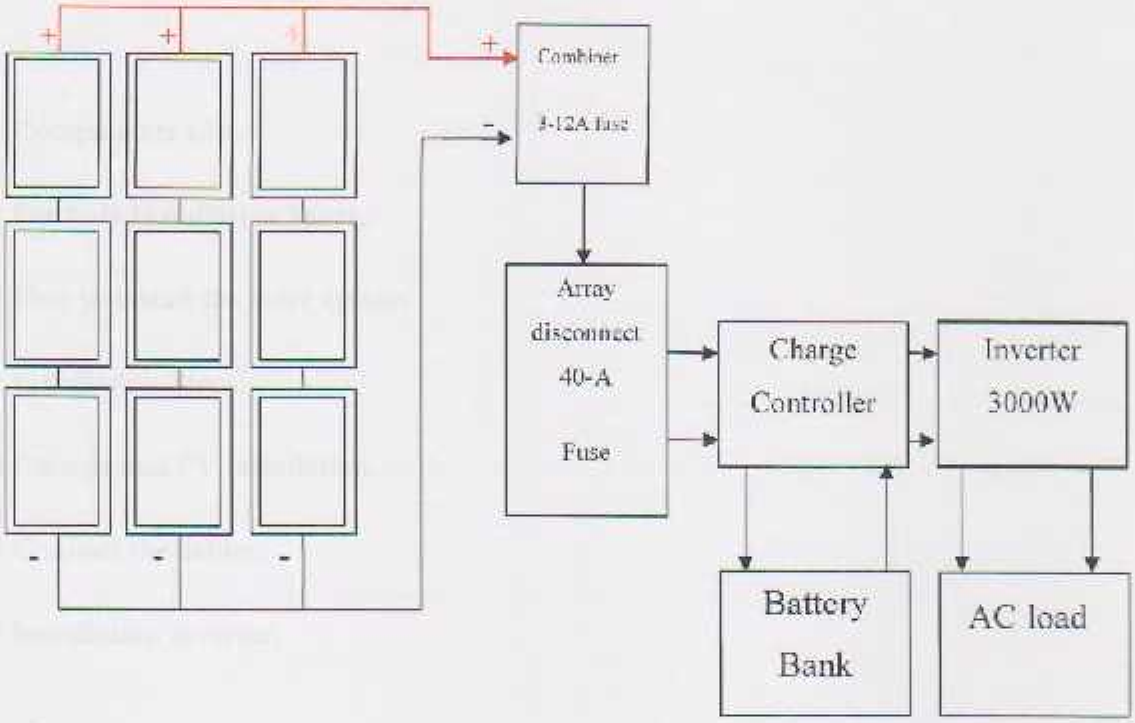


Figure 4-10 The final design of the solar system

CHAPTER FIVE

SYSTEM IMPLEMENTATION

5.1 Components List.

5.2 For Safe Installation Work.

5.3 How to install the solar system

5.4 Installation Steps.

5.5 Clamps and PV installation.

5.6 Connect the cables.

5.7 Installation inverter.

5.1 Components List

The system consists of physical components such as:

1. Front tilts.
2. Rear tilts.
3. Rail.
4. Rail splice.
5. End clamp.
6. Mid clamp.
7. Inverter box (used to cover the inverter and save it from damage).

And electrical component such as:

8. PV module 250W.
9. Inverter (Danfoss 3KW).
10. DC cables.
11. AC&DC circuit breakers.

The following tables show photographs of all system components shown Table 5.1and Table 5.2.

Table 5-1 Components of system structure

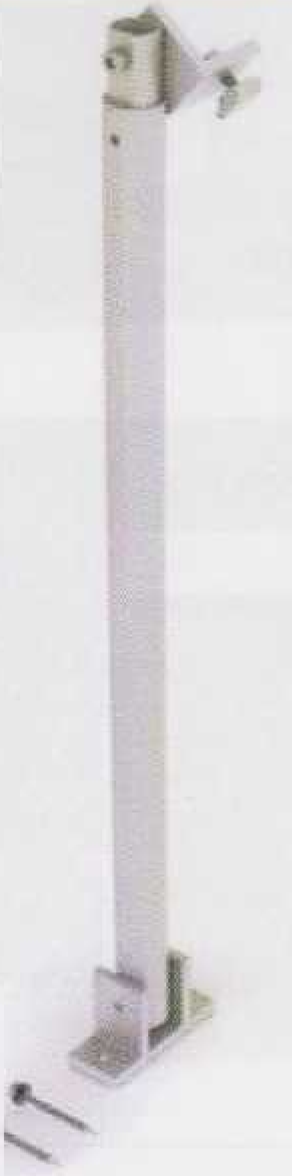
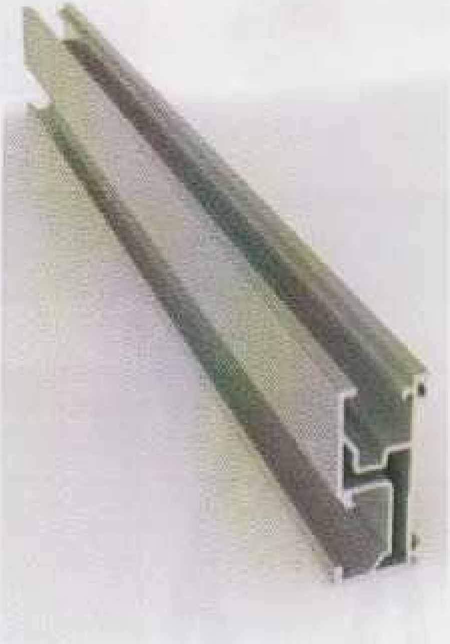
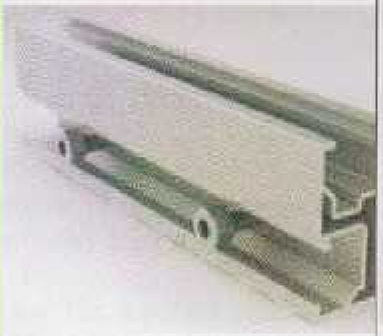
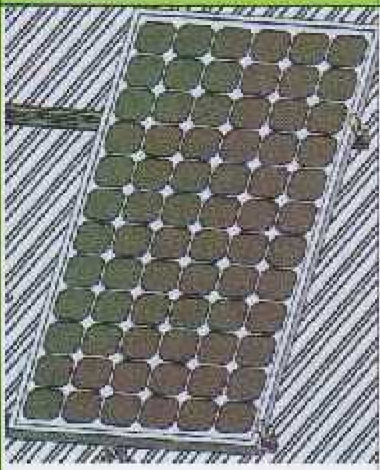
Model name	Front tilts	Rear tilts	Rail
Picture			

Table 5-2 Components of system structure and electrical components

Model name	Rail splice	Mid clamp	End clamp
Picture			
	PV module 250W	Inverter (Danfoss 3KW)	Cables
			

5.2 For Safe Installation Work

This is critical information regarding electrical and mechanical installation and safety information which you should know before starting installation.

- Stop work during stormy weather. Solar modules can be caught in the wind, causing you to fall.
- Never step or sit on the glass surface of a solar module. The glass may break, resulting in shock or bodily injury. The module may also stop generating power.
- Always use the supplied parts to attach the solar modules and mounts. Use of weaker parts, such as screws that are too short, is dangerous and may cause the solar modules or mounts to fall.
- Always use the specified tools. The solar modules or mounts may fall if the installation is not strong enough, for example when parts are not tightened sufficiently.
- Do not modify or cut parts. Doing so is dangerous. Safety cannot be guaranteed.

✓ Before starting installation we must check the following points

1. Determine the wind loads for the installation site. Check with your local building and safety department for the specific requirements. Make certain that the roof structure can support the live and dead loads resulting from the installation of the PV array.
2. Install solar modules facing south, if possible. Installations facing east and west are also possible, although the amount of power generated will be lower.

5.3 How to install the solar system?

1. In the beginning you choose the right place on the roof of the building, so that the relative power of the plate in order to reduce the length of the wire.
2. Determine the direction of the sunrise on climate change for the region, and the aim of being able to make use of sun during the day, and often the choice is toward the south. And the angle of tendency during the summer 27°.
3. Start collecting PV structure and components installed in the well surface in order to avoid falling into the danger of the destruction of the PV structure of the wind force during the winter. Shown this Figure 5-1 to 5-13 to explain this step.
4. Install solar panels on the aluminum structure by use end clamp and mid clamp. Shown Figure 5-15 to 5-18 to explain this step.
5. Connecting wire between the solar panels, respectively, in order to get a high voltage until the system is capable of running the inverter. Shown Figure5-19.
6. Installation of the inverter and connect with the AC network. We then connect the wires coming from the solar system of the inverter, taking into account the polarity of wires. Shown Figure 5-20 to 5-22 to explain this step.
7. Installation of external cover cabinet order of protection from external influences.

5.4 Installation Steps

1. The front tilts are pre-assembled. First separate the items as demonstrated.

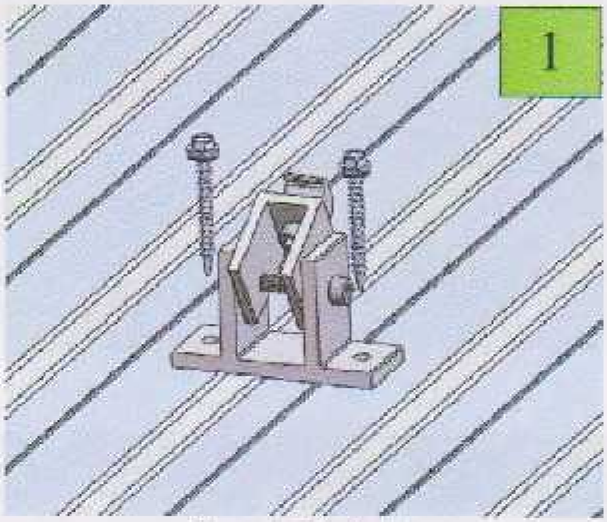


Figure 5-1 First step

2. The distribution of the front tilts as shown in the Figure 5-2.

Figure 5-2 Scanned step

(Hint: the distance between each front tilt is L=140cm)

3. Fasten the rail on the front tilts; the two sides of rail should keep equal distance with the front tilts .Shown the figure5-3 and Figure 5-4.

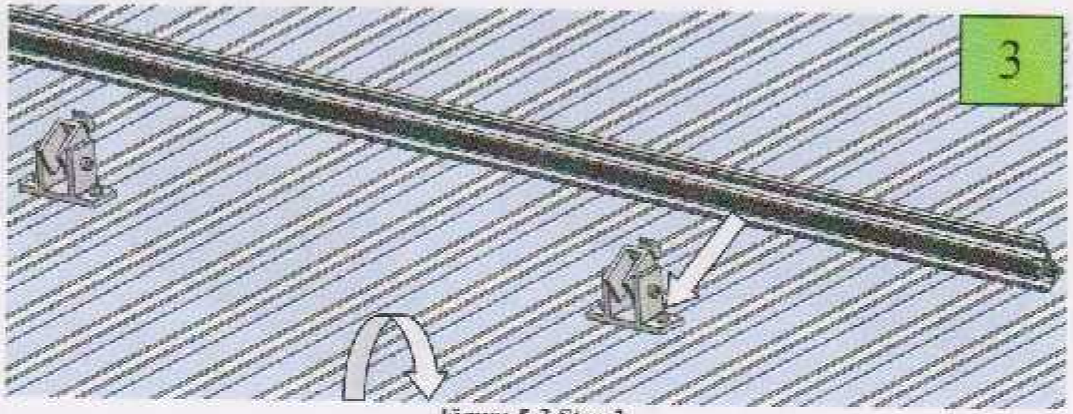


Figure 5-3 Step 3

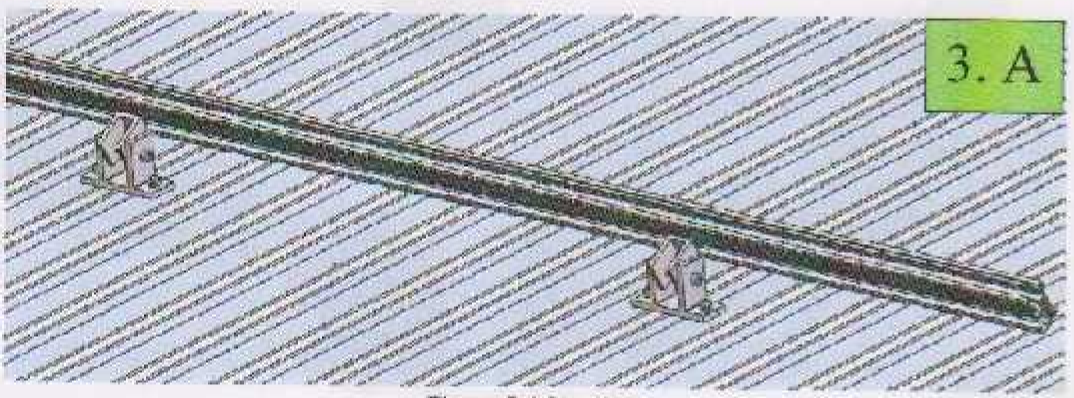


Figure 5-4 Step 3.A

4. Connect the front tilts and rail using screw as shown in Figure 5-5.

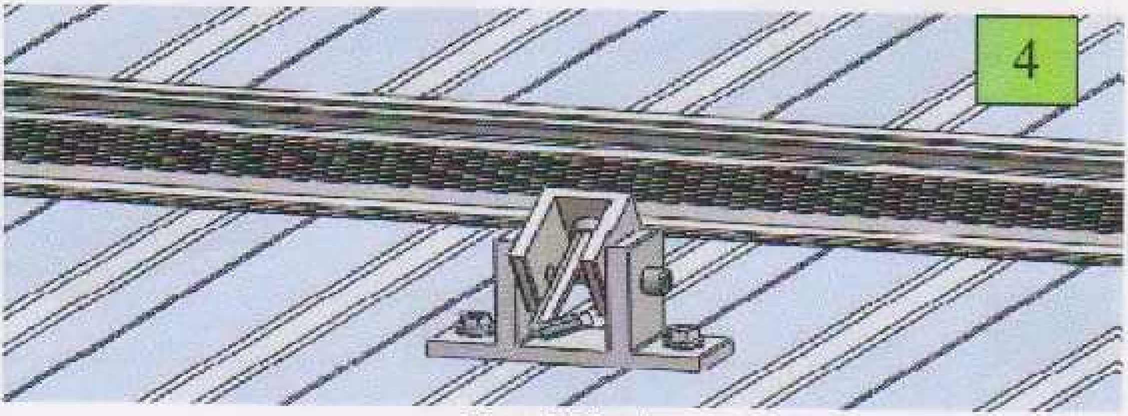


Figure 5-5 Step 4

5. Installation of the splice to connect multiple rails together. Slide the splice on the rear side of the pre-assembled rails. Fasten the first bolt firmly. Then slide the next rail into the splice. Shown in Figure 5.6.

