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Research Paper

A NOVEL MAXIMUM POWER POINT TRACKING BASED TPWC CONTROL FOR PERMANENET MAGNET SYNCHRONOUS GENERATOR DRIVE WECS

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Wind power has become a rapidly growing technology as a kind of renewable energy resources. This paper presented by variable speed wind generators (PMSG) in hybrid Remote Area Power Supply (RAPS) for improved voltage and frequency control together with maximum power point tracking. Most of the systems do not capture power at every wind speed. Reduce this problem proposed a power electronic converter, planned for efficiency, simplicity and ruggedness. A Simple Three-Point Weight Comparison method (TPWC) which is a Maximum Power Point Tracking (MPPT) algorithm used in a wind turbine PMSG system with a diode bridge rectifier. The output DC power is operated by additional grid side Quasi Z-source inverter uses the PI controller technique. The main thrust is to produce maximum power and maintain a constant voltage at the output in spite of variation in wind velocity. The performance is investigated using Sim-Power Systems block sets with MATLAB and also implemented the performance.

Keywords: Permanent Magnet Synchronous Generator (PMSG), Maximum Power Point Tracking (MPPT), Three-Point Weight Comparison Algorithm (TPWC), Wind Energy Conversion System (WECS), Remote Area Power System (RAPS)

INTRODUCTION

There has been a tremendous increase in wind power in the present decades. Wind turbines represent an integral part of the electricity network. This trend is expected to increase in the coming decades. Small WECS have been used in remote locations where conventional grid is not available. Recently small WECS are being considered to be used in parallel with the local grid. The design and operation of such a power system are challenging due to the absence of a main grid supply system. Also, these power supply schemes are usually characterized by networks having low X/R

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ratios, low damping, and lack of reactive power support which may cause unexpected voltage and frequency excursions outside the allowable limits (Zhou *et al.*, 2007). When designing and implementing RAPS Remote Area Power Supply systems, voltage and frequency control are the most important aspects to be controlled. Then at low wind speed the WECS feeds partially the loads and at high wind speeds the exceeding energy is injected into the grid. This leads to the reduction of the utility bill with the consequent amortization of the initial investment cost. Within this context cost and practical implementation. In addition, coordination between different system components, maximum power extraction from the renewable energy sources, power quality (e.g., harmonics, voltage unbalance, flicker, etc.), and cost optimization of system operation and components are the other major issues of interest (Mendis *et al.*, 2009). The selection of the suitable generation mix of a RAPS system is entirely dependent on the availability of resources (Edwards and Negnevitsky, 2008). Diesel-based power increased attention given to environmental concerns and the operating costs associated with diesel power supply schemes make this option less favorable (Haruni *et al.*, 2010).

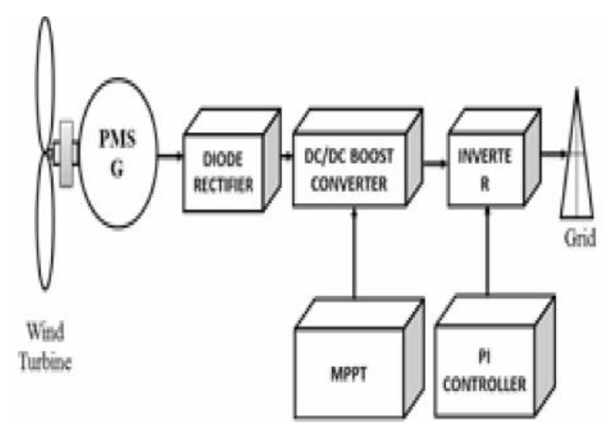
There has been a recent trend for such diesel-fed isolated power systems to be replaced with renewable energy-based power supply schemes. Among several renewable energy options available, wind is identified as the fastest growing energy industry in the electricity market (Zhou *et al.*, 2009). However, intermittency associated with wind profiles together with the variability of load demand make operation of wind-based power systems challenging especially when they operate in a standalone environment. The integration of an energy storage into such a power system can be seen to provide improved security and performance (Shi *et al.*, 2010; Yang, 2010; Mendis *et al.,* 2010; and Jin and Wang, 2010). In general, variable speed wind turbine generator technologies are preferred in a standalone power system as they provide better voltage and frequency regulation compared to constant speed generators such as induction generators (Cheng *et al.*, 2009). The battery storage system and dump load are able to assist in maintaining the active power balance during over and under generation conditions as well as sudden load changes using PMSG and DFIGURE generator (Nishad Mendis *et al.*, 2012).

