JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 1058 - 1065
https://publishoa.com
ISSN: 1309-3452

A Review on Pmsg Based Wind Energy Conversion System

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ABSTRACT

In this paper, a PMSG based wind energy conversion system with various MPPT techniques has been explained. The main aim of the paper is to review the WECS, maximum power point techniques, the behavior of sensor-based and sensorless operation of the wind turbine. In this paper PMSG based WECS is used due to its gearless and low noise operation. Different types of MPPT techniques are available, those are Hill-Climbing Search (HCS), Optimal Torque Control (OTC), Power Signal Feedback (PSF), and Fuzzy Logic Control (FLC) and Perturb and Observe (P&O) discussed. A sensorless wind turbine is compared to a sensor-based wind turbine. The wind turbine output is mainly depending upon the speed of the blades. When the speed of the wind increases then the speed of the blade increases and vice-versa. The direction of wind flow is not constant all the time, to control those different mechanisms are explained. A gearbox in a wind turbine is generally used for the conversion of the low speed of the rotor into a higher speed. Different types of gearbox ratios will make the generator speed to be increased.

INTRODUCTION

The increase in power demand resulted in the usage of non-renewable energy sources such as oil, coal, natural gas that becomes the main cause for the pollution. Due to these energy sources, CO2 emission and the greenhouse effect are increased when compared to the 1990s. As a consequence, renewable energy sources (RES) such as solar, wind, hydro have come into action and become the trend in development and reducing pollution [1]. The usage of renewable energy sources is improving gradually at present. These are the sources that can be used by anyone, anywhere, and anyway. As the world increased its reliance on renewable energy resources due to the decreased availability and the increased pollution levels of conventional energy resources. Wind energy is the most effective source for the generation of electricity among renewable energy resources like solar energy and hydro energy etc. The use of sensors in WECS is to record the operation of components in wind turbine. Mainly sensors in wind turbines are for maximization of efficiency and to reduce the operating costs. Wind turbines might be less safe, more costly to operate, unable to detect and repair faults, and less reliable and the life span of wind turbines will be reduced compared to their original life span if they didn't have sensors. Mostly, wind energy generation stations require precise data about each turbine and its components, which can only be delivered by sensors connected to a command center. Electrical and optical sensors are employed in a variety of ways in wind turbines. If the vibration levels are increased can result in harming of the turbine. The mostly used sensors are for monitoring, detection of fault and communication for information. Sensors used in wind turbines are eddy current sensors, sensors for displacement, sensors for acceleration, wind sensors, temperature sensors etc. The main role eddy current sensor is to identify current operation These sensors also detect the run-out time, and also detects the rotation of the turbine [1].

This condition makes the shaft to orient off-center instead of its origin. While a small time of run-out is always present, bearings can cause exceed the limits, requiring the turbine to be shut down for repair which is usually the result of strong wind loads. Obviously, being able to track run-out over time permits for essential preservation to be carried out before severe loss or sudden fault happens. In wind turbines, accelerometers are used to detect and monitor vibration in main, yaw, and slew bearings, as well as other rotating components such as the main generator output shafts. Vibration data obtained can be utilized to track variations over time and predict potential breakdowns. The temperature sensors are also employed in situations where temperature increases indicate that a component of a subsystem is overheating however by using sensors in high quantity makes the turbine heavier which leads to a decrease in the rotating speed of the turbine which is a disadvantage for the wind turbine. So, sensorless operation of a wind turbine is developed. The main aim of the sensorless wind turbine as the sensors in the wind energy conversion system increases the complexity and decreases the turbine reliability. Here in the PMSG based wind conversion system a sensor-less operation-based speed and rotor position is developed.

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Grating encoding and rotating transformer are two common sensors. Because the working environment for wind turbines is generally poor. Sensors are readily destroyed, and wind reliability is questionable. The size of the turbine system will be lowered. Mechanical structure damage of wind energy conversion system due to wind speed change can be reduced by controlling the natural wind for maximum power point tracking and then stability increases. Many control methods were proposed to control the active power and reactive power of wind systems using PMSG to overcome the various disruptions and limitations that occurred during the operation of the system. High power tracking performance is required for excellent operating ability. Multiple control strategies Were enforced for maximum power point tracking in wind energy conversion systems. The common method for PowerPoint tracking is nonlinear methods. Some of the non-linear methods are the neural network method, d-q vector method, robust control methods, etc. To identify the error in PowerPoint tracking using a universal controller. RBF neural network method is preferred for the optimal control of PMSG based wind energy conversion system for maximum power [2]. A non-linear feedback control method is proposed to control the network disturbances. Generally, sensors of a highly sensitive nature are used for highest power tracing and to observe natural wind speed. Speed estimation method with sensorless MPPT for enhancement of maximum power tracking. Kalman filtering effect is implemented to operate the speed sensorless PMSG.

