

Genetic Algorithm Method Based MPPT for Utility Grid Connected Photovoltaic Systems Using MATLAB/Simulink Software

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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 utilized 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 GA 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 GA and 90.41 KW for INC respective only comparison results, GA has clear upper hand over P&O method in terms of performance.

Keyword:MPPT, solar PV, INC, GA, Boost converter, Utility grid, MATLAB/Simulink, bridge inverter.

1. Overview

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.

Even today, the majority of energy generation done 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. After simulating our effect with the use of Simulink we would similar to equate the result of these MPPT methods.

2. Literature review

The detailed literature review in the area of PV solar, other renewable energy resources and MPPT method/techniques to track maximum power are presented in this chapter. The various studies show that a solar panel converts 21-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel.

Yong Li, Sarminah Samad [1] in 2020 discussed that the tendency towards employing a combined system for generating electricity has significantly increased. In this respect, the combination of a photovoltaic (PV) system and an energy storage system has captured the attention. In this respect, this paper develops a control system for a combined energy system, comprised of a PV and a battery in the grid-connected mode.

Xun Ge et al. [2] in 2020 discussed that the paper develops a control scheme for a hybrid energy system, including a photovoltaic (PV) panel and a battery energy storage (BES) system. The capital cost of PV systems is considerably high today and it has been continuously trying to mitigate the manufacturing cost and also, several research works have been devoted to developing effective methods to maximize the power output of these generation systems.

N. Priyadarshi, et. al. [3] in 2019 discussed that Maximum power point trackers (MPPT) are required in order to obtain optimal photovoltaic power. To achieve this task, an intelligent fuzzy particle swarm optimization (FPSO) MPPT algorithm has been proposed in this paper. Also, an inverter control strategy has been gated with a ripple factor compensation-based modified space vector pulse width modulation (SVPWM) method. The proposed system performance is verified under varying sun irradiance, partial shadow, and loading conditions.

M. Kermadi E. M. Berkouk [4] in 2019 discussed, a modified maximum power point tracking (MPPT) algorithm based on particle swarm optimization (PSO) technique is proposed. This algorithm aims to maximize the power extracted from a photovoltaic (PV) system with Lithium-ion (Li-ion) battery under partial shading

condition (PSC). The proposed algorithm aims to reduce the time wasted during the exploring phase by using a variable sampling time. To do this, a comparator between the reference voltage given by the PSO algorithm and the output voltage of the PV array is integrated.

Emad M. Ahmed et al. [5] in 2019 discussed that the integration of photovoltaic (PV) systems with three-phase four-wire (3P4W) distribution networks has imposed several challenges related to existing unbalanced loads, reactive power generation and harmonics content. In this paper, a multifunctional distributed maximum power point (MPPT) controller for grid integration of PV systems is proposed.

K. Ding, X. Bian, H. Liu, T. Peng [6] in 2019 discussed that the performance of a photovoltaic (PV) module is mostly affected by array configuration, irradiance, and module temperature. It is important to understand the relationship between these effects and the output power of the PV array.

Rozana Alik, Awang Jusoh [7] in 2018 presents the impact of partial shading to the PV system and proposes an enhanced Perturb and Observe (P&O) algorithm with a checking algorithm. This checking algorithm compared all existed peaks on the PV curve to clarify the global maximum power point (GMPP). The boost converter duty cycle is calculated using voltage at MPP (VMPP), identified through a variable step size P&O algorithm.

Neeraj Priyadarshi [8] in 2018 discussed the experimental realization of grid-connected photovoltaic (PV) system using dSPACE DS 1104 control board. To obtain high tracking efficiency, an adaptive Neuro-Fuzzy inference system (ANFIS)-based maximum power point tracking (MPPT) algorithm is proposed. The performance of the system is improved by fuzzy logic control (FLC), which generates the switching signal to the power switches of inverter.

Alivarani Mohapatra et. al. [9] in 2017 discussed that a concise and an organized review of various maximum power point tracking (MPPT) algorithms implemented in the photovoltaic (PV) generation system useable under partial shading condition. Various algorithms, PV modeling techniques, PV

array configurations and controller topologies have been widely explored till date.

R. Benkercha S. Moulahoum I. Colak [10] in 2017 discussed that the Grid Connected Photovoltaic System (GCPV) has become more used system in renewable energy. Several researches have been carried out to improve the efficiency and the decrease of energy losses. One of the important components used to increase the efficiency is the DC/DC boost converter.

