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# Power quality improvement of integrated PV/wind grid-connected system

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## ABSTRACT

***Integrated PV/Wind grid connected system is emerging as a solution to duo problems of conventional power system of high transmission losses and shortage of conventional sources. Traditionally integrated non-conventional system of electricity generation obtained from different sources is collected at a common DC bus or are connected electrically through power converters to extract maximum energy. The incorporated power converter topologies utilizes different generators and control strategy to supply the load according to their voltage and harmonic content. The work done is to analyze the interface of solar electric and WGS to restore grid characteristics. A converter has been designed using neutral point clamped MLI to control the grid parameter as well as PV/Wind hybrid system parameter simultaneously for improving power quality of the system.***

***Keywords***: *Integrated PV/Wind grid connected system (IPVWGS), Wind Power Generation (WPG), Maximum Power Point Tracking (MPPT), Multi Level Inverter (MLI), Point of Common Coupling (PCC).*

## 1. INTRODUCTION

Conventional Power system suffers from the duo problems of high transmission losses and shortage of conventional sources to generate electricity. Hence power engineers focuses on grid connected operation of distributed generation (DG) like wind and solar. Grid connected operation of DG reduces the transmission losses, increases the reliability and efficiency. But high penetration of DG may increase the power quality (PQ) issues since the electric behaviour of the DG is DC and they require Power converters (PC) to convert the DC into AC. The PC are non-continuous devices hence they distort the fine sine wave of utility network particularly at PCC. The PC are required to integrate the DG into the grid in compliance with the grid code. But the high switching frequency of the inverters injects the harmonics into the system. Therefore, integration of these DG like PV/wind hybrid power system can be utilized for overcoming the intermittency and generation more reliable power with higher quality to the electrical grid and rural areas. However, both the PV energy and wind energy are intermittent in nature and immensely dependent on the environmental conditions such as the variations of solar irradiance and wind speed. Hence a robust inverter control is require to meet the grid code requirement of Integrated PV/Wind grid connected system (IPVWGS).

Seeing to the emerging demand of PV/Wind generation, a lot of research work has been done for coordinated controlled grid connected operation. In [2] authors presents a novel design architecture for control of multiple grid tied DGs. [3] suggests asymmetric inverter control with battery back-up in PV/wind hybrid power system. [4] Presents sliding mode control strategy for standby IPVWGS.

This paper presents a Feed Forward Control Loop converter design for IPVWGS to improve the PQ of the system. The work done is to analyze the interface of solar electric and WGS to restore grid characteristics. A controller has been designed to control the grid parameter as well as PV/Wind hybrid system parameter simultaneously.
The paper is organized as; in section 2, proposed inverter topologies are discussed in brief. In section 3, proposed work is presented. Section 4 presents the simulation results followed by conclusion at last.

## 2. INTEGRATED PV/WIND GRID CONNECTED SYSTEM (IPVWGS)

The system configuration IPVWGS is presented in Figure 1. The studied system consist of PV generation with 0.1MW rating and WPG with 1.5 MW rating. The PV station and wind farm are integrated to the main PCC-bus through converters installed at DC-buses of both the system to inject the generated power and enhance the PQ of the system. The PV station consists of 10 series and 50 parallel modules electrically connected to achieve the desired power capacity. Moreover, the PV output is connected to the DC/DC boost converter to step up array output voltage, and aggregated DC/AC inverter to convert the generated DC power to AC power. The incremental conductance MPPT technique is implemented to extract maximum power from PV under variable solar irradiance. Also, the PV station is connected with the PCC-bus through 260 V/25 KV ▲/Y transformer. On the other hand, the WPG is designed using permanent magnet synchronous generator driven by turbine. Furthermore, the WPG includes the grid side converter (GSC) for maintaining the DC-bus voltage constant. A modified MPPT technique based on mechanical power measurement is implemented to capture the maximum power from wind farm during variation of the wind speed. The WPG is interconnected with the PCC-bus through 575V/25 KV ▲/Y transformer. The designed system is controlled to operate at power factor of unity, and the active power injected is transmitted to the electrical grid through 30 Km transmission lines and 25 KV/120 KV Y/▲ transformer.

