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A Complete review of FLC MPPT Technique and Comparison with INC Technique

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Abstract: In recent years, all around the world, considerable technological growth has been observed to improve the availability of electrical energy in the most ecological way. Under partial shading conditions, maximum power point tracking techniques track the point at which full power can be taken out. Thus the net efficiency of a photovoltaic system is improved. This paper evaluates, methods such as incremental conductance (INC) and fuzzy logic controller (FLC) are evaluated. The simulation results obtained are developed under the software MATLAB / Simulink. Both techniques (INC) and (FLC) are used with a boost DC / DC converter and a load. These results show that the fuzzy logic controller is superior to and faster than the conventional incremental conductance (INC) technique in dynamic response and steady-state in regular operation.
Keywords: MPPT; PV; technique INC; technique FLC; Boost DC/DC.

I. INTRODUCTION

The energy demand is increasing daily with an ever- increasing population, which is the most challenging aspect of the modern world; the energy demand is freakingly high compared to the previous decades. The conventional sources of energy have a limit & will get depleted some days. The consumption rate of all such conventional sources of energy is proportional to their life expectancy. To fulfilling the ever-increasing energy demnd, other sources are now utilizing.

Renewable energy sources have become the best alternative to produce electricity all over the world in the past few decades. Among all the sources, the photovoltaic generation system attracts more attention because of its capability to generate electricity efficiently. However, the magnitude of output depends on atmospheric conditions such as temperature & solar irradiation. MPPT techniques are required to improve the efficiency & effective usage of solar energy.

For extracting maximum energy from the PV panel array, an appropriate duty cycle is configured with the DC/DC converter. This DC/DC converter must be capable of transferring maximum energy to load. A DC/DC converter provides an interface medium that regulates the PV panel & the load to ensure that the load must be closer to MPP.

As a result, several studies have focused on photovoltaic systems. They have tried to develop algorithms to extract the maximum energy converted by the panel and then allow an optimal operation of the system photovoltaic system [3]. Since the 1970s, a significant number of MPPT control techniques have been developed, beginning with simple techniques such as MPPT controllers based on the feedback of voltage and current [4], to more efficient controllers using algorithms to calculate MPP of the PVG photovoltaic generator (photovoltaic panel PV), among the most used technique (Incremental conductance (INC)).

Recently, many robust control techniques have been associated with the MPPT control, such as fuzzy logic controller (FLC) for increasing the efficiency of solar panels.

This paper is ordered as follows; section II shows a model of the PV system, demonstrating basic operating principles for INC and FLC techniques, respectively. Simulation results, analysis and discussion, are illustrated in Section III. & at the end, conclusions are given in Section IV.

II. MODEL OF PHOTOVOLTAIC SYSTEM

The photovoltaic system consists of four blocks, as shown in “Fig 2”. The first block represents the energy source (photovoltaic panel), the second block is a static DC-DC converter, the third block represents the load and the fourth block represents the control system (MPPT). Radiation (R) is an incident on the photovoltaic panel. It generates a voltage (V) and current (I). The temperature of the PV solar is measured atT [12]. The main role of the static converter is to ensureimpedance matching so that the photovoltaic panel PV delivers maximum energy. For commanding the DC/DC converter, we have been carried out using MPPT based on two techniques; INC and FLC [1].

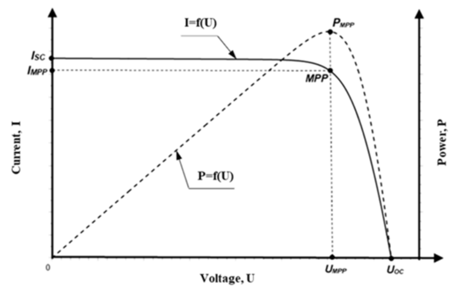

Fig. 1 Characteristic Of i=f(V) of

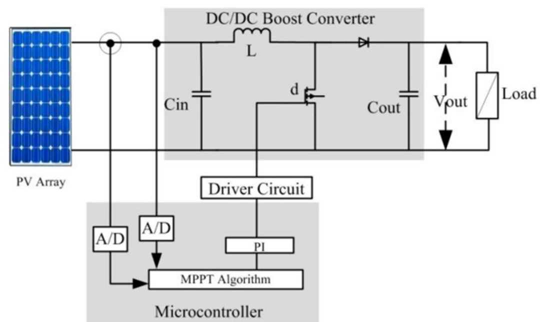

Fig.2 Block Diagram of a general photovoltaic system

A. PV Solar Module

The PV solar module used in this study consists of 66 polycrystalline silicon solar cells electrically configured as five series strings. Its main electrical specifications are shown in Table 1.