3. 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.

i. Photovoltaic Cell

Photoelectric cell is the semiconductor system that changes light to electrical power by photovoltaic. If energy (power) of photon of brightness is superior than 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. 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 have 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. The working temperature is increased because a great part of solar radiation is not changed to electricity but is absorbed by panel as heat.

IEquivalent circuit and Mathematical Model

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

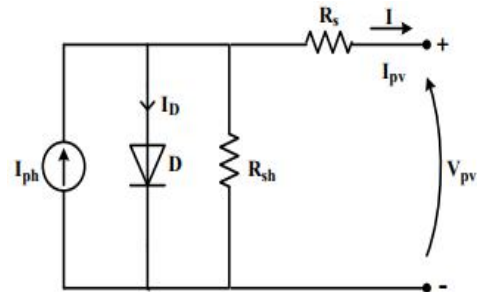


Fig. 1: The equivalent circuit of a PV array.

Where, R_s is the array series resistance in Ohm,

R_p is the array parallel resistance in Ohm,

I and V are the output current and voltage of the array in Ampere and Volt.

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

Where, I_{ph} is photo current in Amp,

I_{rs} is saturation current in Amp,

N_s and N_p 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,

I_{scr} is Short circuit current at reference Temperature in Amp,

I_{rr} is reverse saturation current in Amp,

T_r is reference temperature in Kelvin,

S is solar irradiance in mW/Sq. cm,

K_i is S.C. current Temp. coefficient in (Amp/Kelvin),

K is Boltzmann's constant,

E_g 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_{g0} = band gap at 0k and,

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

4. An Overview for Maximum Power Point Tracking

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 understand first. Different configuration of PV systems are 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 I_{mpp} and V_{mpp} . The product this two will eventually

give value of maximum power.

4.1 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, $P = V I$

The above relation is differentiated on both sides, which gives

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

AtMPP, 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.

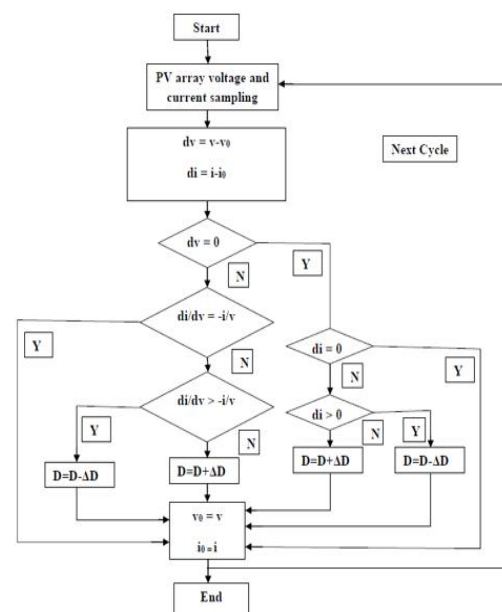


Fig. 2 Incremental conductance MPPT algorithm flow chart

4.2 Genetic Algorithm

Genetic Algorithm was envisaged by John Holland [67] at the university of Michigan, in the 1970s. It is based on the Darwinian evolution theory of survival of the fittest which states that the fitter and stronger individuals in a population have a higher chance of creating offspring for the next generation by random mutation and natural selection. It can be implemented as an optimization search procedure which uses the principles of genetics and natural selection by modelling possible solutions to a search problem as strings of zeroes and ones. Each point in a parameter or solution space can be encoded by Genetic algorithm (GA) in a binary bit string, which is called the chromosome. For example, if a particular point (8, 5, 7) in a three-dimensional space, is to be transformed, it can be represented by a concatenated binary string of 1000, 0101, 0111. Here each coordinate is encoded by a gene which is represented by four binary bits. Encoding plays a key role in determining the GA's performance as it helps to translate problem specific knowledge directly to the GA framework. After the creation of a generation comprising of these points, each of these points is also assigned a fitness value which is given by the evaluated value of the objective function at that point. Generally positive values of the objective function are preferred.

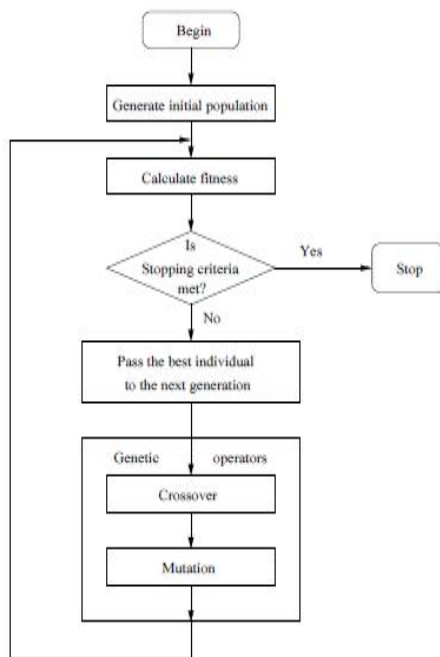


Figure 3: GA algorithm flowchart

5. 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 Genetic Algorithm (GA) 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 need 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.

