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A Comparative Study on Maximum Power Point Tracking Techniques for Utility Grid Connected Photovoltaic Systems using ANFIS and INC Method

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Abstract- It is a well-known fact that the dependency of non-renewables sources needs to be reduce to deal with global warming. Solar energy is one such option which is in abundance in India. Solar PV cell are utilised to trap this energy and convert it to electrical energy. The PV cell has the ability to convert near about of 20 % of solar energy to electrical energy. The output of PV cell depends on solar irradiation and panel temperature and panel terminal voltage, based on which MPP can be attained. Hence work is to be done to achieve that point operation for MPPT.This work presents a comparative study between two maximum power point tracking (MPPT) methods in MATLAB/Simulink program that are incremental conductance method and genetic algorithm-based method. The study is performed with variable irradiation and temperature. On simulation, the results obtained are found to give boost converted output voltage of 502.13 V for ANFIS MPPT method and 501.50 V for INC MPPT method. In addition, the output power of boost converter for variable irradiation is found out to be 92.26 KW for ANFIS and 90.41 KW for INC respective only comparison results, ANFIS has clear upper hand over P&O method in terms of performance.

Keywords- MPPT, solar PV, INC, ANFIS, Boost converter, Utility grid, MATLAB/Simulink, bridge inverter.

I. INTRODUCTION

In recent times, continuous efforts are made to increase the contribution of renewables to reduce dependency on fossil fuel-based resources around the globe for the generation of electric power. The solar PV system is one such option, which is gaining its contribution globally each year. Its increase in popularity is due to a reduction in its cost due to technological enhancement. At present globally, 4800 GW is generated using Solar PV. A growth of around 60% was observed in the case of grid-connected solar PV systems; at present contributing around 21 GW [1 -5].

Even today, the majority of energy generation did using non-renewable energy sources due to the cost of generation. However, these sources lead to a major threat of global warming. Besides, these sources are responsible for other types of pollutions which ultimately leads to damage to the ecosystem.

Hence sources like solar are gaining importance. In-country like India, solar radiations are available in abundance in most of the country for major times of the year. Besides, the process of converting this solar energy to electrical energy is comparatively easy. Both grid-connected and distributed solar PV system has big advantages.

At present Indian government has made an objective to accomplish an established limit of renewables in India to around 175 GW by the year 2022, out of which the principal giver will be a solar-based system, which will add to around 65% of the absolute limit because of high capacity of solar energy in the Indian subcontinent.

The objective of the present work is to understand the importance of MPPT and to implement it to a PV panel in Matlab software to find a point where the PV panel will deliver maximum power [6- 20]. After simulating our effect with the use of Simulink we would similar to equate the result of these MPPT methods.

II. PHOTO VOLTAIC (PV) SYSTEM

In this chapter the modeling and design of overall system such as PV system, boost converter, load and MPPT controller has been presented.

Photoelectric cell is the semiconductor system that changes light to electrical power by photovoltaic. If energy (power) of photon of brightness is superior to the band gap, then an electron of the system is emitted also flow of an electron of system forms current. But the photovoltaic cell is different type of photo diode, when the light of sun falls down on device of cell is converted.

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Voltage or current by photo effect however this cell is always forward biased. Translation of photo - voltaic energy to electrical and thermal power of system has been use for many years. To conversion the PV power to electrical, photo voltaic are used. Photovoltaic modules make use of the photoelectric effect in order to directly perform the above conversion.

Solar panels convert solar radiation to electricity with efficiencies in the vary of 5% to 20%, of system depend on form of the photovoltaic cell. Polycrystalline silicon PV cells offer the highest range of possibilities for applications. For consequence of their modest price relative to the mono crystalline silicon cells, and their considerable stability and efficiency (about 15%).

Furthermore, these cells are sold in type of panels having dark blue appearance which is esthetically pleasant. When the temperature of a so PV module is increased, the efficiency drops. This can usually result in an efficiency drop off of 0.5% per °C progress in the cell operating temperature [21-40]. The working temperature is increased because a great part of solar radiation is not changed to electricity but is absorbed by panel as heat.

