Journal of The Gujarat Research Society

ISSN: 0374-8588
Volume 22 Issue 1, January 2020

Control Solutions for Wind Energy Conversion Systems

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ABSTRACT: Due to rising demand and the threat of zero carbon footprints, renewable energy techniques are gaining popularity. Wind energy has a lot of potential as a source of energy. Wind energy's rising popularity tends to produce high-quality output power in terms of grid integration. Controlling the electricity generated by wind energy necessitates the use of a suitable controller. Maximum power point tracking (MPPT), grid side controller (GSC), and machine side controller (MSC) connected with wind energy conversion systems have been evaluated in a number of research papers reports (WECS). A survey on pitch angle-based control, on the other hand, has not been the only subject of any such assessments. This study examines pitch angle controllers, maximum power extraction controllers, and grid synchronization controllers in detail. As a result, this study provides a thorough examination of overall control measures for Control of wind energy conversion. The goal of this review study is to serve as a useful resource for future wind energy research.

KEYWORDS: Wind Energy Conversion, Pitch Angle Controller, Maximum Power Point Tracking, Machine Side Controller, Grid Side Controller.

1. INTRODUCTION

Any country's development is dependent on energy. The rapid growth of the world's population and urbanization has resulted in an increase in energy demand all across the world. Modernizations in the agricultural and irrigation sectors has a tendency to rapidly increase energy demand. Fossil fuel is currently the most important source of energy. Many countries are finding it difficult to bridge the supply and demand imbalance due to the depletion of fossil fuels. Furthermore, fossil fuels have a significant detrimental environmental impact, such as the greenhouse effect. Energy is primarily considered in terms of affordability, accessibility, and environmental friendliness. In order to offset the disadvantages of fossil fuels, renewable energy generation is garnering a lot of attention. Solar, wind, tidal, wave, and biomass are examples of renewable energy sources. Solar and wind energy are employed for electricity generating because they are abundant and generally available. Solar and wind energy's dependability is greatly dependent on climate variations and nature's unpredictability. As a result, grid integration and energy storage are major concerns. Wind energy is the most rapidly expanding renewable energy source. It covers a wide range of engineering disciplines[1].

Wind power generation has increased by a factor of ten in the last few years. Despite the phenomenal expansion of wind energy, researchers face numerous hurdles, including grid connectivity, the unpredictable nature of wind, and wind turbine location .To integrate the wind turbine into the power grid, more advanced contemporary generators, power converters, and controllers must be built. The Wind Energy Conversion System (WECS) generates power that is proportional to the wind speed[2]. As a result, even minor changes in wind speed have a significant impact on the amount of power extracted. Because the grid voltage must have a consistent amplitude and frequency, this power is incompatible with the grid. As a result, in

Journal of The Gujarat Research Society
ISSN: 0374-8588
Volume 22 Issue 1, January 2020

order to achieve maximum power and constant voltage in WECS, some control measures must be implemented. Figure 1 depicts a typical grid-connected WECS. The wind turbine is either directly connected to the generator or through a gearbox. The kinetic energy of the wind is converted into mechanical energy by the wind turbine. By using a generator, mechanical energy is converted to electrical energy. Through converters, the wind energy system is connected to the grid. At rated wind speed, the wind turbine's rated output power can be obtained. The output power is mechanically regulated by the pitch angle controller. The angular speed, which governs the mechanical output power, is controlled by the wind turbine's output torque. Turbines with high-rated generators have a pitch angle built in to protect the wind generator against abrupt gusts of wind. When the wind speed is low, the blade pitch is altered to allow the rotor to revolve at a faster pace, boosting the machine's power[3].

