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A STUDY OF WIND ENERGY CONVENSION SYSTEM (WECS) USING AN INTELLIGENT OPTIMISED CONTROLLER

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ABSTRACT

The growing relevance of wind energy as a sustainable power source highlights the need to guarantee the reliability and stability of wind energy conversion systems (WECS). The ability of the system to endure low voltage conditions determines whether operations can be maintained during grid disruptions. Grid interruptions may affect the DFIG-based WT system. When the grid voltage drops, exposing the rotor windings to carry over voltages, overcurrent develops. The rotor side converter is damaged and the voltage across the dc-link capacitor is raised due to this overcurrent. Extremely hazardous torque oscillations in DFIG-based WECS are caused by high rotor inrush current and dc link overvoltage. In order to disconnect DFIG from the grid, it is necessary to deactivate the rotor side converter using crowbar resistors. The DFIG mimics the operation of a SCIG, or squirrel cage induction generator, when its magnetization reaches the stator level and it absorbs reactive power from the grid network. Voltage fluctuations are caused by the system's increased reactive power consumption when the rotor side converter is switched off. Grid failures may cause wind power to suddenly stop flowing, and disconnecting WECS can lead to issues with the system's frequency and voltage control.

KEYWORDS: Wind Energy Convension System, Intelligent Optimised Controller, DFIG mimics, voltage control, power consumption, rotor side converter.

INTRODUCTION

The development of an intelligent optimized controller for LVRT in DFIG-based WECS has the ultimate objective of ensuring grid code compliance, improving system reliability, and minimizing the risk of disconnection during grid faults. This will ultimately contribute to the stability of the power grid and the integration of renewable energy sources into the grid. The purpose of this controller is to enhance the fault ride-through capabilities of the system while simultaneously ensuring that its operation remains stable and dependable.

Among the most important aspects of the development of such a controller are:

1. In the first place, fault detection and classification refers to the process of putting in place algorithms that can quickly identify and categorize grid failures. This gives the controller the ability to react appropriately depending on the kind and degree of the fault.

2. Control Strategy Design The process of developing intelligent control strategies that will allow the DFIG system to govern its voltage and current responses during grid disturbances. This will ensure that the LVRT is in compliance without compromising the stability of the system.

3. Artificial intelligence and machine learning techniques: the use of AI-based models, such as neural networks or fuzzy logic systems, to forecast fault situations in advance or optimize control parameters in real-time for improved LVRT performance to achieve superior overall performance.

4. The use of optimization methods such as genetic algorithms, particle swarm optimization, or model predictive control in order to fine-tune controller settings and improve system performance in a variety of failure situations is referred to as optimization algorithms.

5. Implementing the created controller in hardware-in-the-loop simulations or real-time experiments to test its efficacy and resilience in boosting LVRT capacity is the fifth step in the hardware implementation and validation process.

RENEWABLE ENERGY UTILIZATION

Throughout the course of the technological development of the human race, energy has been both a remarkable source and a notable need. For the purpose of satisfying the ever-increasing demand for energy in the 21st century, power producing systems are steadily expanding in size. Urbanisation and rapid population expansion are the primary contributors to the current energy crisis that the world is experiencing. Renewable energy

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systems and non-renewable energy systems are the two primary categories that are used to classify power production systems. [1] These categories are categorised according to the exhaustibility of the systems. Non-renewable energy is taken from finite sources such as nuclear fuels and fossil fuels (coal, crude oil, and natural gas), while renewable energy is obtained from natural resources such as the sun, biofuel, wind, water stream, geothermal, and tides. Renewable energy is a kind of energy that is derived from natural resources.

