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Simulation of a Solar Cell Model in Matlab for Grid-Connected PV Based Generation System

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Abstract – Photovoltaic (PV) creation is rising increasingly fast as a renewable energy basis. This paper presents modeling and imitation of the network-linked PV creation system under MATLAB. The PV producer is linked to the boost DC-DC converter, the control systems based on the utmost power point tracking (MPPT) with P&O algorithm assists PV array to produce the utmost power to the network with change weather circumstances and then incorporated into the AC value network by DC/AC inverter manage the power active and reactive for achieved the unity power factor in connection point. In this paper, dissimilar cases are simulated, and the consequences have established the validity of models and control schemes.

Keywords: Photovoltaic array, Modeling, Network-connected photovoltaic system, MPPT control, Power

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1. INTRODUCTION

There are much concerned with the fossil fuel as these are fast exhaustion and the much environmental problems are caused by the conventional power production. Renewable energy basis such as photovoltaic (PV) panels and wind-generators, are extensively used. PV systems are the most direct way to convert solar radiation into electricity and are based on the PV consequence experiential by Henri Becquerel in 1839.It is moderately usually definite as the materialization of an electric voltage between two electrodes attached to a solid or liquid system upon shining light of the system. Practically, all PV devices incorporate a PN junction in a semiconductor across which the photo voltage is increased and such campaigns are called solar cells. The semiconductor material has to be able to absorb a large part of the solar spectrum.

The PV production is gaining increased importance as a renewable basis. It is used today in many areas e.g. battery charging; water pumping, office power contribute water heating systems, satellite power systems. The PV systems have the advantage of being maintenance and pollution-free but their installation cost is elevated and in mostly requests; they require a power conditioner (DC/DC or DC/AC converter) for load user communication. As PV components motionless have comparatively squat conversion competence and in general system price can be reduced using high efficiency power conditioners which intended to extract the maximum possible power from the PV module.

The PV generators exhibit non-linear I-V distinctiveness. Alternatively, the most favorable operating point changes with the solar irradiation, cell hotness [2]. Online track of the utmost power point of a PV array is an essential part of any triumphant PV system. An assortment of greatest power point tracking methods is developed in journalism. For example, MPPT [3] is implemented with a boost converter the Incremental Conductance algorithm is based on the principle that the slope of the PV array power curve is zero at the MPP (maximum power point). It has imaginary that double boost converter pedestal MPPT by means of fuzzy logic has been reported [4]. So as to haul out the utmost quantity of supremacy from the PV creator and observe' control process for the MPPT of a PV system under variable temperature. This technique evaluate the PV output power before and after and adjusts the duty cycle of the switch control waveform for MPPT as a function of the evolution of the power input at the DC/DC boost converter and it is compulsory to compute the PV array output power and to change the duty cycle of the DC/DC converter control signal.

This paper presents the psychoanalysis & control model and representation of the electric element of a PV production system connected to the utility network by a boost converter and DC/AC inverter. The measured PV scheme is constituted of KC200GT solar array category. The model contains a detailed illustration of the different components of the conversion system as the solar array, adapted and control systems. The simulation results show the control performance and dynamic behavior of network connected PV system.

2. PV ARRAY

PV cell is the most basic production part in PV system. This model contains of a photocurrent foundation I_{ph} , a nonlinear diode, series resistance R_s which represents the internal losses and shunt resistance, R_{sh} in parallel with diode to take into account leakage current to the ground as shown in Fig. 1.