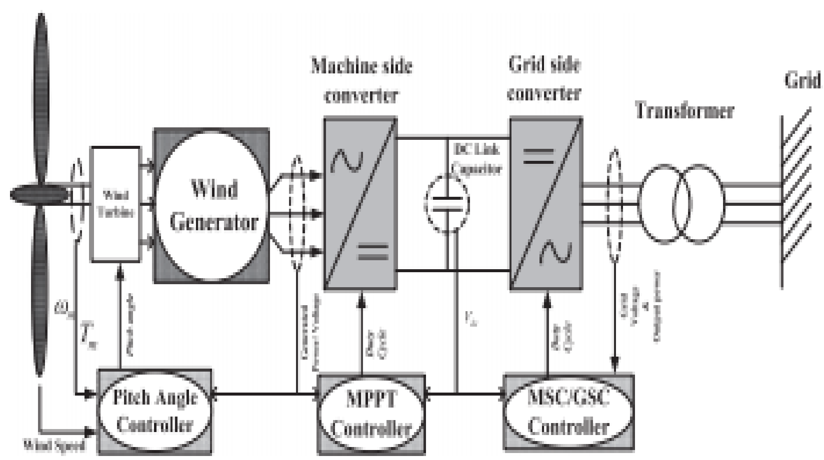

Figure 1: Typical configuration of grid connected WECS.

When the wind speed changes, the rotational speed should fluctuate as well, so that the greatest power is extracted. The mechanical torque is changed by the pitch angle to get the most power out of the available wind. The mechanical output power can be changed by modifying the rotor speed. The amount of power generated by the wind generator changes as the wind speed changes. When the rotor is rotated at m for the specified wind speed, the maximum power is obtained. Wind generating facilities highlight the difficulties of wind speed variability, nonlinearity, and uncertainty. To solve them efficiently, an advanced controller is necessary. Integrating an advanced controller into WECS in order to improve power conversion and blade control design efficiency. Many studies have been conducted in order to establish a WECS control technique that can be integrated into the grid. The controllers must be simple, dependable, and cost-effective, as well as able to endure the fluctuations that occur during operation. The numerous control strategies utilized in WECS are depicted in Figure 2.