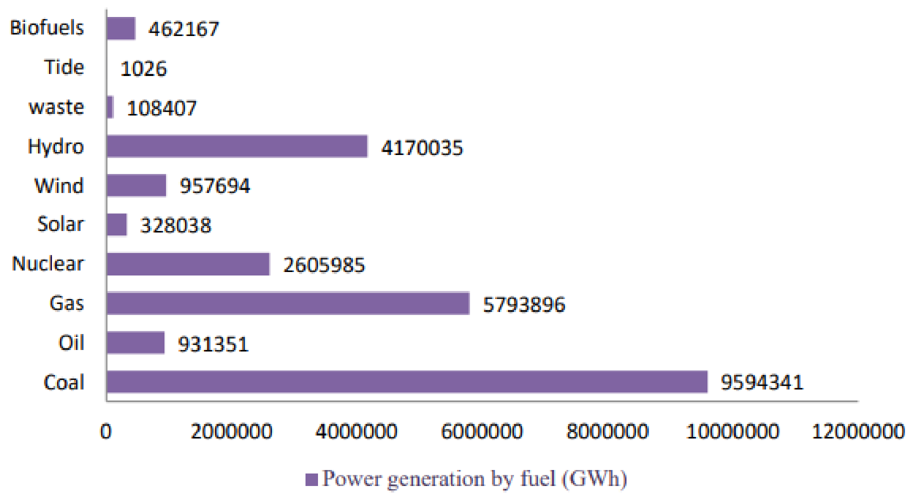

Figure 1 World Gross Electricity Productions

Figure 1 depicts the statistics on world gross electricity productions from various energy sources that were organized by the International Energy Agency (IEA) in 2018. These statistics clearly demonstrate that the majority of the world's electricity production is dependent on conventional fossil fuel, which excludes unwanted by-products that are harmful to the biosphere. Excessive use of fossil fuels, in turn, results in the development of environmental issues that are not desired.

Because renewable energy sources are abundant in nature and do not do any harm to the environment, they make a substantial contribution to the creation of power. This is owing to the fact that they are environmentally friendly. The incorporation of renewable energy sources into the power system is a very significant step forward for WECS. The overall capacity of India's power generating is 401 gigawatts (GW). According to the statistics provided by the Central power Authority (CEA) as of April 2022, renewable energy accounts for 28 percent of the total power output in India, with a capacity of 111 gigawatts (GW). Wind power in India has reached 40.5 gigawatts (GW), which accounts for 10% of the country's total installed capacity. According to the Global Wind Energy Council (GWEC), the total installed capacity of wind turbines around the globe has increased to more than 837 gigawatts (GW), which has assisted the world in avoiding more than 1.2 billion tons of carbon dioxide being released into the atmosphere per year (Dec 2021). The Ministry of New and Renewable Energy (MNRE) of the Government of India has set a goal of achieving net zero energy by the year 2070, and one of its targets is to attain 140 gigawatts (GW) of wind energy by the year 2030.

WIND ENERGY SYSTEMS

Increasing concerns about unnatural weather change, natural contamination, and energy security have accelerated the interest in motivating renewable and ecologically friendly sources of energy, such as wind, solar power, hydropower, geothermal, hydrogen, and biomass, as a replacement for non-sustainable energy sources. These sources of energy include wind, solar power, hydropower, geothermal power, and geothermal power. The use of wind energy has the potential to provide the necessary answers to the changing dynamics of the global environment and the urgent need for energy. Electricity is the most widely used kind of energy in residential settings, commercial establishments, and industrial settings. As of right now, renewable energy accounts for 19% of the total power production around the globe. In the course of the last few decades, there has been a significant increase in the utilization of control measures as a result of population growth and contemporary innovation. Regular assets such as coal, oil, and gas that have been sources of fuel for power plants, industries, and automobiles for a significant amount of time are in risk of being depleted at an extremely rapid pace. [3] Biomass energy, hydropower energy, solar energy, and wind energy are all examples of different types of sustainable power sources. Because wind is a clean source of energy and does not produce any waste products during the process of wind power production, it is the sustainable power source that is seeing the highest demand among all of these other types of electricity.

