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# Comparative Analysis between Fuzzy Logic Controller (FCL) and Artificial Neural Network (ANN) based MPPT Methods on PV Module in MATLAB/Simulink

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**ABSTRACT:** There exist numerous maximum power point tracking techniques in today's market to maintain the operation of PV module at maximum power such as off-line techniques, on-line or hill-climbing (HC) techniques and artificial intelligence (AI) techniques. Numerous approaches for improving, adapting, and optimizing these techniques have been published. However, they differ in many aspects such as tracking speed, tracking accuracy, steady-state efficiency and dynamic efficiency, number of sensors used, complexity, and cost. These MPPT techniques fail or deviate from tracking the correct maximum power point (MPP) under sudden or ramp variations of solar irradiation and ambient temperature as well as under partial shading with oscillations around MPP. The maximum power point tracking-based computational intelligence techniques that properly detect the global MPP are stated. This thesis present various soft computing technique like artificial neural Network, fuzzy logic controller to achieve maximum power point tracking solution in PV module. Also, a comparative study for MPPT in PV module by using two different artificial intelligent controllers which are fuzzy logic controller (FLC) and artificial neural network (ANN). Intelligent controllers have gained wide popularity in the application of controlling system output voltage. We develop MATLAB/Simulink. Model to performed different global condition for maximum utilized solar radiation to achieved maximum power output. and we developed MATLAB program for modelling of the sun position, solar radiation, etc

**KEYWORDS:** Photovoltaic module, Artificial Neural Network (ANN), fuzzy logic controller (FCL), Maximum power point tracking (MPPT)

## I. INTRODUCTION

Solar photovoltaic energy systems (PVES) have been used to feed loads in remote areas as well as in central power plants connected to the electric utility. Many research works have been done to reduce the cost of the generated energy from the PVES. One of the most important factors of research work is to reduce the cost of generated energy by increasing the generated energy from the PVES by modifying its performance operations.[01,02,] This can be achieved by tracking the maximum power available from the PV systems which can increase the generated energy from PVES considerably and reduce its cost. The device used to track the maximum power available from the PVES is called maximum power point tracker (MPPT). MPPT uses a controlled technique to control the power electronics converters to be sure it extracts the maximum power available from the PVES. Conventional MPPT techniques like perturb and observe, hill climbing, incremental conductance, etc., have been introduced a long time ago, and they were working for unshaded PVES very well. But, in case of partial shading conditions, multi-peaks in the P-V curve of the PV array are generated, and these peaks may trap the conventional techniques to fall within one of the local peaks.[05] With the advances of artificial intelligence, soft computing, and metaheuristic techniques, this limitation can be overcome, whereas metaheuristic techniques can track the global peaks in shaded or unshaded PVES which became a new trend in the tracking of the maximum power of the PVES. Many metaheuristic techniques are introduced and discussed in this thesis like Artificial Neural Network (ANN), fuzzy logic controller (FCL) particle swarm optimization (PSO), gray wolf optimization (GWO), genetic algorithm (GA), ant colony optimization (ACO), whale optimization (WO), simulated annealing (SA) [6]

### 1.1 Maximum Power Point Tracking (MPPT)

Maximum Power Point Tracking is electronic tracking - usually digital. The charge controller looks at the output of the panels and compares it to the battery voltage. It then figures out what is the best power that the panel can put out to charge the battery. Assume your battery is low, at 12 volts. An MPPT takes that 17.6 volts at 7.4 amps and converts it down so that what the battery gets is now 10.8 amps at 12 volts. Now you still have almost 130 watts, and everyone is happy. Ideally, for 100% power conversion you would get around 11.3 amps at 11.5 volts, but you have to feed the battery a higher voltage to force the amps in. And this is a simplified explanation - in actual fact, the output of the MPPT charge controller might vary continually to adjust for getting the maximum amps into the battery.[7]