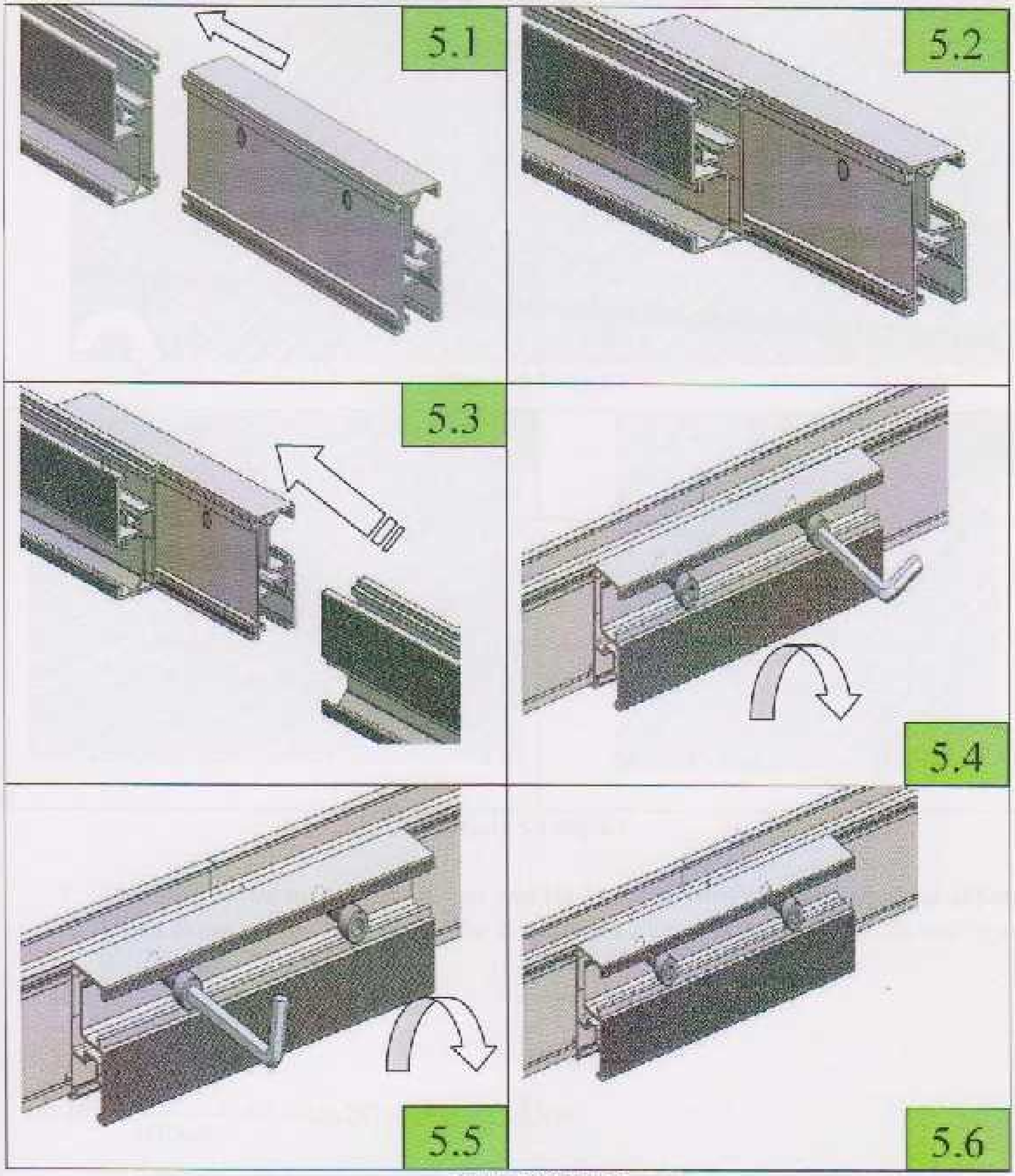


Figure 5-6 Step 5

6. Install rear tilts keep front and real tilts in one Straight line one front tilt to where south position fixed on to the roof by screws one real tilt. Shown Figure 5-7 and Figure5-8.

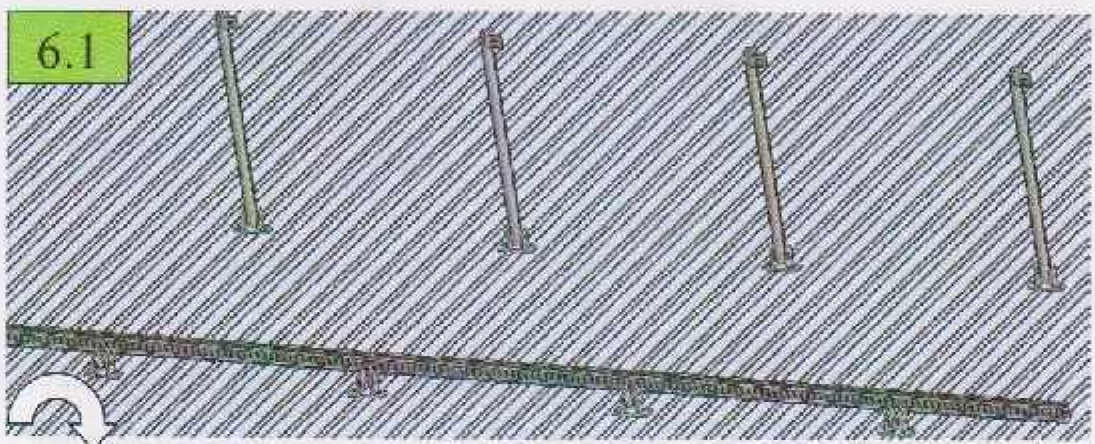


Figure 5-7 Step 6.1

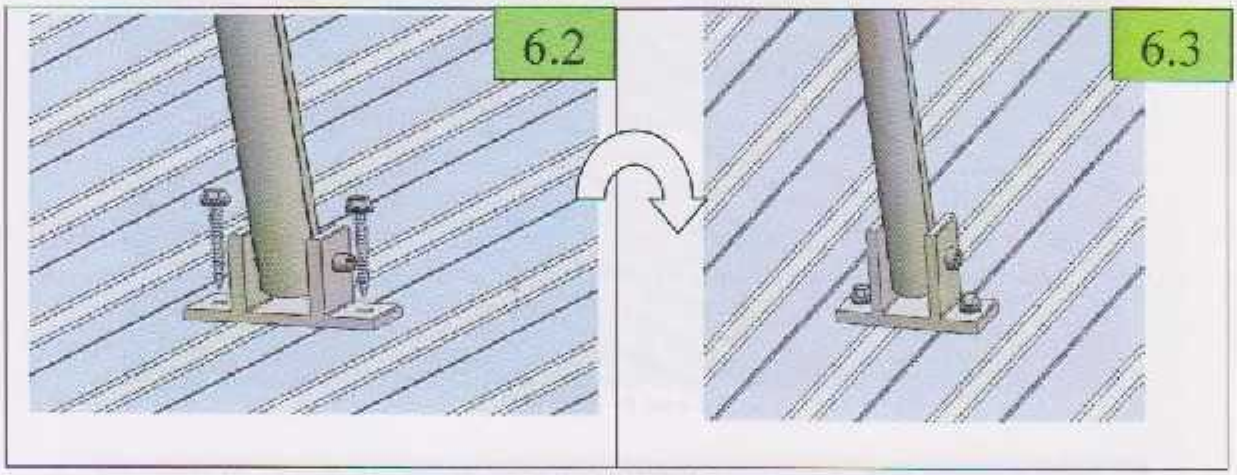


Figure 5-8 Step 6.2

7. The distance between front tilt and real tilt is decided by the panel size and adjustable angel, in our project we find that the distance is 120cm and the angel 28°.Shown figure 5-9.

$$\cos 28^\circ = \frac{L}{L(\mathrm{Re}ar)} \rightarrow L = \cos 28^\circ \times 65.5cm = 123cm$$

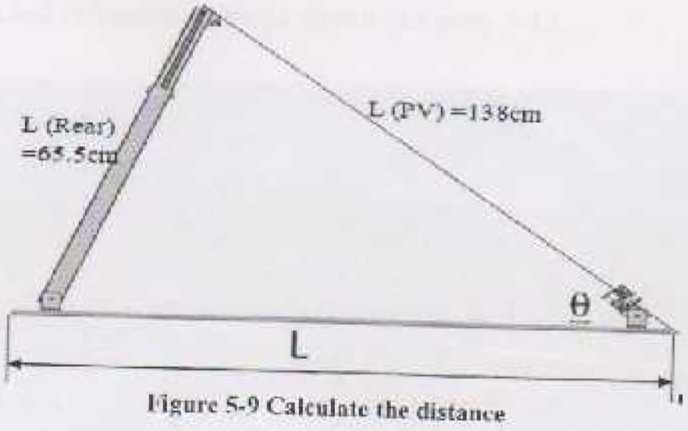


Figure 5-9 Calculate the distance

8. Fasten the rail on the real tilts shown in the Figure 5-10.

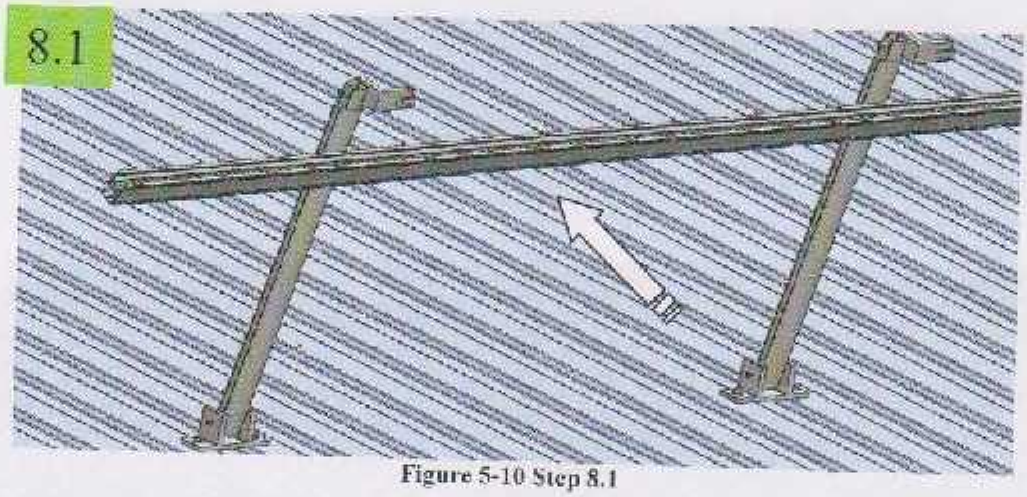


Figure 5-10 Step 8.1

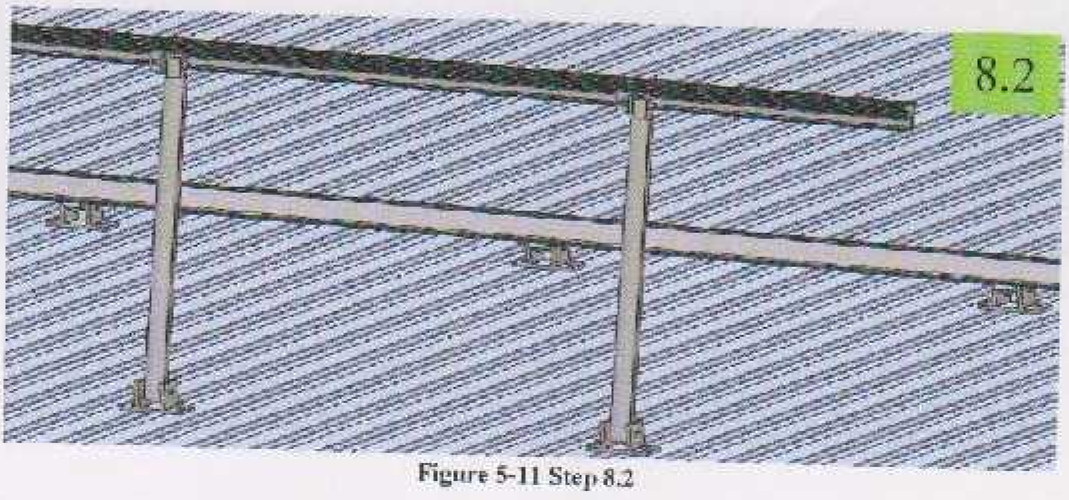


Figure 5-11 Step 8.2

Connect the rear tilts and rail using screw as shown in Figure 5-12.

