إقـــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Modeling and Simulation for Renewable Energy System based on Solar Power at Al-Shifaa Medical Complex in Gaza

Decision Support System Approach

نموذج محاكاة لنظام طاقة متجدد يعتمد على الطاقة الشمسية في مجمع الشفاء الطبي في غزة
نظام دعم اتخاذ القرار

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

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نظام دعم اتخاذ القرار

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ **سامح سعدى صالح أبو وردة** لنيل درجة الماجستير في **كلية *التجارة*/** قسم **إدارة الأعمال** وموضوعها:

نموذج محاكاة لنظام طاقة متجدد يعتمد على الطاقة الشمسية في مجمع الشفاء الطبي في غزة – نظام دعم اتخاذ القرار

Modeling and Simulation for Renewable Energy System based on Solar Power at Al-Shifaa Medical Complex in Gaza Decision Support System Approach

وبعد المناقشة التي تمت اليوم الاثنين 17 ربيع الأول 1437هـ، الموافق 2015/12/28م الساعة العاشرة صباحاً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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أ.د. سامي سليم أبو ناصر	مناقشاً خارجياً	....

وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في **كلية *التجارة*/** قسم **إدارة الأعمال**.

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق ،،،

نائب الرئيس لشئون البحث العلمي والدراسات العليا

أ.د. عبدالرؤوف علي المناعمة

Abstract

Based on decision support system and using the MATLAB/Simulink application, the aim of this study is to build a simulation model to design a solar electrical energy system for Al-Shifaa Medical Complex to help the decision makers with appropriate tool and statistics that help them to sort out the electricity problem at the hospital. It illustrates the number of solar panels, inverters and space needed to provide power to meet the specified design criteria besides all additions needed for the success of this project.

Abstract – Arabic

مستندة على نظام دعم اتخاذ القرار ومستخدمة برنامج الماتلاب، هدفت هذه الدراسة إلى بناء نموذج محاكات لنظام طاقة شمسية لمجمع الشفاء في غزة لمساعدة صناع القرار في المجمع في اتخاذ القرار المناسب من أجل حل مشكلة الكهرباء. ويوضح النموذج عدد الوحدات الشمسية والمحولات الكهربائية والمساحة المطلوبة من أجل إنجاح عملية اتخاذ القرار المناسب وانجاح المشروع.

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Last but not least, I would like to thank everyone contributed to the success of this dissertation.

Dedication

This humble work is dedicated:

To my devoted parents who paved the way of success for me and my brothers. They made us and saved our future as if no one ever would does.

To my sweetheart, my beloved Amina who supports me and stands around the hour pushing and motivating me to advance.

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List of abbreviations and Acronyms

- A: Amper
- A: Ideality factor
- AC: Alternating Current
- Ah: amper per hour
- BOS: Balance of System
- DC: Direct Current
- DSS: Decision Support System
- Ec: amount of energy that will restore the batteries
- I: Current delivered by the cell
- Id: Current through the diode
- Imax: Inverter maximum permissible current
- Ipv: photo generated current proportional to the illumination, it is the short-circuit current
- Is: the diode saturation current
- Isc: short circuit current
- k: Boltzmann constant
- kHz: Kilo hertz
- kW/m^2: Kilowatt per meter squared
- kW: Kilo watt
- kWh/m^2: Kilo watt per meter squared
- MPP: Maximum Power Point
- NOCT: Nominal Operating Cell Temperatures
- Pmax: maximum power point
- PV: Photovoltaic
- q: elementary charge
- Smin: minimum area of Photovoltaic system
- T: Junction temperature in K
- Umax: Maximum permissible input voltage of the inverter
- Umpp: Unit maximum power point
- Uoc: Unit open circuit voltage
- V: Voltage
- Vd: Voltage across the diode
- Voc: open circuit voltage
- Wp/m^2: maximum peak power per meter squared
- Wp: maximum power peak

Chapter 1: Introduction

1.1 Introduction

1.2 Problem Statement

1.3 Importance of Study

1.4 Study Objectives

1.5 Study Assumptions

1.6 Study Methodology

1.7 Data Collection Methods

1.8 Study Outline

1.1 Introduction

In the recent years, green power has attracted attention in many countries worldwide. Recent study has shown that 13.8% of the energy consumed across the world is generated from green energy resources that are steadily increase and improved over the time (World Energy Council for Renewable Energy, 2004).

Concerning Gaza, the electrical power situation has been deteriorating since 2006 after the Israeli shelling on the only power plant therein. The Power plant is fully dependent on fuel supplies. Due to the tight siege imposed on Gaza, there is a severe shortage in the fuel supply needed for the power plant. Therefore, the majority of Gazan households and institutions – including health institutions and hospitals – have power cuts for at least eight hours per day. In the same context, great many of life aspects have been suffering due to the continuous power failure (OCHA, 2014).

The power plant bombardment was crowned with an economic siege that hinder the plant restoration and maintenance. The Gaza's strip actual needs of electrical energy is about 350 Megawatts; however, the current available amount is around 140 Megawatts. All these factors have increased the hospital needs for renewable and green power systems.

In the Gaza, the flow of electric energy is intermittent at best where it goes off for 20 hours at many regions. Consider that in Al-Shifa Medical Complex, which is the largest medical complex in Gaza, the power goes out for an average of 12 hours each day. This poses an enormous challenge to running the complex; surgeries are jeopardized, neonatal ventilators at premature babies rooms stall, the cold chain is interrupted, and countless everyday tasks get derailed.

Based on the abovementioned information, this study aims at designing a simulation model for a renewable and green electric power system for the largest hospital in Gaza; Al-Shifaa Medical Complex.

1.2 Problem Statement

While the electricity crisis continues to deteriorate in Gaza, there is a need to find a solution for it especially in hospitals under the tight circumstances the strip undergoes. The non-stop function of the hospitals is an important factor why there is need for such renewable system where consumption is very high in hospitals due to the continuous operation, the large rooms, the medical equipment and the electric motors and devices.

In an interview with the technical team at the Hospital, it was tell that the hospital's consumption of electricity is 2,130 kWh/day.

The hospital provides medical services for around one million persons who are besieged in Gaza and deprived from receiving medical treatment outside. Therefore, the hospital needs continues electricity current to be capable of delivering sufficient medical services to all patients and affected people in the strip.

In addition, efforts are being put by the hospital's management to design and study the feasibility of establishing a solar system for the hospital.

Importance of Study

The proposed study focuses on the renewable and green power system (Solar Systems) in Al-Shifaa Medical Complex in Gaza. It shows the importance of establishing such system in the target hospital.

Moreover, the proposed study helps both the private and governmental sectors in making decisions about funding and establishing such system in Gaza's hospitals through providing deep and practical simulation for the system suiting the hospital.

Furthermore, the proposed system will reduce the expenses incurred by the hospital for the purchase of fuel needed for electrical power generators' operation. According to the hospital's technical team, the monthly fuel expenses is about 566,440.12 ILS (The total fuel cost for year 2014 is 6,797,281.44 ILS).

1.3 Study objectives

1.3.1 Main objective

The general aim of this study is to build a simulation model to design a solar electrical energy system for Al-Shifaa Medical Complex to help the decisions makers with appropriate tool and statistics that help them to sort out the electricity problem at the hospital. It is going to illustrate the number of solar panels needed to provide power to meet the specified design criteria besides all additions needed for the success of this project.

1.3.2 Sub objectives

a) Designing a simulation model to help decision makers establishing improved power solar system for Al-Shifaa medical complex as well as providing them with all alternatives that facilitate this task for them.

b) Providing a decision support system based on simulation to be a useful tool in designing the solar system for the whole complex.

c) Evaluating the performance of using the simulation model by the decision makers at the hospital.

d) Provide recommendations that will help managers to take best decision that help in alleviating the electricity problem at the Complex.

1.4 Study Assumptions

The study assumptions are:

a) The simulation model is based on information, statistics and data retrieved from the Al-Shifa technical management team during year 2014.

b) The simulation model exclude any hindrances caused by the political situation and governmental constraints. In other words, it is assumed that all necessary equipment required for the solar system can be imported.

c) The simulation model is going to be applied as soon as fund is available for the hospital (118,5500 US$).

1.5 Study Methodology

The study is going to be made as follow:

a) Required data were collected from the Ministry of Health, Al-Shifaa Medical Complex and Technicians; the data were classified and arranged in order to choose best alternatives.

b) Prerequisite consultations were made with experts in solar systems during designing the model in order to accurate calculations about the space needed, electrical conductors.

c) The model was designed and tested using the MATLAB/Simulink software simulation package; other computer application might were utilized to give best results needed.

d) The final model was discussed with experts in renewable green energy to get feedbacks and notes that would be considered and reflected.

e) Estimations and probability distribution were provided through analyzing the statistical dated retrieved.

1.6 Data Collection Methods

a) Existing data provided by Maintenance and Technical Support Department at Al-Shifaa Medical Complex.

b) Specifications provided by professional at renewable green electric systems (Solar Systems)

c) Interviews with specialists (Formal and Informal).

1.7 Study Outline

The research is planned to be documented as follow:

Table (1): Research Outline

Chapter	Details
Chapter One	Includes an introduction to the research where it presents: problem statement, importance of study, study objectives, study assumption, study methodology, scope and limitations, data collection methods and previous studies.
Chapter Two	Theoretical Framework that reviews many literatures related to the study.
Chapter Three	Focuses the light on several related studies that previously carried by specialists.
Chapter Four	Reviews simulation and modeling process of the system; renewable green solar system for Al-Shifaa Medical Complex and creating the model.
Chapter Five	Conclusion and recommendations.

Chapter 2: Literature Review

2.1 Al-Shif Medical Complex

2.2 Photovoltaic System

2.3 Methods of Converting Solar Energy to Electricity

2.4 Advantages of Solar Power Systems

2.5 Disadvantages of Solar Power Systems

2.6 Mechanism of Photovoltaic Cell

2.7 Energy Loss in a Solar Cell

2.8 Solving Solar Power Issues

2.9 Using MATLAB and Simulink to Simulate Solar Power System for Al-Shifa Medical Complex

2.10 What is DSS?

2.1 Introduction

Al-Shif Medical Complex is the largest medical complex and central hospital in Gaza, located in the neighborhood of North Rimal in Gaza City in the Gaza Governorate. was originally a British Army barracks, but was transformed into a center to provide treatment for quarantine and febrile diseases by the government of the British Mandate of Palestine. Prior to the 1948 Arab-Israeli War, al-Shifa was the only hospital in Gaza. When the Egyptians administered Gaza after the war, the quarantine and febrile diseases department was relocated to another area in the city and al-Shifa developed into the central hospital of Gaza. Initially, a department for internal medicine was established, followed by a new wing for surgery, and subsequently new buildings for pediatrics and ophthalmology were added to the hospital. In 2013, a special surgical building was opened. (Husseini and Barnea, 2002).

