

## Power Quality Improvement Under Linear and Non-Linear Load Conditions with Solar PV System with PnO Technique

Vishnu Kumar Jabdoliya<sup>1</sup>, Kapil Dev Kansal<sup>2</sup>  
(Department of Electrical Engineering, Jaipur Institute of Technology, India)

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**Abstract:** As per the increasing demand of power government and private sector are getting more focused on non-conventional energy sources. Solar and Wind are major among these sources. Solar power is used in this proposed work as energy source from Sun. various recent research are going on and continuous growth is observed in the area of power generation from solar energy as India have targeted 37.5 GW power generation in 2020.

Practical conditions considered for the proposed system are:

- 1) Variable irradiation for solar PV system
- 2) Proper MPPT controllers for Converters
- 3) Grid Connection
- 4) Linear and non-linear load configuration

In this thesis the major problem of power quality, that need to improve in every system of solar as it is variable in nature. The system of 33kW solar PV system with variable irradiation situation is used for power generation source. As system components Boost converter, maximum power tracking system, DC-AC converter, load and grid is connected. For specifically power quality improvement for practical conditions it is taken as variable irradiations and load are also taken as linear and non-linear. The system is connecting to normal grid system. As far as variability of irradiation it is needed to measure maximum power point (MPPT) for better results, for this purpose the technique used in PnO controllers. The analysis for power quality will focus of parameter as voltage, current and power of source i.e solar PV and grid. Further analysis of boost converter and MPPT controllers' voltage and current. Variation of same parameters also observed for both linear and non-linear loads.

**Key Word** :non-conventional; solar power; irradiation; PV system; MPPT; Converter; Grid

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### I. Introduction

Now a day's demand of electrical power is increasing exponentially. To fulfill this demand various power resources are used, which are classified into two major types as conventional and non-conventional. Non-conventional energy can be further classified as solar energy, wind energy, bio-fuels sources, geothermal energy, tidal energy, hydro power etc. The total power installation in the country India is 308834.28 MW (approx.), from which 45916.95 MW is derived from renewable sources (RS); it is 14.86% of whole generation. Power derived from the solar energy is 8513.23 MW which is again 18.54 percent of the total RS up till November 2018. Solar and wind energy are major resources in this era. To obtain maximum energy from these resources is important aspect to be considered. Researchers are working to find out the new techniques to obtain optimized process and utilize maximum energy from these incredible resources.

The techniques introduced by various authors in solar energy. The most applicable techniques are FLC (Fuzzy Logic Controller), MPPT (Maximum Power Point Tracking), PID controller and ANN (Artificial Neural Network). FLC, MPPT and PID controllers are majorly put to use in controlling as well as optimizing the power generated by solar energy. These techniques can be implemented as per requirement and conditions of getting output. For power storage, batteries are used and for battery management system these techniques frequently used with control systems. Understanding of appropriate technique for particular system is very important to gain maximum output from running system.

As per classification on the basis of control technique, there are three types. These are direct, indirect and probabilistic methods. There are direct methods, which include differentiation perturb along with observing feedback voltage and incremental conductance, fuzzy logic and neural network. This dissertation focuses on the comparison between fuzzy logic controller and PID controllers to manage battery charging and discharging process.

### Importance of Renewable Resources

Nature has conveyed vitality over its various sources. Extensively, these wellsprings of vitality can be named, sustainable and non-inexhaustible wellsprings of vitality. The huge thickness of vitality put away in sustainable structure has pulled in more consideration than that with non-inexhaustible ones. An Earth-wide temperature boost and air contamination have recently turned out to be not kidding issues around the world. These are brought about by the arrival of ozone harming substances and fumes vapor, the volumes of which develop constantly by virtue of rising vitality needs. Then again, our stores of petroleum products keep on diminishing. The weariness of Fossil fuel and issues of an Earth-wide temperature boost that are brought about by customary power age has lead us to turn towards the ceaseless sustainable power sources (RES) than any time in recent memory in the previous years.

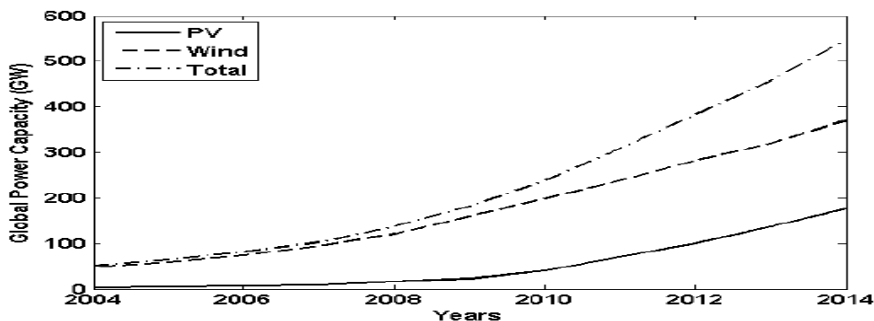


Fig. 1. Growth of Global Power Capacity of Wind and Solar Resources

Sustainable power source (RE) sources are turning into an inexorably significant piece of our capacity age as the valuable stores of non-renewable energy sources are drawing nearer to exhaustion. Out of the accessible Renewable Energy innovations, wind vitality and sun based vitality sources appear as the most satisfying choices, as they are pervasive, accessible free of expense, and condition well disposed. Natural and financial advantages identified with the decrease of both carbon dioxide outflow and transmission misfortunes have made disseminated sustainable age frameworks turned into an aggressive arrangement.

