Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 2, 2020

Review Article

CONTROL OF SINGLE-PHASE GRID-CONNECTED INVERTERS FOR VOLTAGE REGULATION WITH NON-LINEAR LOADS

Vemuri Sai Chand[1], Namburi Chandu Srinivasa Manikantha Surya[2], M. Srikanth[3], B. Jyothi[4]

1,2,3,4,Department of EEE, Koneru Lakshmaiah Edaucation Foundation, Vaddeswaram, A. P, India.

Received:16.11.2019 ***Revised: 25.12.2019*** ***Accepted: 09.01.2020***

Abstract
This work deals with the development of renewable energy sources. In this project we are going to present the working simulation model of solar panel using SIMULINK in MATLAB. The main objective is combined application of renewable energy concepts and control systems for the qualitative and quantitative improvement of electricity generated from solar and wind sources. The power generated from the general solar and wind sources is generally at a certain level. But the addition of solar and wind sources and control systems will surely be more in quantity and by the application of power electronic converters the power generated will be more efficient. By synchronizing this generated power with smart grid, the consumer as well as the producer will get profited and satisfied
Keywords:PV System, Boost converter, Inverter, Filter, Grid synchronization, non-linear loads

DOI: http://dx.doi.org/10.31838/jcr.07.02.62

INTRODUCTION

Solar Power is generated from sun light. Solar power is used in 2 ways.1) Active solar power 2) Passive Solar Power. Active solar energy is used effectively in such Activities as washing clothes and heating air. Modern technology has offered several ways of utilizing these existing resources. In present days because of technology improvement people are using Maximum power extracting from the Rotating solar panel by using Light dependent resistor. Solar power is just a DC power source. It is important to have some basic level of knowledge on P-N junction diode working to know the complete working mechanism of photo voltaic effect.

In olden days, wind energy was used as a source to get the sailing boats sailed based on the direction of wind. The generator present in the wind turbine generates an alternating current (AC). Some turbines contain an AC to DC converter. DC current is converted from alternating current through a rectifier and then again back to alternating current through an inverter. The main function of this is to synchronize the frequency and the phase of grid.

PV SYSTEM

Working of PV panel: Solar panels act by consuming light from the sun PV cells or battery, producing Direct current after that conversion process the generated energy into usable alternating current (AC) (since the usable form of energy is in AC power form) power by need to be a suitable rated inverter . Alternating current is then stepped up or stepped down for suitable rating accordingly. The brief working mechanism of solar panel is a PV cells are a mixture of silicon n-type and semiconductor material p-type silicon. P-type semiconductor material is lightly doped whereas the n-type semiconductor is a heavily doped semiconductor material in which their interaction will be a potential barrier. It generates electricity by making electrons excite across the junction (potential barrier) between the various levels of doped silicone by using sunlight.When the solar panel emits sunlight, photons touch the upper surface. Their photons carry the excited energy down the cell. The photons in the lower, p-type semiconductor layer, give up their excited energy to electrons. The electrons absorb this energy and get ready to move into the upper, n-type layer around the potential barrier and get bombarded. Since the flow of electrons is electricity the energized electrons will flow, and the energy will be generated.

BOOST CONVERTER

The control of the maximum power point, as stated in the introduction, is basically a problem that suits the load. To change the panel's input resistance to match the load resistance, if a DC – DC conversion process (using buck converter) is needed (by adjusting duty cycle). The Buck conversion efficiency has been studied to be peak for a DC – DC conversion process converter, so a buck-boost converter and minimal for a boost converter, but as we intend to use our system either for grid joining or for a pumping stations system that requires 230 V at the ends of a production, we are using a boost converter[1-5].

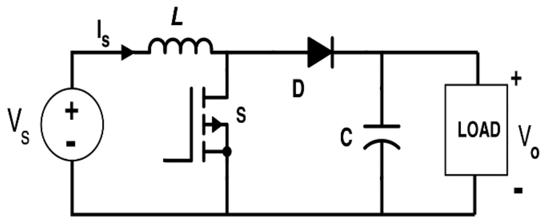

Fig 1: Circuit diagram of a Boost Converter

Mode 1 of the Boost Converter process: Whenever the switch is activated, the inducer is charged, and the energy is stored through the battery. In this mode the inductor current rises (exponential rate), so we assume that the inductor charging, and discharge is linear for accuracy. The diode prevents the current from flowing and therefore the charge current remains static due to the discharge of the condenser.

