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# GRID IMPACT STUDY OF MICRO-GRID WITH AN IMPROVED TRANSIENT RESPONSE USING PV PANEL IN MATLAB-SIMULINK

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**ABSTRACT**:

The paper present a system that convert a power generated from a renewable resources to a source having same voltage and frequency with respect to traditional power plant. As the conventional fossil fuel resources such as Coal, Diesel, Gas etc is limited in quantity which will run out very soon. Hence all the researchers throughout the world are looking for alternative form of energy[1]. As a consequence the penetration of WIND & PV – generated electrical energy into the grid system is increasing exponentially worldwide [2]. The paper consist of PV array, boost converter, 3phase VSC Inverter, synchronous generator and utility grid. PV system has low conversion efficiency, so to improve conversion efficiency it is important for PV system to work always at its maximum power point. Maximum Power Point Tracker (MPPT) control technique is used to get maximum power as possible [3]. The voltage source inverter interface with grid and transfer an energy drawn from PV array to the grid by keeping the common voltage & frequency constant. The simulation results such as voltage, current, output power for each various combination have been recorded. The simulation has been accomplished in a Software of MATLAB Math Works.

***KEYWORDS***: *PV Panel, Boost Converter, MPPT, P&O, DFIG, 3 Phase VSC.*

## I. INTRODUCTION

In the last few years renewable energy have experienced one of the largest growth areas worldwide in percentage of over 30% per year, Compared with a growth of coal and lignite energy.

The goal of European Union community (EU) is to reach 20% in 2020, but the EU-27 energy share is only 17% of world energy. The US, with 22% of energy share, has adopted similar goals under the pressure of public opinion concerned by environmental problems and in order to overcome the economical crisis. However, the policies of Asia and Pacific countries, with 35 % of energy share, will probably be more important in the future energy scenario. In fact countries like China and India require continuously more energy (China energy share hasincreased 1 point every year from 2000).

The need for more energy of the emerging countries and the environmental concerns of the US and the EUincreases the importance of renewable energy sources in the future energy scenario.

## II. INTRODUCTION TO PV PANEL IN MICRO GRID

**SOLAR CELL :** A **solar cell** [4] or **photovoltaic cell**, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or anartificial light.

### Modelling of Solar Cell in Matlab

The terminal equation of current [5] & voltage of the PV - array is given by,

$$I = N_p I_{PH} - N_p I_S [\exp( q(V/N_S + IR_s/N_p) /KT_c A)-1]-(N_pV/ N_s + IR_s) /R_{SH}$$

The parameters along with the values used in modeling the PV Array are given

| Symbol | Parameter | Value |
|---|---|---|
| v | solar cell output voltage | 21.8 |
| IpH | Photocurrent | 1.866 |
| Is | cell saturation current | 4.215e-08 |
| q | electron charge | 1.6 X10 $^{-19}$ c |
| k | Boltzmann's constant | 1.38 X10 $^{-23}$ J/K |
| TC | cell's working temperature | 298 K |
| A | ideal factor | 1.3 |
| RSH | shunt resistance | |
| RS | series resistance | 0.45 |
| ISC | cell's short-circuit current ata 25°C and 1kW/m$^2$ | 3.11 |
| NP | number of solar cells in parallel | 1 |
| Ns | number of solar cells in series | 36 |

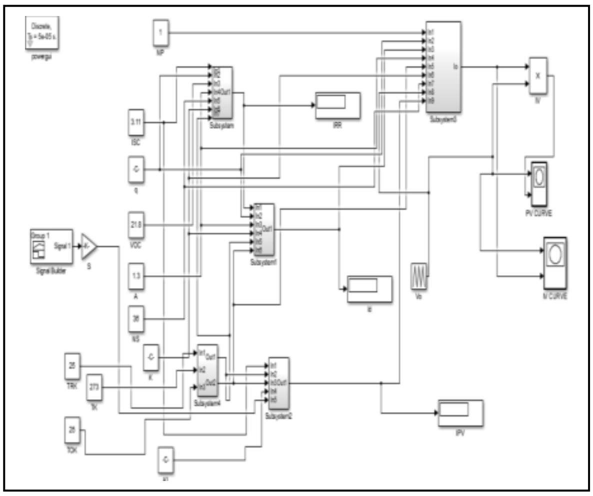


Figure1: Simulink model of PV panel with varying irradiance If there is a change in environmental condition [6] than the solar irradiation also changes :

