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Research Article

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Performance Enhancement of Grid Connected PV System by Using Incremental Conductance MPPT Technique

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Abstract The power output of Photovoltaic arrays is constantly changes with weather conditions such as: solar irradiation and temperature. This paper shows a modified control strategy to enhance performance of grid connected PV system is depend on Incremental Conductance (IC) method. The maximum power point tracking (MPPT) is based on IC algorithm and IC is one of paramount techniques to achieve the MPPT in PV systems. The main objective of the control is to maintain the MPPT operation under different solar irradiations. Comprehensive models of PV system, power electronic converter, 3-phase inverter and IC algorithm are executed in MATLAB / SIMULINK environment.

Keywords PV systems; MPPT technique; IC algorithm

1. Introduction

Due to the diminishing of the traditionally at energy sources and the increasing problem of environmental pollution, the utilization and research about the renewable energy, for example: PV system, wind energy have been concerned with more attention [1-2]. PV system is essential renewable energy sources. On the contrary to conservative sources as Fossil fuels; the solar energy is free and clean source. PV generation system has two main problems; first, the conversion at efficiency of electric power generation was very low-slung particularly at conditions when irradiation is low and the quantity of an electric energy generated by PV array variations incessantly with climate environments. Second, the "PV array" V-I curve was nonlinear and differs with temperature, and radiation. In overall, there is a Fred point on the V-I or P-V curve known as (MPPT), at which the full PV system operates with maximum efficiency and achieve MPP.

PV generation system was connected with grid, addition, it provides active electric energy, and further can make available reactive electrical power. Traditional PV system generated using high frequency or power frequency transformer to become the high voltage is based on the converter. Conversely, transformer usually takes up huge area. Because it can rise voltage of output PV cells also it can improve energy availability through ideal control [3].

MPPT is an electronic system that connected between PV power source and grid to extract MPP from PV array and investigation the highest efficiency. The numerous of MPPT techniques were developed for increasing efficiency from PV systems and satisfy of the optimal MPPT. These techniques differ in different sides such tracking speed oscillations around MPPT cost and hardware required for execution. Most famous MPPT controller available are such as fractional short circuit current fractional open circuit voltage [4-6], perturb and observe [6-10], incremental conductance (IC) algorithm [11-16], incremental resistance [17-18], ripple correlation control [20-21], fuzzy logic [22-23], artificial neural networks [23-24], particle swarm optimization [26-28] and sliding mode control [29-30]. This paper introduces modified control strategy to performance enhancement from PV grid connected system is depend on "IC" algorithm for MPPT technique. The models at different system components with their control arrangements are simulated using MATLAB/SIMULINK® environment.

System Description

Figure1 shows the circuit diagram of PV grid connected system. The system under study consist of two main schemes the first scheme is powered diagram and contains: PV array supply, DC link capacitor, boost converter, three phase inverter and 3-phase grid connected system. The second scheme is the control scheme MPPT by using IC algorithm and the inverter controller using PI controllers with 3- phase PV grid connected system.

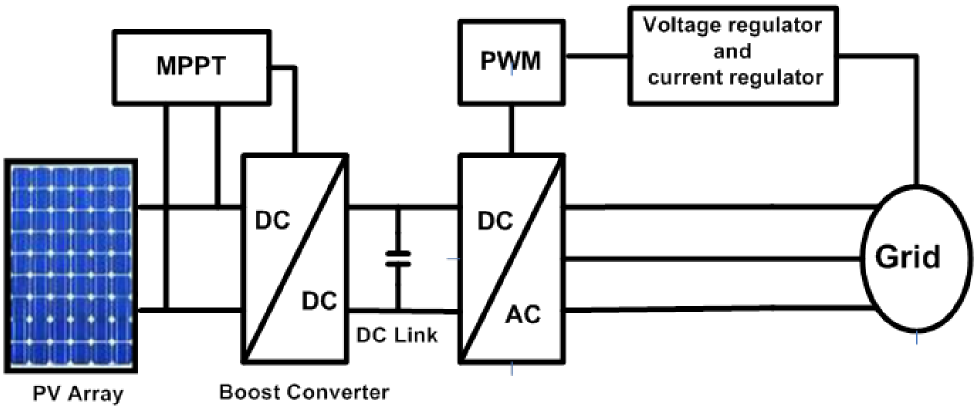

Figure 1: Grid connected of PV system

A. PV Modeling

A PV array was built up by combined series/parallel combinations of PV module; Fig. 2 shows the PV cell equivalent circuit [17];

