# QUADRATIC BOOST CONVERTER BASED AC MICRO GRID SYSTEM WITH IMPROVED DYNAMIC RESPONSE

Ms.Rizwana Shaik[1], Mr.Venkateswarulu Gaddam [2], Mr.Akhib Khan Bahamani[3]

[1] *PG.Scholar, Department of Electrical and Electronics Engineering, Narayana Engineering college, Nellore, Andhra Pradesh, India*

[2]*Head of the Department and Professor, Department of Electrical and Electronics Engineering, Narayana Engineering college, Nellore, Andhra Pradesh, India*

[3]*Associate Professor, Department of Electrical and Electronics Engineering, Narayana Engineering college, Nellore, Andhra Pradesh, India.*

## Abstract

**Background/Objectives**: To simulate quadratic boost converter based AC micro grid system in open loop system; to simulate quadratic boost converter based AC micro grid system in closed-loop-system; to diminish THD of AC Micro-grid system using QBC; to enhance the-dynamic-response for AC Micro-grid system using QBC.

**Methods/Statistical analysis**: Comparison of open loop, proportional integral & proportional resonant closed loop QBCIMGS(quadratic boost converter inverter micro grid system) is simulated using Mat lab SIMULINK.

**Findings**: Comparison of open loop, proportional integral & proportional resonant closed loop QBCIMGS (quadratic boost converter inverter micro grid system) is simulated using Mat lab SIMULINK as it is done in terms of Settling time and steady state error. Both Settling time and steady state error is diminished using PR controller. Hence, PR controlled closed loop QBCIMGS is superior to PI controlled closed loop QBCIMGS. The benefits of-proposed-system are reduced harmonic-content and fast response.

**Improvements/Applications**: By using PR controller, the settling time is reduced from 5.0 Sec to 3.6 Sec; the steady state error is reduced from 4.3 V to 3.3 V.

***Keywords***: (PV) Photo voltaic panels, (QBCIMGS) Quadratic Boost Converter Inverter Micro Grid system, (BESS) Battery energy storage system.

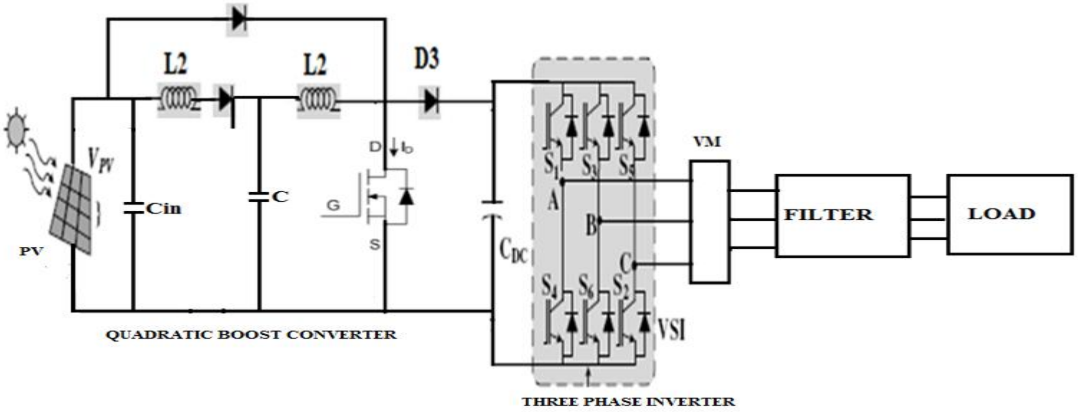
## 1. Introduction

Now-a-days, global warming and fossil fuels depletion are the big problems facing today by every country in our world. These problems are more dangerous and can be decreased by shifting the method of generating power into a different methodologies. The growth of generating energy is by using the renewable energy resources(RER) as they are environmental friendly. Majority of power is generated by using the Photovoltaic (PV) panels and the fuel cell stacks as RERs. Since, there is no emission of any greenhouse gases they are non-polluting and can produce clean electricity to the consumers. Energy can be stored in batteries, but the power generated from these resources has low output voltage and require a bank of batteries.This leads an extra space and weight and higher cost results impractical issues. Therefore, an interface is required to step-up the voltage obtained from these resources.

Majorly, the topology that acts as an interface is a Boost converter. Boost converter is a popular non-isolated power stage technology. Boost converters step up an input voltage to higher level voltage required by the loads. The boost converter has the advantage of energy storage in inductor and supplying it to the load at required voltages. The input current of a boost converter is continuous or non-pulsating, because both the input current and inductor current are same. Small signal, transient performance, power dissipation and electromagnetic interference are considered while designing the converter circuit. But the conventional boost converter has some limitations such as they are unable to switch faster; Not suitable for high power conversion and also withstand high temperatures. Quadratic Boost Converter is a new topology which has certain merits over conventional boost converter such as increasing the efficiency and voltage gain without increasing the number of switches used or the duty cycle. This converter injects less current ripple into the source, thereby the efficiency and the life span can be improved with that of the PV arrays.

The Quadratic Boost Converter has the following advantages compared to the conventional boost converter as: Less voltage spike,High output power,High efficiency, Less harmonics in output, Improved voltage regulation.
The scheme of the Quadratic Boost Converter in a simple two-bus system is illustrated in Fig.1.

**Figure.1. Quadratic Boost Converter based AC Micro Grid system**



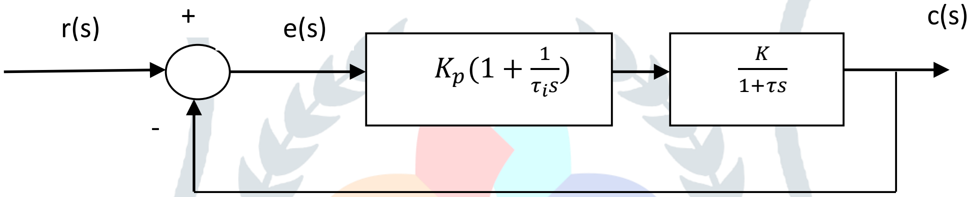
## 2.Controllers

The controllers to be used are: PI controller, PR controller without compensator, PR controller with compensator

### 2.1 Proportional Plus Integral (P-I) Controller:

The block diagram of the closed loop system using P-I controller is given in Fig. 2.