ISSN: 0374-8588
Volume 22 Issue 1, January 2020

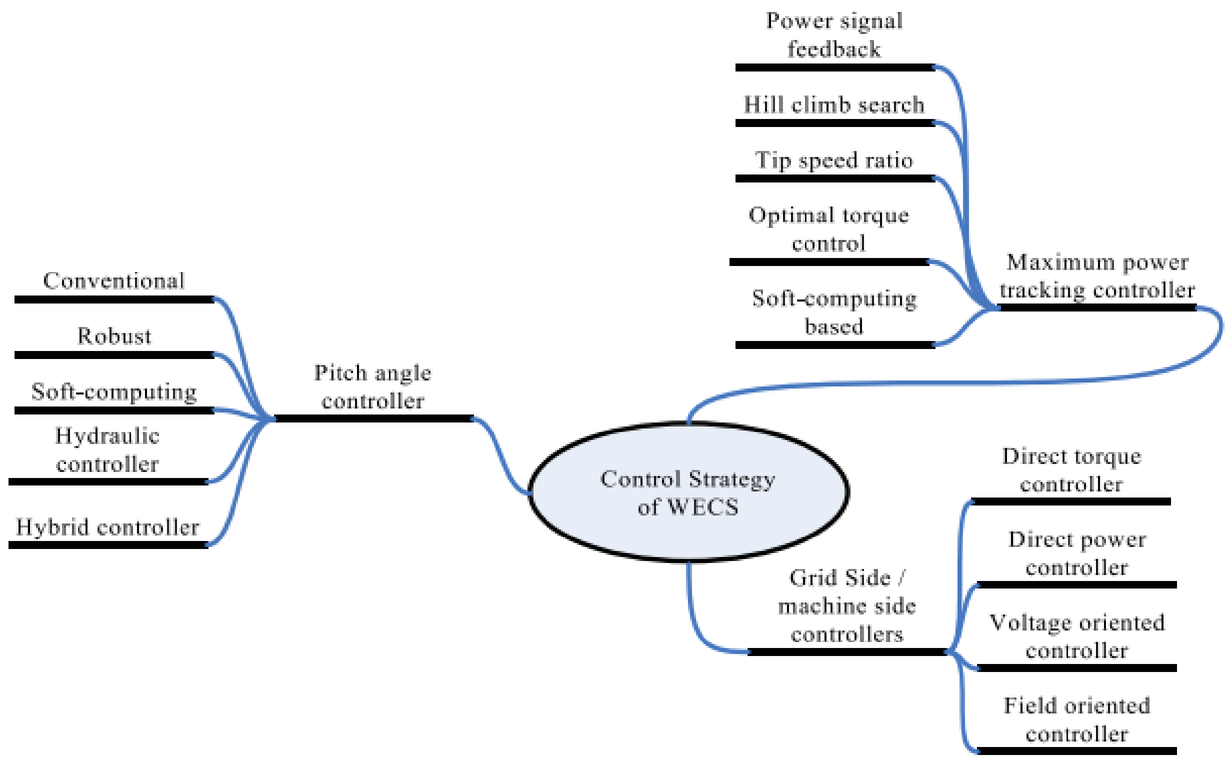

Figure 2. Different Control Strategy of WECS.

The pitch angle controller controls the rotor speed during higher wind speeds, safeguarding the generator, and if the controller is unable to keep the rotor speed below the ideal speed, it works as a braking device[4].

2. LITERATURE REVIEW

Ph.Delarue et al. in their case study suggested that a growing number of conversion methods have been proposed to gather wind energy and convert it to electricity. An energetic macroscopic model is utilized to explain such systems made up of extremely distinct parts in this paper. Based on energy considerations, this representation yields a simulation model of the total system. Furthermore, using simple inversion techniques, a control structure may be inferred from this representation. As a result, the theoretical control structure can be used to demonstrate various wind turbine management tactics. A 750 kW wind energy conversion system is investigated and simulated to demonstrate this modeling and control methodology[5].

R. Datta et al. in their case study suggested that the peak power of a wind energy conversion system (WECS) is tracked in this research using a method that is independent of turbine characteristics and air density. By adjusting the speed in the desired direction, the algorithm seeks for the highest power. The generator is run in speed control mode, with the speed reference dynamically changing in response to the magnitude and direction of active power changes. The P-/spl omega/ curve's peak power points correspond to dP/d/spl omega/=0. The optimum point search algorithm takes advantage of this characteristic. The generator in question is a wound

ISSN: 0374-8588
Volume 22 Issue 1, January 2020

rotor induction machine with a stator that is directly linked to the grid and a rotor that is wound[6].

Md. Arifujjaman et al. in their case study suggested that Furling is the most prevalent method for controlling the aerodynamic power extraction from the wind in the small wind turbine business. This work models a tiny wind turbine with a furling mechanism and the ensuing dynamics using the Matlab/ Simulink environment. The model replicates using a load-control mechanism to regulate the wind turbine's speed. The maximum-power extraction from a tiny wind turbine is examined using tip-speed ratio and hill-climbing control methods. The behaviour of two dynamic controllers has been simulated. The controller uses the in the first way. To control the load and operate the wind turbine at its best, information on wind speed and rotor speed is used[7].

Hyong Sik Kim et al. in their case study suggested that this study focuses on the three primary electrical characteristics of the wind energy conversion system (WECS): Wind turbine generators (WTGs), power electronics converters (PECs), and grid-connection difficulties are the three main concerns. The current condition of wind turbine generators is examined and compared in terms of several parameters, as well as the current WECS market trends of 'Variable Speed,' 'Multi-MW,' and 'Offshore.' In addition, the other critical component of the WECS, PECs, will be addressed, along with the topologies and modulation schemes available in the present WECS market. Furthermore, three major WECS difficulties related to grid-connection, fault-ride through (FRT) capability, and harmonics [8]

3. DISCUSSION

3.1. Hydraulic controller:

The collective pitch angle controller is a hydraulic controller that uses a hydraulic actuator to operate all of the blades at the same time. The hydraulic actuator is installed in the spinning hub, along with an accumulator tank that converts the energy into linear movement. Hydraulic pitch controllers have a number of advantages, including reduced complexity, safer operation, and durability. Hydraulic controllers have a lower initial cost than electromechanical controllers, but they are more expensive to operate and maintain. In the past, several hydraulic controller-based pitch angle controllers have been implemented. Recent hydraulic system research has focused solely on pitch system modeling, detailed dynamic analysis, and reliable and efficient control systems. Although the hydraulic pitch mechanism has a high power-to-mass ratio and is reliable, it falls short in terms of accuracy.

