Grid Connected Photovoltaic Power System Regulated By using DC-DC Boost Converter with IC and IR Technique

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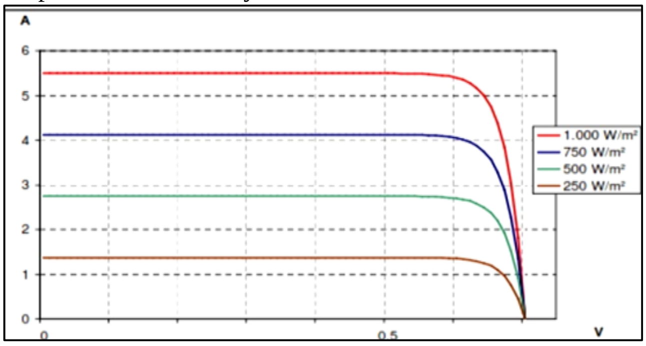
Abstract— This paper put forward to set up a grid connected photovoltaic (PV) power plant of 100 KW. The maximum power point tracking (MPPT) of the PV power plant is restrained by using a proposed fusion between the incremental conductance (IC) and integral regulator (IR) control. This fusion is applied to the PV power plant with the help of dc-dc boost converter. The proposed fusion collects advantages of MPPT methods. The contemplated grid connected system contains both AC and DC networks similar to distribution generation (DG) with the use of multi-bidirectional converters. AC sources and AC loads are also coherent to AC network whereas DC sources and DC loads are associates with the DC network. DC and AC links are associated by systems with energy storage. This grid connected PV system can regulate in a grid-tied or isolated mode. For continuous power exchange between DC and AC links at the time of multifarious supply and demand conditions. The Grid connected PV plant is simulated using MATLAB and SIMULINK.

Key words: PV Array, Conductance and Regulator, Maximum Power Point Tracking, DC-DC Boost Converter

I. Introduction

A lot of research works have been demonstrated in recent years for using the energy of solar as an alternative resource. PV solar energy is composed from the ultra violet light (rays) of the sun, which is revolving directly into electrical energy by using chemical reaction. PV solar energy is the most assuring renewable energy resources, where it is inexhaustible, silent operation, clean and free to harvest [1]. The main detriment of PV is the low efficiency of energy adaption in comparison to other alternative resources. PV solar system is a nonlinear source of energy, where its operation based upon on solar irradiation level and ambient temperature of PV array [8].



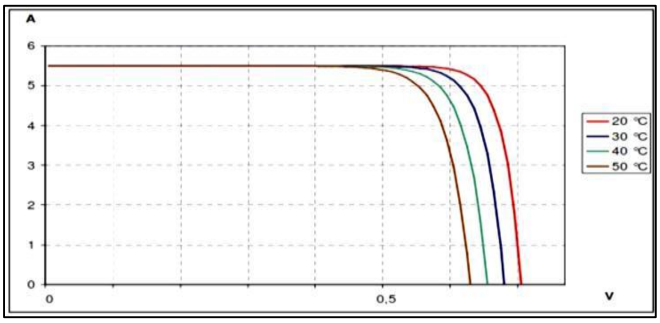


Fig. 1: Nonlinearity characteristics of PV solar cell due to effect of solar irradiation and temperature [8]

MPPT comes in motion of extract the maximum power generated from PV panels. Using incremental conductance (IC) method for attaining maximum power point of PV is a faddy method because the algorithm of this method is simple and also easy to implement. However, IC method has a difficulty with the presence of electrical noise that is produced from the nonlinearity of PV panels. This nonlinearity of PV panels is because of the fluctuation in solar irradiation level and ambient temperature. These alterations affect PV panels in term of diminishing the electrical power generated and its efficiency [2]. Fig.1 shows the behaviour of PV solar cell against different solar irradiation levels and temperature degrees.

