SIZING AND ANALYSIS OF A STAND-ALONE PHOTOVOLTAIC AND WIND SYSTEM

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To my beloved parents, thank you.

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ABSTRACT

This project discusses the sizing process of a stand-alone hybrid Photovoltaic (PV) and Wind system that will be used at a house located in Hodan, Mogadishu, Somalia. The development of the system is intended to reduce the use of non-renewable energy sources and the causes of major pollution. It is important to establish renewable energy in rural areas where the availability of fuel is costly for grid expansion. Wind energy systems are becoming increasingly accepted, more cost-competitive than conventional energy systems. A photoelectric generation system can be paired with other renewable energy sources such as wind turbines with the benefit of being a powerful summer and winter, day and night with best output during this time when PV energy is reduced (usually in winter and night), and vice versa. However, to use this system there are several factors that need to be focused on. One of the factors is sizing, this is a major factor that needs to be focused because if there is a mistake during calculations there is a probability that the outcome of the design system will not be able to supply enough energy required by the load. Firstly, a hybrid PV and wind system are sized according to the house's electrical load requirement. Secondly, the performance of the system in terms of energy and cost is analysed. Thirdly, the optimum configuration of the hybrid system is identified. First, the system is designed to generate power 100% from the PV, then 100% from the wind. During the hybrid system sizing, the total energy is split into two halves. One half (50%) of the energy required from the load is received from the PV system. While the other half (50%) is received from the wind system. Eventually, the result found was compared and analysed which is obtained after sizing the system. After comparing and analysing the system, the PV system was best according to less cost than the other systems and cost estimated is RM37,924.43 ($9,481.11).

ABSTRAK

Projek ini membincangkan Proses Ukuran sistem PV hibrida dan Angin mandiri yang akan digunakan di sebuah rumah yang terletak di Hodan, Mogadishu, Somalia. Pengembangan sistem ini bertujuan untuk menghilangkan penggunaan sumber tenaga yang tidak boleh diperbaharui dan penyebab pencemaran besar. Penting untuk mewujudkan tenaga boleh diperbaharui di kawasan luar bandar di mana ketersediaan bahan bakar mahal untuk pengembangan grid. Sistem tenaga angin semakin diterima, lebih berdaya saing berbanding sistem tenaga konvensional. Sistem penjanaan fotolistrik dapat dipasangkan dengan sumber tenaga yang boleh diperbaharui lain seperti turbin angin dengan kelebihan menjadi musim panas dan musim sejuk yang kuat, siang dan malam dengan output terbaik pada masa ini apabila tenaga PV dikurangkan (biasanya pada musim sejuk dan malam), dan begitu juga sebaliknya. Namun, untuk menggunakan sistem ini terdapat beberapa faktor yang perlu diberi perhatian. Salah satu faktornya adalah ukuran, ini adalah faktor utama yang perlu diberi tumpuan kerana jika terdapat kesilapan semasa pengiraan ada kemungkinan hasil sistem reka bentuk tidak akan dapat membekalkan tenaga yang diperlukan oleh beban. Akhirnya, hasil yang dijumpai dibandingkan dan dianalisis yang diperoleh setelah ukuran sistem. Setelah membandingkan dan menganalisis sistem, sistem PV adalah yang terbaik mengikut kos yang lebih rendah daripada sistem lain dan kos yang dianggarkan adalah RM37924.43 ($9,481.11).

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

DC	–	Direct Current
AC	–	Alternating Current
PV	–	Photovoltaic
%	–	Percentage
MW	–	Mega Watt
KW	–	Kilo Watt
E	–	Energy Consumption
Q	–	Quantity of Electrical Appliances
PR	–	Power Rating of Electrical Appliances
t	–	Operating Time of Electrical Appliances
$\sum E_{ac}$	–	Total Daily Energy Consumption
η_{inv}	–	Percentage of Inverter's Efficiency
P_{AC}	–	Total AC Power Demand
t_{OP}	–	Weighted Average Operating Time
E_1	–	Energy Required for Load 1
t_1	–	Operating Time for Load 1
E_2	–	Energy Required for Load 2
t_2	–	Operating Time for Load 2
E_n	–	Energy Required for Load n^{th}
t_n	–	Operating Time for Load n^{th}
I_{array}	–	Required Solar Array Current
η_{batt}	–	Battery System Charging Efficiency
V_{SDC}	–	System Voltage of the Battery
PSH	–	Peak Sun Hour
C_S	–	Soiling Derating Factor