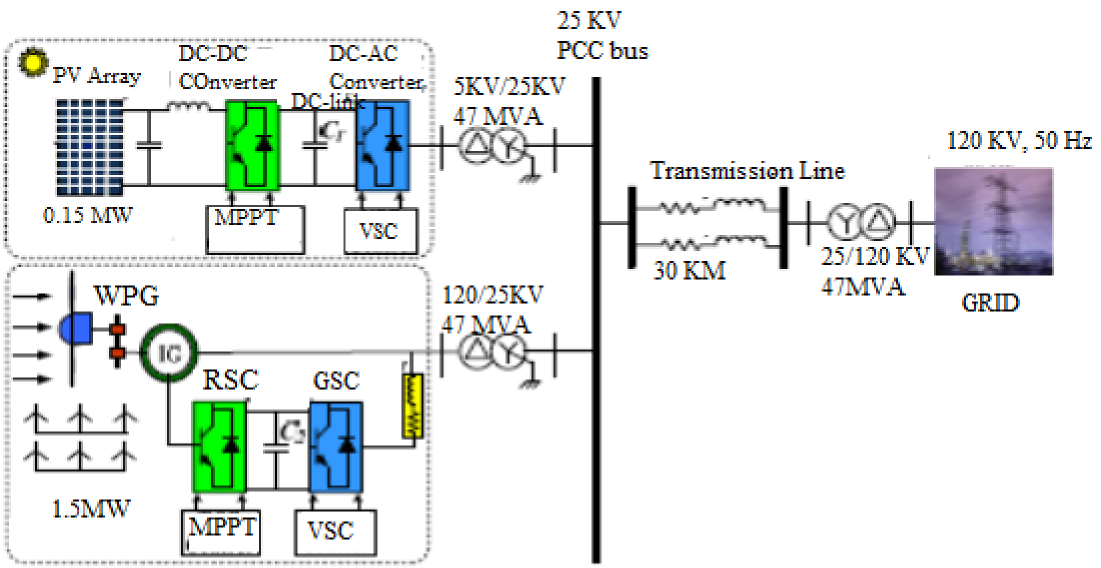


**Fig. 1: Schematic of proposed IPVWGS**

## 3. SIMULTION MODEL OF PV SYSTEM

A PV system is designed having 50 parallel strings and 10 Series-connected modules having power capacity of 150 KW. The complete simulation model pf the PV system with the proposed PI controller is presented in figure 2. The PV-VI characteristics of the system is given in figure 3. To obtain the constant DC output from Solar system a DC-DC boost converter is designed with switching frequency 5 kHz. The PV system's generated variable DC output is tracked using MPPT algorithm. In this work incremental and conductance (IC) MPPT is used to generate the gate pulse for DC-DC boost converter in a way to stabilize DC output of solar for under variable environmental conditions of irradiance and temperature. Figure 4 Presents the DC output of boost converter. The boost converter is given input from solar and the boost converter is generating approximately 600 V DC output. For converting this regulated DC output into synchronized AC an inverter s designed with PI controller. Three phase universal bridge is used to design an inverter the pulses are generated for gating the switches of IGBT. A sinusoidal PWM is used to generate the gating signals. A phase lock loop algorithm is used to synchronize the inverter output with grid. The output voltage and current of inverter is shown in figure 5 and 6 respectively.