Wind power is one of the sources that is both the most readily accessible and the fastest in terms of speed. The production of electricity from wind does not involve the use of any fuel, and it is capable of delivering a significant amount of energy to satisfy the requirements of the global market. In recent years, there has been a typical annual increase in the introduced wind energy limit of 25%. Additionally, there is a current total introduced limit of around 238,000 MW, which indicates that wind energy is likely to play a significant role in the future of the world's energy supply. From the time when humans first started using sailboats and sailing ships, wind control has been employed for a considerable amount of time. At the very least, according to Ackermann, vertical pivot windmills have been deployed by the Afghan good kingdoms for the purpose of pounding grain ever since the seventh century BC. The usage of windmills with a horizontal axis was discovered to have occurred about the year 1000 AD among individuals from the Tibetan, Chinese, and Persian cultures. [4]

WIND TURBINES

An axis of horizontal wind turbines, also known as horizontal axis wind turbines (HAWT), and an axis of vertical wind turbines, also known as vertical axis wind turbines (VAWT), are both elements that are considered to be part of the physical configuration. In the beginning, vertical axis designs were taken into consideration due to the fact that they provide the advantageous characteristics of being omni-directional (and thus do not need a yaw-framework) and having gears and generating equipments located at the foot of the tower. On the other hand, the VAWT was unable to achieve a high level of proximity in the market for business due to the following negative marks:

- Low efficiency of aerodynamic.
- It is not possible to have a gearbox of a large VAWT at ground level because of the weight and expense of the transmission shaft. This is because houses are often located at ground level.

In HAWT, the blades rotate in a direction that is parallel to both the ground and the wind stream. Every single one of the larger turbines that are used in modern wind farms are HAWT turbines. This is due to the fact that HAWT turbines are better suited for controlling huge wind energy amounts. [5] HAWT, on the other hand, are susceptible to the turning around loads of gravity, which demonstrates that there is a limit on the size of hydroelectric turbines. It is possible to regulate the pivot of HAWT and VAWT primarily via the use of drag drive, which is dependent on the model of the edge shown in Figure 2.

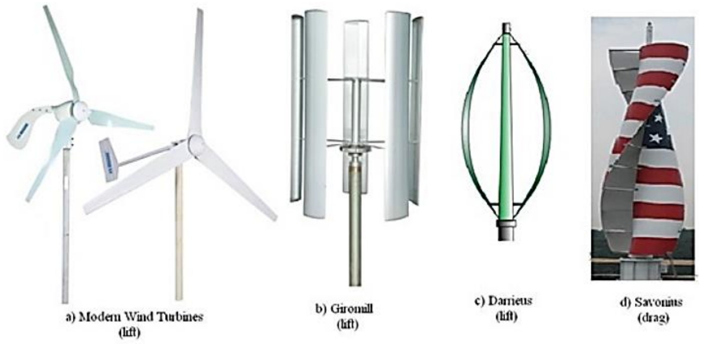

Figure 2: Examples of HAWT (a) and VAWT (b, c and d)

a) Number of Blades

The sharp edges should make as much contact as possible with the wind that is blowing within the cleared zone in order to get the maximum amount of twist energy that is feasible from the wind. Theoretically, the productivity of a wind turbine may be increased by increasing the number of cutting edges it contains. Nevertheless, in the real world, when there are a greater number of sharp edges, there will be a greater impedance inside the cutting edges. In a similar vein, it is more likely that the front will be affected by the disturbance caused by the weaker wind stream location. From the perspective of assistant unfaltering quality, the number of front lines of HAWT should be odd and more unmistakable or identical to three. If this is the case, then the dynamic characteristics of the turbine rotor should be similar to those of a plate. As a consequence of this, the great majority of wind turbines that are readily available in the current day are three-blade structures.

b) Betz Limit

According to the Betz law, we are able to seamlessly convert less than 17/26, which is equivalent to 59.4% of the engine essentialness in the wind, into mechanical imperativeness by using a wind turbine. This is due to the fact that the wind continues to possess some velocity after it has passed through the wind turbine. A portion of the electrical vitality is lost in the gearbox, bearing, generator, power converter, transmission, and other components, while the rest of it is sent to the transmission. The vast majority of earthly rotors that have three sharp edges are capable of achieving a general viability of about fifty percent.

Generally speaking, wind control generation makes use of turbines that are either fixed speed or variable speed, and these turbines may be separated into four significant categories. One of the most significant differences between these wind turbine compositions is the fact that the rotor's streamlined efficiency would not be ideal for a variety of wind speeds and situations.