Most of the research is going on renewable energy sources to generate power. In those RES solar energy is a type of energy source which converts radiated energy that was obtained from the sun is converted into electricity through solar panels. The produced electricity is connected to the grid. Among all the renewable energy sources wind energy conversion systems (WECS) that are nothing but wind turbines have become popular due to their operation. There is a superior advantage of using wind energy i.e., its initial cost is low [6]. There are different types of a wind turbine according to their axis of rotation. From the fig-a shows the vertical axis wind turbine (VAWT) which has the axis of rotation vertical to ground. The fig-b is a horizontal axis wind turbine (HAWT) which has the axis of rotation parallel to ground.

According to the usage of generators in the wind turbine, there are different types [12]. Mostly used wind turbine generators are doubly-fed induction generators (DFIG), permanent magnet synchronous generators (PMSG). A permanent magnet synchronous generator (PMSG) has become more popular because of its supremacy characteristics when compared to DFIG. In any wind system when the speed of wind varies the turbine characteristics vary. Consequently, stability, efficiency, and maximum output will vary. The conversion of wind energy to electrical energy can be maximized by using different control methods. PMSG has tremendous supremacy to develop power obtain from the wind turbine. The PMSG has a tendency to run at minimum speed and also less usage of the gearbox. In PMSG usage of nacelle equipment is minimized, maintenance and mechanical losses are low and efficiency is more when compared to DFIG [13].

PMSG has high efficiency when compared to other generators. In pursuance of, maximum power point tracking (MPPT) technique is used to overcome the problems in a wind turbine. When the MPPT technique is coupled to the wind turbine it tracks the maximum power where it reaches the maximum efficiency. Then, it will continue to operate the whole system in that efficiency. There are many available MPPT techniques that maximize the efficiency of the system. Right now, the popular control strategies are power signal feedback control (PSFC), optimal tip speed ratio (OTSR), optimal torque (OT), perturb and observe(P&O), incremental conductance, and fuzzy logic control [9]. PSF control is a control method obtained by optimal mechanical power vs wind speed. By using the output of the curve, the generator characteristics are determined and the type of tracking technology is decided. The sample block diagram is shown in the fig. 1.

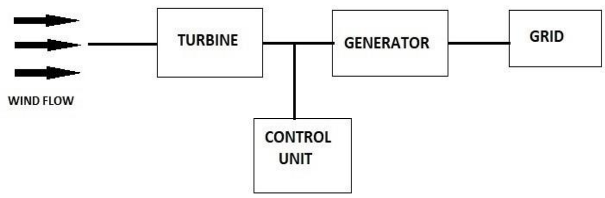

FIGURE 1: Sample block diagram

The proposed P&O technique is a well-known and most used technique in present days. This method is proposed due to its simplicity in simulation and low cost. The P&O technique deals with the speed of the rotor that which changes according to the wind speed [10]. This technique agitates the rotor speed in wind turbine and observes the final result of the turbine by analyzing the slope of the speed-power curve and then analyzing the efficiency of the system.

This P&O technique can be applied for the variable step-size also. It affiliates with the optimal power curve to crack the loss-tracking problem. The modified P&O technique deals to increase the tracking of the system [11]. This technique requires the anemometer, which is used to measure the speed of the wind and thereby run the rotor of the turbine.

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PMSG WIND TURBINE

- *Structure of Wind turbine*

In general, wind turbines can able to produce wind speeds above 6.7mph. The blades of the wind turbine may damage when the flow of the wind reaches 55mph. This is the maximum velocity of the wind in the wind turbine. So, the wind turbines are designed to maintain the aerodynamic torque by the principle of pitch angle controller. The structure of wind turbine is shown in fig. 2.

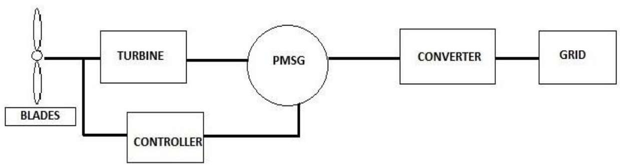

FIGURE 2: Structure of wind turbine

In the structure of the wind turbine, a blade pitch mechanism is used to adjust the rotational mechanism and resultant power not to cross limits. Due to this the requirement of the gearbox is less.

