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STUDY ON GRID-CONNECTED POWER QUALITY IMPROVEMENT OF WIND FARMS BASED ON REPETITIVE CONTROLLER

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Abstract. The project highlights the wind energy and the process followed in the wind farms in order to generate the energy by using wind power and wind capacity as well. Moreover, it has been observed that wind energy is also considered one of the most effective electrical energy sources. The application of wind energy can be beneficial for different aspects of the business sectors of different countries across the globe and this is possible because of its cost-effectiveness. Furthermore, this study encompasses the strategies employed within wind farms to preserve and efficiently harness wind power for the generation of electrical energy. Notably, the project delineates the utilization of a diverse array of instruments, each instrumental in the conversion of wind power into valuable wind energy. Beyond the realm of technology, wind farms grapple with a spectrum of formidable challenges, stemming from the inherently capricious nature of wind. In addition, various issues concerning power quality and the stability of the power system have also been identified within these wind farms. To ameliorate these multifaceted challenges, the project introduces a range of meticulous control measures for implementation.

Key words: Wind farms, Wind turbines, motor, instruments, grid, access, power, issues, voltage.

1. Introduction. Wind farms are also known as wind power plants in which different modern technology-based equipment and software applications have been used to generate energy from the wind forces. It has been observed that the power of wind and the forces of wind are converted into electricity power. This kind of energy source which is provided by high-power wind sources is also known as renewable energy. The capacity of generating electricity-based energy is not limited to a particular amount. Moreover, this kind of energy source is the "lowest cost energy source". Among different types of equipment, the most useful equipment utilized in wind farms in order to generate electricity from the wind forces is wind turbines. With the help of wind turbines, the developer can use the forces of surrounding winds and conserve them and convert them into electricity energy. Apart from different advantages it has been observed that different challenging situations are also observed in the wind farms while converting the wind forces into electricity energy. The uncontrolled nature of wind forces results in the development of different types of challenging situations. Apart from this various other issue are also observed in the wind farms such as power quality-related issues, and the stability of the power system-related issues as well.

As the global energy landscape undergoes a transformative shift towards sustainability and renewable sources, wind energy has emerged as a prominent and environmentally responsible solution. Wind farms, comprising arrays of wind turbines, play a pivotal role in the generation of clean electricity. However, the integration of wind energy into the electrical grid introduces a unique set of challenges, particularly with regard to power quality. Wind energy is inherently intermittent due to the variable nature of wind speeds. This intermittency can result in fluctuations in power generation and, consequently, issues related to power quality when integrated into the grid. Voltage and frequency variations, harmonics, and flicker are some of the power quality concerns that grid operators and utilities must contend with. The need to enhance the quality and reliability of electricity supplied to consumers underscores the significance of this research.

By conducting an in-depth analysis of the Repetitive Controller's application in wind farms, this research

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aims to contribute to the broader goal of optimizing the performance of wind energy systems while ensuring high-quality power delivery. It underscores the importance of stable and reliable electricity supplies as we strive to meet the ever-increasing demand for clean and sustainable energy. In a world seeking to reduce carbon emissions and mitigate the effects of climate change, the enhancement of grid-connected power quality in wind farms is a critical step towards realizing a more sustainable and environmentally responsible energy future.

2. Objectives. Different motivation has been observed behind the development of this study. Hence these motivations are further illustrated as the objectives of this study in the below section.

1. To identify the issues of different power quality control aspects of the wind farms
2. To investigate the challenging conditions the wind conservation farm can experience due to power grid
3. To find out the various ranges of controllers that are used in the wind farms
4. To describe the role of wind turbines in the enhancement of production capacity of the electricity energy in the wind farms
5. To examine the innovative ideas and their contribution to the improvement of the output level of wind farms

3. Methodology. The conducted study is based on the different information which is collected about wind farms and the technology used in wind farms as well. It has been observed that different types of motors and turbines are used in wind farms for converting wind energy into electricity power [1]. Information about different challenging conditions and the different innovative strategies adopted by wind farms are also incorporated in this study. It has been observed that all data are mainly secondary in nature. As the use of secondary information has been observed in the development of this research project, therefore, it can be stated that the use of the qualitative method is also present in the research project as well.

