OPTIMIZATION OF STAND-ALONE PHOTOVOLTAIC SYSTEM BY IMPLEMENTING FUZZY LOGIC MPPT CONTROLLER

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For my beloved mother, wife, son and daughter

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ABSTRACT

A photovoltaic (PV) generator is a nonlinear device having insolation-dependent volt-ampere characteristics. Since the maximum-power point varies with solar insolation, it is difficult to achieve an optimum matching that is valid for all insolation levels. Thus, Maximum power point tracking (MPPT) plays an important roles in photovoltaic (PV) power systems because it maximize the power output from a PV system for a given set of condition, and therefore maximize their array efficiency. This project presents a maximum power point tracker (MPPT) using Fuzzy Logic theory for a PV system. The work is focused on a comparative study between most conventional controller namely Perturb and Observe (P&O) algorithm and is compared to a design fuzzy logic controller (FLC). The introduction of fuzzy controller has given very good performance on whatever the parametric variation of the system.

ABSTRAK

Penjana photovoltaic (PV) adalah sejenis peranti tidak lelurus yang mempunyai spesifikasi volt-ampere yang bergantung kepada ketumpatan sinaran matahari. Oleh kerana titik maksimum kuasa berubah-ubah mengikut kecerahan sinaran matahari, maka ia adalah sukar untuk mencapai nilai padanan maksimum yang sah untuk setiap peringkat kecerahan. Oleh itu, pengesanan titik kuasa maksimum (MPPT) memainkan peranan penting dalam system kuasa photovoltaic (PV) kerana ia dapat memaksimumkan kuasa keluaran dari sistem PV untuk satu set keadaan dan seterusnya memaksimunkan kecekapan tatasusunan PV tersebut. Projek ini mempersembahkan satu pengesan titik kuasa maksimum (MPPT) yang menggunakan teori fuzzy logic untuk sistem PV. Kerja-kerja ini memfokuskan kepada satu kajian perbandingan antara pegawal paling konnventional iaitu P&O algoritma dan dibandingkan dengan rekabentuk pengawal fuzzy logic (FLC). Pengenalan kepada pengawal fuzzy logic telah memberikan prestasi yang sangat baik dalam apa sahaja perubahan parameter system tersebut.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

In the last years global warming and energy policies have become a hot topic on the international agenda. Developed countries are trying to reduce their greenhouse gas emissions. Renewable energy sources are considered as a technological option for generating clean energy. Among them, photovoltaic (PV) system has received a great attention as it appears to be one of the most promising renewable energy sources. Photovoltaic power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components.

However, the development for improving the efficiency of the PV system is still a challenging field of research. MPPT algorithms are necessary in PV applications because the MPP of a solar module varies with the irradiation and temperature, so the use ofMPPT algorithms is required in order to obtain the maximum output power from a solar array.

Therefore, the motivation of this thesis is to obtain the maximum power point (MPP) of photovoltaic (PV) system by using Fuzzy Logic Controller (FLC). Hence, this thesis focused on the well-known Perturb and Observe (P&O) algorithm and compared to a design fuzzy logic controller (FLC). A simulation work dealing with MPPT controller, a DC/DC Boost converter feeding a load is achieved. The result will show the validity of the proposed Fuzzy Logic MPPT in the PV system.

1.2 Project Background

A photovoltaic system for isolated grid-connected applications as shown in Fig. 1.0 is a typically composed of these main components:

i. PV module that converts solar energy to electric power
ii. DC-DC converter that converts produced DC voltage by the PV module to a load voltage demand.
iii. Digital controller that drives the converter operation with MPPT capability.

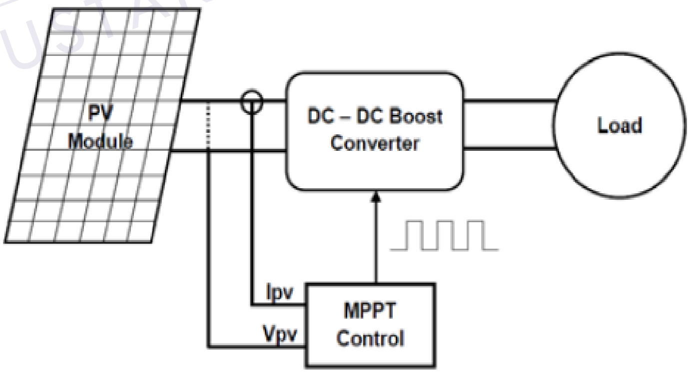

Fig. 1.0. Typical diagram of MPPT in a PV System

1.2.1 PV Equivalent Circuit

The model of solar cell can be categorized as p-n semiconductor junction; when exposed to light, the DC current is generated. As known by many researchers, the generated current depends on solar irradiance, temperature, and load current. The typical equivalent circuit of PV cell is shown in Fig. 2.0.