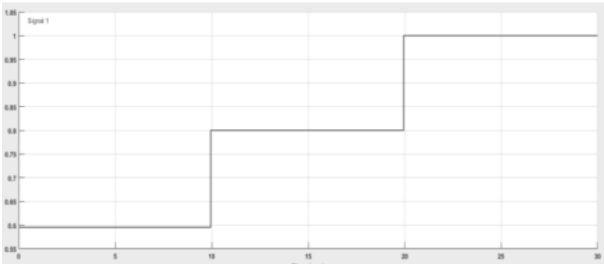


Figure 2: plot of irradiance with respect to time

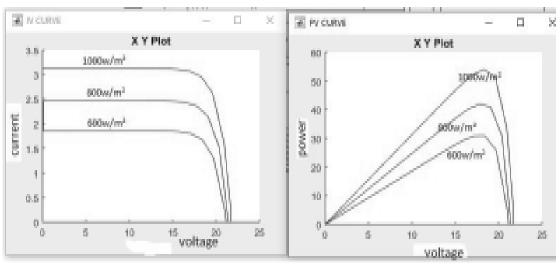



Figure 3: IV & PV Characteristics of PV array

## III. MAXIMUM POWER POINT TRACKING

The maximum power point tracking (MPPT) [7] method consider is to automatically find the current IMPP or voltage VMPP at which a PV array should work to extract the maximum output power PMPP under a given temperature and irradiance. Most of MPPT methods respond to variations in both irradiance and temperature, but some are precisely more useful if temperature is approximately constant. There are different MPPT algorithms [8] [9] and among these Techniques, the Incremental conductance algorithms and the P&O Algorithms are generally used. In this project Incremental Conductance method is used because of several advantages Over the other such as:

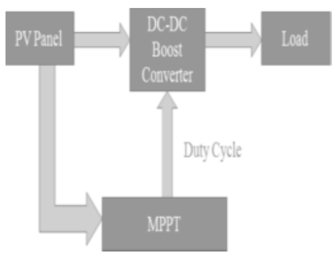



Figure 4: circuit arrangement for mppt

- Incremental method can calculate the direction, for which the array's point changed in order to reach the MPP.
- Incremental method does not go on the wrong direction when conditions in system changes rapidly.

This method exploits the assumption of the ratio of change in Instantaneous conductance is equal to the negative of output Conductance,

We have, P = V I

Applying the chain rule for the derivative of products yields to

∂P/∂V = [∂(VI)]/ ∂V

At MPP, as ∂P/∂V=0; Hence ∂I/∂V = - I/V

The MPPT regulates the PWM control signal of thedc – to – dc boost converter until the condition:

(∂I/∂V) + (I/V) = 0 is satisfied. In this method the peakthe peak power of the module lies at above 98%

of its incremental conductance

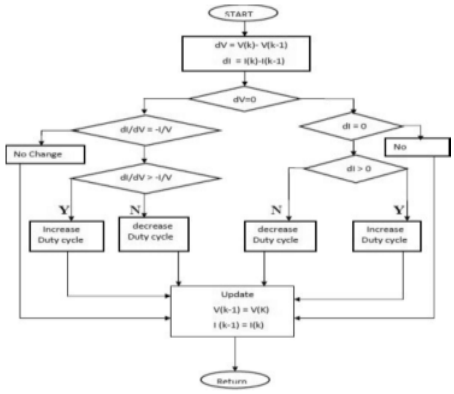



Figure 5 : Flow chart for Incremental Conductance

## IV. BOOST CONVERTER

A boost converter [10] is shown in Fig. 1. Only a switch is shown, for which a device belonging to transistor family is generally used. Also, a diode is used in series with the load.

The inductance of the load is small. An inductance, L is assumed in series with the input supply.