## II. MODELING OF THE SOLAR SOURCE

The annual orbit of the earth around the sun . The distance between the earth and the sun changes throughout the year, the minimum being  $1.471 \times 10^{11}$  m at winter solstice (December 21) and the maximum being  $1.521 \times 10^{11}$  m at summer solstice (June 21). The year-round average earth– sun distance is  $1.496 \times 10^{11}$  m. The amount of solar radiation intercepted by the earth, therefore, varies throughout the year, the maximum being on December 21 and the minimum on June 21.

|                                                  |                                                                                                                                                                                                                                                                                                                             |
|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Reckoning of time</b>                         | The time when the sun crosses the meridian of the observer is the local solar noon. It usually does not coincide with the 12:00 o'clock time of a locality                                                                                                                                                                  |
| <b>Equation of time</b>                          | Due to factors associated with the earth's orbit around the sun, the earth's orbital velocity varies throughout the year, so the AST varies slightly from the mean time kept by a clock running at a uniform rate. The variation is called the equation of time (ET).<br>$EOT = 9.87 \sin(2B) - 7.53 \cos(B) - 1.5 \sin(B)$ |
| <b>Solar angles</b>                              | $R = a(1 \pm e)$                                                                                                                                                                                                                                                                                                            |
| <b>Declination angle <math>\delta</math></b>     | $\delta_s = 23.45^\circ \sin[360(284 + n)/365^\circ]$                                                                                                                                                                                                                                                                       |
| <b>Solar altitude angle, <math>\alpha</math></b> | $Z = 90 - \alpha$                                                                                                                                                                                                                                                                                                           |
| <b>Solar azimuth angle, <math>\theta</math></b>  | $\sin \theta = \frac{\cos \delta \sin \omega}{\cos \alpha}$                                                                                                                                                                                                                                                                 |
| <b>Hour angle</b>                                | $\omega = 15^\circ (AST - 12h)$                                                                                                                                                                                                                                                                                             |
| <b>Incidence angle <math>\theta</math></b>       | $\cos(\theta) = \sin(L) \sin(\delta) \cos(B) - \cos(L) \sin(\delta) \sin(B) \cos(\delta_s)$                                                                                                                                                                                                                                 |
| <b>Solar Time and Angles</b>                     | $\text{solar Time} = \text{LST} + \text{ET} + (l_{st} - l_{local}) \cdot 4 \text{ min/degree}$                                                                                                                                                                                                                              |

## III. MODELLING OF PHOTOVOLTAIC SOURCE AND MPPT

A solar cell is modelled as a p–n junction with nonlinear characteristics to describe its electrical response. To analyze these characteristics, a mathematical model of the solar cell is derived from mathematical equations in terms of solar cell inputs and outputs. The simplest equivalent circuit of a solar cell is a current source connected in parallel with a diode as shown in Figure 3.1. The output of the current source is directly proportional to the light falling on the cell. During darkness, the solar cell is not an active device and it works as a diode. It produces neither current nor voltage. However, if light falls on the solar cell, it generates a diode current. The diode, D, determines the I–V characteristics of the cell. A series resistance,  $R_S$ , represents the resistance inside each cell, while the shunt resistance,  $R_{SH}$ , is neglected because it has a large resistance value. [01,02]

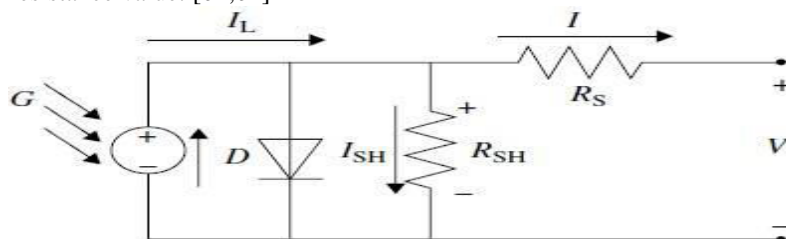


Fig 3.1 Equivalent circuit of solar cell

In an ideal solar cell, it is assumed that  $R_S = 0$  and  $R_{SH} = \infty$ . The net current of the cell is the difference between the photocurrent,  $I_L$ , and the normal diode current, which is given by

$$I = I_L - I_0 \left\{ e^{\frac{q(V+IR_S)}{nKT}} \right\} - \frac{V+IR_S}{R_P} \quad (1.2)$$

