# Permanent Magnet Synchronous Generator for Wind Energy Conversion Systems (WECS): A Review

Y. Mastanamma [1]*, Dr. D. Subbarayudu [2]

***Abstract*: Variable design control has shown that it is easy to use existing electronics for the variable speed wind energy converter control. Its main disadvantage is the increase in mechanical stress due to the squawking, which can, nevertheless, be reduced using different techniques. The paper presents Sliding Mode Control (SMC) Design for Variable Speed Wind Farm Systems (VS-WFS), which is based on and linked to an electrical network using the Permanent Magnet Sync Generator (PMSG).This paper recommendations various aspects of PMSG including topology with controlled and uncontrolled rectifier, grid connected and standalone mode of operation using different control methods PMSG-based W. The overall performance assessment of PMSG can be augmented through the use of advanced optimization techniques by a number of control mechanisms. A qualitative analysis based on the techniques is carried out and the relevant benefits and disadvantages are discussed.***

***Index Terms*: Permanent Magnet Synchronous Generator (PMSG), Sliding Mode Controller (SMC), Wind Energy Conversion System (WECS)***

## I. INTRODUCTION

Renewable sources of energy are regarded as among the most viable resources in the world today. An independent power source is illuminates the entire world, alternative power sources are pre-requisite. At present situation, solar, wind, hydro and ocean always seem to be sources of renewable energy as alternate of traditional sources. Furthermore, wind is regarded as the rapidly growing source of energy from all new sources of power that does not pollute and can easily be harvested. Contemporary advances in the modern technology of wind turbines required the design of a more strong control system. The new control techniques improved the efficiency of wind and made it more profitable and reliable. The main objective and unbiased feature of the paper is the option for a better control strategy on the PMSG-based wind turbines and a qualitative study of various wind turbine controllers. Wind energy conversion (WECS) is now increasingly popular because of its offshore applications due to the removal of the gearbox and the excitation box.

Wind energy is also one of the renewable energy generation methods that has been of particular interest in past years [1][2]. The permanent magnet synchronous generator is equipped with conditions such as low wind speed, maximum energy-to-weight ratio in direct drive, etc., so that wind turbine is very widely used [3],[4]. The number of wind farms is increasing every day so that the wind turbines grid connection situation is more valuable than in the past. Some countries therefore need to correct grid codes for maintaining grid-connected wind turbines. The wind turbine needs to begin connecting with the grid, even during a grid failure, according to new grid codes [5]. Furthermore, this generator can again reduce weight, losses, costs and repairs and maintenance needs [6]. Furthermore, with the advance of electronic power, wind farm systems are currently allowed to take part proactively through appropriate generation control methods in distribution system operation [7-8].

This control method is also helpful in synchronous machines. The potential power of this control method is effectively demonstrated by research on the use of SMC in PMSGs[14]. The resilience of SMC is the ability to manipulate high-order structures while showing resilience to instabilities and changes in model parameters [15]. SMC research into PMSGs illustrates the potential of this control method and emphasizes SMC's commitment to achieve the objective of increasing the efficiency level of MPPT[16]. Findings shown in the study of using SMCs with permanent magnet synchronous engines and second-order SMCs used on PMSGs are further proved by the strength of SMC as a viable approach for efficacious synchronous machine management [17],[ 18],[ 19].

Even though the good characteristics of SMC make it an ideal method of control, it really does not exist in the real world without fault. The so-called chattering phenomenon leads to an entirely understandable level of attention. The system's response to SMC oscillates over the desired reference called the sliding surface due to un-ideal switching device [20]. The main contributions and organization are summarized as follows: In Section 2 we describe background details of different sliding mode control schemes. We finally concluded the paper in section.

## II. EXISTINGN MODELS

The implementation of the wind turbine aerodynamics, PMSG dynamics, and SMC control architecture in SIMULINK is shown by Fig 1. The nominal PMSG parameters used are listed in Table 1. Parameter variations were implemented within the Generator Dynamics block.

