CHAPTER ONE

INTRODUCTION

1.1. Overview

Renewable energy sources such as wind and solar energies are characterized by variations and stochastic power production. In its current technological level, the popular renewable sources such as wind and solar energy have some unavoidable serious drawbacks that require careful and continuous research and development as well as innovation. These drawbacks can be divided into three major categories; operational, economical and dynamical.

From operational point of view, popular renewable sources have higher and risky levels of variability. From economical point of view, most renewable energy sources currently show competitive economical properties. From dynamical point of view, the behavior of host smart grid power systems is significantly modified by the dynamic characteristics [1].

PV systems in Sudan have been mostly limited to residential housings and boats where connection to the electrical grid is difficult. Grid connected systems have not been widely developed in Sudan due to both technical and economic barriers with no support from the government. Getting concession to feed energy into the grid has been a relatively complicated process suited for professional electricity producers.

1.2 Problem Statement

Most of the electricity in Sudan is generated using the hydroelectric generation. It has a very high construction cost and requires continuous maintenance. As well, transmission capacity increase in case of demand increase is a burden. On the other hand, Sudan faces a serious problem of discontinuity of electricity supply, especially in the capital and main big cities. The hydro-power generators fail to feed their rated generation mainly in the rainy season -June to October- ; because of the accumulation of the mud in the dams.

1.3 Aims and Objectives

- To design PV system.
- To calculate the yearly energy and losses of system.
- To measure the current-voltage (I-V) characteristics of the available PV modules.
- To analyze grid performance and operational data.

1.4 Methodology

The system has been done by analytical method. Then a simulation and testing the PV system have been done by ETAB software. At last, simulation and analysis of a modified IEEE 9 bus radial testing grid have been done by ETAB software.

1.5 Project Outline

Chapter one: gives general description about project.

Chapter two: reviews the components of PV system.

Chapter three: shows the methodology of designing system by analytical method and simulation method.

Chapter four: this chapter is mainly to present the result have been obtained

Chapter five: includes conclusion and recommendation

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of photons that are incident on it to electrical energy, which is a natural and synthetic marvel. A separate cell unit can be connected to a frame module, also known as a solar panel. Different solar cells in a unified set, all arranged in the plane represents a solar photovoltaic board or module. PV modules usually have a glass in front of the panel, allowing light to pass through, while ensuring that the semiconductor plate is protected inside the case. Solar cells are usually associated and arranged in series or parallel module, depending up on the requirement of the customer. The parallel interface unit gets higher current; however, the problem that shadow effects can turn off weaker (less bright) parallel strings (different permutations of cells) can cause great unpleasant effects and may cause damage because of their enlightened complicity and the reversal of dark cell tendencies. A series of stacked units are usually autonomous and not parallel, but starting from 2014, each module provides a singular power box on a regular basis and connects in parallel.

2.2 The Working Principle of Solar Cells

The working principle of solar cells is based on the photovoltaic effect, i.e. the generation of a potential difference at the junction of two different materials in response to electromagnetic radiation. The photovoltaic effect is closely related to the photoelectric effect, where electrons are emitted from a material that has absorbed light with a frequency above a material-dependent threshold frequency.

2.3 Stand Alone PV Systems

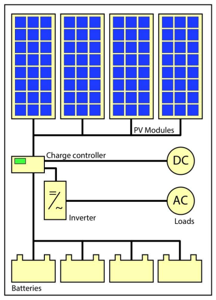
Stand-alone systems rely on solar power only. These systems can consist of the PV modules and a load only or they can include batteries for energy storage. When using batteries charge regulators are included, which switch off the PV modules when batteries are fully charged, and may switch off the load to prevent the batteries from being discharged below a certain limit? The batteries must have enough capacity to store the energy produced during the day to be used at night and during periods of poor weather. Figure 2.11.shows schematically example of stand-alone systems (large PV system with both DC and AC loads).

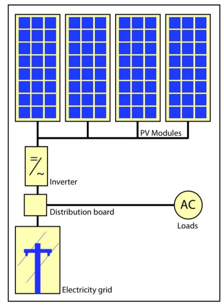
2.4 On Grid Systems

Grid-connected PV systems have become increasingly popular for building integrated applications. As illustrated in Fig. 2.12.they are connected to the grid via inverters, which convert the DC power into AC electricity. In small systems as they are installed in residential homes, the inverter is connected to distribution board, from where the PV-generated power is transferred into the electricity grid or to AC appliances in the house. These systems do not require batteries, since they are connected to the grid, which acts as a buffer into that an oversupply of PV electricity is transported while the grid also supplies the house with electricity in times of insufficient PV power generation.