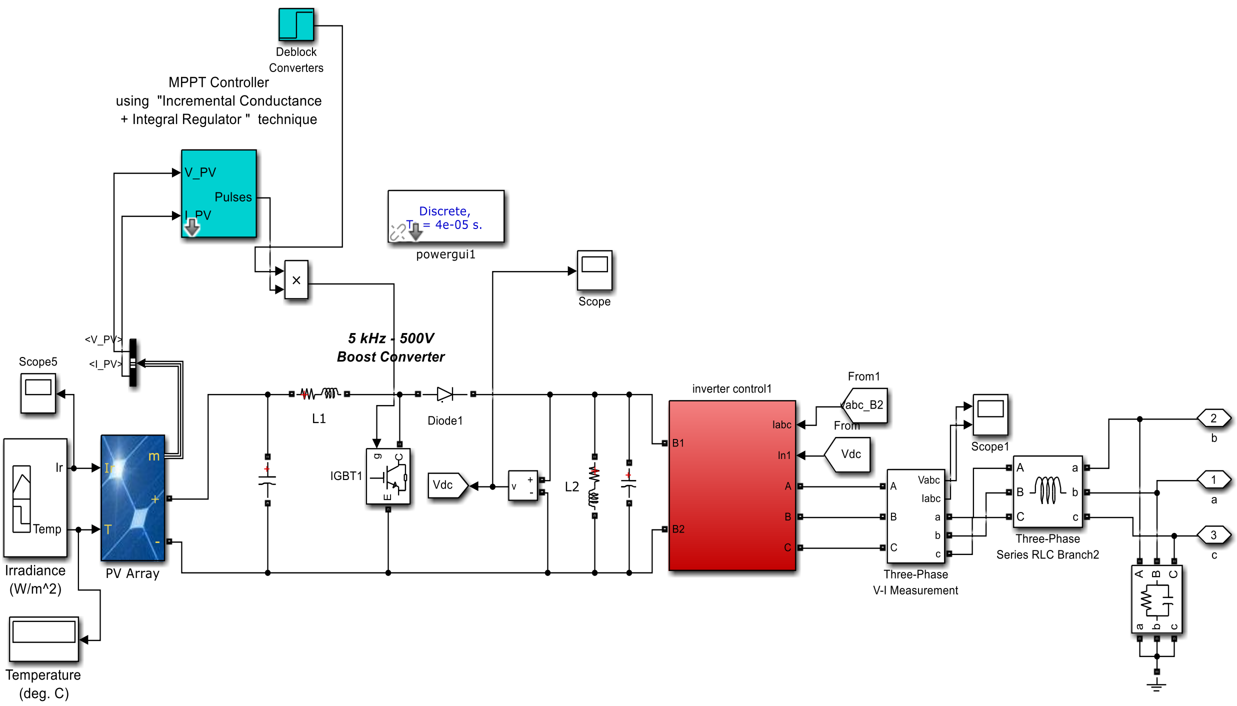


**Fig. 2: Simulation model of PV system**

 