1) Mathematical Models of the PV Panel

The mathematical models of the PV panel are defined below. “Fig. 3” shows the equivalent circuit of a solar panel. A solar panel comprises of several photovoltaic cells employing series or parallel or, series-parallel external connections.

I-V characteristics of solar panel shown in equation 1

$$I = I_{PV} - I_O[\exp(\frac{V+RsI}{aVt}) - 1] - \frac{V+IRs}{Rp} \ldots\ldots\ldots(a)$$

- I_{PV} is the photovoltaic current
- I_O is the reverse saturated current
- R_S & R_P are the series & parallel resistances of the solar panel respectively
- $V_t = \frac{NKT}{q}$ is the thermal voltage & N is the no. of cells connected in series
- Charge of the electron is q
- K is the Boltzmann constant
- T is absolute temperature

Equations 2 & 3 show a linear relationship of I_{PV} with light intensity & varies with changing temperature & I_O is temperature-dependent.

$$I_{pv} = (I_{pv,n} + KOT)\frac{G}{Gn} \ldots\ldots\ldots\ldots(b)$$

$$I_o = \frac{Isc+KOT}{\frac{\exp(Voc+KvOT)}{aVt} - 1} \ldots\ldots\ldots\ldots\ldots\ldots(c)$$

$I_{pv,n}$, V_{oc} & I_{sc} are the PV current, open-circuit voltage & short circuit current, respectively.

- K_v= Open circuit voltage to Temp. ratio;
- Ki is the coefficient of short-circuit current variation with temperature;
- ΔT=T-Tn is the deviation from standard temperature, G the light intensity;

2) Irradiation Influence on PV

Figures 4 & 5 show the characteristics & variations of solar panel modules with changing temperature.

B. DC-DC Boost Converter

DC-DC boost converter is used here for stepping up the dc voltage, acting as a parallel chopper, as shown in fig.6.
The other use is for matching the load characteristics with solar panels.
Here it converts the input voltage to a higher output voltage as given by the equation below;

$$V_{out} = \frac{Vin}{1-\alpha} \qquad \text{(d)}$$

The converter's output voltage is directly proportional to the input voltage & the value of α lies between 0 & 1.
This converter always acts as a voltage booster.
For reducing the ripple current, a smoothing inductor is present in the boost converter & for lowering the voltage undulations across the load, a capacitor is present in it.

Technical specifications in Table 1

Maximum Power	310W
Open Circuit Voltage (V_{OC}) (V)	64.8
Short circuit current I_{SC} (A)	5.92
Current at maximum power point I_{MP} (A)	5.54
Voltage at maximum power point V_{MP} (V)	54.9