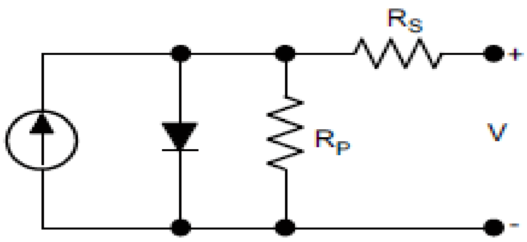

Figure 2: PV cell equivalent circuit

The main equation that depicts the V- I curves of PV cell is known by the next equation; the output current of PV cell is known by[17].

$$I = I_{PV} - I_O \left(e^{\frac{q(V+IR_S)}{nkT}} - 1 \right) - \frac{V + IR_S}{R_P} \quad (1)$$

Where:

I is the output current of the PV module in A, I_O is the Diode saturation current, I_{PV} is the photo-generated current in A, R_S is the series resistance in Ω, R_P is the parallel resistance in Ω, n is the Ideality factor [from 1: 2], k is the Boltzmann constant [1.38x10-23J/K], q is the Electron charge [1.6x10-19 C] and T is the Temperature [ºK].

This equation demonstrates the of PV current on temperature and thus reliance of energy drawn by PV array. The model under study is rated 100-kW PV array based on 330 Sun power modules [SPR-305]. The array contain of 66 strings of 5 series-connected modules that is parallel- connected [5*66*305 W= 100 kW].

B. DC-DC Converter

The boost converter electrical circuit is illustrates in Fig. 3. It is named boost because output voltage is larger than the input. The boost converter contains of boost inductor; and (IGBT) switch [17].

In the detailed model, boost converter rise voltage from 280V to 500V. The boost converter uses MPPT technique that automatically differs the duty cycle to produce desired voltage to produce maximum energy from PV array.

From the output waveform it's clear that the measured or output voltage from boost converter constantly hang near its reference value. For this operation the modulation index of the boost converter control maintain changing so that voltage output which can track desired voltage under variable solar radiation.

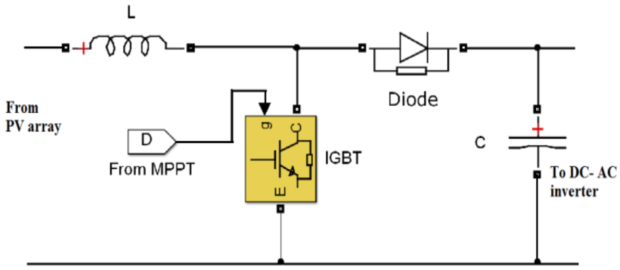

Figure 3: Boost converter circuit diagram

C. Voltage and Current Control Using Dynamic Error Driven PI Controllers

The dynamic error driven PI control scheme is described in Fig. 4. The error signal between the RMS actual voltages (Vrms) of 3-phase inverter with the reference voltage (Vref) in pu is the control triggering signal. The saturated output of the PI controller is then used as the modulation index for the pulse width modulation PWM generator to obtain the output switching control signals. The PI controller is used to compensate the dynamic error signals. When the desired operating condition is reached, the dynamic total error signal will become close to zero. A pulse width modulation technique was implemented for the inverter supplied by the PV array.

The general transfer function of a PI controller can be represented in (2) [19].

$$G_c(s) = K_p + K_i.\frac{1}{s} = K_p\left[1 + \frac{1}{T_i.s}\right] \quad (2)$$

$$G_c(s) = \frac{Kp\,(T_i.s+1)}{T_i.s} \quad (3)$$

Where, *Kp*: Proportional gain, *Ki*: Integral gain and *Ti*: Integral time constant.

The PI controller can compensate the dynamic input error signals and obtain the output switching control signals at each sampling interval. When the desired operating point is reached, the error signal will become close to zero and the output switching control signals will remain unchanged [19].

The main control objective here is keeping the system running a very close point to the maximum photovoltaic power tracking curves.