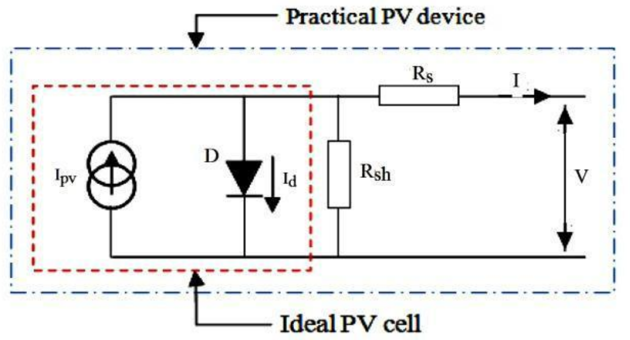

Fig. 1: Single-diode mathematical model of a PV cell

The mathematical relationship for the voltage and current in the single-diode corresponding route can be described as:

Where,[1] ph is photocurrent; I_s is diode saturation current; q is electron charge (1.602×10^{-19} C; k is Boltzmann's constant (1.381×10^{-23}); T is cell temperature; A is PN junction ideality factor.

Photocurrent is the function of solar radiation and cell temperature described as:

$$I_{ph} = \left(\frac{S}{S_{ref}}\right) \times \left[I_{ph,\,ref} + C_T\left(T - T_{ref}\right)\right]$$

Where, S is the real solar radiation (W/m2);

S_{ref}, T_{ref} are respectively the solar radiation, cell absolute temperature, photocurrent in standard test conditions; CT is the temperature coefficient (A/K).

Diode saturation current I_s varies with the cell temperature as:

$$I_s = I_{s,\,ref} \times \left(\frac{T}{T_{ref}}\right)^3 \times \exp\left[\frac{q \times E_g}{A \times k} \times \left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]$$

Where, I_s, ref the diode saturation is current in standard test conditions; Eg is the Band-gap,cell semi-conductor (eV) depending on the cell material.

Pv cells, usually considered to have the same uniqueness, are set together in series and parallel to appearance arrays. The equivalent circuit of PV array can be described as illustrated in Fig. 2.

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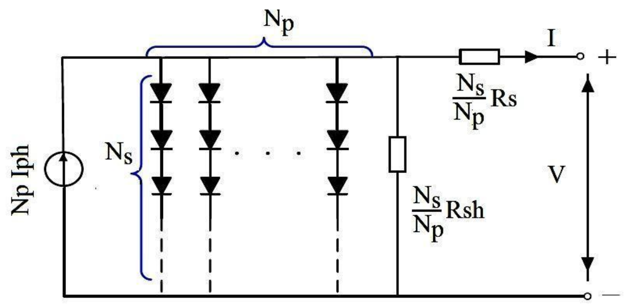


$$I = N_P I_{ph}$$

Fig. 2: Single-diode mathematic model of a PV cell

$$I = N_p I_{ph} - N_p I_s \left[\exp\left(\frac{q}{A k T}\left(\frac{V}{N_s} + \frac{I \times R_s}{N_p}\right)\right) - 1\right] - \frac{N_p}{R_{sh}}\left(\frac{V}{N_s} + \frac{I \times R_s}{N_p}\right)$$

$$- N_p I_s \left[\exp\left(\frac{q}{A k T}\left(\frac{V}{N_s} + \frac{I \times R_s}{N_p}\right)\right) - 1\right] - \frac{N_p}{R_{sh}}\left(\frac{V}{N_s} + \frac{I \times R_s}{N_p}\right)$$

Where Ns and Np's are respectively cell numbers of the series and parallel cells.

The above model has been implemented using Matlab/Simulink as depicted in the figure 3. All parameters of the model use the data in **Table A**

Table A: Parameters of KC200GT solar array at 25°C; A.M.1,5; 1000 W/m^2

Parameters (2)	Value
Referenced solar irradiance, S_{ref}, W/m^2	1000
Referenced cell temperature, T_{ref}, K	298
Cell numbers of a PV module	54
Nominal short-circuit voltage, A	8.21
Nominal array open-circuit voltage, V	32.9
Array current maximum power point, A	7.61
Array voltage maximum power point, V	26.3
Current / temperature coefficient, A/K	3.18×10^{-3}
Voltage / temperature coefficient, V/K	-0.123
Band-gap energy, E_g, eV	1.237
Cell internal resistance, R_s, Ω	0.2273
Rsh, Ω	540.55
p-n junction ideality factor, A	0.065 %