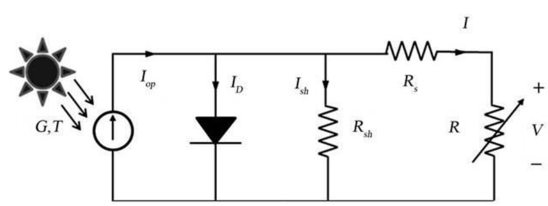

Fig.3 Equivalent circuit of solar module

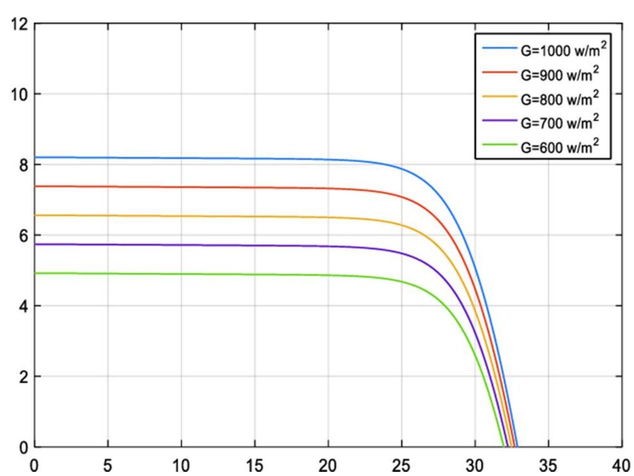

Fig.4 Characteristics of i=f(v) for different solar irradiation

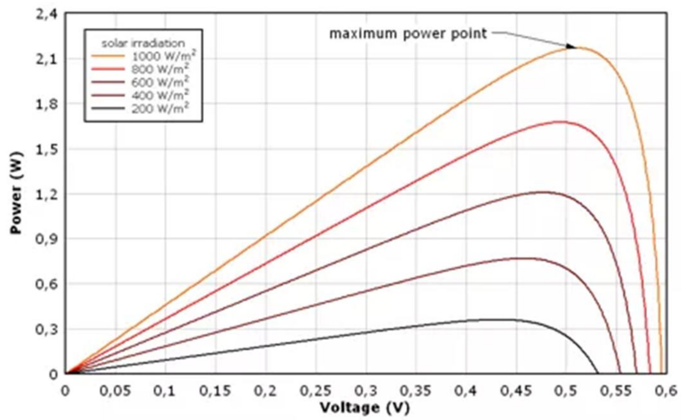

Fig.5 Characteristics of P=F(V) for different irradiations

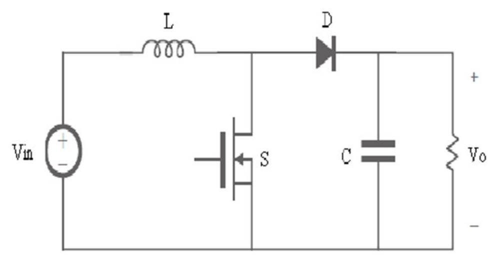

Fig.6 A schematic dig of Boost DC-DC converter circuit

C. Maximum Power Point Tracking (MPPT) Techniques

The MPPT is necessary for the optimal & efficient working of a photovoltaic system. The principle of operation depends on the duty cycle of the DC-DC converter to maximize the power delivered.

Here, we are discussing two methods Incremental conductance method (INC) & Fuzzy Logic Controller (FLC)

1) Incremental Conductance (INC) technique: The incremental conductance algorithm detects the slope of the P-V curve, & the MPP is tracked by searching the peak of the P-V curve.

The conductance is defined by the below relation:

$$G=I_{PV}/V_{PV} \quad \text{......................} \ (e)$$

An Incremental variation is given by:

$$DG= DI_{PV}/DV_{PV} \quad \text{......................} \ (f)$$

Fig.7 shows the following conditions:

$d P_{PV}/d V_{PV} > 0$, Left of MPP
$d P_{PV}/d V_{PV} < 0$, Right of MPP
$d P_{PV}/d V_{PV} = 0$, at MPP.

Following relation describes the relation between conductance & $d P_{PV} /d V_{PV}$:

$$\frac{dP_{PV}}{V_{PV}} = \frac{d(I_{PV} * dV_{PV})}{V_{PV}}$$

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$I_{PV} = V_{PV} * \frac{dI_{PV}}{dV_{PV}}$

$= I_{pv} + V_{PV} * \frac{dI_{PV}}{dV_{PV}}$

$= I_{pv} + V_{PV} * \frac{OI_{PV}}{OV_{PV}}$..........(g)

Hence, the modified above all three conditions can be rewritten as:

$OI_{PV}/OV_{PV} > -I_{PV}/V_{PV}$, Left of MPP

$OI_{PV}/OV_{PV} < -I_{PV}/V_{PV}$, Right of MPP

$OI_{PV}/OV_{PV} = -I_{PV}/V_{PV}$, at MPP

Hence, by comparing the instantaneous conductance to the incremental conductance, the MPP can be traced by following the procedure shown in fig,