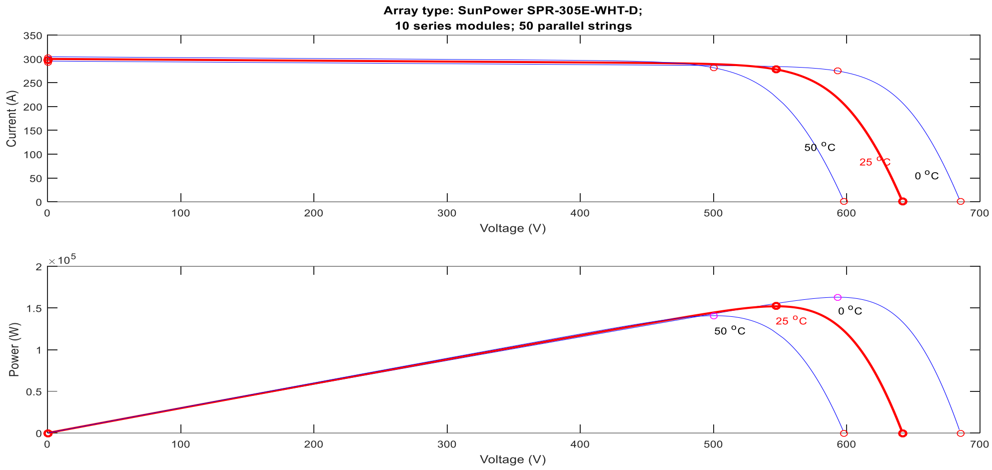


**Fig. 3: V-I and P-V characteristics curve of the PV system**

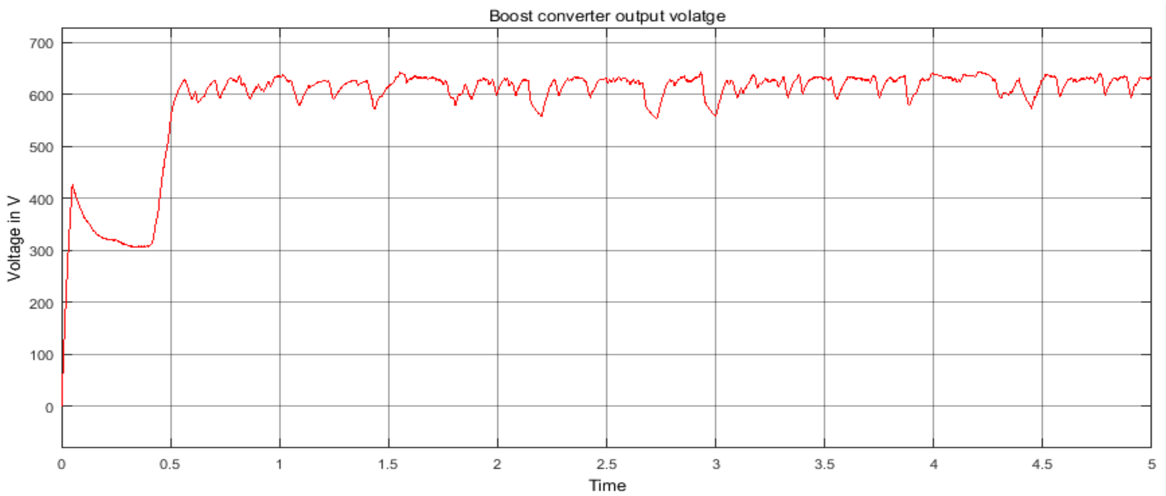


**Fig. 4: DC output of boost converter under variable irradiance**

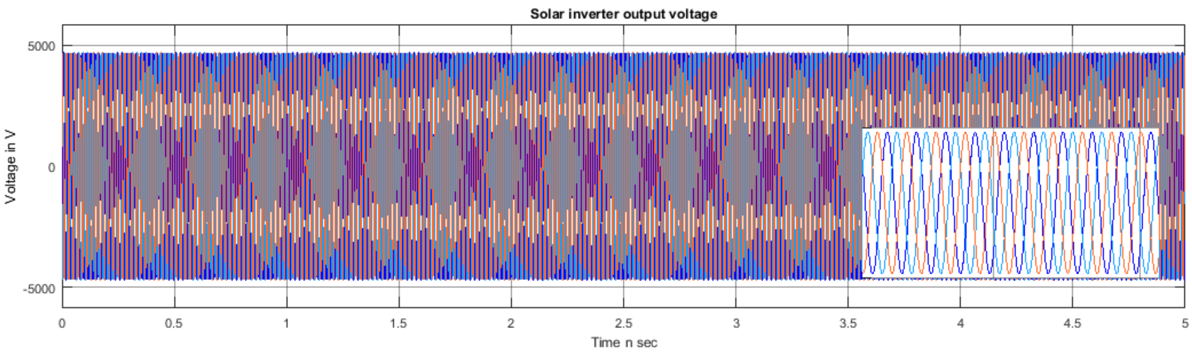


**Fig. 5: Output voltage of inverter of solar system.**

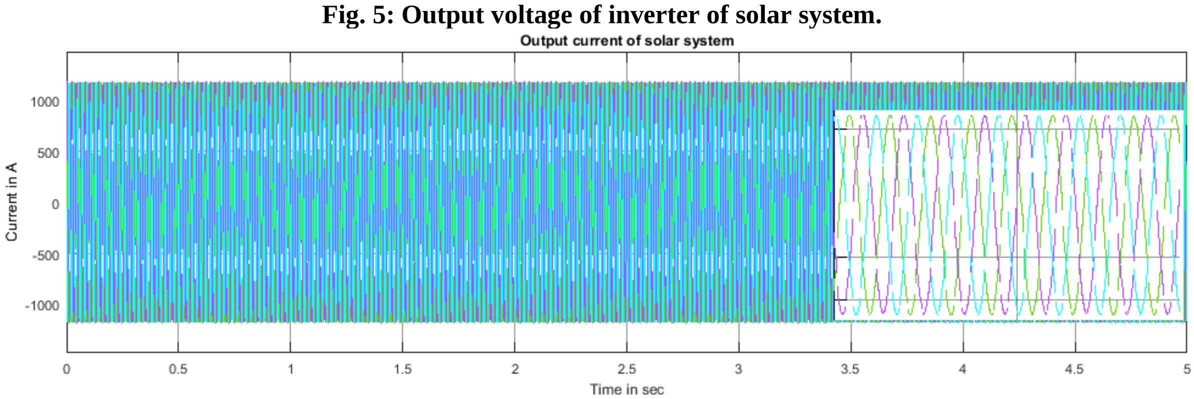


**Fig. 6: Output current of inverter of solar system.**

## 4. SIMULATION MODEL OF WIND SYSTEM

In the proposed IPVWGS system, WPG is designed using permanent magnet synchronous generator as shown in figure 7. To generate synchronous output for grid connected operation an AC-DC-AC converter is employed at the terminals of WPG. In the

 

WPG also ICMPPT is used to trigger the IGBT connected in boost converter. The DC output obtain from boost converter is synchronized with the grid using PLL and PI based AC converter. The output voltage and current of WPG inverter side is shown in figure 8 and 9 respectively.