3.2. Applications:

The blade is controlled by an electromechanical actuator in an electric pitch controller. An electric motor, a gearbox, a power supply unit, and an energy storage system are all included. The rotating hub houses the actuator and energy storage devices, while the nacelle houses the power supply. The gear box is used to change the speed of the electric motor. During power outages, the energy storage supplies enough power to the pitch controller. The electric pitch angle controller is more efficient and has a faster response time than the hydraulic pitch angle controller. When compared to hydraulic controllers, the power/mass ratio is low, despite the fact that they are favored because to low maintenance. The electric pitch angle controller is more efficient and has a faster response time than the hydraulic pitch angle controller. The mass-to-

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power ratio is despite the fact that they are hydraulic controllers, they have a low cost Mainly because to the cheap maintenance and operation costs .Many studies on electromechanically based pitch angle controllers have recently been conducted. Various models are available compares the results of four groups divided into four categories, because of its simplicity and speed, hybrid controllers are widely used response tracking. The rotor speed or generated power is controlled by a PI/PID controller in a traditional pitch angle controller. It's best used in modest wind energy conversion systems. The typical controller's pitch reference is obtained mostly from input parameters such as rotor speed and generator power. To increase the control performance of a system with a non-linear characteristic, a conventional converter with gain scheduling is used. To overcome the sensitivity of aerodynamic torque to pitch angle, gain scheduling is used. The system's aerodynamic sensitivity is determined by the variance in output power as a function of pitch angle. The controller gain and the system's sensitivity are inversely proportional[9].

3.3. Advantage:

For pitch angle controllers across a wide variety of wind speed regions, another approach of providing generalized predictive control is provided. This method is not used since the control system is unstable when there is a big output power error. This approach is solely based on the output power error, which is derived by subtracting the cut-in speed from the actual wind speed. The control system will become unstable if the difference is considerable, resulting in large fluctuations in output power. Wind speed data is necessary to determine the output power error, which raises the system's cost and complexity. To compensate for the system's non-linearity, a feedback/feed forward based control method is provided. With each modification in the operating system, the controller gains are updated. Because it does not require online parameter estimate, this control system responds faster to changes in operating conditions. They are determined by the characteristics of the wind turbine in use at the time. As a result of the steady feature of controller gain at different operating points, the system's complexity is raised. A multi model predictive control approach. All operational areas are applied to the pitch controller. To reduce flicker emission and create smooth electricity, the generator's power and speed are adjusted. The maximal yield capacity of the controller is demonstrated using a globally constrained stable closed loop system and Lyapunov based analysis. Without knowing the particular type of the wind turbine, the control method enables for aerodynamic rotor power management[10].

3.4 .Working:

In order to efficiently predict the rotor speed without any sensor, the soft computing technique and a robust controller are combined. In terms of stability, this system performs admirably. The SCT technique, which primarily uses ANN, is paired with a traditional controller to reduce system complexity and improve dynamic performance .To address the uncertainty of the wind system due to variable wind speed, the ANN, specifically the Radial Bias Function Network (RBFN), is employed to compute the proportional and integral gain of the traditional controller. To analyse the frequency deviation and enhance the response rate, the optimization technique is used with the SCT technique. The soft computing technology and a robust controller are used to efficiently forecast the rotor speed without any sensor. This system works admirably in terms of stability. To reduce system complexity and increase dynamic performance, the SCT technique, which predominantly employs ANN, is combined with a standard controller.

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The ANN, specifically the Radial Bias Function Network (RBFN), is used to compute the proportional and integral gain of the classical controller to address the uncertainty of the wind system due to changeable wind speed. The optimization technique is combined with the SCT technique to analyse the frequency deviation and improve the response rate. Fuzzy sliding mode loss minimising control with RBFN for PMSG based WECS in all wind speed areas. The best uncertainty bound is calculated using a fuzzy inference method. A pitch controller based on RBFN is trained online to project an appropriate pitch reference. The hardware is created, and the system's dynamic performance is evaluated. Even with parameter uncertainties, the system performs as expected. Figure 3 show that DE Based Hybrid Pitch Angle Controller.