After a brief occupation by Israel during the 1956 Suez Crisis, the returning Egyptian administration, under directives by president Gamal Abdel Nasser, paid more attention to the health and social situation of Gaza, and al-Shifa was expanded to include departments for obstetrics and gynecology. They established a new health administration for the Gaza region, later building several clinics throughout the city that were attended by doctors from the hospital (Alejandro, 2009). The largest department in al-Shifa was internal medicine (100 beds), then pediatrics (70 beds), surgery (50 beds), ophthalmology (20 beds) and gynecology (10 beds).

The chronic electricity deficit affecting Gaza over the past nine years has disrupted the delivery of basic services and undermined already vulnerable livelihoods and living conditions; Al-Shifa Medical Complex are one of the most affected one (OCHA, 2015).

Since the outbreak of the electricity crisis, efforts have been put by many of hospitals' management to install solar power systems. Thus, studies are been made to give clear vision about the feasibility of such systems. This study comes to investigate the feasibility of a solar power system for Al-Shifa Medical Complex in Gaza.

2.2 Photovoltaic System

The sun has produced energy for billions of years. Solar energy is the sun's rays (solar radiation) that reach the earth. On a bright, sunny day, the sun shines approximately 1,000 watts of energy per square meter of the planet's surface, and if we could collect all of that energy we could easily power our homes and offices for free (Reference).

A photovoltaic system (PV), also solar PV power system, or PV system, is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution, as prices for storage devices are expected to decline (Cloete, 2013).

Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarized as balance of system (BOS). Moreover, PV systems convert light directly into electricity and shouldn't be confused with other technologies, such as concentrated solar power or solar thermal, used for heating and cooling.

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts. Nowadays, most PV systems are grid-connected, while off-grid or stand-alone systems only account for a small portion of the market (Fritz, 2012).

Operating silently and without any moving parts or environmental emissions, PV systems have developed from being niche market applications into a mature technology used for mainstream electricity generation. A rooftop system recoups the invested energy for its manufacturing and installation within 0.7 to 2 years and produces about 95 percent of net clean renewable energy over a 30-year service lifetime (Fraunhofer ISE, 2014).

2.3 Methods of Converting Solar energy to electricity

Photovoltaic (PV devices) or “solar cells” – change sunlight directly into electricity. The photovoltaic cell was discovered in 1954 by Bell Telephone researchers examining the sensitivity of a properly prepared silicon wafer to sunlight. Beginning in the late 1950s, photovoltaic cells were used to power U.S. space satellites. The success of PV in space generated commercial applications for this technology. The simplest photovoltaic systems power many of the small calculators and wrist watches used everyday. More complicated systems provide electricity to pump water, power communications equipment, and even provide electricity to our homes (Greyling, 2012).

Solar Power Plants - indirectly generate electricity when the heat from solar thermal collectors is used to heat a fluid which produces steam that is used to power generator. Out of the 15 known solar electric generating units operating in the United States at the end of 2006, 10 of these are in California, and 5 in

Arizona. No statistics are being collected on solar plants that produce less than 1 megawatt of electricity, so there may be smaller solar plants in a number of other states (Omole, 2006).

Figure (1): Solar panels absorb energy to produce hydrogen at SunLine Transit Agency.

2.4 Advantages of Solar Power Systems

It is clearly that Solar Power Systems have many advantages; here are some of these advantages that Island (2004) mentioned:

a) Solar energy is a clean and renewable energy source.

b) Once a solar panel is installed, solar energy can be produced free of charge.

c) Solar energy will last forever whereas it is estimated that the world's oil reserves will last for 30 to 40 years.

d) Solar energy causes no pollution.

e) Solar cells make absolutely no noise at all. On the other hand, the giant machines utilized for pumping oil are extremely noisy and therefore very impractical.

f) Very little maintenance is needed to keep solar cells running. There are no moving parts in a solar cell that makes it impossible to really damage them.

g) In the long term, there can be a high return on investment due to the amount of free energy a solar panel can produce, it is estimated that the average household will see 50% of their energy coming in from solar panels.

2.5 Disadvantages of Solar Power Systems

Despite the advantages it have, Solar Power Systems have some disadvantages as Island (2004) mentioned:

a) Solar panels can be expensive to install resulting in a time-lag of many years for savings on energy bills to match initial investments.

b) Electricity generation depends entirely on a countries exposure to sunlight; this could be limited by a countries climate.

c) Solar power stations do not match the power output of similar sized conventional power stations; they can also be very expensive to build.

d) Solar power is used to charge batteries so that solar powered devices can be used at night. The batteries can often be large and heavy, taking up space and needing to be replaced from time to time.

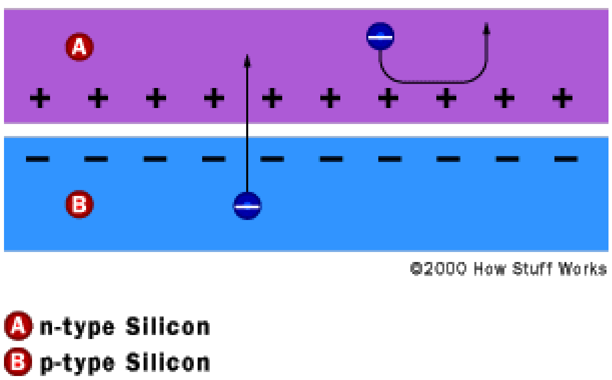
2.6 Mechanism of Photovoltaic Cell

A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. A photovoltaic cell is a non mechanical device usually made from silicon alloys (Tafticht et al., 2008).

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity (Castaner, 2002).

Silicon crystals are all electrically neutral. In n-type Si our extra electrons are balanced out by the extra protons in the phosphorous. In p-type Si missing electrons (holes) were balanced out by the missing protons in the boron. When the holes and electrons mix at the junction between N-type and P-type silicon, however, that neutrality is disrupted. Do all the free electrons fill all the free holes? No. If they did, then the whole arrangement wouldn't be very useful. Right at the junction, however, they do mix and form a barrier, making it harder and harder for electrons on the N side to cross to the P side. Eventually, equilibrium is reached, and we have an electric field separating the two sides (Castaner, 2002).

Figure (2): The effect of the electric field in a PV cell



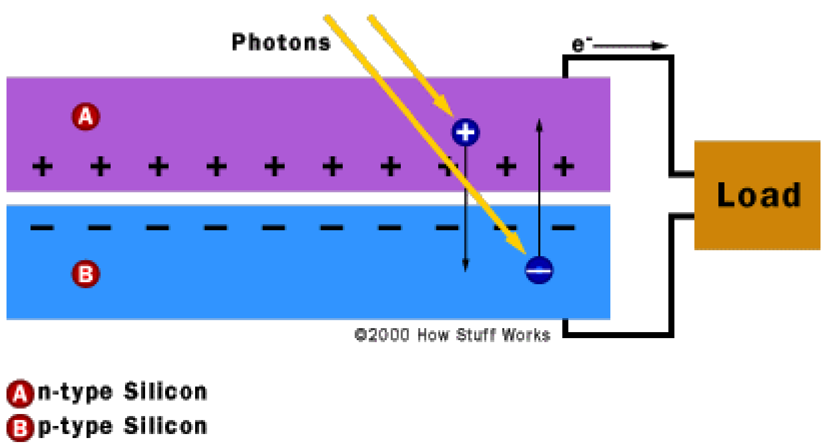
This electric field acts as a diode, allowing (and even pushing) electrons to flow from the P side to the N side, but not the other way around. It's like a hill -- electrons can easily go down the hill (to the N side), but can't climb it (to the P side).

Therefore, an electric field acting as a diode in which electrons can only move in one direction.

When light, in the form of photons, hits our solar cell, its energy frees electron-hole pairs.

Each photon with enough energy will normally free exactly one electron, and result in a free hole as well. If this happens close enough to the electric field, or if free electron and free hole happen to wander into its range of influence, the field will send the electron to the N side and the hole to the P side. This causes further disruption of electrical neutrality, and if we provide an external current path, electrons will flow through the path to their original side (the P side) to unite with holes that the electric field sent there, doing work for us along the way. The electron flow provides the current, and the cell's electric field causes a voltage. With both current and voltage, we have power, which is the product of the two (Niemann, 2004).

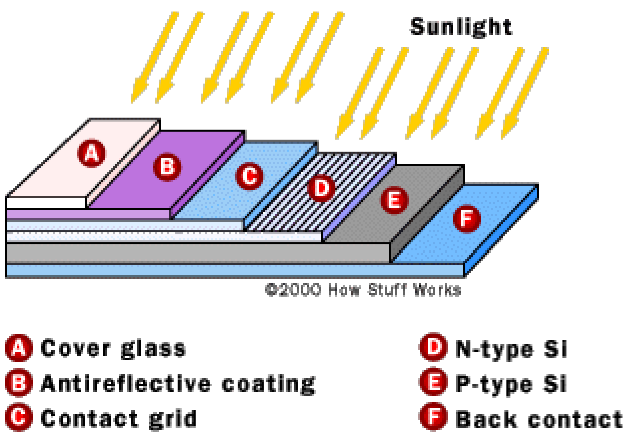
Figure (3): Operation of a PV cell



There are a few more steps left before we can really use our cell. Silicon happens to be a very shiny material, which means that it is very reflective. Photons that are reflected can't be used by the cell. For that reason, an antireflective coating is applied to the top of the cell to reduce reflection losses to less than 5 percent.

The final step is the glass cover plate that protects the cell from the elements. PV modules are made by connecting several cells (usually 36) in series and parallel to achieve useful levels of voltage and current, and putting them in a sturdy frame complete with a glass cover and positive and negative terminals on the back (Erickson, 2001).

Figure (4): Basic structure of a generic silicon PV cell



The performance of a photovoltaic array is dependent upon sunlight. Climate conditions (e.g., clouds, fog) have a significant effect on the amount of solar energy received by a photovoltaic array and, in turn, its performance. Most current technology photovoltaic modules are about 10 percent efficient in converting sunlight. Further research is being conducted to raise this efficiency to 20 percent.

Single-crystal Silicon

Single-crystal silicon isn't the only material used in PV cells. Polycrystalline silicon is also used in an attempt to cut manufacturing costs, although resulting cells aren't as efficient as single crystal silicon. Amorphous silicon, which has no crystalline structure, is also used, again in an attempt to reduce production costs. Other materials used include gallium arsenide, copper indium diselenide and cadmium telluride. Since different materials have different band gaps, they seem to be "tuned" to different wavelengths, or photons of different energies. One way **efficiency** has been improved is to use two or more layers of different materials with different band gaps. The higher band gap material is on the surface, absorbing high-energy photons while allowing lower-energy photons to be absorbed by the lower band gap material beneath. This technique can result in much higher efficiencies. Such cells, called **multi-junction cells**, can have more than one electric field (Erickson, 2001).