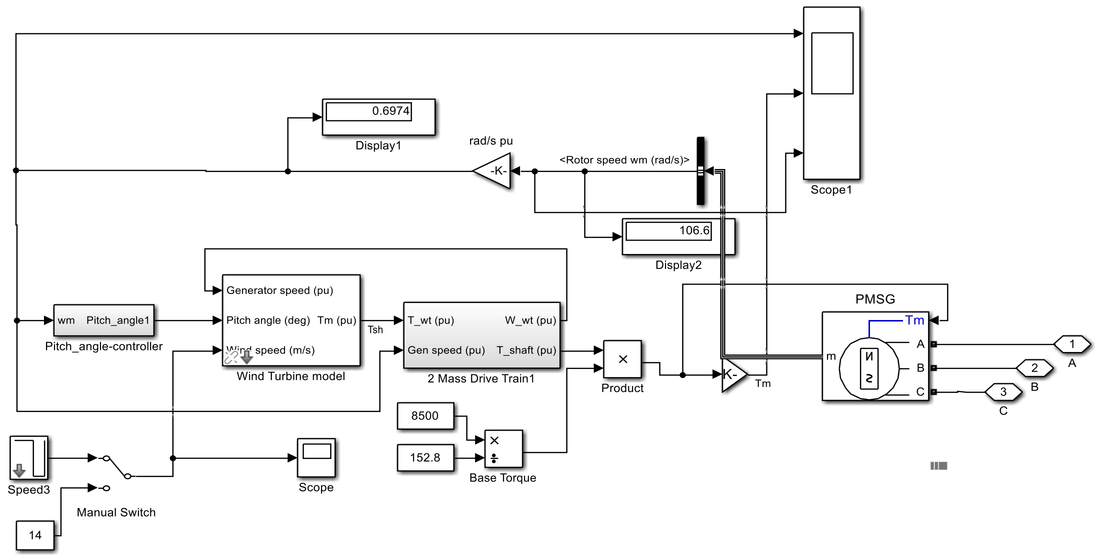


**Fig. 7: Simulation Model of Wind system**

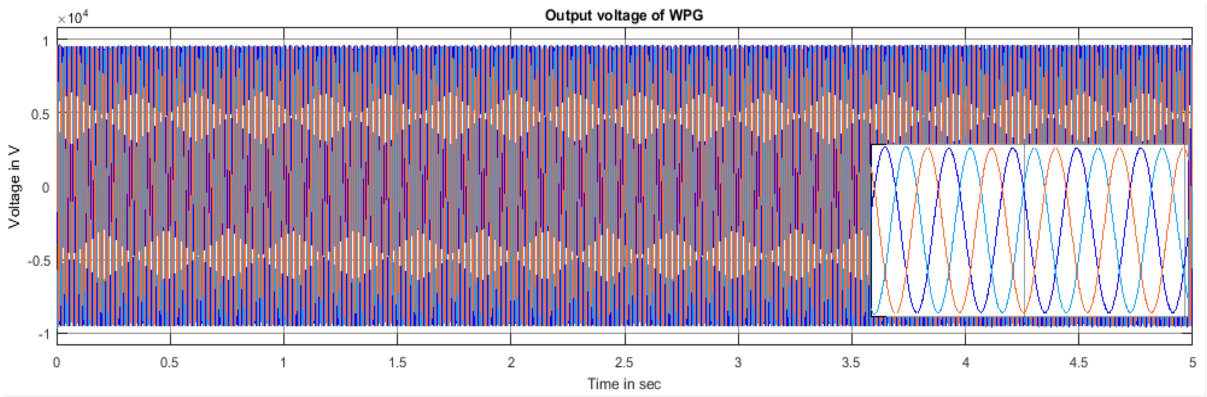


**Fig. 8: Output voltage of inverter of WPG system**

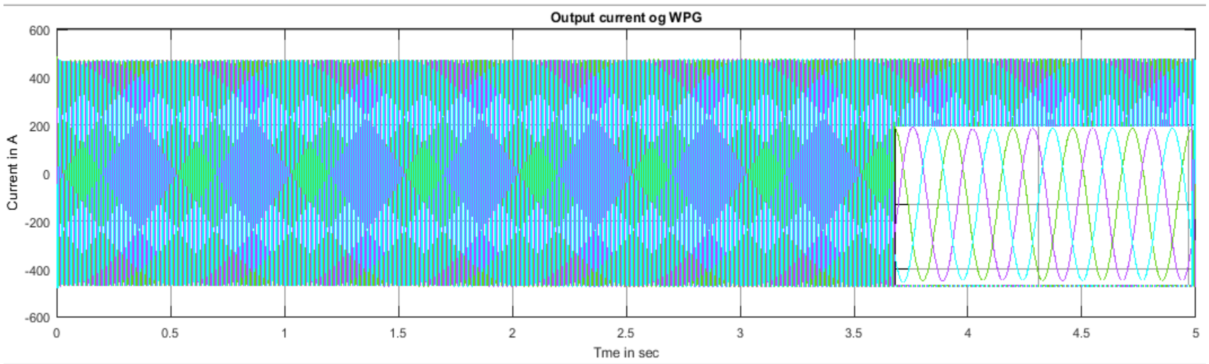


**Fig. 9: Output current of inverter of WPG system**

## 5. PROPOSED IPVWGS SYSTEM

The determinations of generators, integrated system topology and control calculation are the real issues while utilizing these sustainable power sources. The researchers are developing lots of technologies for integrating distinctive kinds of sustainable power sources and their operational perceptions in grid associated and off grid mode. In this work designing simulation and modelling of PV/wind hybrid system is presented to meet grid characteristics. An effective controller design is mandatory for the hybrid system to have efficient interfacing of power conversion circuits and controllers strategies to meet the load demand and to maintain the power quality of the utility system. The complete simulation model of the system design is presented in figure 10. The output voltage and current of the system is synchronized at PCC with the grid using PI and PLL. Figure 11 and 12 presents the output voltage and current at PCC when the hybrid PV/W system is integrated with grid. From the figures it is clear that the system designed is completely synchronised with the grid which also been verified by the Power factor at PCC as shown in figure 13. The system has been analysed for variable solar irradiance and wind speed to check the effectiveness of the proposed controller. The design parameters for the system simulated is shown in table 1.

 