2.5 Hybrid Systems

Hybrid systems consist of combination of PV modules and a complementary method of electricity generation such as a diesel, gas or wind generator. A schematic of a hybrid system shown in Fig. 2.13.In order to optimize the different methods of electricity generation, hybrid systems typically require more sophisticated controls than stand-alone or grid-connected PV systems. For example, in the case of a PV/diesel system, the diesel engine must be started when the battery reaches a given discharge level and stopped again when battery reaches an adequate state of charge. The back-up generator can be used to recharge batteries only or to supply the load.





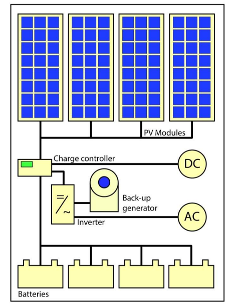


Fig. (2.1) **Figure (2.2)** **Figure (2.3)**

Fig. (2.1): a complex PV system including batteries, power conditioners, and both DC and AC loads.

Figure (2.2): Schematic representation of a grid-connected PV system.

Figure (2.3): Schematic representation of a hybrid PV system that has a diesel generator as alternative electricity source.

2.6: Components of PV systems

In order to use solar electricity for practical devices, which require a particular voltage and/or current for their operation, a number of solar cells have to be connected together to form a solar panel, also called a PV module. For large-scale generation of solar electricity solar panels are connected together into a solar array.

2.6.1 PV modules

A PV module is a larger device in which many solar cells are connected, as illustrated in Fig.2.14.The names PV module and solar module are often used interchangeably. A solar panels as illustrates in fig 2.14 c), consists of several PV modules that are electrically connected and mounted on a supporting structure. Finally, a PV array consists of several solar panels. An example of such an array is shown in Fig. 2.4 (d).

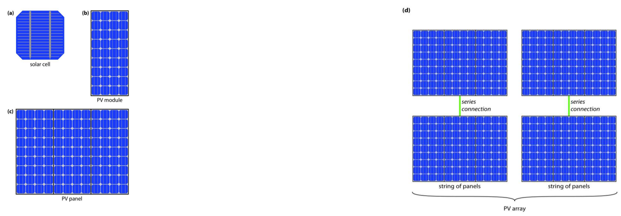


Figure (2.4): Illustrating (a) a solar cell, (b) a PV module, (c) a solar panel, and (d) a PV array.

2.6.1.1 Series and parallel connections

If we make a solar module out of an ensemble of solar cells, we can connect the solar cells in different ways: first, we can connect them in a series connection as shown in Fig. 2.15. (A). in a series connection the voltages add up. For example, if the open circuit voltage of one cell is equal to 0.6 V, a string of three cells will deliver an open circuit voltage of 1.8 V.

Figure Fig. 2.15. (d) *Shows* the I-V curve of solar cells connected in series. If we connect two solar cells in series, the voltages add up while the current stays the same. The resulting open circuit voltage is two times that of the single cell. Whereas the current still is that of one single solar cell. Secondly, we can connect solar cells in parallel as illustrated in Fig. 2.15 (c), which shows three solar cells connected in parallel. If cells are connected in parallel, the voltage is the same over all solar cells, while the currents of the solar cells add up. If we connect three cells in parallel, the current becomes three times as large, while the voltage is the same as for a single cell, as illustrated in fig 2.15. (d).

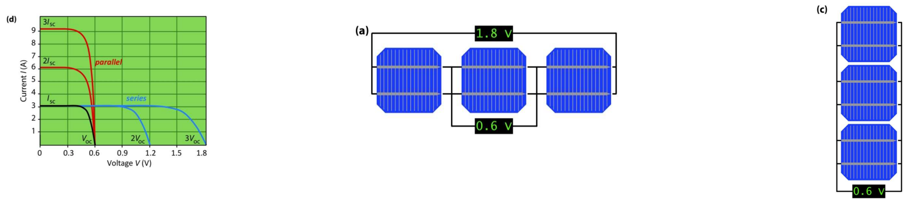


Figure (2.5): Illustrating (a) a series connection of three solar cells and (c) Illustrating a parallel connection of three solar cells. (d) I-V curves of solar cells connected in series and parallel.