Sustainable power sources appear to be a satisfying vitality source so as to manufacture an economical and eco-accommodating vitality economy in the coming decade. Photovoltaic (PV) boards and wind generators are essential sprinters, among the inexhaustible assets. RES have the advantages of being common and contamination free, however their upkeep and taking care of expenses are high.

Vitality the executives must be increasingly solid and productive in "brilliant" urban areas, for us just as for children. A shrewd city coordinates and upgrades a lot of reliant open and private frameworks to accomplish a superior degree of adequacy and productivity. These frameworks incorporate vitality, water, transportation, social insurance, legislative administrations, open wellbeing, training, and data and correspondence innovation (ICT) frameworks. A smart city should be viewed as a "system of systems."

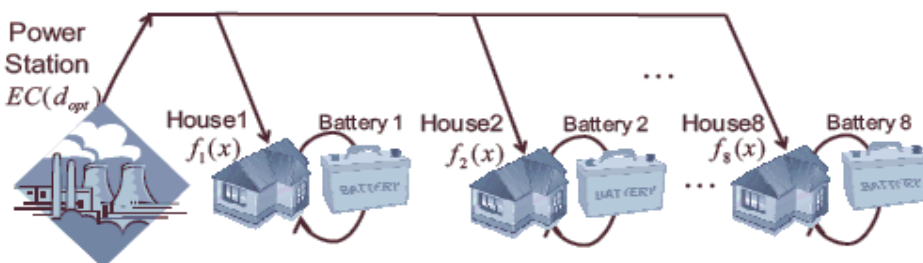


Fig. 2. Basic model of a smart city

Notwithstanding, the sun based breeze vitality yield is influenced by the geographic and occasional climatic conditions. Henceforth, there is a requirement for a reinforcement control framework to improve the unwavering quality of the vitality supply. Despite the fact that, there is an improvement in these innovations, the downsides remain the principle hindrances to their usage, which are significantly their discontinuous nature and high capital expense. There is a dynamic cooperation between the heap request and the sustainable power source that can prompt vital issues of intensity quality and soundness. In this manner, it is basic to deal with the progression of vitality all through the mixture framework so as to expand the working existence of the layer and to ensure there is a nonstop vitality stream.

into electric flows. PV cells are ordinarily comprised of silicon. They come in two assortments in particular crystalline and dainty film type. The acquired PV cell yield voltage is a component of the photocurrent, which is for the most part controlled by the heap current and furthermore relies upon the sun powered light level that is seen during the activity.

Any autonomous sunlight based cell control framework charges the battery from the sun oriented cells in the daytime and supplies control from the battery to a heap during the evening. Customary frameworks played out this switchover strategy by checking the battery voltage consistently and legitimately yielding location flag there from by a control circuit. To screen the battery activity status, be that as it may, an upkeep capacity is required to watch remaining

Energy collecting strategies are created for providing capacity to remote gadgets, for example, sensor hubs in a system which can't get steady power. In the remote circumstance, the gadgets ought to be self-sufficient and self-controlled with a vitality source. The vitality reaping produces electrical vitality from the encompassing condition or from sustainable sources, for example, sun oriented, wind, vibration, or warm vitality, along these lines the gadgets work for a more extended lifetime with the enhancements of the created vitality. The greatest power point following (MPPT) system can be utilized to acquire the most extreme power from a vitality reaping gadget. It keeps up the working voltage of the reaping gadget to most extreme power point so the collecting gadget produces vitality with greatest power. The yield control  $P_o$  and the voltage of most extreme power  $V_{opt}$  are determined and got beneath from the model:

$$P_o = V_o \times [(V_{oc} - V_o) / R_s]$$

$$V_{opt} = (1/2) V_{oc}$$

Electric vehicles (EV) use batteries as the main energy storage components. They are sized to provide the required power along with the energy demand of the car. This leads to an over sizing of the batteries in order to deliver high power and to avoid unwanted degradation due to acceleration and braking. An ultra-capacitor (UC)-based hybrid energy storage system (HESS) is suggested and researched in order to improve the battery lifetime.

## II. Solar Cell Modelling

The ideal equivalent circuit of voltage gain using solar irradiation is designed as current source connected in parallel to diode and shunt resistance as shown in fig.3.

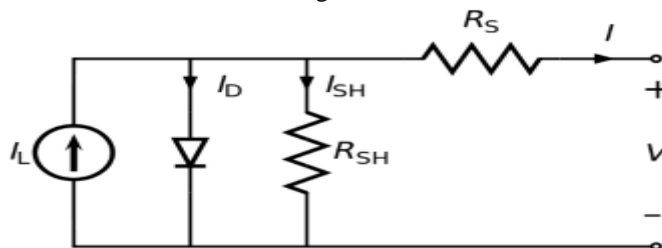


Fig.3. Equivalent circuit of solar PV cell

Relation between current and voltage characterized in the below equation, which is calculated from fig.3.

$$I = n_p I_{ph} - n_p I_{sc} \left[ e^{\left( \left( \frac{q}{kT} \right) \left( \frac{V}{n_s + IR_s} \right) \right)} - 1 \right]$$