A new commandment in the development of the MPPT of PV Array is to different types of algorithm or techniques such as perturb and observation (P&O), incremental conductance (IC). The main benefits of using these techniques are the increment in stability margin and efficiency of the system. IC technique is the most faddish because of its high performance, maximum efficiency and accuracy. Most of the works in this field trade with the mal-operation of PV array especially at high temperature degree and low solar irradiation level [3]. Therefore, this paper contemplated a fusion between IC control method and dc-dc boost converter used as a result for controlling MPPT of PV panels. The contemplated fusion between IC and boost converter will serviceable on 100 KW grid connected PV power plant. This fusion can improve efficiency, stability and time response of the plant especially, with presence of continuous variation of solar irradiation level and temperature degree. This paper is methodically as follows: Section II introduces the modelling of PV Array, and is followed by a deliberation on MPPT algorithms and dc-dc boost converter. Section III presents the IC control, the boost converter control and the mixture of the two controls for MPPT of PV system. Simulation results are carried and discussed in Section IV. Finally Section V concludes the results.

II. PV PLANT SYSTEM MODELING

A. *PV Mathematical Model*

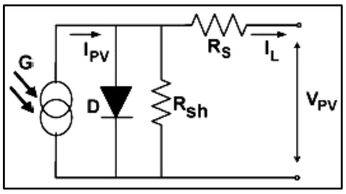


Fig. 2: Equivalent Circuit diagram of the PV model [9]

PV Solar cell is fabricated with P-N junction that is made from the semiconductor materials or other Industrial alloys. The solar irradiation level or Electromagnetic energy of the sun can be transform to electricity by using the PV solar cell. PV module contains the hatches of PV solar cells that are connected in series and parallel to produce the required current and the desired voltage. PV solar cell is characterized as a current source which is connected with other components of electrical. The equivalent circuit model for PV solar cell is shown in Fig.2.

To model PV solar cell, there are multifarious methods. The popular and powerful simulation tribune to perform PV modelling work is done by using MATLAB - SIMULINK [6]. The different parameters of PV module can be resolved by examining the manufacturer datasheet. The mathematical equations of PV module are represented as the following [7]:

The equation for photo-current (I_{ph}) of the PV module is:

$$I_{ph} = \frac{[I_{sh} + K_i(T - 298)]xG}{1000} \quad (1)$$

Where; K_i is the solar cell's short current temperature coefficient (A/ºC), G is the solar irradiance level (W/m2) and I_{sh} is the solar cells short-circuit current (A) at standard test conditions (STC).

The equation for reverse saturation current (I_{rs}) of PV module is:

$$I_{rs} = \frac{I_{sh}}{\left[\exp\left(\frac{qV_{oc}}{N_s kAT}\right) - 1\right]} \quad (2)$$

Where; V_{oc} is the open circuit voltage (V), k is the Boltzman's constant (1.38x10-23 J/K), N_s is the number of series solar cells in each PV module, T is temperature in (K), q is electron charge (1.6x10-19 C) and A is ideal factor.

The equation for saturation current (I_o) of PV module is:

$$I_0 = I_{rs}\left[\frac{T}{T_r}\right]^3 \exp\left[\left(\frac{qE_g}{Ak}\right)\left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \quad (3)$$

Where; E_g is the band gap of silicon material (1.1ev) and T_r is the reference temperature (25 ºC).

The equation for output current (I_{pv}) of this PV module is:

$$I_{pv} = N_p I_{ph} - N_p I_0\left[\exp\left\{\frac{(q(V_{pv} + I_{pv}R_s))}{N_s AkT}\right\} - 1\right]$$

Where; V_{pv} is the output voltage of PV module (V), N_p is the number of parallel solar cells in each PV module, I_{pv} is the output current of PV module (A), R_{sh} is the shunt resistance of solar cells and R_s is the series resistance of solar cells. Because of ($R_{sh} >> R_s$), so branch of R_{sh} will be neglected.

B. *DC-DC Boost Converter Model*

DC-DC boost converter is used to constrain the dc output voltage of PV panels by increasing its magnitude. The regulation of output voltage is normally attained with the help of PWM and the switching device used is normally MOSFET or IGBT. The complete configuration of the dc-dc boost converter which is connected with PV panel is shown in Fig.3. MPPT is attain when the controller algorithm varies and adapts the duty cycle value (D) of PWM unit that is used to produced pulses for the switching device (IGBT) connected in dc-dc boost converters circuit to control dc voltage of PV panels [14].

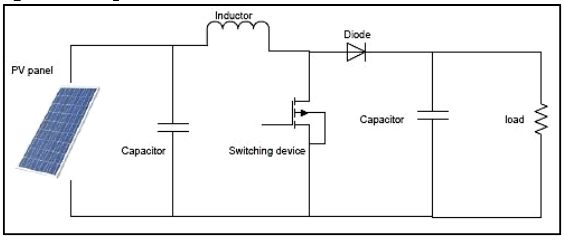


Fig. 3: PV panel connected with dc-dc boost converter [14].