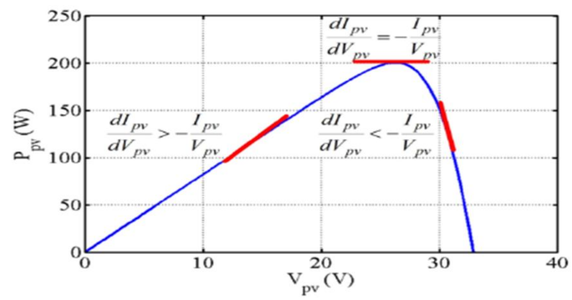

Fig.7 PV Plot for INC method

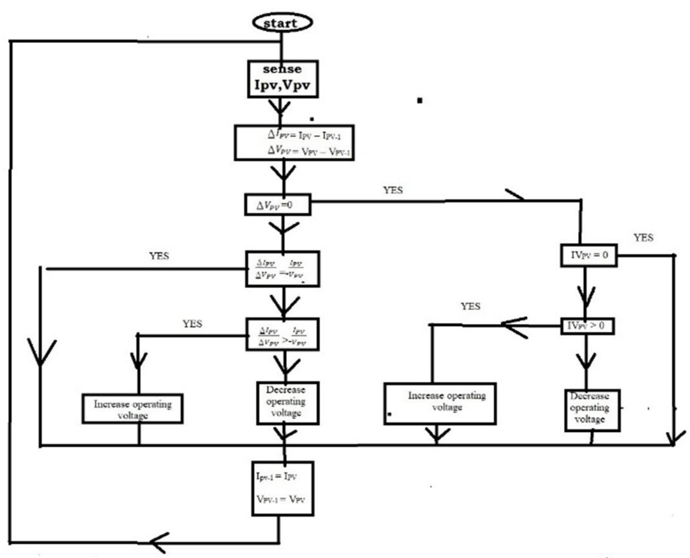

Fig.8 Flow chart of INC technique

2) Fuzzy Logic Controller (FLC) technique for PV MPPT: The proposed method uses the power to voltage variation and voltage variation as the inputs, which significantly simplifies the computation. On the one hand, FLC offers the advantage of being robust and relatively simple to develop, and it does not require the exact knowledge of the regulation. Conversely, the FLC has the benefits of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity.

It generally comprises three steps: fuzzification, aggregation, and defuzzification.

A) Fuzzification: The inputs which we provided gets converted into a function named membership function. For calculating the power from PV array, I_{PV} & V_{PV} are provided as inputs. The error E(k) can be calculated & ∆E(k) can be calculated as shown below:

$$E(k) = \frac{P_{PV}(K) - P_{PV}(K-1)}{V_{PV}(K) - V_{PV}(K-1)} \ldots\ldots\ldots\ldots (h)$$

$$\Delta E(k) = E(k) - E(k-1) \ldots\ldots\ldots\ldots (f)$$

Such variables are expressed in linguistic variables, for example, positive big (PB), positive small (PS), positive medium (PM) etc., by using a basic fuzzy subset. These variables are defined in the mathematical membership function.

B) Aggregation: This step is for controlling the output variables by going through the calculation & conversion to the linguistic variables based on the member function.
The FLC output is based on some rules, which depend on the if-then concept.

C) Defuzzification:
It is totally an inverse operation of fuzzification, where the numerical value is easily calculated by the external atmosphere from a fuzzy definition.

III. DISCUSSION OF SIMULATION RESULTS

A. Simulation Results

1) At temperature- 25°C & irradiation of 1000 W/m^2, both the algorithm have been observed & plotted in fig. 10. The graph shows the plot at temp. 25°C & 1000 W/m^2 irradiation at different values of power, voltage & current.

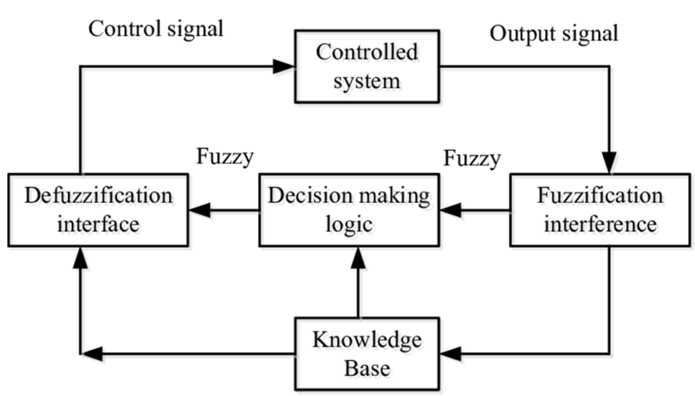

Fig.9 Block diagram of Fuzzy logic control technique

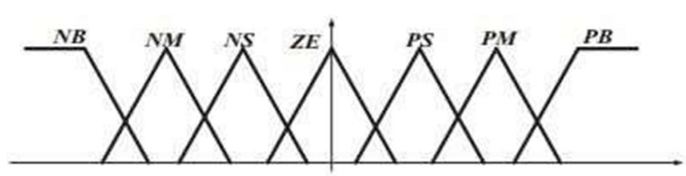

Fig.10 Membership Function

Table 2: Rules of the Membership function

e/De	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
ZE	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