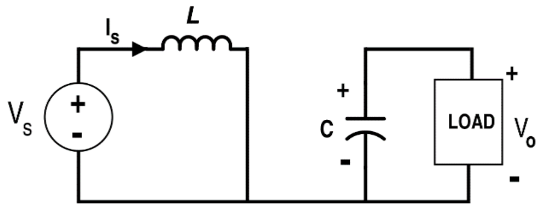

Fig 2: Mode I operation of boost converter (DC – DC)

Mode II of the Boost Converter process: Available Type II the button exists disconnected as well as therefore a diode short circuited. Power supply collected around-the inducer is released by reverse polarity from condenser. The flow current of load stays steady during service.

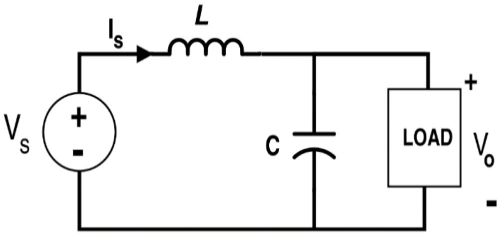

Fig 3: Mode II operation of Boost Converter

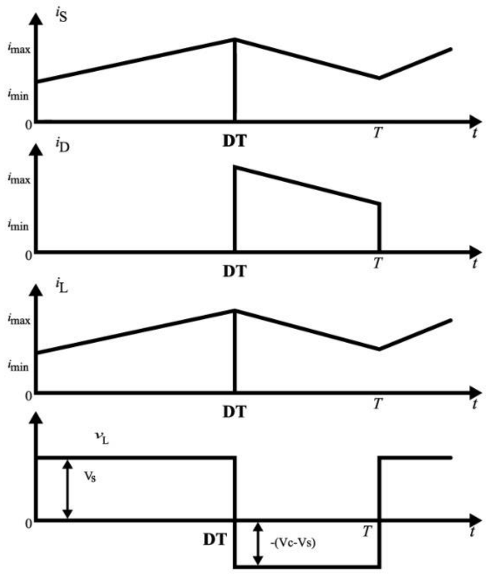

Fig 4: Boost converter waveforms

IVGRID CONNECTED INVERTER

An electronic control system or circuitry is a power inverter or inverter that converts direct current (DC) to AC. Input voltage, output voltage and frequency voltage as well as overall power handling depend on the specific device or circuit model.

An electrical grid is a network that is interconnected to provide power to customers from producers. This consists of following things as shown in Fig:5. 1) generating stations supplying electrical power; 2) electrical substations for stepping up electrical voltage for transmission; or down for distribution; 3) high-voltage transmission lines carrying electricity from remote sources to demand centres; 4) distribution lines linking individual customers; 5) Power stations can be placed

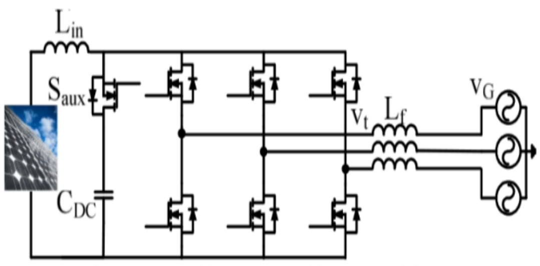

Fig 5: Block diagram of Grid connected inverter

This effective as well as reactive energy pumped to substation is independently operated. So it is considering this 3 ϕ alternating current outgoing in 2 dimension dq structure combined with altering the parameter of the q-axis to be zero. By considering that point, the next step of the investigation is to decide how to make this active power or reactive power to disconnect can be accomplished by regulating the output inductor current. Since the current outgoing inductor will run regulating inverter's function, the document will discuss acceptable methods of inverter control. It is believed that the switches of the converter and the generation of the output are lossless. The above figure represents the block diagram of the circuit.