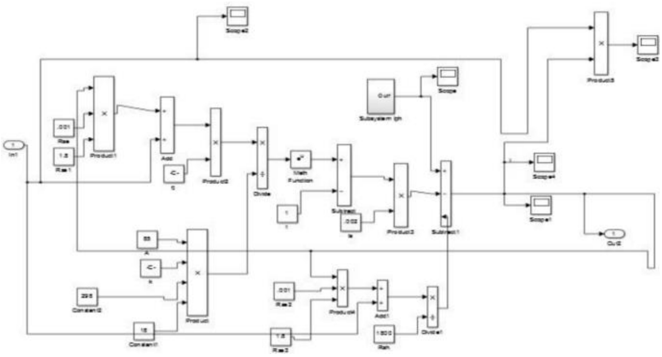


Fig. 3: PV array model implemented in Matlab/Simulink

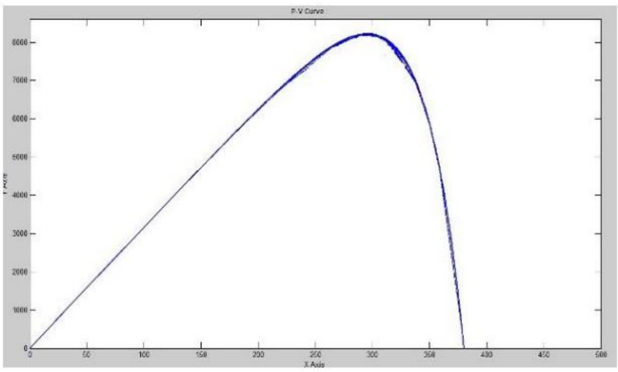


Fig. 4:P-V Characteristic curves of the PV array irradiation solar constant 1000 W/m^2

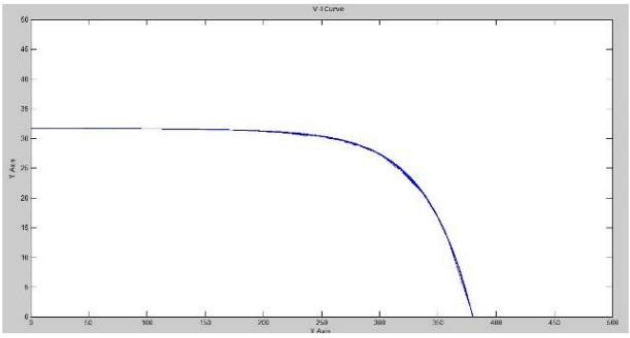


Fig. 5: V-I Characteristic curves of the PV array

As shown in Figures 4 and 5, a PV array has nonlinear Characteristics of PV array are simulated as Fig. 4 and Fig.5

Voltage-current characteristics, and there is only one unique operating point for a PV production system with a maximum output power under a particular environmental condition.

3. NETWORK-CONNECTED PV PRODUCTION SYSTEM

The penetration of renewable basis in to the power system has been increasing in the recent years. Network connected PV generator systems always a connection to the electrical network via a suitable inverter because a PV module delivers only DC power. Figure 6 is the configuration of the network-connected PV production system. PV array is connected to the DC bus via a DC/DC boost converter and AC network via AC/ DC inverter. The inverter has its self-governing control purpose (boost inverter control PV generator to generate the maximum power and network inverter control the active and reactive at AC bus to be constant).

3.1 Document PV production system

The PV generator using in the proposed systems is constructed with four KC200GT solar modules connected in series [a solar module is assembled of 54 cells]. When it connected to the network and it should be unified into the network using power electronics to convert DC to AC power. So as to improve the efficiency of the PV construction design, PV array should be forbidden to create the utmost power by a MPPT algorithm, so as to extract the maximum possible power from the PV panels in all the irradiation circumstances. The MPPT based in P&O algorithm is realized by controlling the DC/DC boost converter.