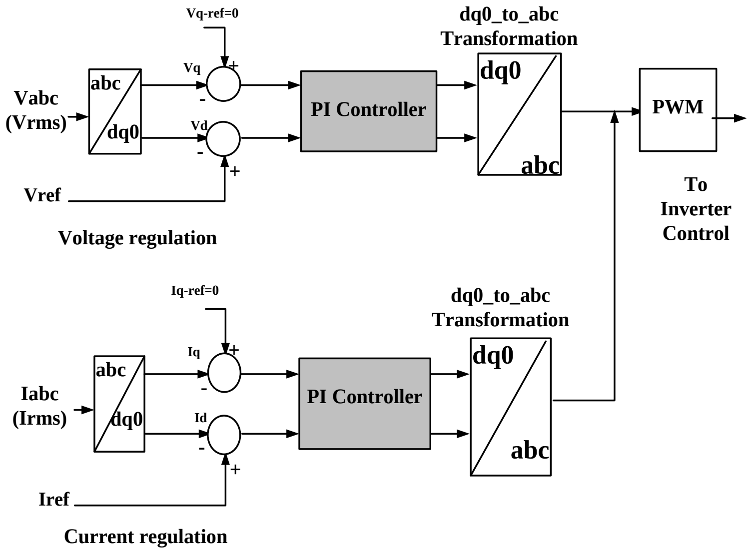

Figure 4: The dynamic error-driven PI Controller

3. Incremental Conductance MPPT

The IC algorithm it has numerous significant merits such as, simple, cost effective and easy to implement.

The hill of the P -V curve is equal zero on the MPPT, growing on the left of the MPPT and reducing on the rightward adjacent of the MPPT Fig.5 shows that. The equations of this method are as follows [11]:

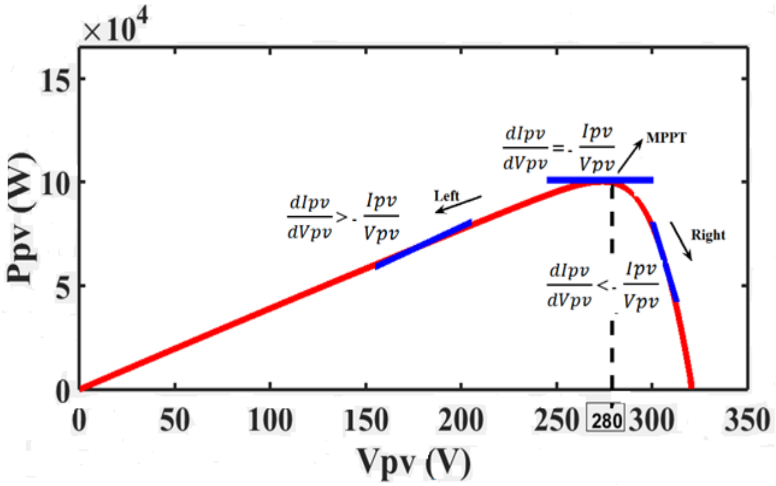

Figure 5: IC algorithm power - voltage curve

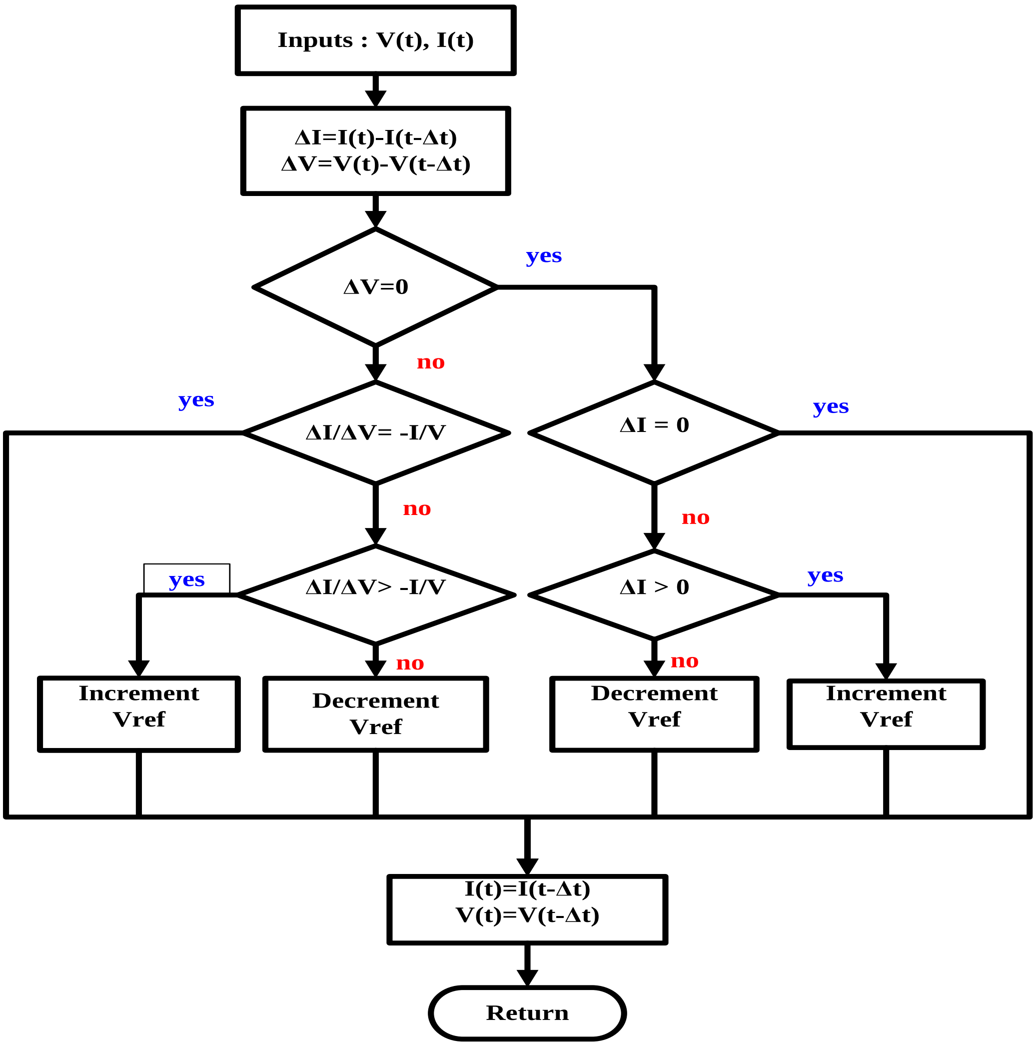

Figure 6: Incremental Conductance MPPT Flow chart

$$\frac{dI_{PV}}{dV_{PV}} = -\frac{I_{PV}}{V_{PV}} \quad \text{At MPPT} \tag{4}$$

$$\frac{dI_{PV}}{dV_{PV}} > -\frac{I_{PV}}{V_{PV}} \quad \text{Left of MPPT} \tag{5}$$

$$\frac{dI_{PV}}{dV_{PV}} < -\frac{I_{PV}}{V_{PV}} \quad \text{Right of MPPT} \tag{6}$$

The IC MPPT flow chart is illustrated in Fig 6. The right hand adjacent represents the instantaneous conductance and left hand adjacent of equations represents IC of P-V module. The ratio of variation in output conductance is the same the negative output conductance, the PV array will run at the MPP [12]. Where, V is PV voltage, I is PV current.

4. Results and Discussion

Figures 7 and 8 illustrate the tracks variations of the operative point of PV system at I-V and P-V curves under increasing solar radiation with controller.

At 1000 w/m^2 solar radiation, PV voltage with controller is 280 V, PV array current with controller is 380 A, and PV array power approximately is 100 kW. At 800 W/m^2 solar radiations, PV voltage with controller is 280 V, The PV current with controller is 300 A and The PV power with controller is 80 KW. At 600 w/m^2 solar radiation, PV voltage with controller is 280 V, The PV current with controller is 220 A and The PV power with controller is 60 KW, The select of suitable operating point with controller is MPPT.

The simulation is originated on a system described by the information indicated in the Appendix.

