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# Enhancement of Transient State in MPPT Techniques for PV Grid Connected System

**Neha Sunil Dahate, N. R. Bhasme**

***Abstract***: ***Instead of using non-renewable energy sources, industry researchers have wide applications in renewable energy sources such as hydro, wind and solar which are highly preferable because of having huge advantages like easily erectable and abundance in environment. For obtaining the high quality in electric power system, the system requires special conditions while connected to the grid. This paper shows the interfacing of Photovoltaic system connected to 3-phase grid. To ensure the highest output power of Photovoltaic system, a DC to DC converter with Maximum power point tracking (MPPT) is required. In this work, comparative analysis has been carried out for the MPPT techniques with topology β- method which is connected in parallel to perturb and observe method. The above proposed method enhances the dynamic performance of the system and effective under the steady state as well as transient state. The proposed system is implemented and simulated in MATLAB/Simulink. Analysis of simulation results are carried out for validation of system.***

***Keywords: Photovoltaic system, PV Modules, DC-DC converter, voltage source inverter, Synchronous reference frame (SRF), MPPT controller, 3-phase Grid.***

## I. INTRODUCTION

The requirement of energy is predominantly increases due to huge population, urbanization and industrialization. Traditional energy sources are limited so that the researchers are highly rely on renewable energy source. Nowadays, renewable power generation system is used in domestic and industrial purpose. Solar energy generation has become an important part in power generation system which is related to solar heating, photovoltaic, concentrated photovoltaic, solar architecture and artificial photosynthesis. Photovoltaic (PV) system converts radiant energy into electrical energy (direct current) by using photo-voltaic effects [1]. Generation and consumption of power plays a key role in economic growth. Solar panels are capable of converting 30-40% of total energy falling on its panel into usable electrical energy.

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For achieving higher efficiency, charge controllers are employed in solar power system. The MPPT techniques are used to extract the maximum power from PV system. The various MPPT techniques are used in solar system such as Incremental conductance (I&C) method, Fuzzy logic method, Perturb and observe (P&O), Beta method (β), parabolic method and other advanced method.

The perturb and observe method is used for both the transient and steady state. In transient state more oscillations occur which give rise to power loss in the system. Therefore beta method is introduced which shows better transient response and less fluctuations in the steady-state.

The main objective of model is to develop a power electronics interface for a 3- phase grid connected PV which is capable to extract maximum power from the Photovoltaic arrays by using beta technique and P&O technique. The comparative analysis of MPPT methods is to be done for better efficiency and stability in the system. An inverter is implemented to convert the dc output voltage into a voltage compatible with the utility grid. This method is implemented using MATLAB/Simulink model and dynamic behavior of the PV connected to grid system is observed.

## II. SYSTEM CONFIGURATION

The basic block diagram of PV system connected to grid system using voltage source inverter as shown below in Fig. 1.

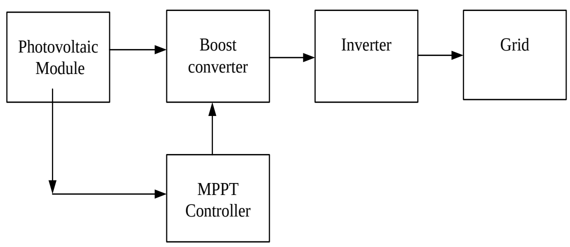


**Fig. 1. Block diagram of photovoltaic system connected to the grid**

Block diagram consist of various components such as boost converter, utility grid, photovoltaic module and inverter, loads.

### A. PV Module

Photoelectric cell or photovoltaic panel is a semi-conductor device that transforms sunlight rays to electrical energy by the PV outcome. The equivalent circuit diagram of photovoltaic cell is as shown in Fig. 2. The resistances are connected in series and shunt to fulfill energy requirements.