Photovoltaic cells, like batteries, generate direct current (DC) which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using inverters, solid state devices that convert DC power to AC (Chung, 2004).

2.7 Energy Loss in a Solar Cell

Visible light is only part of the electromagnetic spectrum. Electromagnetic radiation is not monochromatic -- it is made up of a range of different wavelengths, and therefore energy levels.

Since the light that hits our cell has photons of a wide range of energies, it turns out that some of them won't have enough energy to form an electron-hole pair. They will simply pass through the cell as if it were transparent. Still other photons have too much energy. Only a certain amount of energy, measured in electron volts (eV) and defined by our cell material (about 1.1 eV for crystalline silicon), is required to knock an electron loose. We call this the band gap energy of a material. If a photon has more energy than the required amount, then the extra energy is lost (unless a photon has twice the required energy, and can create more than one electron-hole pair, but this effect is not significant). These two effects alone account for the loss of around 70 percent of the radiation energy incident on our cell (Abdul-Latif et al., 2004).

Material with a low band gap cannot be chosen. Unfortunately, the band gap also determines the strength (voltage) of our electric field, and if it's too low, then what make up in extra current (by absorbing more photons), it is lost by having a small voltage. Remember that power is voltage times current. The optimal band gap, balancing these two effects, is around 1.4 eV for a cell made from a single material.

There are other losses as well. The electrons have to flow from one side of the cell to the other through an external circuit. The bottom with a metal can be covered, allowing for good conduction, but if completely cover the top, then photons can't get through the opaque conductor and the current will be lost (in some cells, transparent conductors are used on the top surface, but not in all). If contacts are only put at the sides of cell, then the electrons have to travel an extremely long distance (for an electron) to reach the contacts. It worth mentioning, silicon is a semiconductor -- it's not nearly as good as a metal for transporting current. Its internal resistance (called series resistance) is fairly high, and high resistance means high losses. To minimize these losses, our cell is covered by a metallic contact grid that shortens the distance that electrons have to travel while covering only a small part of the cell surface. Even so, some photons are blocked by the grid, which can't be too small or else its own resistance will be too high (Fernia et al., 2004).

2.8 Solving Solar-power Issues

Certainly, no one would accept only having electricity during the day, and then only on clear days, if they have a choice. There is a need for energy storage -- batteries. Unfortunately, batteries add a lot of cost and maintenance to the PV system. Currently, however, it is a necessity if it is want be to be completely independent. One way around the problem is to connect the house to the utility grid, buying power when it is needed and selling to them when producing more than needed. This way, the utility acts as a practically infinite storage system. The utility has to agree, of course, and in most cases will buy power from other places at a much lower price than their own selling price. Special equipment are also needed to make sure that the sold power to the utility is synchronous with theirs -- that it shares the same sinusoidal waveform and frequency. Safety is an issue as well. The utility has to make sure that if there's a power outage in the neighborhood, the PV system won't try to feed electricity into lines that a lineman may think is dead. This is called islanding (Niemann, 2004).

If it is decided to use batteries, they will have to be maintained, and then replaced after a certain number of years. The PV modules should last 20 years or more, but batteries just do not have that kind of useful life. Batteries in PV systems can also be very dangerous because of the energy they store and the acidic electrolytes they contain, so they need a well-ventilated, non-metallic enclosure for them.

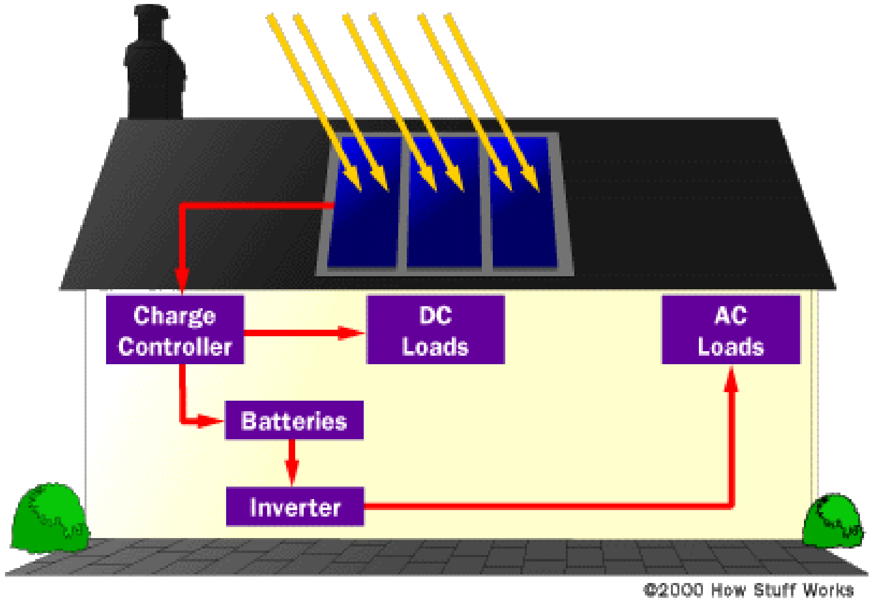
Although several different kinds of batteries are commonly used, the one characteristic they should all have in common is that they are deep-cycle batteries. Unlike your car battery, which is a shallow-cycle battery, deep-cycle batteries can discharge more of their stored energy while still maintaining long life. Car batteries discharge a large current for a very short time -- to start your car -- and are then immediately recharged as you drive. PV batteries generally have to discharge a smaller current for a longer period (such as all night), while being charged during the day (Luque et al., 2003).

The most commonly used deep-cycle batteries are lead-acid batteries (both sealed and vented) and nickel-cadmium batteries. Nickel-cadmium batteries are more expensive, but last longer and can be discharged more completely without harm. Even deep-cycle lead-acid batteries can't be discharged 100 percent without seriously shortening battery life, and generally, PV systems are designed to discharge lead-acid batteries no more than 40 percent or 50 percent (Luque et al., 2003).

In addition, the use of batteries requires the installation of another component called a charge controller. Batteries last a lot longer if care is taken so that they aren't overcharged or drained too much. That's what a charge controller does. Once the batteries are fully charged, the charge controller doesn't let current from the PV modules continue to flow into them. Similarly, once the batteries have been drained to a certain predetermined level, controlled by measuring battery voltage, many charge controllers will not allow more current to be drained from the batteries until they have been recharged. The use of a charge controller is essential for long battery life.

The other problem besides energy storage is that the electricity generated by your PV modules, and extracted from your batteries if you choose to use them, is not in the form that's used by the electrical appliances in your house. The electricity generated by a solar system is direct current, while the electricity supplied by your utility (and the kind that every appliance in your house uses) is alternating current. You will need an inverter, a device that converts DC to AC. Most large inverters will also allow you to automatically control how your system works. Some PV modules, called AC modules, actually have an inverter already built into each module, eliminating the need for a large, central inverter, and simplifying wiring issues (Ladner-Garcia, 2008).

Figure (5): General schematic of a residential PV system with battery storage



Throw in the mounting hardware, wiring, junction boxes, grounding equipment, overcurrent protection, DC and AC disconnects and other accessories and you have yourself a system. Electrical codes must be followed (there is a section in the National Electrical Code just for PV), and it's highly recommended that the installation be done by a licensed electrician who has experience with PV systems. Once installed, a PV system requires very little maintenance (especially if no batteries are used), and will provide electricity cleanly and quietly for 20 years or more (Rashid, 2006).

2.9 Using MATLAB and Simulink to Simulate Solar Power Systems.

MATLAB is an interactive programming language that can be used in many ways, including data analysis and visualisation, simulation and engineering problem solving. It may be used as an interactive tool or as a high level programming language. It provides an effective environment for both the beginner and for the professional engineer and scientist.

SIMULINK is an extension to MATLAB that provides an iconographic programming environment for the solution of differential equations and other dynamic systems (Niemann, 2001).

The package is widely used in academia and industry. It is particularly well known in the following industries: aerospace and defence; automotive; biotech, pharmaceutical; medical; and communications. Specialist toolboxes are available for a diverse range of other applications, including statistical analysis, financial modelling, image processing and so on. Furthermore, real time toolboxes allow for on-line interaction with engineering systems, ideal for data logging and control (Walker, 2001). MATLAB is used for research and teaching purposes in a number of disciplines, including Engineering, Communications, Maths & Stats and Environmental Science.

2.10 What is Decision Support System (DSS)?

Decision support systems are earning an increasing popularity in different domains, including engineering, business, and medicine. They are important especially in situations when the amount of available information is prohibitive for the feeling of an unaided human decision maker, and in which precision and optimality are very important. Decision support systems can help human cognitive deficiencies by integrating various information sources, providing intelligent access to relevant knowledge, and helping the process of structuring decisions. They can also employ artificial intelligence methods to heuristically address problems that are intractable by formal techniques. They can also support choice among well- defined alternatives and build on formal approaches, such as the methods of operations research, engineering economics, statistics, and decision theory (Marek J. Druzdzel and Roger R. Flynn 2010).

2.10.1 Benefits of DSS

Suitable application of decision support system increases efficiency, productivity, quality and effectiveness, speed up the process of decision making, increases organizational control, encourages exploration and discovery on the part of the decision maker, and gives many businesses a reliable and comparative advantage over their competitors, allowing them to increase output, make optimal choices for parameters and their technological processes, planning business logistics, operation in hazardous environments, or investments, speeds up problem solving in an organization, facilitates interpersonal communication , promotes learning or training, generates new evidence in support of a decision, Helps automate managerial processes , in addition to improve customer and employee satisfaction (Wikipedia,2014).

2.10.2 Types of DSS

There are varieties of DSSs; these can be categorized into five types as follows:

a) Communication-driven DSS

A communication-driven DSS use network and communication technologies to facilitate collaboration on decision-making. It supports more than one person working on a shared task.

b) Data-driven DSS

A data-driven DSS or data-oriented DSS emphasizes access to and manipulation of a time series of internal company data and, sometimes, external data. Simple file systems accessed by query and retrieval tools provides the elementary level of functionality.

c) Document-driven DSS

A document-driven DSS uses storage and processing technologies to document retrieval and analysis. It manages, retrieves and manipulates unstructured information in a variety of electronic formats. A search engine is a primary tool associated with document driven DSS.

d) Knowledge-driven DSS

A knowledge-driven DSS provides specialized problem solving expertise stored as facts, rules, procedures, or in similar structures. It suggests or recommends actions to managers.

e) Model-driven DSS

A model-driven DSS emphasizes access to and manipulation of a statistical, financial, optimization, or simulation model. Model-driven DSS use data and parameters provided by users to assist decision makers in analyzing a situation; they are not necessarily data intensive (Dan Power, 2011).