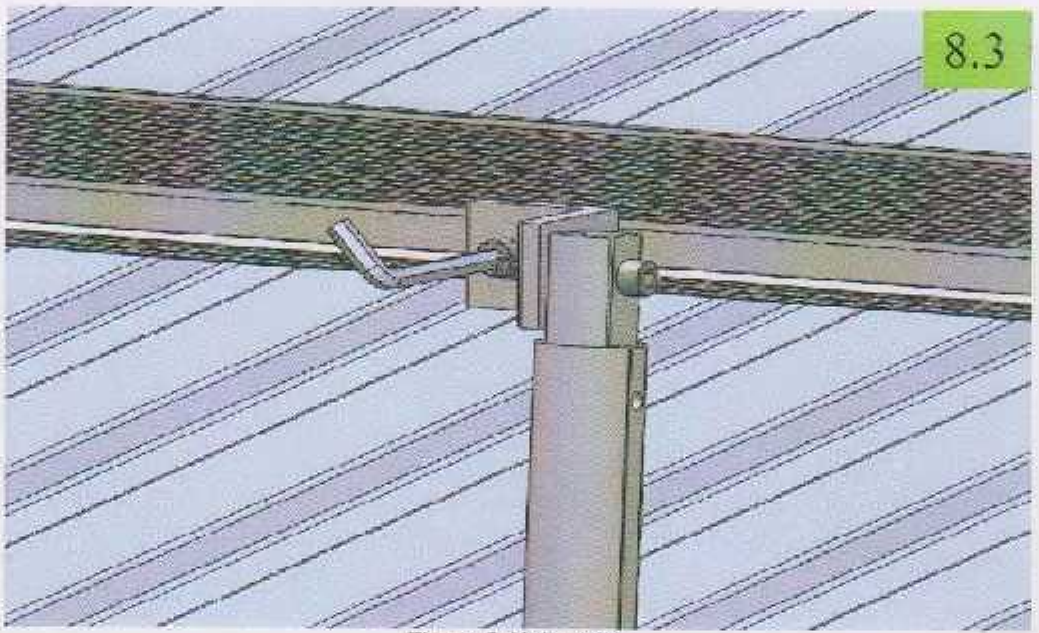


Figure 5-12 Step 8.3

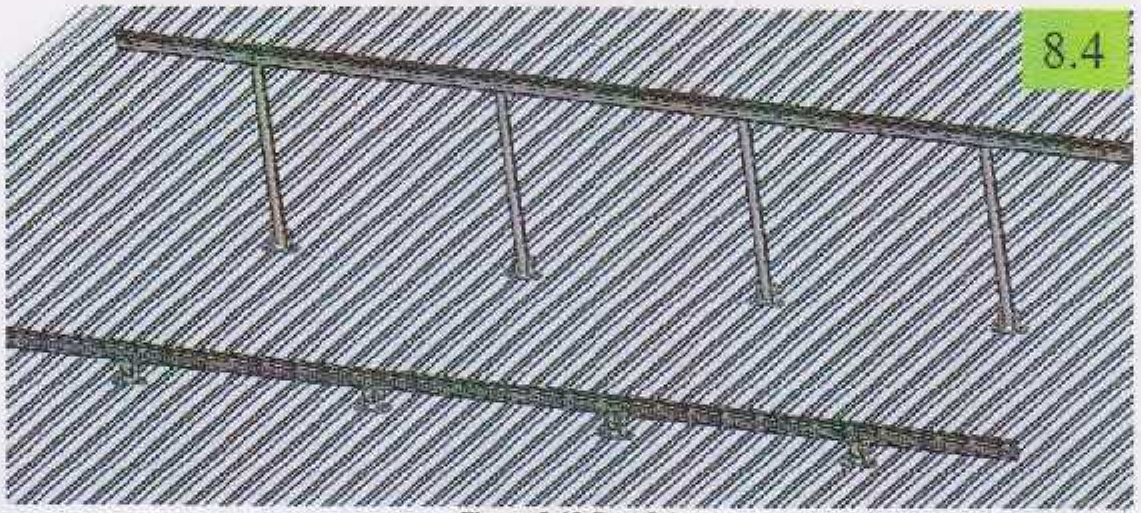


Figure 5-13 Step 8.4

The complete PV Structure

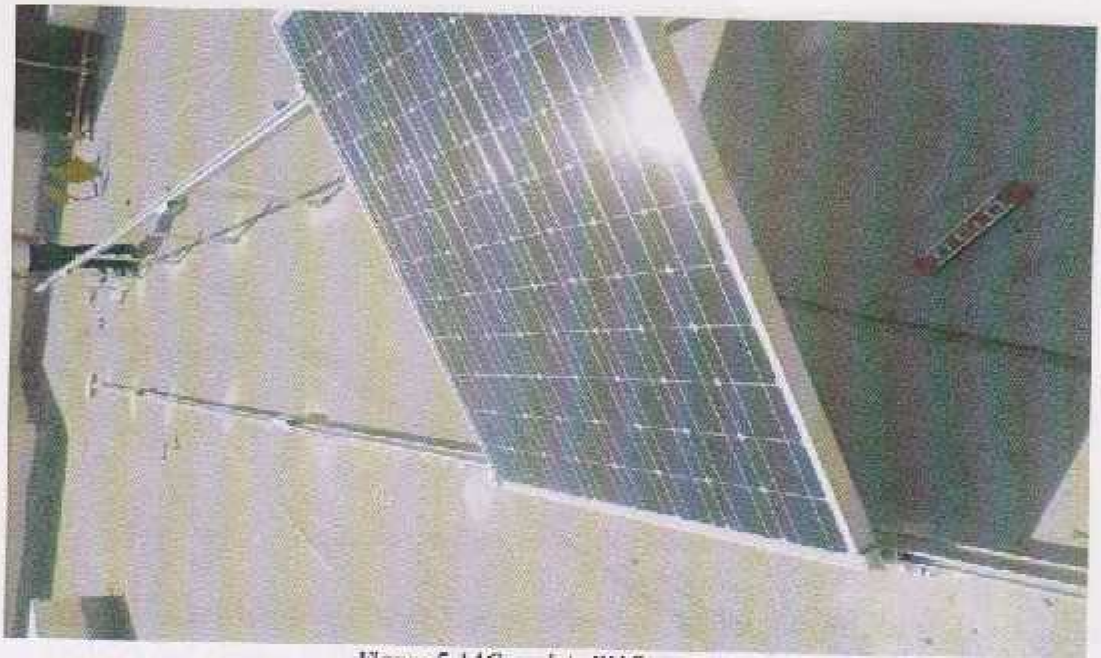


Figure 5-14*Complete PV Structure*

5.5 Clamps and PV installation

- Clamps installation.

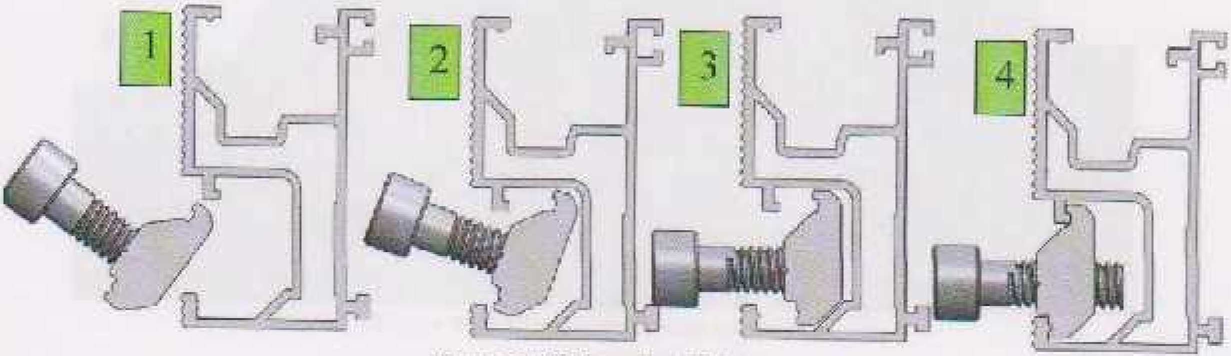


Figure 5-15 Clamp installation

- Place the first module. Slide the end clamp tightly against the module and fasten it. Install the end clamp and mid clamps shown in the Figure5-16.

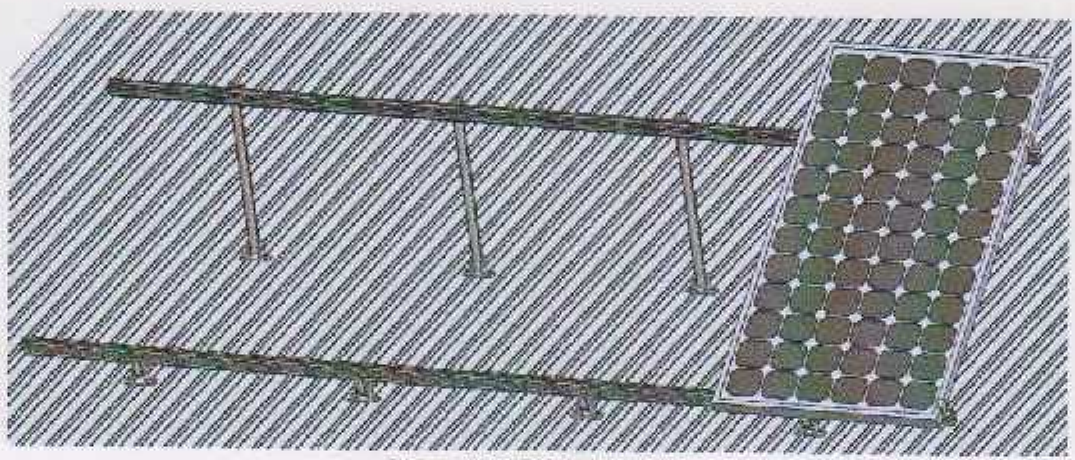


Figure 5-16 PV installation

(Hint: The edge of solar panel to the rail distance: 25mm-30mm)

- Slide the next module against the installed module. Fasten the mid clamp. Install other modules and clamps in this way. Keep module even.

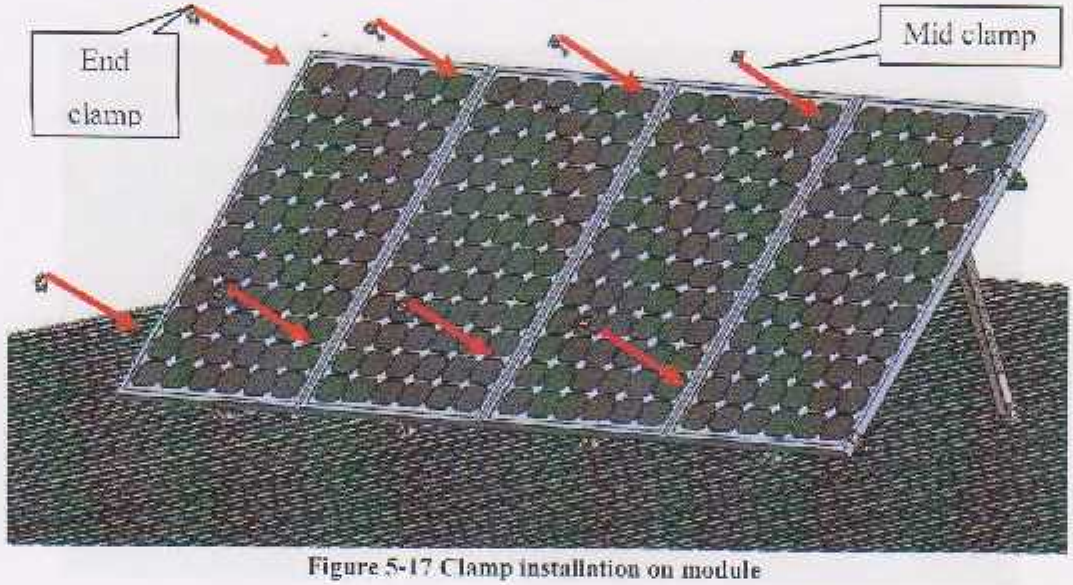


Figure 5-17 Clamp installation on module

Figure 5-18 Complete system

5.6 Connect the cables

Connect all units on series shown in the Figure5-19.