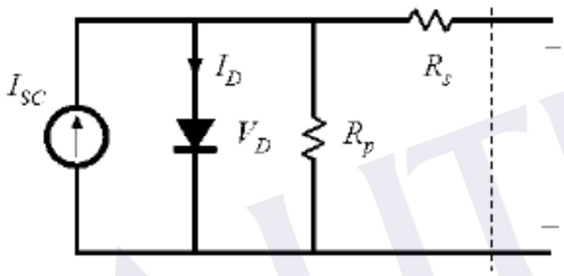

Fig. 1.1 Typical circuit of PV solar cell

The basic equations describing the I-V characteristic of the PV model are given in the following equations: [11]

$$0 = I_{SC} - I_D - \frac{V_D}{R_p} - I_{PV} \quad \text{...........(1.0)}$$

$$I_D = I_0(e^{V_D/V_T} - 1) \quad \text{...........(1.1)}$$

$$V_{PV} = V_D - R_S I_{PV} \quad \text{...........(1.2)}$$

Where:

I_{PV} is the cell current (A).

I_{SC} is the light generated current (A).

I_D is the diode saturation current (A).

R_s is the cell series resistance (ohms).

R_P is the cell shunt resistance (ohms).

V_D is the diode voltage (V).

V_T is the temperature voltage (V).

V_{PV} is the cell voltage (V).

1.2.2 PV Module Characteristic

The photovoltaic modules are made up of silicon cells. The silicon solar cells which give output voltage of around 0.7V under open circuit condition. When many such cells are connected in series we get a solar PV module. Normally in a module there are 36 cells which amount for a open circuit voltage of about 20V. The current rating of the modules depends on the area of the individual cells. Higher the cell area high is the current output of the cell. For obtaining higher power output the solar PV modules are connected in series and parallel combinations forming solar PV arrays. A typical characteristic curve of the called current (I) and voltage (V) curve and power (W) and voltage (V) curve of the module is shown is shown in Fig.1.2

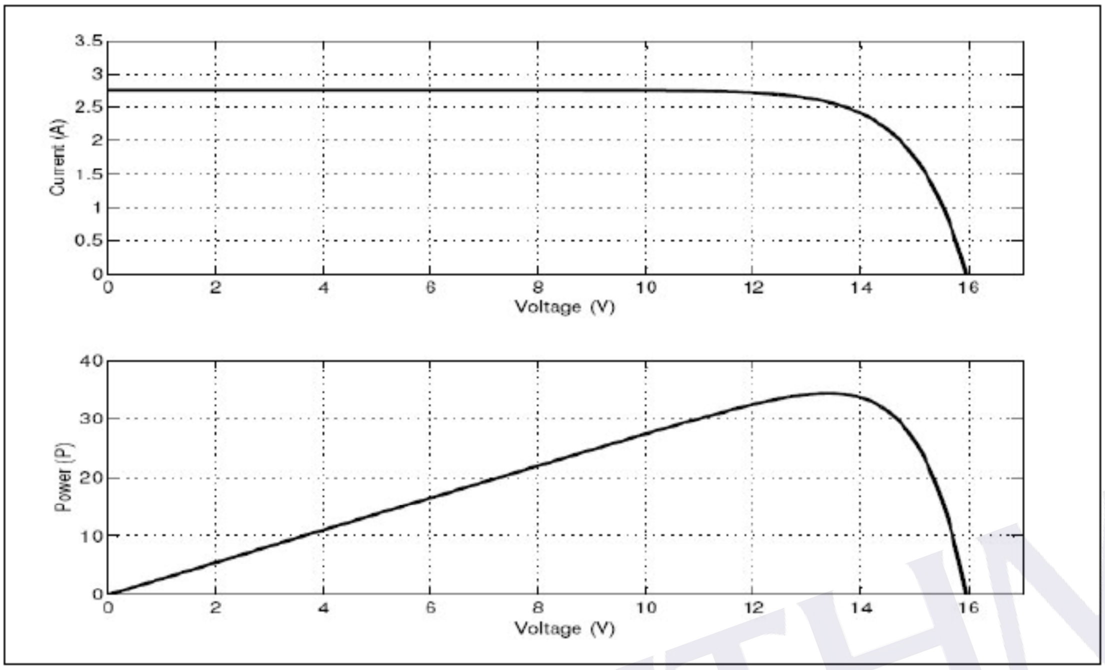

Fig.1.2 Characteristics of a typical solar PV module.