The paper proposes by produce maximum power and maintains a constant voltage at the output in spite of variation in wind velocity. Mainly using Three-Point Weight Comparison method (TPWC) which is a Maximum Power Point Tracking (MPPT) algorithm used in a wind turbine PMSG system with a diode bridge rectifier.

PMSG BASED WIND CONVERSION SYSTEM

This paper proposes the maximum power for wind energy conversion systems based on permanent magnet synchronous generators. Generator output is converted into DC by using a diode bridge rectifier in Figure 1. Then the DC output voltage is given to Quasi z-source inverter. Here using an MPPT controller to extract the maximum power. By using three point comparison algorithm, maximum power

Figure 1: PMSG Based Wind Conversion System



corresponding to any wind velocity can be captured. But the time taken to reach MPP is long and a considerable amount of power loss takes place during the tracking phase. The output DC power is controlled by additional grid side inverter using the PI controller technique.

The tip speed ratio ª is defined as:

$$\lambda = \frac{\omega R}{v} \quad \text{...(1)}$$

where, µ, *R* and *V* represent turbine rotational speed,

Turbine blade radius and the wind velocity respectively.

In general, the power captured from the wind turbine can be written as:

$$P_m = C_p(\lambda, \beta)\rho \frac{A}{2} v^3 \quad \text{...(2)}$$

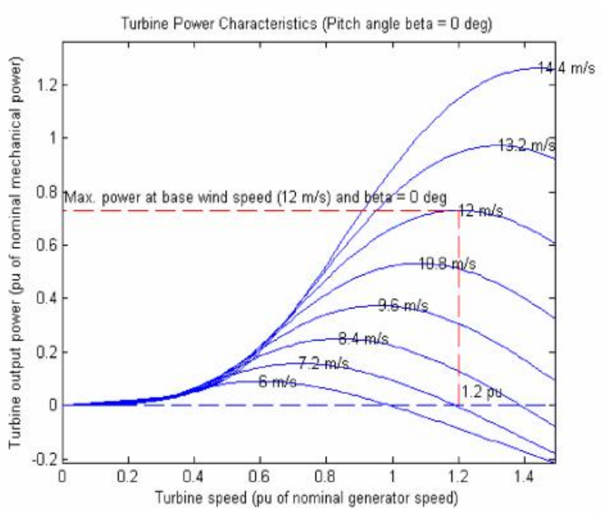
where C_p(ª,) is the power coefficient, ° is the air density, *V* is the wind speed, *R* is the blade radius, is the blade pitch angle and ª is the tip speed ratio. The value of maximum wind turbine output power per unit can be obtained by putting zero pitch angle and Betz limit, when the velocity of wind turbine is 12 m/s.

It is not suitable for real time application. In this proposed paper, maximum power can be captured in different wind turbine speeds. Considering the generator efficiency ¦*G*, the total power produced by the WG *P* is

$$P = \eta G P_m \quad \text{...(3)}$$

The WG power coefficient is maximized for a tip-speed ratio Value opts when the blade pitch angle is â = 0æ%. The WG power curves for various wind speeds are shown in Figure 2. It is observed that, for each wind speed, there exists a specific Point in the WG output power versus rotating-speed characteristic where the output power is maximized. The control of the WG load results in a variable-speed WG operation, such that maximum power is extracted continuously from the wind (MPPT control). The value of the tip-speed ratio is constant for all Maximum Power Points (MPPs), while the WG speed of rotation is related to the wind speed as follows:

Figure 2: Turbine Output Characteristics (Zero Pitch Angle)



$$\Omega_n = \lambda_{opt}\frac{V_n}{R} \quad ...(4)$$

where Ω_n is the optimal WG speed of rotation of a wind

Velocity V_n besides the optimal energy production capability, another advantage of variable-speed operation is the reduction of stress on the WG shafts and gears, since the blades absorb the wind torque peaks during the changes of the WG speed of rotation. The disadvantage of variable-speed operation is that a power conditioner must be employed to play the role of the WG apparent load. However, the evolution of power electronics helps reduce the power-converter cost and increases its reliability, while the higher cost is balanced by the energy production gain. The torque curves of the WG, consisting of the interconnected wind-turbine/generator system, for various generator output voltage levels under various wind speeds, are shown in Figure 3. The generator is designed such that it operates in the approximately linear region corresponding to the straight portion of the generator torque curves in Figure 4, under any wind-speed condition.