CONTROL MECHANISM OF GRID CONNECTED INVERTER

A feedback management scheme, similarly calling Closed-loop Management Scheme, stands as monitoring approach that utilizes by idea an wide open ring system is Called as forwards direction although maintains 1 or many control loop directions among the production as well as i/p. Reference to a "response" it's called as a little part to thatproduction remains "backwards" in the source through produce portion in device's arousal. Feedback control methods were intended through routinely attain as well as keep required performance situation by means of contrasting. This will be achieved by producing an inaccuracy sign which makes up the gap between the reference production as well as involvement. Or put it another way, a "closed loop system" is an entire system.

To provide a variable irradiance and variable temperature we are using closed loop control path which was one of the concepts in control systems so that the two input parameters irradiance, temperature could be varied in the Simulink and the respective outputs will be generated [6-8].

Incremental conductance MPPT Controller used:

Using incremental conductivity form, MPPT was acquired after (d/dV) (P) = 0 where P = V*I

$$(d/dV)(V*I) = I + (V*(d/dV)(I)) = 0$$

$$(d/dV)(I) = -I/V$$

dV, dI = Specific components of ripples V and I, measured with a T MPPT skidding moment frame.

I , V = Imply standards of V and I were calculated using a T MPPT slipping moment frame.

Integrated controller minimizes error (d / dV)(I) + I / V)

Regulator output = Duty cycle correction

Electrical grid consists of various components. The various components involved in the grid can be represented in fig 6 the forms of feeders by replacing them with suitable impedances and naming them get named as the feeders and suitable 3-phase loads are designed by calculating the original loads impedances and getting them designed. The above figure represents the simulation of electrical grid using subsystem block and other suitable load representations for a grid consisting of load.

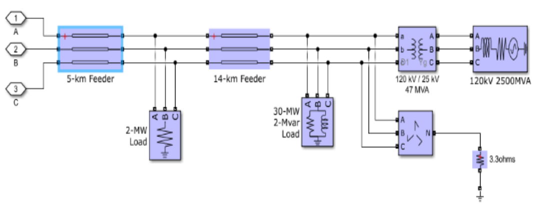

Fig6: Electrical grid simulation

(b) Total algorithms for power point monitoring:

A normal PV panel transforms into electrical energy just 30% - 40% of the incident sunlight. To increase this solar plate's performance, the MPPT monitoring procedure was applied. Corresponding to MPPT Proposal, a circuit's power output is upper limit after this circuit's Thevenin impedance (source impedance) equals the impedance of load. Therefore, our issue of measuring the MPP is reduced towards a challenge that matches impedance. On supply on the side, we are using a DC - DC converter attached through solar plate so increase the output voltage for various applications such as motor charging. With the adjustments to the boost converter's service cycle accordingly, we can balance the impedance of the origin with the impedance of the load.

Different methods of MPPT: -

The MPP is tracked using different techniques. Some of the most widely used approaches exist:

1) Perturb and Observe (hill climbing method)

2) Incremental Conductance method

3) Fractional short circuit current

4) Fractional open circuit voltage

5) Neural networks

6) Fuzzy logic

This algorithm choosing alters that period difficulty that the procedure takings toward control the MPPT, the asking price of implementation then the comfort of operation.

Perturb & Observe:

The simplest technique is Perturb & Observe (P&O). About this we use 1 detector, i.e. this voltage detector, to sense the voltage of the PV array and the deployment expense is less because easier implementation. This moment difficulty of this procedure is much a smaller amount so when it comes near to the MPPT does not end in MPPT after that it continues to interrupt both ways. While this is happening, the process is near the MPPT & can we establish an acceptable fault regulate to utilize waiting work that will eventually increase the moment difficulty of the procedure[12-15]. The approach doesn't, however, consider the quick alteration in irradiance rate (because of what are the maximum power point tracking adjustments) and considers it to be a switch to maximum power point owing towards disruption and it ends up measuring this incorrect Maximum power point. So, we are using gradual increment of conductivity technique is avoid this problem.

Incremental Conductance method:

Gradual conductivity process uses both current as well as voltage detectors for measure electrical energy and flow power from photovoltaic collection output.

At MPP, the photovoltaic curve is 0.