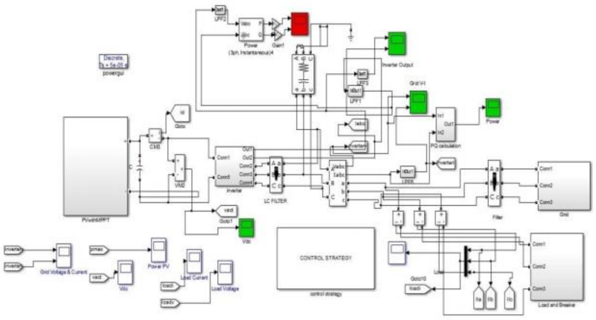


Fig. 6: Configuration of the network-connected PV production system

3.2 Maximum power point tracking

The 'Perturb and Observe' (P&O) algorithm is the most popular MPPT algo because it is simpler and require fewer measured variables straightforwardness. Fig. 7 shows the flowchart of P&O technique and functions by constantly measuring the terminal voltage and current of the PV array, then constantly perturbing the voltage by adding a little commotion, and then scrutinizes the changes of the output power to determine the next control indication. If the power augments, the perturbation will carry on in the similar direction in the following step, otherwise, the perturbation direction will be inversed.

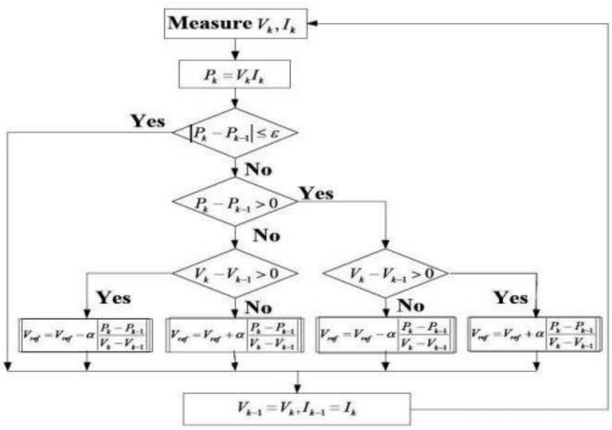


Fig. 7: P&O algorithm flow chart [6]

Where V_k, I_k are respectively the voltage and current of PV array at the moment; V_{k-1}, I_{k1} are respectively the voltage and current of PV array at the last sampling time.

3.3 Boost circuit and its control

For first-stage PV production system, boost chopper circuit is always used as the boost DC/DC converter. The DC-DC converter raises the low solar voltage to a suitable level corresponding to the optimal PV power. A capacitor is generally connected between PV array and the boost course, which is accustomed to decrease far above the ground frequency harmonics.

The duty cycle of the boost converter is determined by MPPT control system, then constantly perturbing between 0 and 1. T_s is the period of a switching cycle. When the IGBT is closed, the inductance voltage and capacitor voltage meet the following relationship:

$$\begin{cases} L_{pv} \dfrac{d\,I_{pv}}{d\,t} = V_{pv} = v_{L(on)} \\ C_{dc} \dfrac{d\,V_{dc}}{d\,t} = I_{dc} = i_{C(on)} \end{cases}$$

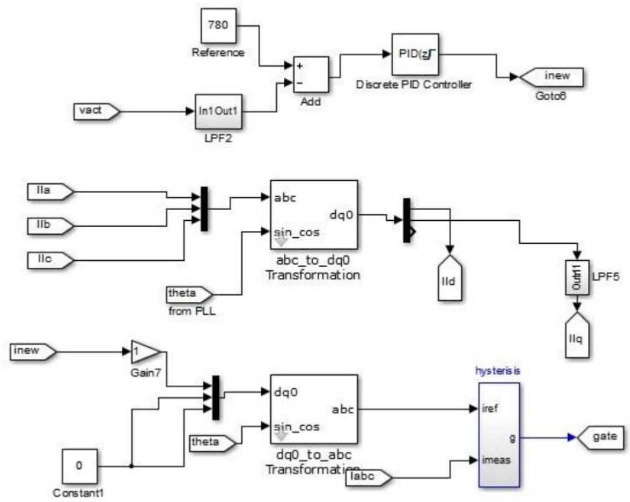


Fig. 8: Control Strategy for DC/DC converter

Similarly, when the IGBT is open, the equations of inductance voltage and capacitor voltage are described as:

$$\begin{cases} L_{pv} \dfrac{d\,I_{pv}}{d\,t} = V_{pv} - V_{dc} = v_{L(off)} \\ C_{dc} \dfrac{d\,V_{dc}}{d\,t} = I_{dc} - I_{pv} = i_{C(off)} \end{cases}$$

The maximum power point by regulating the duty cycle □ is used to control the boost converter as shown in Figure 9. The P&O algorithm is used to find the maximum power point of the PV system [7].

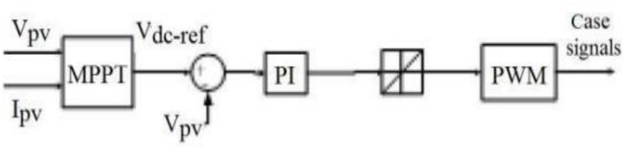


Fig. 9: Control structures of boost converter and MPPT algorithm

4. NETWORK-CONNECTED INVERTER

PV array with boost DC-DC inverter are connected to the ac network via AC/DC inverter. In conclusion, the filter is intended to reduce high-order harmonics introduced by the PWM modulation of the DC/AC converter.

The control strategy mainly consists of the DC/AC converter is designed to supply current into the utility line by regulating the bus voltage to 400V and organize the power stream to the network, according to the proposed system of power which is based on the control of active and hasty power. In the power DC-AC converters, active and reactive power as of the network-side inverter can be specified by:

$$\begin{cases} P_g = 1.5\times\left(v_{gd}\times i_{gd} + v_{gq}\times i_{gq}\right) \\ Q_g = 1.5\times\left(v_{gq}\times i_{gd} - v_{gd}\times i_{gq}\right) \end{cases}$$

Where, v_{gq} , v_{gd} , represent the d, q components of the voltage at connection point, i_{gq} , i_{gd} , represent d, q components of the line current.

In the reference frame synchronized with the Vgd = Vg, network voltage, vgq = 0, so

$$\begin{cases} P_g = 1.5\times v_{gd}\times i_{Gd} \\ Q_g = -1.5\times v_{gd}\times i_{gq} \end{cases}$$

The inverter uses hysteresis switching and controls active power by manipulation of direct-axis current while holding reactive power at 0 VAr.

$$\begin{cases} i_{gd,ref} = \left(K_{gd,p} + \dfrac{K_{gd,i}}{S}\right)\times\left(V_{dc,ref} - V_{dc}\right) \\ i_{gq,ef} = -\left(K_{gq,p} + \dfrac{K_{gq,i}}{S}\right)\times\left(Q_{dc,ref} - Q_g\right) \end{cases}$$

The electrical model presented by three-phase voltages at the AC side of the inverter at Figure 1, is given by:

$$\begin{cases} v_{ga} = v_a - \left(L_f\times\dfrac{di_a}{dt} + R_f\times i_a\right) \\ v_{gb} = v_b - \left(L_f\times\dfrac{di_b}{dt} + R_f\times i_b\right) \\ v_{gc} = v_c - \left(L_f\times\dfrac{di_c}{dt} + R_f\times i_c\right) \end{cases}$$