Chapter 3: Previous Studies

3.1 Local Studies

3.2 International Studies

3.3 Commentary on the Previous Studies

3.1 Local Studies

Ward (2014), Study Title: "A prospected Study for Development of Berths Facility Services (Loading and Unloading) Of Gaza Seaport Using Simulation Techniques"

This study aimed at designing a simulation model for berths facility services of the planned Gaza seaport. In this research Arena software package (A queuing model of the logistic activities related to the arrival, berthing, and departure processes of ships) used to simulate of berths facility services of the planned Gaza seaport , to reduce the service time in loading and unloading which helps in reducing the service cycle time including the waiting time in queue and hence more ships will be served.

After analysis by Arena, it was recommended to add two crane on berth A to serve two by two crane for each one at the same time which minimize the loading and unloading time and to use this model by decision makers in Palestinian port authority and local government institutions to manage the seaport at high performance.

Nqirah (2014), Study Title: "Using a Simulation Model for Crisis and Emergency Management (A Case Study on Coastal Municipalities Water Utility "CMWU"):

This study aimed at developing a highly efficient and effective simulation-based decision-making tool, which can be, applied in real-time management situations. It simulates the using of mobile pumps to discharge and dispose flooded storm water from incident areas through efficient and effective resources reallocation to finish the assigned tasks as quickly as possible to minimize the loss of life, asset and property.

In this research, Arena software package used to combine the using of discrete logic with continuous models to facilitate a solution for the flooding problem due to high storms and rain falls that struck Rafah city from time to time. The model is flexible enough to fit with dynamic situation changes and has the ability to interface with other interactive models using GIS maps, national databases and user-friendly interfaces in order to deal with high complex crisis and emergency flooding problems.

Osman (2012), Study Title: "Utilizing Solar Energy in King Faisal Specialist Hospital & Research Center Riyadh, Saudi Arabia"

This study aimed at designing a solar energy system for King Faisal Specialist Hospital and Research Center (KFSHRC) that can clearly lift a significant proportion of its electric load and allow for future expansion of the facility. It illustrates the number of solar panels needed to provide power to meet the design criteria.

This study undertook only one building (The North Tower), one of the newest buildings within the hospital where an integrated design was made taking on all power shortages issues collectively. The study provided an alternative approach and provided a comprehensive solution.

3.2 International Studies

Shayesteh (2015), Study Title: "Efficient Simulation Methods of Large Power Systems with High Penetration of Renewable Energy Resources - Theory and Applications"

This study aimed at reviewing different methods which can be used for simplifying the power system studies, including the power system reduction. A comparison among three important simplification techniques was also performed to reveal which simplification results in less error and more simulation time decrement. It introduced, described and discussed different steps and methods for power system reduction, including network aggregation and generation aggregation.

The study revealed that using power system simplification techniques and specially the system reduction can provides many important advantages in studying large-scale power systems with high share of renewable energy generations. In most of applications, not only the power system reduction highly reduces the complexity of the power system study under consideration, but it also results in small errors. Therefore, it can be used as an efficient method for dealing with current bulk power systems with huge amounts of renewable and distributed generations.

Shiau et al (2014), Study Title: "Circuit Simulation for Solar Power Maximum Power Point Tracking with Different Buck-Boost Converter Topologies"

This study aimed at investigating the development of a circuit simulation model for maximum power point tracking (MPPT) evaluation of solar power that involves using different buck-boost converter topologies including SEPIC, Zeta, and four-switch type buck-boost DC/DC converters.

The circuit simulation framework developed in this study provides the possibility of investigation and evaluation of a solar power MPPT system without the need of any hardware system and instruments. It is especially useful in the early stage of the development of a solar power management system. It can also be used for evaluating the performance of other power converters and MPPT algorithms.

Giglmayr (2013), Study Title: "Development of a Renewable Energy Power Supply Outlook 2015 for the Republic of South Africa"

This study aimed at highlighting the current challenges and justifying the need for a sufficient forecast method regarding an increased amount of renewable energies. A 2015 annual time series simulation of every approved project until mid-2013 is undertaken, assuming that every plant will be on grid by the end of 2014.

The model's methodology is split into four different approaches regarding four different technologies, including solar photovoltaic, wind, hydropower, and concentrated solar power. Hourly based annual load behavior results throughout in the achievement of a prospective amount of electricity contribution. Therefore, knowledge about system loads behavior, such as evaluations regarding high-demand scenarios and fluctuation bandwidths, is developed. The result contains a variety of information about the prospective supply, which might serve for trendsetting decision-making.

Kraj, et al (2013), Study Title: "Simulation and Optimization of a Multi-Renewable Energy System for Remote Power Generation at Fernando de Noronha, Brazil"

This study aimed at introducing the simulation of Multi-Renewable Energy Systems (MRESs) and aimed at facilitating the optimization of multifunctional power systems for remote autonomous power generation. A multi-objective optimization using an evolutionary algorithm evaluates objectives within the geographical and economical constraints of the simulated MRES configuration.

The results show the simulated system behaviour over a period of 24 hours and indicate the optimized points of operation of the system. The complimentary existence of wind and solar resources increase the renewable energy ratio (RER) and offset diesel fuel dependence. Coordinating more than one renewable resource for generation in addition to the backup diesel system is necessary to support the critical loads of a remote community.

Busawon et al (2012), Study Title: "Acausal Modeling and Simulation of the Standalone Solar Power Systems as Hybrid DAEs"

This paper aimed at developing an acausal model, which is based on the HDAE, to simulate the solar power system. The proposed model presents the nonlinear algebraic constraints, which are introduced by the PV array and the battery, as DAEs. Moreover, it models different modes of the battery operation as a hybrid system. The Modelica language is employed to describe the system as an acausal model organized as separate Modelica classes for different components. The OpenMod-elica environment as an integrated modeling and simulation Modelica tool-set is used to simulate the system with the DASSL general purpose integrator. The PV array and the lead-acid battery bank are separately simulated and validated with information available in datasheets that show very good accuracy. The whole solar power system is also simulated and discussed thoroughly indicating accurate prediction of all the system behaviors including mode transitions. The highest level Modelica codes as well as a summary of the battery Modelica class are presented.

Rodrigues et al (2010), Study Title: "Simulation of a Solar Cell considering Single-Diode Equivalent Circuit Model"

This paper aimed at designing a single-diode photovoltaic cell models. Comprehensive simulation studies were carried out in order to adequately assess temperature dependence, solar radiation change, diode ideality factor and series resistance influence. A comparison between an ideal model single-diode solar cell and a model of single-diode solar cell with a series resistance is also presented.

The results of study has shown that the behavior of ideal solar cell model and the behavior of the solar cell with series resistance model are studied in this paper. The solar cell with series resistance model offers a more realistic behavior for the photovoltaic systems. Particularly, this model is to be considered in panels with series cells, because the series resistance is proportional to the number of solar cells in the panel.

Omole (2006), Study Title: "Analysis, Modeling and Simulation of Optimal Power Tracking of Multiple-Modules of Paralleled Solar Cell Systems"

This study aimed at developing a method to optimize the energy extraction from a proposed renewable energy generation system. In order to achieve this, the components and subsystems have to be analyzed and validated. The validated models can then be used to maximize the power output of the conversion system.

The simulation results indicate that a significant amount of additional energy can be extracted from a photovoltaic array by using simple analog or digital maximum power point trackers. This results in improved efficiency for the operation of renewable energy generation systems. The improved efficiency should lead to significant cost savings on the long run.

Commentary on the Previous Studies

As the subject of modelling and simulation is getting more and more interest and focus due to its importance in various fields for countries, the previous studies were collected from different countries and backgrounds, which give the researcher a clear vision of modeling and simulation literature, definition, importance and objectives.

Through the previous studies, it is noticed that some local studies, like Ward (2014) and Nqirah (2014), are alike to the current study since they tackle a real problem Gaza suffer. Many other studies were based on assumptions like Osman (2012) and Busawon et al (2012).

The current study applies modeling and simulation on the Solar Power System needed for Al-Shifa Hospital. MATLAB simulation programme is utilized in this study to give the best optimal solution for hospital decision-makers.

Chapter 4: Construction of the Simulation Model

4.1 Objective

4.2 The Basics of the System

4.3 The Methodology of Modeling

4.4 Mathematical Model of PV Cell

4.5 Sensitivity Analysis

4.6 Operating and Checking the Model

4.1 Objective

The first objective is to assess the number of solar panels needed to produce the annual electricity consumption of Al-Shifa Hospital. Then to identify the area needed to install the solar power system.

The current model also aims to help the Hospital’s management to take accurate decisions to install solar power system for some/all units within the hospital through providing them with a model that help them to identify the electricity needed, the costs and the area.

In short, if it is intended to install a solar power system for a single unit within the hospital, the Hospital’s management need to provide the module with few details like the amount of electricity and number of hours. Automatically, the system will generate the design of system, the number of PV cells, the capcity on inverters, the curve and direction of installation and the needed costs. It also provide the electrical circuit that is needed in the case. The price of solar cells and inverters might need to be modified since prices differ from brand/company to another.

4.2 The basics of the system

When a new photovoltaic system is proposed on an existing building, an analysis of the factors influencing the production must be performed.

These factors include:

- The global irradiation available kWh / m^2 .year
- The orientation in degrees (°) relative to the south
- The inclination in degrees (°) relative to the horizontal
- The available surface in m^2
- The technology used (effectiveness or Wp / m^2)
- The integration system or installation
- The resulting shadows

4.2.1 Hospital consumption

Hospital's consumption depends on the equipment and devices used:

Table (2): Hospitals consumption of Energy

Systems	Power (kW)	Duration (h)	Consumption (kWh/day)
Kidney dialysis services	85	12	1020
Operating rooms	25	6	150
kindergarten Service	25	24	600
Intensive care	5	24	120
heart Intensive care	5	24	120
Laboratory	5	24	120
TOTAL (per day)	**150**		**2130**

4.2.2 Additional data

- **Site:** Gaza
- **Insolation:** 320 days per year
- **Autonomy:** 07 days in case of bad weather

- **The batteries:** lead acid accumulators (each accumulator generates a voltage of 48V)
- **The panels:** WHM320W-400W

4.3 The methodology of modeling

After collecting all the data needed, the researcher started building the system using MATLAB/Simulink software. Some calculations were made before starting building the model. Following are the steps of work:

4.3.1 Energy Consumption

- Energy Consumption = **777 450 kWh / year**
- Power requirement = **150 kW**

The system must deliver a minimum power equal to the hospital power requirement and must ensure the annual consumption.