Figure 3: WG Power Curves at Various wind Speeds

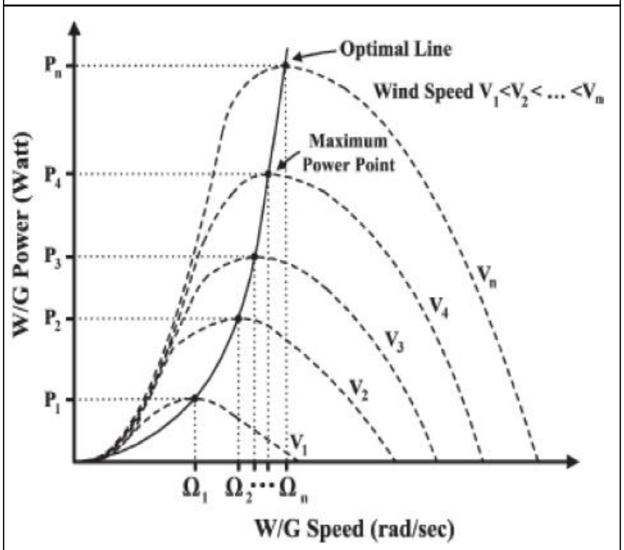
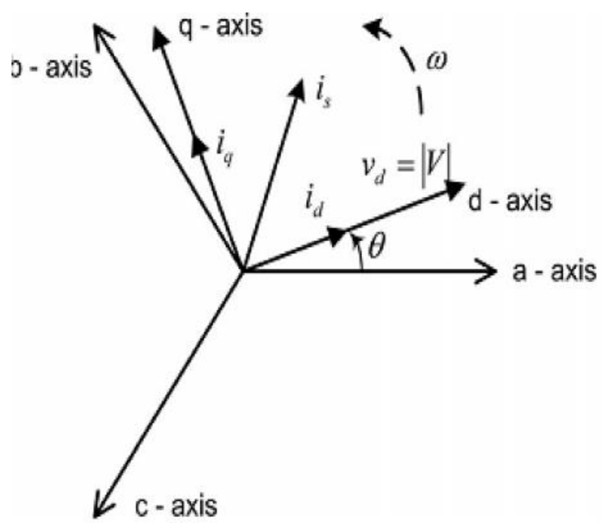


Figure 4: Voltage Vector Orientation Scheme for LSC of PMSG



PMSG-BASED STANDALONE POWER SYSTEM

This section covers the standalone operation of the PMSG based direct drive wind generator system. Considering simplicity and reduced cost, an arrangement where a PMSG is connected to an uncontrolled three-phase diode bridge rectifier, inverter system. However, with this arrangement, the DC-link voltage of the wind energy system varies in an uncontrolled manner and hence a DC/DC converter is included in the DC link. The operation of the battery storage system and dump load is coordinated with a view to regulate the DC-link voltage.

$$P_{inv} = v_{ds} i_{ds} \quad ...(5)$$

$$Q_{inv} = v_{ds} i_{qs} \quad ...(6)$$

$$v_{ds} = v_{ds} - v_{ds}^{*} + Lwi_{qs} \quad ...(7)$$

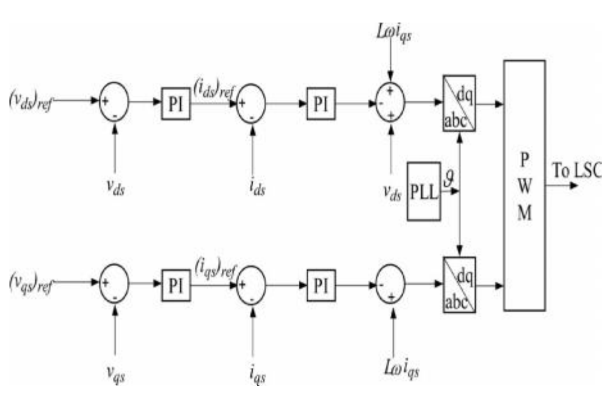
$$v_{qs1} = -v_{qs}^{*} + Lwi_{ds} \quad ...(8)$$

$$v_{ds}^{*} = Ri_{ds} + L\frac{di_{ds}}{dt} \quad ...(9)$$

$$v_{qs}^{*} = Ri_{qs} + L\frac{di_{qs}}{dt} \quad ...(10)$$

The main objectives of the inverter control strategies are to regulate the load side voltage and frequency. An approach based on vector control is employed for the Line Side inverter Control (LSC). In this regard, R–L filter arrangement used to develop the control strategy for the LSC. A voltage orientation scheme (i.e., $vqs = 0$) is opted for LSC in order to achieve decoupled control of active and reactive power as given in Zhou *et al.* (2009) and Shi *et al.* (2010). The vectorial representation of the voltage orientation scheme is shown as in Figure. 4. The vector representation of this three-phase system can be simplified into (Yang, 2010; and Mendis *et al.*, 2010). Furthermore, the voltage drop across the filter is given in Luu *et al.* (2008) and Jin and Wang (2010) which are functions of currents ids and iqs, respectively. The entire inverter control system designed for the LSC