(d/dV)(P) MPP = (d/dV)(VI)

I +VdI/dVMPP = 0

(d/dV)(I) MPP = -(1/(V/I))

Left-hand side is the solar panel's instant conductance. If this instant conductance is equal to that PV conductance, formerly Maximum power point is reached. we're simultaneously feeling this current as well as the Voltage. It eliminates mistake due for the variation during radiation exposure[9-11]. This is difficulty as well as expense for completion, however, are rising. While they descend the collection of protocols, complexities as well as development expenses continues to rise, while fitting for a very complex program. Therefore, the most widely used protocols are Perturb and Observe and gradual increment Conductivity process. We selected the Perturb & Observe protocol to our analysis between the two because of its simplicity of implementation.

Fractional SCC:

The close linear relationship between VMPP and VOC of this photovoltaic array has resulted in the fractional VOC process at different radiation exposure and temperature rates.

VMPP = k1 Voc

Here k1 stands the proportionality relentless. Because k1 depends upon this feature for photovoltaic collection utilized, those are typically measured in advance in experientially determining VMPP and VOC at various irradiance and temperature rates are same photovoltaic collection. It was confirmed that the variable k1 is between 0.71 and 0.78. Once k1 is determined, by briefly shut down the power converter, VMPP can be calculated with VOC measured periodically. It comes with some drawbacks, though, including temporary power loss.

Fractional open circuit voltage:

Existing Tiny ISC benefits in reality is IMPP remains roughly proportional to this ISC in Photovoltaic range under various atmospheric conditions.

IMPP =K2 Isc

Here K2 remains stable of proportionality. k2 must be calculated affording the photovoltaic collection is used, just as for small VOC method. It is generally found that the constant k2 is0.78 – 0.92. During service, ISC measurement is difficult. Normally add extra Turn to the energy transformer for a regular shortening of photovoltaic range therefore, that ISC will measure by using a current device.

Fuzzy logic:

Over the past decade, control microcontrollers have made MPPT popular with the use of fuzzy logic control. Ambiguous logic devices are having some benefits to dealing by vague outputs, do not have a precise statistical pattern, and nonlinearity processing.

Neural Network:

Neural nets are another MPPT application method which is also well suited for integrated circuits. Typically, the neural grids are having 3 levels: i/p, hidden, and o/p. In each layer, these total joints differ and remain reliant on client. The i/p variables can include photovoltaic factors such as VOC and ISC, information such as, or any combination of, irradiance and temperature;

Characteristics of different MPPT techniques listed in the table1

MPPT Technique	Convergence speed	Implementation Complexity	Periodic Tuning	Sensed Parameters
Perturb & Observe	Varies	Low	No	Voltage
Incremental Conductance	Varies	Medium	No	Voltage, Current
Fractional Voc	Medium	Low	Yes	Voltage
Fractional Vsc	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural Network	Fast	High	Yes	Varies

Perturb & Observe Algorithm:

This Perturb & Observe algorithm notes of photovoltaic plates operational energy disturbed little bit increase, so this resultant energy shift also +ve, so these are heading in this way of MPP as well as those are continuing to disturb in this usual way. In case ΔP is -ve, we're leaving this path of the maximum power point identifications are disturbance given must be changed[16-25].

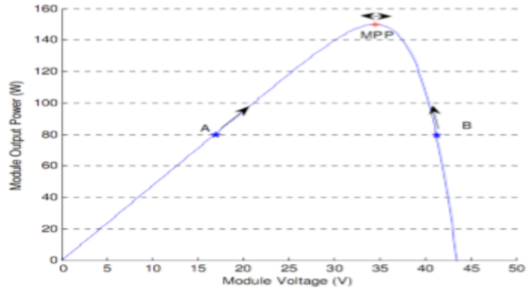

Fig 7: PV Curve with MPPT point conditions

Attributes of the solar panel display MPP and A and B working points shown in fig 7.

This displays the graph of output energy to the battery versus voltage of the part at a given irradiation For a Sun Table. The point marked as MPP is the maximum power point, which is the maximum theoretical performance of the PV table. Taking both A & B 2 stages of action. As illustrated above figure, point A is on the MPP's left side. We can therefore shift towards the MPP by supplying the voltage with a positive trading Point B, meanwhile, MPP's on the right - hand side. After we are giving a +ve perturbation, the half-p value is negative, therefore it is imperative to change the direction of perturbation to achieve MPP. Below is the flowchart for the P&O algorithm shown in fig 8.