4.3.2 Weather conditions

It is highly important to put in consideration all the conditions that might affect the system; weather mainly.

4.3.2.1 Insolation

- **The number of hours of sunshine**

We do not have the data on the number of hours of sunshine on Gaza. We take the data found that is 320 days a year. This gives 7680 hours of insolation.

– **The number of hours of full sunlight**

However, in a day, even without cloud, the electrical production of the photovoltaic panel varies continuously depending on the position of the sun and is at its peak only for a brief period at noon. The number of hours of full sunlight is equivalent to the value concerning the photovoltaic electricity producer. This value is less than the number of hours of sunshine per year.

Therefore, it is important to consider that the number of hours of full sunlight is equivalent to **4450 hours.**

– **The solar constant**

For the production of photovoltaic electricity, we must consider the solar constant. The solar constant expresses the amount of solar energy that would receive **a 1 m^2** area located at a distance of 1 AU (Astronomical Unit), average distance Earth-Sun, facing perpendicular to the Sun's rays, in the absence of atmosphere. The value of the solar constant at the ground level (with atmosphere) is **1 kW/m^2.** This value is also considered as maximum solar radiation or irradiance.

4.3.3 Temperature

The temperature is an important parameter in the behavior of photovoltaic modules.

The conversion of the photovoltaic cells of the solar energy into electrical energy is of the order of 15%. The rest of the energy is 80% dissipated as heat and 5% reflective.

The change in temperature results in the variation of the maximum peak power (Wp) delivered by the cell.

Thus, a rise in temperature results in a decrease of the maximum power. (Section of sensitivity analysis provides more details in this regard). The power peak (Wp) of a photovoltaic system corresponds to the electrical power delivered by that system in standard conditions of sunlight (1000 W / m^2), temperature (25 ° C).

Here, standard temperature condition is applied for the full year for the production of photovoltaic energy. This will be the maximum production.

In practice, we need to use correction coefficients given by manufacturers related to temperature for voltage, current and power. In addition, any masks as drop shadows, foams can lower our production (and in particular the level of radiation), we will consider that we have none.

For this study, the researcher consider the solar radiation is maximum in all times.

4.3.4 Exposure

Electricity production using photovoltaic panels depends on the geographic location (latitude, longitude and altitude) and climatic conditions. Orientation and tilt of photovoltaic panels is included as well.

Table (3): Yearly output for different orientation and tilt angels (%of maximum)

Orientation Chart showing yearly output for different orientation and tilt angles (%of maximum).														
Tilt (°) from horizontal		Orientation - Compass bearing (°) measures from North												
	Horizontal	West			S.W.			South			S.E.			East
		270 °	255 °	240 °	225 °	210 °	195 °	180 °	165 °	150 °	135 °	120 °	105 °	90 °
	0 °	90	90	90	90	90	90	90	90	90	90	90	90	90
	10 °	89	91	92	94	95	95	96	95	95	94	93	91	90
	20 °	87	90	93	96	97	98	98	98	97	96	94	91	88
	30 °	86	89	93	96	98	99	100	100	98	96	94	90	86
	40 °	82	86	90	95	97	99	100	99	98	96	92	88	84
	50 °	78	84	88	92	95	96	97	97	96	93	89	85	80
	60 °	74	79	84	87	90	91	93	93	92	89	86	81	76
	70 °	69	74	78	82	85	86	87	87	86	84	80	76	70
	80 °	63	68	72	75	77	79	80	80	79	77	74	69	65
	90 °	56	60	64	67	69	71	71	71	71	69	65	62	58
	Vertical	Near horizontal 0 ° inclinations are not recommended as the self-cleaning cannot be relied on at less than about 10 °												

It is clear from the table above, every orientation and every inclination of the photovoltaic system corresponds to a correction factor of production. For this study, the location is considered in the following configuration: south orientation and inclination of 30 °.

4.3.5 The type of producer of photovoltaic energy

This is a stand-alone photovoltaic system and it will not be connected to the grid. In addition, the entire production of electricity will be consumed.

4.3.6 The main types and characteristics of photovoltaic cell

There are 3 main types of photovoltaic cells:

Table (4): Types of photovoltaic cells

	Amorphus silicon	polycrystalline silicon	monocrystalline silicon
Efficiency	-	+	++
Commercial Efficiency	5 – 9 %	11 – 15 %	12 – 20 %
Lifetime (Years)	+/- 10	+/- 30	+/- 30
Price	++	+	-

The conversion efficiency is the ratio of the power supplied by the cell on the light power it receives.

4.3.7 Determining the installation of photovoltaic panels

Here, all retrieved data is considered as follow:

4.3.7.1 The manufacturer data:

In this model, Monocrystalline Photovoltaic panels were used; type WHM 400W of Huaian Weihao New Energy Technology Co., Ltd. with a peak power of 400Wp with the following characteristics:

Table (5): Characteristics of used solar panels

Electrical characteristics	
Maximum Power	400 Wp
Voltage at Pmax	50.5 V
Current at Pmax	7.92 A
Open Circuit Voltage	60.4 V
Short Circuit Current	8.5 A
Material characteristics	
Module Dimension	1950 x 1320 x 50 mm
Cell Type	Monocristalline
Cell Dimension	156 x 156 mm
Number of cells	96

4.3.8 Determining of the annual electrical energy produced by m²:

The conversion efficiency of a cell is 20%.The annual electric power is expressed by the following formula:

- **Ee** = Efficiency x maximum radiated power per m2 x number of hours of sunlight
- **Ee** =0.2 x 1 kW / m² x 4450 = **890 kW / m²**

4.3.9 Determining the minimum area of photovoltaic system:

- The electrical consumption was set at = **777 450** kWh per year.
- The minimum area S_{min} is therefore expressed by:
- S_{min} = Consum / Ee = 777 450 / 890 = **874 m²**

So a minimum area of the photovoltaic system is needed: **874 m²**.

Photovoltaic panels convert solar energy into electrical energy available in the form of a DC voltage.

This DC voltage is sent to an inverter, which converts the AC voltage to standards compliant with our electrical distribution network. Moreover, the inverter has conversion efficiency and therefore it require a larger surface to ensure the minimum electrical consumption average.

As a first approximation, the conversion efficiency for the inverter is taken by 90%. So it would take a minimum area revalued at:

S_{rev} = 874 + (874 x 0.1) = **961 m²**.

4.3.10 Determining the number of cells and photovoltaic panels

A minimum area of 961 m² was determined. A cell having dimensions 0,156 m x 0,156 m, i.e. a surface area of **0,024 m²**, it is deduced that **39484 cells** are needed.

So knowing that a panel is composed of **96 cells**, **411** solar panels are needed to provide all the necessary electricity.

4.3.11 Determining the inverter

4.3.11.1 Connecting the panels in series or parallel:

It is determined that 411 photovoltaic panels are needed; 400 Wp Monocrystalline WHM 400W.

The use of **411** identical photovoltaic panels gives the equivalent overall electrical power (peak power) that is **164.4kWp.**

Therefore, there are two connection options for the panels (serial or parallel). It should be noted that in the case of a series connection, the voltages are added and the current remains constant, and in the case of a parallel connection of current are added and the voltage remains constant.

In both cases, the optimal sunlight conditions, the overall electrical power produced will remain unchanged **164.4 kWp.**

However, if the irradiation conditions were different (masks), the two connection modes would differentiate.

4.3.11.2 Principles of selecting the inverter:

For the choice of the inverter, the following two principles were applied:

- The maximum power of the installation (peak power) must be greater than the rated power of the inverter by setting performance.
- Consider the implantation conditions and orientation panels.

4.3.11.3 Dimensioning the inverter:

In this study, the installation consists of 411 panels of 400Wp whether **164.4 kWp**. The correction factor is **164.4 / 150 = 1.096.**

Step 1: a quick dimensioning is performed through the power of the installation.

The installation consists of 411 modules with a peak power of **400 Wp**, a total peak power is **411 × 400 = 164.4 kWp.**

Exploring the range of inverters, it was found that the inverter **Sunny Central 150** is suitable.

Table (6): Characteristics of invertors used

	Sunny Central 150
MPP voltage range	450 ... 820V
Maximum DC voltage	880 V
Maximum DC current	354 A
PV Max Power	175 kWp
Efficiency	95.3 %

Step 2: the number of PV modules in series was calculated where datasheet of the Sunny Central 150 indicates the following:

- The maximum allowable voltage of the inverter input is **Umax = 880 V.**
- The MPPT voltage range of the inverter input is **[Umppt, min - Umppt, max] = [450 V - 820 V].**

It can be determined that the number of PV modules in series compatible with MPPT voltage range of the inverter by:

Minimum number of panels in series = E (Umppt, min / (Umpp x 0.85))

Maximum number of panels in series = E (Umppt, max / (Umpp x 1.15))

- Where E(x) means the integer part of x.
- The coefficient 1.15 is an increase coefficient for calculating the MPP voltage at -20 °C.
- The 0.85 factor is a reduction factor for calculating the MPP voltage at 70 °C.

Based on the calculation, the number of modules in series must be between **10 and 14.**

It remains to check that with 14 modules in series, it is hard reach the maximum permissible input voltage of the inverter **Umax = 880 V.**

To do this, the maximum voltage is calculated to provide a photovoltaic string composed of 14 modules in series. This maximum voltage is equal to **14 × 1.15 × Uoc = 12 × 60.4 × 1.15 = 972.44 V**. The maximum voltage delivered by the photovoltaic system is higher than the maximum permissible input voltage of the inverter (Umax = 880 V).

Therefore, a configuration with 12 modules in series is compatible with the maximum allowable voltage of the inverter **(12 × 1.15 × Uoc = 12 × 60.4 × 1.15 = 833.52 V).**

Step 3: the number of PV strings in parallel was calculated

The specification of the inverter indicates that the maximum permissible current is **Imax = 354 A.**

The maximum number of PV strings in parallel could be calculated by the following simple formula:

Number of strings in parallel = E (Imax / (Icc x 1.25))

- Where E(x) means the integer part of x.
- The coefficient 1.25 is a safety factor set.

Based on the calculation, the number of photovoltaic strings, must be equal to E (354 / (8.5 x 1.25)) = 33.

Step 4: the power compatibility was checked

- Number of panels = **12 x 33 = 396**
- Power = **396 x 400 = 158.4 kWc**
- Maximum Photovoltaic Power admissible by the inverter = **175 kWc**

This installed capacity is compatible with the maximum power of the inverter input.

