
DESIGN IMPLEMENTATION OF SOURCE SIDE CONVERTER FOR PMSG BASED WIND ENERGY CONVERSION USING MPPT

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Article Received: 14 February 2026

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Article Revised: 05 March 2026

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Published on: 25 March 2026

DOI: <https://doi-doi.org/101555/ijrpa.2953>

ABSTRACT

In last decade, due to several limitations of conventional sources of energy such as high cost of fossil fuels, contribution towards pollution and environmental damage, scarcity in resources, there is an urge for the utilization of renewable sources of energy. Among several forms of renewable sources of energy, specifically wind energy conversion system is the most cost effective and technologically improvable. In variable speed operation, it is important that the generated power from PMSG should be optimized. There fore in order to capture as much power as possible from wind during change in wind speed, maximum power point tracking controller is implemented. Among several methods, the most efficient method of MPPT technique is Perturbation and observation (P&O) which has its own virtues. Here simulation evaluation is done to know the working of MPPT and successfully optimize the generated power during a step change in wind speed. In addition to power optimization, variation in load as well as wind speed during variable speed operation, results drift in system voltage and frequency which in turn leads to generation loss owing to line tripping, power swings and also black outs. Therefore in order to reduce the change in system voltage and frequency to the smallest possible value, a voltage frequency controller is required.

INTRODUCTION

There are two types of energy sources in the world i.e. renewable energy source and conventional energy sources. Renewable energy sources are the type of energy sources which are plenty in quantity and are derived from earth. Wind energy, solar energy, geo thermal and bio mass are different types of renewable energy sources. These resources are inexhaustible

in nature. The known advantages of renewable energy sources are its clean nature, abundant in quantity and most importantly it is eco friendly unlike non renewable energy sources. Now days more research is going on the enhancement of technology which can efficiently convert the renewable energy sources into useful electrical energy sources. Though the literal conversion efficiency of renewable energy sources is lower than that of conventional energy source, the technology is developed and improvised on daily basis to improve its efficiency above 90%. On the other hand conventional sources of energy are contributing towards pollution, it's depleting in quantity and exhaustible. Because of several disadvantages renewable energy sources can be used as alternatives to it. Among different types of renewable sources of energy, wind energy is the most cleanest and the efficient source of energy. The major advantages of wind energy are wind-generated electricity doesn't pollute the water, air or soil. It doesn't contribute towards global warming. It doesn't consume large amount of water needed by other energy sources. It is caused by every day solar radiation. Its supply is abundant unlike solar power during bad weather condition and night time. The price of electricity generation by wind power plant is comparatively lesser than other modes of generation. It contributes towards the economy of middle class and low class communities. It also creates employment opportunities for highly skilled workers. It's very fast and easy to install. In a year many large utility scale wind power plants are installed. There are different components of a SWECS, of which the most important is the type of generator used. There are several types of generators used such as Self-excited induction generator (SEIG), doubly fed Induction generator (DFIG) and permanent magnet synchronous generator (PMSG). Among these generators, PMSG has several advantages which make it very usable for WECS. It doesn't require an additional dc supply for excitation circuit. By eliminating the excitation, energy savings of 20% can be had by simply using magnets. It doesn't use slip rings, so it is simpler and maintenance free. The condensers are not required for power factor maintenance unlike in induction generator. It is also advantageous over geared driven segment IG system. Induction generator requires leading reactive power to build up terminal voltage. On other hand DFIG has shorter range of operation unlike PMSG. It is quite 2 complex management of LVRT in wind farms. LVRT is low voltage ride through capacity of a wind turbine: that is the ability to overcome severe voltage dips on main grid without turning off. driver regulates their operation. An ultrasonic sensor is used to continuously measure the distance from the human target, and an ESP32/ESP8266 microcontroller processes this data to generate control signals. This ensures that the robot can follow the user smoothly while avoiding collisions. Thus, the project aims to design a low-cost, portable, and

effective robotic assistant that demonstrates the practical application of robotics in everyday life.

a) **Literature review**

A. Global Wind Report, Annual Market Update 2012 – GWEC This report presents a comprehensive analysis of global wind power installations and market growth up to 2012. It highlights regional capacity additions, policy influences, and investment trends shaping the wind energy sector. The document serves as a key reference for understanding worldwide wind industry development and future projections. Communication)-2020.

B. F. Blaabjerg et al., 2012 – Power Electronics Converters for Wind Turbines. This paper discusses modern power electronic converter topologies used in wind turbine systems, particularly in multi-megawatt applications. It examines efficiency, reliability, and grid compliance requirements of converter systems. The study also outlines technological advancements improving wind energy conversion performance.

