Optimal Solar Power Tracking System Using Fuzzy Logic Controller

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Abstract: *This paper presents a distinctive step-by-step method for the simulation of photovoltaic modules with fuzzy logic using MATLAB Simulink. In this study one-diode alike circuit is employed in order to examine I-V and P-V characteristics of a typical 36 W solar module. "Mamdani" is proposed fuzzy logic control (FLC) is based to control the maximum power point tracking (MPPT) for a photovoltaic (PV) system. The fuzzy logic control technique uses to specify the size of incremental current in the current command of MPPT. The result of convergence time of maximum power point (MPP) of the proposed algorithm is better than that of the conventional Perturb and Observation (P&O) technique. the maximum power point varies with radiation and temperature, it is difficult to maintain optimum power operation at all radiation levels. Many MPPT techniques have been advocated, developed and implemented. These methods vary in several aspects such as complexity, convergence speed, cost, range of effectiveness, ease of software implementation.*

Keywords: Certificate Authority, Certificateless Public Key Cryptography, Chosen Plaintext Attack, KGC, RSA, PRE, SEM.

1. NOMENCLATURES

Vpv is output voltage of a PV module (V)

Ipv is output current of a PV module (A)

T_r is the reference temperature = 298 K

T is the module operating temperature in Kelvin

Iph is the light generated current in a PV module (A)

Io is the PV module saturation current (A)

A = B is an ideality factor = 1.6

k is Boltzman constant = 1.3805 x 10^{-23} J/K

q is Electron charge = 1.6 x 10^{-19} C

R_s is the series resistance of a PV module

I_{SCr} is the PV module short-circuit current at 25 ^oC and 1000W/m^2 = 2.55A

Ki is the short-circuit current temperature co-efficient at ISCr = 0.0017A / ^oC

X is the PV module illumination (W/m^2) = 1000W/m^2 E_{go} is the band gap for silicon = 1.1 eV N_s is the number of cells connected in series

Np is the number of cells connected in parallel

2. INTRODUCTION

Due to the increased demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. The promising incentives to develop alternative energy resources with high efficiency and low emission are of great importance to reduce the emission of greenhouse gases and decrease the dependence on fossil fuels. Among the renewable-energy resources, solar energy is the most essential and prerequisite resource of sustainable energy because of its ubiquity, abundance, and sustainability. Regardless of the intermittency of sunlight, solar energy is widely available and completely free of cost [1].

Photovoltaic source are widely used today in many applications such as battery charging, water heating system, satellite power system, and others applications. Recently, researchers have strongly promoted the use of solar energy as a viable source of energy. Solar energy possesses characteristics that make it highly attractive as a primary energy source that can be integrated into local and regional power supplies since it represents a sustainable environmentally friendly source of energy that can reduce the occupants' energy bills [2]. It can generate direct current (DC) electricity without environmental impact and emission by way of solar radiation. The DC power is converted to AC power with an inverter, to power local loads. Fuzzy logic has been considered as an efficient and effective tool in managing uncertainties and nonlinearities of systems since Zadeh's seminal paper was published [1]. A Fuzzy Controller is generally designed in the light of experience and expert knowledge. Fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans [2, 3 and 4]. One of the most simple and popular techniques of MPPT is the Perturb

& Observation P&O technique. The main concept of this method is to push the system to operate at the direction, which the output power obtained from the PV system increases. PV system cannot be modeled as a constant DC current source because its output power is varied depending on the load current, temperature and irradiation. Generally, MPPT is adopted to track the maximum power point in the PV system. The efficiency of MPPT depends on both the MPPT control algorithm and the MPPT circuit. The MPPT control algorithm is usually applied in the DC-DC converter, which is normally used as the MPPT circuit. The Typical diagram of the connection of MPPT in a PV system is shown in Fig. 1.