**Figure.2. Proportional plus integral control action**



It is evident that the P-I action provides the dual advantages of fast response due to P-action and the zero steady state error due to I-action. The error transfer function of the above system can be expressed as:

$$\frac{e(s)}{r(s)}=\frac{1}{1+\frac{KK_p(1+\tau_i s)}{\tau_i s(1+\tau s)}}=\frac{\tau_i s(1+\tau s)}{s^2\tau\tau_i+\left(1+KK_p\right)\tau_i s+KK_p} \qquad (1)$$

It can be concluded that the steady state error would be zero for P-I action. As well, the closed loop characteristic equation for P-I action is:

$$s^2\tau\tau_i+\left(1+KK_p\right)\tau_i s+KK_p = 0 \qquad (2)$$

From which we can attain, the damping constant (*ξ*) as:

$$\boldsymbol{\xi}=\left(\frac{1+KK_p}{2}\right)\sqrt{\frac{\tau_i}{KK_p\tau}} \qquad (3)$$

Whereas, for simple integral control the damping constant (*ξ)* is:

$$\xi=\left(\frac{1}{2}\right)\sqrt{\frac{\tau_i}{K_\tau}} \qquad (4)$$

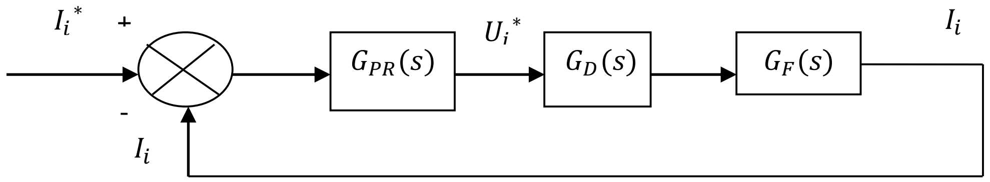
On comparison one can easily examine that, by varying the $K_p$ term, the damping constant(*ξ)* can be increased. It is to be concluded that by using P-I control, the steady state(SS) error can be come down to zero, simultaneously, the transient response (TR)can be improved.

### 2.2 Proportional resonant controller:

The current controller have significance on the quality of the current supplied by the (PV) photo voltaic inverter to the grid, and the controller that provides a high quality of sinusoidal output with small distortion by avoiding creation of harmonics.

A single-phase feed-back current loop is used to adjust the grid current. A proportional resonant (PR) control strategy is used as compensator to trail a sinusoidal current reference frame. The basic control loop diagram with PR control is as shown in fig.3.

Figure.3. control loop diagram with PR controller



Transfer function of the ideal PR controller is as below:

$$G_{PR}(s) = K_p + K_R \frac{s}{s^2 + \omega_0{}^2} \qquad (5)$$

Where, $K_p$ = proportional gain of the controller

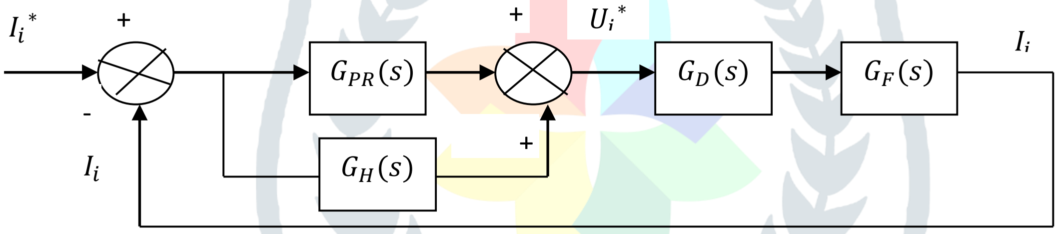
$K_R$ =resonant gain of the controller

$\omega_o$=resonant frequency of the controller in general which is frequency of the grid

### 2.3 PR Controller with compensator:

To reduce the harmonics generated during fluctuations in the load within short interval, PR harmonic compensator along with our PR controller is used. The basic control loop diagram of PR with compensator as shown in Fig.4

Figure.4. control loop diagram of PR controller with compensator



The harmonic compensator GH (s) is represented by

$$G_H(s) = \sum_{h=3,5,7,\dots\dots} K_{lh} \frac{s}{s^2 + (h\omega_0)^2} \qquad (6)$$

Where, $K_{lh}$ resonant gain term of particular harmonic ,

$h\omega o$ is the resonant frequency of that harmonic.

Eq. (5) represents an ideal harmonic compensator which can give stability problems due to an infinite gain that can be stated for the fundamental PR controller. To stay away from these problems, the harmonic compensator equation[9] can be made non-ideal by representing it using (6)

## *3. Simulation Results and Discussion*

### *3.1. Open loop QBCIMGS:*

Circuit diagram of open loop quadratic boost converter-inverter based Microgrid system (QBCIMGS) with disturbance is delineated in Fig.5. 'Voltage-across-PV' is delineated in Fig.6. & its-value is 58V. 'Voltage-across-wind' is delineated in Fig.7. & its-value is 60V. 'Voltage-across-quadratic-boost-converter' is delineated in Fig.8.& its-value is 480V. 'Output -voltage-across inverter RL –load' is delineated in Fig.9. & its value is 450V. Output current through inverter RL –load is delineated in Fig.10. & its value is 3.8A. Output power is delineated in Fig.11. & its value is 820W.

Figure.5. Simulation diagram of open loop QBCIMGS with disturbance using wind and solar generating system