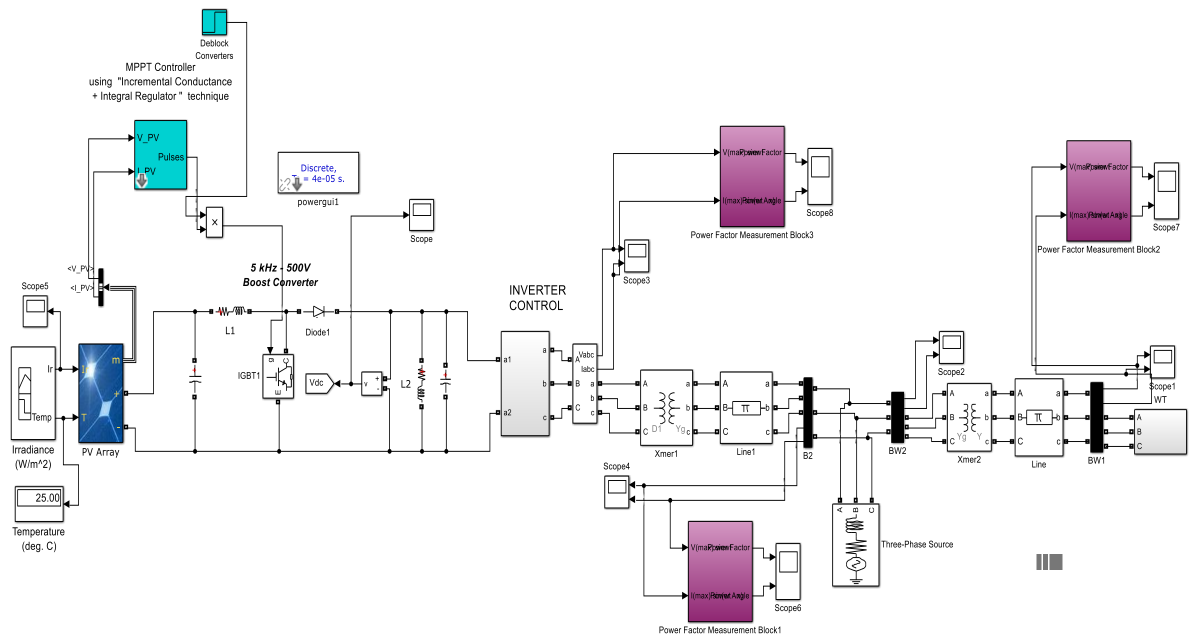


**Fig. 10: Complete simulation model of proposed IPVWGS**

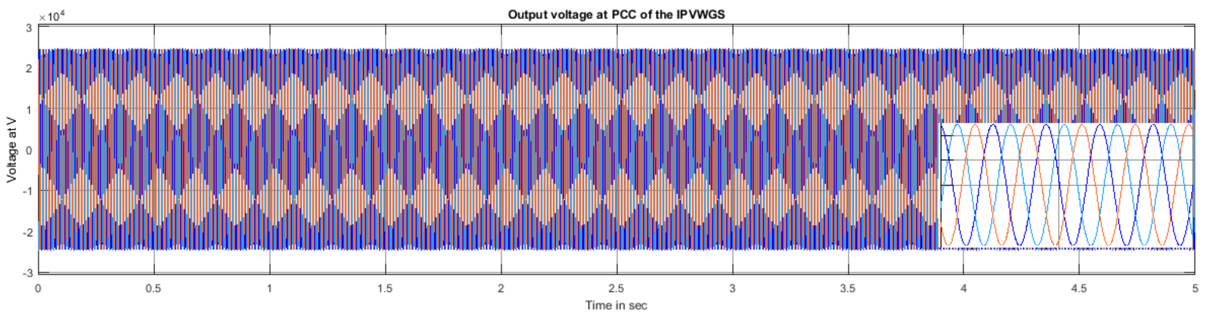


**Fig. 11: Output voltage of the proposed IPVWGS system at PCC**

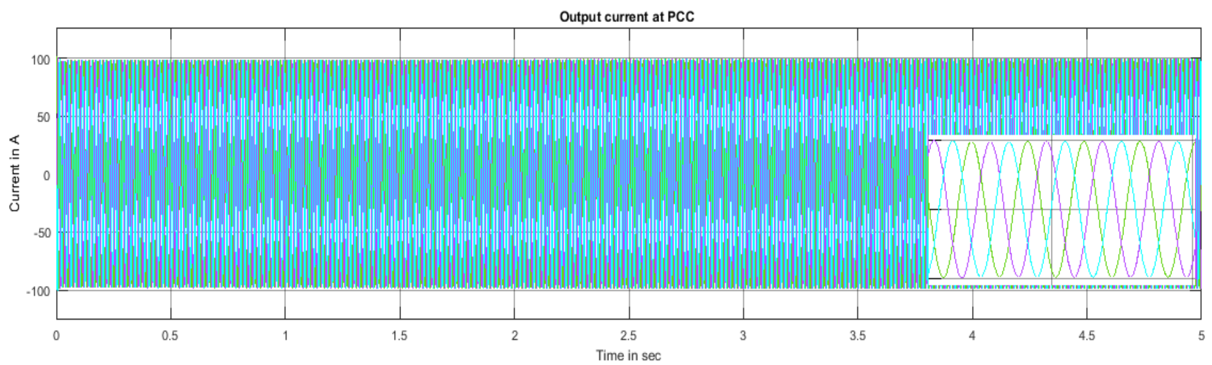


**Fig. 12: Output current of the proposed IPVWGS system at PCC**

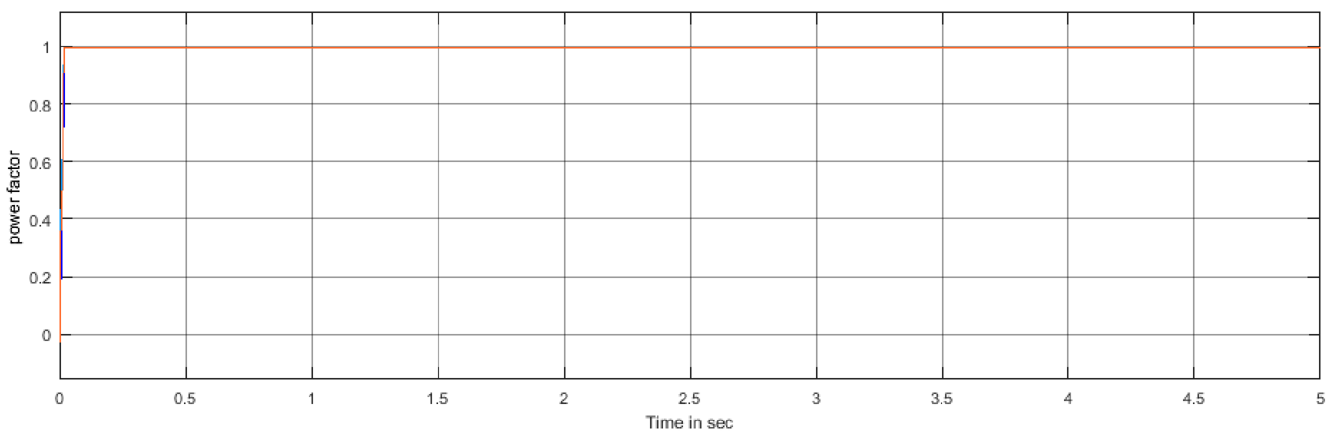


**Fig. 13: Power factor of the proposed IPVWGS system at PCC**

**Table 1: Parameter selection**

| Parameter | Value |
|---|---|
| PV rating | 0.15 MW |
| DC voltage output | 4700 V |
| switching frequency | 5kHz |
| Boost converter inductor | 150mH |
| Boost converter capacitor | 100µF |
| Filter inductance | 100mH |
| Filter resistance | 0.01 ohm |
| Filter capacitance | 1000 µF |
| Output voltage of DC/AC inverter | 25KV |
| Output current of DC/AC inverter | 60A |
| DC voltage of WPGS | 9 KV |
| AC voltage of WPGS | 1 KV |
| Rating of WPGS | 1.5 MW |
| Voltage at PCC | 25KV |

## 6. CONCLUSION

A control architecture based on Pi and PLL is proposed for grid connected operation of Integrated PV/wind grid connected system. The efficacy of the proposed topology is verified by employing level shifted PWM techniques under the condition of variable solar irradiance and wind speed. At all the variable environmental condition the proposed system gives constant output at PCC. To increase the number of DG system by this topology is easily possible to large extends which is a new direction in this field. The performance of the multifunctional VSC has been demonstrated for unity power factor since the output at PCC is completely synchronized and mitigate the non-linearities of the system. The result shows that the proposed topology has better performance than the conventional one. It is detected that the proposed inverter has superior characteristics in terms of the required devices, control requirements, cost, reliability and efficiency.

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