4.3.12 Calculating the number of batteries

A photovoltaic installation usually includes batteries to make electricity available at night or when the sun is veiled. to calculate the number of batteries needed in a facility, following steps should be taken:

Step 1: the desired autonomy should be determined.

The storage capacity needed depends mainly on two parameters: the energy consumed per day, the battery life of your system, that is to say the number of days that must withstand without sun.

Autonomy generally varies between 3 and 15 days. The figure chosen depends on two factors:

- The weather conditions
- The reliability we want of the system

The amount of energy consumed by the system during this period is:

Daily Consumption x Autonomy

- Hospital Consumption = **2130 kWh / day**
- Autonomy desired = **07 days**
- Ec = 2130 kWh x 07 days = **14910 kWh**

Step 2: losses added

The electricity that comes out of the batteries cannot entirely arrive to the load. Some is lost in the wires and in the DC-AC conversion (the inverter). The amount of energy that will restore the batteries is actually:

Ec = Energy consumed / (Efficiency of the inverter x (1- Line Losses))

If the values of the loss are unknown, theses average values can reveal it:

- Efficiency of the inverter = **0.9**
- 1-Line Losses = **0.97**

Ec = 2130 /(0.953 x 0.97) = **2304 kWh**

Step 3: Consider the maximum depth of discharge batteries

Since the used batteries have a longer life, it is recommended to not unload them completely: maximum depth of discharge should be set. Generally, this depth varies from 30 to 80%. A good intermediate value is 50% that is to say that just the half of the capacity of the batteries will be used.

The capacity of the batteries need to be:

Capacity = To Restore Energy / Maximum Deep Discharge

For the installation at the Hospital, a maximum depth of 50% discharge is taken. Thus, battery capacity shall be:

- Capacity = 2304 / 0.5 = **4608 kWh**

Step 4: Deducing the number of batteries

To move from kWh to a number of batteries, we must multiply by 1000, divided by the voltage of the batteries and by the battery capacity (Ah) and round up.

- **Batteries with a voltage of 12V and 200Ah capacity:**
- Number = (4608 x 1000) /12 / 200 = 1920
- So, **1920 batteries** of 12V and 200 Ah capacities are needed.

4.3.13 Sizing of DC-DC converter:

The minimum specifications in order to realize a DC-DC boost converter are:

- Input voltage ranging from Vemin and Vemax;
- Output voltage VS with relative ripple $\Delta Vs/Vs$= xx %;
- Power required for the load P_L;
- Frequency f = xx kHz.

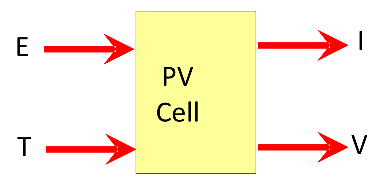
It is used to transfer the DC current to the batteries and the inverter, using MPPT algorithm for the tracking of the maximum power point of the photovoltaic system.

4.4 Mathematical model of the PV cell:

Numerous mathematical models exist and are used for the representation of the highly nonlinear behavior of photovoltaic cell resulting from semiconductor junctions.

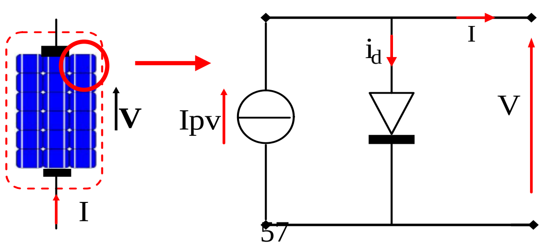
The typical pattern of the photovoltaic cell is built on four variables (the figure below). The two input variables are the temperature and the solar radiation (illumination), while the output variables are the current supplied by the cell, and the voltage.

Figure (6): Input and output variables



A PV cell can be modeled from the equation defining the static behavior of the PN junction of a conventional diode and the reaction of the semiconductor to the solar radiation. Thus, shows the simple electrical equivalent circuit of a PV cell.

Figure (7): simple electrical equivalent circuit of a PV cell



- I_{PV} : Photo generated current proportional to the illumination, it is the short-circuit current.
- I : Current delivered by the cell.
- V : Voltage of the cell.
- I_d : Current through the diode, deduced from the equation 1.

$$I_d = I_s\left[\exp\left(\frac{qV_d}{AkT}\right) - 1\right] \qquad [1]$$

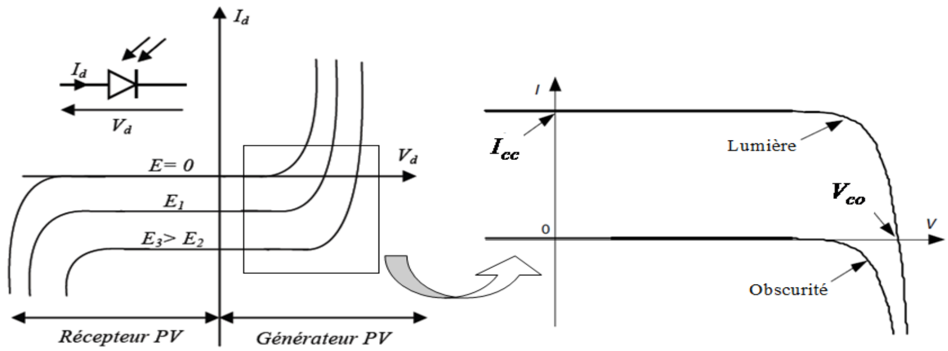
With:

- I_s : The diode saturation current.
- T : Junction temperature in K.
- A : Ideality factor.
- V_d : Voltage across the diode.
- q : elementary charge ($q = 1.6.10^{-19} C$).
- k : Boltzmann constant ($k = 1.38.10^{-38} J/K$).

The thermodynamic potential could be displayed $V_T = \frac{kT}{q}$.

Figure (8) shows that it is quite normal that the characteristic of the PV cell is almost that of a diode in the dark where the effect of the illumination characterized by the current photo-generated does not occur.

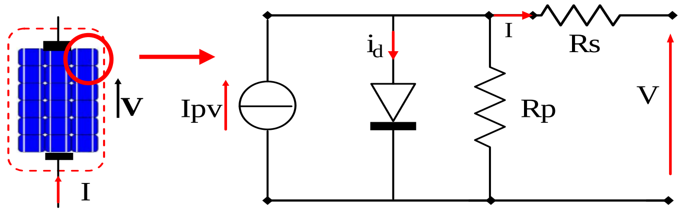
Figure (8): characteristic of the PV cell



4.4.1 Mathematical model with a single diode:

The model with a diode of a photovoltaic cell is the classic model of the literature it involves a current generator for modeling the incident light flux, a diode for the polarization phenomenon the cell, two resistors (series and shunt) for losses.

Figure (9): with a diode of a photovoltaic cell



The current delivered by the cell, in the case of this model is given by the following equation:

$$I = I_{PV} - I_d - I_{R_P} \quad [2]$$

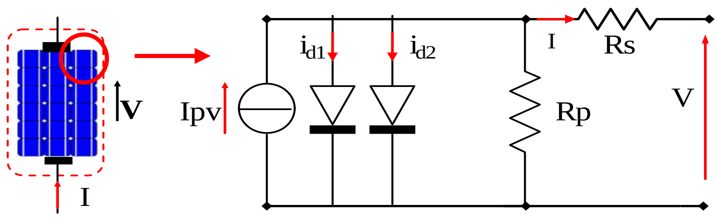
$$I = I_{PV} - I_s\left[\exp\left(\frac{q(V + R_S I)}{AkT}\right) - 1\right] - \frac{(V + R_S I)}{R_P} \quad [3]$$

The cell model described by equation (3) representing the expression of the current-voltage characteristic has undergone many simplifications and is commonly used as a first approach to simulate the behavior of the cell.

4.4.2 Mathematical model with a two diodes:

The two diodes model is shown in the figure below:

Figure (10): two diodes model



Equation (4) drawn from the electric diagram of two diodes model represents the current delivered by the PV cell:

$$I = I_{PV} - I_{d1} - I_{d2} - I_{R_P} \qquad [4]$$

The diodes currents Id1 and Id2 are:

$$I_{d1} = I_{s1}\left[\exp\left(\frac{qV_{d1}}{A_1 kT}\right) - 1\right] \qquad [5]$$

$$I_{d2} = I_{s2}\left[\exp\left(\frac{qV_{d2}}{A_2kT}\right) - 1\right] \qquad [6]$$

In summary, when developing the expression of cell current model based in two diodes, equation (4) would be written:

$$I = I_{PV} - I_{s1}\left[\exp\left(\frac{q(V + R_S I)}{A_1kT}\right) - 1\right] - I_{s2}\left[\exp\left(\frac{q(V + R_S I)}{A_2kT}\right) - 1\right] - \frac{(V + R_S I)}{R_P}$$

[7]

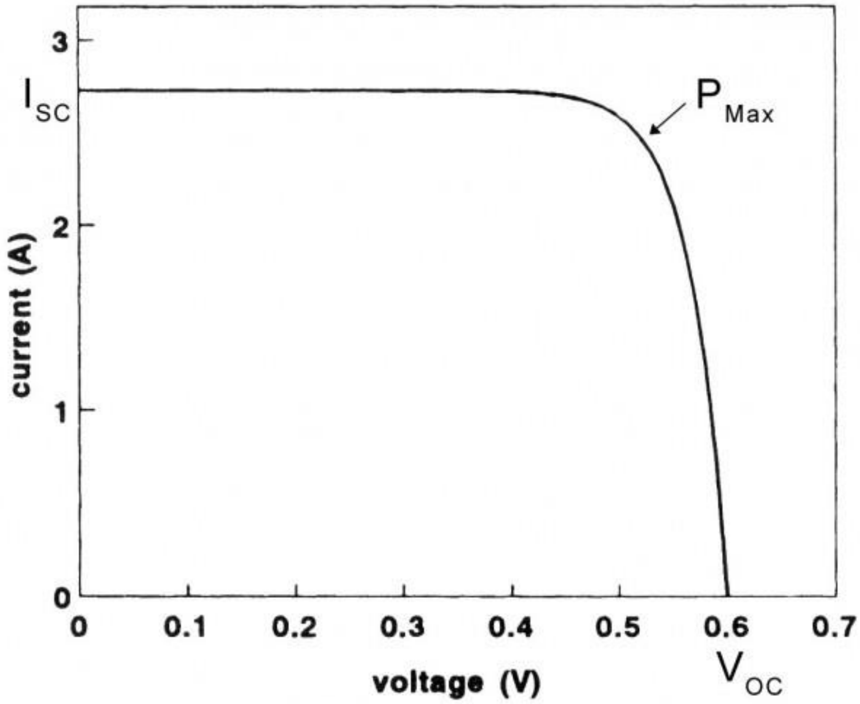
In the literature, the first term of the exponential corresponds to conduction phenomena of electrons from the neutral zone of the junction (diffusion and recombination) with A1≈1 and the second term of the exponential corresponds to recombination of carrier in the electronic charge zone with A2≈2.