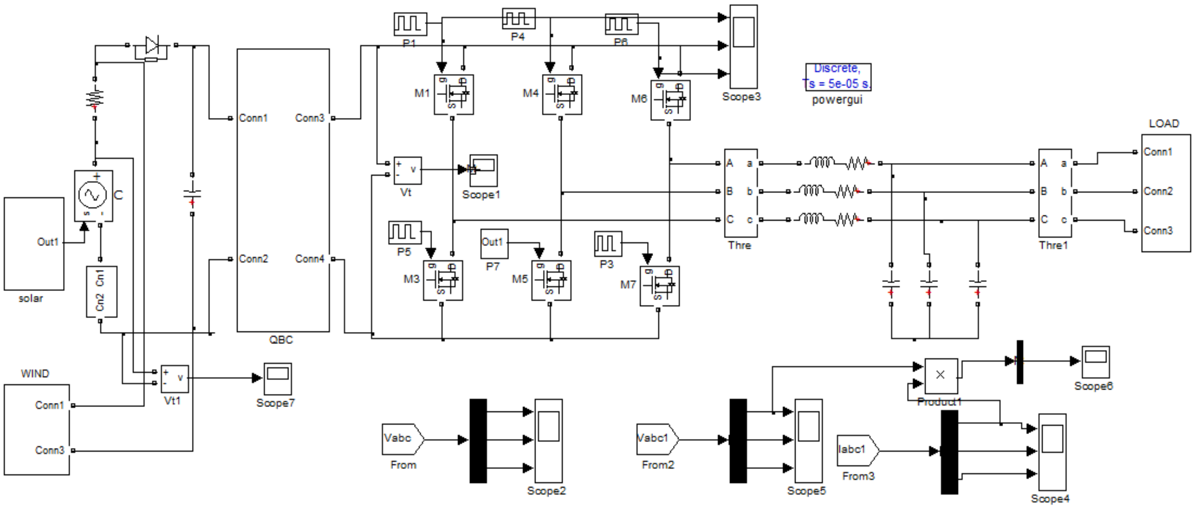


Figure.6. Voltage across PV Source

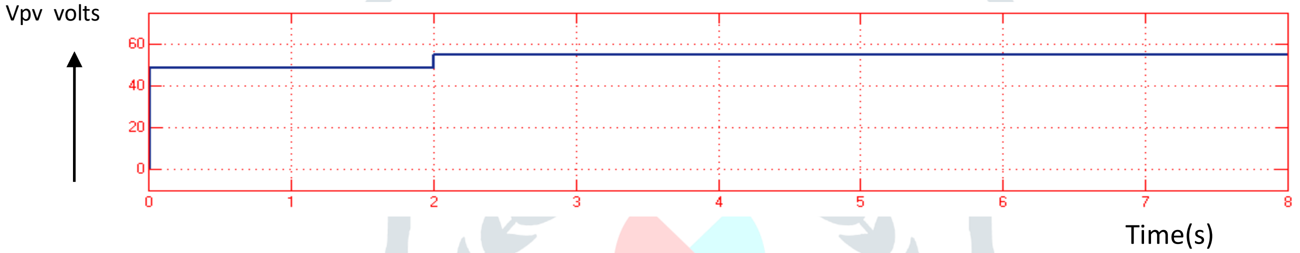


Figure.7. Voltage Across wind generating system

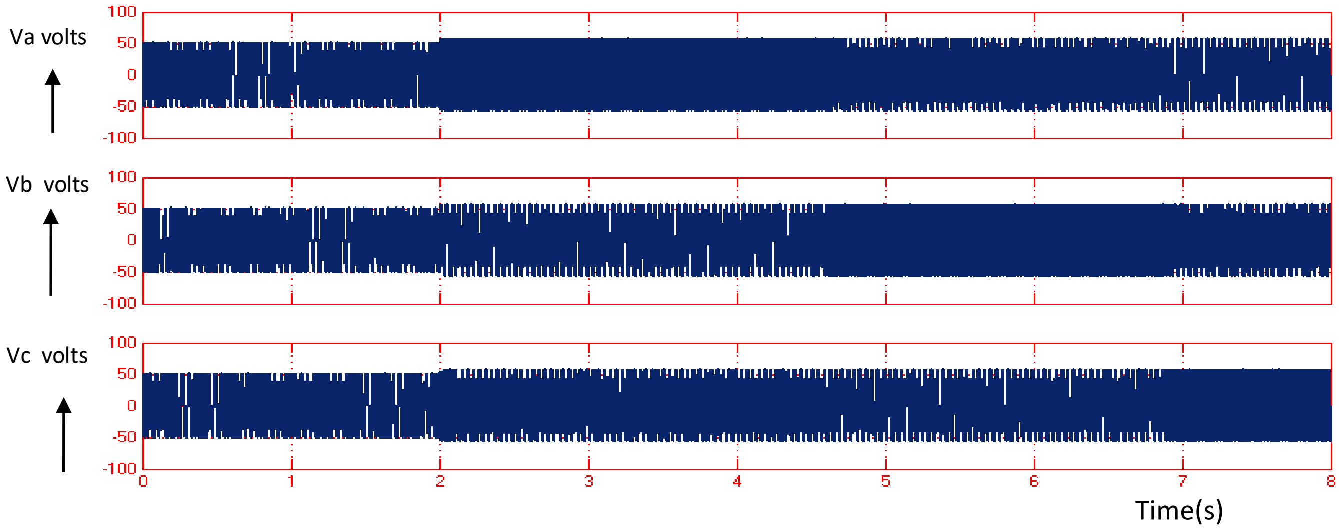


Figure.8. Voltage across quadratic boost converter

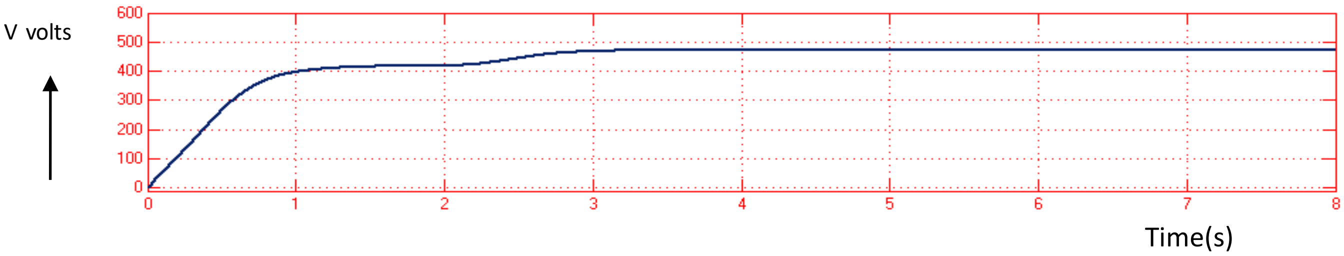


Figure.9. Output voltage across inverter RL -load

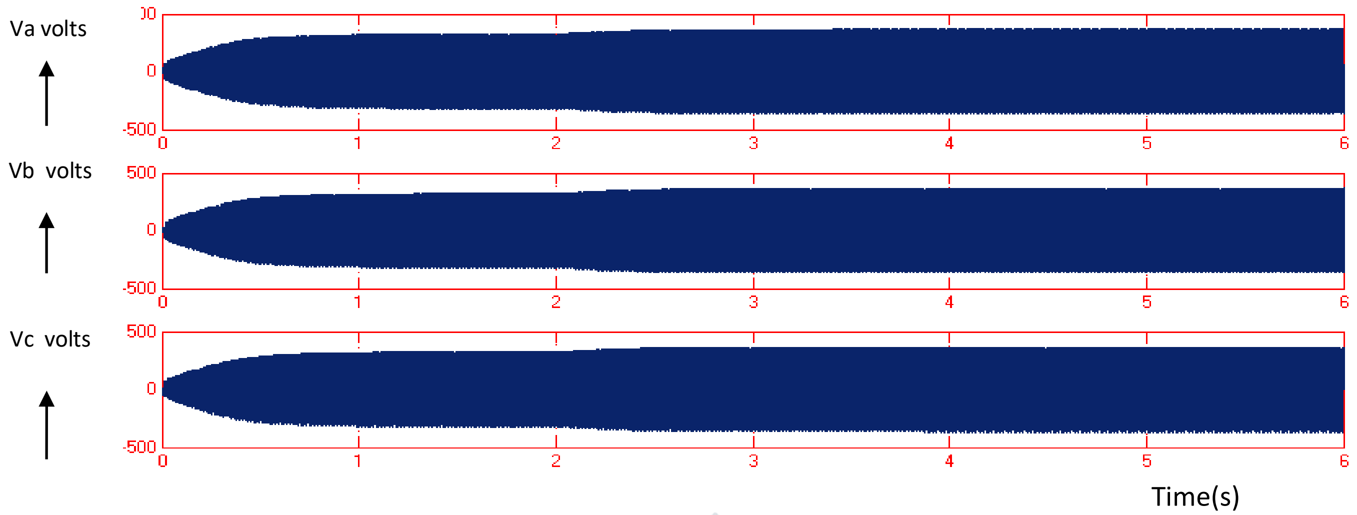


Fig.10. Output current through RL load

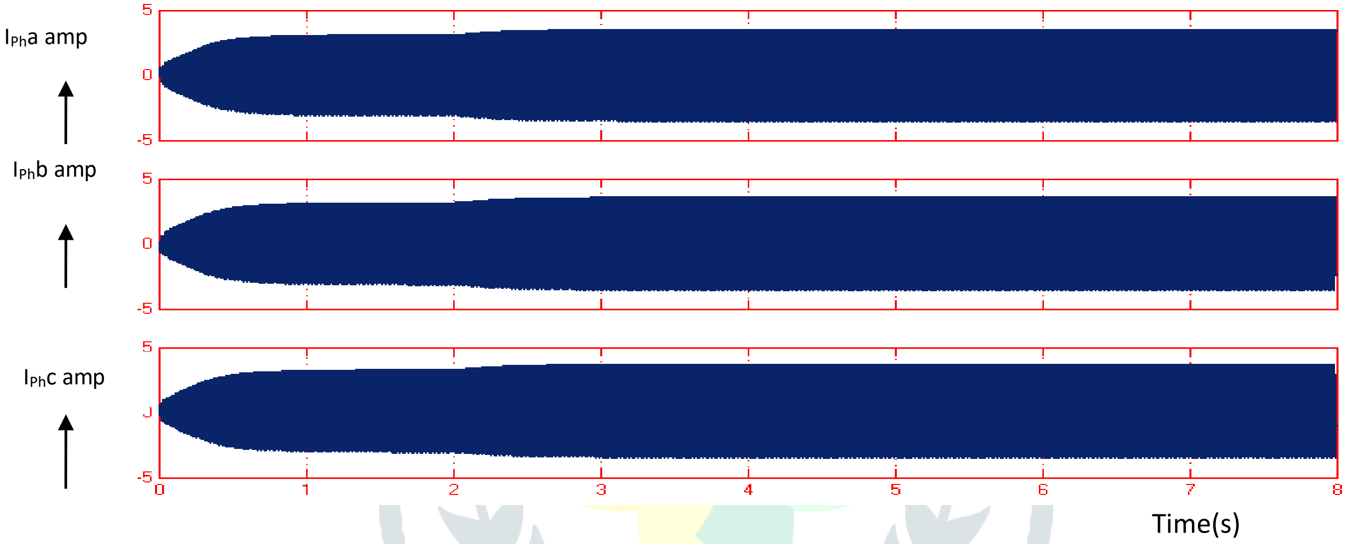
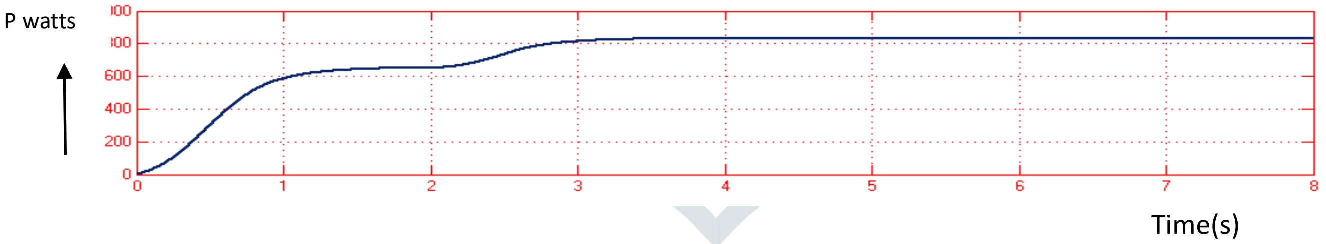


Figure.11. Output power across RL-Load



### *3.2 Closed loop QBCIMGS with PI controller:*

Circuit diagram of Closed loop quadratic boost converter-inverter based microgrid system (QBCIMGS) with PI controller is delineated in Fig.12. ‘Voltage-across-PV’ is delineated in Fig.13. & its value is 58V. ‘Voltage-across-wind’ is delineated in Fig.14. & its -value is 60V. ‘Voltage-across-quadratic-boost-converter’is delineated in Fig.15. & its-value is 430V. Output voltage across inverter RL –load is delineated in Fig.16. & its value is 400V. Output current through inverter RL –load is delineated in Fig.17.& its value is 3.5A. Output power is delineated in Fig.18. & its value is 700W.