- *Fluctuations of Wind Turbine*

In wind energy conversion systems, the power fluctuations take place due to the wind speed variation. The speed of the wind turbine is directly proportional to its generated output power [14]. These fluctuations will become more severe when the penetration of wind generation is increased. The wind generators are typically operated at their maximum power point tracking [7]. So, the power generation must have acceptable fluctuations while it is operating at MPPT otherwise over-generation takes place at the night-time hours where the power demand is low. So, an efficient hybrid model is implemented for smoothing the wind power fluctuations [16].

- *Oscillations*

In the wind energy conversion system, it is required to reduce the oscillations in the fundamental output voltage and current. A hybrid space vector pulse width modulation (HSVPWM) scheme is involved to improve the quality of output ac power. As the wind speed changes, there will be variations in frequency and voltage magnitude [8]. So, MPPT based single-ended primary inductor converter has been implemented to provide a constant supply irrespective of wind speed [21].

- *Stability*

In any system, stability plays an important role. The stability should be high for a healthy system. In any wind turbine as the speed of the wind is not constant there will be more fluctuations [17]. Stability implies the whole system efficiency; the efficiency is high in stable systems. The stability depends upon the fluctuations, when the fluctuations are more in the system then the stability varies according to the speed of the wind. The stability is indirectly dependent upon the speed of the wind. As, the speed varies then the speed of the blades varies, when the speed of the blades varies then the speed of the rotor of the turbine varies [27]. So, that the stability of the system varies. When the stability is high then the whole system is healthy. The system stability is more the efficiency is also more in that system. The characteristics of wind speed and power is shown in fig. 3.

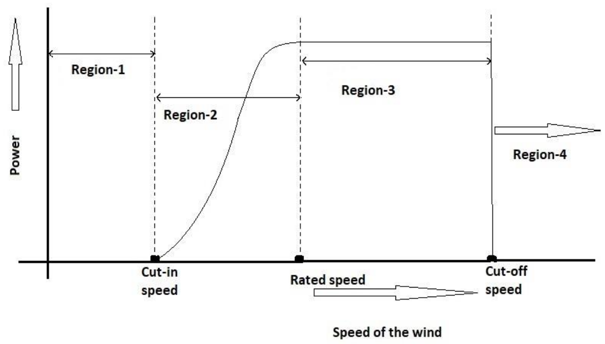

FIGURE 3: Characteristics of wind speed and power

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ISSN: 1309-3452

From the graph, region-1 is the initial reason where the speed is less than the minimum speed. In this region, the wind turbine will not rotate and the power is zero. The second region is the cut-in speed [19]. This is the minimum speed of the wind turbine to generate minimum power. The third region is the rated speed region where the constant speed occurs. And finally, the last region is a cut-off region. This is the deadly region where the whole wind turbine will damage for the speed [15].

WIND TURBINE

Wind turbines are nothing but rotatory machines that can generate electricity from the kinetic power of the wind [18]. Wind turbines transform wind into electricity. The efficiency of a wind turbine is based on the number of blades used [20]. If the blades are more efficient will be more if the blades are less the efficiency will be less. The wind turbine can be constructed by using a single blade, double blade, triple-blade. The blades are used as per the application.

- *Working principle*

The wind turbine works on the principle that transforming of wind energy into electrical energy. When the wind blows on the turbine blades the rotor spins around and captures the kinetic energy from the wind and turns the central driveshaft that supports them.

- *Wind Energy Conversion System*

$$P_w = \frac{1}{2} C_p(\lambda, \beta) \rho \pi R^2 V_w^3 \quad \text{………(1)}$$

[5] Where, Cp is the power coefficient of the wind turbine,
λ is the tip speed ratio,

$$T_m = \frac{1}{2} C_p(\lambda, \beta) \rho \pi R^3 \frac{V_w^2}{\lambda} \quad \text{………(2)}$$

[5] Where T_m is the mechanical torque at the input of the wind turbine
β is pitch angle

$$C_p = 0.22\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)\exp^{\frac{-12.5}{\lambda i}} \quad \text{……(3)}$$

$$\lambda i = \frac{1}{\frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}} \quad \text{…….(4)}$$