Types of Wind Turbine

The partitioning of wind turbines may be done in two different methods. In the first place, the classification is determined by the position of the axis of rotation of the wind power system, and in the second place, it is determined by the variation in wind acceleration. The wind turbines may be divided into two categories: HAWT and VAWT. There are two types of wind turbines: those that operate at a constant speed and those that operate at varying speeds. Both types of wind turbines are classified according to the wind speed assortment.

HAWT

In recent times, the HAWT has emerged as the most common wind turbine that is coupled with a matrix. The majority of them are made up of a few rotors that have blades installed. When it comes to this particular kind of wind turbine, the rotor shaft and the electrical generator are positioned at the highest point of the apex, which is a location where the wind is less intense and the wind has more horsepower.

VAWT

Within the framework of the wind turbine, the primary rotor shaft of a VAWT is positioned in a vertical orientation. The Darrieus rotor type vertical axis wind turbine system, which is the most popular form of VAWT, is seen in Figure 1.5 (b). The generators and gearboxes of this kind of wind turbine are positioned in close proximity to the ground, which makes it simple to repair and conduct maintenance operations on the components. Additionally, this type of wind turbine is able to receive wind from any direction without the need for a yaw system. These are the primary advantages of this type of wind turbine configuration. Despite the fact that it has a number of benefits, this particular type of wind turbine has a number of drawbacks, including a low starting torque, a tendency to stall when the wind is blowing strongly, and the fact that it is used for low-power applications like battery charging due to its very low power output. As a result, the popularity of VAWT is lower when compared to HAWT.

Constant Speed Wind Turbine

The gearbox, the low and high speed shaft, and the asynchronous generator are the components that make up this sort of turbine, which is a straightforward design.

The majority of the time, a squirrel-cage induction generator is attached in order to provide power from this sort of framework. Because this turbine system operates at a constant speed, there is no need for a power-electronic converter. As a result, the system's structure is straightforward when it comes to its construction. In light of the fact that the generator is specially interfaced with the utility framework by means of a turbine transformer machine, the network is responsible for imposing synchronous frequency on the machine. The speed of rotation of the asynchronous generator is not precisely constant and varies within ±3% to ±8% of the synchronous speed, which is a very small amount. As a result, this kind of turbine is comparable to a wind turbine system that operates at a constant pace.

Variable Speed Wind Turbine

Despite the fact that it is essentially mind-boggling, this kind of wind turbine framework is more frequent in comparison to wind turbines that operate at a constant pace. This is because the turbine framework is able to give the greatest amount of energy possible due to the fact that its speed fluctuates continuously. For the purpose of connecting the machine to the transmission framework, a powerful state control converter is used on a consistent basis. Currently, there are two types of wind turbines that are more commonplace. Both of these wind turbines have variable speeds. The wind turbines in question are the DFIG wind turbine and the Fully Rated Converter (FRC) wind turbine, both of which are equipped with synchronous or enlistment generator premise.

WIND ENERGY CONVERSION SYSTEMS

As a result of the rapid development of respective technology, renewable energy conversion systems, and more especially Wind Energy Conversion System (WECS), are making a significant contribution on a global scale. Wind, which is a source of energy, contains a potential energy in the atmosphere that is favorable. The kinetic energy that is present in the wind is converted into electrical energy by the wind energy systems. The wind energy system has the potential to provide a useful output in terms of utility grid integration, which may help to reduce the gap that exists between supply and demand. The worldwide market places an emphasis on energy production that is based on wind farms because of the economic excellence, ease of maintenance, and absence of emission techniques that these farms use. [7]

In most cases, the energy is associated with a number of similar problems, including accessibility, price, and environmental friendliness. Because wind energy systems do not produce any emissions during the generation of power, they are considered to be ecologically friendly. Wind is an abundant renewable source that is also readily accessible, and as a result, it has the potential to be economically viable for use in the production of electricity. As a result, it is anticipated that wind energy will serve as the primary source of fuel for the expansion of the power production system.

Before wind power can be included into the infrastructure of the electric grid, it must first go through the following stages:

- Accumulation of the wind resources
- Transition of procured wind power into the electrical form
- Consolidation of attained electrical energy into the grid

As can be seen in Figure 3, a contemporary wind energy system is made up of a number of different components. These components include the tower, the rotor, the wind turbine, the gearbox, the generator, the nacelle, and the power converter structure.