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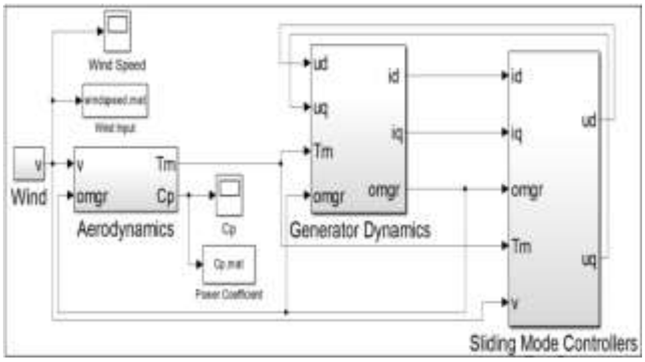


**Fig.1. Simulink Model**

The entire above Peripheral device, which is known for its reliability due to the system's un-modeled dynamics, provides the ideal features for use in controlling permanent magnet synchronous generators used in variable speed wind power conversion systems. Evaluation of this direct control technique using dynamic models of the d axis, q axis and high velocity rotational shaft currents indicates a high performance in the extraction of power from a different wind resource.

Fig.2 shows the typical WECS structure. It comprises a PMSG side rectifier and a grid side inverter connected via a dc-link system. The rectifier controls the PMSG's power, torque or speed. The disconnection of the condenser enables completely separate control of each power electronic system. The inverter is responsible for synchronizing the WECS power generated with the electrical grid and for maintaining the dc-link voltage constant. In addition, the inverter should be able to change the reactive and active power that WECS can exchange and reach the unit power factor (UPF) of the system. In addition, as the WECS is increasingly being incorporated into the modern electrical network, it is necessary that these systems can also operate in an irregular and grid disturbance, in accordance with IEEE standards and new grid codes [21]. As a result, the power quality of WECS creates significant challenges for electricity generation control strategies [21].

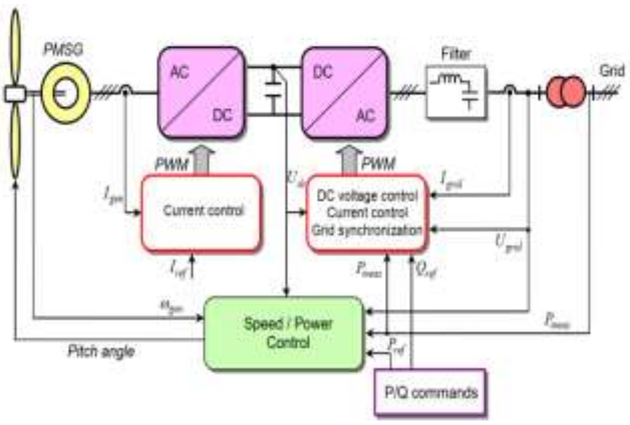


**Fig.2. Typical structure of WECS connected to an electric network**

This paper envisages a PMSG-based Variable Speed Wind Farm System (VS-WFS). The block diagram of the WFS is shown in the figure. The system includes 3 PMSGs which are linked to a common DC-bus system. Each PMSG in the VS-WFS is connected via a rectifier to the DC bus. Thus, speed controls have been used to optimize the energy extracted from wind below the rated power range, while the control goals of the grid inverter system are to produce the energy from the PMSG sides to the electric network, to regulate the voltage of the DC-link system and to achieve the VS-WF Speed Power Factor Unit (UPF).

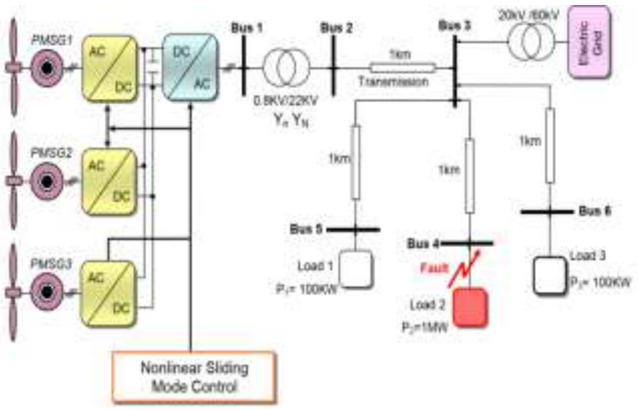


**Fig.3. Configuration of the system**

Furthermore, VS-WFS has a powerful nonlinear multivariate with numerous highly uncertain factors and instabilities. For such reasons, the SMC approach is used to achieve optimum control of the VS-WFS and Lyapunov analysis ensures stability of the regulators. The purpose of the control approach is to maximize the extracted power with the lowest possible impact for defective and normal working conditions on the power grid frequency and the voltage. On the other hand, a WFS pitch control scheme is in place to prevent wind turbines from being damaged by excessive wind speeds. System responses with the proposed SMC method will also be validated through simulation results and compared with conventional Proportional Integral (PI) controller systems based on the Vector Control (VC).