A current source type PV model is discussed in this section. The equivalent circuit is also shown.

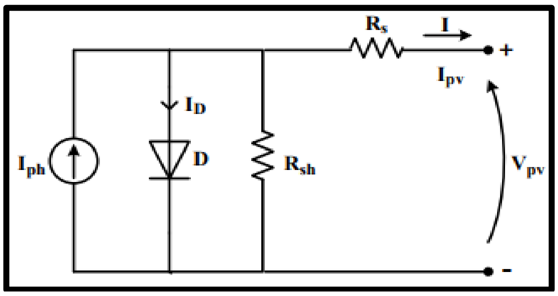

Fig 1. The equivalent circuit of a PV array.

Where, Rs is the array series resistance in Ohm,
Rp is the array parallel resistance in Ohm,
I and V are the output current and voltage of the array in Ampere and Volt.

$$\mathbf{I} = \mathbf{N_p} \times \mathbf{I_{ph}} - \mathbf{N_s} \times \mathbf{I_{rs}}\left[\mathbf{e}^{\left(\frac{q\times V}{A\times K\times T}\right)-1} - \left(\frac{\mathbf{V} + \mathbf{I} \times \mathbf{R_s}}{\mathbf{R_{sh}}}\right)\right] \quad (1)$$

Where, Iph is photo current in Amp,
Irsis saturation current in Amp,
Ns and Np are the number of series and parallel modules respectively,
q is charge on electron in coulomb,
A is diode ideality factor,
T is cell Temperature with change in irradiation in degree kelvin.

Now,

$$I_{ph} = I_{scr} + K_i \times (T - T_r) \times S \quad (2)$$

$$I_{rs} = I_{rr} \times \left(\frac{T}{T_r}\right)^3 \times e^{\left(\frac{q\times E_g}{K\times A}\times\left(\frac{1}{T_r}-\frac{1}{T}\right)\right)} \quad (3)$$

Were,
Iscris Short circuit current at reference Temperature in Amp,
Irris reverse saturation current in Amp,
Tr is reference temperature in Kelvin,
S is solar irradiance in mW/Sq. cm,
Ki is S.C. current Temp. Coefficient in (Amp/Kelvin),
K is Boltzmann's constant,
Eg is band gap energy of semiconductor used cell in joules, also,

$$E_g = E_{g0} - \left(\frac{\alpha \times T^2}{T + \beta}\right) \times q \quad (4)$$

Where, E_{go} = band gap at 0k and,

$$V_{oc} = \left(\frac{A \times K \times T}{q}\right) \times \ln\left(\frac{I_{ph}}{I_{rs}}\right) \quad (5)$$

III. MAXIMUM POWER POINTTRACKING

Due to miss-match between power generated by Solar PV system and load connected, the efficiency of system is very poor. Certain methods needed to incorporate with system to increase efficiency. Such type of methodology of improving/maximizing power generation of PV system is known as Maximum power Point Tracking.

Since, the V-I characteristic of Solar PV system is non-linear by nature, in order to make it utilizable for load, boost converters are used along with panel. The synchronization between load and generation can be done by modifying duty cycle of this converter using MPP.

In order to plan the control system, the configuration of PV system is to be understood first. Different configuration of PV systems is possible like the most basic one comprised of PV systems suppling power directly to inverter which is further connected to grid.

Another type of connection is possible in which instead of suppling whole amount of power to grid, a part is kept to be stored in battery bank storage. A third type of configuration is also possible in which full generated power is stored in battery bank. The advantage of such system is that we don't need to connect each panel with a separate inverter instead we can have a centralized connection of single micro inverter for all increasing efficiency by 20 %.

The MPPT systems are connected to those conversion devices of system which have the ability to modulate current or voltage of supply generated by PV panel. This power electronic based device has the responsibility to convert supply in the form according to load demand. As discussed earlier the MPPT section is performed with converter section. The point where MPP occurs have a certain value of current and voltage termed as Impp and Vmpp. The product this two will eventually give value of maximum power.