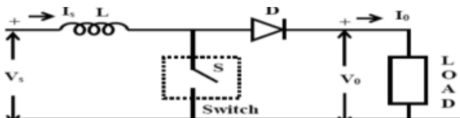



Figure 6 : Boost Converter

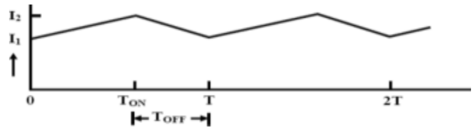



Figure 7: Waveform of source current

**Mode of Operation**

Mode-1 (charging )

In this mode switch, S (i.e, the device) is turned ON during the period, $T_{ON} \geq t \geq 0$ , the ON period being $T_{ON}$ .The output voltage is zero ($V_O = 0$), if no battery (back emf) is connected in series with the load, and also as stated earlier, the load inductance is small. The current from the source ( $I_S$ ) flows in the inductance L. The value of current increases linearly with time in this interval, with (di/dt) being positive. As the current through L increases, the polarity of the induced emf is taken as say, positive, the left hand side of L being +ve. The equation for the circuit is,

$V_S = L \frac{dI_S}{dt}$ or, $\frac{dI_S}{dt} = \frac{V_S}{L}$

Mode – 2 (discharging) :

The switch, S is put OFF during the period, $T \geq t \geq T_{ON}$ , the OFF period being $T_{OFF} = T - T_{ON}$.

($T = T_{ON} + T_{OFF}$) is the time period. As the current through L decreases, with its direction being in the same

direction as shown (same as in the earlier case), the induced EMF reverses, the left hand side of L being -ve. So, the induced emf (taken as –ve in the equation given later) is added with the supply voltage, being of the same polarity, thus, keeping the current ($I_O = I_S$) in the same direction. The current ($I_s = I_o$) decreases linearly with time interval , $T_{OFF}$ , as the output voltage is assumed to be nearly constant at $V_o \approx V_0$, ($di_s/dt$) being negative as $V_s < V_o$ , which is derived as

The equation for the circuit is

$$V_S = V_0 + L\frac{dI_S}{dt} \quad \text{or,} \quad \frac{dI_S}{dt} = \frac{V_S - V_0}{L}$$

From mode1 & mode2 the average value of the output voltage is

$$V_0 = V_s\left(\frac{1}{1-K}\right)$$

Where K is the duty ratio, $k = \frac{T_{ON}}{T}$ ; with its range as $1 \geq k \geq 0$. The output voltage is always output voltage for solar panel the value of duty ratio is ratio is higher than the input voltage, So, this is called boost converter .The source current is assumed to be continuous.

**Mathematical Calculation**

From the mppt plot of input and for solar panel the value of duty

Vs = 273 ; Vo = 500 volt

$$K = \frac{(V_0 - V_S)}{V_0} = \frac{(500-273)}{500} = \frac{227}{500} = 0.454$$

## V. INVERTER

A device that converts dc power into an ac power at a desired output voltage and frequency is called an [11] inverter. Some industrial application of inverter [12] are for adjustable-speed ac drives, induction heating,stand by air-craft power supplies, UPS for computer, HVDC transmission line etc.

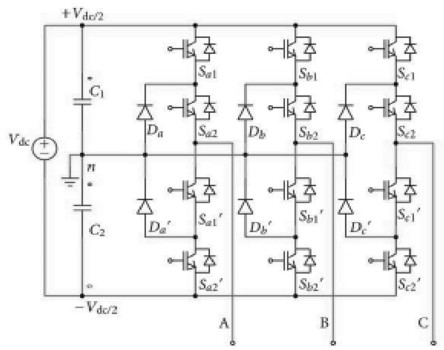


Figure 8: 3 level IGBT inverter

The chapter provides an overview on neutral point clamped three level inverter (3-level bridge inverter[13] of selected force commutated power electronic device. Series RC snubber circuit are connected in parallel with each switch device, As capacitor ($C_S$ ) in parallel with the device is sufficient to prevent unwanted (dv/dt) triggering of switches. The inverter comprise of 3 arms for three phases.

**Switching states**

Switching states that are shown in table1, can represents the operating status of the switches in the three-level NPC inverter. When switching state is '1', it is indicated that upper two switches in leg A connected and the inverter terminal voltage VAn volts , which means the voltage for terminal A with respect to the neutral point n , is +E, whereas '-1'denotes that the lower two switches are on, which means VAn volts = -E . When switching state '0', it indicates that the inner two switches S2 and S3 are connected and VAn = 0v through the clamping diode, depending on the direction of the load current iA. When Dn1 is turn on, the load current will be positive ( iA>0) and the terminal A will be connected to the neutral point 'n' through the conduction of Dz1 and S2 . Table shows switching status for leg A. Leg B and leg C have the same concept.

