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Solar Photovoltaic System using FLC MPPT Technique

Aniruddh Shinde[1], MFAR Satarkar[2], Pritam Gaikwad[3], Prachi Kotwal[4]

[1]*M-Tech Scholar, Department of EE, Dr.Babasaheb Ambedkar Technological University, Lonere, India*
[2]*Head Of Department, Department of EE, Dr.Babasaheb Ambedkar Technological University, Lonere, India*
[3]*Assistant Professor, Department of EE, Dr.Babasaheb Ambedkar Technological University, Lonere, India*
[4]*Assistant Professor, Department of EE, Dr.Babasaheb Ambedkar Technological University, Lonere, India*

Abstract – *This paper present gets maximum power from the solar PV system. In this paper, we have used the technique of Fuzzy Logic Controller-based MPPT used for a 1.8KW solar PV system. The DC-DC boost converter is used to generate high voltage. The solar PV system is designed and simulated using MATLAB/Simulink.*

Key Words: Solar PV module, DC-DC Boost Converter, Fuzzy Logic Controller based MPPT

1. INTRODUCTION

Power Enhancement day by day in this world. Renewable energy sources like solar energy, wind energy, and tidal energy are being used. It also gives a quick introduction to the various techniques used by different countries to get over the energy situation as well as a framework for using such techniques in countries that are lagging in energy production in getting to obtain the benefits of energy sources, which are bountiful in the world [1]. The power quality of the grid-linked RESs can be enhanced by utilizing different MPPT formulas. The fuzzy logic controller maximum power point tracking utilizes a DC-DC boost converter for controlling the solar input voltage to the optimal power. Different techniques of optimal power monitoring in solar PV power applications have been reported in literary works [2]. The MPPT formula plays an essential contribution in producing optimal power. In this research study work, the FLC-based controller is designed in a MATLAB atmosphere for the solar PV system. Ultimately, the simulation outcomes of the controller help to observe the output of the system in the different loading conditions [3], [4]. The authors concluded that the recommended method has gotten over the conventional methods.

1.1 DESIGN OF SOLAR PV Module

The solar PV module is light energy converted into electrical energy. Many types of solar PV modules such as Monocrystalline, Polycrystalline, and thin-film PV modules.
The equivalent circuit is shown in Fig. 1. [5], [6].

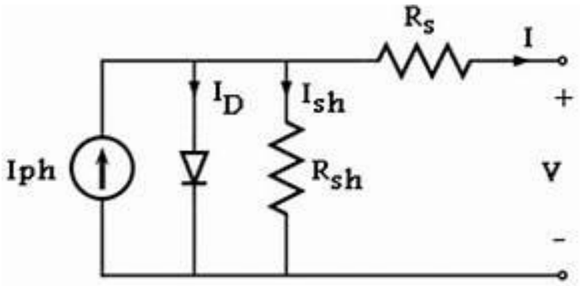


Fig -1: The equivalent circuit solar PV module

A diode is connected in anti-parallel with the light-produced current source. The output current obtained by Kirchhoff law:

$$I = Iph - Id \quad (1)$$

$$Id = Iph - Isat\left[\exp\left(\frac{Vd}{nvT}\right) - 1\right] \quad (2)$$

$$I = Iph - Isat\left[\exp\left(\frac{Vd}{nvT}\right)\right] \quad (3)$$

Where Iph is the photon current at given irradiance at given T. Vd & Id is the voltage across diode and diode current. It is reversed bias saturation current. n is the identify factor and vT is the thermal voltage.
Thermal voltage can be defined as,

$$Vt = \frac{KT}{q} \quad (4)$$

Where K is the Boltzmann constant ($1.38065*10^{-23}$J/K), T is the temperature in degree and q is the charge of the electron ($1.60217*10^{-19}$C).

The equation of this equivalent circuit using Kirchhoff's current law:

$$I = Iph - Id - Ish \quad (5)$$

$$Ish = \frac{V+RsI}{Rsh}$$

The I-V characteristics of Pthe V module in equation (5)

$$I = Iph - Io\left[\exp\left(\frac{v+RsI}{Vt}\right) - 1\right] - \frac{V+RsI}{Rsh} \quad (6)$$

Where the maximum PowerPoint and I-V and P-V characteristics are shown in Fig. 2. and the use for 150W PV module, No. of Parallel strings is four and No. of Series connected modules per string is three, also increase.