I_{mp}	–	Maximum Power Current
V_{array}	–	Required Solar Array Voltage
$C_{\%V}$	–	Temperature Coefficient for Voltage
T_{max}	–	Maximum Expected Module Temperature
T_{ref}	–	Reference Temperature
V_{mp}	–	Maximum Power Voltage
P_{wind}	–	Power Generate
CP	–	Maximum Power Coefficient
ρ	–	Air Density
A	–	Rotor Swept Area
V_{wind^3}	–	Wind Speed
I_{CC}	–	Current Rating of the Charge Controller
I_{CC_W}	–	Current Rating of the Wind Charge Controller
B_{out}	–	Required Battery Bank
t_a	–	Reserved Days
r_d	–	Average Discharge Rate of the Battery Bank
DOD_a	–	Allowable Depth of Discharge
B_{rated}	–	Rated Battery Bank Capacity
C_{Trd}	–	Temperature and Discharge Rate of Battery Bank
P_{inv}	–	Power Rating of Inverter

CHAPTER 1

INTRODUCTION

1.1 Background Study

Global warming, scarcity of traditional resources, and continued rising oil prices have attracted global interest in the development and use of renewable energy sources. Renewable energy is a clean energy source that can meet energy demand without causing environmental pollution. Wind and solar sources have the potential to reduce reliance on conventional energy sources, but the random behavior of both sources shows serious deficiencies. While solar power can only be used during daylight, wind speeds are extremely variable to provide a reliable source of energy[1].

The development of renewable sources in remote areas where the fuel supply is expensive grid expansion is a necessity. Wind energy systems are becoming more cost-competitive than conventional energy systems and are increasingly accepted. The cheapest renewable energy source in many countries of the world in solar energy has demonstrated its unique advantages in remote areas where energy transmission costs are very high, although solar energy is too expensive to be economic; there is not even a source of energy. Integration of wind and solar sources in the right form can overcome their unpredictable nature drawbacks and climate change[2].

The operation of a stand-alone photovoltaic (PV) system depends among other Factors in the input of energy and energy demand or load to the plate surface. Sunlight radiation contains random components that make it impossible to know exactly how much power the system will receive over a given period. Then, before building an independent photovoltaic system, it is important to consider its dimensions generator and storage systems for expected loads using the sizing method.

The PV array of stand-alone photovoltaic systems, the size of the inverter, and the battery are an important part of the system design. In this section, solar radiation data is required for the intended location of the installation site, load requirements, photovoltaic modules, inverters, batteries, and their operational efficiencies. Finally, mark the behavior of many students and easily advance the sizing method. Applicable and reliable [3].

The wind comes from the movement of air due to the pressure of atmosphere gradients. The wind flows from the largest pressure area to the low-pressure area. The higher the air pressure gradient, the higher the wind speed, and the consequences with the increase in wind power that can be taken from the wind, energy-converting machine.

Wind production and movement are complicated by several factors. The most important of these factors is the uneven heating of solar; Coriolis effects are caused by earth-orbiting and local geographical conditions [4].

However, due to its many derivative properties, the need to integrate a variety of reliable system resources creating a hybrid system based on renewable energy sources. Fortunately, depending on the location and duration, the PV energy and wind energy can be complimentary. However, it is necessary to include some energy storage to meet the loading requirements.

Stand-alone or connected grid application a Photoelectric generation system can be combined with other alternative energy sources like Wind turbines with the advantage of being an effective summer and winter, day and night with the best products during this period when PV energy is limited (usually in winter and night), and vice versa.