III. TYPES OF MPPT CONTROL METHOD

A. *Incremental Conductance and Integral Regulator Control Method*

The prevailing method for regulating MPPT of PV system is known as the incremental conductance (IC) and integral regulator (IR). The IC and IR control algorithm is the perturbation on the appetite maximum power point that is produced by PV as shown by the help of following equations [10]:

$$\frac{dP}{dv} = 0 \qquad \text{At MPP}$$
$$\frac{dP}{dV} > 0 \qquad \text{Left of MPP}$$
$$\frac{dP}{dV} < 0 \qquad \text{Right of MPP}$$

The incommodity of using this method is the continual perturbation even after reaching at the maximum point.

IC and IR technique generates the desired direct duty cycle values (D) to generate the desired output. The benefit of generating duty cycle (D) is emending steady state error and overshoot of the output. However, it is quiet difficult to get the required value of duty cycle (D) [11]. When the voltage and the power of PV panel are increasing, the perturbation will be improved or increase by a step size that is ΔD to be add up with the duty cycle value D to produce next cycle of perturbation and also to force the operating point shift towards maximum power point (MPP). The inputs of IC and IR technique are the voltage of PV panels and generated current where the output of IC and IR is the generated D. The generated value of duty cycle (D) is habituated as an input for PWM unit. This PWM unit is habituated to produce accurate pulses desired for switching device that is IGBT or MOSFET of dc-dc boost converter. Ultimately, the dc-dc boost converter can regulate MPPT of PV panels or PV Array [11]. There are some research composition for upgrading IC and IR technique connate as the peak current control. These composition aims to accumulate the system response, to conquer the amplitude of power oscillations existent the maximum power point and to generate lower power losses [12].

B. Perturb and Observe method

Perturb and Observe is the simple algorithm of MPPT which is connate to modify the operating current or voltage of the photovoltaic (PV) system up to the maximum power point is attained. For example, if the voltage is accumulating on a panel then the output power of a PV panel is also accumulating, then the PV system accumulate the operating voltage until the power at output starts to reduce. When this level comes, the voltage is continually decreasing till the maximum power at output comes and this procedure is continued till the maximum power point (MPP) is come. Thus, the value of power at output is approximately oscillates near a maximum power point (MPP) until it equalizes. Perturb and observe (P&O) is the widely used MPPT method due to its effective and simple enforcement. The major drawback of the perturb and observe (P&O) method is that in the steady state the functional power oscillates about the maximum power point. Also, the (P&O) algorithm can track a faulty path, when there is continual variation in irradiance levels.

IV. SIMULATION RESULTS AND DISCUSSIONS

A. Simulation of 100 KW PV Array

In this work, the selected PV module is called SunTech Power (PLUTO 305W). The type of PV module is monocrystalline. Table II shows the detailed parameters of (PLUTO 305 W) PV module at Standard Testing Condition (STC). These parameters are used to build a PV array by using MATLAB-Simulink as shown in Fig.6. The most significance parameters are short-circuiting current and open-circuit voltage. The photo current in PV array is the short circuit current (I_{sc}) value of PV panels and the open circuit voltage (V_{oc}) is determined by supposing the output current is zero. PV panels are assorted to be with good quality and large efficiency if its fill factor is approx equal one [8].

Parameter	Value
Maximum Power (P_{MPP})	305.14 W
Maximum Output Voltage (V_{MPP})	38 V
Maximum Output Current (I_{MPP})	8.03 A
Short Circuit Current (I_{sc})	8.57 A
Open Circuit Voltage (V_{oc})	45.3 V
Temperature Coefficient of (V_{oc})	- 0.283 %/ºC
Temperature Coefficient of (I_{sc})	0.0706 %/ºC
Temperature Coefficient of (P_m)	- 0.356 %/ºC
Normal Operation Cell Temperature(NOTC)	50 ºC