| Switching states | Device switching status (phase A) | | | | Inverter Terminal Voltage ($V_{AZ}$) |
|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | |
| 1 | ON | ON | OFF | OFF | E |
| 0 | OFF | ON | ON | OFF | 0 |
| -1 | OFF | OFF | ON | ON | -E |

Table 1: Definition of switching states

**Mathematical Calculation:**

The RMS value of line to line output voltage of 3 a level voltage source controller is given by :VLL _vsc = ( m * Vdc * 0.6124) volts

Where,

$$M = \text{modulation index} = \frac{peak\ value\ of\ carrier\ trangular\ wave\ (Vr)}{peak\ value\ of\ reference\ wave\ (Vc)}$$

From the the MATLAB simulation Vdc (input voltage to inverter) = 500 v

m = 0.84

Than by the help of equation 1 ; VLL _ vsc = 0.82 * 500 * 0.6124 = 251.208 volts

Graphical Plot

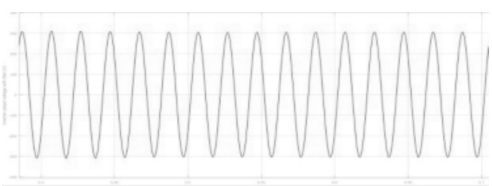


Figure 9: Inverter output voltage with filter

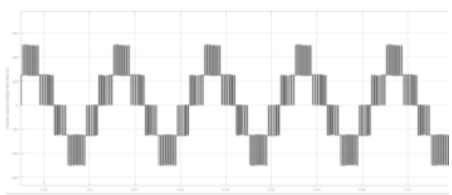


Figure 10 : Inverter output voltage without filter

## VI. CONCEPT OF FILTER

The use of inverter with output LC filter[14] allows for generation of out pot sinusoidal voltage with lowharmonic distortion, suitable for uninterruptible power supply system.

In this paper application of LC filter to a grid of (25 kv) fed by 3 level inverter of with switching frequencybelow 2000 Hz is described.

The PWM VSI offer at it terminal output voltage waveform which are closer to rectangular. This waveformcauses several problem on the load (motor) and cable such as :

1. The 1st one is voltage spikes on the motor terminals caused by (dv/dt ) during switching transition. This (dv/dt) of the inverter output voltage causes reflection on the cable which may cause the motor terminal voltage to see double the voltage step. This phenomena depends on the cable length. The critical cable length for 500v/µsec is 100m range, for 1000v/µsec in the 50m range, for 10,000v/µsec in the 5m range.

2.

**Filter Design :** To get sine waveform, the resonance frequency[15] of the filter has to be well below the lowest harmonic frequency of the inverter voltage resulting

from PWM. The resonance frequency helps in calculatingdamping and stability. It can be found by the product of

L and C

**3. Mathematical Calculation:**

$$\omega_r = \frac{1}{\sqrt{LC}}$$

4. If L = 1 mH

4. C = 100 µF

5. $r = \frac{1}{\sqrt{(1*e-3)*(100*e-6)}}$ = 3162.27 Hz

Harmonic analysis of inverter with filter

THD Comparison :

| No | Output Voltage (%THD ) Without Filter | Output Voltage (%THD ) With Filter |
|---|---|---|
| 1 | 46.29 | |
| 2 | | 0.46 |

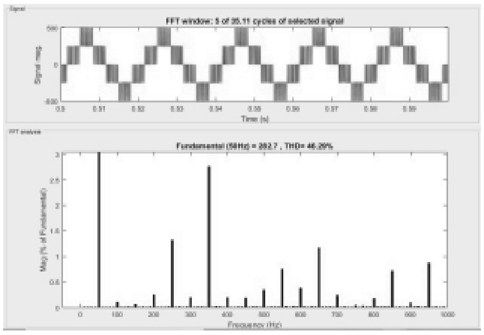


Figure11 : Plot of harmonic on output voltage without Filter

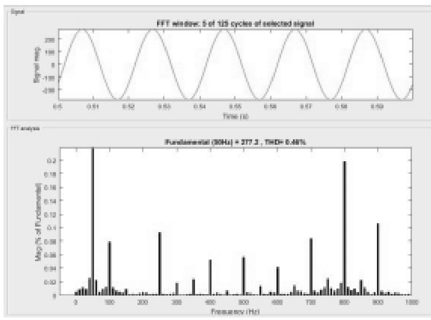


Figure12 : harmonic on output voltage with Filter

## VII. CONTROL STRATEGY

A supply system with large no of synchronous machine connected in parallel is referred as grid. Any additional machine, whether to operate as source (generator, pv array, wind etc) or load (motor) is connected in parallel with bus bar.