Figure 5: Vector Control Scheme for PMSG Inverter

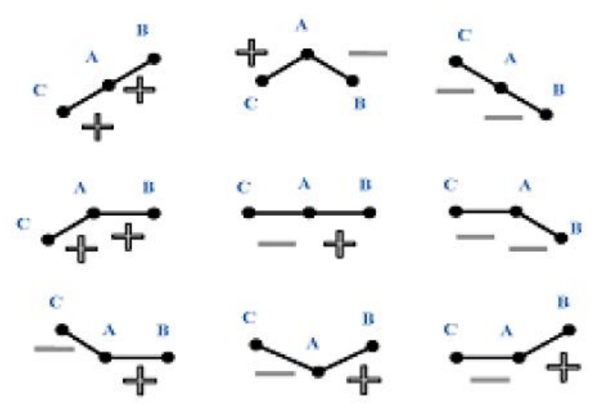


is shown in Figure 5. A virtual Phase Lock Loop (PLL) is used to define the orientation angle and frequency for the LSC. The PI controller parameters associated with the LSC control scheme shown in Figure 5.

TPWC METHOD

The proposed system of comparison method used in MPPT tracking. P&O algorithm compares only two points, which are the current operating point and the subsequent perturbation point, to observe their changes in power. But Three Point Weight Comparison Method (TPWC) gives, compare the two points at the result of point is again compared to another point so accuracy and efficiency is given. In Figure 6. TPWC method is proposed to avoid having to move rapidly the operating point.

Figure 6: Possible States of the Three Perturbation Points

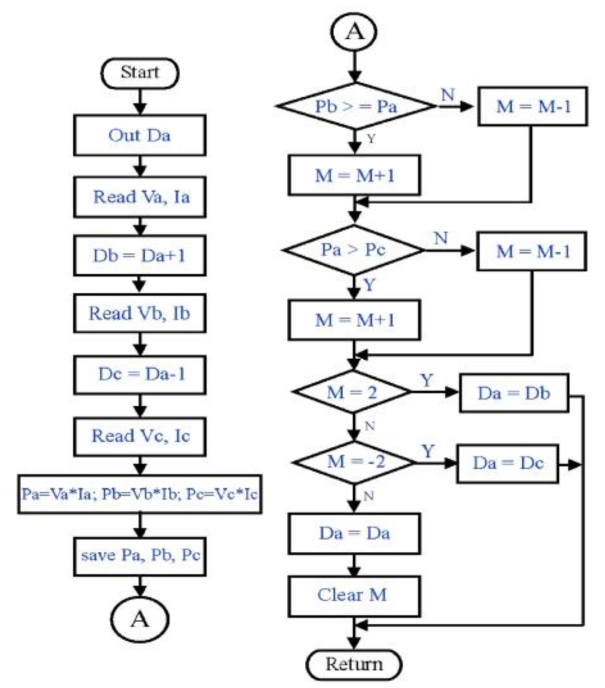


The MPPT can be traced weighting. Otherwise, the status is assigned a negative weighting of the three measured points. If two are positively weighted, the duty cycle of the converter should be increased. The algorithm of the three-point weight comparison is run periodically by perturbing the terminal voltage and comparing the output power on three points of the V-P curve. The three points are the current operating point (A), a point, B, perturbed from point A, and a point, C, with doubly perturbed in the opposite direction from point B. The nine possible cases. In these cases, for the point A and B, if the Wattage of point B is greater than or equal to that of point A, the status is assigned a positive weighting. Assigned a negative weighting. Otherwise, the status is assigned a negative weighting of the three measured points. If two are positively weighted, the duty cycle of the converter should be increased. On the contrary, when two are negatively weighted, the duty cycle of the converter should be decreased. The MPP is reached or the power has changed rapidly and the duty cycle is not to be changed also presents a flow chart of the TPWC algorithm.