In [22] a robust and reliable power system is proposed with a combination of a 3-wheel drive trainer on the machine side and a z-source inverter on the grid as a bridge between the grid and the machine. Fig.4 shows the schematic diagram of the Z-source converter-based PMSG WECS. Space vector modulation and operating principles of Z-source network in development of the modulation scheme. The optimized control proposed is to be developed in two control approaches such as unit-power-factor control and rotor flux-orientation control. A separate active and reactive power control is achieved. MPPT is achieved through the control of the Z-source shoot-through cycles.

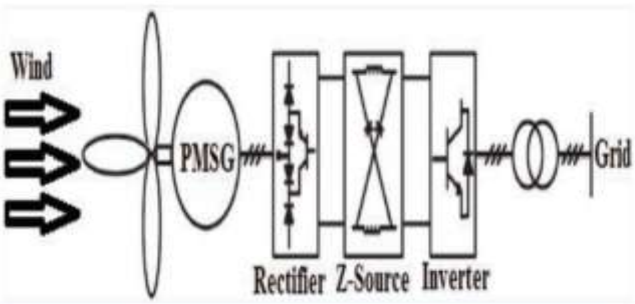


**Fig.4.Schematic diagram of PMSG based WECS with Z-source converter.**

In [25] a novel new schemes for a grid-connected


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PMSG-based variable-speed WECS with a fuzzy fractional order, proportional integral+ I (FFOPI+I). The controller uses a bidirectional converter to control the system with non-linear load. The controller continues to develop an FLC in parallel with the Fractional Order PI (FOPI) and conventional PI controllers. The initial parameters of the FFOPI+I controller are computed using a frequency approach to produce a search space and then an algorithm for the selection of optimum parameters to use particle-swarm-optimization (PSO).

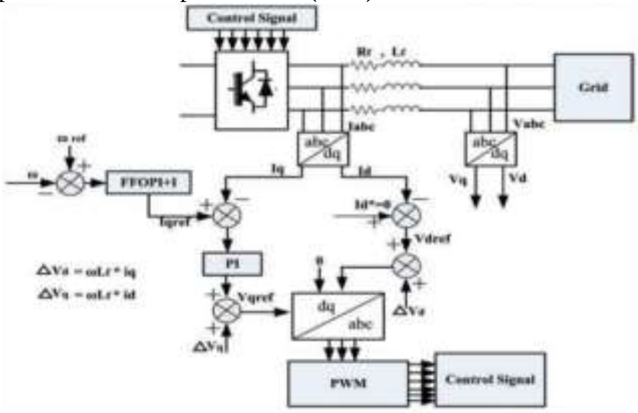


**Fig.5.Schematic diagram of the control scheme with FFOPI+I controller**

In [24], smart controllers are implemented to achieve maximum power for a Switched-Reluctance Generator (SRG), WECS. These controllers are predicated on the FL and ANN strategies. The controller adjusts the rotational speed of WT by setting the turning angle and changing the SRG turning angle. Simulation results demonstrate the energy efficiency and accuracy of the ANN controller as compared to the FL controller [25] proposes a model-predictive control that improves the dynamic response and enables flexible operation of parallel connected generators by removing dependence on the voltage and frequency synchronization.

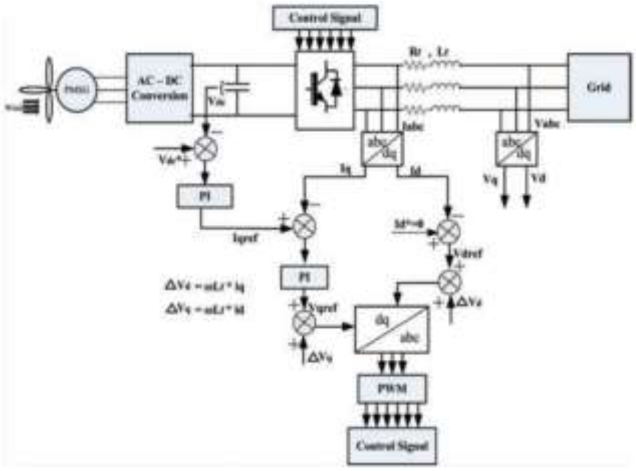


**Fig.6.Control scheme of grid side converter (GSC)**

Arrangement demonstrates that the micro grid is operationally viable from the distribution network grid under islanding. An enhanced fast dynamic system for the regulation of Matrix-Converters (MC) is advocated in [26] with an optimum tuning-PI controller and modified hysteresis-current controller. In order to achieve maximum power, enhanced Bacterial Foraging Optimization (BFO) algorithm is used for active and reactive currents control of PMSG. The active and reactive power of BFO can be supplied to the grid in normal and defective situations.