The Hybrid Renewable Energy System (HRES) is made up of several types of renewable energy. Energy sources such as photovoltaic (PV) and wind energy (WE). Adding-on battery-storage (BS) enables two-way power to save excess energy and take care of load demand throughout the day, irregularities, and at night. Using different sources of energy, creating a hybrid system enhances the efficiency of the system. It provides energy reliability and reduces energy storage.

Requirements for systems containing single RES. The wind, in essence, the power system, is nowhere to be found. There is not enough wind speed photo-voltaic wind hybrid system (PWHS) with BS a very reliable power source [5].

The proposed technology solution relies on photovoltaic energy and wind, which is a generator that can generate electricity to meet energy demand. However, one of the limitations of using this technology in remote locations to provide energy supply throughout the year is the availability of energy sources; for example, if there is no sun and wind, the PV system and wind farm do not generate electricity; however, to ensure freedom and security of energy supply, increasing the difficulties associated with using this clean technology by increasing their integration with fossil fuels, Very important compared to each other and/or individuals. The power of hybrid systems is still not attractive due to the difficulty in achieving optimal system design. Therefore, many different technical and economic analysis strategies are presented in the hybrid power system in the literature to determine the most reliable configurations at the lowest cost. This is why we offer a scale and sensitivity study to facilitate the design of a hybrid system [6].

1.2 Problem Statement

Somalia is a country with a good climate, which makes the weather in Somalia predictable. In Somalia, hybrid photovoltaic and wind are best suited for adaptation because photovoltaic can be used as the weather in Somalia is very hot, and Somalia gets more than enough sunlight all year. Also, the wind should be used in the case of rainy or cloudy days, and also Hybrid solar and wind systems are offered for the day and night operations. Somalia has the longest coastlines in Africa after Madagascar. However, to use this system, several factors need to be focus on. One of the factors is sizing; this is a major factor that needs to be a focus because if there is a mistake during calculations, there is a probability that the outcome of the design system will not be able to supply enough energy required by the load. If excess energy is generated, there will be an overwhelming waste that we can avoid if the calculations are done correctly. Also, excess energy by the system will cause an increase in system cost. Due to the sizing steps involved many steps and calculations, this may lead to calculation error. So, in this project, all the components such as solar panel, wind turbine, inverter, battery, and charging circuit need to be carefully calculated to get the desired results.

Eventually, this project focuses on obtaining the optimum of hybrid solar and wind systems individually after sizing from source to the load according to their energy and cost.

1.3 Objectives

The objectives of this project are:

I. To size a hybrid PV and wind system for the house.
II. To analyse the performance of the system in terms of energy and cost.
III. To identify the optimization usage of the system.

1.4 Scope of the Study

This project is divided into three major phases:

i. This project focuses on the sizing for load of small house
ii. Selected load below 1KW
iii. Selected sizing and analysis of PV, wind and hybrid PV wind system
iv. Comparing PV, wind and hybrid PV wind systems by their performances individually according to their energy and cost.
v. All the works and analyses are done using manual calculations.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

As promising power generation sources, wind and solar power are regarded. These renewable energy, with free access and a nice environmental impact, are ubiquitous. Practically and fixed costs, their convergence remains beneficial for electricity production in isolated regions. In some examples, the independent use of solar and wind energy sources will lead to significant over-sizing, which makes the deployment of single renewable energy sources very expensive. The use of one of the optimization sizing methods has been discovered to assist with ensuring the optimum energy reliability and minimal system costs for the potential deployment of hybrids. Also, the use of solar and wind renewable energy sources (RES), which give a practical method of electricity production in remote areas, shows significant interest[5].

2.2 Solar Energy

The solar is an important and limitless of free energy (solar energy) for the planet Earth. At this moment, new advances are being used to create energy from gathered sun lights based its energy. These methodologies have recently been demonstrated and are comprehensively practiced all through the world as renewable options as opposed to standard non-hydro advancement. As seen an assessment of the non-hydro renewable power limits between countries for 2012. Hypothetically, solar energy has the possibility and sufficiently satisfy the energy requests of the whole world if advancements for collecting and giving were instantly available. Almost 4,000,000 exajoules (1EJ = 1018J) of solar energy arrives on the earth every year, ca. 5 × 104 EJ of which is claimed to be successfully harvestable. since this great potential and expansion in mindfulness, the responsibility of solar that based energy to the worldwide energy supply is yet irrelevant [7].