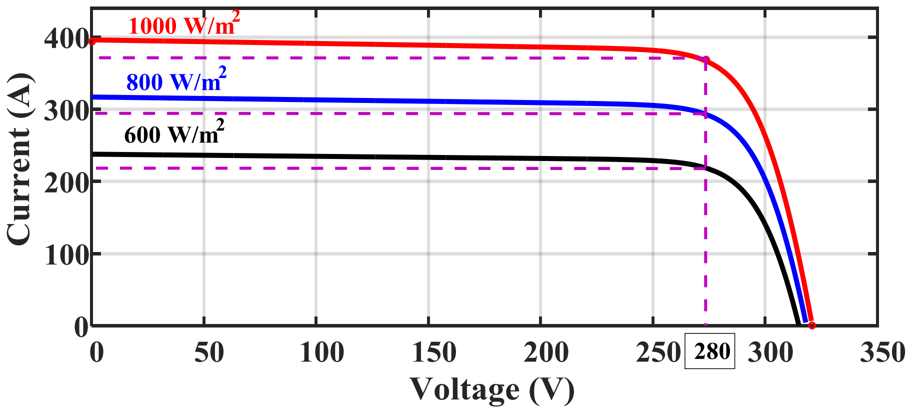

Figure 7: I-V curves for different values of solar radiation at temperature of 25°C

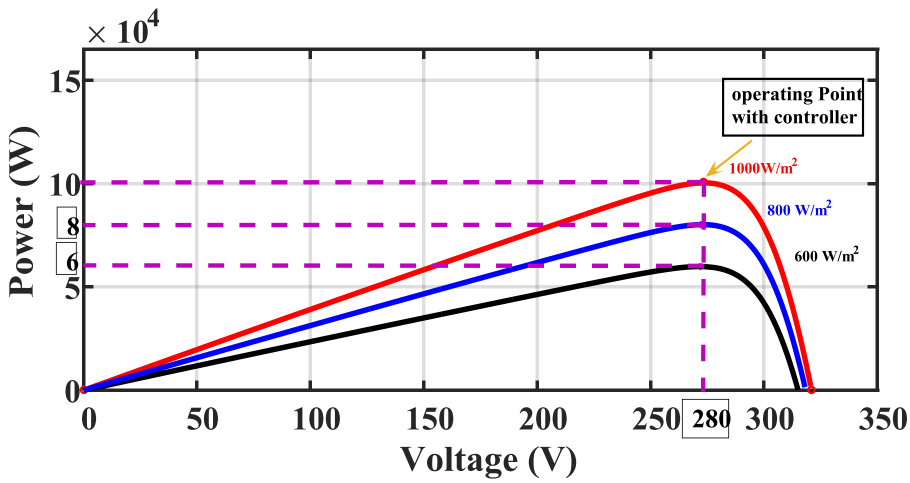

Figure 8: P-V curves for different of solar radiation at the same temperature

Figure 9 illustrates the grid connected PV system under different solar irradiation. As seen in Fig. 10 that PV generation power, current, and voltage with and without controller.

At 1000 w/m^2 solar radiation, PV power with controller is 280 kW and without controller is approximately is 75 kW. At 800 W/m^2 solar radiations, The PV power with controller is 80 KW and without controller is 75 KW. At 600 w/m^2 solar radiation, The PV power with controller is 60 KW and without controller is 55 KW. From results we see with presence of the controller that PV array is maintained to the best track of the maximum power. The PV voltage with controller is constant with variation from solar radiation and good agreement between the PV power and PV current with solar radiation profile. As consequence the MPPT with controller is achieved.