1. Incremental Conductance (INC) Algorithm:

This technique of MPPT works with a simple hypothesis that "ratio of change in output conductance is equal to the negative output conductance or Instantaneous conductance"

Since we know the relation,

$$\mathbf{P = V\,I}$$

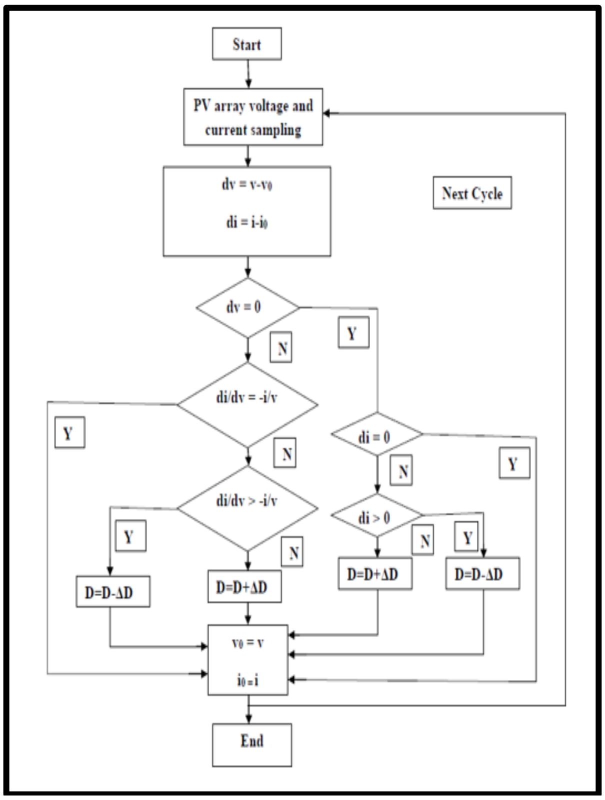

Fig 2. Incremental conductance MPPT algorithm flow chart.

The above relation is differentiated on both sides, which gives

$$\frac{\partial P}{\partial V} = -\frac{\partial (VI)}{\partial V}$$

At MPP, as $\partial P/\partial V = 0$, on substituting above value will give

$$\frac{\partial I}{\partial V} = -\frac{I}{V}$$

The LHS gives the value of instantaneous conductance of PV panel whereas right side gives instantaneous value. When LHS= RHS, MPPT is achieved. In this method both parameters are taken in to account hence the effect on error of variation of solar light is eliminated. The primereason behind using INC method is its cost effectiveness. Hence, in this technique the duty cycle is regulated by PWM control of a dc-dc boost converter until the above condition is satisfied. The Flow chart of INC MPPT is shownbelow.

2. ANFIS:

ANFIS stands for Adaptive Neuro-Fuzzy Inference System. The ANFIS controller combines the advantages of fuzzy controller as well as quick response and adaptability nature of ANN Fundamentally, ANFIS is about taking a fuzzy inference system (FIS) and tuning it with a back propagation algorithm based on some collection of input-output data. This allows your fuzzy systems to learn.

A network structure facilitates the computation of the gradient vector for parameters in a fuzzy inference system. Once the gradient vector is obtained, a number of optimization routines are applied to reduce an error measure. This process is called learning by example in the neural network literature.

Some Constraints are as follows:

Since ANFIS is much more complex than the fuzzy inference systems discussed so far, all the available fuzzy inference system options cannot be used.

Specifically, ANFIS only supports Sugeno systems subject to the following constraints:

- First, order Sugeno-type systems.
- Single output derived by weighted average defuzzification.
- Unity weight for each rule.

An error occurs if your FIS matrix for ANFIS learning does not comply with these constraints. Moreover, ANFIS is highly specialized for speed and cannot accept all the customization options that basic fuzzy inference allows, that is, one cannot make own membership functions and defuzzification functions; that to make do with the ones provided.