3.1. Power Quality Issues of Wind Farms. The motivation that has been observed behind the development of the wind farm is to utilize the wind forces and convert them into electric energy. The quantity of the electric energy can be described by its voltage and frequency [2]. Due to the variation in the frequency power generated in the form also varies as well. This can cause lower quality of the generated electric energy. Moreover, it has been observed that it is next to impossible to maintain a constant frequency and voltage for the electrical power generated by using the wind forces in the wind farm [3].

Wind energy, as an increasingly prevalent renewable energy source, has brought substantial benefits in reducing greenhouse gas emissions and enhancing sustainability. However, the integration of wind farms into the electrical grid introduces power quality challenges that must be effectively addressed. One of the primary issues pertains to the variable and intermittent nature of wind. Wind speeds fluctuate, leading to inconsistent power generation, which can result in voltage and frequency variations. These variations can, in turn, disrupt the stability of the grid and affect the quality of electricity supplied to consumers.

Harmonics are another significant concern associated with wind farms. Harmonics are unwanted, high-frequency electrical disturbances that can lead to equipment malfunction and efficiency losses. The non-linear characteristics of power electronic converters within wind turbines can introduce harmonics into the electrical grid, impacting the overall power quality. Additionally, flicker, which is the rapid variation in voltage magnitude, can be generated by wind turbines, causing undesirable fluctuations in lighting and equipment performance, and potentially leading to discomfort and inconvenience for end-users

Among different problems, the development of harmonic distortion is considered as one of the major issues, and due to this issue it has been observed that a wrong measurement has been detected by the wind turbine [4]. Among different reasons, some common reasons for developing this situation differ in the speed drivers of the wind farms. When this differentiation between two-speed drivers becomes then this causes the development of harmonic distortion. Moreover, it also needs to be noted that "large concentrations of arc discharge lamps", and "saturation of magnetization of transformer" are another two reasons which also contrived in the development of the harmonic distortion [5]. Due to this harmonic distortion, the voltage in the grid of the wind farm got influenced and it started fluctuating as well. There are two different harmonic voltage grids that have been noticeable in the wind farm which affected the measurements of the voltage unit. These two grids are "harmonic of 5th and 7th grids".

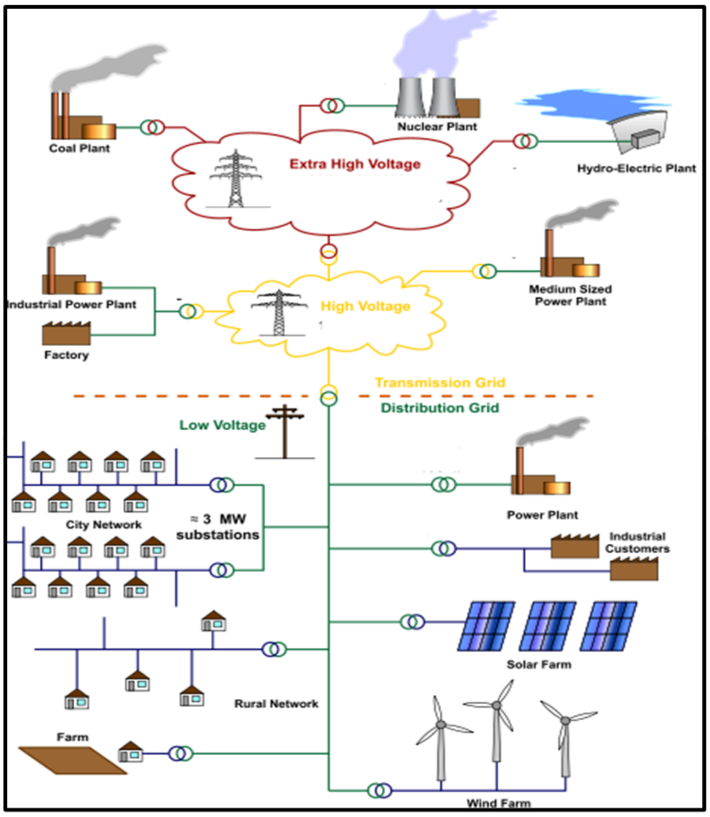

Fig. 3.1: Power quality issues of wind farms

3.2. Power Grid Challenging Conditions of Wind Conservative Farm. It has been observed that the "intermittent nature of the wind energy" is one of the highly influential challenging situations developed in the wind form which in turn creates power grid-related challenging conditions. In other power plants, the developer has the ability to control the power that is used in order to generate electrical energy [6]. Though in case it has been observed that the speed and the force of the air cannot be controlled by the developer as a result of this the developer finds it difficult to match a high-speed containing air and convert them into electrical energy as well. Due to this uncontrolling power of the air, the output generated after the conversion has also become out of control and out of expectation as well [7].