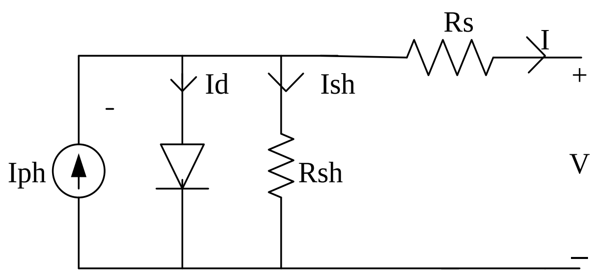


**Fig. 2. Circuit diagram of equivalent electrical cell**

$$I_{ph} = I_d + I_{sh} + I \qquad (1)$$

$$I_d = I\left(e^{\frac{q(v+IRs)}{KTA}} - 1\right) \qquad (2)$$

$$I = I_{ph} - I_o\left(e^{\frac{q(v+IRs)}{KTA}} - 1\right) - \frac{V+IRs}{Rsh} \qquad (3)$$

Where,

V= Load voltage (voltage)

I= Cell current (ampere)

Id= Diode current (ampere)

Rs= Internal series resistance (ohm)

$R_{sh}$= Parallel resistance (ohm)

Io= Diode inverse saturation current (ampere)

T= Temperature (Kelvin)

K= Boltzmann constant ($1.38\times10^{-23}$ J / K)

n= Idealist factor (near about1.92)

q= Electrical charge ($q=1.6\times10^{-19}C$)

Tracking maximum power point is necessary in photovoltaic application as it helps in maximizing the utilization of PV panel which increases its overall efficiency [7]. Fig. 3. and Fig. 4. shows the following graph of voltage and power that has been obtained by simulating the PV panel at $25^0$C.

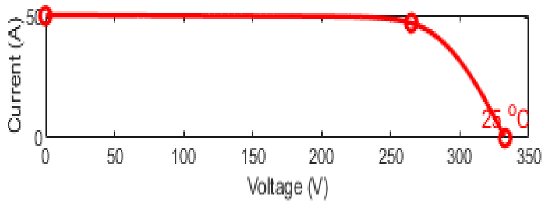


**Fig. 3. I –V Curve obtained by simulation**

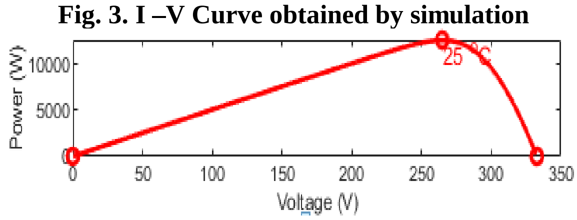


**Fig. 4. P–V Curve obtained by simulation**

### B. DC to DC Boost Converter

This type of boost converter is used to convert DC-DC with rising voltage across output which has a decreasing source voltage, it also termed as step-up DC-DC converter.

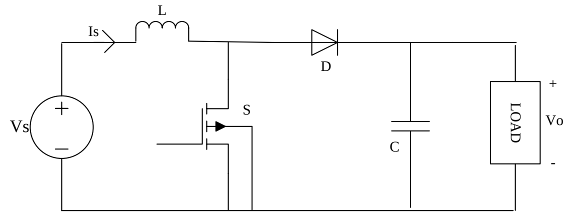


**Fig. 5. Equivalent circuit of DC to DC converter**

Fig.5. Illustrate the MPPT boost converter circuit which has switch S (MOSFET), output diode D, L inductor for boosting, C capacitor filter and resistive load. While the semiconductor device is closed, the current start flowing and stores the energy thus the current through inductor will increase. Off-state means the switch is open energy stored will starts discharging in opposite polarity and starts charging the capacitor and the current will start flowing in the load. By considering its steady state the transfer function of the boost type converter is achieved. The DC voltage transfer function is [1,9]:

$$M(\delta) = \frac{Vo}{Vi} = \frac{-\delta}{1-\delta} \qquad (4)$$

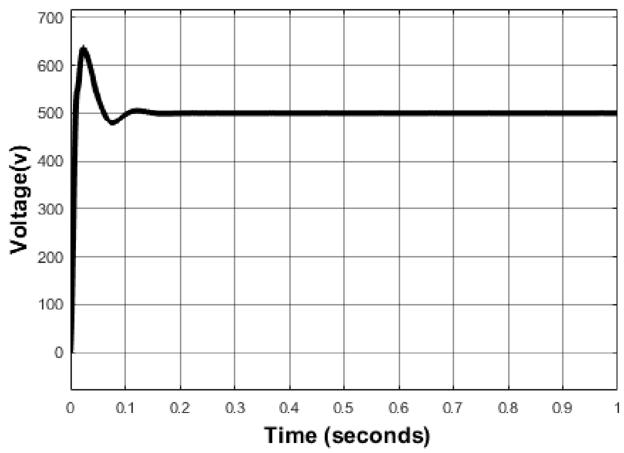


**Fig. 6. Output waveform of boost converter**

Fig. 6. Shows the output voltage of the boost converter that generates 500V DC.

### C. Inverter

In this system the main part is inverter which consists of semiconductor switches with the synchronous reference frame (SRF) controller which helps to provide perfect switching pulses for controlling the inverter as per the requirement. Inverter converts DC power to AC power which is produced from the photovoltaic array. This AC power needs continuity of the power and voltage quality as it is necessary for the grid. Following operations are performed by an inverter.

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- Reduction of harmonics
- Grid synchronization
- Control of DC link voltage
- Controls active and reactive energy flow.

Synchronous Reference frame controller (SRF) is used for synchronization of grid voltage $V_{abc}$ and grid current $I_{abc}$ with the inverter voltage and frequency by converting *dq0* components to *abc* components. It consist of Parks transformation, PI controller, Phase locked loop (PLL).

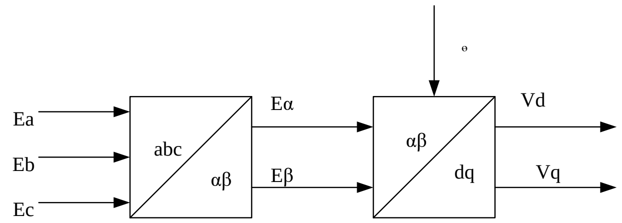


**Fig. 7. SRF Phase locked loop**

Fig.7. shows the transformation of *abc* to *dq0*. In SRF phase locked loop, the 3-phase grid voltage are inclined by an angle of 120 degree from each other and further converted into *dq0* reference frame in a two stage transformation process i.e. *abc* frame to *αβ* reference frame and then to *dq* reference frame [4].

### D. Other devices

For better performance, filter used in the output of boost converter is required for the elimination of higher order harmonics from the system.

### E. Modelling of Grid

Fig 8 shows the equivalent circuit of the grid between various levels of voltage.

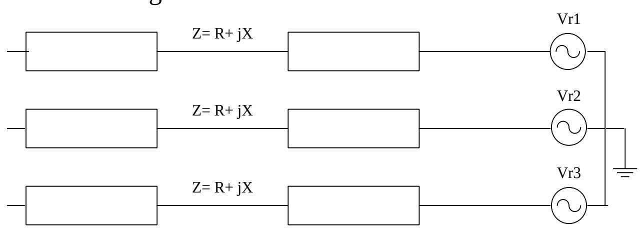


**Fig. 8. Grid equivalent circuit**

The various conditions for the synchronization of the grid and PV system are discussed below:

- Voltage tuning: The voltage matching is necessary so that, the voltage of both the system should be equal.
- For the synchronization of PV and the grid system, it is required to achieve phase sequence matching otherwise the synchronization is not possible. Both systems will have 120 degree phase difference for all the three phases.
- Frequency matching: For frequency matching of the system, the frequency of the PV system should be slightly higher than the grid frequency but it should not be less than the frequency of the grid.

There is a significant impact of these PV modules on utility grid since the capacity of these PV systems is increasing considerably. Grid-connected PV system has power quality issues because of harmonic injection and also stability is affected.