The photocurrent,  $I_L$ , depends on reference first and second temperatures,  $T_1$ , and  $T_2$ , respectively, and it is given by

$$I_L = I_L(T_1) + K_0(T_2 - T_1) \quad (1.3)$$

$$I_L(T_1) = I_{SCT1,nom} \left( \frac{G}{G_{nom}} \right) \quad (1.4)$$

$$K_0 = \frac{I_{SCT2} - I_{SCT1}}{T_1 - T_2} \quad (1.5)$$

where  $G$  is the present solar radiation and  $G_{nom}$  is the solar radiation at the reference test

The saturation current of the diode,  $I_0$ , is given by

$$I_0 = I_{0T1} \left[ \frac{T}{T_1} \right]^{\frac{3}{n}} e^{\frac{qV_{qT1}}{nk \left( \frac{1}{T} - \frac{1}{T_1} \right)}} \quad (1.6)$$

Where

$$I_{0T1} = \frac{I_{SCT1}}{e^{\frac{qV_{qT1}}{nk} - 1}} \quad (1.7)$$

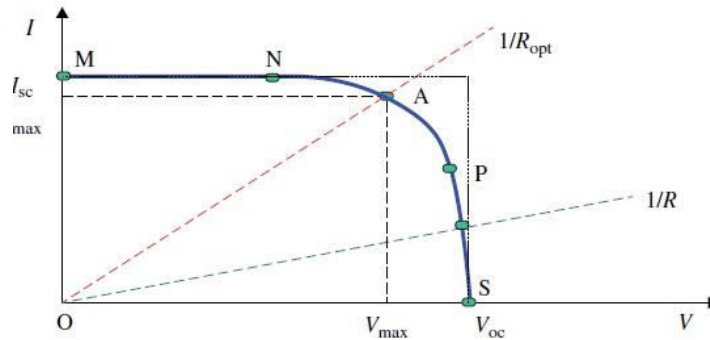


Fig 3.2 I-V characteristic curve of a solar cell.

#### IV. SOFT COMPUTING MPPT TECHNIQUES

##### 4.1 The MPPT based Fuzzy logic controller:

Renewable energy resources have a wide range of applications for the Fuzzy Logic controllers (FLC). From the last decade, the requirement of FLC has been increased due to simplicity. FLC also deals with the imprecise input, which does not need any accurate mathematical model for the controller. FLC can easily handle nonlinearity conditions for obtaining the maximum power from PV Modules. It is capable of performing in any weather condition or any change in the temperature or irradiance level [10]

##### 4.2 Modeling for Experimental Investigation of Photovoltaic on Fuzzy logic Controller (FCL) Based MPPT Module Under Outdoor condition:

**A10 Green technology A10J-S72-175PV** module is experimented. The measuring instruments are digital multimeter with DC accuracy:  $\pm 0.5\% + 3$  digits and AC accuracy:  $1\% + 3$  digits and auto digital lux meter with measuring range varying from 2000 to 50,000 lx which are utilized for measuring I-V. The measurement under STC provided by manufacturers