Moreover, the availability of wind is another challenging situation faced by the developers of wind farms. The high range of availability of the wind makes suitable conditions for generating electrical energy from the wind forces [8]. On the other hand, a minimum amount of wind availability is required for generating electrical energy. When the availability of the air is below the minimum range then this situation creates an inability in the development of electrical energy [9]. In addition to that it has been observed that it lowers the production rate of electrical energy. Moreover, the uncertain condition of the wind capacity also results in the development of different issues regarding the power quality issues of the produced electrical power. It has been observed that this uncertain condition also resulted in the development of instability in the electrical power as well [10].

3.3. Types of Controllers used in Wind Farms. Different types of controllers have been used in these wind farms and these controllers have been involved in impacting the production rate of the generated electrical energy [11]. Moreover, it has been observed that wind turbines are responsible for conserving the winds from the surrounding areas. Therefore, the winds collected by the wind turbines are monitored by the controller that is used in the wind farms as well. Along with different computer devices and OS, systems are also involved in

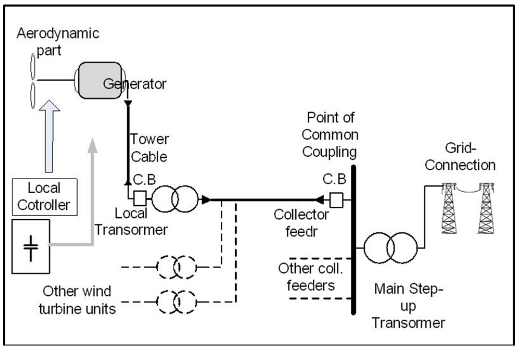

Fig. 3.2: Power grid challenging condition of wind conservative farm

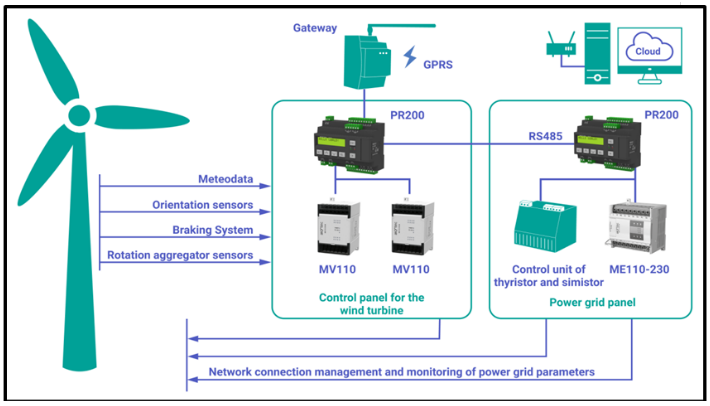

Fig. 3.3: Controllers used in wind farms

playing the role of the controller which can be able to control the speed and the capacity of the wind turbine that is used in the wind farms [12].

Apart from that the mostly used controllers of wind farms are "large numbers of switches", "hydraulic pumps", "valves, and different shaped motors" as well. These all have the ability to control the working capability of the wind turbulence that is used in wind farms [13]. Moreover, the size of the wind turbulence is also another aspect that can also control the power of the wind turbulence as well. These controlling machines are also helpful for impacting the performance capability of the wind turbulence and it enhances the capability of conserving the wind only in one cycle. When the wind conservation capacity becomes high then it is also helpful for enhancing the production rate of the generating electrical energy [14].

3.4. Innovative Ideas that can improve the Wind Farm Output LevelI. Different types of innovative ideas have been observed which are considered one of the measures that are helpful for enhancing the capability as well as the effectiveness of the wind farms in terms of maximizing the production rate of the electrical energy by those wind farms [15]. The inclusion of retrospective measures is considered as one of the innovative ideas and in case the developer used this measure in the controlling aspect then it has the capability to maximize the performance capability of the wind farms. Moreover, thus specific measures are also involved in developing different opportunities for controlling the capability of the wind turbines and maximizing the capacity of the wind turbines as well [17].