C. Z. Chen et al., 2009 – Review of Power Electronics for Wind Turbines. This work provides a detailed review of power electronic technologies used in wind energy conversion systems. It covers DFIG, PMSG, and full-scale converter configurations along with their control strategies. The paper emphasizes grid integration challenges and evolving converter solutions.

D. M. Liserre et al., 2011 – Multi-MW Wind Turbines and Wind Parks. This paper reviews the development of large-scale wind turbines and wind farm systems. It discusses offshore challenges, grid codes, and high-power converter configurations. The study focuses on system reliability and efficient integration of multi-MW turbines.

E. UpWind Project Report, 2011 – Very Large Wind Turbines. This report investigates the technical and structural limits of very large wind turbines, particularly for offshore applications. It addresses aerodynamic, mechanical, and electrical design challenges. Solutions are proposed to enhance scalability and long-term reliability.

F. X. Yang et al., 2012 – PM Generator Design for Large Wind Turbines. This paper focuses on the design and control of permanent magnet synchronous generators for large wind turbines. It discusses electromagnetic design optimization and control techniques for improved efficiency. The study highlights reliability improvements in direct-drive systems.

G. K. Ahsanullah et al., 2012 – Review of PM Generator Designs. This research reviews different permanent magnet generator configurations used in direct-drive wind turbines. It compares structural designs, efficiency levels, and cost considerations. The paper evaluates performance trade-offs between various PM generator topologies.

H. M. Arifujjaman & L. Chang, 2012 – Reliability of Converters in WECS. This paper compares the reliability

performance of different power electronic converters used in grid-connected wind systems. It analyzes thermal stress, failure rates, and operational lifespan. Recommendations are provided to enhance system durability and reduce maintenance costs.

System block diagram

The proposed project focuses on the design and implementation of a Permanent Magnet Synchronous Generator (PMSG)-based Wind Energy Conversion System (WECS) integrated with a Maximum Power Point Tracking (MPPT) control strategy to enhance energy extraction efficiency under varying wind conditions. The methodology follows a systematic approach that includes mathematical modeling, simulation, controller design, hardware implementation, and performance evaluation. Initially, a comprehensive model of the wind turbine is developed based on aerodynamic principles. The mechanical power extracted from the wind is expressed as a function of air density, swept area, wind speed, and the power coefficient, which depends on the tip-speed ratio. This model enables the analysis of turbine behavior under variable wind speeds. The mechanical output of the turbine drives the PMSG, which is selected due to its high efficiency, reliability, gearless operation, and suitability for variable-speed wind applications. The electrical behavior of the PMSG is modeled using the d–q axis transformation method to describe stator voltage, current, electromagnetic torque, and rotor dynamics equations. These mathematical models are implemented in MATLAB/Simulink to simulate system performance before hardware realization. The generated three-phase AC output from the PMSG is converted into DC using a diode bridge rectifier. A DC–DC boost converter is then employed to regulate and step up the rectified voltage to a suitable level for the load or battery storage system. The duty cycle of the boost converter is controlled using an MPPT algorithm to ensure maximum power extraction. In this project, a suitable MPPT technique such as Perturb and Observe (P&O) or Tip Speed Ratio (TSR) control is implemented. The MPPT controller continuously measures system voltage and current, calculates instantaneous power, and adjusts the converter duty cycle to track the optimal operating point corresponding to maximum power. The complete system, including wind turbine, PMSG, rectifier, DC–DC converter, and MPPT controller, is simulated under varying wind speed profiles to evaluate dynamic response, output power stability, tracking efficiency, and overall system performance.

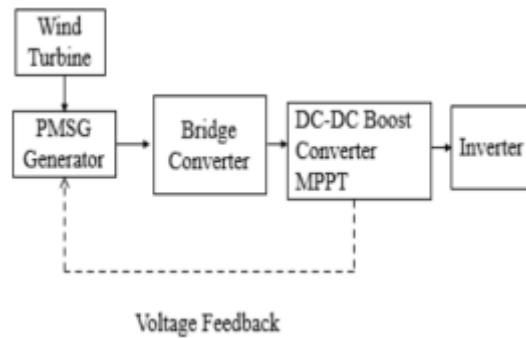


Figure 1. Proposed Block Diagram.