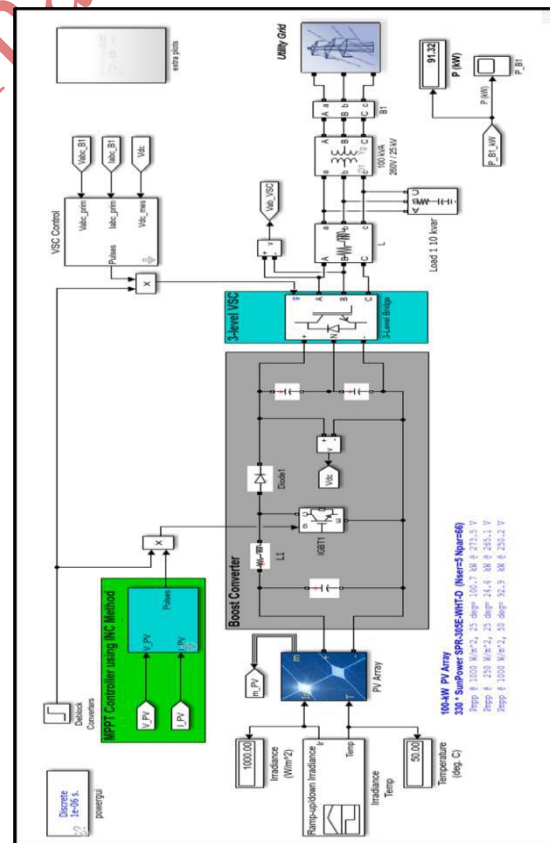


Figure 4: Simulation model of system with INC MPPT method

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 V_{pv} (V)	251.71
2.	Panel Current I_{pv} (A)	268.07
3.	Irradiation (W/m ²)	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