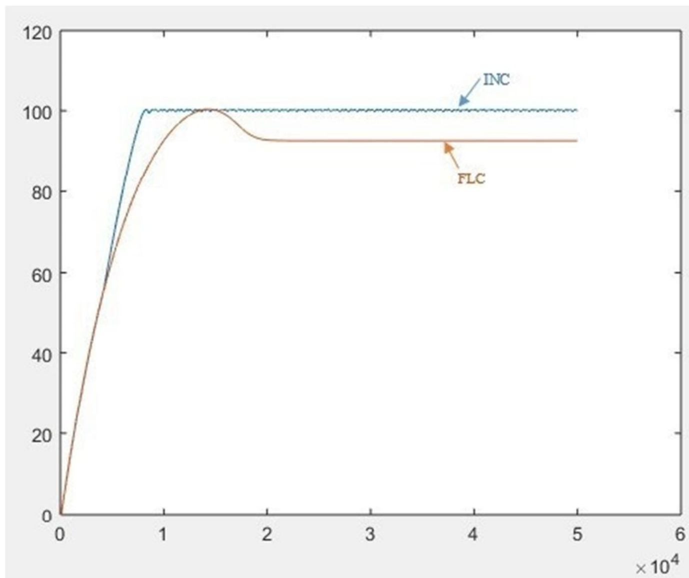

Fig. Plot for Power of INC & FLC techniques at t=25°C &1000 W/m^2

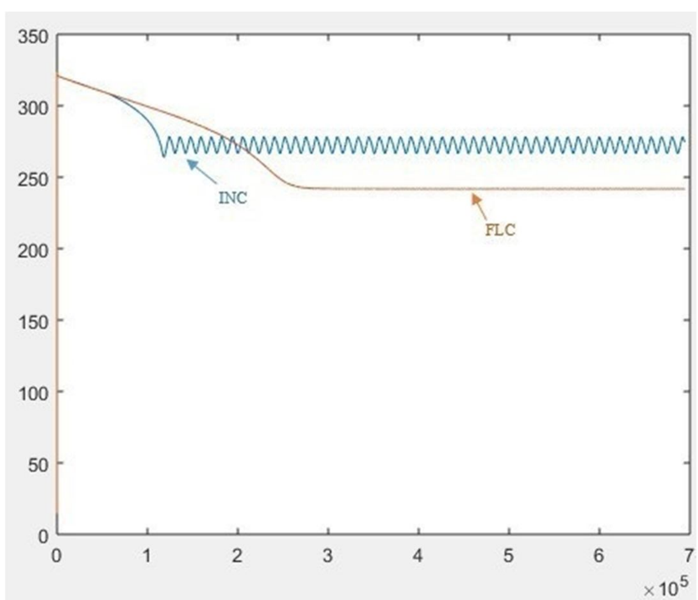

Fig. Plot for Voltage of INC & FLC techniques at t=25°C &1000 W/m^2

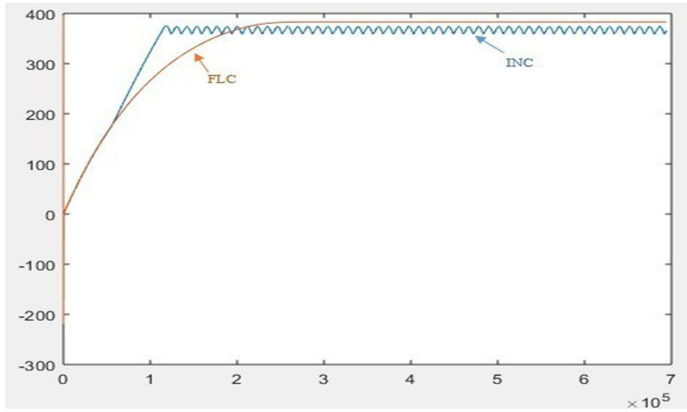

Fig. Plot for current INC & FLC techniques at t=25°C &1000 W/m^2

Above are the plots of Power, Voltage & Current of both INC & FLC techniques; it has been observed in the above plots that the INC technique plot converges towards the optimal values with oscillations while the FLC technique plot converges quite smoothly.

2) Results with temp.=25°C & different solar irradiation values.