MPPT Algorithm

The three point weight algorithm coding is given below in Figure 7. And then compare

Figure 7: Algorithm for Three Point Weight Comparison



the set points at the result of point is again compared to another point. The DC-DC converter is controlled MPPT algorithm. For an example of coding is given by,

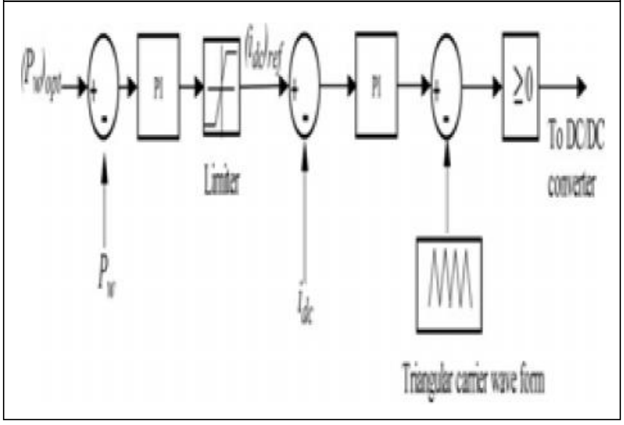
```
function D = TPW(V,I,T)
persistent P3 P2 P1 dP dPe d dd n;
if isempty(V)
    V=20;
end
if isempty(I)
    I=0;
end
if isempty(P1)
    P3=0;
end
if isempty(P2)
    P2=0;
end
if isempty(P1)
    P1=0;
end
if isempty(dP)
    dP=0;
end
if isempty(d)
    d=1;
end
if isempty(dd)
    dd=0;
end
```

```
if isempty(n)
    n=1;
end
    if (T > n*0.02)
    n = n + 1;
%   P1=P2=P3;
    P2=V*I;
    dP=P2-P1;
    dPe=dP-P3;
    if (dd==0)
        if dP>1
        dd=0.01;
        d=d+dd;
    else
        if dP<-1
        dd=-0.01;
        d=d+dd;
    else
        dd=0;
        end
    end
```

CONTROL STRATEGY FOR DC / DC CONVERTER

The duty cycle of the DC/DC converter (i.e., boost converter) is generated The outer loop compares the actual wind power PW with the reference to the optimum power (PW) opt. The PI controllers associated with the control scheme shown in Figure 8 are tuned using parameters.

Figure 8: Maximum Power Extraction Control Strategy for PMSG



SIMULATION RESULTS

MATLAB/SIMULINK is a block of library tool for modelling, simulating and analyzing dynamic systems The simulation result of the constant output power at variable wind speed is simulated and the results are better than the conventional methods. Besides the improvement in the converter efficiency, reduced mechanical and electrical stress.

Simulation Model

The simulation model for PMSG with controller, wind energy conversion system is shown in Figure 9.

Figure 9: Simulation for Proposed Method

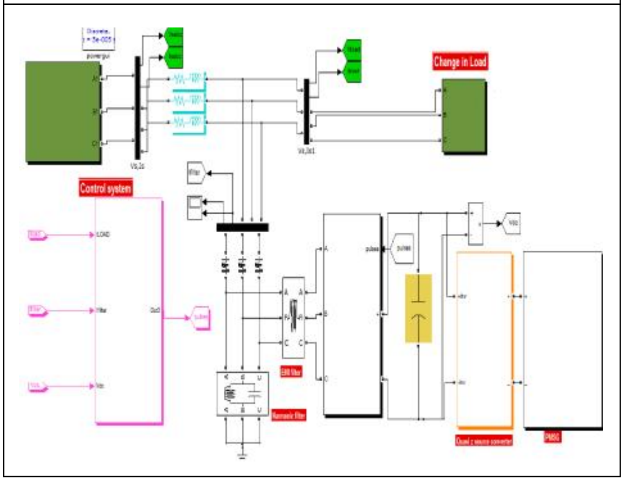


Figure 10 shows the PMSG output voltage using an MPPT controller by MATLAB. Figures 11 and 12 shows the inverter output voltage of480Volt AC is constant for different wind velocities in the Grid. Figure 13 shows the duty cycle variation of wind velocity using an MPPT controller. Table 1 shows the Wind PMSG based results and Quasi Z source converter output voltage.