The important requirement for a grid are

1. frequency should be same
2. phase angle should be constant and the
3. magnitude of voltage are not affected even if there is a variation excitation or power of a synchronousmachine connected to it.

To meet the above condition a control system is needed.

Since solar energy ia always varying and dynamic in nature so MPPT controller extracts maximum power from PV panel, than on passing through Boost converter it acts as input to an inverter.This input is fed to the [16] Inverter control system which maintain the dc link voltage of the inverter constant. This dc link voltage [17] is treated as reference voltage for the PI controller of $V_{DC}$ Regulator.

To control the grid voltage and current, Phase Lock Loop (PLL) and current regulator is used. In this control topology the sinusoid three phase measured value of voltage and current of a grid is first converted to stationary dqo frame of reference called park's transformation before feeding to PID controller

**Park's Transformation ( abc to dqo)**

Park's transformation uses frame of reference on the rotor. Robert H Park (1902-1994) derived this for a synchronous machine and so this is the same as a synchronous frame of reference. For an induction machine it is important to distinguish between a synchronous reference frame and a reference frame on the rotor. In the 3 phase system all the phases are 120 ° electrically spaced. For Park's the Transformation is in order :

abc >> αβ >> dqo

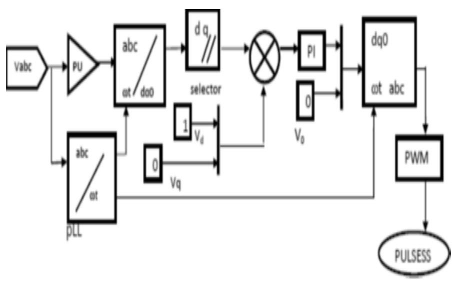



Figure 13: Control Topology of Voltage

i.e. (a b c) is first transformed into 2 phase stationary frame

α β) than to (d q o) reference frame which rotates atsynchronous speed.

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} \cos\theta & \cos(\theta-120) & \cos(\theta+120) \\ \sin\theta & \sin(\theta-120) & \sin(\theta+120) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} * \begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix}$$

$$\begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120) & \sin(\theta-120) & 1 \\ \cos(\theta+120) & \sin(\theta+120) & 1 \end{bmatrix} * \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