The photovoltaic current is dependent on its temperature and solar insulation, is given as-

$$I_{ph} = \left[ (I_{sc} + k_i (T - T_r)) \times \frac{S}{1000} \right]$$

Similarly the saturation current is represented as:

$$I_{sc} = I_{rsc} \left( \frac{T}{T_r} \right)^3 e^{\left( \frac{q E_{gap}}{kA} \right) \left( \frac{1}{T_r} - \frac{1}{T} \right)}$$

Where

$N_p$  = number of cells connected in parallel

$N_s$  = number of cells connected in series

**Maximum Power Point Tracking (MPPT)**

Ordinarily a sun based board can change over just 30-40% of the all-out occurrence sun based light into electrical vitality. Greatest Power Point Tracking (MPPT) is utilized to improve the effectiveness of a specific sun based board. Most extreme Power Point Tracking (MPPT) is a calculation that is utilized to separate greatest force from PV under explicit conditions. Most extreme intensity of a PV board relies upon variables, for example, sun powered light, surrounding temperature and cell temperature. Typically, a PV module produces most extreme force voltage at cell temperature of 25°C. Anyway relying upon outside temperature it can fall or rise. MPPT checks the yield of a specific PV board and in the wake of contrasting it and battery voltage chooses the most effective voltage for example greatest force point voltage. The reason for a MPPT framework is applying legitimate opposition in the wake of inspecting yield of PV cell so as to get greatest force.

MPPT is best in cooler conditions in light of the fact that PV module works better at cold temperatures. It is additionally extremely viable when the battery is profoundly released in light of the fact that progressively current can be removed under low charge conditions. MPPT gadgets are incorporated with power hardware making an electric force converter framework in type of sunlight based inverters which convert DC capacity to AC power.

**MPPT Techniques**

There are various strategies used to follow the most extreme force point, for example,

1. **Perturb and observe**(slope climbing strategy)
2. Gradual Conductance strategy
3. Current breadth
4. Consistent voltage
5. Fuzzy Logic Control
6. Neural system

**Perturbation and Observation (slope climbing strategy)**

Annoy and watch is perhaps the most straightforward technique because of its lower estimation of time intricacy. This technique utilizes one voltage sensor which detects the PV voltage and measures power. On the off chance that force builds, the calculation is intended to accomplish consistent force. Be that as it may, this strategy can bring about motions of intensity yield on the grounds that the calculation keeps on irritating recursively much in the wake of coming to MPP. This can be illuminating by setting a blunder cutoff to end the recursion. It is anything but difficult to actualize and is known as slope climbing technique since it relies upon the ascent and fall of intensity versus voltage bend as for most extreme force point.

Algorithm of Perturbation and Observation

NOTE: The difference in obligation cycle must be done toward MPP.

- STEP-1: Instate beginning worth, most extreme worth, least estimation of obligation cycle and furthermore the augmentation incentive to expand/decline the obligation cycle.
- STEP-2: In the event that pace of progress in force and pace of progress in voltage both are negative, at that point obligation cycle must be diminished else on the off chance that pace of progress in voltage is sure, at that point obligation cycle must be expanded.
- STEP-3: On the off chance that pace of progress in power is sure however pace of progress in voltage is negative, at that point obligation cycle must be expanded else if pace of progress in voltage is certain, obligation cycle must be diminished.
- STEP-4: On the off chance that the obligation cycle esteem surpasses the greatest introduced esteem or is lesser than the base instated esteem, at that point the obligation cycle esteem must not be changed and it must be same as the past worth.
- STEP-5: The initial four stages ought to be rehashed that implies ought to be in for or while circle until Maximum Power point is reached.

**III. Result**

In this section of thesis simulation and design of proposed system of solar/PV with 33kW with linear and non-linear load connected and controlling through MPPT of PnO controller for power quality improvement is represented. Different parameters used and design in MATLAB are as below:

**Table 1. Solar/PV module Parameters**

Solar Parameter	
Parallel strings	9
Series-connected modules per string	17
Output Power	33kW
Module	1Soltech 1STH-220-P

Maximum Power (W)	218.871
Open circuit voltage Voc (V)	36.6
Voltage at maximum power point Vmp (V)	29.3
Temperature coefficient of Voc (%/deg.C)	-0.36101
Cells per module (Ncell)	60
Short-circuit current Isc (A)	7.97
Current at maximum power point Imp (A)	7.47
Temperature coefficient of Isc (%/deg.C)	0.10199
T_cell (deg. C)	[45 25]
Shunt resistance Rsh (ohms)	350.2415
Series resistance Rs (ohms)	0.38174