In this paper, we propose a comparison between P&O and a fuzzy controller for Mamdani zero-order. Among the renewable energy resources, the energy due to the photovoltaic (PV) effect can be considered the most essential and prerequisite sustainable resource because of the ubiquity, abundance, and sustainability of solar radiant energy. It can generate direct current electricity without environmental impact and contamination when exposed to solar radiation. Being a semiconductor device, the PV system is static, quiet, free of moving parts, and has little operation and maintenance costs.

PV module represents the fundamental power conversion unit of a PV generator system.

The output characteristics of a PV module depend on the solar insolation, the cell temperature and the output voltage of the PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications.

Mathematical modelling of PV module is being continuously updated to enable researcher to have a better understanding of its working. [1]- [6]

In this paper, a step-by-step procedure for simulating PV module with subsystem blocks, with user-friendly icons and dialog in the same way as Matlab/ Simulink block libraries is developed. Section III presents the PV module equivalent circuit and equations for Ipv, the output current from the PV module. The reference model presented in section IV provides data for Solkar make 36 W PV module for simulation. In section V, the step-by-step modelling procedure of PV module is presented with simulation results. Finally, brief conclusions are drawn in Section VI.

3. MATHEMATICAL MODEL FOR PHOTOVOLTAIC MODULE:

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater then the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation.

The equivalent circuit of a PV cell is as shown in Figure 1.

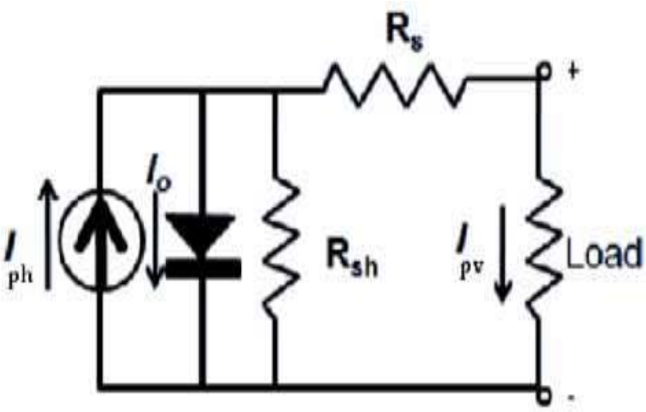

Figure 1- PV cell modeled as diode circuit

The current source Iph represents the cell photocurrent. Rsh and Rs are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of Rsh is very large and that of Rs is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays. The photovoltaic panel can be modelled mathematically as given in equations (1)- (4) [3] – [5].

Module photo-current:

$$I_{ph} = [I_{SCR} + K_i(T - 298) \times \lambda / 1000] \quad (1)$$

Module reverses saturation current - Irs:

$$I_{rs} = I_{SCr} / [\exp(qV_{OC} / N_s kAT) - 1] \quad (2)$$

The module saturation current I0 varies with the cell Temperature, which is given by

$$I_0 = I_{rs}\left[\frac{T}{T_r}\right]^3 \exp\left[\frac{q * E_{g0}}{Bk}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}\right] \quad (3)$$

The current output of PV module is

$$I_{PV} = N_P * I_{ph} - N_P * I_0\left[\exp\left\{\frac{q * (V_{PV} + I_{PV}R_s)}{N_S AkT}\right\} - 1\right] \quad (4)$$

Where $V_{pv} = V_{oc}$, $N_p = 1$ and $N_s = 36$

4. MODEL OF THE SYSTEM

Solar make 36 W PV modules is taken as the reference Module for simulation and the name-plate details are given in operating condition assuming the constant temperature and constant irradiation (200 W/m2).