Figure 10: PMSG Output Voltage Curve for the Wind Velocity of 10 m/s

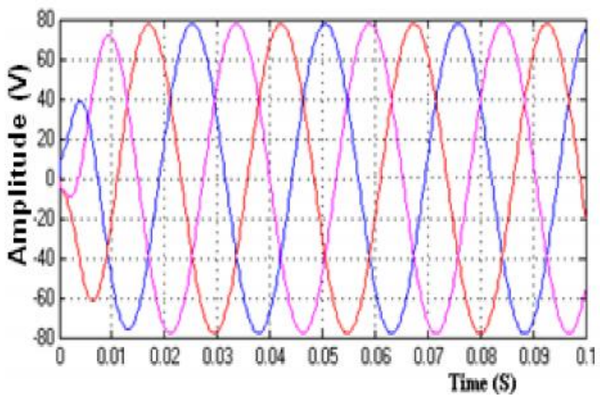


Figure 11: Quasi Inverter Output Voltage

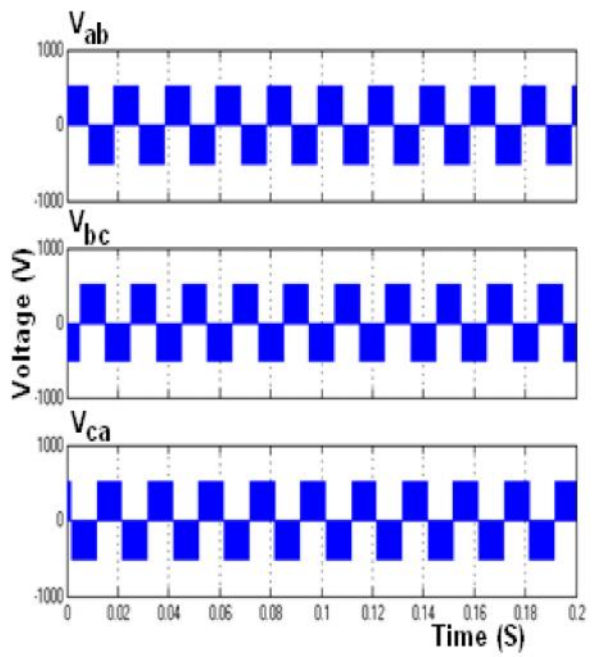


Figure 12: Output Voltage Curve

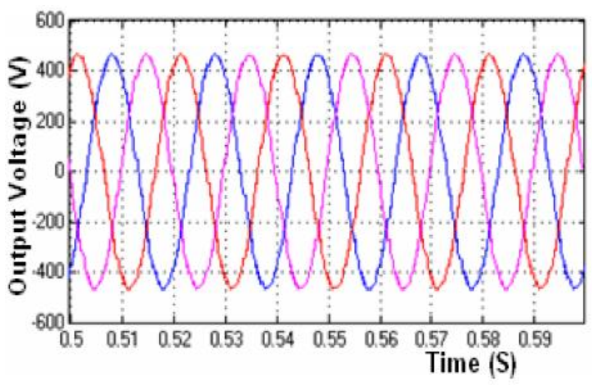


Figure 13: Duty Cycle Variation of Wind Velocity

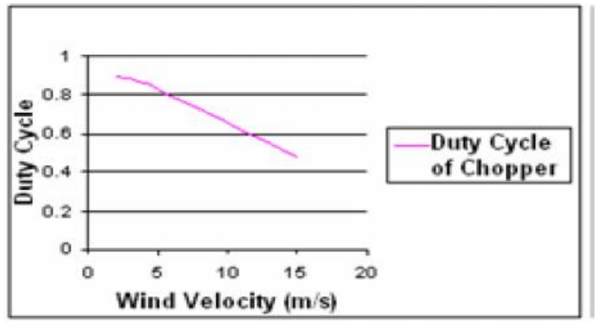


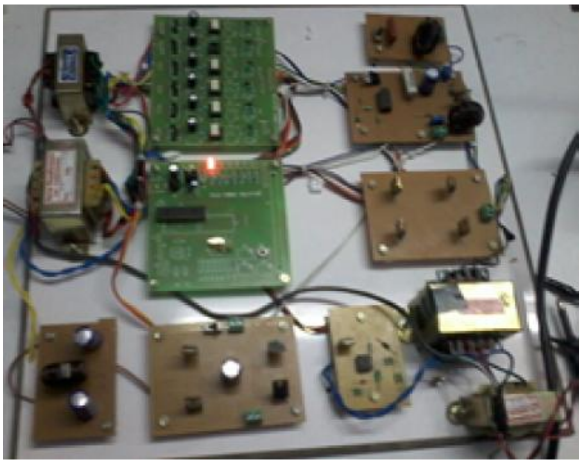
Table 1: Wind and PMSG Output Result

WIND and PMSG	
Output voltage	200 V
Output current	50 A
Torque	12 Nm
Wind speed	12 m/s
Cut in speed	7 m/s
PMSG speed	150 RPS
Quasi Z-Source Converter	
Output voltage	500V
Output current	50A
Inverter	
Output voltage	480V
Output current	40 A
Grid Line	
Voltage	480 V
Current	40 A
Frequency	50 Hz