a) Circuit Design and its Explanation

The circuit is a wind energy battery charging system that converts the variable electrical output of a wind turbine into a regulated DC voltage to charge a battery while being controlled by a microcontroller. The wind turbine generates three-phase AC power which enters the circuit through the input connector and is rectified by a six-diode bridge (D7–D12) to produce pulsating DC. A filter capacitor smooths this voltage to obtain an unregulated DC supply whose magnitude depends on wind speed. This DC voltage is then fed to a boost converter stage consisting of an inductor (L1), MOSFET switch (Q1), diode (D1), and output capacitor (C3). The boost converter increases the voltage level so that even low wind speeds can still provide sufficient voltage to charge the battery. The switching of the MOSFET is controlled using a PWM signal generated by the microcontroller, typically a PIC16F877A, and the duty cycle determines the output voltage according to the boost converter principle. A MOSFET driver stage using transistors Q2 and Q3 amplifies the control signal from the microcontroller to ensure fast and efficient switching of the MOSFET. Voltage divider networks are used to sense both the wind generator voltage and the battery voltage, allowing the microcontroller to monitor system conditions and regulate the charging process to prevent overcharging. The measured values are also displayed on an LCD module for real-time monitoring. A separate regulated power supply section provides a stable 5 V supply for the control circuitry using a transformer, rectifier diodes, filter capacitors, and a voltage regulator such as the 7805 voltage regulator. Overall, the circuit efficiently converts variable wind energy into controlled electrical power and manages battery charging through microcontroller-based PWM control and voltage feedback.

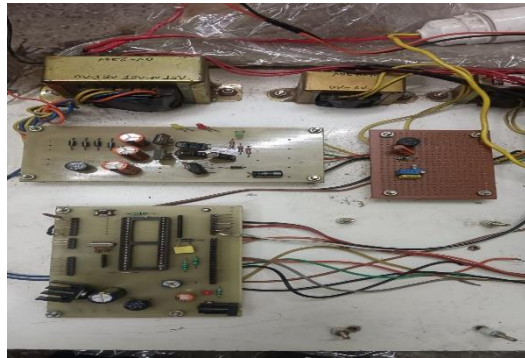
Figure.2 circuit diagram representation.

SOFTWARE REQUIREMENTS

The circuit represents a microcontroller-based wind energy conversion and battery charging system designed to convert the variable electrical output from a wind turbine into a regulated DC supply suitable for charging a battery. The wind turbine produces three-phase AC power that varies with wind speed. This AC voltage is applied to a six-diode bridge rectifier which converts the AC signal into pulsating DC. A filter capacitor connected at the rectifier output smooths the waveform and produces a relatively stable DC voltage. However, since the generated voltage changes depending on wind conditions, this DC cannot be used directly for battery charging and therefore requires further regulation and control. To regulate and increase the generated voltage, a boost converter is used. The boost converter consists of an inductor, a switching MOSFET, a diode, and an output capacitor. When the MOSFET switch turns ON, current flows through the inductor and energy is stored in its magnetic field. When the MOSFET turns OFF, the stored energy in the inductor is released and added to the input voltage, causing the output voltage to rise to a higher level than the input. The diode directs this energy toward the output while preventing reverse current flow, and the capacitor filters the output to produce a smooth DC voltage suitable for charging the battery. By adjusting the duty cycle of the switching signal, the output voltage of the boost converter can be controlled. The switching signal for the boost converter is generated by a microcontroller, typically the PIC16F877A, which acts as the main controller of the system. The microcontroller reads voltage signals from different parts of the circuit through voltage divider networks. These divider circuits scale down the generator voltage and battery voltage to safe levels that can be measured by the analog-to-digital converter (ADC) of the microcontroller. Based on these measurements, the microcontroller adjusts the PWM duty cycle to maintain efficient battery charging and protect the battery from overcharging or excessive voltage.



III. HARDWARE IMPLEMENTATION



g) Hardware Image

For the Buddy Basket a compact inverter topology can be implemented to efficiently manage power from the 12V battery and supply stable voltage to the motors and electronics. The proposed system uses a DC-DC boost inverter topology, which steps up or regulates the battery voltage as required. The primary components include a MOSFET-based H-bridge circuit, a pulse-width modulation (PWM) controller, voltage regulators, and filter capacitors to ensure smooth output. The H-bridge configuration allows bidirectional control of the DC motors, enabling forward, backward, and turning movements. The PWM signals are generated by the ESP32/ESP8266 microcontroller, which also handles ultrasonic sensor input for distance control. Voltage regulators are used to supply stable 5V and 3.3V outputs for the microcontroller and sensors. This topology ensures efficient energy usage from the 12V battery while providing the necessary control and protection for the motors. It is compact, cost-effective, and suitable for mobile robotic applications, making it ideal for indoor human-following operations. The design also allows future scalability, such as integrating higher-power actuators or adding IoT features.