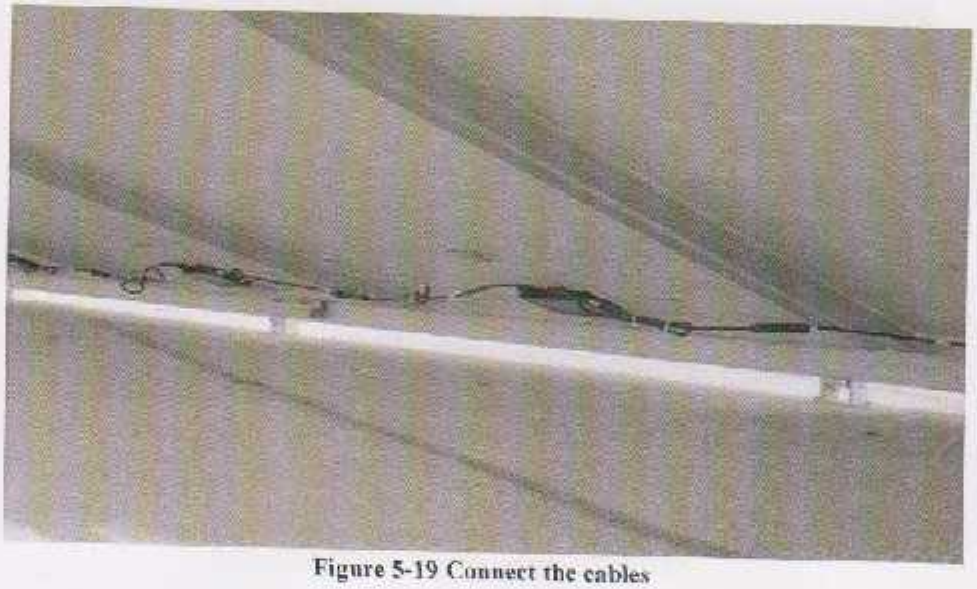


Figure 5-19 Connect the cables

5.7 Installation inverter

1. Install the base to carry the inverter shown in Figure 5-20.

Figure 5-20 Step 1 install the base

2. Install inverter

Figure 5-21 Step 2

3. Connect cables on grid and inverter shown Figure5-22.

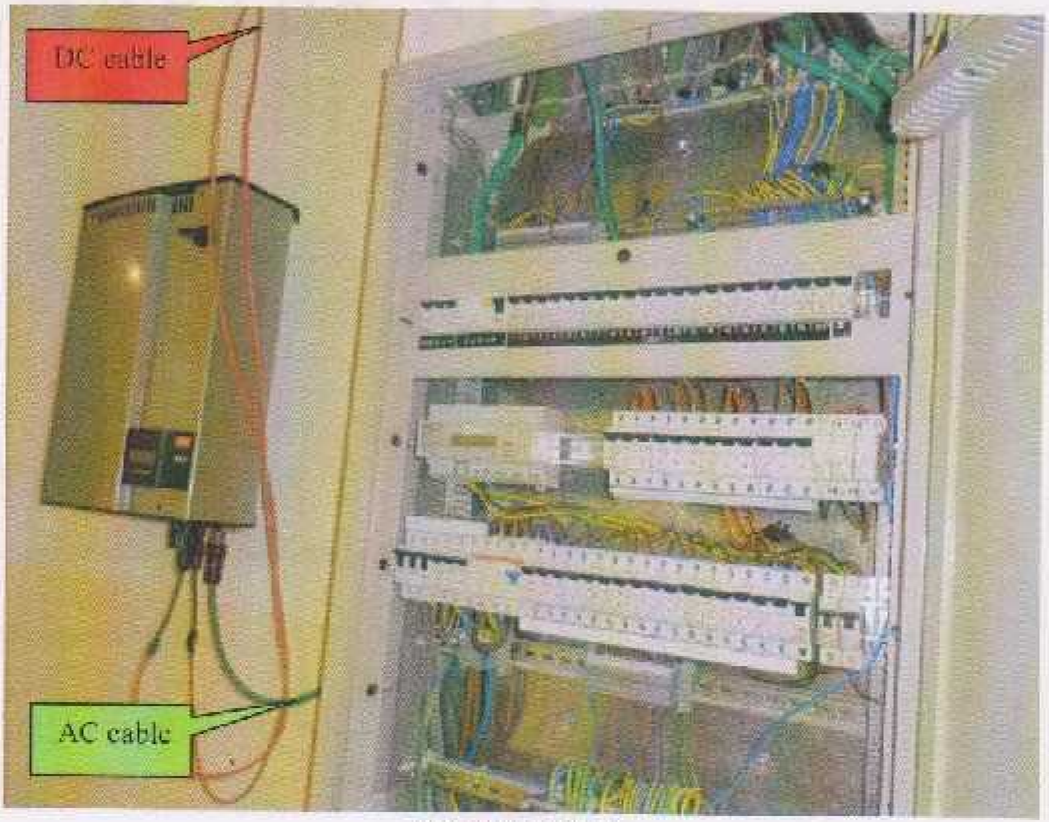


Figure 5-22 Step 3

Complete install inverter shown Figure 5-23.

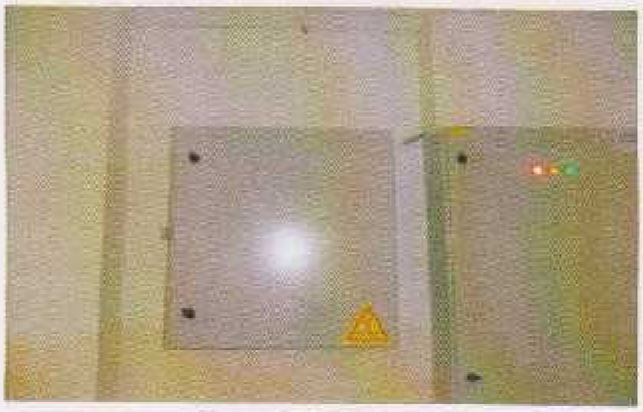


Figure 5-23 Final step

CHAPTER SIX

PROTECTION

6.1 Electrical protection.

6.2 Requirement of the electrical protection system.

6.3 Component earth.

6.4 Connect DC circuit breaker.

6.5 Connect AC circuit breaker.

6.6 Connect earth set.

6.1 Electrical protection

Electrical protection it is protect the electrical system from dangerous that happened from fault in the electrical system. From that the electrical protection not prevent occur the electrical fault but it is prevent the dangerous which is damage the system. So the electrical protection is the science solves the electrical fault and the effect of it with small speed to make continuity in the system.

6.2 Requirement of the electrical protection system

An over current is the current greater than the rated current of the circuit. It may occur in tow ways:

1. As an overload current.
2. As short-circuit of fault current.

These condition need to protection against in order to avoid damage system circuit.

- **Overload**

Overload current occurring when we connect to the system loads more than the allowable value of loads. we can protect the system from overload current by connecting an overload contactor parallel to the load adjusted to equal or less of the max. full load current, to explain this shown Figure 6-1.

- **Short circuit**

A short circuit current flow in the system when a "dead short" occurs between life conductors. Prospective short circuit current is the same, but the term is usually used to signify the value of short circuit at a fuse or circuit breaker position, to explain this shown Figure 6-2.

6.3 Component of earth

1. AC circuit breaker.
2. DC circuit breaker .
3. Earth set.

6.4 Connect DC circuit breaker

In this inverter there is DC circuit breaker shown Figure 6-1.

Figure 6-1 DC circuit breaker

6.5 Connect AC circuit breaker

Figure 6-2 AC circuit breaker

6.6 Connect earth set

Connecting with the earth system to protect it from current leakage to the outside structured.

1. Connect earth set on PV structure shown Figure6-3.

Figure 6-3 Step 1

2. Connect earth set on DB shown Figure 6-4.

Figure 6-4 Step 2

CHAPTER SEVEN

RESULTS

7.1 Practical results.

7.2 Analysis of the practical result.

7.3 Summary of result.

7.1 Practical results

- The energy consumption rate of the office every day =8.1KWh/day, so annual energy =2956KWh/year.
- Average power output of the solar system every day =8.7KWh/day, so annual energy =3176KWh/year.
- Average output power from solar system per day =1407Wh.
- Maximum output power from solar system in hours noon =1805Wh.
- Average PV current/day =4.9A
- Average PV voltage/day = 372V.
- AC grid voltage = 230V.
- Maximum AC grid current =8.1A.
- Average production per day = 12KWh, at sun insulations =10 hours.
- The system total production from 7/5/2013 to 19/5/2013 is 154KWh.This practical results confirm with theoretical results.

7.1 Practical results

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7.2 Analysis of the practical results of the system

After running the system and follow-up of energy production during the month 5, we work a study of energy production over the next year and got the following results.

The following Table7-1 to Table 7-12 to explain brightness of the sun at one day of months January to December, to show the rate energy production at one hour per day. And the following Figure 7-1 to Figure 7-12 to show Graphical representation of expected product energy at one day of January to December.

Table 7-1 Energy production rate during the day of January

Brightness of the sun	Energy WH
6.40-7.40am	200
7.40-8.40 am	350
8.40-9.40 am	500
9.40-10.40 am	650
10.40-11.40 am	700
11.40-12.40 am	800
12.40-1.40pm	1000
1.40-2.40 pm	900
2.40-3.40 pm	650
3.40-4.40 pm	400
Total production/day	6150

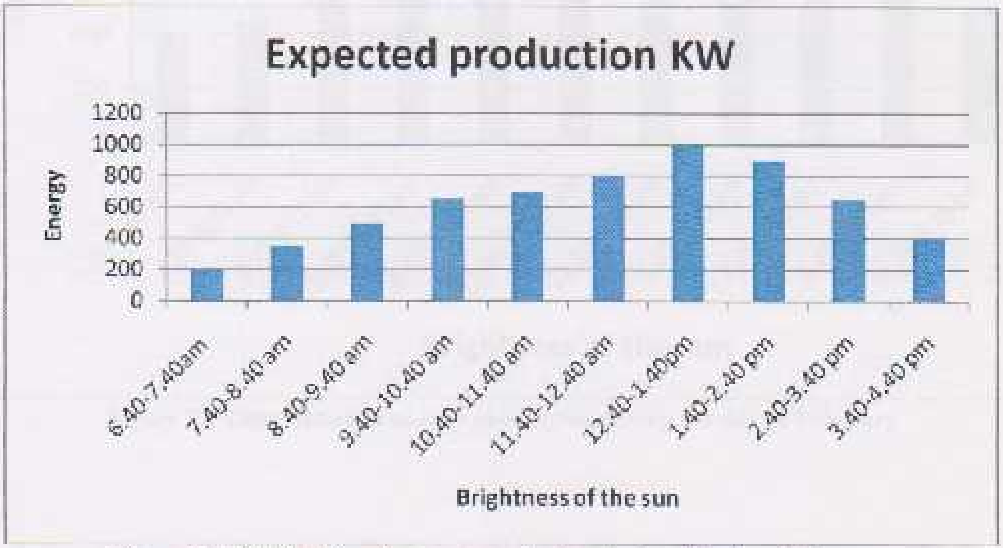

Figure 7-1 Distribution of energy production during the day of January

Table 7-2 Energy production rate during the day of February

Brightness of the sun	Energy Wh
6.25-7.25 am	400
7.25-8.25 am	450
8.25-9.25 am	600
9.25-10.25 am	850
10.25-11.25 am	900
11.25-12.25 am	1100
12.25-1.25 pm	1200
1.25-2.25 pm	1300
2.25-3.25 pm	900
3.25-4.25 pm	700
4.25-5.25 pm	500
Total production/day	8900

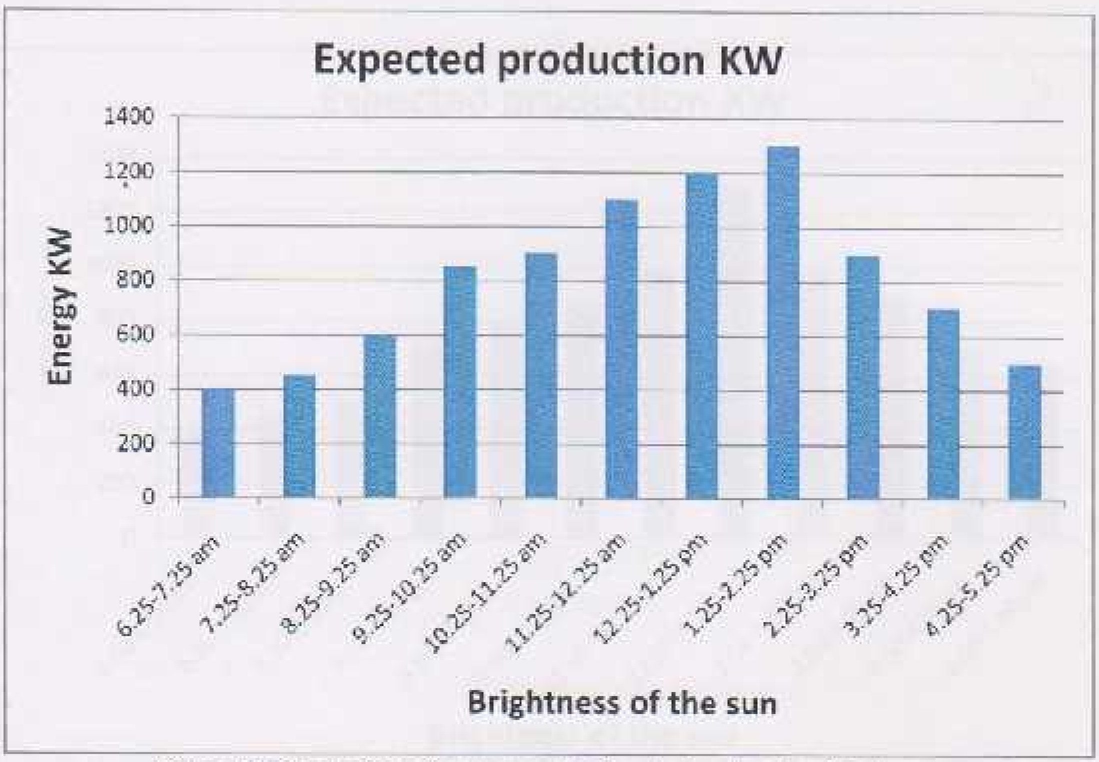

Figure 7-2 Distribution of energy production during the day of February

Table 7-3 Energy production rate during the day of March

Brightness of the sun	Energy Wh
5.50-6.50 am	400
6.50-7.50 am	450
7.50-8.50 am	500
8.50-9.50 am	700
9.50-10.50 am	800
10.50-11.50 am	850
11.50-12.50 pm	1000
12.50-1.50 pm	1300
1.50-2.50 pm	1000
2.50-3.50 pm	900
3.50-4.50 pm	700
4.50-5.50 pm	650
Total production /day	9250