HARDWARE IMPLEMENTATION

Figure 14 shows the simulation results were studied and a prototype of the simulated system is designed and this design promises the necessary constraint formulated and satisfies low cost and compact structure and the components used in the system is discussed in this process.

Figure 14: Experimental Setup Connection



The AC power (15 V) is given to the rectifier from the AC source. Here rectify the DC power. In this DC power is Stored in a storage capacitor for withstanding capability. The DC power is fed to the converter in before that goes through the Zero Cross Detector (ZCD). Here sense the signal and produce the equal pulses comes from the signal using particular unit. Particular is used for amplifying the signal because it produces a weak signal into strong signal. Phase shift is modulated from the ZCD signals. So that gives the signals Voltage and Current are in phase and the same sequence.

In this DC power is fed the converter, converts the DC into AC. The AC power is fed to the filter section here remove unwanted noise and distortions. Finally gives to the grid section The Experimental result of the (30 V) constant output power at variable wind speed implemented and the results are better than the conventional methods. Besides the improvement in the converter efficiency, reduced mechanical and electrical stress.

The converter part side output was with filter and without filter. The filter connected to converter output was sinusoidal waveform and voltage was 30 V. And the grid interface with system output was sinusoidal waveform with 30 Volts constant output power at variable wind speed.

CONCLUSION

In Figures 15 and 16 shows the without and filter based converter output voltage on MPPT controller. Figure 17 shows the grid based output voltage in constant by using the MPPT controller. Table 2 shows clearly the prototype model outputs. In this paper, a maximum power can be tracked for PMSG in wind energy conversion system. The constant voltage is maintained the grid side by using PID controller. The voltage regulation point of view, the PMSG especially during transient conditions, whereas “better frequency

Figure 15: Converter Interface Without Filter

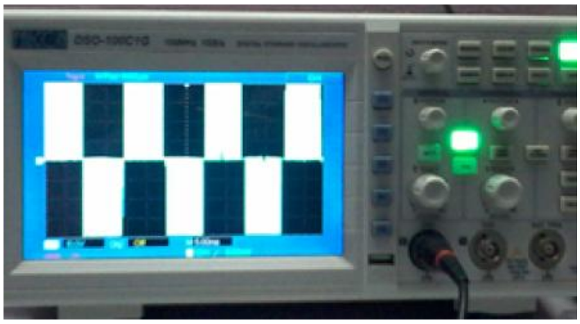


Figure 16: Converter Interface with Filter

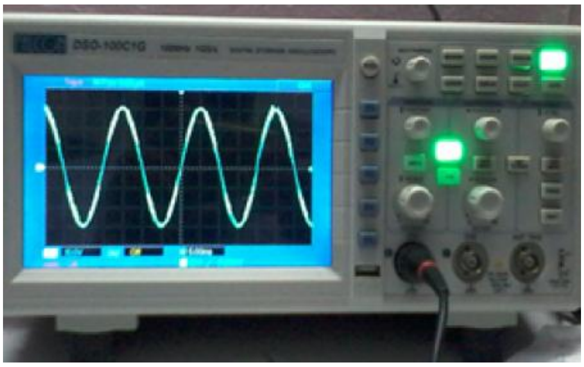


Figure 17: Grid Interface Result

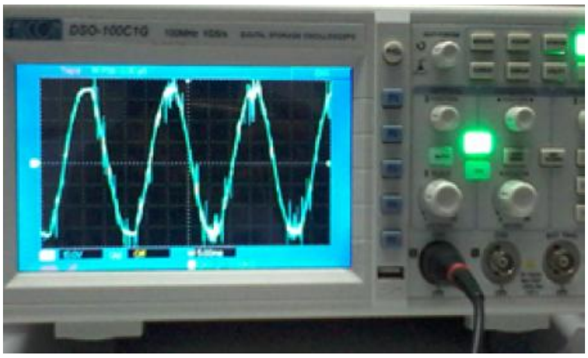


Table 2: Grid Side Output Result

Grid Line	
Input Voltage	230 V
Current	2 Amps
Frequency	50 Hz
Output Voltage	30 V
Current	2 Amps

regulation" is obtained from the PMSG-based system. The proposed control, coordination scheme for using fuzzy controller, which also caters to maintain the active power balance ensures the optimal sharing of active power while regulating the voltage and frequency. Simultaneously and independently of the reactive power exchange, allow to greatly enhance the performance and restraint of the electric system.The fast response of power electronic devices and the enhanced performance of the proposed control technique of Fuzzy controller used.