The fuzzy inference system that has been considered is a model that maps:

- Input characteristics to input membership functions,
- Input membership function to rules,
- Rules to a set of output characteristics,

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- Output characteristics to output membership functions, and
- The output membership function to a single-valued output, or
- A decision associated with the output.

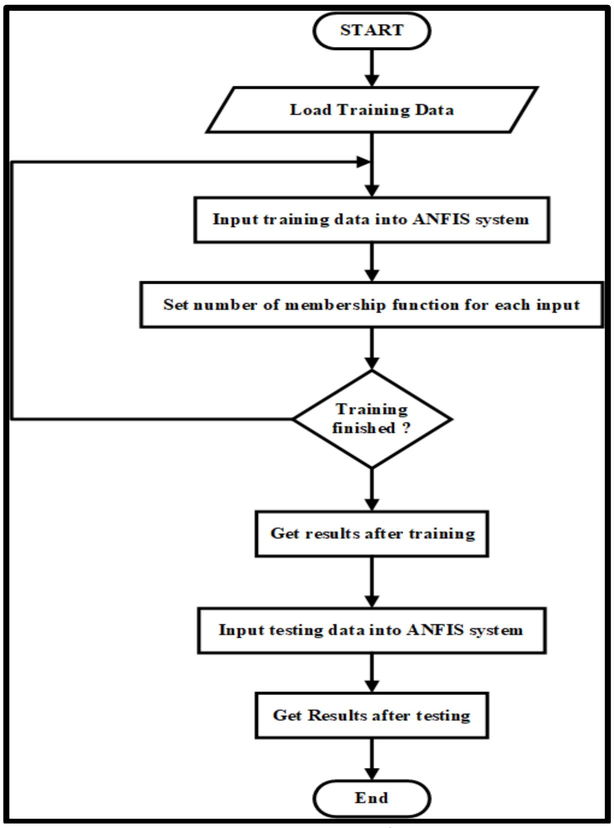

Fig 3. ANFIS algorithm flowchart.

IV. RESULT AND DISCUSSION

In this unit designed solar PV Simulink model on MATLAB software is presented and its analysis is shown to increasing efficiency with the help of two methods incremental conductance (INC) and Adaptive neuro fuzzy interface system (ANFIS) MPPT techniques/methods. The simulation is performed for variable irradiation varying from 1000 to 225 W/m2 at temperature varying from T = 25 to 50°C.

In this section, simulation model of PV system designed for INC MPPT on MATLAB/Simulink is shown and discussed. The reason to vary the value of irradiation is to create an effect of cloud, which hinder the sunlight falling directly on PV array. The irradiation level varies in following pattern as 1000 225 1000 W/m2. This variation in irradiation leads to change in output of PV array.

The variation in irradiation moves MPPT to a new point, which needs to be traced. This simulation considers both steady state and dynamic state response of the system for sudden change in solar irradiation.

In order to obtain suitable voltage, a set of 66 strings connected in parallel, with each string comprised of 5 modules is used.