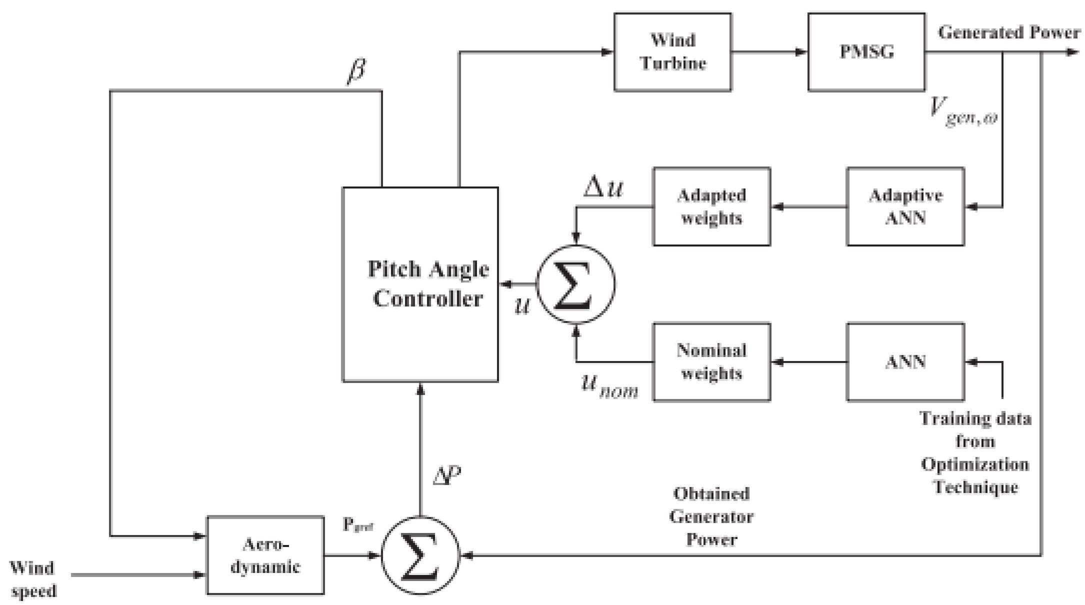

Figure 3: DE Based Hybrid Pitch Angle Controller.

Uneven loss distribution involves uneven stress distribution among semiconductor devices, resulting in the most stressed switching device limiting overall output power and switching frequency. In, the unequal loss distribution is reported alongside other topologies with even distribution, such as and As previously said, a topology that is used to eliminate unevenness among switching devices, and it has been observed that has an advantage over in terms of natural doubling of switching frequency without the use of flying capacitors.

4 .CONCLUSION

In order to harvest energy efficiently from wind, control mechanisms are becoming increasingly important. They are essential in the energy conversion process. The intermittent nature of wind speed makes it difficult to develop a control strategy that ensures a high-quality and reliable power supply. As the number of wind turbines in the electrical grid grows, it is vital to collect

ISSN: 0374-8588
Volume 22 Issue 1, January 2020

power effectively in accordance with the grid code. As previously stated, numerous reviews of MPPT, GSC, and MSC based control strategies have been undertaken. However, the authors of this work conducted a thorough examination of pitch angle-based techniques and analyzed the operation and implementation of these controllers based on a set of criteria. The use of these techniques in the future may result in more reliable power generation as well as a reduction in the overall system's cost and computing speed.

Finally, this review looks at various control techniques as well as the results of previous research in the field of wind energy conversion. The advantages and disadvantages of various control techniques, as well as the limitations of each controller, are thoroughly examined and analysed. This survey aims to present the most recent control technique plan, as well as the most efficient and current research approach to WECS stability and controllability. However, to get the most out of the available energy and produce clean energy for grid integration, you'll need a good controller. Because of the maintenance issues and costs associated with the pitch angle controller, it is mostly utilized for large wind turbines. The MPPT control approach is used to track the variable speed wind turbine's optimum power point. They are usually employed in all of the minor WECS that are available. The MSC/GSC controller is primarily used for WECS grid integration. When the system is grid connected, GSC controllers provide efficient and faster active power control, whereas MPPT controllers are best for standalone systems because they have faster control.

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