REFERENCES

1. Abbey C A and Joos G (2005), "Short-Term Energy Storage for Wind Energy Applications", in Proc. Ind. Appl. Conf., Vol. 3, October 2-6, pp. 2035-2042, Hong Kong.
2. Cheng K W E, Lin J K, Bao Y J and Xue X D (2009), "Review of the Wind Energy Generating System", in Proc. Int. Conf. Advances Power Syst. Control, Oper. Manage., November 8-11, pp. 1-7, Hong Kong.
3. Edwards D and Negnevitsky M (2008), "Designing a Wind-Diesel Hybrid Remote Area Power Supply (RAPS) System", in Proc. Int. Conf. Sustainable Energy Technologies, November 24-27, pp. 406-414, Singapore.
4. Haruni A M O, Gargoom A, Haque M E and Negnevitsky M (2010), "Dynamic Operation and Control of a Hybrid Wind-Diesel Standalone Power Systems", in Proc. 25th Annu. Conf. Appl. Power Electron. Conf. Expo., February 21-25, pp. 162-169, CA.
5. Hongxin J, Yang F, Yu Z and Weiguo H (2010), "Design of Hybrid Energy Storage Control System for Wind Farms Based on Flow Battery and Electric Double-Layer Capacitor", in Proc. Power Energy Eng. Conf., March 28-31, pp. 1-6, Chendu, China.

6. Jin C and Wang P (2010), "Enhancement of Low Voltage Ride-Through Capability for Wind Turbine Driven DFIGURE with Active Crowbar and Battery Energy Storage System", in Proc. Power Energy Soc. General Meeting, July 25-29, pp. 1-8, Minneapolis, MN.

7. Luu T, Abedini A and Nasiri A (2008), "Power Smoothing of Doubly Fed Induction Generator Wind Turbines", in Proc. 34th Annu. Conf. Ind. Electron. Soc., November 10-13, pp. 2365-2370, Orlando, FL.

8. Mendis N, Muttaqi K, Sayeef S and Perera S (2009), "Power Generation in Isolated and Regional Communities: Application of a Doubly-Fed Induction Generator Based Wind Turbine", in Proc. 19th Australasian Universities Power Eng. Conf., September 27-30, pp. 1-6, Adelaide, Australia.

9. Mendis N, Muttaqi K, Sayeef S and Perera S (2010), "Control Coordination of a Wind Turbine Generator and a Battery Storage Unit in a Remote Area Power Supply System", in Proc. Power Energy Soc. General Meeting, July 25-29, pp. 1-7, Minneapolis, MN.

10. Nishad Mendis, Muttaqi M, Saad Sayeef and Sarath Perera (2012), "Standalone Operation of Wind Turbine-Based Variable Speed Generators with Maximum Power Extraction Capability", *IEEE Transactions on Energy Conversion*, Vol. 27, No. 4.

11. Shi G, Cao Y F, Li Z and Cai X (2010), "Impact of Wind-Battery Hybrid Generation on Isolated Power System Stability", in Proc. Int. Symp. Power Electron. Electr. Drives Autom. Motion, June 14-16, pp. 757-761, Pisa, Italy.

12. Yang T C (2010), "Initial Study of Using Rechargeable Batteries in Wind Power Generation with Variable Speed Induction Generators", *IET Renewable Power Generation*, Vol. 2, June, pp. 89-101.

13. Zhou Y, Ferreira J A and Bauer P (2007), "Grid-Connected and Islanded Operation of a Hybrid Power System", in Proc. Power Eng. Soc. Conf. Expo. Africa, July 16-20, pp. 1-6, Johannesburg, South Africa.

14. Zhou Y, Ferreira J A and Bauer P (2009), "How New Technology Developments will Lower Wind Energy Costs", in Proc. CIGRE/IEEE PES Joint Symp. Integr. Wide-Scale Renewable Resources into the Power Delivery Syst., July 29-31, pp. 1-7, Calgary, Canada.