4.4.3 Development of mathematical model of the photovoltaic generator:

The current-voltage characteristic of the PV cell derived from equation (7) passes through three points:

- The short-circuit current (**I_{sc}**).
- The open circuit voltage (**Voc**).
- The maximum power point (**P_{max}**).

Figure (11): vertical portion of the characteristic



The figure above shows that in the vertical portion of the characteristic, the PV cell can be considered as a constant voltage generator and in its horizontal part as a constant current source.

The parameters of the current-voltage characteristic are highly dependent on temperature and illumination. It can be distinguished on the following equations:

$$I_{PV} = I_{PV}(T = 298°K)\frac{E}{E_0}\left[1 + K_0(T - 298°\mathrm{K})\right] \qquad [8]$$

$$I_{s1} = K_1 T^3 \left[\exp\left(\frac{-E_g}{kT}\right)\right] \qquad [9]$$

$$I_{s2} = K_2 T^{\frac{5}{2}} \left[\exp\left(\frac{-E_g}{kT}\right)\right] \qquad [10]$$

With:

- $I_{PV}(T=298°K)$: Photo generated current of the cell 25°C.
- E_0 = 1000W/m^2.
- $K_0 = 5.10^{-4}\ A/°K$.
- $K_1 = 1.2\ A/°K^3$.
- $K_2 = 2.9.\ 10^{-5}\ A/°K^{5/2}$.

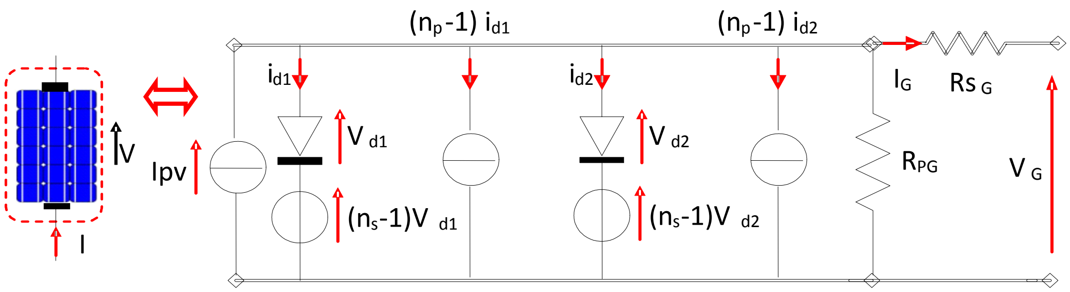
To alleviate calculations, it is considered the temperature of the PV cell identical to the room temperature, because the two quantities are related experimentally by the following expression:

$$T = T_{amb} + \left(\frac{NOCT(°C) - 20}{800}\right)E \qquad [11]$$

The term NOCT (°C) (Nominal Operating Cell Temperature) is defined by the manufacturer. It characterizes the nominal operating temperature of the cell operating in open circuit under illumination of 0.8kW / m² and a temperature of 20 ° C, for a wind speed less than 1m /s.

Using the previously modeled PV cells, to define a photovoltaic generator of n_s cells in series and n_p cells in parallel, we obtain the following equivalent diagram:

Figure (12): Expression of the current delivered by the PV generator



Expression of the current delivered by the PV generator is:

$$I_G = I_{PV,G} - I_{d1,G} - I_{d2,G} - I_{R_p,G} \quad [12]$$

with:

$$\begin{cases} I_G = n_P I \\ I_{d1,G} = n_p I_{d1} \\ I_{d2,G} = n_p I_{d2} \\ I_{PV,G} = n_p I_{PV} \\ I_{R_p,G} = n_p I_{R_p} \end{cases}$$

And using the following notations:

$$\begin{cases} V_G = n_S V \\ R_{S,G} = \dfrac{n_S}{n_p} R_S \\ R_{P,G} = \dfrac{n_S}{n_p} R_P \end{cases}$$

By developing the equation (12) by integrating the previous quantities, it is obtained that the current-voltage characteristic of the generator:

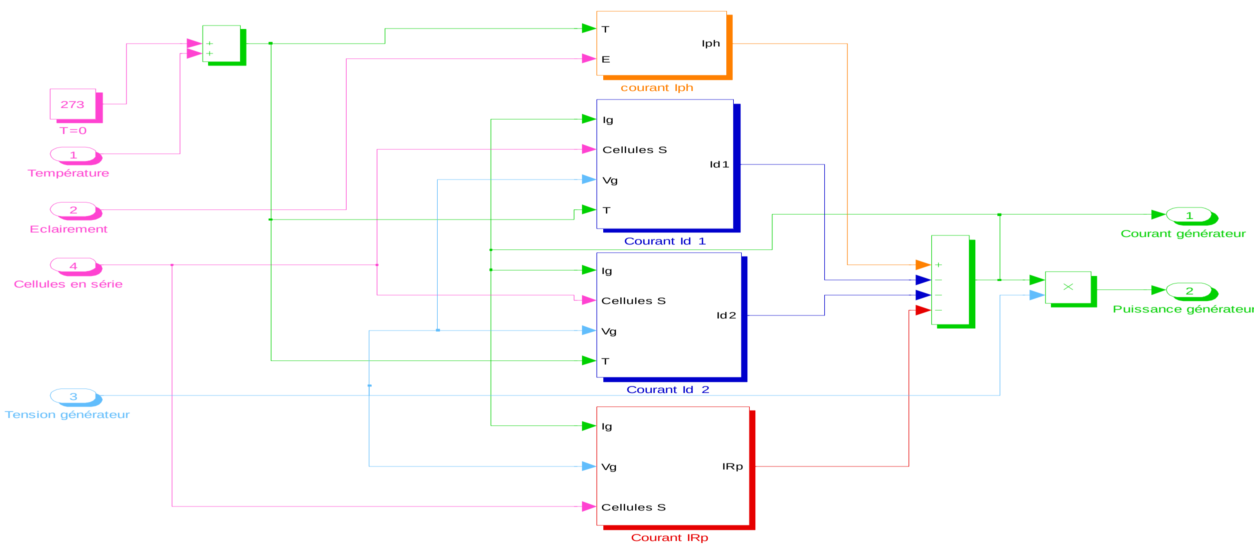
$$I_G = I_{PV,G} - I_{s1}\left[\exp\left(\frac{q(V_G + R_{S,G}I_G)}{n_S A_1 kT}\right) - 1\right] - I_{s2}\left[\exp\left(\frac{q(V_G + R_{S,G}I_G)}{n_S A_2 kT}\right) - 1\right] - \frac{(V_G + R_{S,G}I_G)}{R_{P,G}}$$

[13]

4.4.4 Simulation of the PV generator:

For this, a standard solar module of 36 cells in series was used. The model of the photovoltaic generator was implemented in the environment "MATLAB / Simulink" and got the characteristics I = f (V) and P = f (V).

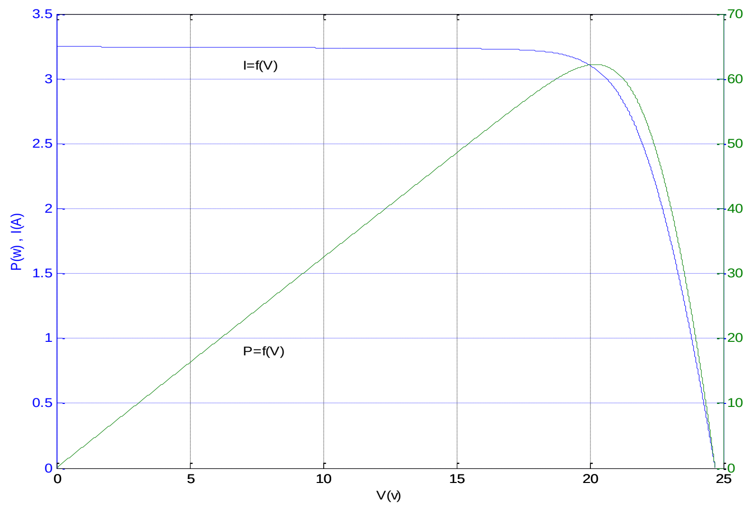
Figure (13): The model of the photovoltaic generator



4.4.4.1 Simulation of the PV generator under standard conditions:

For a temperature of 25 ° C and an illumination of 1 kW / m2, the characteristics I = f (V) and P = f (V) was obtained. The results of this simulation are in figure 14.

Figure (14): Simulation of the PV generator under standard conditions



From the characteristics I = f (V) and P = f (V), it is determined that the open circuit voltage Voc = 24.7V, the short circuit current Isc= 3.248A, the maximum power Pm = 62.21W, current for which the power is maximum I_{max} = 3.08A and the voltage at which the power is maximum V_{max} = 20.19V.

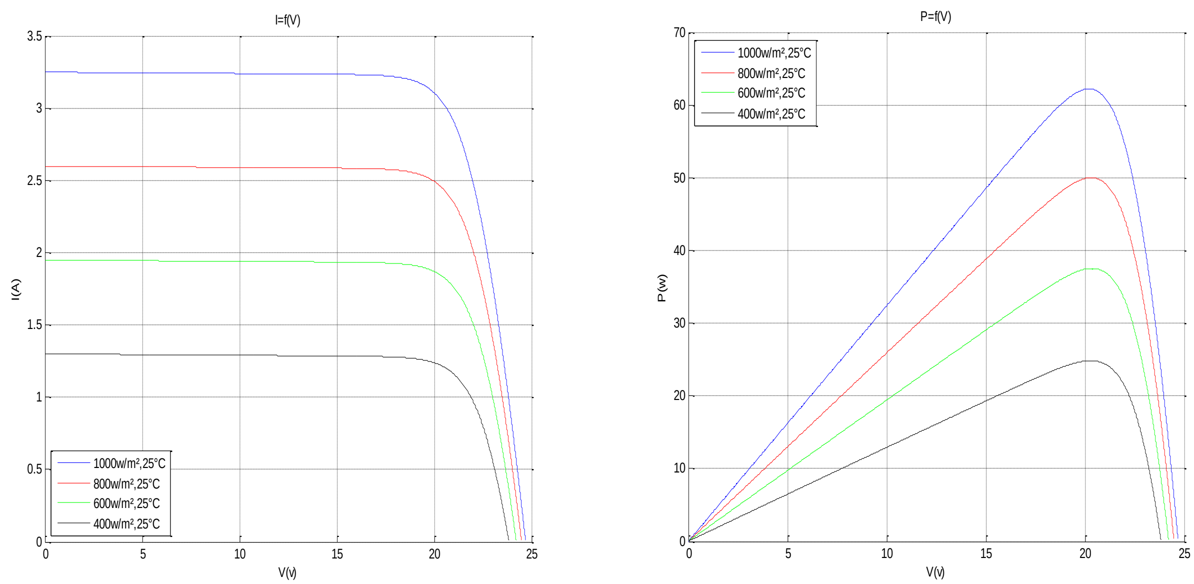
4.5 Sensitivity Analysis

The electrical characteristics of a PV generator varies depending on the temperature, illumination, internal parameters and generally of the nature of the connected load. The behavior of the generator subject to various constraints was simulated. These notions are indeed necessary to understand the behavior of a PV array and then perform operating optimizations.