1.2.3 Need for Maximum Power Tracking

Power output of a Solar PV module changes with change in direction of sun, changes in solar insolation level and with varying temperature as shown in the Fig. 1.3&1.4.

As seen in the PV (power vs. voltage) curve of the module there is a single maximum of power. That is, there exists a peak power corresponding to a particular voltage and current. We know that the efficiency of the solar PV module is low about 13%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and insolation conditions. Hence maximization of power improves the utilization of the solar PV module. A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar PV module and transferring that power to the load.

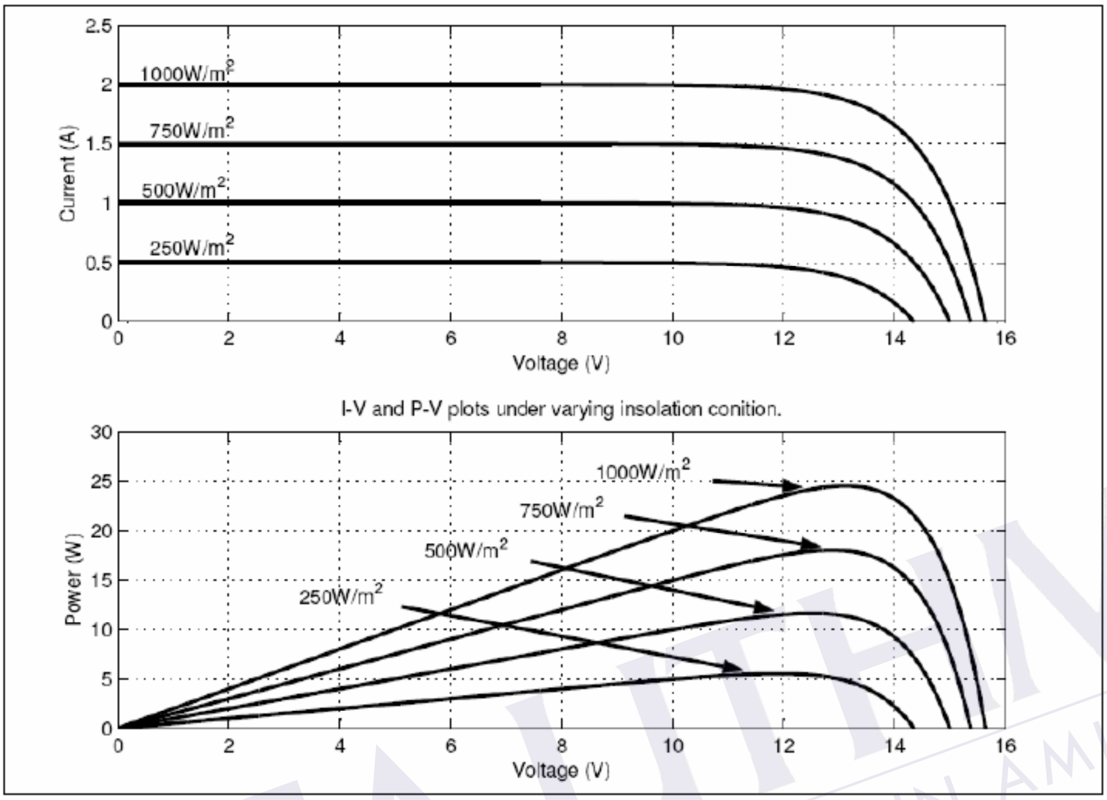

Fig.1.3 Changes in the characteristics of the solar PV module due to change in insolation level.

A dc/dc converter (step up/step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between theload and the module fig.1.5. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