2.2.1 Photovoltaic (PV) Solar Power

The solar energy into an electrical energy conversion using PV cells is called solar photovoltaic (PV). Photovoltaic has various advantages over different advancements, for example, quit energy change, simple plan and establishment, less upkeep necessity, basic transportation, and lightweight. The experimentation identified with PV is presently focused on the development and answer for higher capability and lower cost of panels and systems as shown in Figure 2.1 [8].

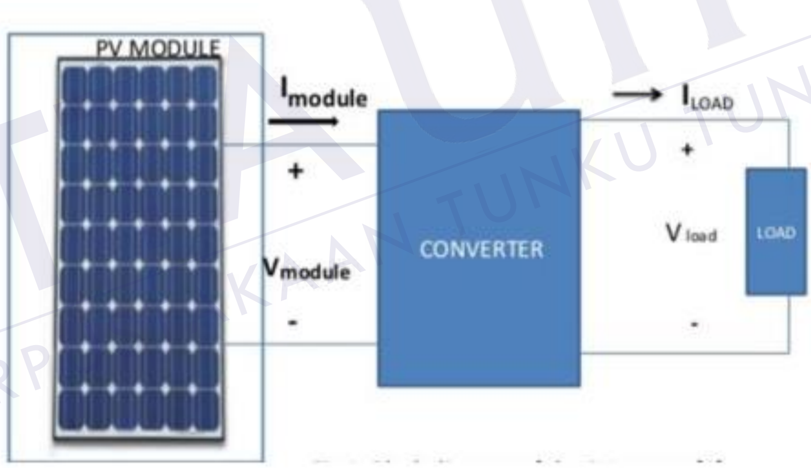

Figure 2.1: Basic Solar power [8].

2.2.2 Structure of Photo-voltaic

The PV cells construction is obvious. It contains 6 unique layers of materials as exhibited in Figure 2.2. Most importantly, the productivity of photons as is assimilation is expanding because of the help of black cover glass surface, and the glass is shielding the cell from the components of air. The reflection misfortunes of the photons are decreased to under 5% by the anti-reflection covering. The moving distance of the Photons was limited by the contact grid, with the goal that is ready to come to the semiconductors. The important of the photovoltaic system is comprising of semiconductors p and n as two narrow layers. In conclusion, the back contact is giving for better conduction[10].