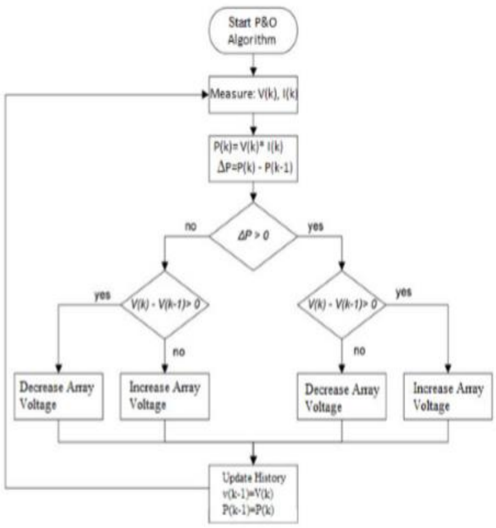

Fig 8. Flowchart of Perturb & Observe algorithm

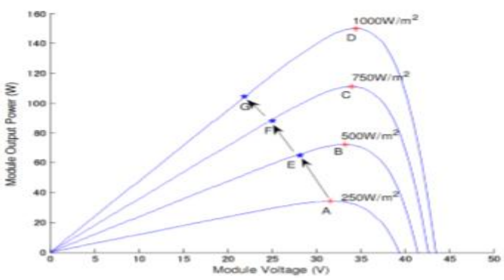

Fig 9: PV Curves for different irradiations

During the case where solar radiation is quickly changing, the MPP is also moving on the curve's right side. The algorithm takes it as a change due to disturbance and adjusts the path of disturbance in the next iteration and thus leaves this maximum power point in the same way as exposed on above graph shown in fig 9. Nevertheless, we only use the detector in this algorithm, which exists voltage on the indicator, towards feel the voltage of the solar array then the implementation cost will not effective as well as simpler to execute. The moment intricacy in this process is very minus, so it does not end in the MPPT after approaches near to MPPT & proceeds to spoil in 2 ways. When this occurs, the algorithm has reached near to the MPPT and we can set an acceptable mistake control or use a delaying process that will eventually increase the algorithm's time complexity.

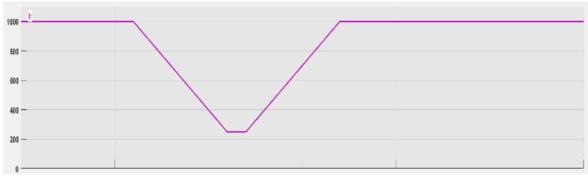

Fig 10. Irradiance considered

The above figure represents the irradiance that was considered for this project. It was a closed loop program that repeats itself n number of times around the same values of 1000 to 400 since it was written in that block. It was a 3 minutes simulation in which the irradiance falls from 1000 to 400 W/m*m. After that it again raises to its normal value and maintained at steady state till the end as shown in fig 10.

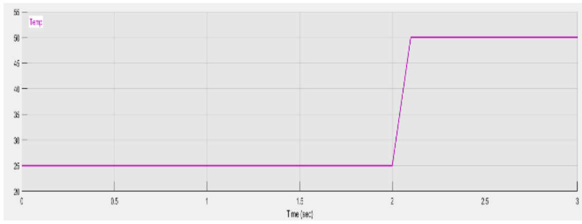

Fig 11. Temperature considered

The figure describes the range of temperatures and pattern of temperatures that we have considered for third project. The range of values are taken from 20 to 55 degrees centigrade. Initially it was maintained at the steady state at 20 degrees and then raised to 50 degrees centigrade. This was also a closed loop program which repeats itself n number of times. This was a closed loop program for 3 minutes as shown in fig11.