Different energy sources are incorporated into the grid using the DC bus. Meta-heuristic Firefly algorithm (FA) controllers are used at the point of common connection for voltage and frequency control. The gains of PI and PID controllers are simultaneously improved by a strong FA and evaluated performance. The PID controller's dynamic responses show better results compared with PI. For a grid-connected PMSG-based WECS, a Maximum Power Extraction Algorithm (MPEA) is offered and can be implemented in practice without either mechanical sensors for WECS through a PMSG[27]. Robust models were proposed to analyze fluctuations in power and voltage, which depend on the network parameters. Flicker emissions can be reduced by activating the voltage control loop developed [28]. The q&d axis current controls the active and reactive power. The phase-angle utility-voltage is identified by the synchronous reference frame in the PLL software. This approach gives WECS with high-quality and low-cost power conversion [29]. The grid-connected PMSG system control scheme is shown in Figure 6. In [30], there are two control schemas for controlling MSC & GSC on both wind farms (WF) using PMSG connected to DC-bus systems, based solely on sliding-mode controllers and classic PI controllers. The control scheme combines a pitch control technique and MPPT to obtain more WF power.

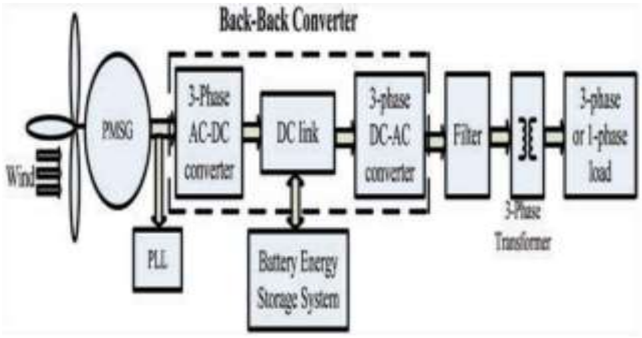


**Fig.7.PMSG based Standalone WECS**

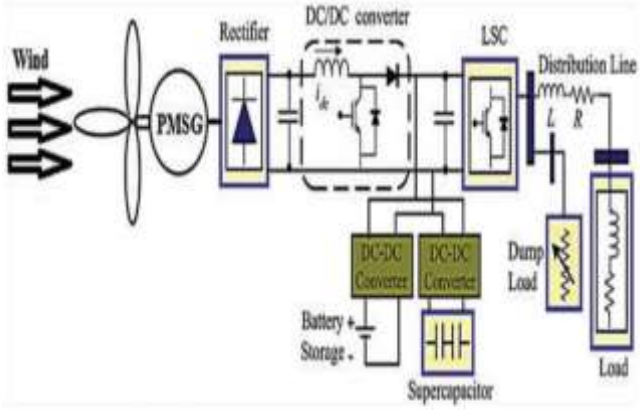


**Fig.8.PMSG based standalone WECS with BESS and super capacitor [32]**


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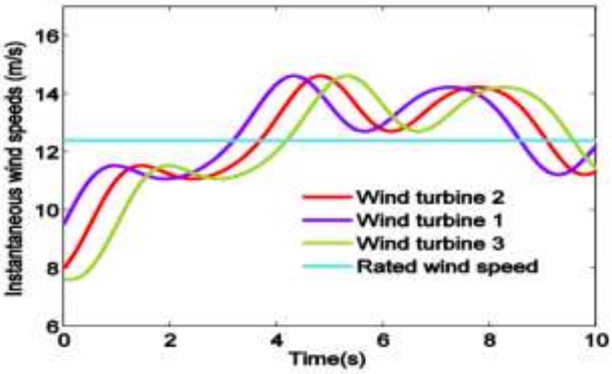
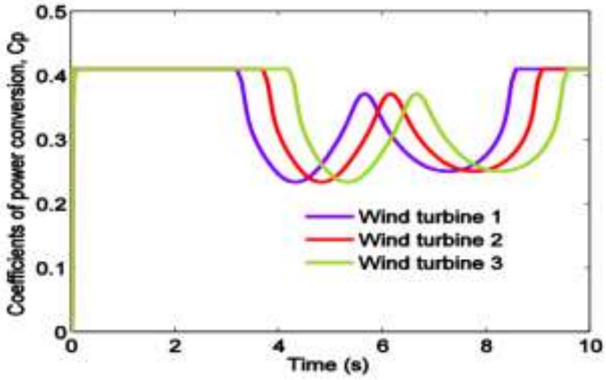
Fig.7 shows a standalone WECS based on PMSG. Here, PMSG's 3-phase ac/dc converter, BESS, and 3-phase dc/ac converter connect to a load. Generally, BESS and super-capacitor / ultra-capacitor support standalone WECS.