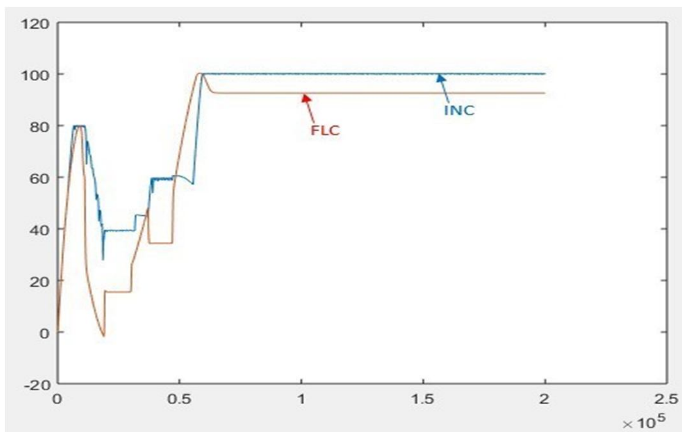

Fig. Plot for Power from INC & FLC techniques at t=25°C & different irradiation

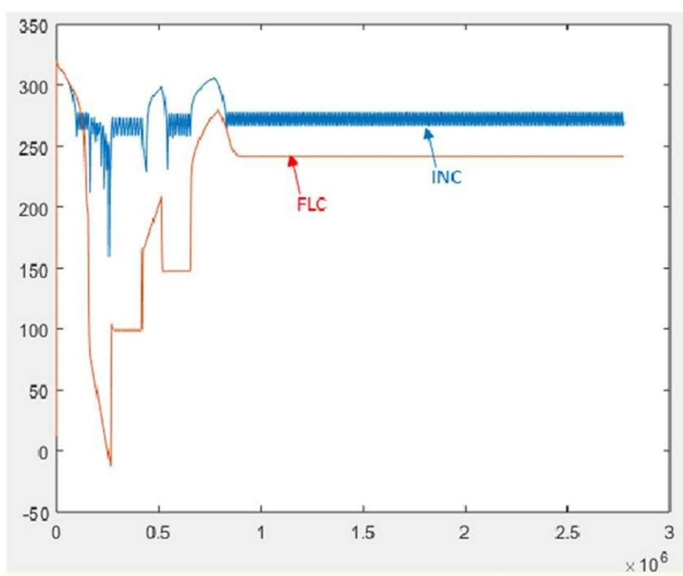

Fig. Plot for voltage at t=25°C & at different irradiation values

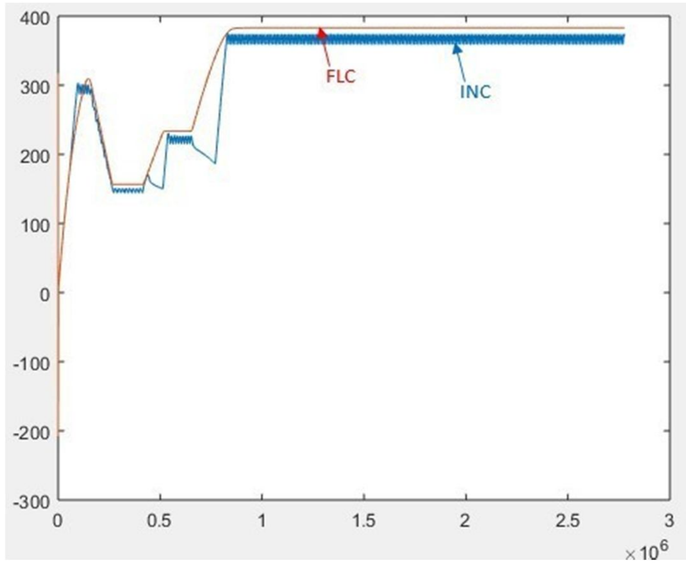

Fig. Plot for current at t=25°C & at different irradiation values

The above three plots show the Power, voltage & current plots at different irradiation values. Both the plots undergo different modifications as compared to previous conditions, but the plot with the INC technique shows much more oscillations as compared to the FLC technique, clearly visible in the plots.

B. Discussions

The simulation plots clearly indicate that the FLC technique shows clearly better results as compared with the INC technique. The plot indicates that at the optimal point of output FLC technique has no oscillation while INC shows some, which implies that it has shown better results in a transient state. But the only problem with this method is its implementation & also the efficiency of this method depends upon the inference table.