Reference of PV panel ratings considered as base values updated in table 2:

Number of Cells Ns	850
Standard Light Intensity S0	1000 w/m^2
Ref. Temperature	25°C
Series Resistance	0.008 Ohm
Shunt Resistance	1000 Ohm
Short Circuit Current	8 A
Saturation Current	2.16e-8 A
Band Energy Eg	1.12
Ideality Factor A	1.2
Temperature Coefficient Ct	0.0024
Coefficient Ks	0
Maximum available power	1.6 kW

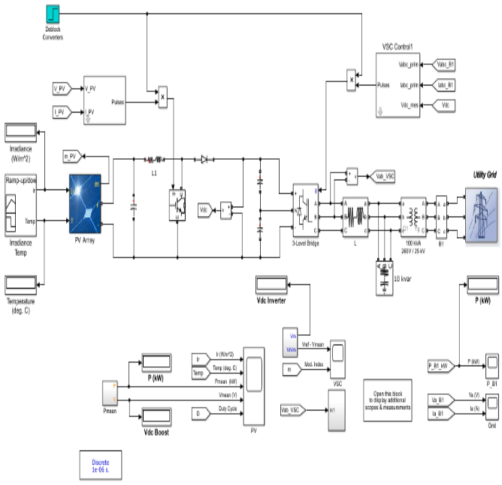

Fig 12: Simulink diagram

The fig 12 represented above shows the circuit simulation of PV- array module works along with the combination of closed loop path program. It consists of number of sub blocks that works behind the simulation program in the workspace to maintain the consistent working of the circuit simulation. The inverter used in this circuit is mainly .

Simulation outputs:

Input Irradiance(W/m*m)	Input temperature(degrees-Celsius)	Output power (KW)
1000	25	97
900	25	82
800	25	67
700	25	27
600	35	94
500	40	97
400	50	97

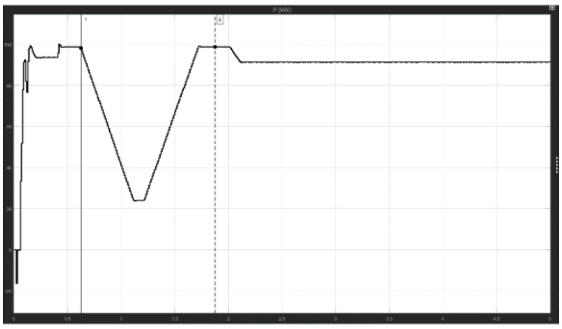

Fig 13. Output Power

The above graph fig13 represents the output wave form of power at the ending terminals of the inverter connected in series to the grid. The photovoltaic production energy is varied by varying those two inputs of the panel i.e.,(Irradiance and temperature).Since the simulation for closed loop path had a time bound of 3 minutes the path is again repeated and it will be remained as steady state values.

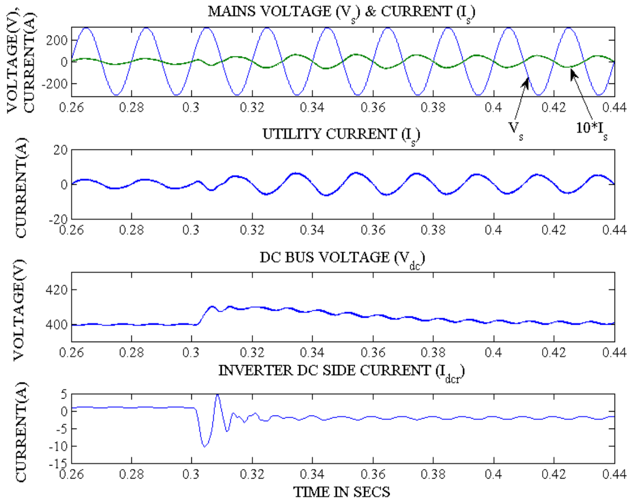

Fig: 14 Output waveforms, Current, voltage

From the output waveforms output voltage and current out of phase from 0.32 to 0.44 sec before that voltage and current are in phase ie power taking from the grid. DC bus voltage 400V.

CONCLUSION:

In this document we studied the operation of a grid-connected solar inverter. Two main control problems have been investigated; the control is the output from the PV panel such that using the closed loop path form the control systems. Based on the simulation, after that if it was made constant the inputs in that solar panel using the MPPT technique the second kind of control which we could perform is the control of output power from the inverter. So, by using these both control techniques the output power could be maintained constant and could meet the load demand by maintaining the required power quality and the reliability on renewable energy sources can be improved.

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