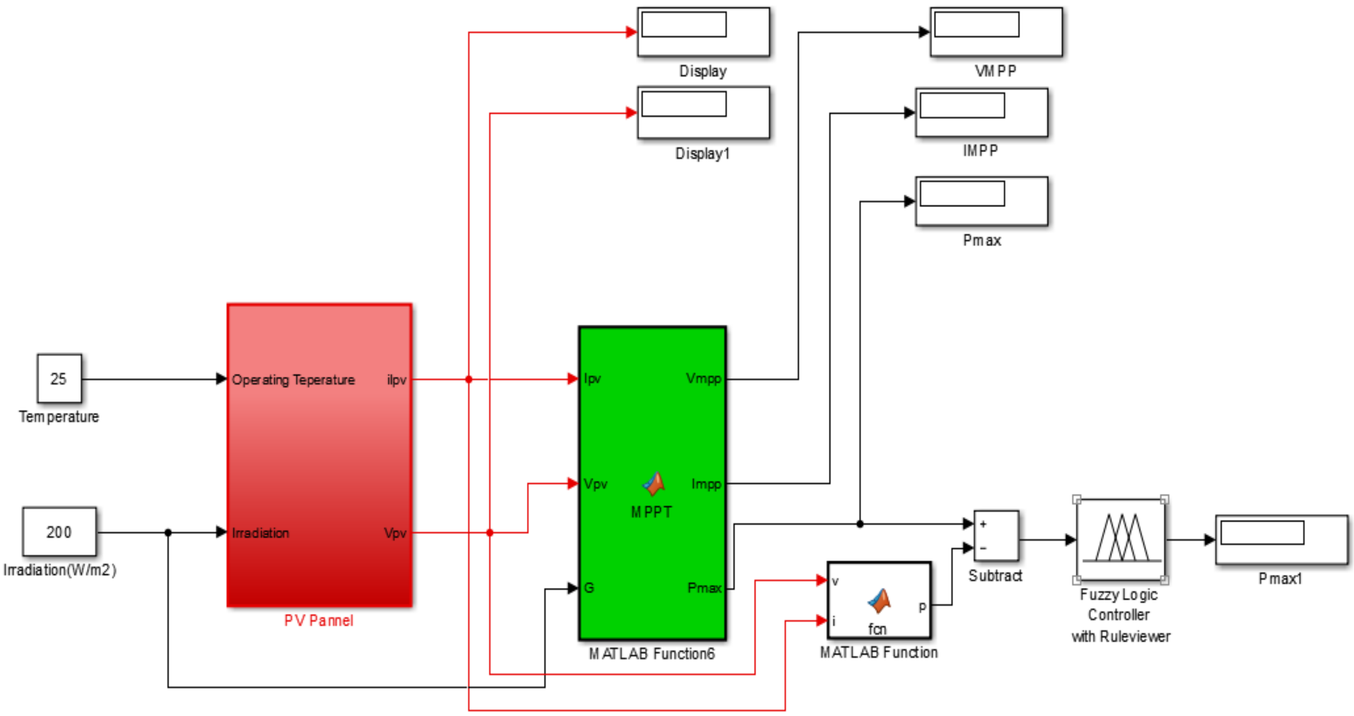

Table 1: electrical characteristics data of solar 36w pv module

Rated Power	37.08 W
Voltage at Maximum power (V_{mp})	16.56 V
Current at Maximum power (I_{mp})	2.25 A
Open circuit voltage (V_{OC})	21.24 V
Short circuit current (Isc_r)	2.55 A
Total number of cells in series (N_s)	36
Total number of cells in parallel (N_p)	1