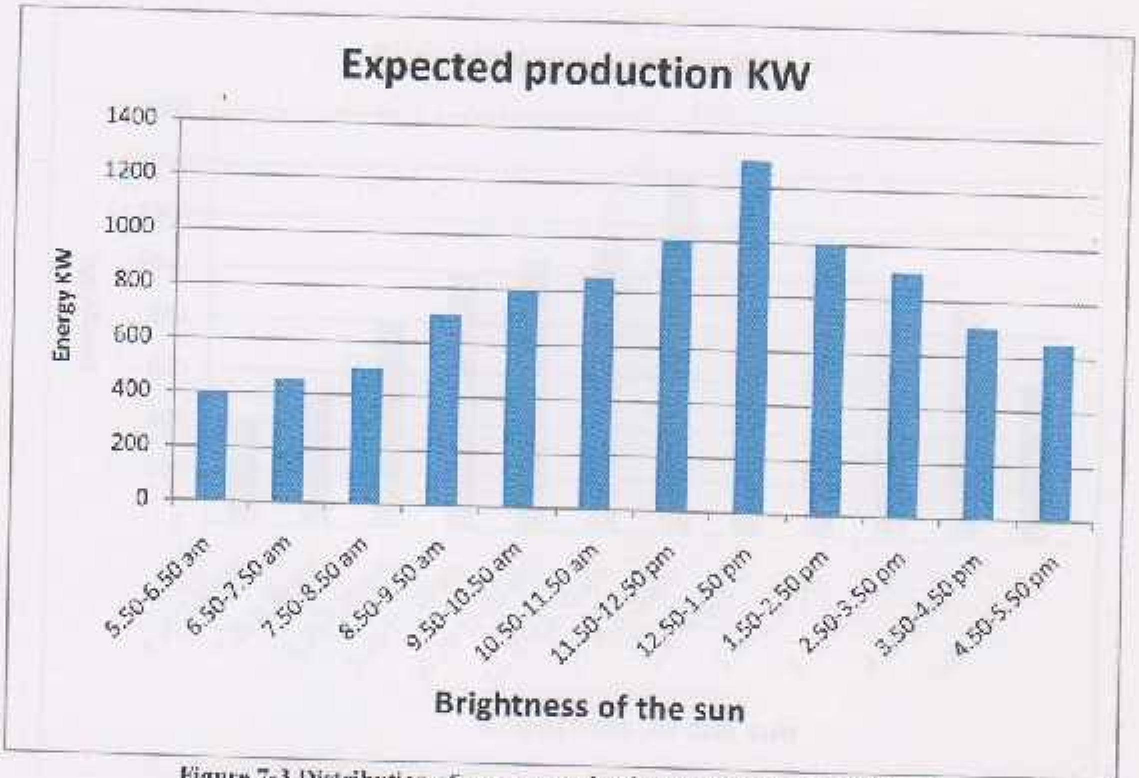

Figure 7-3 Distribution of energy production during the day of March

Table 7-4 Energy production rate during the day of April

Brightness of the sun	Energy Wh
6.30-7.30am	400
7.30-8.30 am	500
8.30-9.30 am	800
9.30-10.30 am	1000
10.30-11.30 am	1050
11.30-12.30 am	1100
12.30-1.30pm	1400
1.30-2.30 pm	1200
2.30-3.30 pm	1100
3.30-4.30 pm	950
4.30-5.30pm	900
5.30-6.30 pm	600
Total production/day	11000

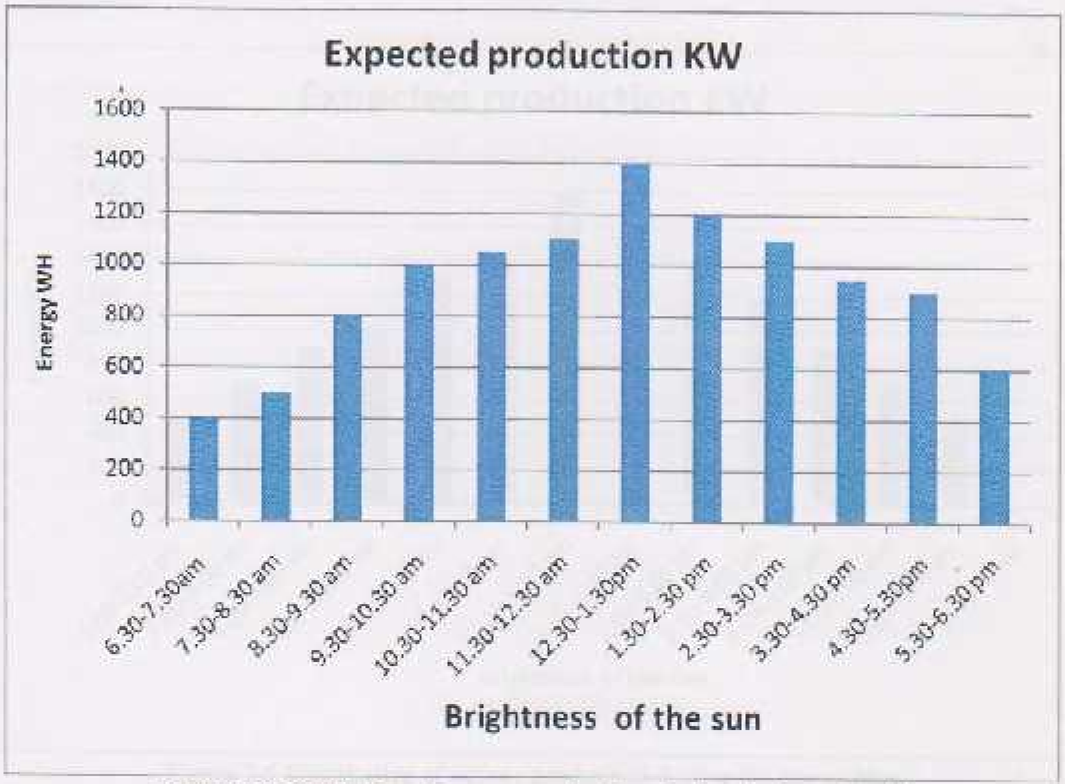

Figure 7-4 Distribution of energy production during the day of April

Table 7-5 Energy production rate during the day of May

Brightness of the sun	Energy Wh
6.00-7.00 am	500
7.00-8.00 am	700
8.00-9.00 am	900
9.00-10.00 am	1000
10.00-11.00 am	1300
11.00-12.00 am	1405
12.00-1.00 pm	1805
1.00-2.00 pm	1700
2.00-3.00 pm	1400
3.00-4.00 pm	1200
4.00-5.00 pm	900
5.00-6.00 pm	700
6.00-7.00 pm	500
Total production	14010Wh

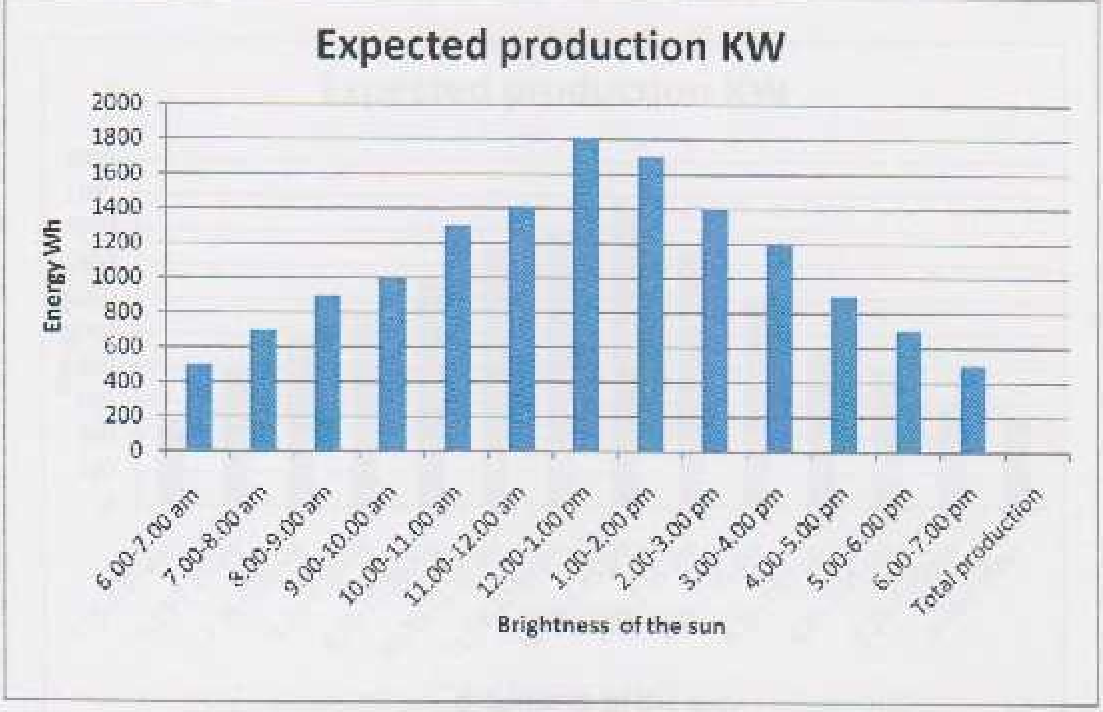

Figure 7-5 Distribution of energy production during the day of May

Table 7-6 Energy production rate during the day of June

Brightness of the sun	Energy Wh
5.35-6.35 am	500
6.35-7.35 am	800
7.35-8.35 am	1000
8.35-9.35 am	1100
9.35-10.35 am	1300
10.35-11.35 am	1500
11.35-12.35 pm	1600
12.35-1.35 pm	1800
1.35-2.35 pm	1500
2.35-3.35 pm	1200
3.35-4.35 pm	900
4.35-5.35 pm	800
5.35-6.35 pm	600
6.35-735pm	500
Total production /day	15100

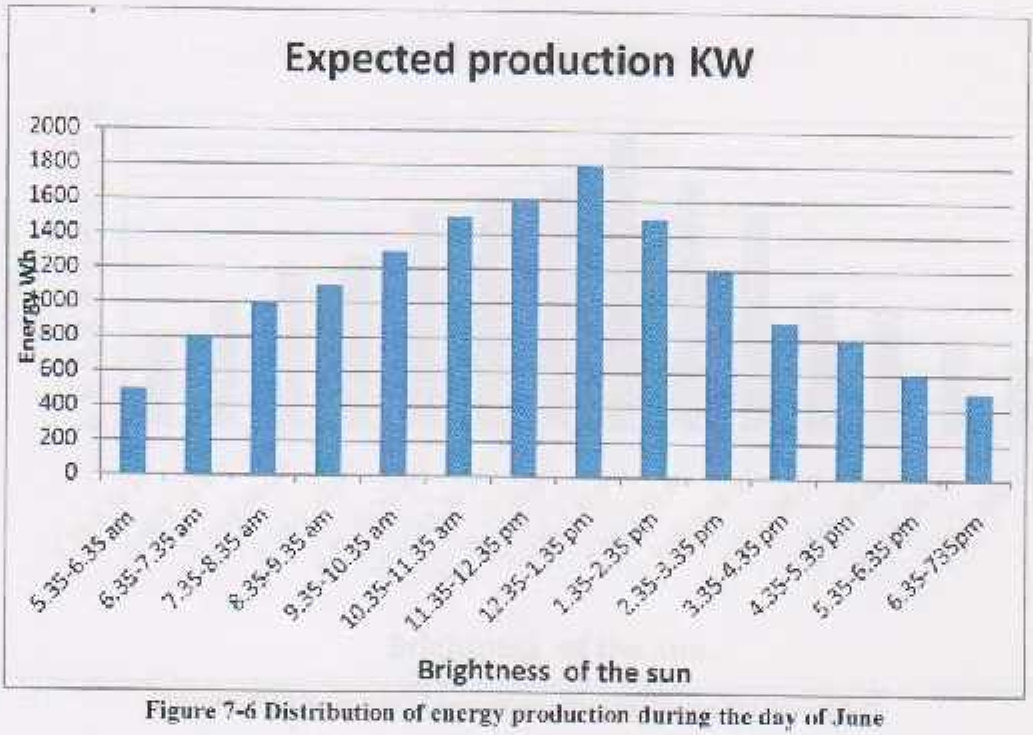

Figure 7-6 Distribution of energy production during the day of June

Table 7-7 Energy production rate during the day of July

Brightness of the sun	Energy Wh
5.38-6.38 am	600
6.38-7.38 am	800
7.38-8.38 am	1000
8.38-9.38 am	1100
9.38-10.38 am	1400
10.38-11.38 am	1500
11.38-12.38 pm	1600
12.38-1.38 pm	1900
1.38-2.38 pm	1600
2.38-3.38 pm	1400
3.38-4.38 pm	900
4.38-5.38 pm	800
5.38-6.38 pm	600
6.38-7.38pm	500
Total production /day	15700

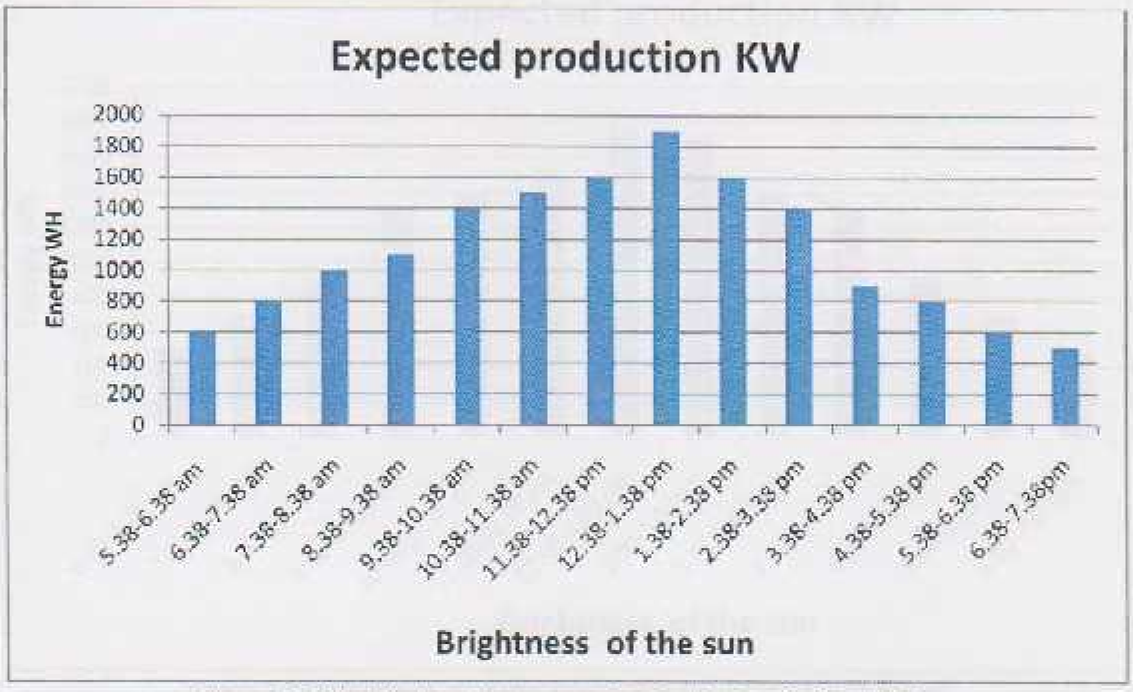

Figure 7-7 Distribution of energy production during the day of July

Table 7-8 Energy production rate during the day of August

Brightness of the sun	Energy Wh
6.00-7.00 am	500
7.00-8.00 am	700
8.00-9.00 am	900
9.00-10.00 am	1300
10.00-11.00 am	1400
11.00-12.00 am	1505
12.00-1.00 pm	1805
1.00-2.00 pm	1700
2.00-3.00 pm	1400
3.00-4.00 pm	1300
4.00-5.00 pm	900
5.00-6.00 pm	700
6.00-7.00 pm	500
Total production/day	14610