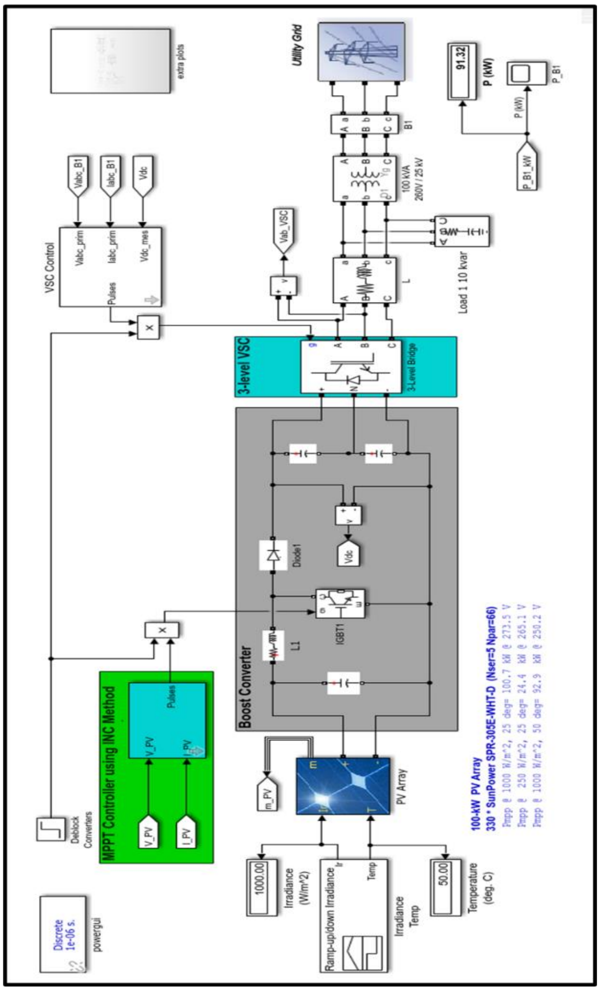

Fig 4. Simulation model of system with INC MPPT method.

On simulating the model, it is observed that there are certain transients are generated in the system at the starting of simulation while converter is drawing system to MPP. The results were summarized and compared in table 1.

Table 1. Output Parameters with INC MPPT Method.

S.No.	Parameters	INC Method
1.	Panel Voltage Vpv (V)	251.71
2.	Panel Current Ipv (A)	268.07
3.	Irradiation (W/m2)	2000
4.	Temperature (0C)	50
5.	PV Maximum Power/MPPT (KW)	90.41
6.	Boost Converter Output Voltage (V)	501.50
7	Boost Converter Output current (A)	260.89

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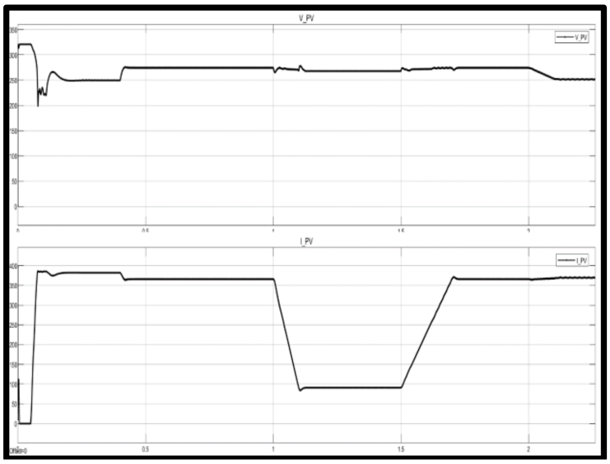

Fig 5. PV array voltage and current with INC Method.

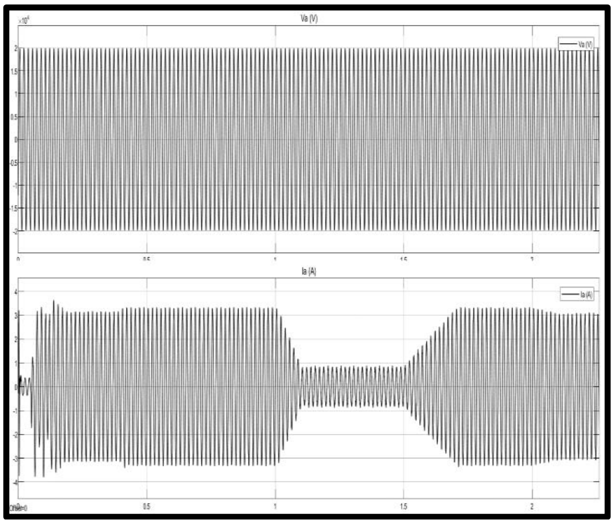

Fig 6. Utility grid voltage and current for INC MPPT method.