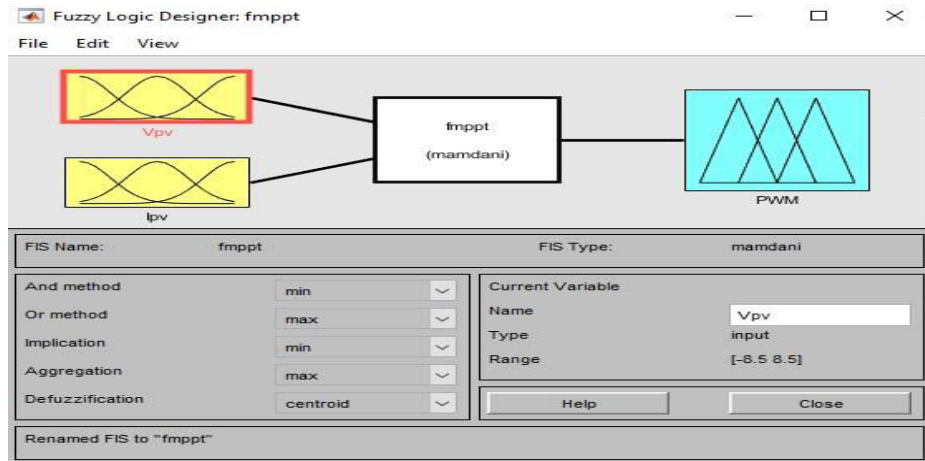


Fig 4.1 fuzzy interface system to import fis file

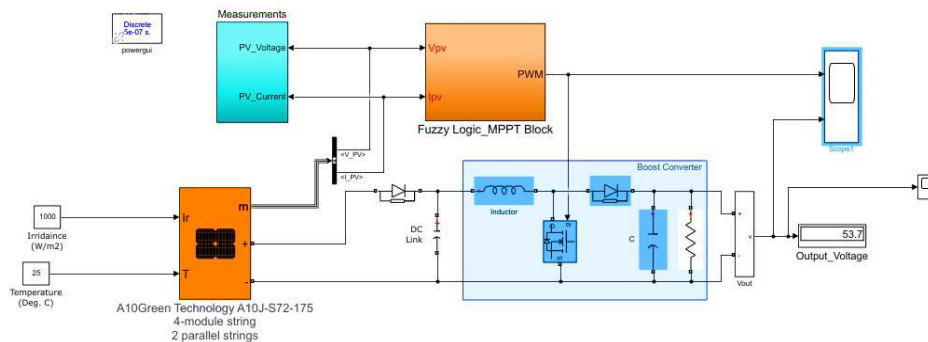


Fig 4.2 Fuzzy Logic Controller Based MPPT of PV Systems Using Matlab Simulink

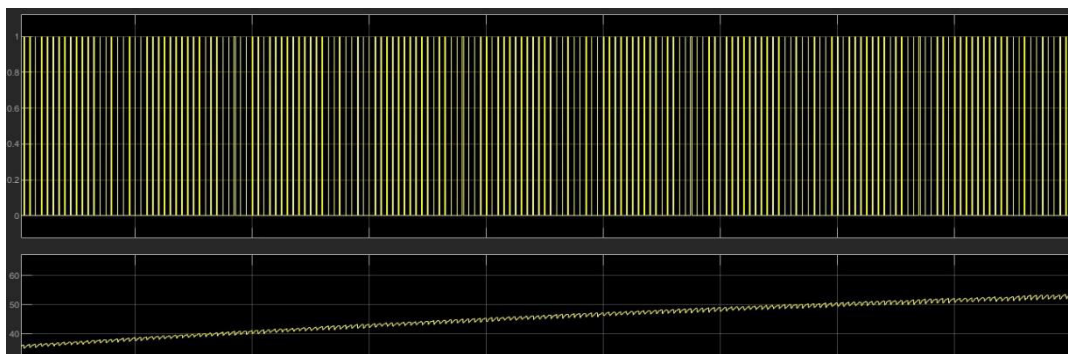


Fig 4.3 result

## V. ARTIFICIAL NEURAL NETWORK

Recently, Artificial Neural Network (ANN) has been strongly developed not only in theory but also in application. A common AN, showed in Fig 5.2, has many layers: input, hidden and output layers. For MPPT, ANN input can be PV array parameters like PV voltages and currents, environmental data like irradiance and temperature, or any combination of these. The output is usually one or several reference signal(s) like a duty cycle signal used to drive the electronic converter to operate at or close to the MPP. The input and output data are from experimental measurement or model-based simulation results. Some studies used ANN to approximate nonlinear function were published

## 5.1 ANN Based Modelling for Experimental Investigation of Photovoltaic Module Maximum Power Production Under Outdoor Condition.