## III. RESULTS

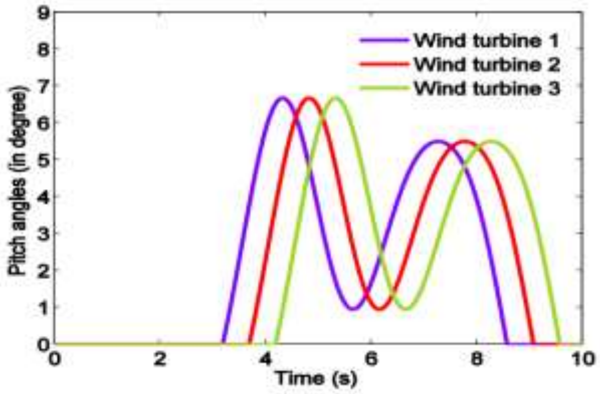
The standalone PMSG-based WECS with BESS and super-capacitor is shown in Figure 8. Synchronous condensers provide reactive power and system inertia. Coordinated control manages the active and reactive power flow here between the elements of the system [31]. Results obtained with rigorous voltage and frequency control, efficient management practices and maximum wind extraction.



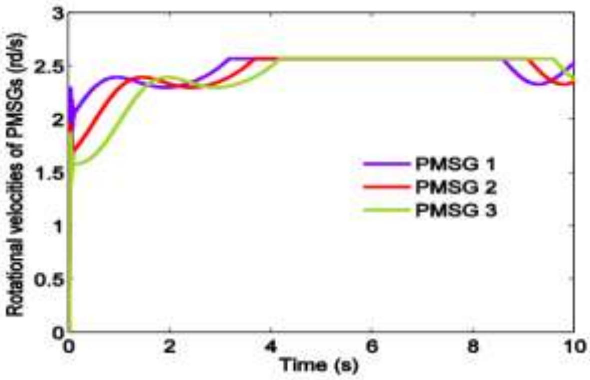

**(a). Instantaneous wind speeds (m/s)**



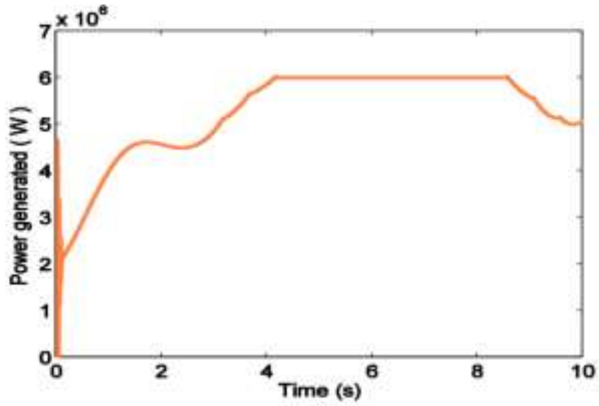

**(b)Coefficients of power conversion Cp**




**(c) Pitch angles β (in degree).**




**(d)Rotors angular velocities of PMSGs**




**(e)Total power generated**

**Fig.9. Waveforms of WFS characteristics with SMC**

## IV. CONCLUSION

In this paper, numerous PMSG topologies have been discussed, including with controlled & uncontrolled rectifier, grid-connected operation, autonomous operation, various control algorithms and PMSG optimization technology, based solely on their peak power generation. Each and every method is defined in terms of the parameters used according to the required specification. By adopting many control mechanisms, advanced optimization techniques can enhance the performance measurement of PMSG. This paper enables to provide beneficial understanding for the long term future of research.

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