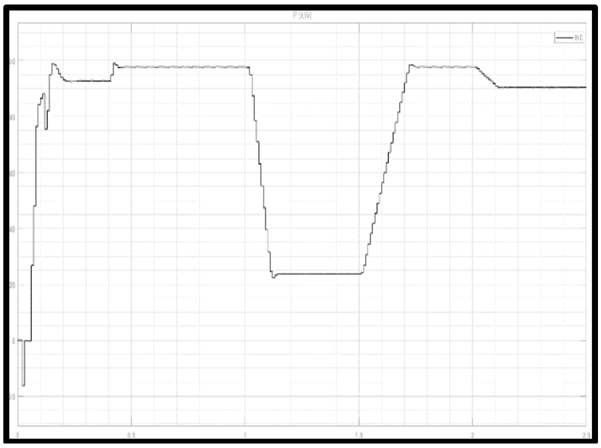

Fig 7. PV array maximum power with INC Method.

1. Simulation Modeling and Result Analysis of ANFIS-MPPT Method:

In this section, simulation model of PV system designed for ANFIS MPPT on MATLAB/Simulink is shown and discussed.

The reason to vary the value of irradiation is to create an effect of cloud, which hinder the sunlight falling directly on PV array. The variation in irradiation moves MPPT to a new point, which needs to be traced.

This simulation considers both steady state and dynamic state response of the system for sudden change in solar irradiation. On simulating this model connection along with control system for MPPT with the help of ANFIS MPPT techniques, effect on various parameters like output power, voltage and current were monitored.

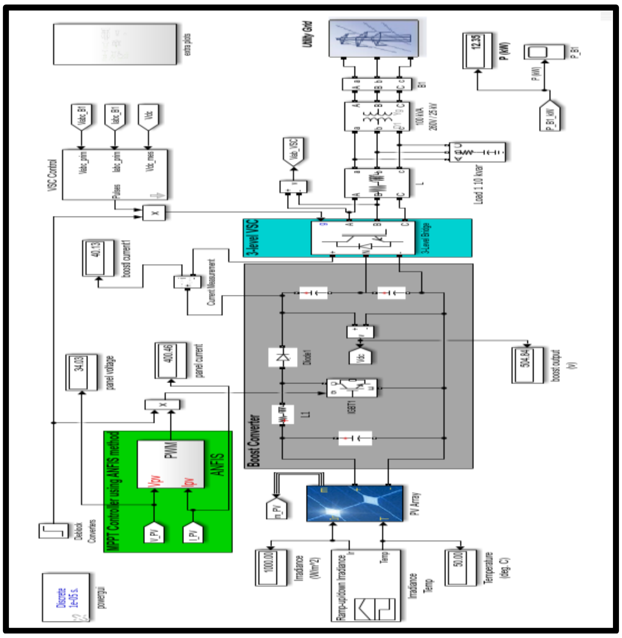

Fig 8. Simulation model of system with ANFIS MPPT method.

On simulating the model, it is observed that there are certain transients are generated in the system at the starting of simulation while converter is drawing system to MPP. The results were summarized and compared in table 2.

Table 2. Output Parameters with ANFIS MPPT Method.

S. No.	Parameters	ANFIS Method
1.	Panel Voltage Vpv (V)	251.81
2.	Panel Current Ipv (A)	268.91
3.	Irradiation (W/m2)	2000
4.	Temperature (0C)	50
5.	PV Maximum Power/MPPT (KW)	92.26
6.	Boost Converter Output Voltage (V)	502.13
7	Boost Converter Output current (A)	260.82

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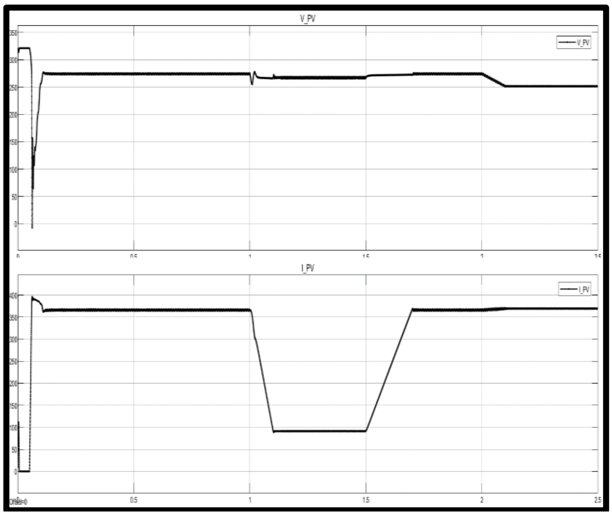

Fig 9. PV array voltage and current with ANFIS Method.