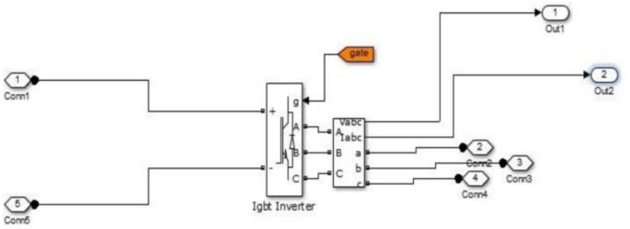
inductance and resistance. Applying Park transformation, {Eq. (11)} represents the electrical model of the network-side inverter in the d, q referential axis. It is given by:

$$\begin{cases} v_{gd} = v_d - \left(L_f\times\dfrac{di_d}{dt} + R_f\times i_d\right) + \omega\times L_f\times i_q \\ v_{gq} = v_q - \left(L_f\times\dfrac{di_q}{dt} + R_f\times i_q\right) - \omega\times L_f\times i_d \end{cases}$$

Where, , is the network frequency.

The current controller still uses PI regulator, described by:

$$\begin{cases} v_{gd,ref} = v_d + \left(K'_{gd,p} + \dfrac{K'_{gd,i}}{S}\right)\times\left(i_{d,ref} - i_d\right) - \omega\times L\times i_q \\ v_{gq,ref} = v_q + \left(K'_{gq,p} + \dfrac{K'_{gq,i}}{S}\right)\times\left(i_{q,ref} - i_q\right) - \omega\times L\times i_d \end{cases}$$



5. SIMULATION RESULTS AND DISCUSSION

A complete Matlab/Simulink simulation of the network connected PV System with the MPPT algorithm and power

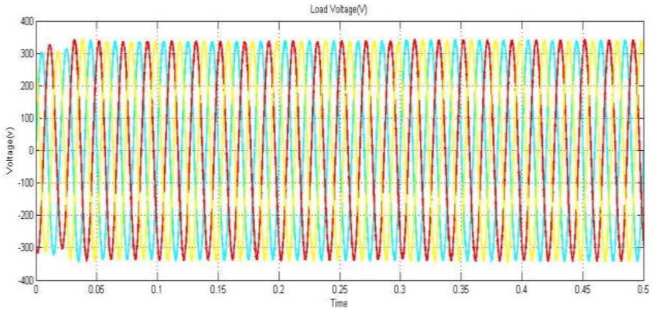


Fig. 10: VSI -Inverter model

Active and reactive control of the network-side inverter has been carried out with the following parameters: The PV Generator is composed of 15 series and 2 parallel KC200GT modules.

Fig. 11 shows simulation results of electric characteristic of the PV generator in irradiation of 1000 W/m2 and temperature of 25°C with MPPT control systems Simulation results of the system studies, the boost converter is controlled with MPPT system as shown the Fig. 8 and 9, in three phase PWM inverter control the active power and reactive powers at AC bus are considered to be constants. The input power P rapidly and accurately reaches the maximum power corresponding to V_{mpp} I_{mpp} after 0.2 s. So, we can demonstrate the importance of the MPPT algorithm performance in resolution of the problem of the degradation of the climatic factors

Fig. 12 shows simulation results of active and reactive powers at the AC bus for compare with the reference values by inverter DC-AC. The inverter control is based on a decoupled control of the active and reactive powers.

The maximum output power of PV system is 6000 W. Set the power demands to be 1800W at the t Є [0, 4.2 sec] after 4.2 sec it is equal to 6000 W. This variation of the active power demands are controlled by the PI regulator with reactive power reference equal to zero. The simulation results present the performance of the control systems