IV. CONCLUSION

In this paper, we have discussed the two MPPT techniques INC & FLC techniques, thoroughly & compared their results with the same sets of parameters & also by changing the irradiation levels.

It has been observed that the FLC technique is advantageous in giving the results oscillation free & working under a transient state. At the steady-state condition also, this method is oscillation free. Despite a bit complex method, it has been concluded that the FLC method in tracking out maximum power point is superior to the INC method.

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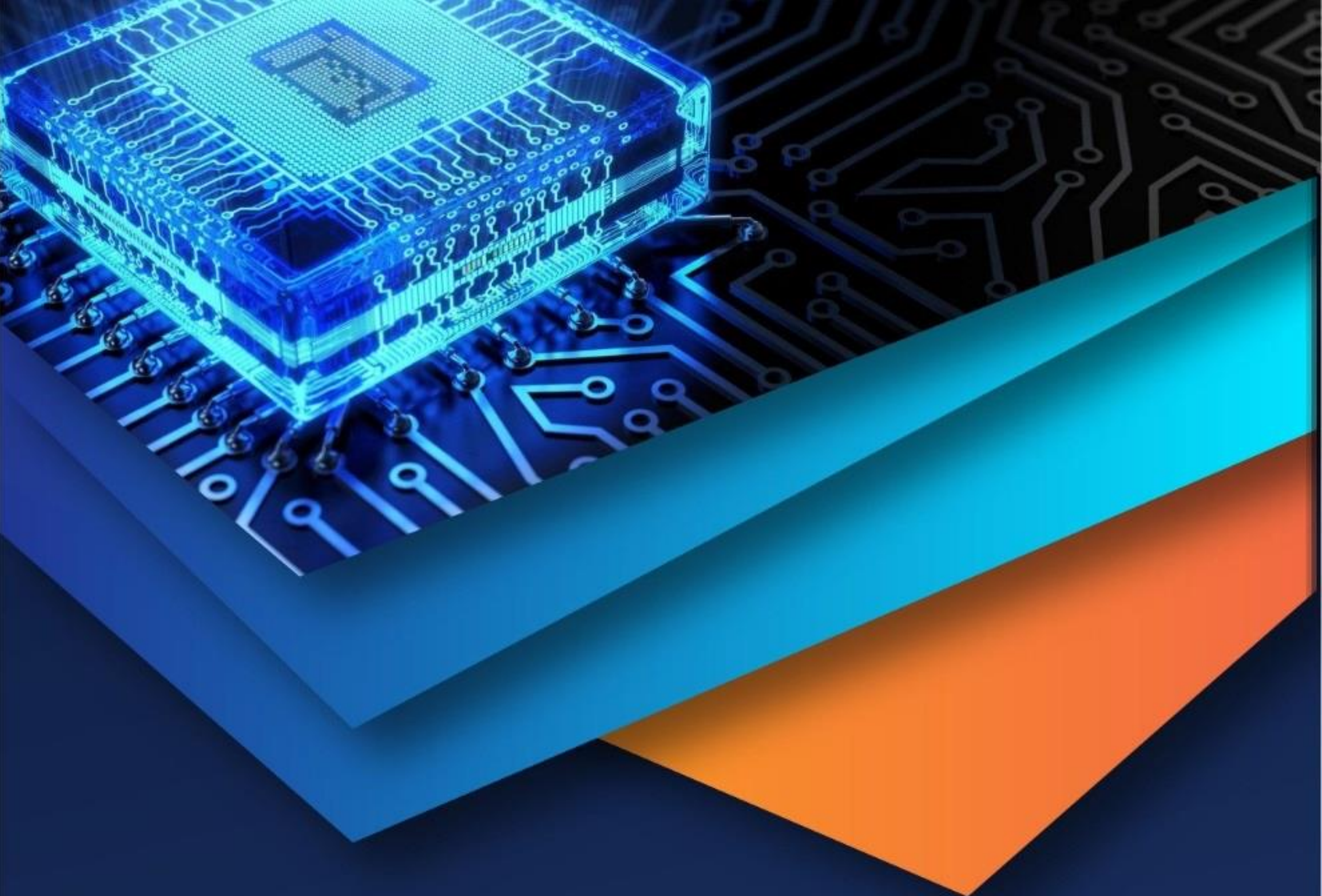

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