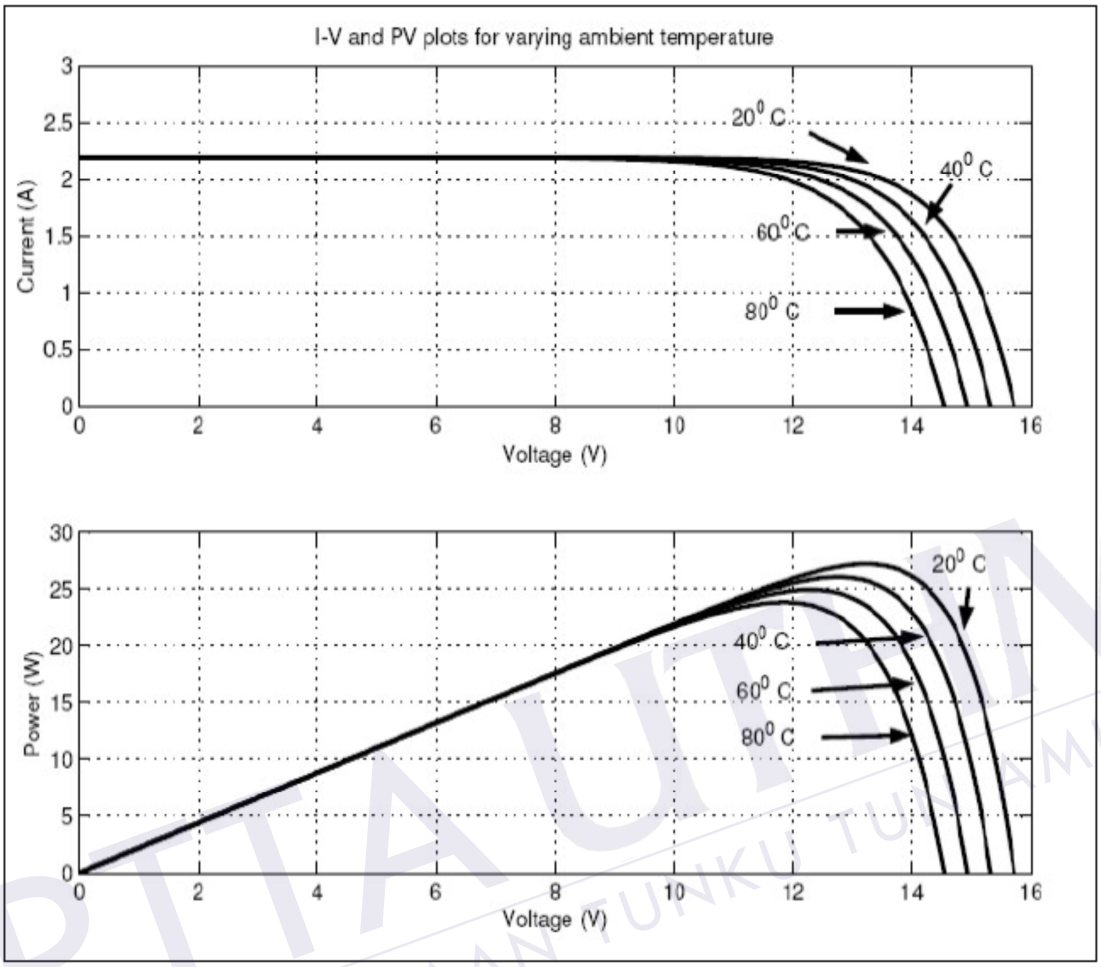

Fig.1.4 Change in the module characteristics due to the change in temperature

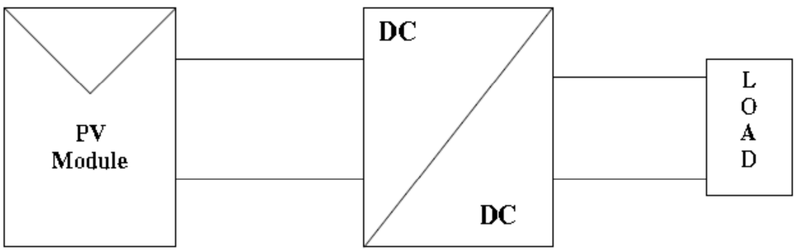

Fig.1.5 Block diagram of a typical MPPT system

1.2.4 How Maximum Power Point (MPP) is obtained.

The maximum power point is obtained by introducing a dc/dc converter in between the load and the solar PV module. The duty cycle of the converter is changed till the peak power point is obtained.

Considering a step up converter is used

$$Vo= (1/(1-D))*Vi……(1.3)$$

(Vo is output voltage and Vi is input voltage)

solving for the Impedance transfer ratio

$$Ro = (1/(1-D))^2*Ri….(1.4)$$

(Ro is output impedance and Ri is input impedance as seen by the source.)

$$Ri = (1-D)^2*Ro…….(1.5)$$

Thus output resistance Ro remains constant and by changing the duty cycle the input resistance Ri seen by the source changes. So the resistance corresponding to the peak power point is obtained by changing the duty cycle. As shown in the fig.1.6.