Generated 1.8KW power. Table-1 shows the parameter of the 150W PV module at 25⁰C and 1000 w/m².

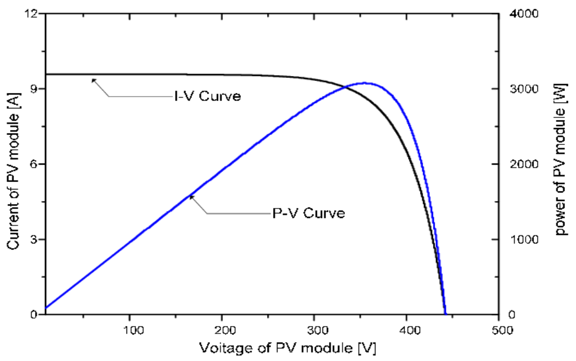


Fig -2: I-V and P-V characteristics of Solar PV module

The circuit diagram of a solar PV system with a DC-DC boost converter and MPPT is shown in Fig. 3. The disadvantage of the conventional MPPT algorithm is the poor efficiency of the weather condition is overcome the problem using the FLC MPPT algorithm [6].

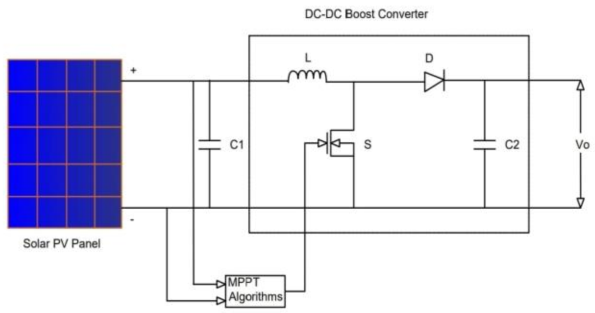


Fig -3: Circuit diagram of solar PV system with a DC-DC boost converter and MPPT

Table -1: 150W PV module at 25⁰C and 1000 w/m²

SR.NO	PARAMETERS	VALUE
1.	Open circuit voltage (Voc)	41.8V
	Short circuit current (IISC	5.05A
2.	The voltage at maximum power poiVmpVmpp)	34.5V
3.	Current at maximum power point (Impp)	4.35A
4.	Maximum output power	150W
5.	Cells per module	72
6.	No. of Parallel strings	4
7.	No. of Series connected modules per string (Ns)	3

1.2 DC-DC BOOST CONVERTER

The dc/dc boost converter we deal with here's a switching converter. Particularly, the dc-dc boost converter is a power electronic devices circuit, which utilizes an inductor, a transformer, or a capacitor as an energy-storage element to transform electric power from one voltage level into another voltage level by switching action. [6].

The operation of the boost converter, on the other hand, is to step up the input voltage and The boost converter circuit has IGBT or MOSFET switch are used. The boost converter operates in two modes When the switch is closed, the inductor stores energy, and the capacitor release energy. When switching open, the inductor releases energy, and the capacitor stores energy. The DC-DC boost converter is shown in Fig. 4. [6]

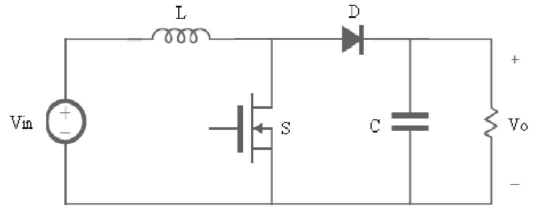


Fig -4: DC-DC Boost Converter

The boost converter parameter values are calculated by the following formulae and Table-2 shows the parameter values of the boost converter:

Table -2: Parameter values of Boost Converter

SR.NO	PARAMETERS	VALUES
1.	Input voltage	125V
2.	Output voltage	400v-500V
3.	Switching frequency	25kHz
4.	Inductance	7mH
5.	Input capacitance	1000µF
6.	Output capacitance	135µF
7.	Resistance	30Ω

$$Duty\ cycle(D) = 1 - \frac{Vs}{Vo} \quad (7)$$

$$Ripple\ current(\Delta IL) = \frac{Vs*D}{Lf} \quad (8)$$

$$Ripple\ voltage\ (\Delta VC) = \frac{Io*D}{Cf} \quad (9)$$

$$Inductance\ (L) = \frac{Vs*D(1-D)}{\Delta IL*f} \quad (10)$$

$$Capacitance\ (C) = \frac{Io*D}{\Delta VC*f} \quad (11)$$

2. MAXIMUM POWERPOINT TRACKING

Monitoring the optimal power point of a photovoltaic array is an important phase of a solar PV system. The huge variety of techniques suggested can make it challenging to identify the very best method to take on when applying a solar PV system. The methods all differ in intricacy, variety of sensing units needed, electronic or analog application, convergence rate, monitoring capability, and set you back efficiency.

The various techniques are used in MPPT for solar PV systems such as Constant Voltage (CV), Temperature (T), Open Voltage (OV), Feedback voltage (Current), Perturbation and Observation (P&O), Incremental Conductance (IC), Fuzzy logic controller (FLC), and Artificial Neural Network [7].

2.1 FUZZY LOGIC CONTROLLER MPPT

The Fuzzy logic controller has large series of applications in renewable resource applications. Using fuzzy logic controllers was enhanced over the last years due to its simpleness, managing imprecise inputs, does not require a precise mathematical design, and can deal with nonlinearity. FLC can be utilized as a controller to acquire the optimal power that the solar PV module [8].

The procedure of a Fuzzy logic controller can be categorized into three phases, fuzzification, rule evaluation, and defuzzification. These elements and the basic style of a FLCS are shown in Fig. 5.

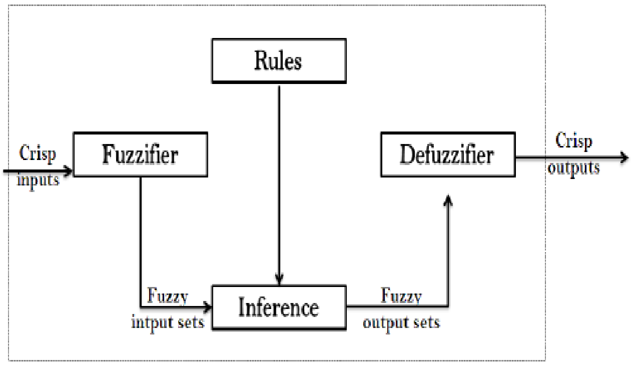


Fig -5: Block diagram of fuzzy logic controller system

The five steps to solve the mathematical of a fuzzy logic system. Step one is to identify input and output variables and decide descriptors for the same. The second step is to define the membership function for each of the input and output variables as shown in Fig.7. The third and fourth step is from rule base, rule evaluation. The last step in the fuzzy logic system is defuzzification [9]. The output of FLC is a change in the duty cycle of the DC-DC boost controller. The procedure of defuzzification transforms the linguistic value of output into a crisp output value. The many methods of defuzzification such as lambda-cut, maxima, weighted average, and the most commonly used centroid method.

In the recommended system, the input variables of the FLC are error (E) and the transform in error (CE) the output of FLC is transformed in the duty cycle. Develop factors to consider and the effectiveness of the fuzzy MPPT formula depend upon the chosen input and the output variable picked. The output variable of the FLC MPPT formula is typically duty ratio regulated for changing the running factor of the PV Module to optimize the power output. One of the most generally utilized input variables for FLC MPPT is the incline of the P-V curve of the PV module and modifications in this slope. Since slope vanishes at the MPP, both inputs can be determined as complying with:

$$E(k) = \frac{Ppv(k) - Ppv(k-1)}{Vpv(k) - Vpv(k-1)} \tag{12}$$

$$CE = E(k) - E(k-1) \tag{13}$$

Where Ppv and Vpv represent the power and voltage in the P-V curve. Error E(k) and CE become the crisp inputs of the fuzzy logic system. k and k-1 are the instants respectively. The flow chart of fuzzy logic controller MPPT is shown in Fig. 6.