3.1 PMSG Model

$$V_d = R_a i_d + L_d \frac{di_d}{dt} - \omega_e L_q i_q \quad \text{……..(5)}$$

$$V_q = \omega_e L_d i_d + R_a i_q + L_q \frac{di_q}{dt} + \omega_e K \quad \text{……..(6)}$$

$$T_e = P\left\{K i_q + \left(L_d - L_q\right) i_d i_q\right\} \quad \text{……....(7)}$$

- *Need of Gear box*

A gearbox in a wind turbine is generally used for the conversion of the low speed of the rotor into a higher speed. Different types of gearbox ratios will help to increase the generator speed of the turbine [22]. Continuous operation and drastic changes in the environment may lead to damage in the gearbox and also gears in wind turbine gearboxes are subjected to intense cyclic loading. As a result, the failure rate of the gearbox system is said to be higher than that of other wind turbine components which leads to the design vigorous turbine gearbox. It is common knowledge in the wind energy sector that enhancing gearbox reliability is one of the most important factors in reducing wind turbine downtime and making wind energy competitive with fossil fuels [28]. There are three types of wind turbine gearboxes: fixed axis gear transmission, classic planetary gear transmission, and closed differential gear drive [23].

The usage of gearbox dependent wind turbine results in the more losses in gearbox. The rise in power has a negative impact on. The gearbox is removed in gearless wind turbines also known as direct drive train. The generator rotates at same speed of turbine in the direct driven machines as the rotor shaft is instead directly connected to the generator, which rotates around the same speed as the blades. Gearless wind turbine technology can be utilized to replace the gearbox, making the turbine more reliable by lowering downtime and repair costs. Costs is a key factor to consider for offshore wind turbines. Some places or terrains are more expensive to send experienced workers to carry out routine maintenance [24]. So gearless operation is coming into enforcement.

The final type is power split, which is characterized by a divided flow of power and force, with input loads shared by components from several stages. In general, the turbine rotates and generates power but it also applies huge moments and force to the power train of the wind turbines. Internal gearbox components can become severely misaligned if the drive train does not effectively isolate the gearbox or if the gearbox is not intended to sustain these loads [25]. A wind turbine includes wind loads, rotor blade aerodynamics, gear dynamics, an electrical generator and a control system. While considering wind turbine gearboxes, uneven air moment can put a lot of stress on the disc and bearings, which leads to run down the turbine and force the machine to halt. When the wind is more powerful the gearbox becomes unsafe. As a result, nearshore turbines are riskier than inshore turbine. Because in wind turbine gearbox causes high maintenance by removing it results in the increase of turbine reliability [29]. The gearbox makes the turbine to increase its weight due to removal of gearbox the overall performance of turbine increases.

The main aim to design wind turbines without gears is to mitigate gearbox failure and transmission losses. The variable-speed direct-drive wind turbine is a type of wind turbine that was introduced 25 years back. Some of the most typical causes of gearbox failure in wind turbines: The service factor is extremely low. Lubrication that is dirty or polluted with water Site conditions, such as capacity factor, limitation, and wind levels, are all factors to consider. Sudden accelerations and load-zone reversals are caused by transient loads. Incorrect bearing settings result in uneven load distribution and severe edge stresses. Direct-drive technology offers additional room for advancement. The placement of gear box in the wind turbine is shown in the fig. 4.

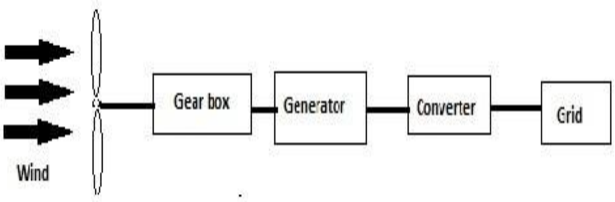

FIGURE 4: Placement of gear box

- *Climatic conditions*

The speed of the blades depends upon the flow of the wind [26]. Wind energy is freely available in the atmosphere. There is no need to pay to the environment. When the speed of the wind increases then the speed of the blade increases. So, that the speed of the rotor increases. The speed of rotational mechanism increases, then the resultant of wind system also increases because, resultant output is directly proportional to the speed of the wind [30]. So, that the output power of the turbine varies when the speed of the wind varies. The direction of the wind is not the same at every instant and the direction is not the same at every instant of time. The direction of the wind is not fixed particularly because the direction and speed of the wind is depending upon nature. So, that the blades of the turbine have to revolve accordingly. The rotor has to be rotated according to the speed and direction of the wind [27].