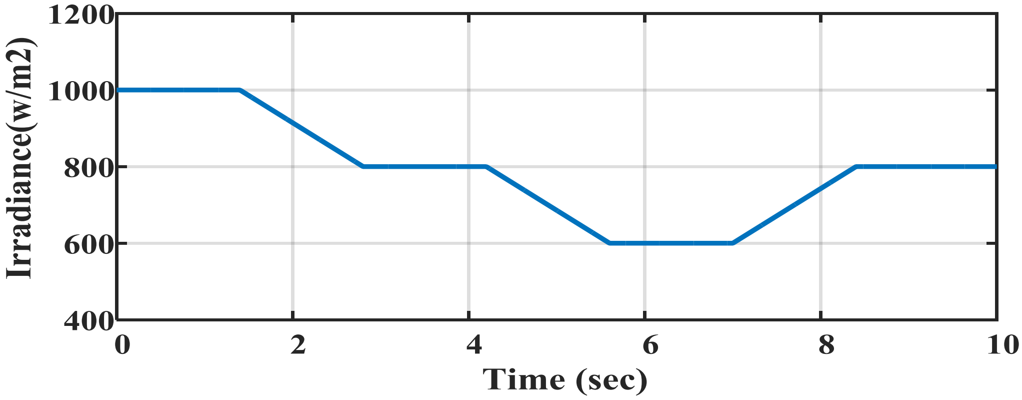

Figure 9: Variation of solar radiation

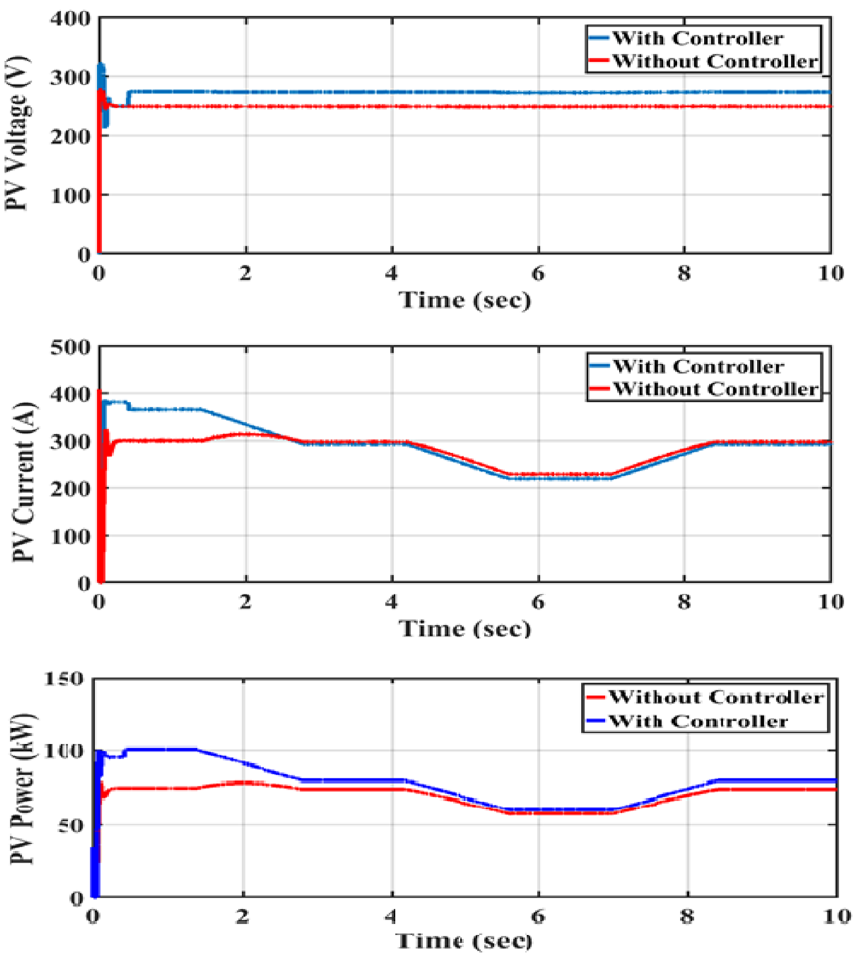

Figure 10: Voltage, current and output power of PV system

Also, Fig. 11 shows the results of the AC output current and voltage waveform with grid connection with controller, the grid voltage is approximate 20 kv. Fig. 12 illustrates AC output power waveform with grid connection with and without controller. From the results the grid connection performs better with presence of the controller. The simulation waveform of a tracking process shows the impacts of the environmental conditions on the PV module performance during ramp changes of irradiance. The systems with IC method can detect ramp change of irradiance. The main parameters of PV solar array are recorded in appendix.