### Artificial Neural Network Based MPPT of 175 W PV System

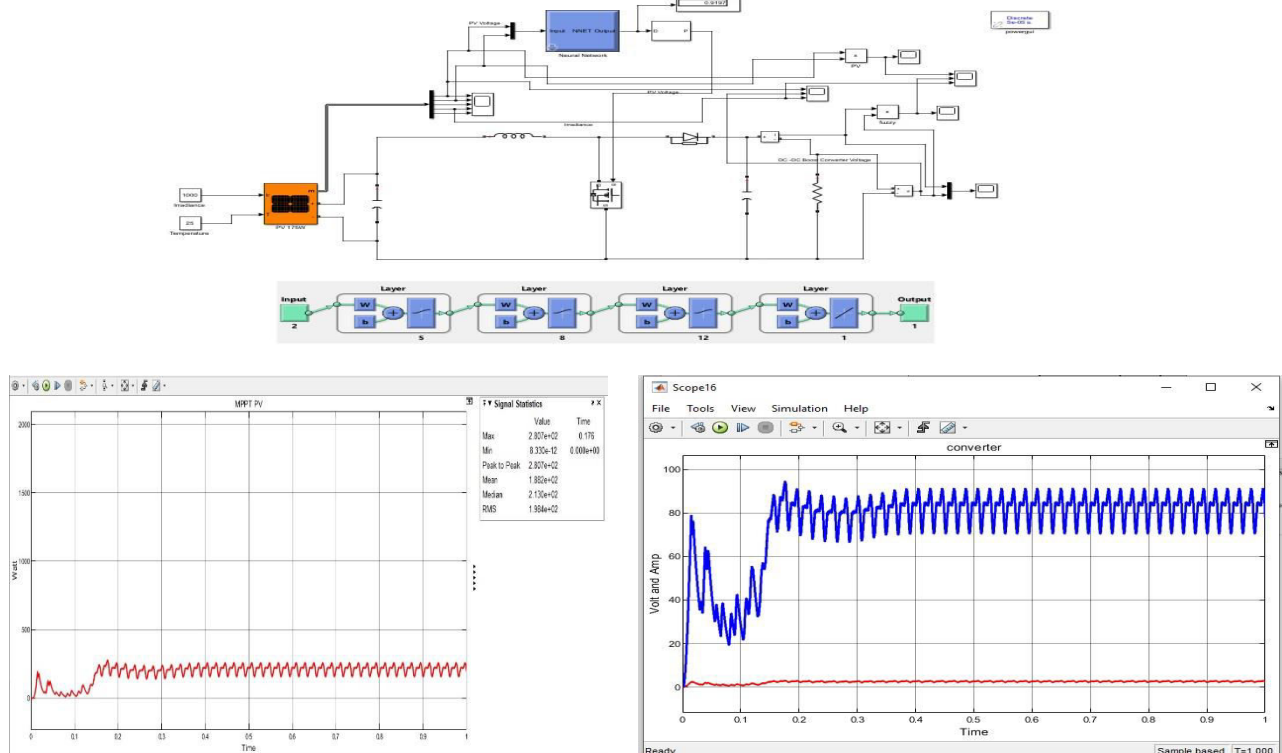


Fig 5.1 a change of power with respect to time in ANN based MPPT controller  
b. voltage and current variation