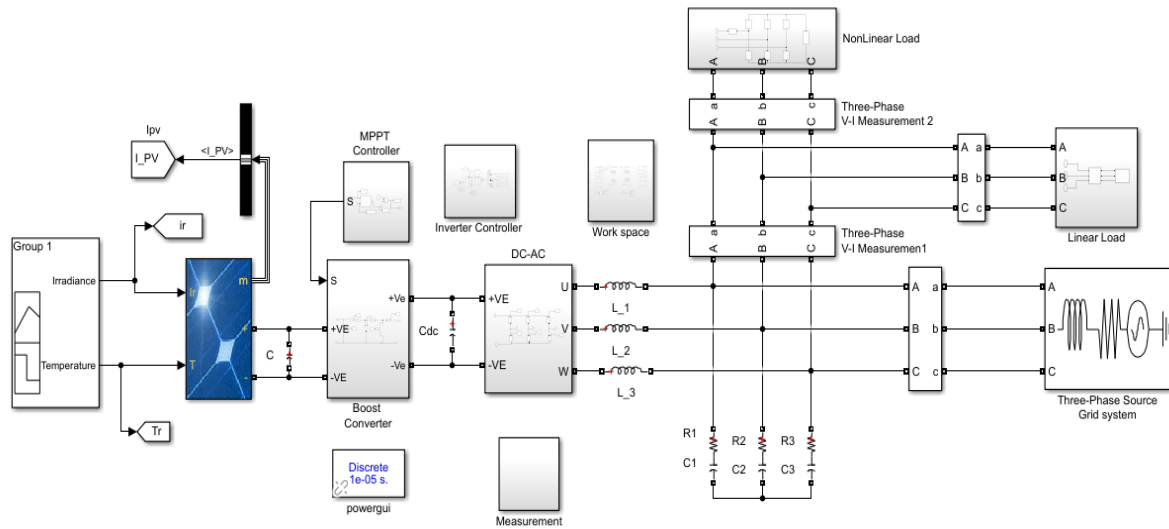


Fig.4. MATLAB model of proposed system

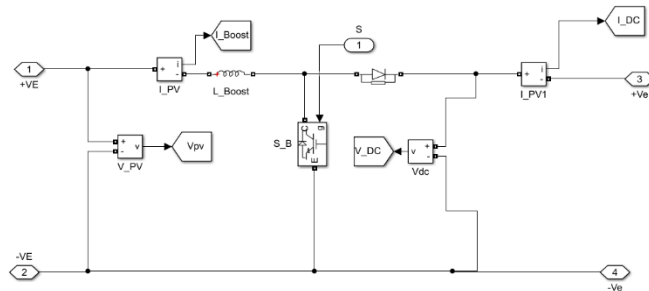


Fig. 5. Boost converter design in MATLAB

Fig.5 shows the boost converter design in MATLAB having  $L=4.5e-3$  H. The power of solar is the input for this boost converter with 33KW and it increases that power for three phase load.

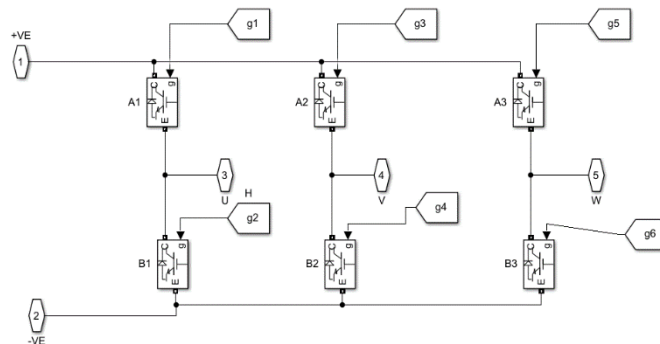
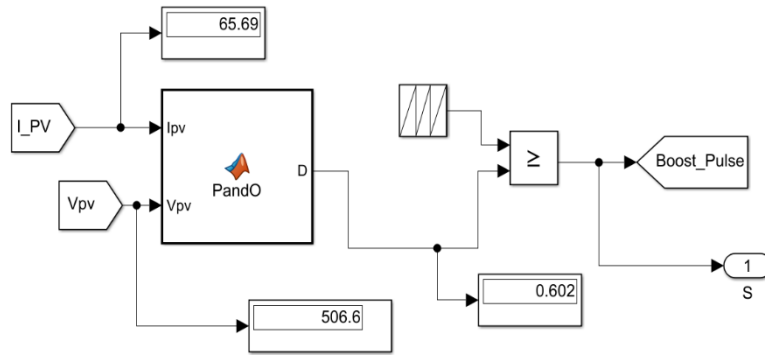


Fig.6. MATLAB design of DC-AC three phase converter

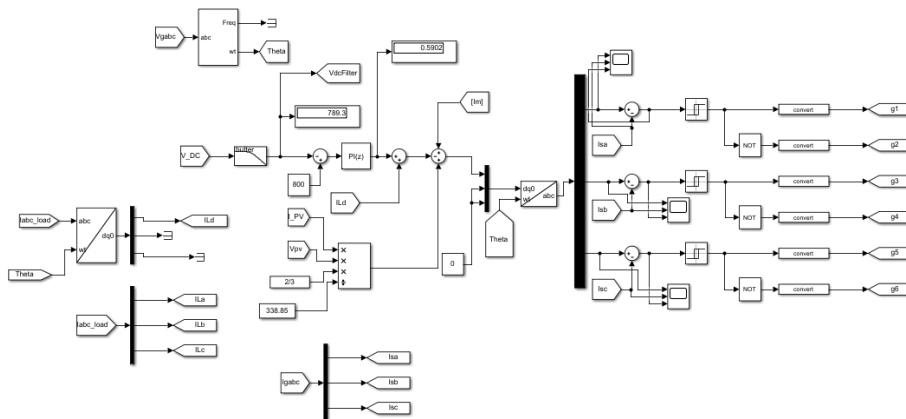
Fig.6. shows the DC-AC three phase converter and the input is from boost converter. IGBT/Diode are used for the design purpose



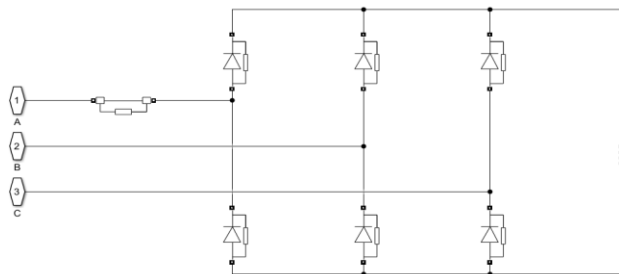
**Fig.7.** MPPT design for solar PV system for maximum power gain.