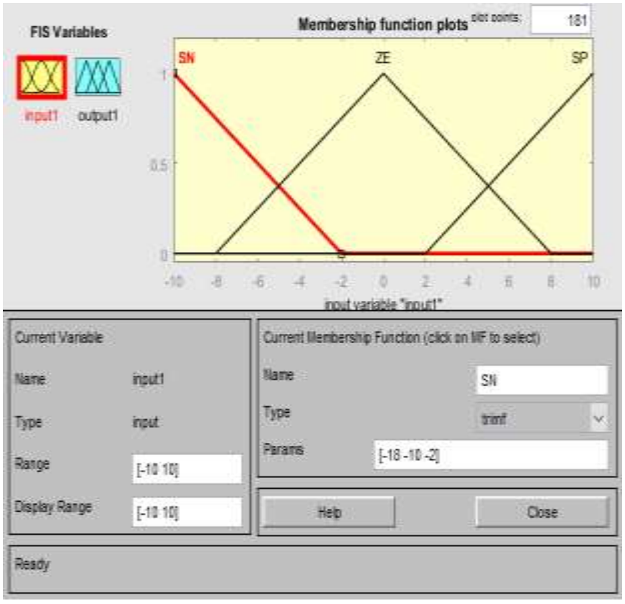

Fig 3.Membership function of inputs

Fig. 2. Simulink model of PV module

Note: The electrical specifications are under test conditions of irradiance of 1 kW/m^2, spectrum of 1.5 air masses and cell temperature of 25^{o}C

The proposed Fuzzy Logic Control has been modelled and simulated using **MATLAB/Simulink**. Fig.2 shows our developed ***Simulink*** model. In the simulation study, the fuzzy logic based MPPT control is simulated and under the

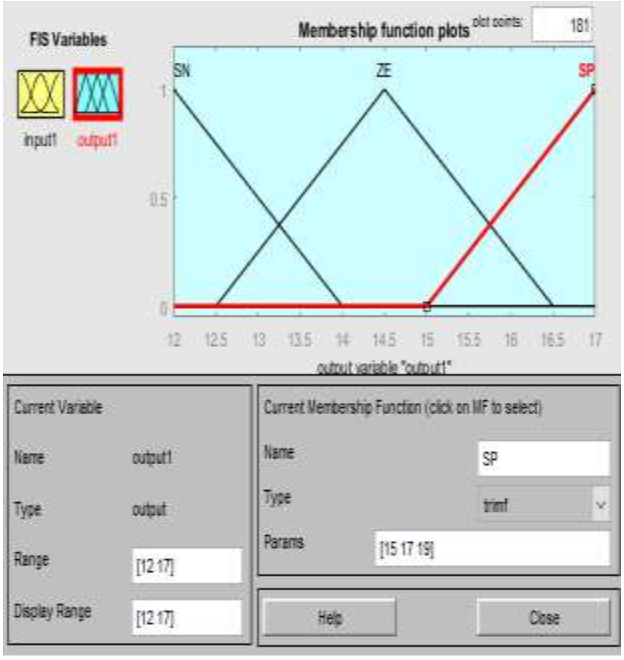

Fig 4(a).Membership function of outputs

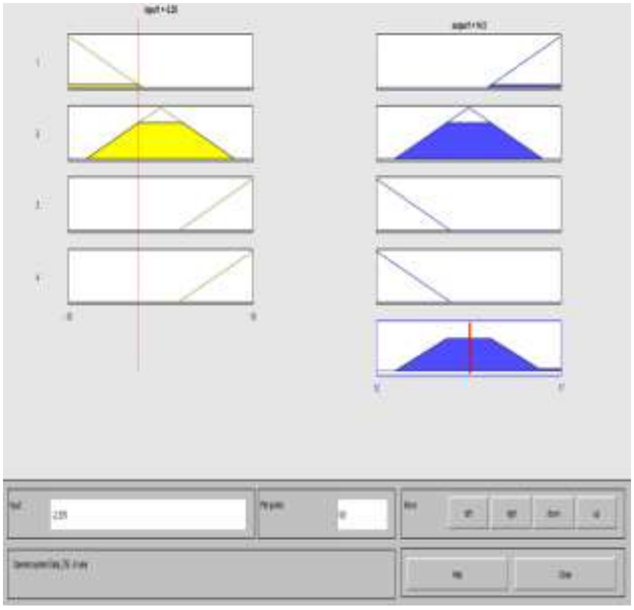

Fig 4(b). Membership function of outputs

5. SIMULATION RESULT:

The final model is shown in Figure 1. The workspace is added to measure Ipv, Vpv, Ppv in this model. The time tout is stored in workspace with scope model can be used to plot graph. The final model takes irradiation, operating temperature in Celsius and module voltage as input and gives the output current Ipv and output voltage Vpv.