## III. MPPT TECHNIQUES

### A Perturb and Observe Technique

P and O technique is normally used technique which is implemented where hardware is used. This technique is different from other techniques, in terms of complexity, range of usefulness, tracking during irradiation and temperature difference. The basic flowchart of P&O is shown below in Fig. 9.

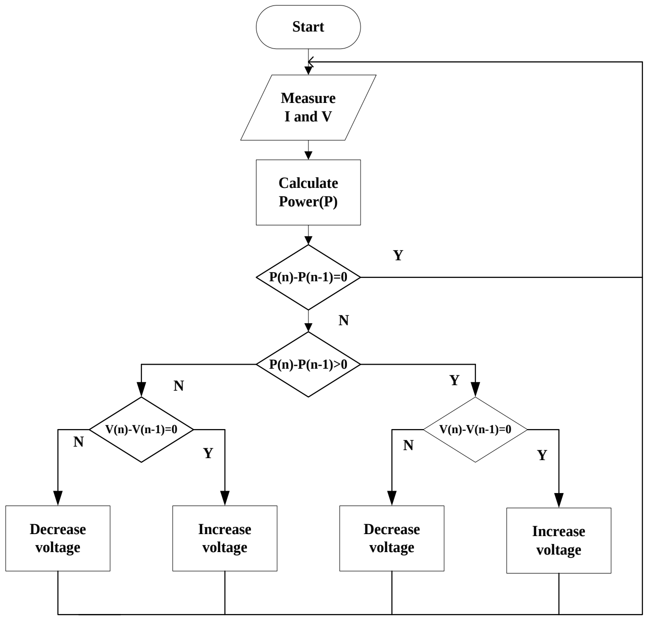


**Fig. 9. Perturb and observe algorithm flowchart**

The mathematical condition for perturbing and observing is dp/dv =0, where P denotes power and V denotes the voltage at output module. In this algorithm, the value of generated power from the solar PV module is calculated and compared with the previous value of power which is stored in a memory of an algorithm, which gives the difference in the value of the power. If any error found in this process, the duty cycle of converter is changed until error is zero.

The algorithm of this method is very simple and it reaches near to the MPP but is not able to achieve MPP and remain continue to oscillates in both directions. This method is mostly used because of its reliability. It is less expensive and easy to implement.

### B Beta Method

The basic principle of beta method is to track an intermediate variable of β rather than changing the power which is given below

$$\beta = \ln\left(\frac{i_{pv}}{v_{pv}}\right) - c \times v_{pv} \qquad (5)$$

Where, $V_{pv}$ and $I_{pv}$ are the photovoltaic module output voltage and output current.

Where,

*C* = Constant of the diode
*q* = Electron charge
*A* = Diode ideality factor
*K* = Boltzmann constant.

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There are two main stages, steady state and transient state conditions which involves fixed steps and variable steps respectively. Fig.10 shows the flowchart of the Beta method. Firstly, the measurement of current and voltage is done then the corresponding values for βa are continuously measured. If βa lies in (βmin, βmax) limits, the steady-state stage is obtained for the Beta method and for all the values which are beyond this range, the Beta method goes into transient stage and this will result in implementation of P&O method. A controlling parameter βg is used in transient stage for calculating ΔD which is expressed as:

$$\Delta D = N \times (\beta_a - \beta_g) \quad (6)$$

Where,

$N$ = scaling factor

$\Delta D$ =Variable step size

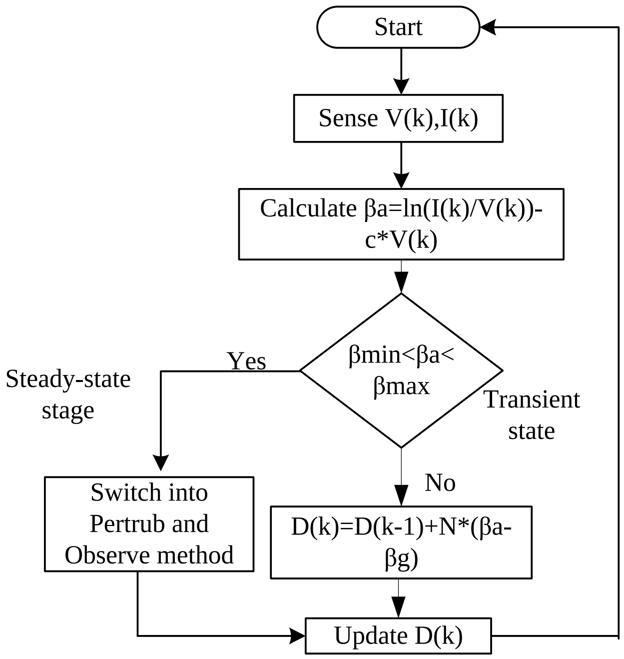


**Fig. 10. Flowchart of the conventional Beta method**

Fig. 10 shows β parameter with its range, ($\beta_{min}$, $\beta_{max}$) along the parameter βg. The range of the parameter β is the function of temperature and irradiance which changes depending upon the environmental conditions of the photovoltaic module.

The scaling factor in the conventional Beta method changes with the converging speed which is varying with the environmental conditions.

For various environmental conditions, the performance for Beta method can be calculated by detecting the range of parameter β. The optimum scaling factors obtained from this process is suitable for restricted operating conditions but the steady-state condition will still have some oscillations. Hence the further optimization is required for the Beta method for both the dynamic and steady–state operations [3,5].

## IV. SIMULATIONS RESULTS

To validate the steady state and the transient state performance, PV-MPPT technique is analyzed by simulating the system in MATLAB/Simulink model as shown in Fig. 11.

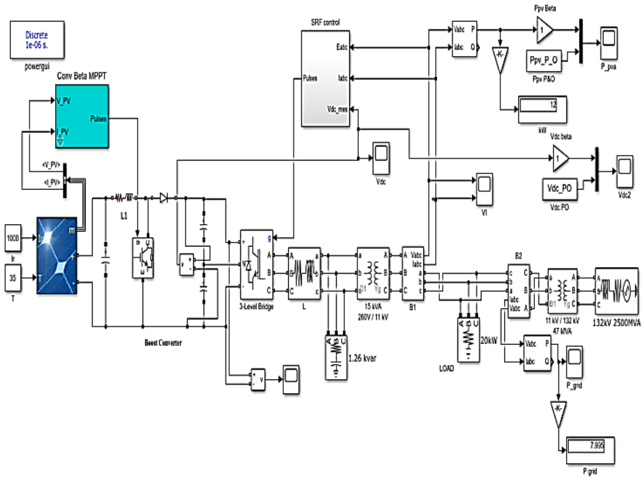

**Fig. 11. MATLAB/Simulink connected to grid**

The simulation model deals with mainly the following circuits: Photovoltaic panel under standard condition of 1000W/m$^2$ and 35$^0$ C converts the irradiance and the temperature to generate the DC current and voltage. The DC-DC boost converter is used to increase voltage and it is controlled by MPPT techniques. For tracking the maximum Power, P&O and Beta method algorithm is used. Thus for converting the DC voltage to AC voltage, 3 phase inverter is used for supplying power to the grid or the local load. The LC filter is used to eliminate the harmonics and step up transformer is used to boost the voltage.

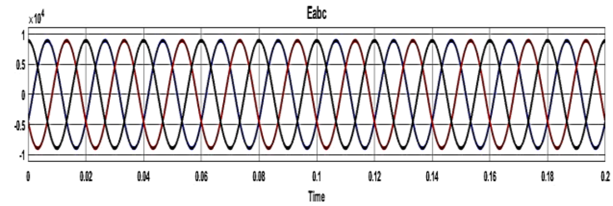


**Fig. 12.Phase voltage waveform connected to grid**

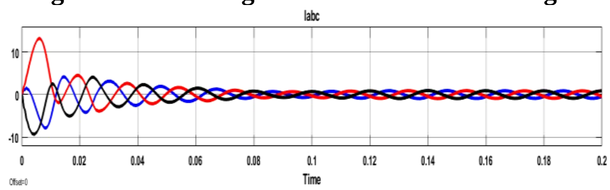


**Fig.13 .Phase Current waveform connected to grid**

Fig.12. shows sinusoidal three phase voltage waveform of PV system connected to 132 kV grids. Fig.13.shows three phase current waveform of PV system connected to the grid. Initially, the phase current value gets drastically increases due to direct connection with grid and the phase current reaches to steady state at t=0.08 seconds.