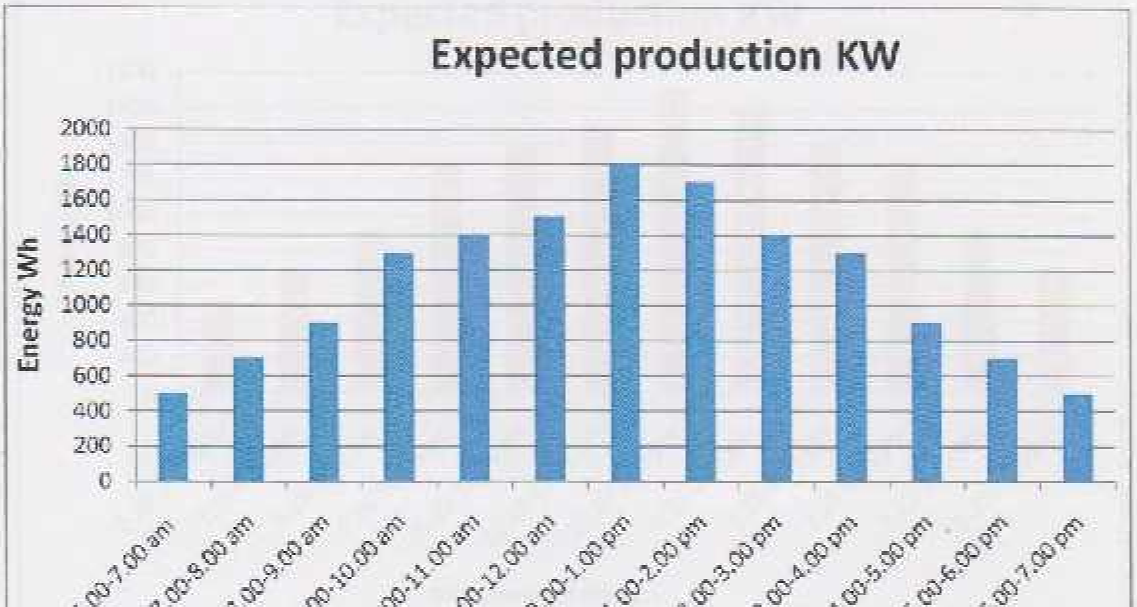

Figure 7-8 Distribution of energy production during the day of August

Table 7-8 Energy production rate during the day of August

Brightness of the sun	Energy Wh
6.00-7.00 am	500
7.00-8.00 am	700
8.00-9.00 am	900
9.00-10.00 am	1300
10.00-11.00 am	1400
11.00-12.00 am	1505
12.00-1.00 pm	1805
1.00-2.00 pm	1700
2.00-3.00 pm	1400
3.00-4.00 pm	1300
4.00-5.00 pm	900
5.00-6.00 pm	700
6.00-7.00 pm	500
Total production/day	14610

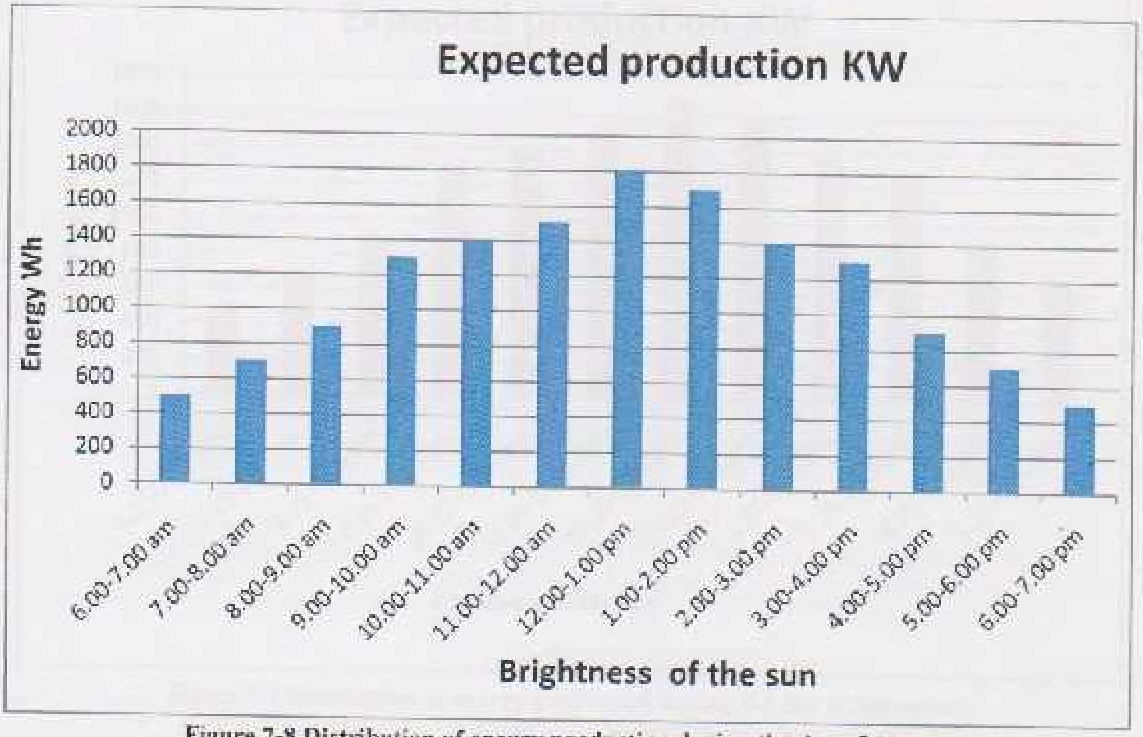

Figure 7-8 Distribution of energy production during the day of August

Table 7-9 Energy production rate during the day of September

Brightness of the sun	Energy Wh
6.25-7.25 am	500
7.25-8.25 am	700
8.25-9.25 am	900
9.25-10.25 am	1300
10.25-11.25 am	1400
11.25-12.25 am	1505
12.25-1.25 pm	1705
1.25-2.25 pm	1600
2.25-3.25 pm	1400
3.25-4.25 pm	1300
4.25-5.25 pm	900
5.25-6.25 pm	700
Total production/day	13910

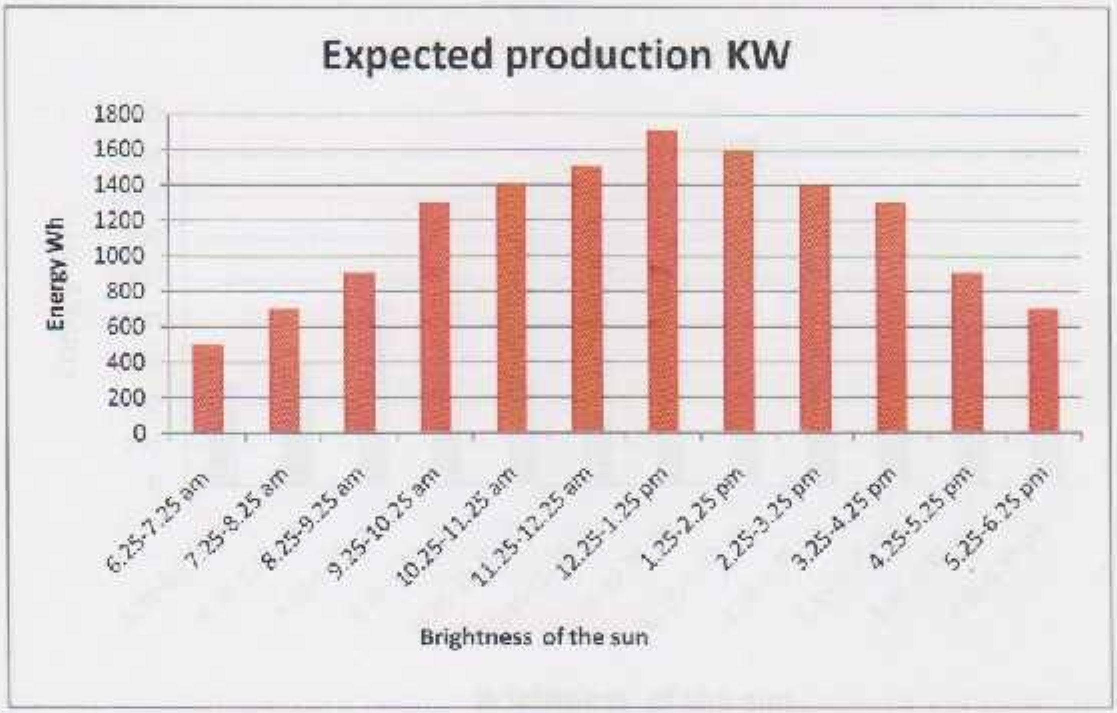

Figure 7-9 Distribution of energy production during the day of September

Table 7-10 Energy production rate during the day of October

Brightness of the sun	Energy Wh
5.35-6.35 am	500
6.35-7.35 am	600
7.35-8.35 am	900
8.35-9.35 am	1100
9.35-10.35 am	1300
10.35-11.35 am	1350
11.35-12.35 pm	1489
12.35-1.35 pm	1700
1.35-2.35 pm	1350
2.35-3.35 pm	1000
3.35-4.35 pm	900
4.35-5.35 pm	800
Total production /day	12989

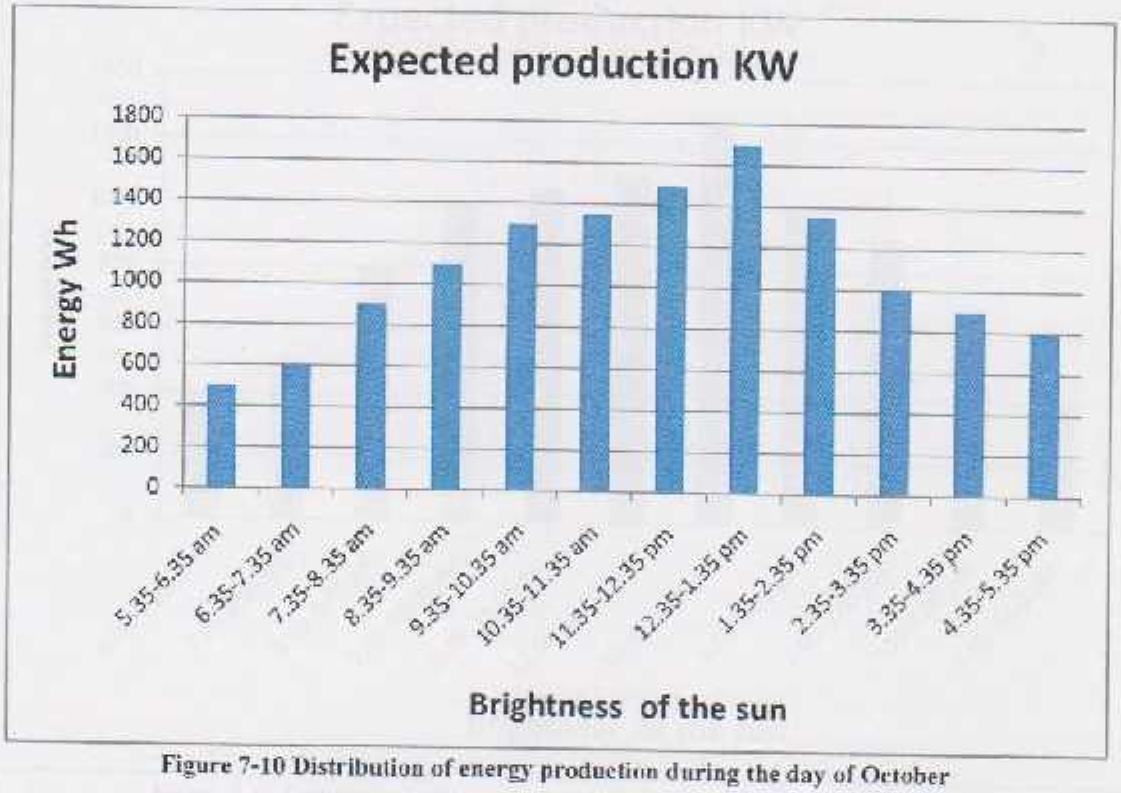

Figure 7-10 Distribution of energy production during the day of October

Table 7-11 Energy production rate during the day of November

Brightness of the sun	Energy Wh
6.05-7.05 am	400
7.05-8.05 am	500
8.05-9.05 am	800
9.05-10.05 am	1000
10.05-11.05 am	1050
11.05-12.05 am	1100
12.05-1.05 pm	1300
1.05-2.05 pm	1000
2.05-3.05 pm	900
3.05-4.05 pm	600
4.05-5.00 pm	400
Total production/day	9050