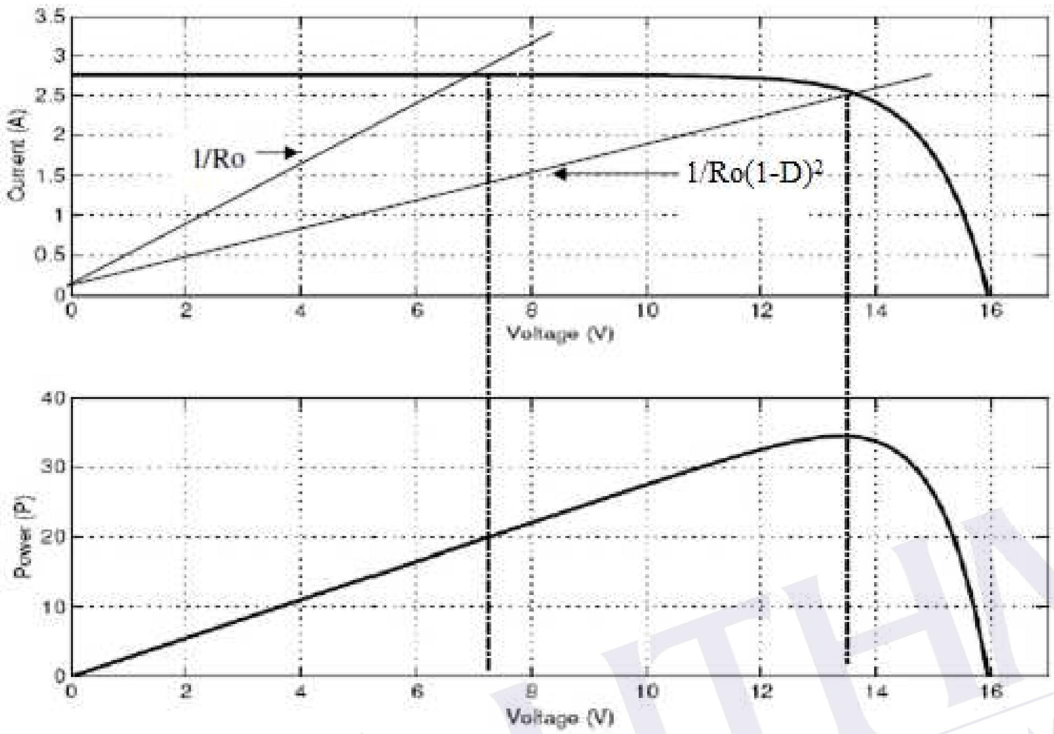

Fig.1.6 DC/DC converter helps in tracking the peak power point

1.2.5 Methods of Peak Power Tracking.

The peak power is reached with the help of a dc/dc converter by adjusting its duty cycle such that the resistance corresponding to the peak power is obtained. Now question arises how to vary the duty cycle and in which direction so that peak power is reached. Whether manual tracking or automatic tracking? Manual tracking is not possible so automatic tracking is preferred to manual tracking. An automatic tracking can be performed by utilizing various algorithms.

i. Perturb and observe [3],[4],[7].
ii. Incremental Conductance [5],[9].
iii. Parasitic Capacitance [9].
iv. Voltage Based Peak Power Tracking [9].

v. Current Based peak power Tracking [9].

vi. Computational Intelligent (e.g. fuzzy logic, neural network) [1],[2]

The algorithms are implemented in a microcontroller or a personal computer to implement maximum power tracking. The algorithm changes the duty cycle of the dc/dc converter to maximize the power output of the module and make it operate at the peak power point of the module. P&O and fuzzy logic algorithm are explained in detailed in the chapter 3.

1.3 Problem Statement

When a PV moduleis directly coupled to a load, the PV module's operating pointwill be at the intersection of its I–V curve and the load linewhich is the I–V relationship of load.

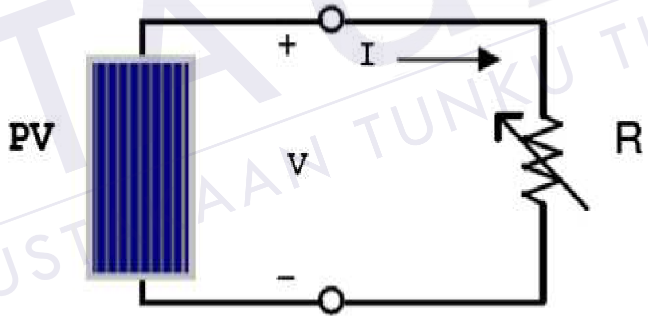

Fig. 1.7 PV module is directly connected to a (variable) resistive load.