Matlab code for plotting XY graph is given below.

```
plot (Vpv,Ipv)
plot (Vpv, Ppv)
```

The code for plotting scope signals is

```
plot(tout,Ipv)
```

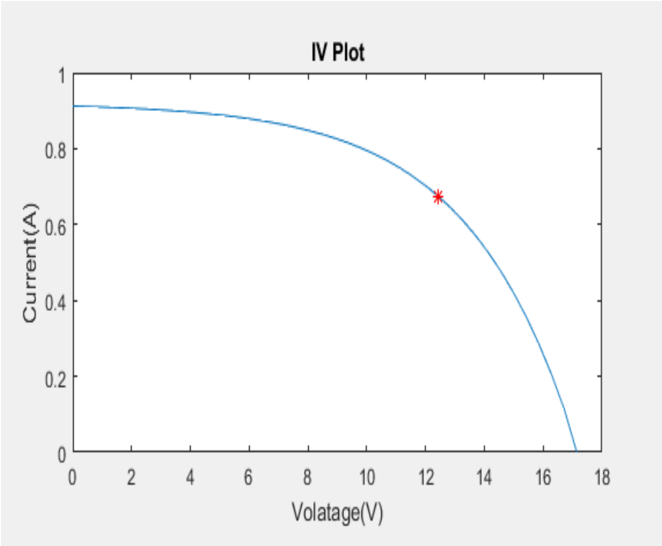

Fig.5. Current-voltage characteristic of a PV module

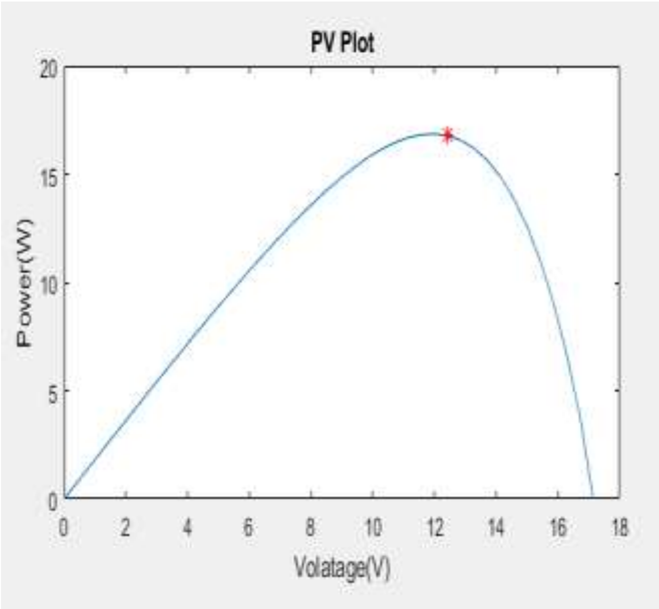

Fig.6. Power-voltage characteristic of a PV module

6. CONCLUSION:

The different results with different robustness test confirm the proper fonctionnement of fuzzy controller with good performance in the atmospheric variations of illumination and temperature there by reducing power losses, with better dynamics than conventional numerical methods. The following fuzzy controller with satisfaction at the sharp variations of temperature and illumination and a fast response time and less than that of conventional algorithms (P & O and INC). This eliminates the fluctuations in the power, voltage and duty ratio in steady state. The controllers by fuzzy logic can provide an order more effective than the traditional controllers for the nonlinear systems, because there is more flexibility. A fast and steady fuzzy logic MPPT controller was obtained. It makes it possible indeed to find the point of maximum power in a shorter time runs.

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