2.6.1.2 Partial shading and bypass diodes

PV modules have so-called bypass diodes integrated. To understand the reason for using diode, we consider modules is partially shaded, as illustrated in Fig. 2.16. (A). the shade can be from an object nearby. Partial shading can have significant consequences for the output of the solar module. To understand this, we consider the situation in which one solar cell in the module shaded for a large part shaded. In a series connection the current is limited by the cell that generates the lowest current, this cell thus dictates the maximum current flowing through the module Prevented by including bypass diodes in the module as illustrated in 2.16. (c), a diode blocks the current when it is under negative voltage, but conducts a current when it is under positive voltage. If no cell is shaded, no current is flowing through the bypass diodes. However, if one cell is (partially) shaded, the bypass diode starts to pass current through. As a result current can flow around the shaded cell and the module can still produce the current equal to that of not shaded.

For cells that are connected in parallel, partial shading is less of a problem, because the currents generated in the others cells do not need to travel through the shaded cell.

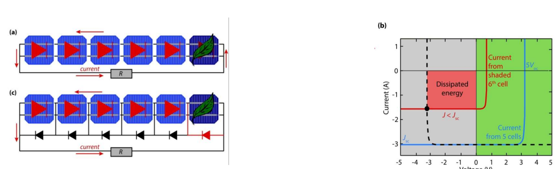


Figure (2.6): Illustrating (a) string of six solar cells of which one is partially shaded, which (b) has dramatic effects on the I-V curve of this string. (c) Bypass diodes can solve the problem of partial shading.

2.6.1.3 Fabrication of PV modules

A PV module must withstand various influences in order to survive a lifetime of 25 years or even longer. Of course, the layer stack may consist of different materials dependent on the manufacturer. The major components are

- Soda-lime glass with a thickness of several millimeters, which provides mechanical stability while being transparent for the incident light.
- The solar cells are sandwiched in between two layers of encapsulates. The most common material is ethylene-vinyl-acetate (EVA).
- The back layer acts as a barrier against humidity and other stresses..
- A junction box usually is placed at the back of the module.

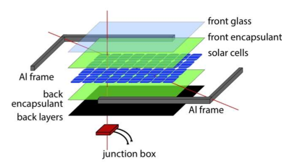


Figure (2.7): The components of a typical c-Si PV module.

2.6.2 Solar inverter

A solar inverter or PV inverter is a type of electrical converter which converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network.

2.6.3 Cables

Cables are used to connect different components of the PV system with each other and to the electrical load. It is important to choice cables of sufficient thickness in order to minimize resistive losses. [2]

2.6.4 Maximum power point tracking

Solar inverters use maximum power point tracking (MPPT) to get the maximum possible power from the PV array. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and determine a resistance (load) to obtain maximum power for any given environmental conditions.

2.7 Grid tied solar inverter

Grid tied solar inverters solar grid-tie inverters are designed to quickly disconnect from the grid if the utility grid goes down. This is an NEC requirement that ensures that in the event of a blackout, the grid tie inverter will shut down to prevent the energy it produces from harming any line workers who are sent to fix the power grid. Grid-tie inverters that are available on the market today use a number of different technologies. The inverters may use the newer high-frequency transformers, conventional low-frequency transformers, or no transformer. The concerns stem from the fact that there is a lack of galvanic isolation between the DC and AC circuits, which could allow the passage of dangerous DC faults to the AC side. [3]

2.7.1 Impact of connecting PV system to the Grid

If the PV penetration is really high Photovoltaic systems can subject the grid to several negative impacts. They are

I. Power Quality problems.

II. Increased Reactive power.

III. Islanding detection difficulty.

2.7.1.1 A. Power quality problems/Harmonics:

The inverter forms the core of the grid connected PV system and is responsible for the quality of power injected into the grid. Inverters also introduce harmonics into the system in the presence of non-linear loads, during DC to AC conversion. Harmonic currents introduce voltage drop and result in distortion of supply voltage.

2.7.1.2 Increased Reactive Power:

Photovoltaic inverters usually operate at unity power factor. Hence they prefer to operate PV inverters at unity power factor, maximizing the active power generation, and accordingly their returns. As a result the reactive power demand met by the PV system is minimal. Hence, the grid is responsible for supplying majority of reactive power, and it makes the distribution transformer operate at a low power factor

2.7.1.3 Islanding Detection:

The condition when the solar system continues to supply to the load even though grid power from the utility is not present is called islanding.

These impacts are dependent on the size and location of the PV system. PV systems are classified into three categories, based on the ratings of the system; Small-scale systems are rated at 10kW or less, Medium-scale systems are rated between 10kW and 500Kw, and large-scale systems are rated above 500 kW[4].