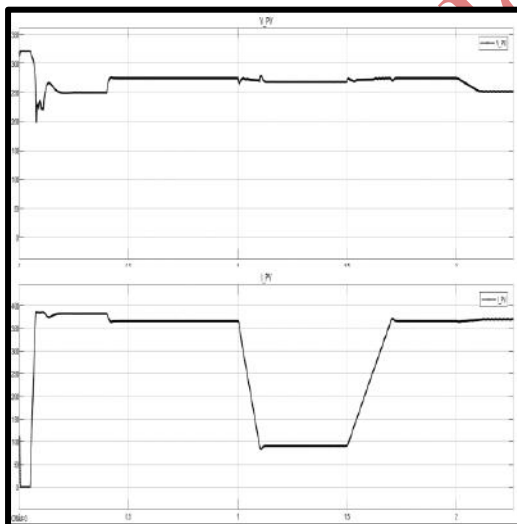


Figure 5: PV array voltage and current with INC Method

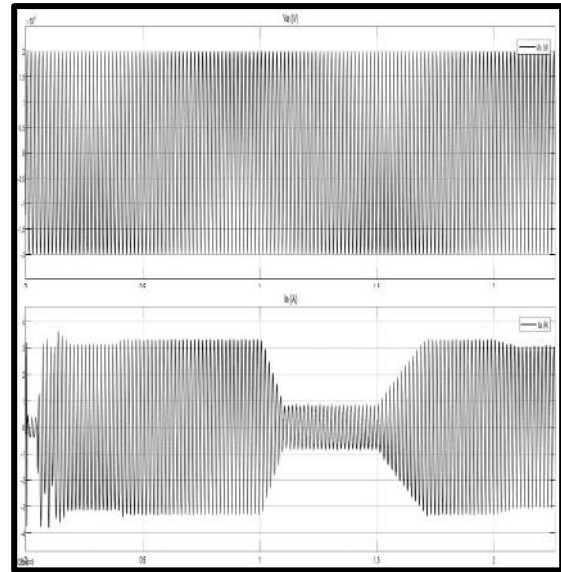


Figure 6: Utility grid voltage and current for INC MPPT method

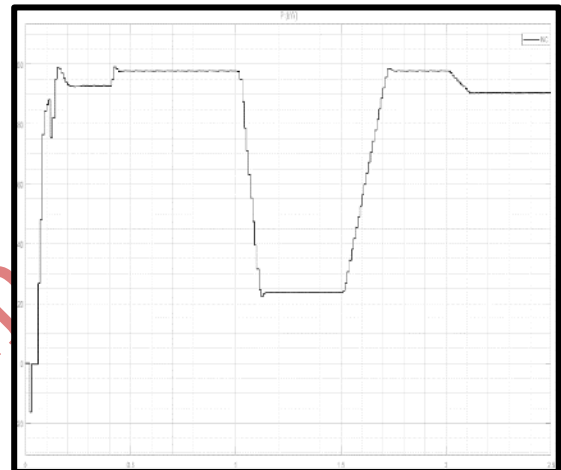


Figure 7: PV array maximum power with INC Method

Simulation Modeling and Result Analysis of GA-MPPT Method

In this section, simulation model of PV system designed for GA 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 need 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 GA MPPT techniques, effect on various parameters like output power, voltage and current were monitored.

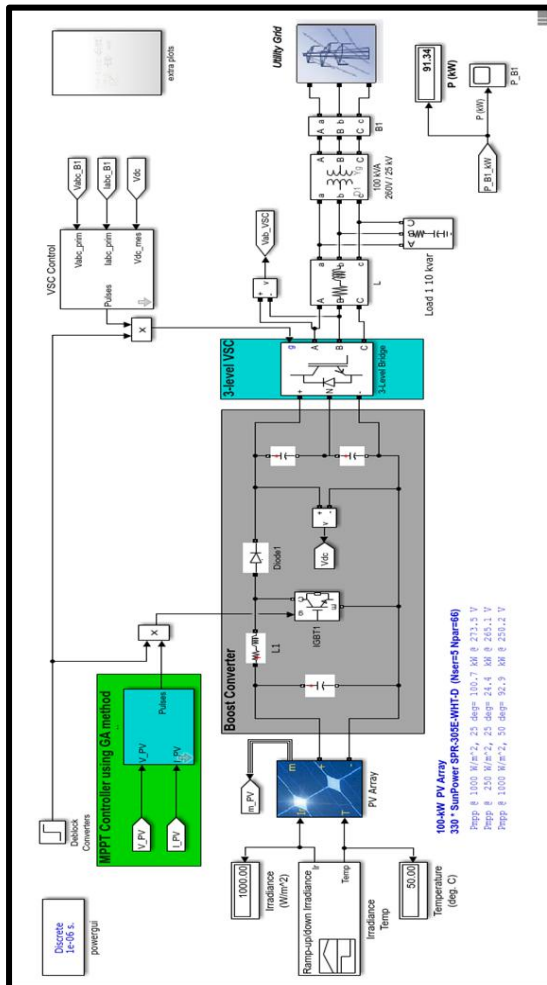


Figure 8: Simulation model of system with GA MPPT method

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 GA MPPT Method

S. No.	Parameters	GA Method
1.	Panel Voltage V_{pv} (V)	251.81
2.	Panel Current I_{pv} (A)	268.91
3.	Irradiation (W/m ²)	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