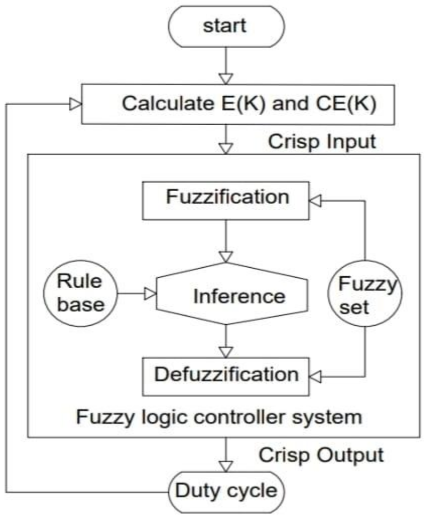
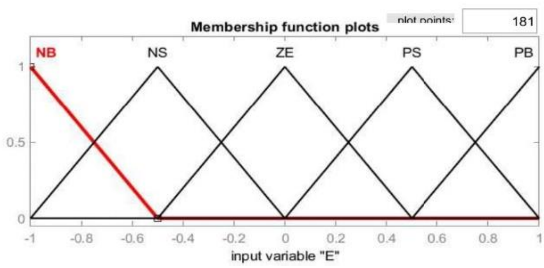


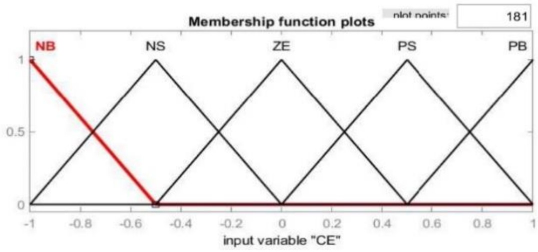
Fig -6: Flow chart of fuzzy logic controller MPPT

The various types of membership functions such as triangular, trapezoidal, and Gaussian specified membership functions. The triangular type membership function is used because it has less complexity when splitting values of the low, medium, and high MF. contrasting various other membership functions.

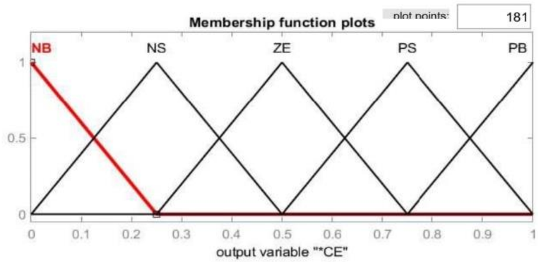
These variables are revealed in various fuzzy sets: NB (negative big), NS (negative small), ZE (zero), PS (positive small), PB (positive big) as shown in the table-3 and Membership function two input and one output variable is shown in Fig. 7.



(a): Input variable “E”



(b): Input variable "CE"



(c): Output variable "*CE"

Fig -7: Membership function two input and one output variable

Table -3: Fuzzy logic Rule-based

CE*(o/p)	CE(i/p)					
E(i/p)		**NB**	**NS**	**ZE**	**PS**	**PB**
	NB	ZE	PB	PB	PB	PB
	NS	PB	PS	PS	ZE	ZE
	ZE	PS	ZE	ZE	ZE	NS
	PS	ZE	ZE	NS	NS	NB
	PB	PB	ZE	NS	NB	ZE