Figure.12. Simulation diagram of closed loop QBCIMGS with PI controller

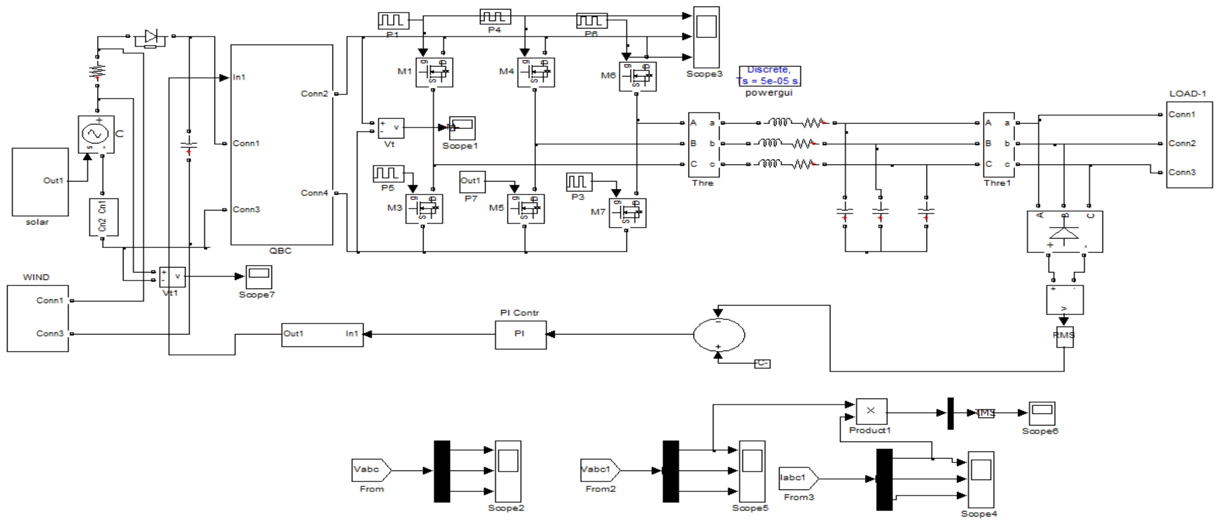


Figure.13. Voltage across PV source with PI Controller

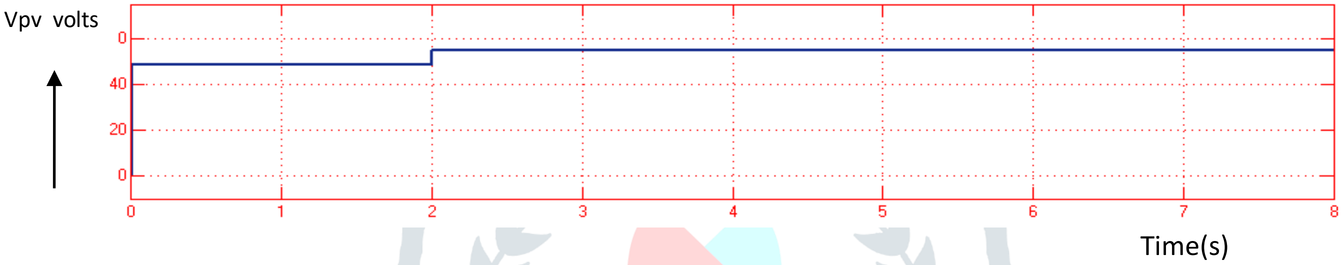


Figure.14. Voltage Across wind generating system with PI Controller

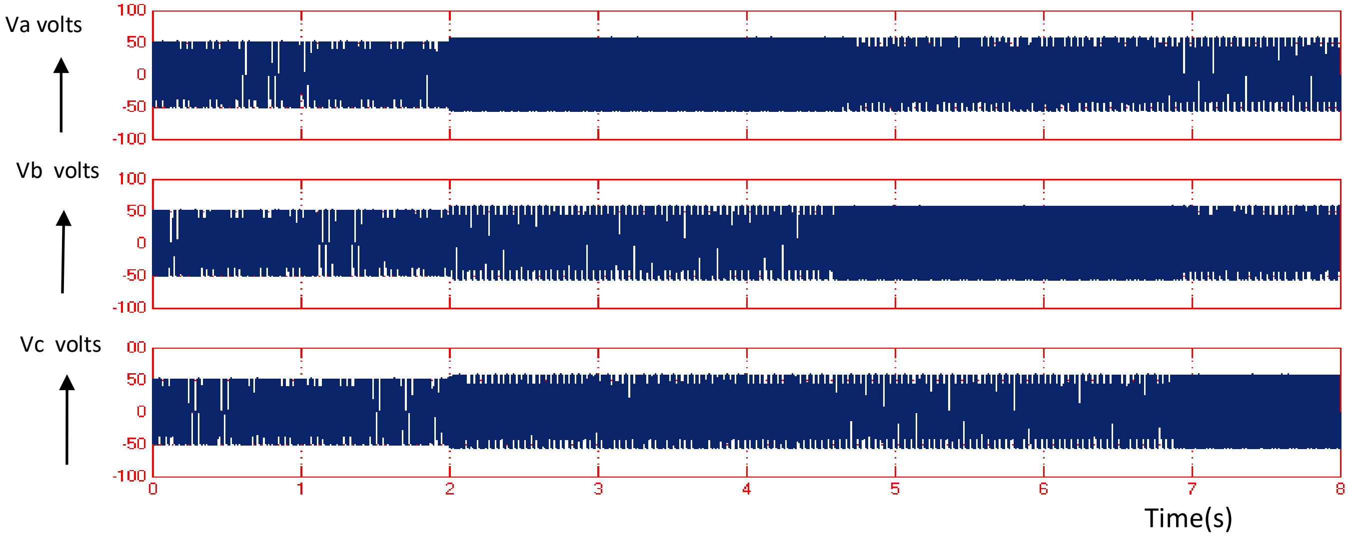


Figure.15. Voltage across quadratic boost converter with PI Controller

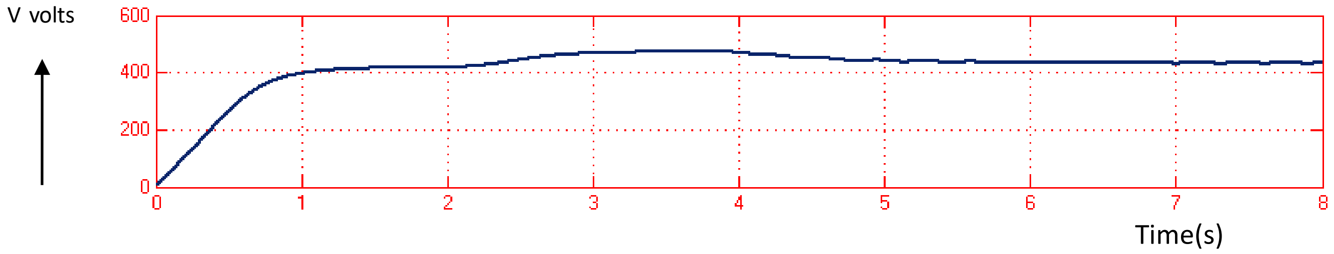


Figure.16. Output voltage across inverter RL-load with PI Controller

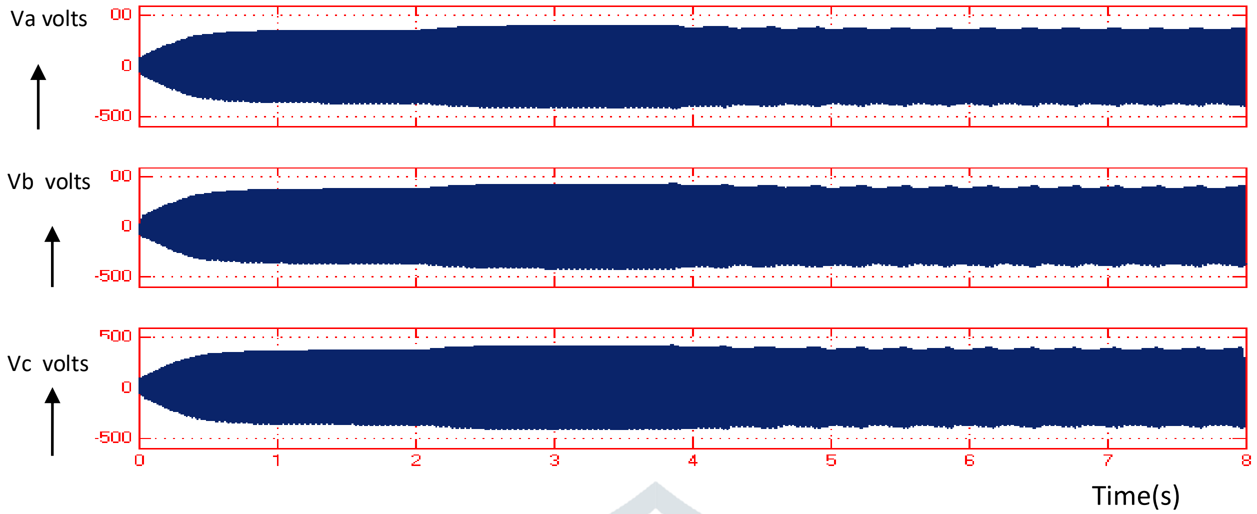


Figure.17. Output current through RL load with PI Controller

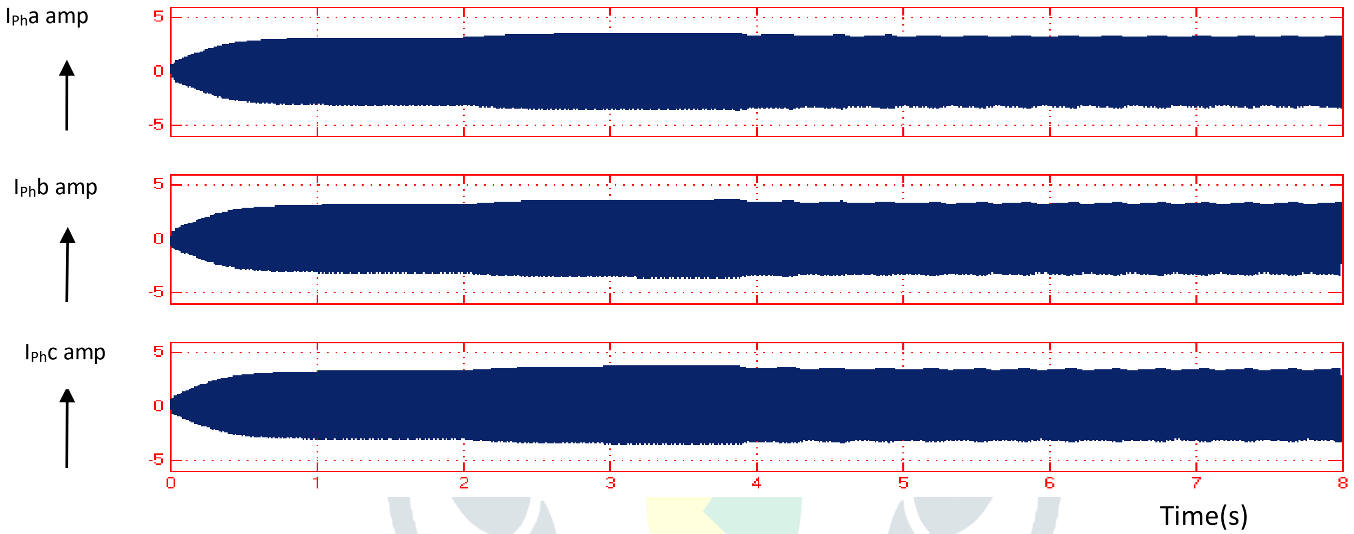
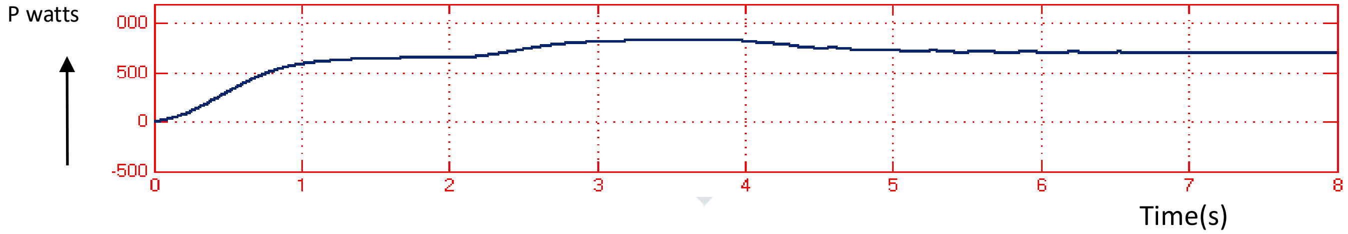


Figure.18. Output power across load with PI Controller



### *3.3 Closed loop QBCIMGS with PR controller:*

Circuit diagram of Closed loop quadratic boost converter-inverter based microgrid system (QBCIMGS)with PR controller is delineated in Fig.19. Voltage across PV is delineated in Fig.20. & its value is 58V. Voltage across wind is delineated in Fig.21. &its value is 60V. Voltage across quadratic boost converter is delineated in Fig.22. & its value is 440V. Output voltage across inverter RL –load is delineated in Fig.23. & its value is 400V. Output current through inverter RL –load is delineated in Fig.24. & its value is 3.5A. Output power is delineated in Fig.25. & its value is 700W.