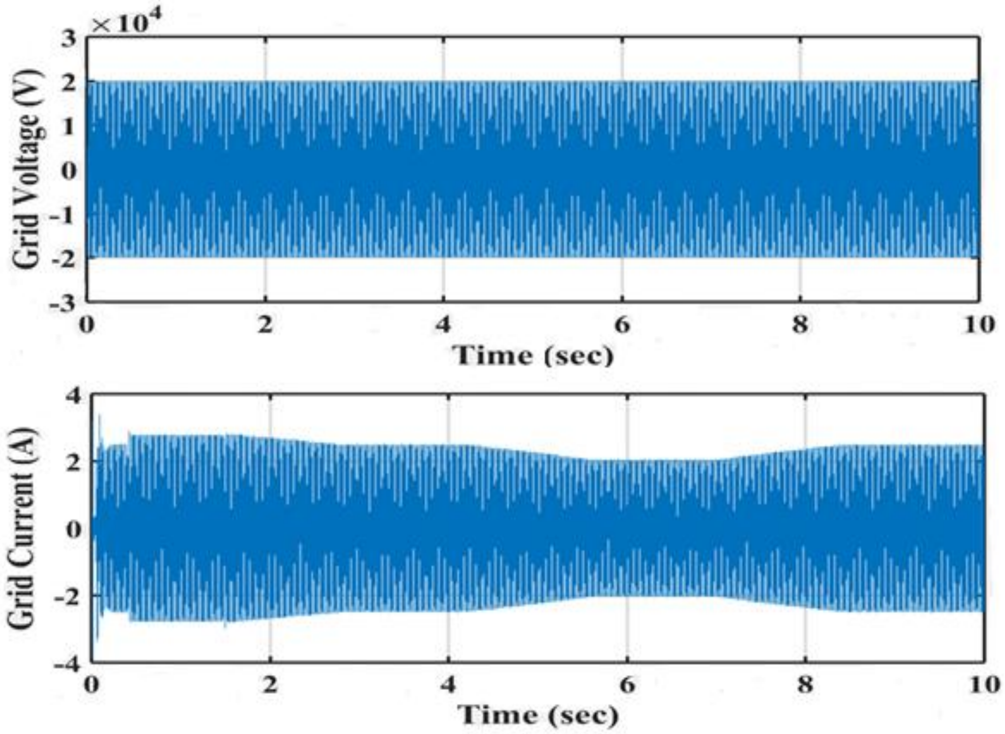

Figure 11: AC output voltage and current waveform with grid connection

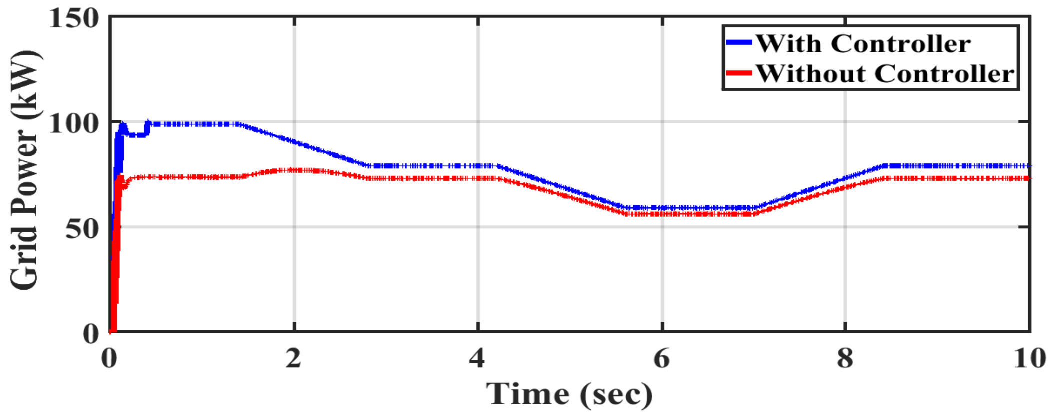

Figure 12: AC power waveform with grid connection

5. Conclusion

This paper presented the comprehensive modeling of PV system with incremental conductance (IC) MPPT method on grid connected photovoltaic system in implanted MATLAB/SIMULINK environment. Results of simulation illustrate the feasibility and robustness of the control system of the proposed technique is based IC. From the simulation results, the affect IC MPPT method at variable solar irradiation. Thecapture the maximum power and controls directly the extracted power from the PV and achieve different advantages which are, fast response, good tracking efficiency , good control for the extracted power and good capability is create to be satisfactory under different operation conditions. By compared between with and without IC MPPT technique, the IC technique gives more stable operation and higher power at different operation conditions.

Appendix: The specification of PV module

Description	Rating
Maximum Power (P_{MPP})	305 W
Voltage at maximum Power (V_{MPP})	54.6 V
Current at maximum Power (I_{MPP})	5.56 A
Open circuit voltage(Vo.c)	64.2 V
Short circuit current ($I_{s.c}$)	5.96 A
Total number of cell in series (N_s)	5
Total number of cell in series (N_p)	66

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