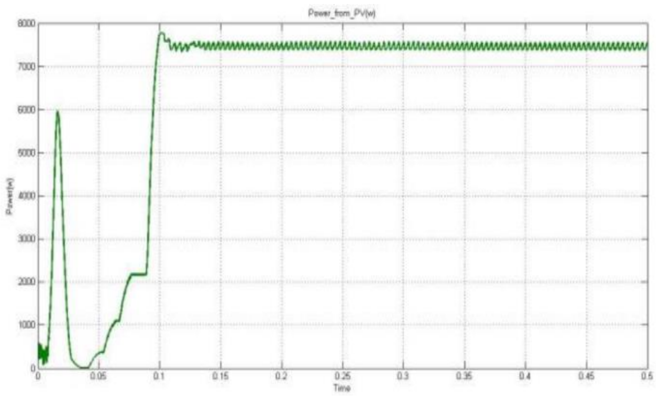


Fig. 11: Tuned Vdc of DC/DC converter

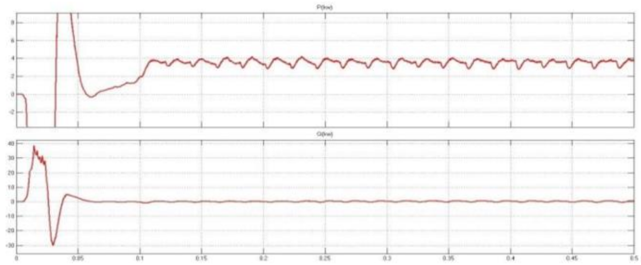


Fig 12: Active and Reactive Power

Fig. 13 (a) and 13 (b) shows the current injected into the main utility and the network side voltage. As it can be noted, the voltage and current are in phase which means that the MP extracted from the PV array can pass into the DC-AC network-side inverter as the whole system operates at unity power factor (Q □ 0) with no reactive power exchange.

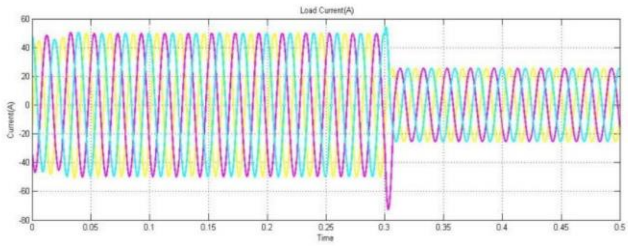


Fig 13(a) Network side voltage

Fig 13(b) Injected current

Applying the inverse Park transformation to d, q current vector components, the phase current references are obtained. These are passed to a PI controller, which outputs the pulses to drive the inverter switches. The output line voltage of the inverter is shown in Fig. 14. Fig. 14: Inverter line three-phase voltage

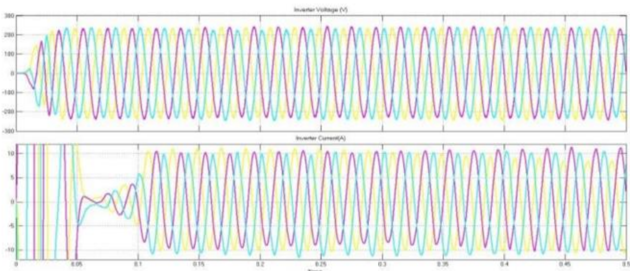


Fig. 14: Inverter line three-phase voltage

6. CONCLUSION

Modeling of network connected converters for solar energy requires not only power electronics technology, but also detailed modeling of the network synchronization techniques. Reactive power in both single and three phase network connections can be achieved by controllers which comparable to field receptiveness control in electrical drives. It is expected that better methods of modeling and control design will make the photovoltaic system more efficient for network integration.

The method incorporated in the simulation displays good results applying considerably low difference between the two PV array voltages. It is suitable for obedience for far above the ground-power applications where V-I uniqueness of two groups are expected to be quite similar by the law of huge information. The measuring system might require preliminary alteration. The case of dissimilar uniqueness due to partial surveillance is not of importance for high-power application since the installation is projected to avoid such an issue. This paper presents a technique to intend and manage of network-connected PV production system, identify its components, and describe how it works. So as to renovate the solar energy resourcefully, the MPPT algorithm for photovoltaic schemes based on P&O algorithm has been presented. It should be tracked to ensure the PV array to generate most power to utility network which explain the following control algorithms used for the inverter DC-AC for regulate active and reactive power sat connection bus. Every simulation results, obtained under Matlab/Simulink environment, show the control performance and dynamic behavior of network connected photovoltaic system provides good results and show that the control system is robust and efficiency.

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