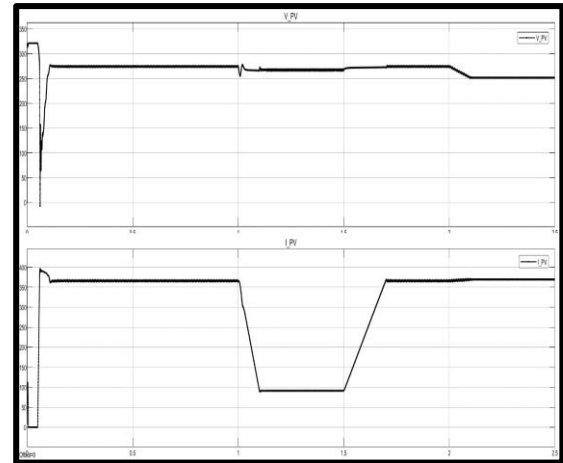


Figure 9: PV array voltage and current with GA Method

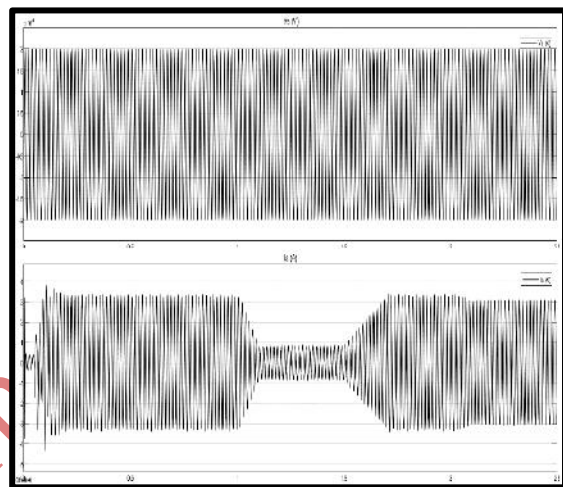


Figure 10: Utility grid voltage and current for GA MPPT method

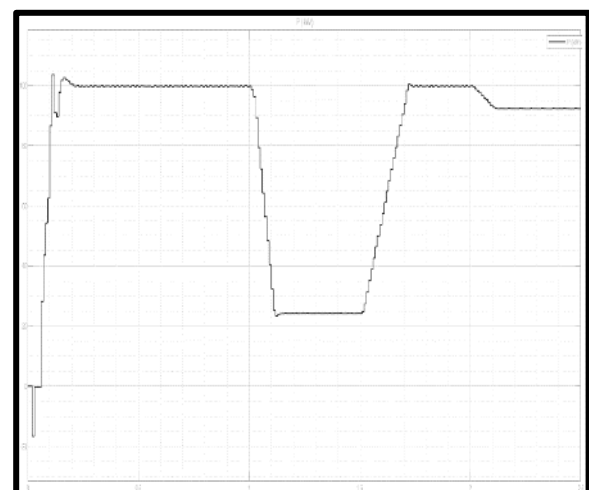


Figure 11: PV array maximum power with GA Method

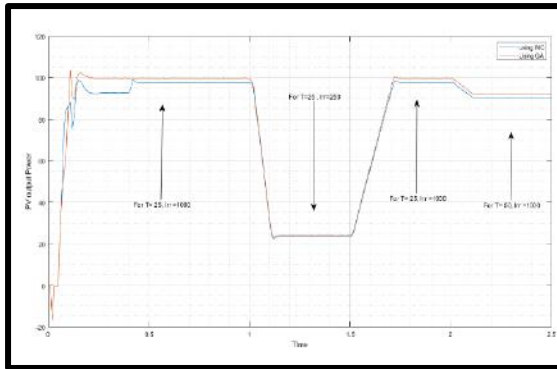


Figure 12: Comparison of PV array maximum power with GA Method

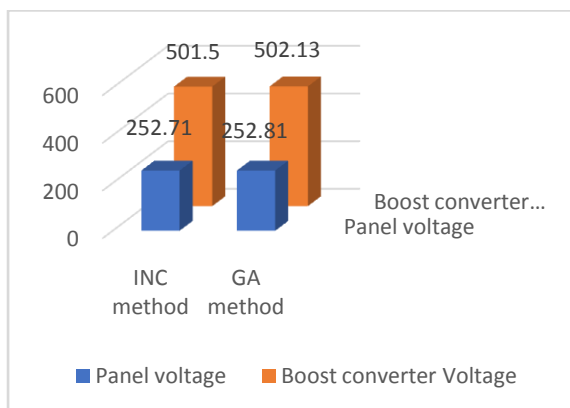


Figure 13: Comparison of PV voltage and converter output voltage with INC and GA Method

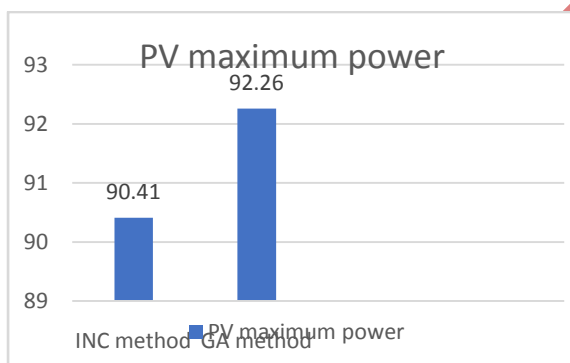


Figure 14: Comparison of PV max power and converter output power with INC and GA Method
In this section, results were evaluated from both INC and GA methods for both cases under consideration and values and plot were displayed through various figures and tables. Values were calculated at both panel end and Boost converter end.

6. 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 GA and INC.

When PV irradiation and temperature are kept varying, 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 are found to be 92.26 KW and 90.41 KW respectively. The result clearly shows that GA 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 GA 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 GA and 90.41 KW for INC respective only comparison results, GA has clear upper hand over P&O method in terms of performance.

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