Table 2: Detailed parameters of PLUTO (305 W) module at STC

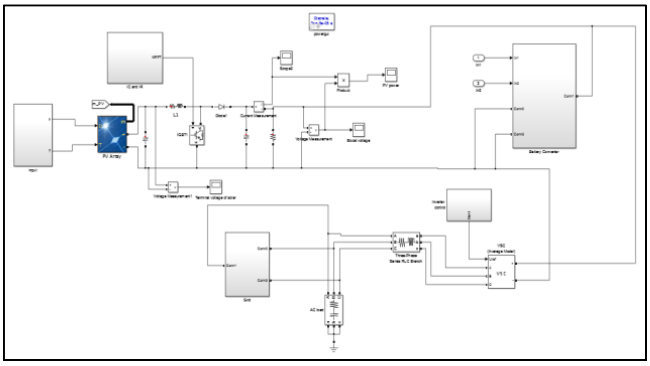


Fig. 6: Grid Connected PV Plant in MATLAB-SIMULINK.

Fig.7 shows the (P –V) and (I –V) characteristics of the simulated PV Array (PLUTO 305 W; 7 series modules; 68 parallel strings). As the solar irradiance value accelerates, the maximum output power is accelerated because of accelerating the output current produced by this PV array.

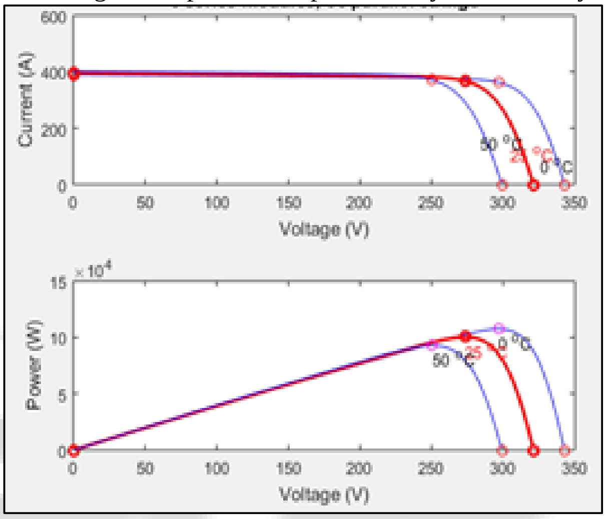


Fig. 7: (I –V) & (P –V) curves of PV Array

B. Simulation of 100 KW Grid Connected PV Plant

The simulated PV array with 100 KW is associated with the dc-dc boost converter. The boost converter is used to monitor the output dc power produced by this PV array. The regulated dc power is the output of boost converter and is given into special type of inverters named as "on grid inverter" to transform it from dc power (output of boost converter) to ac power. The output of inverter is then ac voltage and is stepped up with the help of the power transformer to provide the desired voltage level to the grid. Fig.8 shows a illustrative diagram, which encapsulates the parts of grid connected PV power plant. The maximum power point tracking (MPPT) of this PV plant is regulates by using different types of control schemes. The first one uses IC and IR control method, the second uses P&O method and the third uses the Dc to DC boost converter [16].

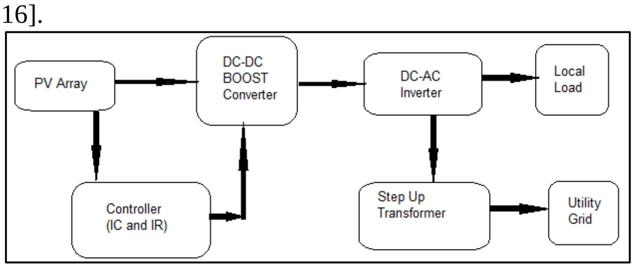


Fig. 8: Schematic diagram for grid connected PV plant.

As shown in Fig. 9, 10, and 11 the reactions of the output ac power of grid side, dc power of boost converter and dc voltage of boost converter respectively, reveals that IC and IR method has better response than using each of them separately.