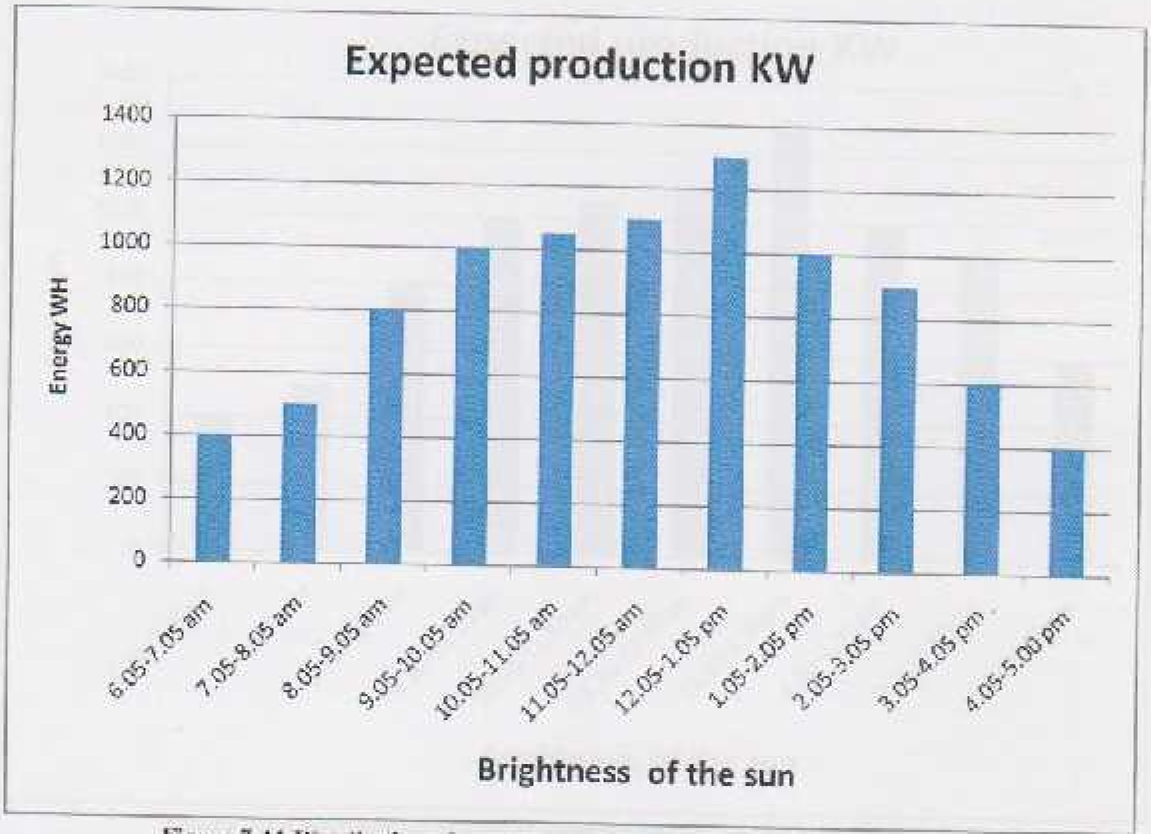

Figure 7-11 Distribution of energy production during the day of November

Table 7-12 Energy production rate during the day of December

Brightness of the sun	Energy Wh
6.30-7.30am	400
7.30-8.30 am	500
8.30-9.30 am	800
9.30-10.30 am	1000
10.30-11.30 am	1050
11.30-12.30 am	1100
12.30-1.30pm	1300
1.30-2.30 pm	1000
2.30-3.30 pm	900
3.30-4.30 pm	600
Total production/day	8650

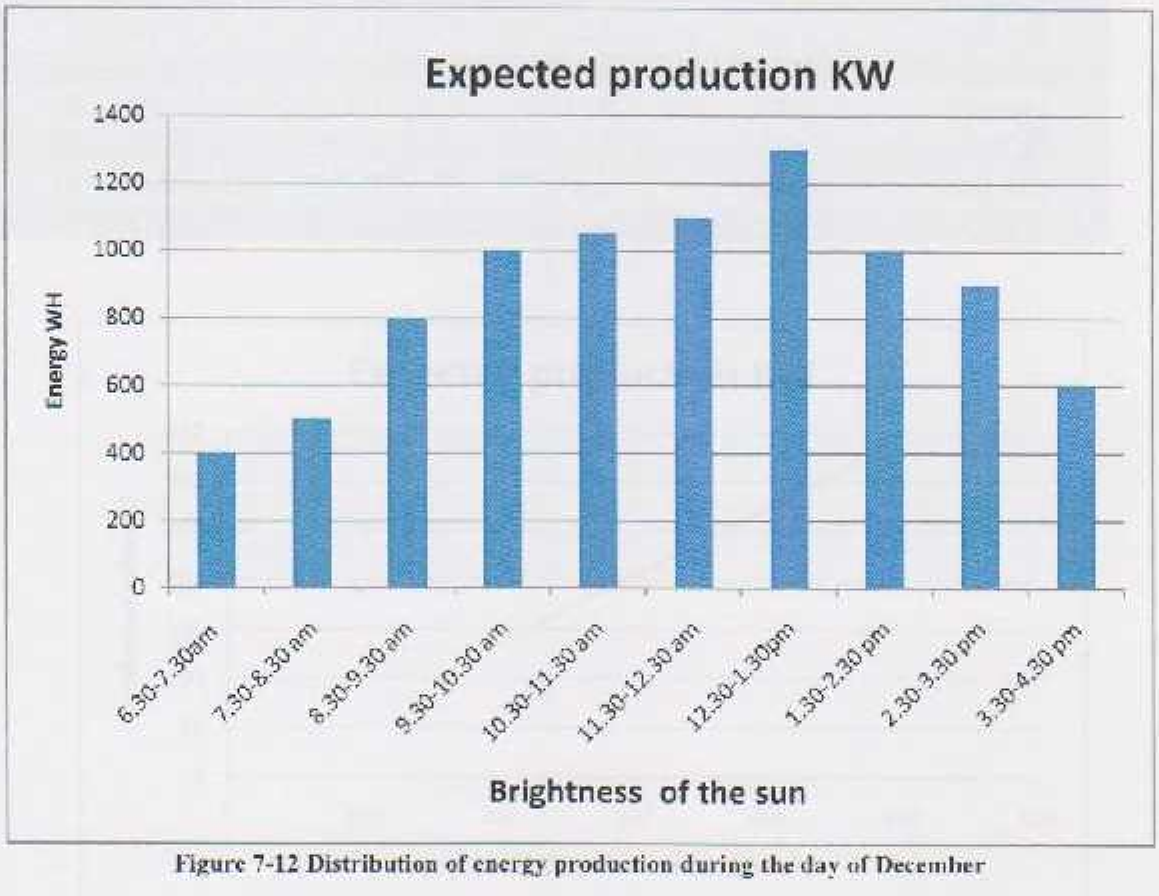

Figure 7-12 Distribution of energy production during the day of December

7.3 Summarize previous results

After study the previous results we concluded this result, shown the Table 7-13 to explain the expect production energy per year.

Table 7-13 Expected production energy per year

Month	No. of day	Production energy /day	Expected production KW	Production value NIS
January	31	6.15	190.65	129.642
February	28	8.9	249.2	169.456
March	31	9.25	286.75	194.99
April	30	11	330	224.4
May	31	14	434	295.12
June	30	15.1	453	308.04
July	31	15.7	486.7	330.956
August	31	14.6	452.6	307.768
September	30	13.9	417	283.56
October	31	12.9	399.9	271.932
November	30	9	270	183.6
December	31	8.6	266.6	181.288
year			**4235**	**2879.8**

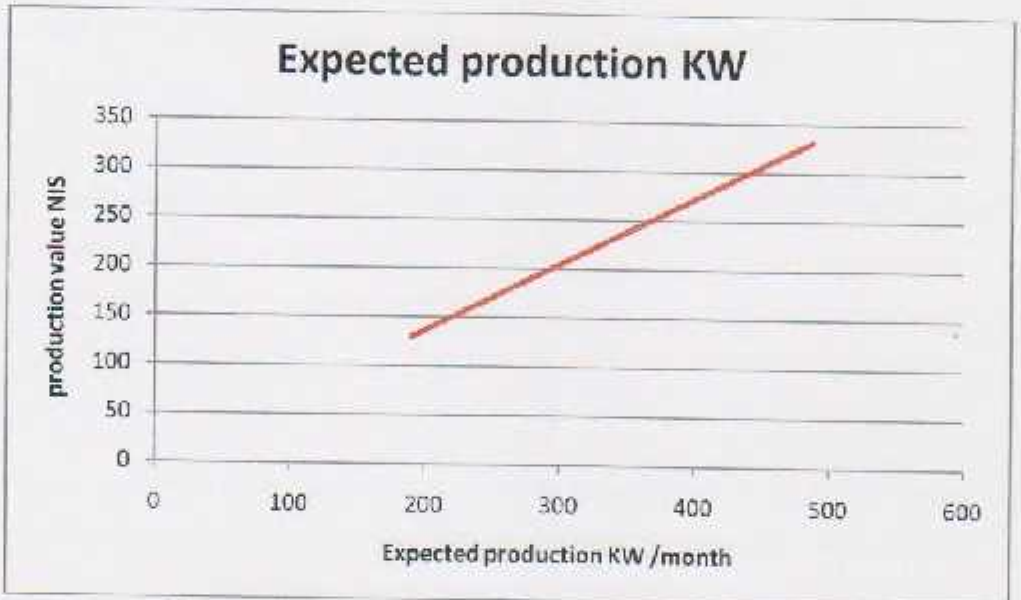

Figure 7-13 Distribution of energy production during per year

CHAPTER EIGHT

CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion.

8.2 Recommendations.

8.1 CONCLUSION

In this work, the model was implemented for solar power system connected to the network and we came to the following conclusions can be drawn:

- ✓ The proposed PV model consists of variable tracking module and voltage drop compensating module that can be used for either dc or ac loads with precise voltage tracking procedure. The added power-status estimator modules create new aspect to this model, where the power shortages can be measured and delivered from alternative sources or main ac-grid.
- ✓ This model can be used for simulating photovoltaic system individually or combined with battery charging unit. During the daytime there is no need of battery unit, resulting in efficiency enhancement, reliability of the system and long life time. Meanwhile, during the night time the load is directly energized from the grid, which in turn enhances the system reliability and reduces the total cost.
- ✓ After calculating the average daily load energy for the office, which is equal to 8.1 KWh, and by using Grid-Tie solar system we find that we need 13 m^2 PV module area, and we need 8 module of (AYAVA SALAR AY Series Monocrystalline) with 250W each.
- ✓ We have implemented "Grid-tie solar system" in the semester because the more efficiency and low operating cost, low maintenance, easy installation, long life and saving in the bills.
- ✓ In this project feeding the electrical loads depends mainly on solar energy, which mainly will feed the loads directly, and the system has been developed to cover all electrical loads in the office efficiently, and the main grid in this system will be used in case of energy shortages when the solar system failed to cover loads fully, where sometimes solar system become unable due to cloudy weather and partially sunny days.

8.2 Recommendations

- Work on the follow-up system on a daily to record data to ensure economic feasibility in the coming days, in order to compare the results of the operation during the year with the theoretical calculations.
- In the future, the system can be linked via the Internet to store data on a daily with the aim of studies and research work in the possibility of the development of the system to be able to fully provide the university and dispensing Country Network.
- Work on development of the system so that it is able to change the angle of inclination, by PID controller.
- Find the possibility of the development of the inverter, so that it provides a load in the case of power break Country Network.
- Find ways to rationalize the consumption of electric power at the university, in order to build a complete solar system provides the university at a lower cost.

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APPENDIX

A

Appendix A

Table A.1 Hourly average solar radiation of typical summer day (11/6/2011).[12]

Hours	**Solar Radiation (w/m^2)**	**Hours**	**Solar Radiation (w/m^2)**
1:00	0	13:00	990
2:00	0	14:00	917
3:00	0	15:00	780
4:00	0	16:00	585
5:00	30	17:00	375
6:00	140	18:00	154
7:00	343	19:00	20
8:00	532	20:00	0
9:00	747	21:00	0
10:00	910	22:00	0
11:00	1019	23:00	0
12:00	1062	24:00	0

These measurements are obtained from the Energy Research Center (ERC).

Table A.2 Ambient temperature in Tubas[12]

Hours	**Ambient temperature (C°)**	**Hours**	**Ambient temperature (C°)**
1:00	22	13:00	32
2:00	22	14:00	32
3:00	22	15:00	31
4:00	21	16:00	31
5:00	21	17:00	29
6:00	22	18:00	28
7:00	23	19:00	26
8:00	24	20:00	24
9:00	25	21:00	24
10:00	27	22:00	23
11:00	28	23:00	22
12:00	31	24:00	22

These measurements are obtained from the Energy Research Center (ERC).
From the data Table A.2. It shows that the maximum temperature occurs around noon time (32°C), and the minimum temperature occurs in the early morning (21°C).

Solar Energy in Palestine

Palestine has high potential of solar energy. It has around 3000 sunshine hours / year and high annual average solar energy radiation which is about 5.4 kWh / m2 - day.

Table A.3 Monthly solar energy on horizontal surface for Tubas District –2011[12]

Month	kWh/m^2-day	Month	kWh/m^2-day
January	2.885	July	8.167
February	3.247	August	8.099
March	5.226	September	6.304
April	6.247	October	4.700
May	7.565	November	3.562
June	8.245	December	2.840

APPENDIX

B

ayava solar

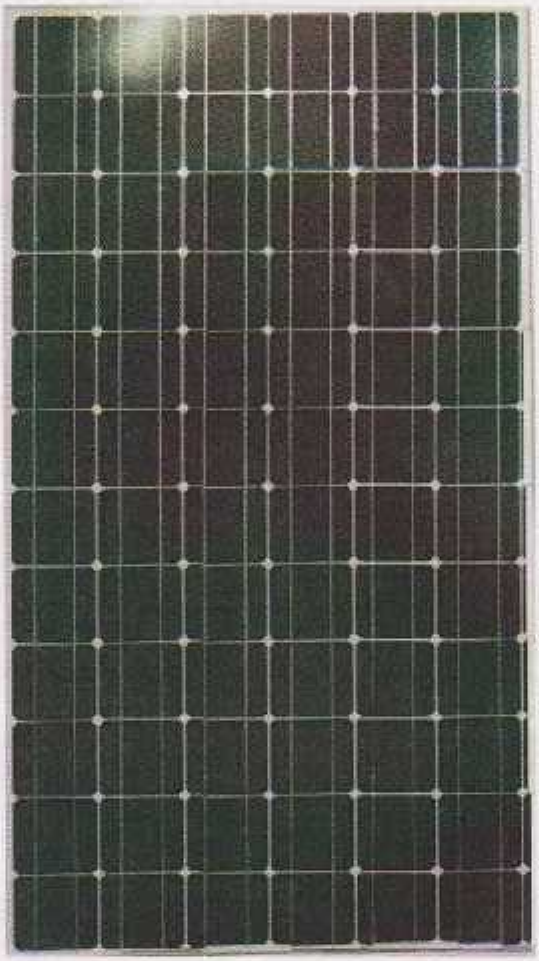
AYAVA SALAR
AY Series Monocrystalline

250 Wp

American quality is now affordable!