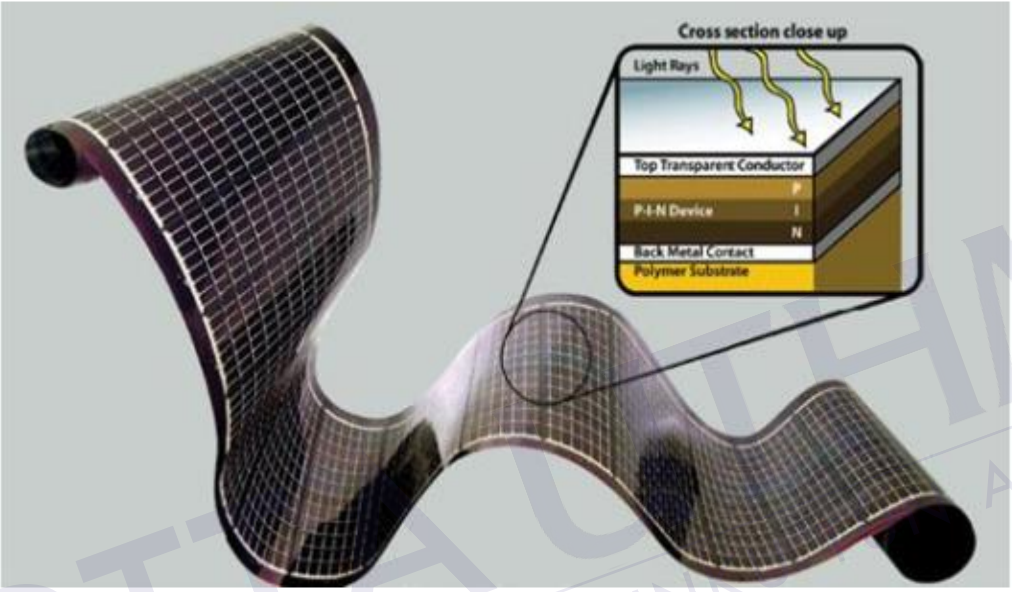

Figure 2.2: PV system Structure [10]

2.2.3 Semiconductors p-n- type

The PV cells referred to previously contain 2 semiconductors p-n which are both made of crystalline silicon. The n-type semiconductor is being made when a portion of their particles of the crystalline silicon is supplanted by particles of another material that has a higher valence band like phosphorus. Thus, an n-type semiconductor is being made which has an overflow of free electrons in its valence band. Then again, a p-type semiconductor is made when a portion of the particles of the crystalline silicon is supplanted by particles with lower valence like boron, and the outcome is the making of another material with deficiency of free electrons and is known as a p-type semiconductor. These missing electrons are called holes [11].

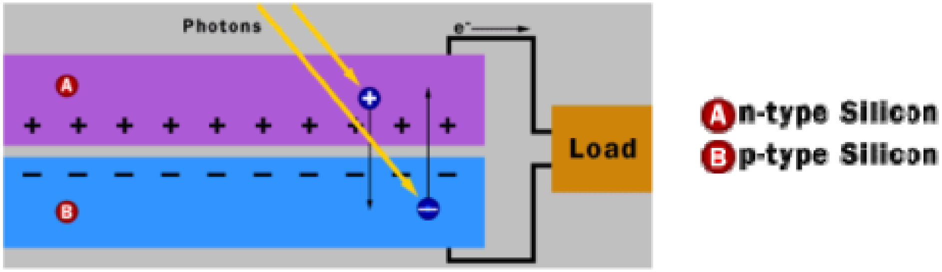

Figure 2.3: Operation of a PV cell [11]

The p-n junction is made while semiconductors are contacting together, the depletion region is made when the electric field is putting together in that specific area. In Figure 2.3, it is shown that dissemination from one semiconductor to the next one that can be ready to make the electrons move， this cycle is made that particles with positively charged one way and particles with negatively charged inverse way [11].

2.2.4 Photovoltaic Effect

The solar light beams are the primary key to make the photovoltaic effect. Electrons will be animated when the photons in the photovoltaic cell presented to the solar light beam. The electrons will hop into the conduction band after it begins moving quickly, and afterward, holes in the valence band left by electrons. Holes of close p-side are joining with electrons pulled in from inverse direction which is n-side[12].

The electric flow in the PV cell is making by electrons, starting with one semiconductor flow over to the next. Likewise, whenever grooved Si surface and the covering of against reflection surface can be utilized, it can certainly increase the assimilation of the photons in the Photovoltaic cell. Other than that, the open-circuit voltage will occur if the current is demonstrated lowest (zero) value, the resistance in the circuit is limitless, and the voltage reaches the greatest value. If not, the short circuit will occur if the current of the circuit shows up at the best value, the resistance of the circuit is zero. The photovoltaic cell's I-V characteristic can be portrayed if the resistance among boundlessness and zero changes, the voltage and current will be decided to change also. The maximum energy point (MPP) of the Photovoltaic cell can be shown in Figure 2.4 [13].