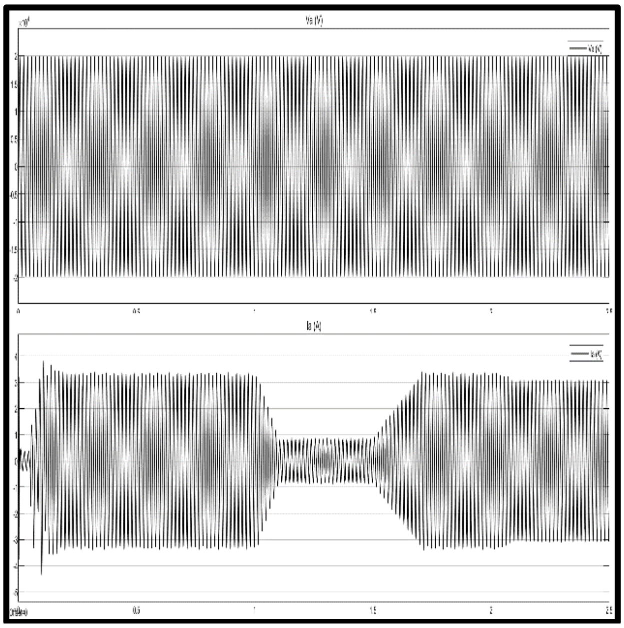

Fig 10. Utility grid voltage and current for ANFIS MPPT method.

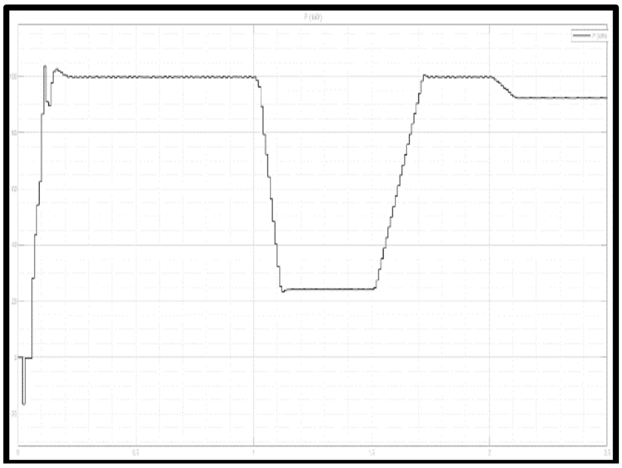

Fig 11. PV array maximum power with ANFIS Method.

In this section, results were evaluated from both INC and ANFIS methods for both cases under consideration and values and plot were displayed through various figures. Values were calculated at both panel end and Boost converter end.

V. CONCLUSION

As discussed in previous chapter, in this work PV model has been successfully designed and simulated on MATLAB/Simulink software. For increasing net output power generation of this PV system, 2 methods have been proposed for balancing. These methods are ANFIS and INC.

When PV irradiation and temperature are kept varing, the boost converter output voltage generated by applying both separately is found to be 502.13 V & 501.50 V. In addition, the o/p power using these two methods for constant irradiation is found to be 92.26 KW and 90.41 KW respectively. The result clearly shows that ANFIS method is superior in comparison with INC for constant irradiation.

The study is performed with variable irradiation and temperature. On simulation, the results obtained are found to give boost converted output voltage of 502.13 V for ANFIS MPPT method and 501.50 V for INC MPPT method. In addition, the output power of boost converter for variable irradiation is found out to be 92.26 KW for ANFIS and 90.41 KW for INC respective only comparison results, ANFIS has clear upper hand over P&O method in terms of performance.

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