MPPT design for solar system for maximum power gain from solar system is shown in fig.7. in which PnO technique is used as controller. Inputs for which are solar voltage and current and it generated pulses for boost converter as per feedback.

Fig.8. represent the construction and design of inverter controller that the inputs are feedback from load voltage and current as feedback.

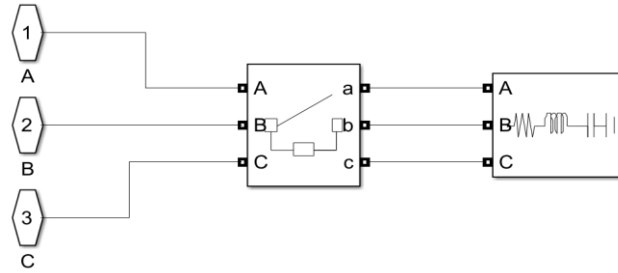


**Fig. 8.** DC-AC inverter controller design in MATLAB



**Fig.9.** Non-Linear load for the system

Non-Linear load connected to the power system is shown in fig 9. with diode and RL load of 50 ohm and 50e-3 H respectively



**Fig.10.** MATLAB design of linear load for system

Fig.10. shows the linear load configuration connected to the power system with three phase RLC load with following parameters:

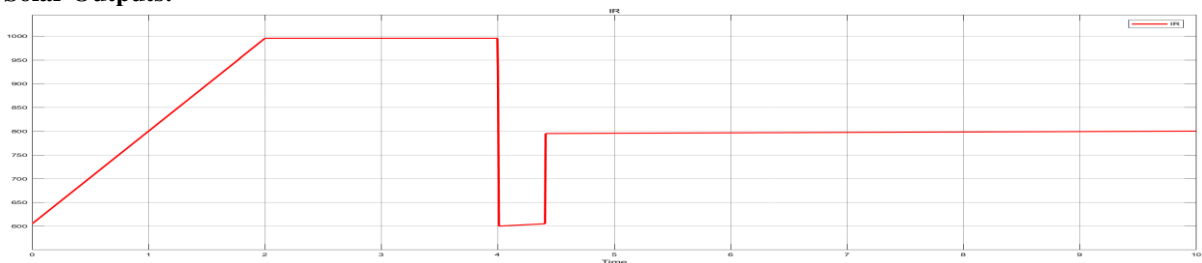
**Table.2.** Parameter configuration of Linear load

Configuration	Y (grounded)
Nominal phase-to-phase voltage $V_n$ (Vrms)	415
Nominal frequency $f_n$ (Hz):	50
Active power P (W):	5.00E+03
Inductive reactive power $Q_L$ (positive var):	100
Capacitive reactive power $Q_c$ (negative var):	100
Load type:	constant Z

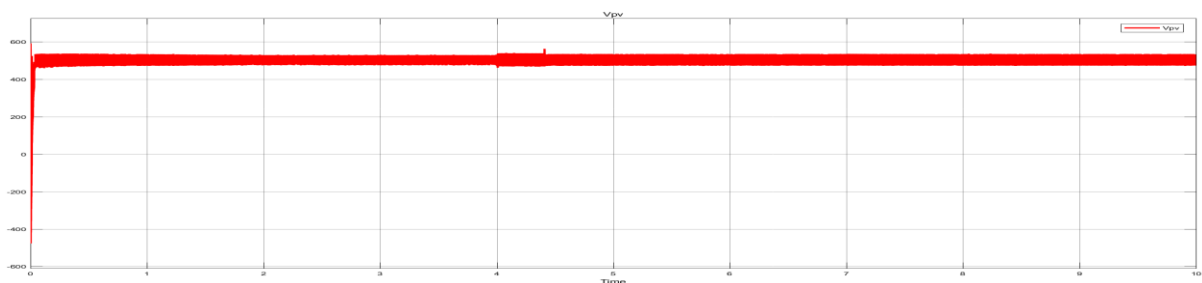
#### IV. Results and Analysis

Results and analysis of proposed work for solar output voltage, current and MPPT output power from boost converter. With linear and non-linear load power quality improvement graphs are represented in this chapter of thesis. Three sections are mentioned as Solar, MPPT boost and Load results.