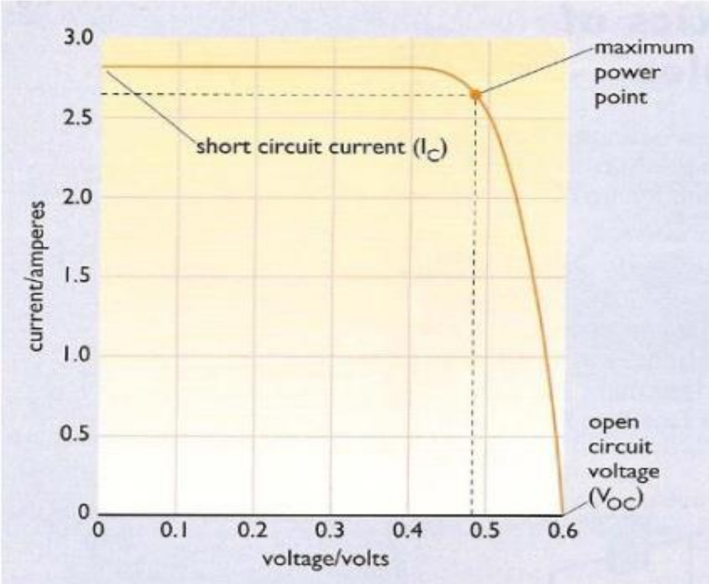

Figure 2.4: I-V curve of typical silicon PV cell under standard test conditions [13]

Finally, global standard test conditions are set up to quantify the energy production of photovoltaic cells. The level of irradiance is characterized as 1000 W/m^2, with the reference of air mass 1.5 solar spectral irradiance distributions and cell junction with the temperature of 25 °C [14].

2.2.5 Main Cell Types

The material that is utilized broadly in the field for the making of photovoltaic cells is silicon. Silicon can be found inside the sand as silicon oxide (SiO2). The end result is described by a high value 99.99999%. The photovoltaic cells of silicon are recognized in four classifications, based on the structure of the fundamental material from which they are made and the specific method for their planning. The sorts are the following ones:

1. Monocrystalline Silicon: The fundamental material is monocrystalline silicon. To make them, silicon is pure, softened, and crystallized into ingots. The ingots are cut into slight wafers (Wafer~300 μm) to build separate cells. The productivity of a single crystal silicon cell makes between 13-16% and it is identified by a significant expense for the production and has a dark blue colour [15].

2. Polycrystalline Silicon: The specific cell is moderately big in size, and it can be simply made into a square shape, which basically removes any inactive region between cells. Its proficiency makes between 10-14%, and it is described by less cost silicon, which is utilized for its production and has a light blue colour.

3. Ribbon Silicon: Ribbon-type photovoltaic cells are made by giving a ribbon from the melted crystal silicon rather than an ingot. Its productivity is around 13% and is high cost with a limited industrial production [16].

4. Technology which uses thin-film solar based cells while the absolute thickness of a semiconductor is about 1 μm. Shapeless or thin-film silicon cells are solids in which the silicon particles are considerably less arranged than in a crystalline structure. By utilizing various junctions such as photovoltaic cells accomplish the most extreme effectiveness, which is assessed at about 13% while the establishment cost is to be decreased. Moreover, the produce of a shapeless silicon cell isn't diminished as temperature increments and is much expensive to make than crystalline silicon [17].

2.2.6 Solar Module

Most of the solar modules accessible and utilized for private and business solar systems are silicon crystalline. These modules comprise a number of strings of solar cells, wired in series (positive to negative), and are placed in an aluminum frame. Every solar cell is fit for generating 0.5 volts. A 36-cell module is estimated to generate 18 volts. In a frame, larger modules can have 60 or 72 cells. The number of amperages is determined by the cell's size or area. The larger the cell, the higher the amperage[9].

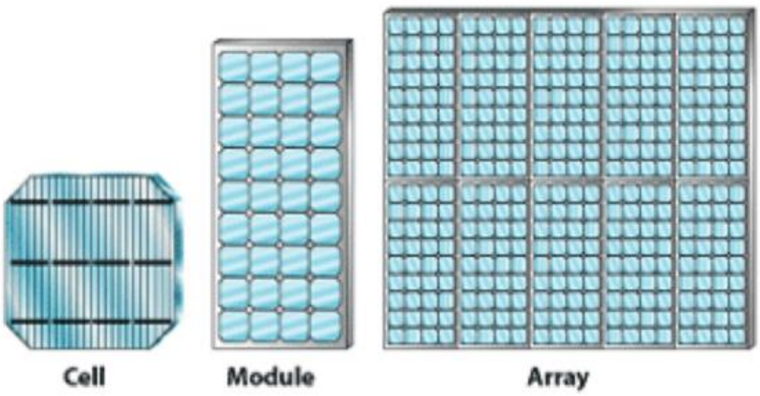

Figure 2.5: I-V curve Demonstrated on cell, module, and array[9].