CONCLUSION

The design and implementation of the source-side converter for a PMSG-based wind energy conversion system (WECS) using MPPT focuses on efficiently interfacing the permanent magnet synchronous generator (PMSG) with a DC bus to maximize energy extraction from variable wind speeds, ideal for small-scale off-grid turbines (100-500W) in areas like Kalachuris, Tamil Nadu. The PMSG, driven by turbine blades at optimal tip-speed ratios ($\lambda=6-8$), produces three-phase AC with frequency and amplitude scaling with rotor speed ($\omega_r = 2\pi n / 60$, n in RPM); an uncontrolled six-diode bridge rectifier (e.g., MUR1560) converts this to pulsating DC ($V_{dc} \approx 1.35 V_{ll_rms}$), smoothed by 100-470 μ F input

capacitors to supply the boost stage without neutral dependency. The boost converter topology—featuring a 220-470 μ H inductor (ferrite core, 15A sat), low-RDS(on) MOSFET (IRF540, $V_{ds}>40V$, $I_d>20A$), Schottky diode (MBR4060PT, $V_f<0.5V$), and output capacitors—steps up erratic 8-25V inputs to stable 12-14V via high-frequency PWM (25kHz) with duty cycle D (30-80%), governed by $V_{out} = V_{in} / (1-D)$ for precise MPPT control. A microcontroller like ATmega328P acts as the MPPT brain, sampling V_{in}/I_{in} through voltage dividers and 0.01 Ω shunt (ACS712 or kelvin sense) at 1kHz via 10-bit ADC, computing $P=V*I$, and running Perturb & Observe (P&O) or incremental conductance algorithms: it perturbs D by adaptive steps (0.5-2%, shrinking near MPP), tracks the power curve $P=0.5 \rho A v^3 C_p(\lambda,\beta)$ peaking at $C_p=0.48$ ($\lambda_{opt}\approx 7$), and responds in <200ms to wind transients while avoiding oscillations via filtering.

REFERENCES

1. "Global Wind Report, Annual Market Update 2012", Global Wind Energy Council (GWEC) [Online]
2. F. Blaabjerg, M.Liserre and K. Ma, "Power electronics converters for wind turbines systems", IEEE Trans. Ind. Appl., vol. 48, no. 2, pp. 708-719, April 2012
3. Z. Chen, J. M. Guerrero and F. Blaabjerg, "A review of the state of the art of power electronics for wind turbines", IEEE Trans. Power Electron., vol. 24, no. 8, pp. 1859-1875, August 2009
4. M.Liserre, R. Cárdenas, M. Molinas and J. Rodríguez, "Overview of multi-MW wind turbines and wind parks", IEEE Trans. Ind. Appl., vol. 58, no. 4, pp. 1081-1095, April 2011
5. X. Yang, D. Patterson, J. Hudgins "Permanent magnet generator design and control for large wind turbines", in Proc. IEEE Power Electronics and Machines in Wind Applications (PEMWA), July 2012
6. K. Ahsanullah, R. Dutta and M. F. Rahman, "Review of PM generator designs for direct-drive wind turbines", in Proc. IEEE 22nd Australasian Universities Power Engineering Conference (AUPEC), September 2012
7. M. Arifujjaman, L. Chang, "Reliability comparison of power electronic converters used in grid-connected wind energy conversion system", in Proc. 3rd IEEE Symposium on Power Electronics for Distributed Generation Systems (PEDG), 2012

8. T. de Freitas, P. Menegáz, D. Simonetti, "Converter topologies for permanent magnetic synchronous generator on wind energy conversion system", in Proc. IEEE Brazilian Power Electronics Conference (COBEP), September 2011
9. Halder, S., & Afsari, K. (2023). Robots in inspection and monitoring of buildings and infrastructure: A systematic review. *Applied Sciences*, 13(4), 2304.
10. Jiang, Q., & Yan, H. (2022). Leader-follower motion control of two line following AGVs using PID algorithm. In Proc. IEEE 5th Adv. Inf. Manage., Communicates, Electron. Autom. Control Conf. (IMCEC), vol. 5, 445–449. N. Sharma and S. Verma, "IoT-Driven Smart Energy Meter with Cloud-Based Data Logging," *International Journal of Computer Applications*, vol. 182, no. 25, pp. 1–7, 2019.
11. Yandong Li; Ling Zhu; Yuan Guo Observer-based multivariable fixed-time formation control of mobile robots)-2020
12. Simon, M. E., Baldissera, F. L., de Queiroz, M. H., & Cabral, F. G. (2023). Multi-robots coordination system for urban search and rescue assistance based on supervisory control theory. *Journal of Control, Automation and Electrical Systems*, 34(3), 484-495.
13. Tsiu, L., & Markus, E. D. (2020). A survey of formation control for multiple mobile robotic systems. *Int. J. Mech. Eng. Robot. Res.*, 9, 1515-1520.