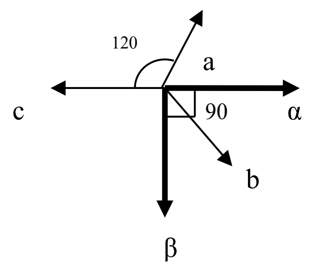



Figure 14: abc to αβ reference frame

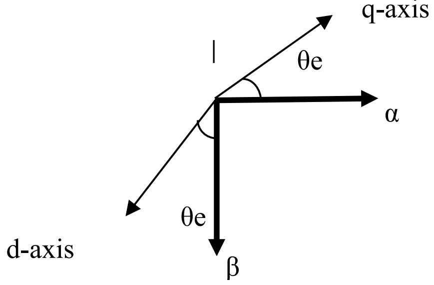



Figure 15 : α-β to d-q reference frame

## VII SIMULATION AND RESULTS

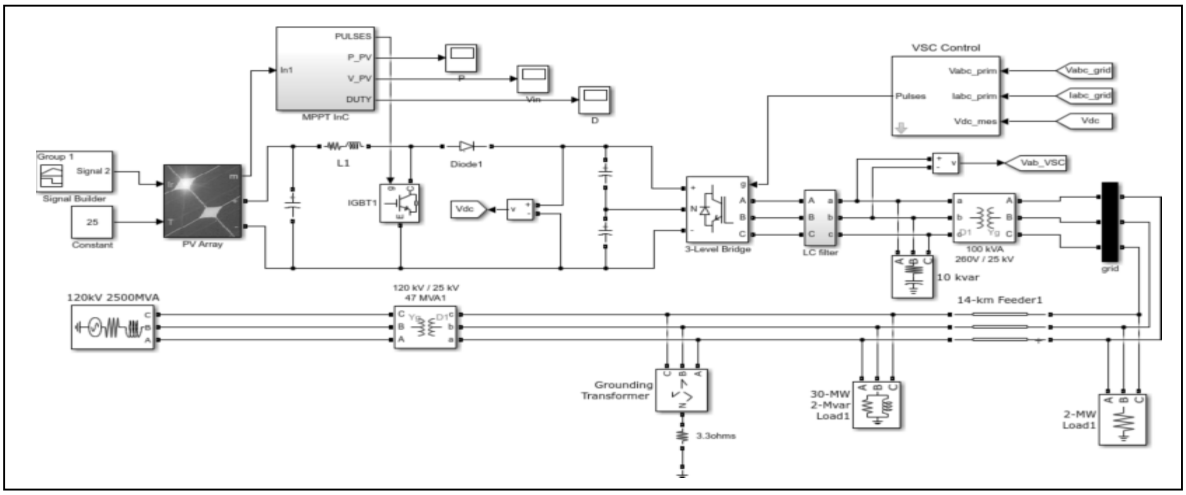



Figure 16 : Simulink model of a 100 KW solar panel connected to a grid

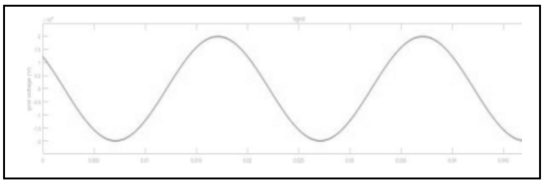


Figure 17: grid voltage connected to PV

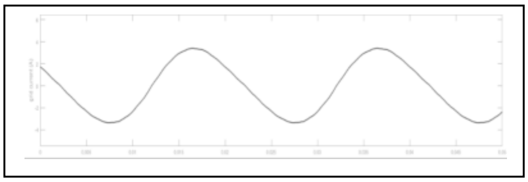


Figure 18: grid current supplied by PV Panel

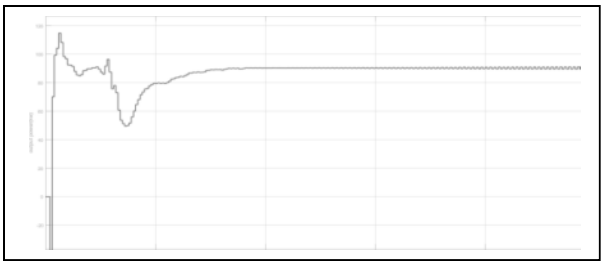


Figure 19: Inverter output power

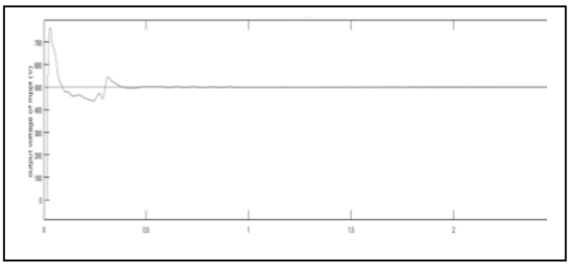
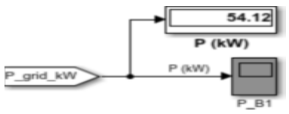
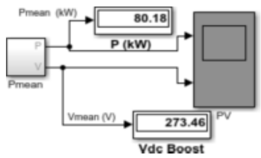


Figure 20`: Boost Output Voltage

**CONCLUSION**



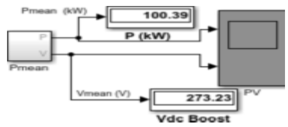




Fig21: Input power at 600 W/m$^2$ Fig22: Input power at 800 W/m$^2$ Fig23: Input power at 1000 W/m$^2$

According to the table, there is very slight Change in solar voltage and duty ratio with the change in Irradiance, therefore we can conclude MPPT is working successfully. The terminal voltage of solar panel is unaffected by varying photon power; only the power supplied by the solar panel changes.

Table 1 Duty Ratio

| S. No | Irradiances (Watt/metre$^2$) | Solar Voltage (Volts) | DC Voltage (Volts) | Duty ratio | Solar Power (Kilo watt) |
|---|---|---|---|---|---|
| 1. | 600 | 272.25 | 500 | 0.455 | 59.88 |
| 2. | 800 | 273.46 | 500 | 0.45308 | 80.18 |
| 3. | 1000 | 273.23 | 500 | 0.45354 | 100.39 |

As a result we are able to regulate the grid voltage with improved transient response regardless of the Irradiation.

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