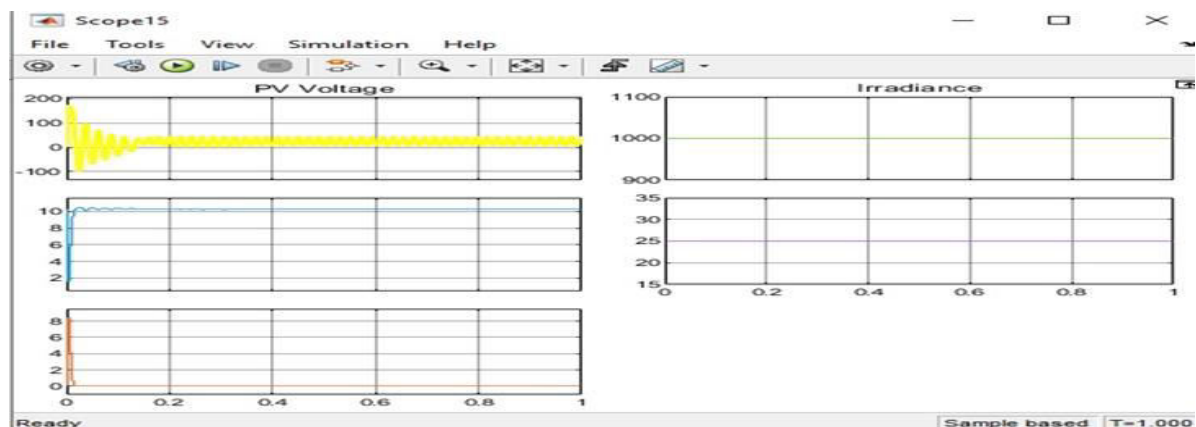
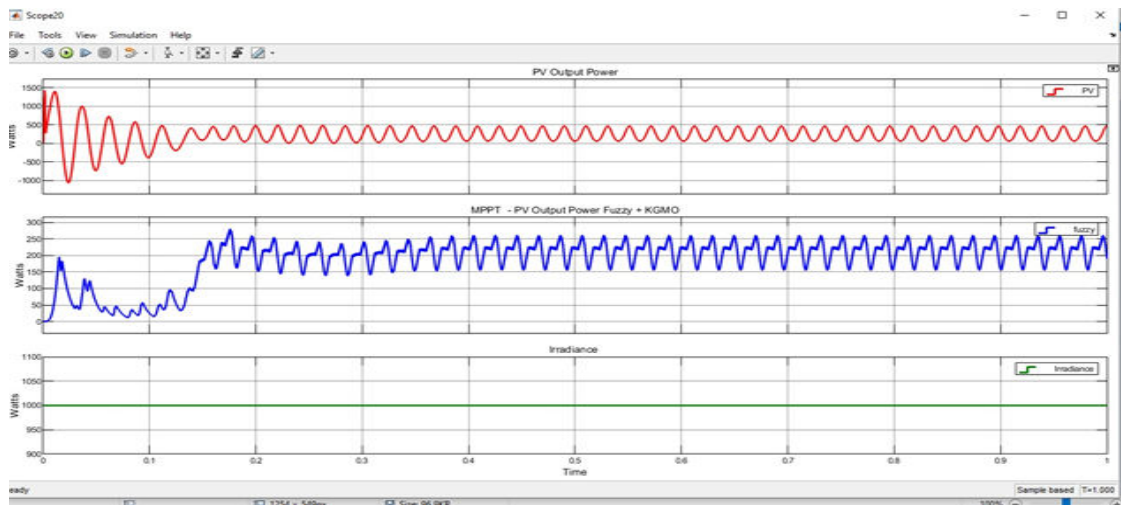


Fig 5.2 variation in PV voltage



## VI. RESULT AND CONCLUSION

The comparison of the convergence time and generated output power for various MPPT control methods under fixed environmental condition

| MPPT Method            | Converging Time (s) | Output voltage(v) | Output Power (Watts) |
|------------------------|---------------------|-------------------|----------------------|
| <b>MPPT Controller</b> | 0.1                 | 56.2              | 172.25               |
| <b>FCL</b>             | 0.05                | 53.7              | 173.4                |
| <b>ANN</b>             | 0.035               | 50.12             | 174.56               |

Solar energy is one of the clean resources of energy but it has challenging issues of low efficiency and low power extraction due to varying environmental conditions. There are many conventional MPPT techniques such as Hill climb, IC and P&O but their associated issues hinder the effective power extraction. AI based MPPT techniques alleviate the challenges of conventional MPPT techniques and are a suitable solution to the low efficiencies in PV systems. This work presented the comparison of various MPPT methods (FLC, ANN, for a PV system under fixed and varying environmental conditions in MATLAB/Simulink environment. The comparison results showed that ANN based MPPT control has better performance in terms of converging time and output voltage power extraction when compared to other MPPT methods. The ANN based control outperformed other methods under fixed as well as varying environmental conditions which makes it a suitable candidate for the MPPT control in PV systems.

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