Features:

- High module conversion efficiency, through superior manufacturing technology
- Guaranteed 0% to +3% Power Tolerance
- Entire module certificated to withstand high wind loads and snow loads (5400Pa)
- Anodized aluminum is mainly for improving corrosion resistance.
- Highly transparent, low-iron, tempered glass, and antireflective coating
- Excellent performance under low light environments
- 25-year warranty on power output; 10-year warranty on materials and workmanship
- Product liability insurance
- Local technical support
- Local warehousing
- 48 hour-response service
- Enhanced design for easy installation and long term reliability



TÜV CE c UL us LISTED

AYAVA SALAR AY Series Monocrystalline
250 Wp

Electrical Specifications:

ITEM NO	AYS250M
Maximum Power (Wp)	250
Maximum Power Voltage (V)	48.5
Maximum Power Current (A)	5.15
Open Circuit Voltage (V)	58.1
Short Circuit Current (A)	5.58
Size of Module (mm)	1580 × 1058 × 46
Size of Glass (mm)	1574×1052×3.2
Size of solar cells (mm)	Mono 125
Number of cells (Pcs)	96
Maximum System Voltage (VDC)	1000
Temperature Coefficients of Isc (%/℃)	0.05
Temperature Coefficients of Voc (%/℃)	-0.35
Temperature Coefficients of Pm (%/℃)	-0.45
Nominal operating cell temperature( )	45±2
Temperature Range( )	-40 to +85
Surface Maximum Load Capacity (Pa)	2400
Allowable Hail Load	ø25mm_23m·s^{-1}
Weight Per Piece (kg)	21.5
Efficiency for module (%)	14.95
Efficiency for cell(%)	17.10
Warranty	5 years product warranty and 90% of power output for the first 10 years of the modules life and 80% for the next 25
Packing	588pcs/40″ container , 14 pallets total per container 42 pcs solar module per pallet

Note:

The specifications and obtained under the standard Test Conditions (STC): 1000W/ m² solar irradiance, 1.5 Air Mass,and cell temperature of 25℃

APPENDIX

C

MAKING MODERN LIVING POSSIBLE

Danfoss

Linea Inverter UniLynx

Cabinet indoor e outdoor monofase con trasformatore 1.8, 3.0, 3.6 e 5.4 kW

SOLAR INVERTERS

Il configuratore di sistema aiuta gli installatori nel dimensionamento dell'impianto fotovoltaico e nella scelta dell'inverter.

Il sezionatore DC integrato assicura la massima sicurezza durante i lavori.

Gli ingressi fotovoltaici separati e indipendenti [illegible] dedicati tracker MPP [illegible] ingresso multistringa.

Massima Versatilità

- **Ingresso CC multiplo**
  Grazie all'ingresso multiplo le perdite di mismatch dei moduli e le perdite dovute a ombreggiamento parziale sono molto ridotte. Se una stringa non opera in maniera ottimale, le due stringhe rimanenti sono in grado di continuare a produrre senza problemi.

- **Un inverter per 16 paesi**
  Tutti gli inverter Danfoss possono funzionare in 16 differenti paesi e sono configurabili sul posto. È possibile selezionare il paese in fase di setup iniziale e l'inverter si configura in accordo alle normative del paese.

- **Configurazione con ingressi indipendenti o in parallelo**
  Il medesimo inverter può funzionare con gli ingressi in configurazione indipendente oppure in parallelo (master/slave), a seconda della configurazione dei collegamenti. Se tutti i pannelli sono identici la configurazione master/slave è quella ideale. Se i pannelli sono di vario tipo, oppure se sono orientati in modo diverso, o hanno modalità di funzionamento differenti, allora la configurazione indipendente è quella ideale in quanto a ciascun ingresso viene assegnato un tracker MPP indipendente. L'inverter effettua automaticamente un controllo delle connessioni e attiva la configurazione appropriata.

- **Compatibile con qualunque tipo di pannello**
  UniLynx ha due versioni: Alta tensione (HV) dedicata ai pannelli che usano celle da 5 pollici, e Media tensione (MV) dedicata a pannelli che usano celle da 6 pollici. L'impiego di range di tensione di ingresso dedicati limita le perdite di potenza e assicura che la tensione di funzionamento della stringa è ottimizzata per la migliore resa energetica. L'inverter può anche essere collegato senza problemi a pannelli a film sottile.

Resa energetica ottimale

- **Alta efficienza del tracker MPP**
  Trackers MPP indipendenti assicurano che il sistema operi sempre alla massima potenza anche in caso di pannelli differenti o orientati diversamente. La precisione del tracker MPP è stata misurata dall'Istituto Arsenal Research di Vienna e in un test (SORRIP) in cui sono stati utilizzati dati statistici rappresentativi delle condizioni tipiche di irraggiamento nel corso dell'anno per calcolare la efficienza. Con irraggiamento costante la precisione del tracker MPP è del 99,9% (Efficienza Europea MPP). In condizioni dinamiche la efficienza del tracker è del 99,4%.

- **Algoritmo "Ride Through"**
  Tutti gli inverter Danfoss hanno un algoritmo integrato detto "Ride Through" che assicura che l'inverter rimanga collegato anche durante gravi disturbi di rete. L'inverter si disconnette dalla rete solo quando vengono oltrepassati i limiti stabiliti della normativa di riferimento.

- **Funzione di derating**
  In caso di condizioni anomale di aumento di tensione di rete, aumento dei livelli di corrente o temperature ambiente troppo elevate, l'inverter si protegge limitando automaticamente la potenza (derating). Questa protezione permette all'inverter di continuare ad operare anche se le condizioni eccedono i normali limiti di funzionamento. Ciò permette di incrementare la resa energetica dell'impianto senza mettere a rischio l'affidabilità dell'inverter, permettendo di aumentarne la vita utile.

- **Avviamento al mattino presto e spegnimento alla sera tardi**
  Gli inverter Danfoss usano una speciale combinazione di due algoritmi MPPT appositamente progettata per funzionare con livelli di irraggiamento elevati o minimi, che assicura una produzione anche in presenza di un irraggiamento basso.

Comunicazione e monitoraggio

- **Comunicazione RS 485**
  Tutti gli inverter possono essere connessi a un sistema di rilevazione dati via cavo seriale RS 485 per la comunicazione dei dati di funzionamento e il monitoraggio degli impianti.

Semplice e sicuro da installare e manutenere

- **Connessioni standard CC e CA**
  Gli inverter Danfoss non possono essere configurati in maniera sbagliata: uno speciale controllo legge il cablaggio di ingresso e configura automaticamente la macchina.

- **Interruttore CC integrato**
  Per la protezione dell'installatore e del personale di servizio, i nostri inverter sono dotati di un sezionatore CC integrato che permette la disconnessione del generatore fotovoltaico in condizioni di assoluta sicurezza.

- **Servizio on-site**
  Gli inverter UniLynx hanno una costruzione modulare. Tutti gli inverter hanno una scheda CA e una scheda CC dedicate per ciascun ingresso. Ogni scheda può essere facilmente sostituita sul posto se necessario.

- **Tool assistenza**
  Il software di assistenza rende il servizio estremamente semplice permettendo al tecnico di configurare e monitorare gli inverter e di aggiornare il software di funzionamento mediante una connessione standard RS 485.

Specifiche tecniche:	ULX 1800	ULX 3000	ULX 3600	ULX 5400
Potenza nominale CC	1800 W	3300 W	3800 W	5400 W
Potenza CC max	1950 W	3300 W	3900 W	5600 W
Massima Potenza FV raccomandata alle condizioni di prova normalizzate (STC)	1950 Wp	3300 Wp	3900 Wp	Esterni: 5400/5600 Wp Interni: 5400 Wp
Potenza nominale CA	1650 W	2750 W	3300 W	Esterni: 4600/5000 W Interni: 4600 W [1]
Max potenza CA	1800 W	3000 W	3600 W	5000/5400 W [1]
Max efficienza	93,70 %	94,70 %	94,29 %	94,30 %
Euro Efficienza	91,80 %	92,70 %	93,20 %	93,40 %
Fattore di potenza	0,97 a > 20 % carico	0,97 a > 20 % carico	0,97 a > 20 % carico	0,97 a > 20 % carico
Potenza di accensione	20 W	20 W	20 W	20 W
Consumo Standby	6 W	8 W	8 W	8 W
Consumo notturno	< 0,2 W	< 0,2 W	< 0,2 W	< 0,2 W
Tensioni:				
Tensione Nominale CC MV	310 V	310 V	310 V	310 V
Tensione Nominale CC HV	450 V	430 V	430 V	430 V
Intervallo di tensione MPP MV - potenza nominale	160-350 V	180-350 V	180-350 V	180-350 V
Intervallo di tensione MPP HV - potenza nominale	260-500 V	260-500 V	260-500 V	260-500 V
Max tensione CC MV Indipendente/Parallelo	450/410 V	450/410 V	450/410 V	450/410 V
Max tensione CC HV Indipendente/Parallelo	600/550 V	600/550 V	600/550 V	600/550 V
Tensione di accensione CC MV	125 V	125 V	125 V	125 V
Tensione di accensione CC HV	250 V	250 V	250 V	250 V
Tensione di spegnimento CC MV	100 V	100 V	100 V	100 V
Tensione di spegnimento CC HV	200 V	200 V	200 V	200 V
Range tensione CA	230 ± 15% V	230 ± 15% V	230 ± 15 % V	230 ± 15 % V
Frequenza griglia	50 ± 5 Hz	50 ± 5 Hz	50 ± 5 Hz	50 ± 5 Hz
Correnti:				
Max corrente CC MV	12 A	2 x 10 (20) A*	2 x 12 (20) A*	3 x 12 (20) A*
Max corrente CC HV	7 A	2 x 7 (11) A	2 x 7 (14) A	3 x 7 (21) A*
Corrente nominale CA	7,2 A	12 A	14,5 A	Esterni 20/22 A / Indoor 20 A
Max corrente CA	8 A	13 A	15,5 A	23 A
Distorsione (THD%)	< 3 %	< 3 %	< 3 %	< 3 %
Altro:				
Dimensioni (LxWxH)	Outdoor 488x434x192 mm/ Indoor 399x386x188 mm	Outdoor 618x434x192 mm/ Indoor 458x399x188 mm	Outdoor 618x434x192 mm/ Indoor 458x386x188 mm	Outdoor 747x434x192 mm/ Indoor 631x386x188 mm
Peso	Outdoor 17 kg/Indoor 14 kg	Outdoor 22 kg/Indoor 20 kg	Outdoor 26 kg/Indoor 26 kg	Outdoor 29 kg/Indoor 25 kg
Rumore acustico	Outdoor 44 dB(A)/Indoor 45 dB(A)	Outdoor 42 dB(A)/Indoor 45 dB(A)	Outdoor 51 dB(A) / Indoor 45 dB(A)	Outdoor 35 dB(A)/ Indoor 40 dB(A)
Intervallo operativo temperatura	-25 ... +60 °C	-25 ... +60 °C	-25 ... +60 °C	-25 ... +60 °C
Efficienza MPP (statica)	99,9 %	99,9 %	99,9 %	99,9 %
Modalità protezione sovraccarico	Cambio del punto di funzionamento	Cambio del punto di funzionamento	Cambio del punto di funzionamento	Cambio del punto di funzionamento
Protezione anti-islanding	Maschera V/f & misura impedenza	Maschera V/f & misura impedenza	Maschera V/f & misura impedenza	Maschera V/f & misura impedenza
Montaggio preferenziale	Flangia a muro	Flangia a muro	Flangia a muro	Flangia a muro
IP	IP 21/IP 54	IP 21/IP 54	IP 21/IP 54	IP 21/IP 54
Isolation monitoring	Incluso	Incluso	Incluso	Incluso
Isolamento galvanico	Trasformatore	Trasformatore	Trasformatore	Trasformatore
Comunicazione seriale	RS485	RS485	RS485	RS485
Display	Display	Display	Display	Display
Sezionatore CC	Sezionatore CC	Sezionatore CC	Sezionatore CC	Sezionatore CC
Modalità stringhe in parallelo	Autodetect	Autodetect	Autodetect	Autodetect
Norme di riferimento:				
Direttiva LVD	73 / 23 / EC	73 / 23 / EC	73 / 23 / EC	73 / 23 / EC
Direttiva EMC	2004 / 108 / EC	2004 / 108 / EC	2004 / 108 / EC	2004 / 108 / EC
Sicurezza EN	EN 50178	EN 50178	EN 50178	EN 50178
Immunità EMC	EN 61000-6-1	EN 61000-6-1	EN 61000-6-1	EN 61000-6-1
	EN 61000-6-2	EN 61000-6-2	EN 61000-6-2	EN 61000-6-2
	EN 61000-4-13, -14, -28	EN 61000-4-13, -14, -28	EN 61000-4-13, -14, -28	EN 61000-4-13, -14, -28
	EN 60146-1	EN 60146-1	EN 60146-1	EN 60146-1
Emissioni EMC	EN 61000-6-3	EN 61000-6-3	EN 61000-6-3	EN 61000-6-3
	EN 61000-6-4	EN 61000-6-4	EN 61000-6-4	EN 61000-6-4
Interferenza rete	EN 61000-3-2, -3	EN 61000-3-2, -3	EN 61000-3-2, -3	EN 61000-3-11, -12
Protezione funzionale Anti Islanding	DIN VDE 0126-1-1	DIN VDE 0126-1-1	DIN VDE 0126-1-1	DIN VDE 0126-1-1
CE	Yes	Yes	Yes	Yes
Standard rete IEC	IEC 61727, EN 50160	IEC 61727, EN 50160	IEC 61727, EN 50160	IEC 61727, EN 50160
Italia	DK5940	DK5940	DK5940	DK5940
Spagna	RD1663	RD1663	RD1663	RD1663

Ottobre 2009

*Max 10 A per stringa

1) Per sistemi fissi in condizioni quasi normali

2) In funzione delle impostazioni del paese

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