4.5.1 Influence of illumination:

It is needed to vary the illumination between 400W / m 2 and 1000 W / m2 for a constant temperature of 25 ° C. The influence of light on the characteristics I = f (V) and P = f (V) is shown in figure 15.

Figure (15): The influence of light on the characteristics I = f (V) and P = f (V)



Concerning the variation of the illumination, it is noticed that for a temperature of 25 ° C, increasing the illumination leads to the increase in maximum power and a slight increase in the open circuit voltage. The short circuit current increases dramatically with increase in illumination. This implies that:

- The optimum power of the generator is substantially proportional to the illumination;

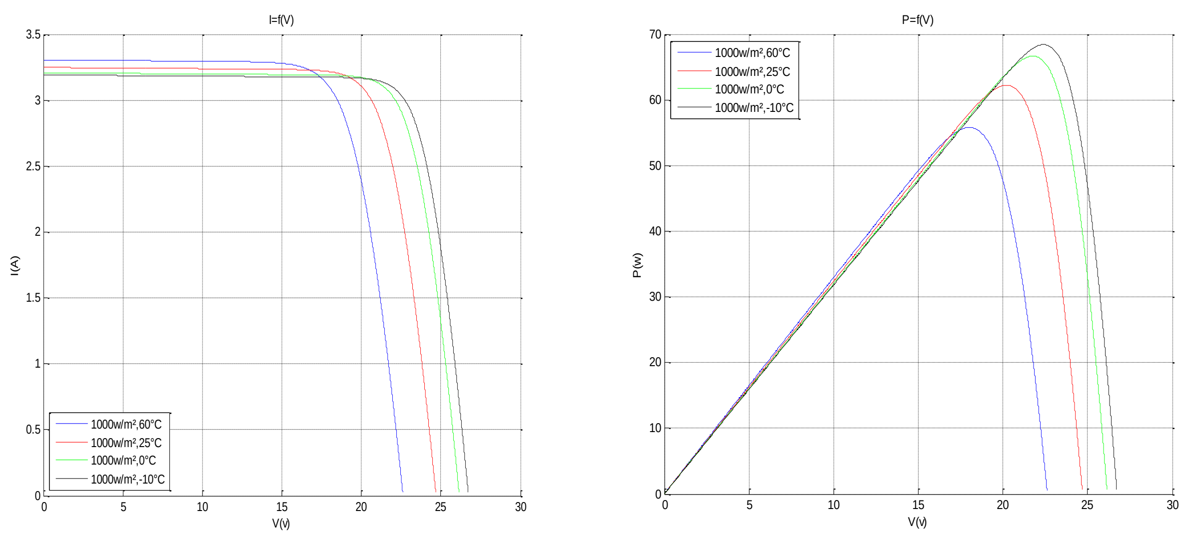
– Maximum power points are approximately at the same voltage.

4.5.2 Temperature influence:

The temperature influence is considerable on the operation of the generator. By varying the temperature between -10 ° C and 60 ° C under an illumination of 1000 W / m2, it is seen that the influence of temperature on the characteristics I = f (V) and P = f (V).

The open circuit voltage decreases considerably with increasing temperature for the same maximum power. By cons, we notice a slight increase in the short circuit current with increasing temperature. For a temperature change, it is deduced that the voltage changes significantly while the current remains constant.

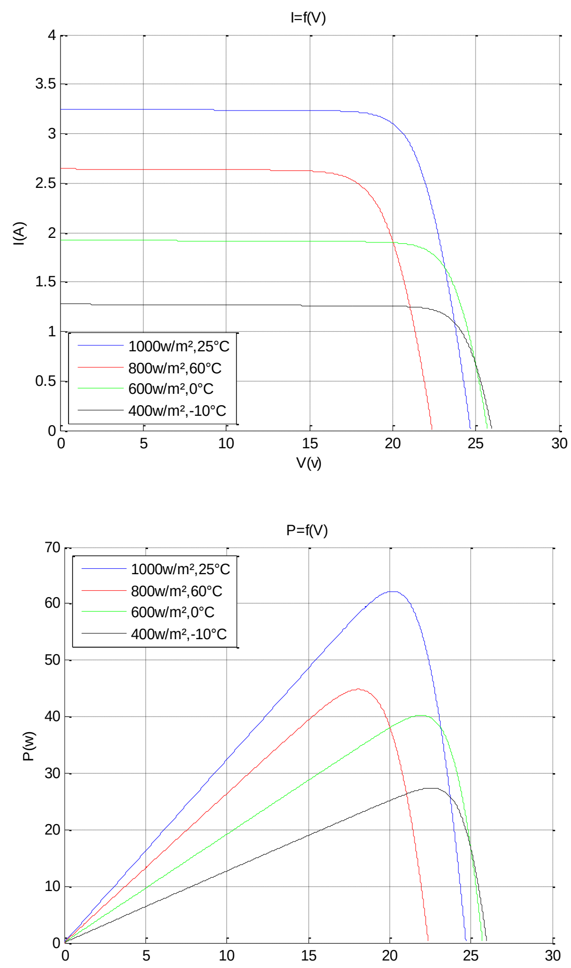
Figure (16): Effect of temperature on circuit voltage



4.5.3 Simultaneous influence of illumination and temperature:

In fact, the variation of the temperature and illumination is random, but is especially simultaneously, which leads to perform a simulation with a simultaneous variation of two meteorological quantities.

Figure (17): Simultaneous influence of illumination and temperature



This simulation confirmed the previous simulations regarding the variation of the illumination and temperature. In fact, the illumination is on the short circuit current and the temperature on the open circuit voltage simultaneously.

4.6 Operating and Checking the Model

After applying all the steps mentioned above, and after making all needed calculations, the researcher got done with the model where he exported a formula that can save all this time and effort into Microsoft Excel. This step was made to make it easier for the hospital management as many of them are not familiar with MATLAB/Simulink.

Following a sample from the model with the following data:

Photovoltaic cell (efficiency)		0.152	Polycristallin		
Number of hours of sunshine per year		7680	Hours		
The number of hours of sunlight equivalent		4450	Hours		
Al Shifa Hospital (Energy / Power)	85	1020			
	25	150			
	25	600			
	5	120			
	5	120			
	5	120			
	Energy	**2130**	kWh/day	**777450**	Kwh/an
	Power	**150**	kW		
The determination of the annual electrical energy produced by m²	Ee	676.4	kWh/m²		
Ee = Efficiency x maximum radiated power per m2 x number of hours of sunlight					
Maximum effective radiated power per m2 = 1 kW / m²					
Determining the minimum area of photovoltaic system	S_min	1149.39385	m²	35m x 33m	
S_{min} = Energy / Ee					
minimum area Photovoltaic reassessed (Inverter Efficiency 90%)		1264.33323	m²	35,55m x 35,6m	
Surface of a cell		0.025281	m²		
Number of cells		50011.2035	cells		
Number of panels		1000.22407	panels		
		1000	panels		
Overall equivalent electrical power (peak power)		185000	Wc		
		185	kWc		
correction factor		1.23333333			
minimum area Photovoltaic reassessed (Inverter Efficiency 97%)		1183.87567	m²		
Number of cells (Inverter Efficiency 97%)		46828.6723	cells		
Number of panels		936.573447	panels		
		936	panels		
Overall equivalent electrical power (peak power)		173160	Wc		
		173.16	kWc		
correction factor (New)					

In this sample, the hospital needs a number of 936 panels and area of 1184 m^2. The number of inverters depends on the capacity of inverters available in the market. Here, it is assumed that the invertor can work for about 25, and to keep a margin of safety, the management shall install 20 cell to each invertor. Here the calculations go as follow:

- **Needed space is = 1184 m^2**
- **# of panels needed = 936**
- **Cost of panel = 200 US$**
- **Cost of Invertor = 500 US$**
- **So, the cost of panels = 936 x 200 = 187, 200 US$**
- **# of inverters needed = 936/20 = 46.8 > 47 inverter.**
- **Number of batteries = (4608 x 1000) /12 / 200 = 1920**
- **Cost of batteries = 1920 x 500 = 960,000 US$**
- **Cost of inverters = 47x500 = 23,500 US$**
- **Head cost (approximately) = 15,000 US$**
- **So, the total cost in this case = 187,200 + 23,500 + 15,000 + 960,000= 118,5500 US$.**

Chapter 5: Results and Recommendations

5.1 introduction

5.2 Main Results

5.3 Recommendations

5.4 Suggested Topics for Future Research Studies.

5.1 Introduction

The major aim of this research is to provide the decision makers at Al-Shifa Medical Complex with very detailed and precise calculations that help them in taking accurate decision regarding installing solar power system. This chapter includes main results and provide some recommendations accordingly.

5.2 Main Results

- Al-Shifa Medical Complex suffers a sever electricity shortage.
- Solar power systems contribute to the alleviation of electricity crisis in Gaza especially the Medical Institutions.
- Solar power systems are less expensive than it is imagined.
- Simulation models are very practical as they give a complete illustration for the needed systems as if they were real.
- This model can be applied either completely or partially.

Table (7): Comparison between the costs of solar system and the current electricity at the Hospital

The Hospital's Electricity Consumption	Cost of Electricity/ Day	The Hospital's Cost of Fuel Consumption	The Cost of the System
2,130 kWh/day	Around 300 US$	147,127 US$	118,5500 US$

5.3 Recommendations

- The Ministry of Health should start installing solar power systems at the medical institutions in the Gaza.
- The proposed model must be updated according to different requirements of the solar power system.
- Professional workers and specialists should manage and install the proposed system.
- There should be integrated information system at the Ministry of Health in cooperation with the Energy Authority.

5.4 Suggested Topics for Future Research Studies

- Developing a solar electrical power station covering all the Gaza Strip.
- Designing and simulating a solar power system for the Islamic University of Gaza.

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