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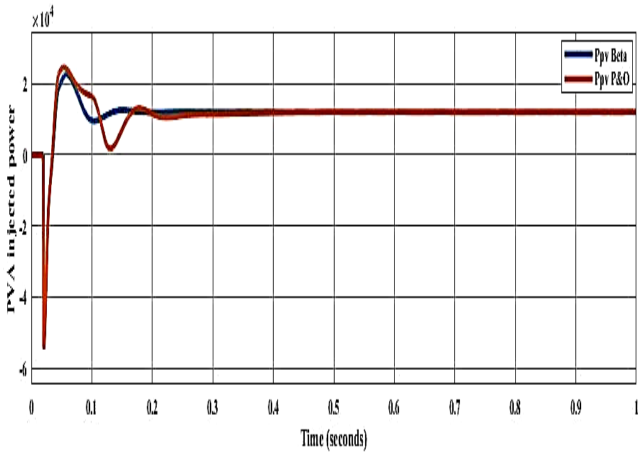


**Fig. 14. Comparison between beta method and P&O method**

The simulation results show the comparison of MPPT techniques in terms of system tracking capability at transient and steady state condition. The comparison results shows that MPP by P&O method takes more time to settle in transient state i.e t=0.3 second and t=0.2 second for β-method shown in Fig. 14. As the perturb and observe method & beta method are connected in parallel and β- method gives better results in transient state during initial state and thereafter use of P&O method gives stability. Thus it gives advantages of both the methods simultaneously.

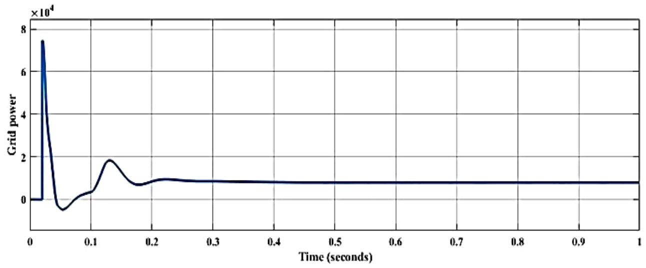


**Fig.15 .Power supplied to grid**

Fig.15 shows the active power supplied to grid connected system obtained from simulation of MATLAB/Simulink model (Fig. 11.). For this model the demand for the load is 20 kW as the Photovoltaic system generates 12 kW and remaining 8 kW power is taken from the grid. Whenever the load demand is less than PV system, the solar inverter supplies remaining power to the grid by fulfilling the requirement of load.

**Table- I: Comparison of settling time (secs) of MPPT techniques such as P&O and β method**

| Sr. No | MPPT Techniques | Settling time (secs) | |
|---|---|---|---|
| | | *Voltage (v)* | *Power Injected(kW)* |
| 1. | P&O | 0.247 | 0.3 |
| 2. | Beta | 0.018 | 0.2 |

## V. CONCLUSION

In this paper, the enhancement of transient state has done through combination of MPPT techniques to achieve better efficiency and stability in the solar power connected to the grid. In transient state, the conventional P&O method has more oscillations which lead to instability and poor dynamic response. To overcome this problem, MPPT techniques such as P&O and β-method are used which are connected in parallel. The settling time and oscillations reduces in this method which improves dynamic behavior of the system so that effective stabilization is achieved. All simulation results obtained in MATLAB/Simulink software under the dynamic stage behavior of the photovoltaic system which gives better efficiency.

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