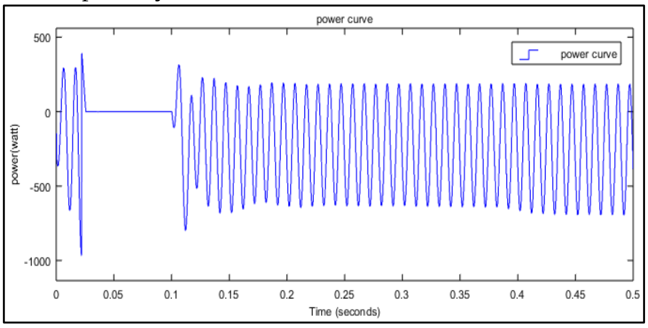


Fig. 9: Output ac power of PV Plant (Grid Voltage)

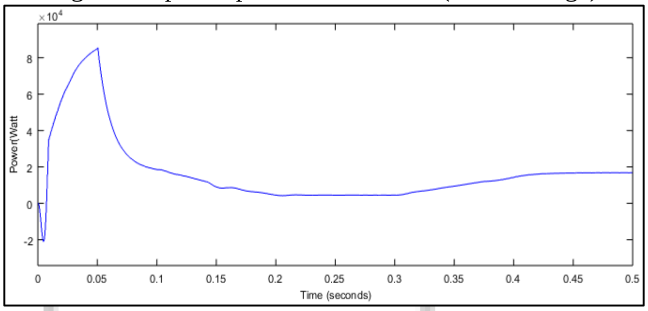


Fig. 10: Output dc power of PV plant

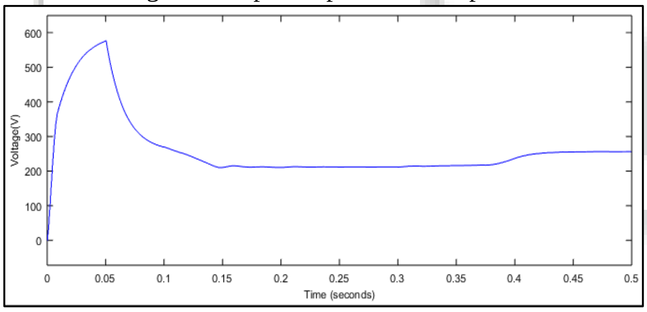


Fig. 11: Output dc voltage of PV plant

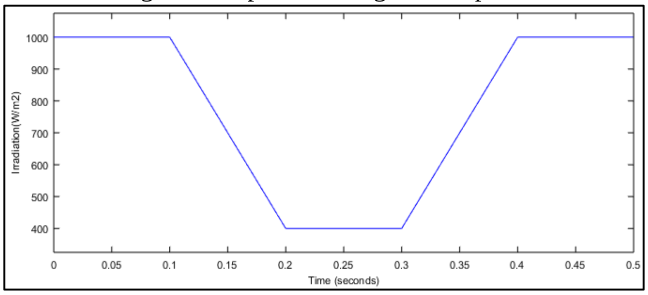


Fig. 12: Solar irradiation curve used in PV plant simulation

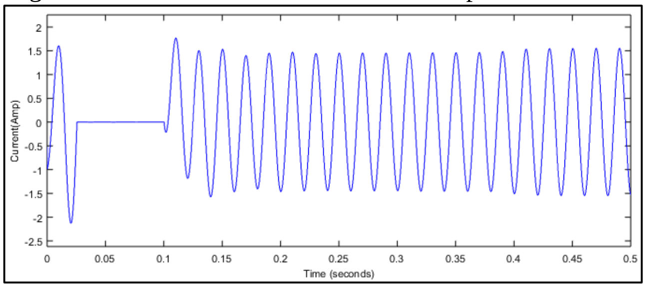


Fig. 13: Output ac current of grid side

The behaviour of the contemplated method is investigated when the level of solar irradiation is variable. Fig. 12 shows the variation of the solar irradiation level used in the PV plant simulation. Fig.13 shows the output ac power (grid side) that produced by the simulated PV power plant when there is variation in the solar irradiation level. The uncontrolled PV plant response shown in Fig.13, discover unstable performance and high oscillation.

Another estimation of the contemplated control method is represented with the help of a three phase fault implicated on ac side of the PV power plant for the time from (0.1 – 0.15) sec**.**

V. CONCLUSION

This paper presents a contemplated controller for MPPT of grid connected PV plants. This controller contains of three parts, which are: Incremental Conductance, the dc-dc boost converter and the PWM unit. The grid connected PV power plant with 100 KW and the contemplated controller for the MPPT are simulated and modelled using MATLAB using SIMULINK. The simulation results illuminate that the contemplated fusion used for controlling MPPT of the PV plant has the best interpretation over another methods separately. And for a three phase fault condition, the IC method with boost converter provides the maximum generated ac power with maximum stable interpretation as compared with the other control methods.

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