Depending upon this condition the wind turbine is designed accordingly. The wind turbine has a fixed mechanism to eliminate this problem in the wind turbine. The mechanism which is used in this wind turbine is known as the Yaw mechanism. The role of this yaw mechanism is to change the direction of the blades with respect to the direction of the wind. Climate is not the same in every season; the power has to be generated round the clock without any interruptions. Because the generation is directly proportional to load + losses. The power which is generated should be more efficient and should be transmitted without any losses. When the losses are more the efficiency of the system decreases [31]. So, that the power should be more reliable. The climatic conditions are not the same at all the times the design of the turbine should be strong and more reliable.

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ISSN: 1309-3452

The turbine has to generate power at any conditions and various speeds of the wind. The turbine has the capacity to generate power by using this yaw mechanism and the speed changes the output power of the turbine also changes. Wind turbines with this mechanism can able to run the turbine at any different variable conditions. So, that in this paper the generator which is used is the PMSG generator it has many features like it can generate power with/without a gearbox. Most the conditions, the wind turbines are placed in hilly areas because the speed of the wind is high in that condition. At particular places, the speed of the wind is normal according to the topology of the earth. The conditions of the wind and its speed vary according to the climate, the turbine will run all the time to generate the power without any interruptions to generate the power [30]. The generated power is connected to the grid to distribute that generated power. The yaw mechanism is used to switch the regulation of the blades of the wind turbine according to the flow of wind and the speed of the wind. The resultant power has some variations due to the speed and direction of the wind. The wind speed is not constant at all times and round the clock. The output has to be transmitted without any fluctuations and the output power should be constant at all times. If not, the power interruptions should be more and the appliances may damage [27]. So, that the output power will be without any fluctuations. The stability of the system will be more when the speed of the wind is constant. It is impossible in this condition because the input is renewable energy sources and impossible to control its speed.

CONTROL TECHNIQUES

- *MPPT Techniques*

MPPT is a technique that is used to trace the highest point in the generated output. MPPT techniques are classified into many types those are Hill-Climbing Search (HCS), Optimal Torque Control (OTC), Power Signal Feedback (PSF), and Fuzzy Logic Control (FLC), and Perturb and Observe (P&O) [20].

The Hill climbing search (HCS) technique deals with the peak power of generated output power. The tracing of the highest power point is depending on the change in speed and output power and the maximum power in the system should be drawn to compensate for the actual output power. [28] To track the maximum power point (MPP), the optimal torque curve is one of the techniques. The torque adjusts according to the speed of the rotor. And this technique is known as the optimal torque control technique. By, using this technique the maximum power is tracked and the power which has to be obtained will be compensated. [31] Power Signal Feedback control technique is a technique that deals with the signal which is obtained from the optimal power curve are given feedback to the system to get desired output of the system. The maximum power point (MPP) is obtained by sending feedback to the system and this technique is known as the power signal feedback (PSF) technique [15]. The fuzzy Logic Control technique is a technique that is as same as the P&O technique which operates on the basis of the duty cycle of the converter which is obtained from the optimal curve, and then the output power is increased or decreased based on the optimal power torque and then this technique is known as Fuzzy Logic Control technique. [5] P&O is known as perturb and observe technique which is operated on the principle, in the obtained generated output this technique is used to observe the various values of output at various inputs which are given to the system to drag the highest power. Input of the turbine which is in the form of wind varies throughout the day, the output varies when the wind fluctuates because the output which is generated is directly proportional to the speed of the blades of the wind turbine [29]. The speed of the turbine is basically depending on the speed of the wind. The control can be done by using P&O and modified P&O techniques. Initially, this technique works based on the technique is needed to install in the system, and then after installing the technique leads to training itself by observing the output which varies according to the time and season. The obtained power will be read by the technique and the system will fix the maximum power point (MPP). By, converting the duty cycle of the converter, the output of the wind turbine will compensate for the output power. And the MPP is the maximum power point in the system and the system needs to generate up to the point to get stability and high efficiency [30].

CONCLUSION

MPPT techniques like Hill-Climbing Search (HCS), Optimal Torque Control (OTC), Power Signal Feedback (PSF), and Fuzzy Logic Control (FLC) and Perturb and Observe (P&O) are discussed. As per the studies from some papers, it is concluded that the HCS technique is better than the other MPPT techniques. Sensorless and sensor-based wind turbines are explained, in the sensor-based wind turbine, the efficiency will be more in addition to this the weight and complexity of the wind turbine increases. To reduce the complexity, a sensorless wind turbine is discussed. As the wind direction is not constant YAW mechanism is used for controlling the rotation of the wind turbine.

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