3. SIMULATION RESULTS OF SOLAR PV SYSTEM USING FLC MPPT

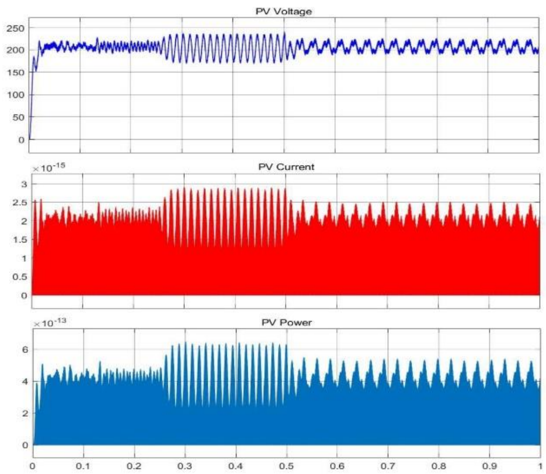


Fig-11: Resistive load: FLC MPPT Output power

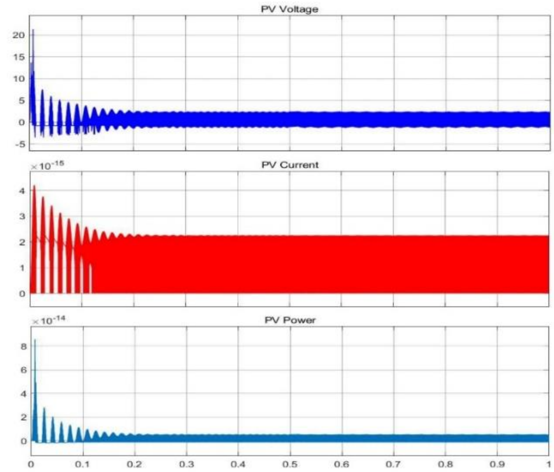


Fig-12: Inductive load: FLC MPPT Output power

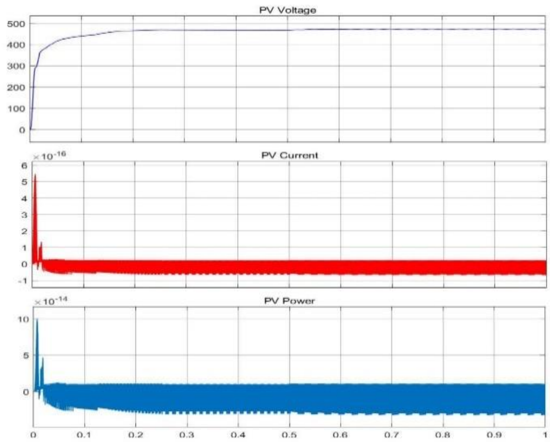


Fig-13: Capacitive load: FLC MPPT Output power

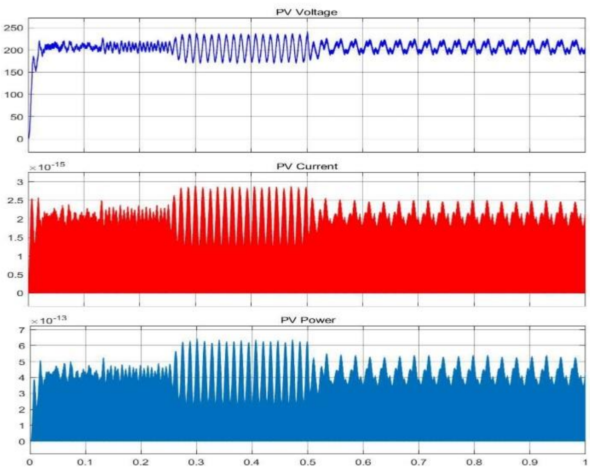


Fig-14: Resistive-Inductive load: FLC MPPT Output power

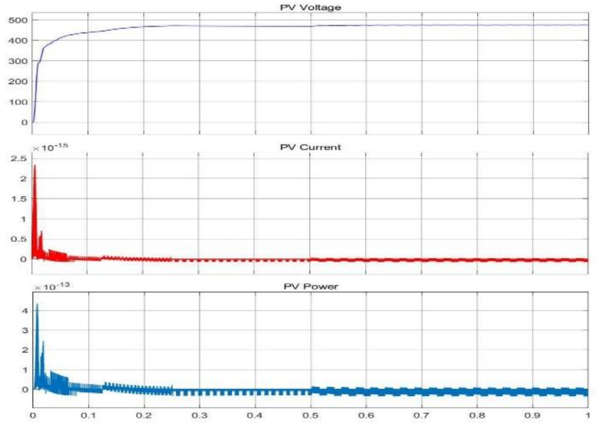


Fig-15: Resistive-Capacitive load: FLC MPPT Output power

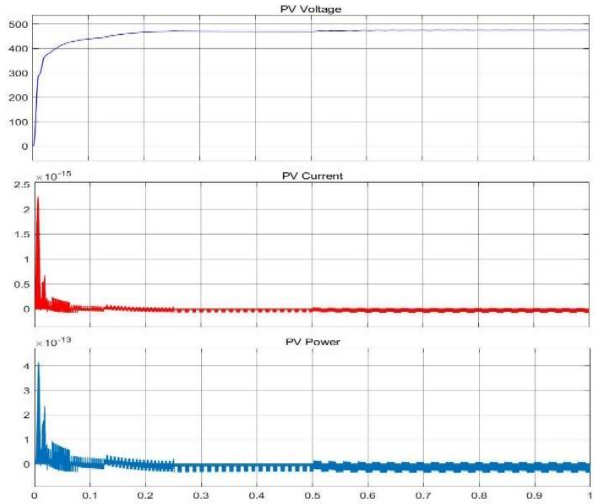


Fig-16: Inductive-Capacitive load: FLC MPPT Output power

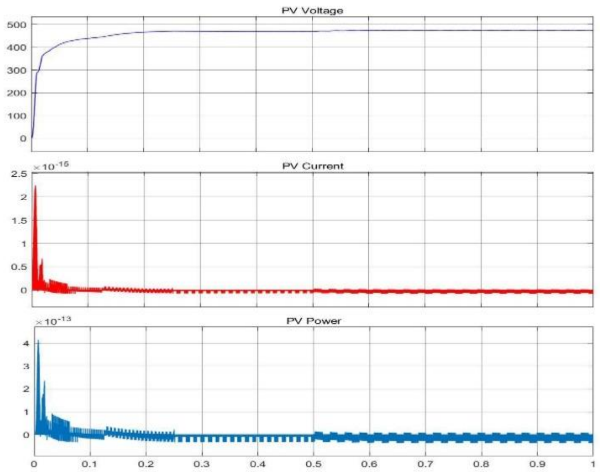


Fig-17: Resistive-Inductive-Capacitive load: FLC MPPT Output power

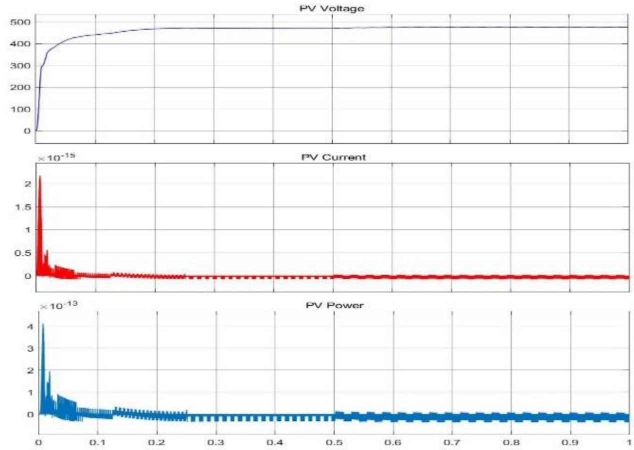


Fig-18: Open circuit: FLC MPPT Output power

Table -4: Results of SPV System in FLC-based MPPT

SR.NO	Load	FLC MPPT Output power		
		Voltage (V)	Current (A)	Power (W)
1.	R	203 V	2.122 A	430.7 W
2.	L	0.7566 V	2.245 A	1.698 W
3.	C	474.9 V	-5.302A	-2517.9 W
4.	RL	203.1 V	2.122 A	430.97 W
5.	RC	474.9 V	-3.841 A	-1824.09 W
6.	LC	474.9 V	-9.721 A	-4616.5 W
7.	RLC	474.9 V	-9.502 A	-4512.4 W
8.	Open circuit	474.8 V	-9.274 A	-4395.8 W

4. CONCLUSIONS

This paper proposed a technique to generate power using the solar photovoltaic system with a fuzzy logic controller-based maximum power point tracking method at different loading conditions. The active power is generated during the Resistive and Inductive, Resistive-Inductive loading conditions. The reactive power is obtained from Capacitive, Resistive-Capacitive, Inductive-Capacitive, Resistive-Inductive-Capacitive load, and Open circuit loading conditions.

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