The solar cell shows the fundamental components in Figure 2.5. A number of cells are wired together and placed in a frame form a solar module. Multiple modules connected together to form an array [9].

2.2.7 Main Principles of PV Systems

A PV cell is infrequently utilized in a single set or independently, since it can't supply enough energy and voltage of electronic device necessity. Because of this explanation, it needs more arrangement of photovoltaic cells to be coupled together and to be associated parallel or in a series for energy manufacturing, to accomplish the more energy produce and voltage as could be expected. A normal photovoltaic system is made of 36 individual 100 cm ²silicon photovoltaic cells and assistant devices which are lead-acid batteries with a common voltage of 12V. This system has the limit of delivering more than 13V during cloudy days and can charge a 12 V battery [18].

To use the system productively, it is needed to focus that how can it functions during different electrical loads associated in the system. As previously mentioned, I-V curve is the main key for the photovoltaic cell; it is mirroring the production and describes a photovoltaic cell. Every parameter of the photovoltaic cell can be done and determined by utilizing the I-V bend [19].

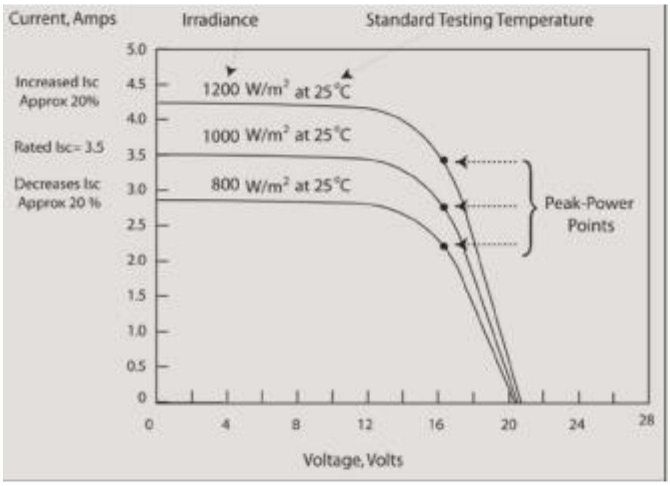

Figure 2.6: I-V curves in different intensities of solar irradiance[19]

In actual conditions, the capacity of a PV system might be changed due to the energy variance of solar radiation throughout some of time. At the point when the light of photovoltaic cells, which provides an electrical resistance, changes, the energy point shifts. This point can be viewed as testing if the electric energy, which is given by the PV cell with a given energy density E and applied on a variable electric resistance. Since the resistance varies, changes can be estimated in current and voltage by using the suitable measurement devices; ammeter and voltmeter. Figure 2.6 shows that presents a peak point in the "knee" of the I-V curve. The results of the electrical current in the maximum energy point are represented.

Utilizing the maximum energy and the suitable I-V curve, the fill factor can be determined. Fill factor is the main characteristic in finding PV cell production, while it can be shown that the proficiency of a photovoltaic system. As the results of the fill factor are close to unit 1, the capability of the system performance will be extended. The fill factor for a PV cell that has a high proficiency is somewhere in between in the range of 0.7 and 0.9 [20].

2.2.8 A Stand-alone PV system

Stand-alone PV systems are utilized in areas that are not effectively available or have no admittance to an electric grid. As shown in figure 2.7, a stand-alone system is free of the energy produced, with the energy being stored in batteries. A Stand-alone PV system contains a PV module or modules, batteries, and a charge controller. An inverter may also add the system for the purpose of converting DC current to the AC current [21].

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