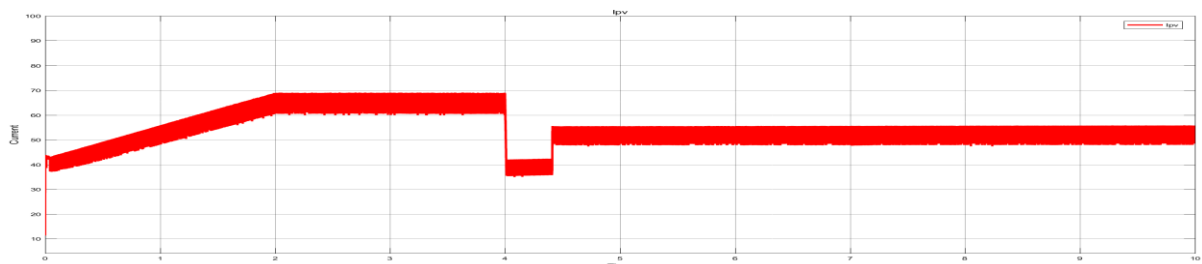
##### Solar Outputs:



**Fig.11.** Irradiation of Solar system



**Fig.12.** Output voltage of solar system



**Fig.13.** Output current of solar system

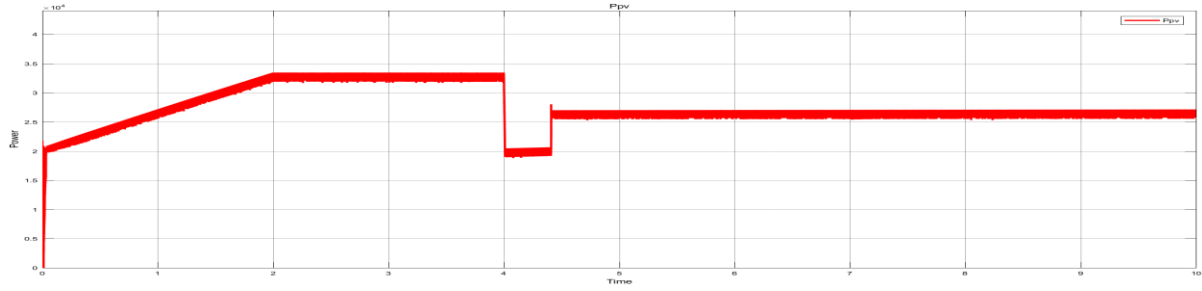


Fig.14. Output Power of solar system

MPPT Boost results.