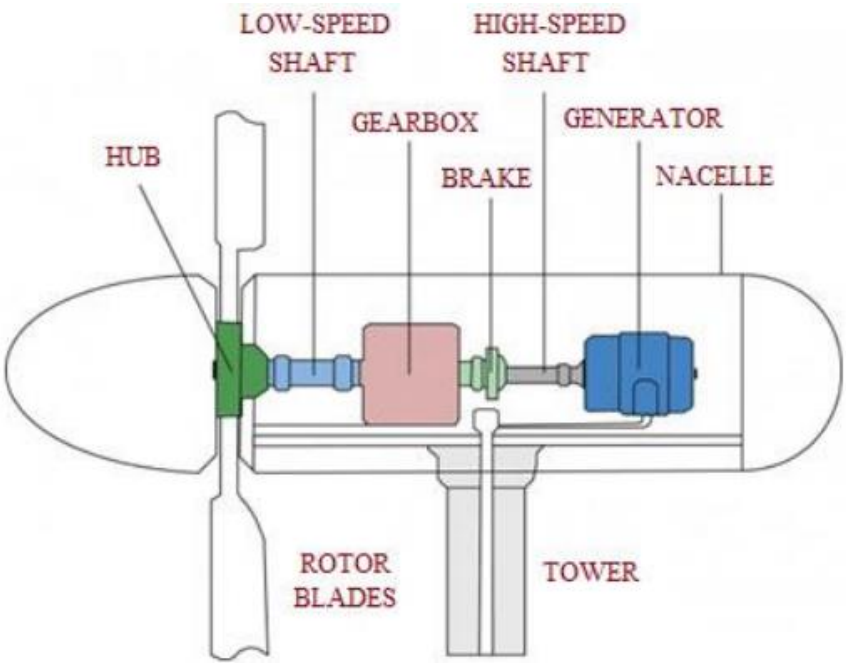

Figure 3 Components of WECS

The horizontal axis design and the vertical axis design are two separate forms of wind turbine layouts that may be distinguished from one another. In a system with a horizontal axis, the rotational axis of the blades is parallel to the ground. On the other hand, in a system with a vertical axis, the rotor blades rotate on an axis that is perpendicular to the ground. In spite of this, the majority of contemporary wind turbines are constructed using a horizontal axis arrangement because of its great efficiency and ability to regulate output even when operated at high wind speeds. In a conventional WECS that is constructed horizontally, the tower raises the whole conversion system to a higher position in order to provide adequate room for the rotor blades to rotate. The velocity of the wind is directly proportional to the height of the tower. This is because the viscosity of the air and the surface aerodynamic drag both contribute to the speed of the wind. [8]

An electrical generator's rotor is made up of a hub and two or more blades, depending on the generator's design. The hub is an aerodynamic component that serves as the attachment point for the blades. Blades are responsible for absorbing the kinetic energy of the wind that is blowing in and transmitting it to the hub. A direct proportional relationship exists between the square of the length of the rotor blade and the amount of wind power that is collected by the aerodynamic component. The blades of the rotor provide rotation with a continuous swept area.

CONCLUSION

Due to the significant part that these systems play in the transition toward renewable energy on a global scale, it is imperative that research and development be carried out in order to develop an intelligent optimized controller for the purpose of enhancing the Low Voltage Ride Through (LVRT) capability in Doubly Fed Induction Generator (DFIG) based Wind Energy Conversion Systems (WECS). As our dependence on wind power continues to grow, it is essential that wind energy systems continue to function in a trustworthy and uninterrupted manner in order to maintain grid stability and dependability. It is essential to have the capacity of LVRT in order to maintain grid connection in the event of voltage disturbances or faults. This protects against unexpected disconnections and guarantees a continuous supply of electricity to the grid. Additionally, developments in control methods, artificial intelligence, and optimization approaches provide interesting possibilities to enhance the responsiveness and flexibility of DFIG-based WECS under low voltage circumstances.

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