Figure.19. Simulation diagram of closed loop QBCIMGS with PR controller

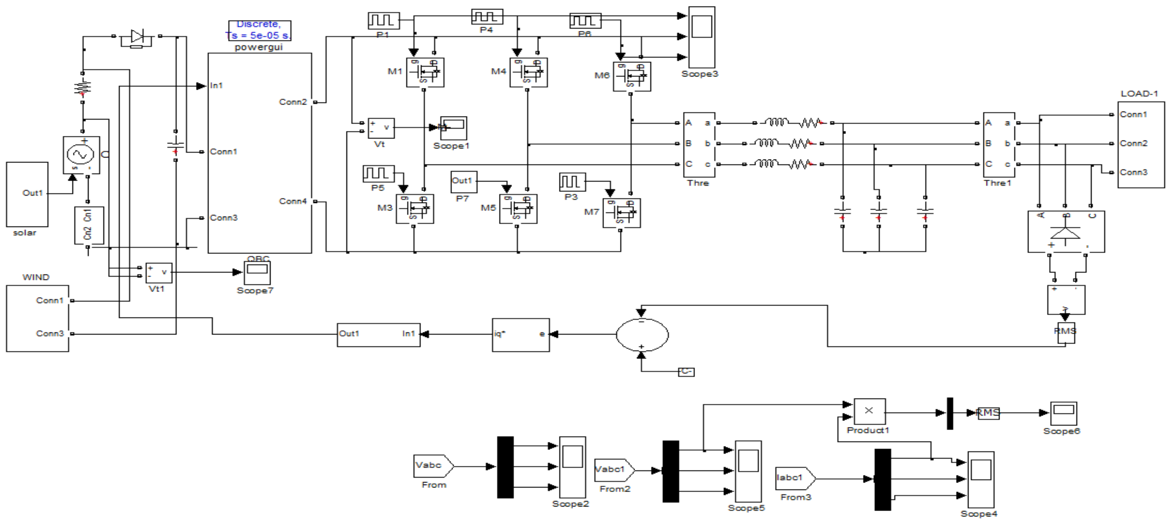


Figure.20. Voltage across PV source with PR Controller

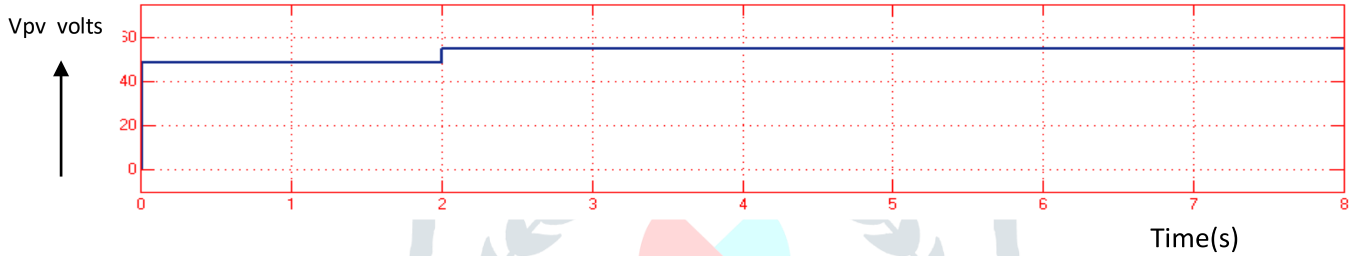


Figure.21.Voltage Across wind generating system with PR Controller

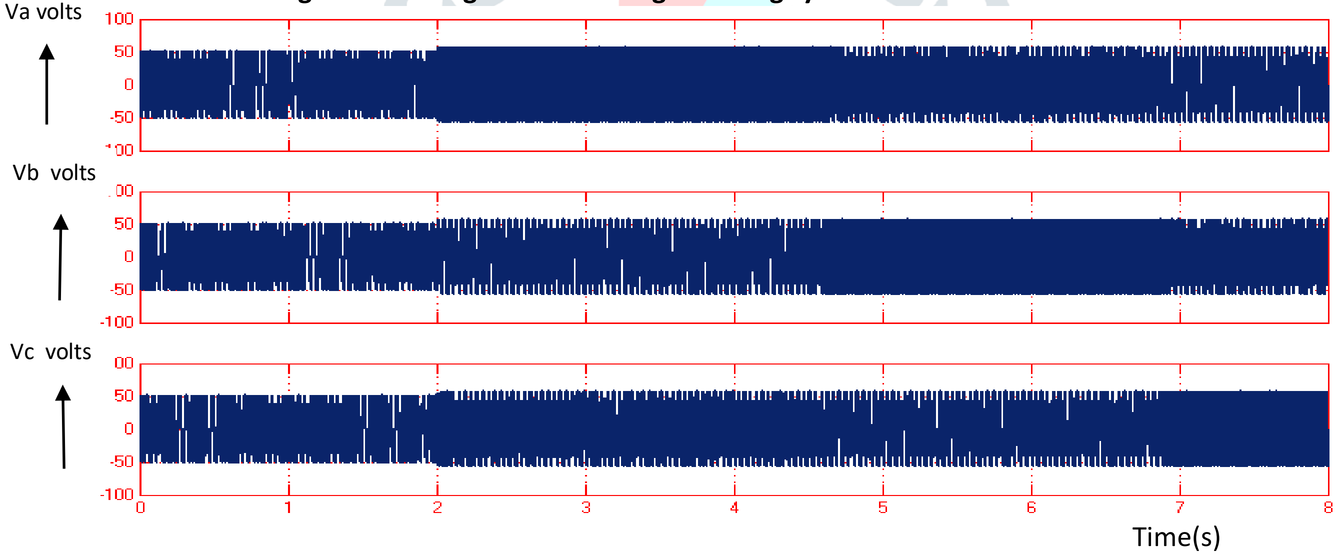


Figure.22.Voltage across quadratic boost converter with PR Controller

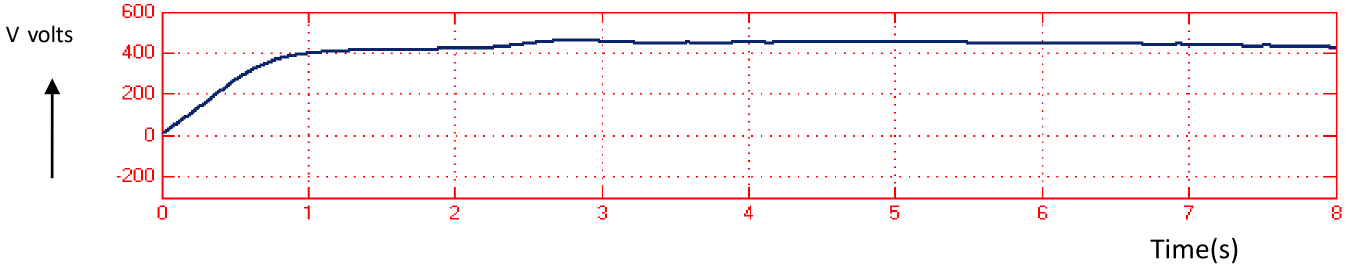


**Figure.23.Output voltage across inverter RL-load with PR Controller**

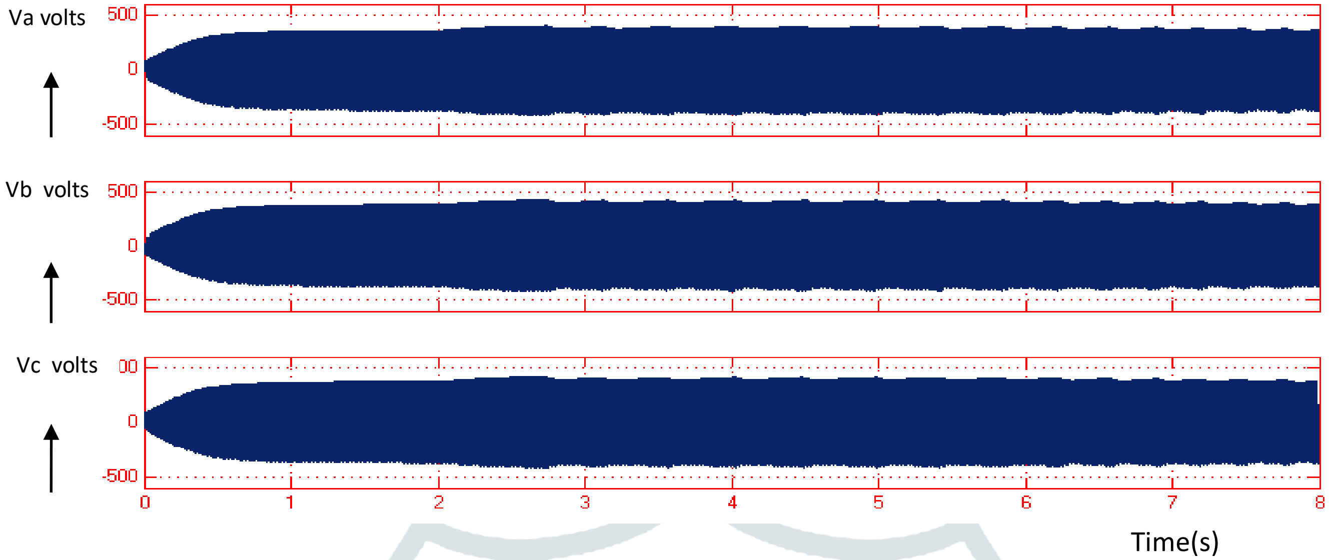


**Figure.24.Output current through RL load with PR Controller**

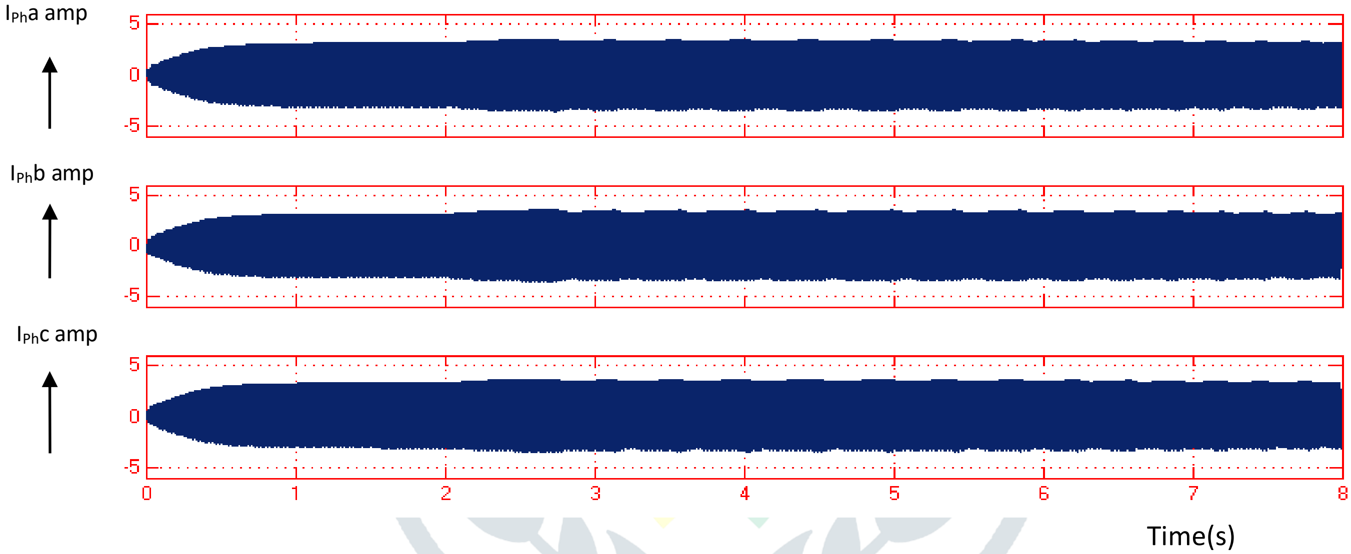


**Figure.25.Output power across load with PR Controller**

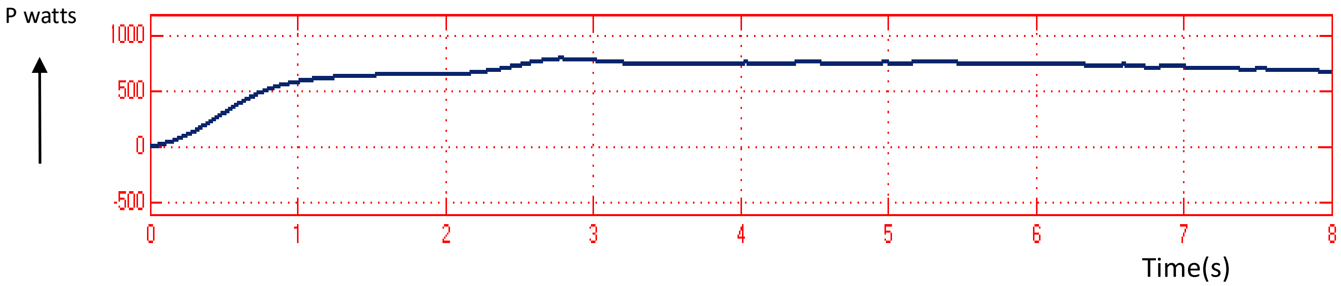


**Table.1. Summary of Time Domain Parameters using PI &PR Controllers for QBCIMGS with wind and solar system**

| Controller | $T_{r(SEC)}$ | $T_{s(SEC)}$ | $T_{p(SEC)}$ | $E_{ss(V)}$ |
|---|---|---|---|---|
| PI | 2.60 | 5.0 | 3.81 | 4.3 |
| PR | 2.40 | 3.6 | 2.80 | 3.3 |

From Table.1. It is concluded that PR controller is more superior than the PI Controller.

## 4. Conclusion

Comparison of open loop and proportional integral & proportional resonant closed loop QBCIMGS (quadratic boost converter inverter micro grid system) is simulated using Mat lab SIMULINK. The comparison is done in terms of Settling time and steady state error. By using PR controller, the settling time is reduced from 5.0 Sec to 3.6 Sec; the steady state error is reduced from 4.3 V to 3.3 V. Both Settling time and steady state error is diminished using PR controller. Hence, PR controlled closed loop QBCIMGS is superior to PI controlled closed loop QBCIMGS. The benefits of-proposed-system are reduced harmonic-content and fast response.

## 5. References

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