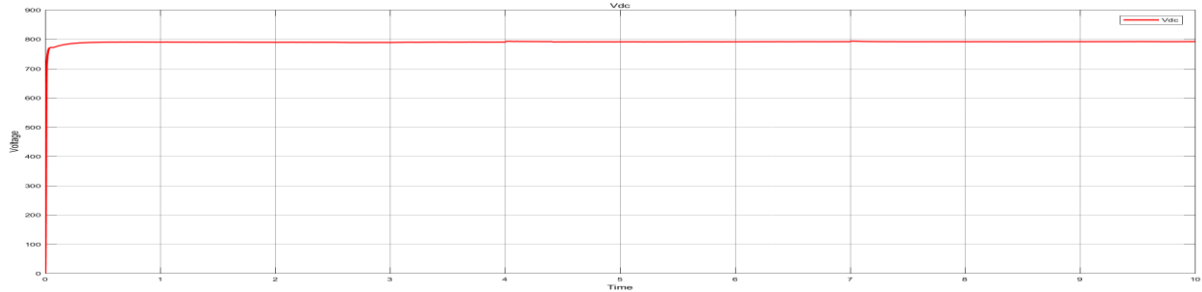


Fig.15. Output DC voltage of coupled capacitor

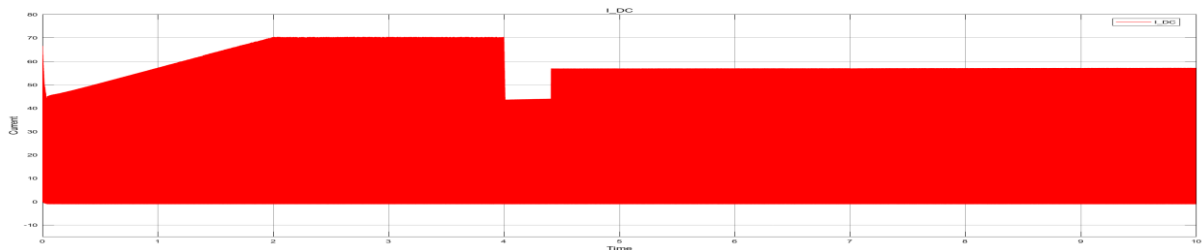


Fig.16. Output DC current of coupled capacitor

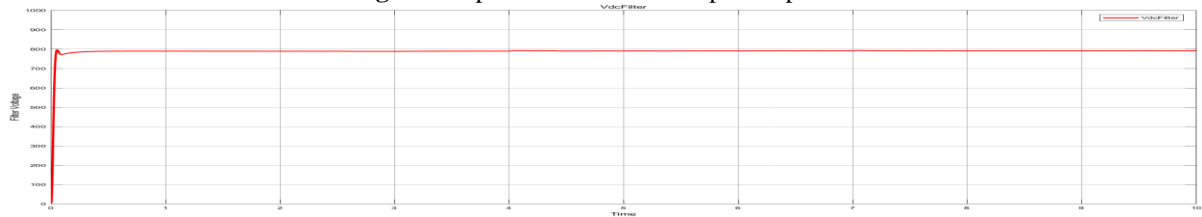


Fig.17. Output DC Filter voltage of coupled capacitor

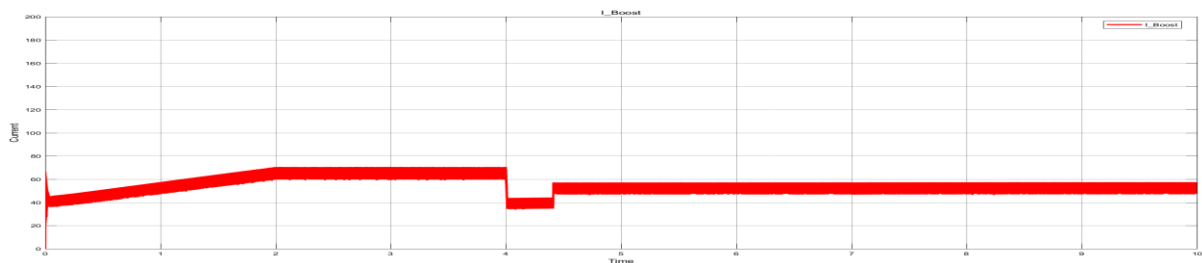


Fig.18. Output current of Boost converter



Load Outputs

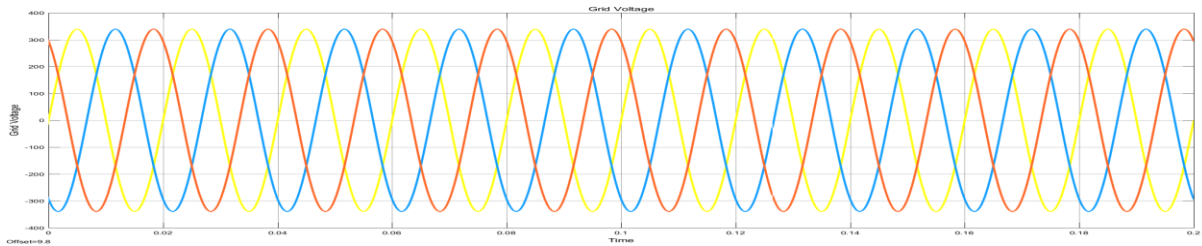


Fig.19. Output Voltage of connected Grid

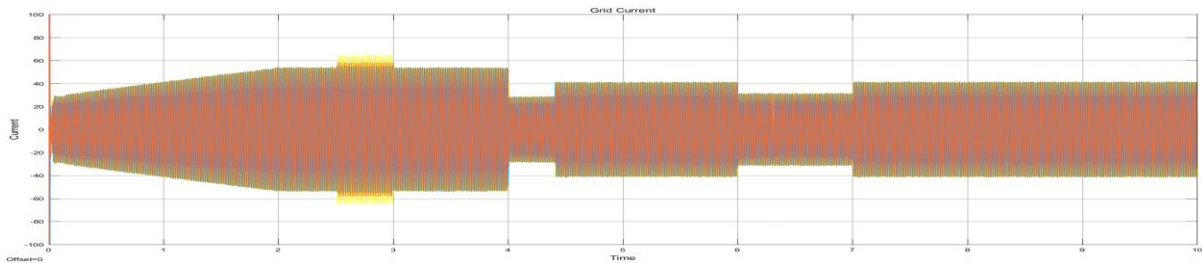


Fig.20. Output current of connected Grid

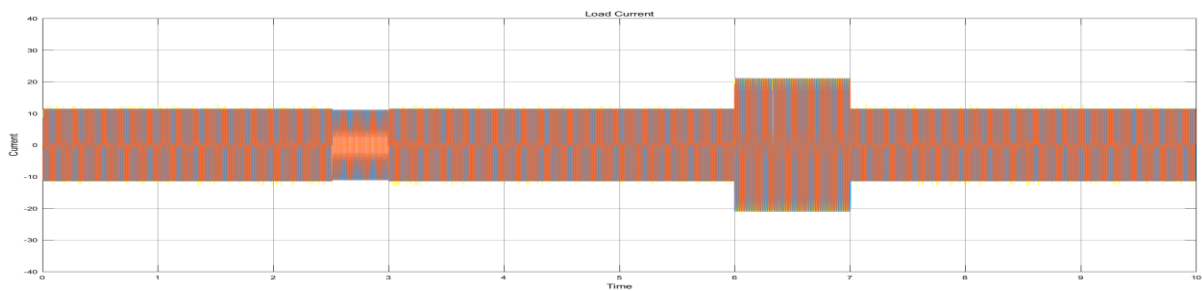


Fig.21. Output current of connected load

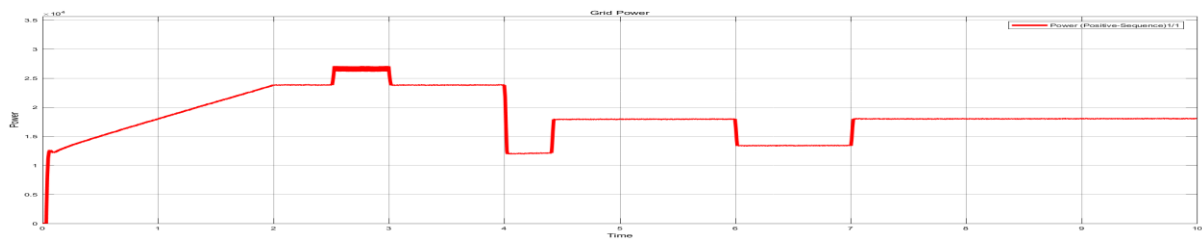


Fig.22. Output Power of connected Grid

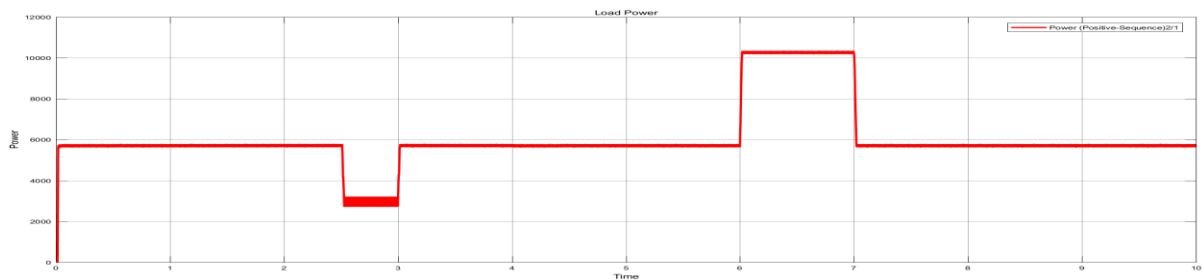


Fig.23. Output power of connected load

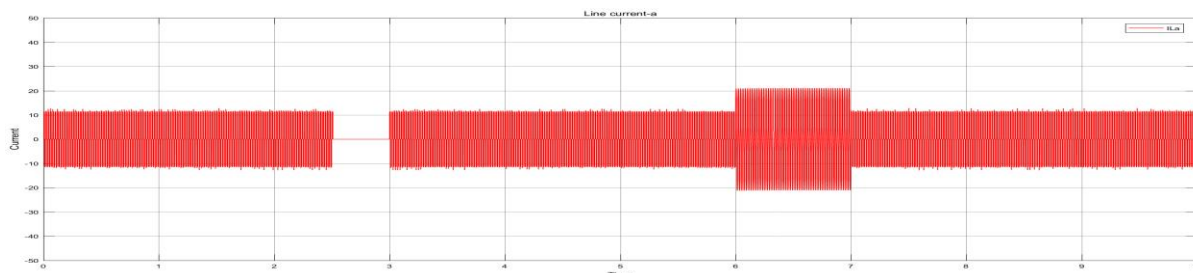


Fig.24. Output line current at load of line A

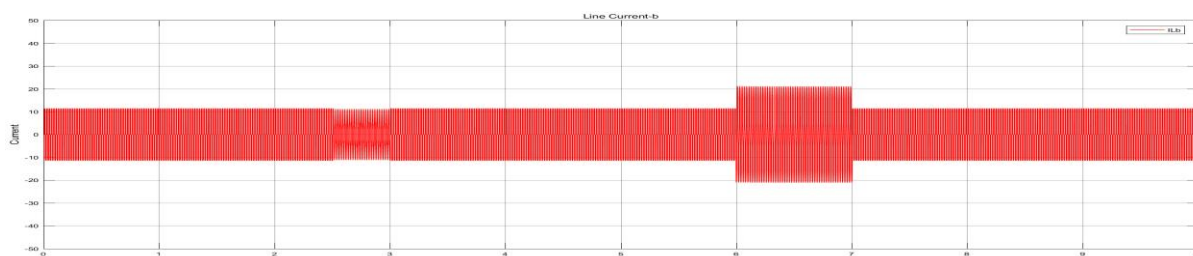


Fig.25. Output line current at load of line B

## V. Conclusion

Practical conditions considered for the proposed system as mentioned in abstract too are:

- 1) Variable irradiation for solar PV system (1000,800&600 W/m<sup>2</sup>)
- 2) Proper MPPT controllers for Converters (PnO technique)
- 3) Grid Connection
- 4) Linear and non-linear load configuration

The system of 33kW solar PV system with variable irradiation situation is used for power generation source. As system components Boost converter, maximum power tracking system, DC-AC converter, load and grid is connected.

For specifically power quality improvement for practical conditions it is taken as variable irradiancies and load are also taken as linear and non-linear. The system is connecting to normal grid system. As far as variability of irradiation it is needed to measure maximum power point (MPPT) for better results, for this purpose the technique used in PnO controllers.

The analysis for power quality shows that solar output voltage is 500 V(Fig.12), current varies as irradiation varies i.e. 68A/40A/53A for 1000/600/800 W/m<sup>2</sup> respectively (Fig.13). Whereas after boost converter this current will be 73A/42A/56A respectively (Fig.18). Solar power generated as per variable irradiation is 33/20/26 kW(Fig.14). The DC voltage is measured 780 V as shown in fig.15 and grid voltage is 330 V in fig.19. Active power measured in fig.22 is 27 kW/13 kW/18 kW and load power is 5800W in non-linear load configuration. The stability is seen by using PnO technique hence power quality also improved with lesser distortions.

**Future Scope:** This work can be extended by implementing more techniques for MPPT like Fuzzy logic and For more complex system Wind can be added for power generation with solar.

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