In Fig. 1.7, a resistive load has a straight line with a slope of $1/R_{load}$ as shown in Fig. 1.8. In other words, the impedance of load dictates the operating condition of the PV module. In general, this operating point is seldom at the PV module's MPP, thus it is not producing the maximum power.

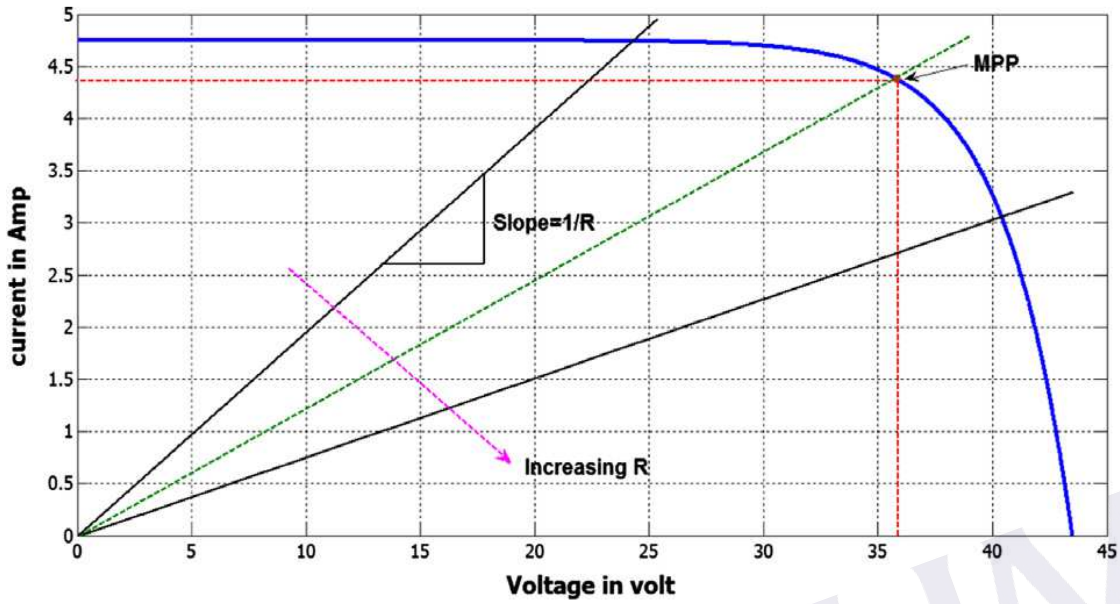

Fig. 1.8 I-V curve of PV module and various resistive loads

To mitigate this problem, a maximum power point tracker(MPPT) can be used to maintain the PV module's operatingpoint at the MPP. MPPTs can extract more than 97% of thePV power when properly optimized [51].

1.4 Project Objectives

The objectives of this project are:-

i. To track the maximum power point (MPP) of PV module by using Fuzzy Logic MPPT controller.
ii. To simulate and analyses the performance of Fuzzy Logic MPPT controller with other conventional controller.

1.5 Project Scopes

The scopes of this project are:-

i. To develop a SIMULINK model of PV module that converts solar energy to electric one.
ii. To develop a SIMULINK model of DC-DC boost converter that converts produced DC voltage by the PV module to a load voltage demand.
iii. To develop a SIMULINK model of Fuzzy Logic Controller (FLC) that drives the converter operation with MPPT capability.

CHAPTER 2

LITERATURE REVIEW

The following literature survey for the current report consists of various papers publishedin the IEEE conferences and the journals.

[1]. Control of DC/DC Converters for Solar Energy System with Maximum PowerTracking. [4].

ChihchiangHua and ChihmingShen.

The object of this paper is to analyze and design DC/DC converters of different types in asolar energy system to investigate the performance of the converters. A simple methodwhich combines a discrete time control and a PI compensator is used to track theMaximum power points (MPP's) of the solar array. The system is kept to operate close tothe MPPT's, thus the maximum possible power transfer from the solar array is achieved.The implementation of the proposed converter system was based on a digital signalprocessor (DSP). Experimental tests were carried out for buck, boost and buck-boostconverters using a simple maximum power point tracking (MPPT) algorithm. Theefficiencies for the system with different converters are compared. The paper is use full in evaluating the response of step up, step down converter for the MPPT system.

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