The measurement technology is also considered another measure of improving the out[ut level of the wind farms [16]. By incorporating these measuring techniques the developer can be able to measure the availability of the wind and the spread of the wind in the surrounding areas of the wind farms and use these measurements

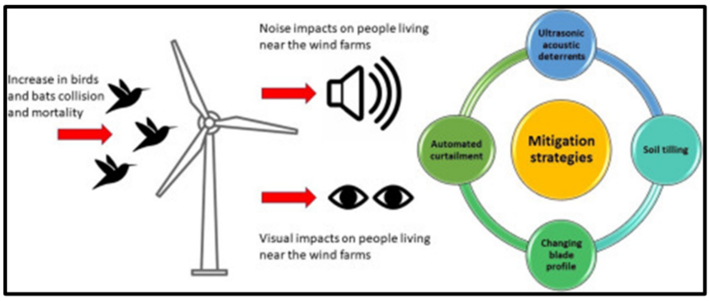

Fig. 3.4: Innovative ideas that can improve the wind farm output level

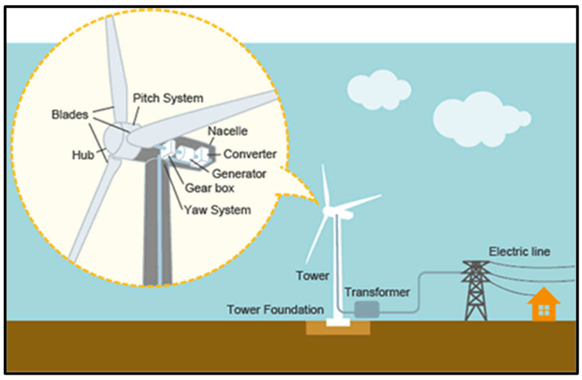

Fig. 3.5: Role of wind turbines

for further conserving the winds from the surrounding areas as well. Moreover, the application of advanced levels of Pitch, Yaw, and rotational speed is also helpful for enhancing the out level of the wind farms [17].

3.5. Role of wind turbines in the wind farm. Wind turbines are involved in contributing a high level of impact in the generation process of electrical energy [18]. Moreover, it has been observed that the application of wind turbines is involved in turning wind power into electrical energy. This whole process of turning wind power into electrical energy is also known as the process of generating electrical energy by using wind power and wind capacity as well. Moreover, it has been observed that the high range of the hands of wind turbines is helpful for arranging greater areas of the wind. With the long hand of the wind turbines, the reaching capacity of the wind turbines exceeds by a high level [19].

With the help of the inclusion of a high-speed-containing motor, the speed of the wind turbine can be increased and this impacts maximizing a greater amount of wind from the surrounding space [20].

4. Results. With the inclusion of different types of technology and software applications, it has been observed that the capacity of wind farms gets maximized and this is helpful for generating a high range of electrical energy. Moreover, the application of wind energy is increasing day by day in different countries due to its cost-effectiveness. The easy way of developing this renewable energy is also another reason for enhancing the usage of wind energy [21].

The above-concerned fig. 4.1 contains the percentage of the utilization of wind farms in different countries. It has been observed that in the year 2016, the UK does not have any exposure to wind farms. On the other hand, in the year 2022, the exposure of wind farms and their utilization in the generation of high levels of electrical energy has reached its maximum. Moreover, other countries of the world also reach their highest range in terms of using wind farms for different purposes of the development of the country.

The above-developed fig 4.2 contains the five different countries of the world which have the largest wind

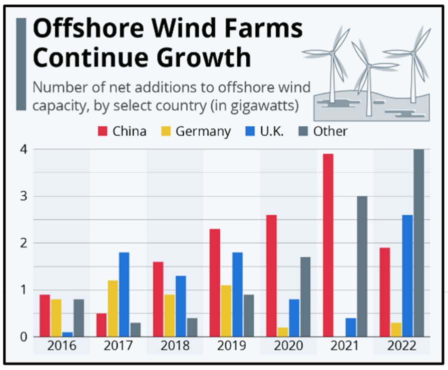

Fig. 4.1: Utilization of wind energy

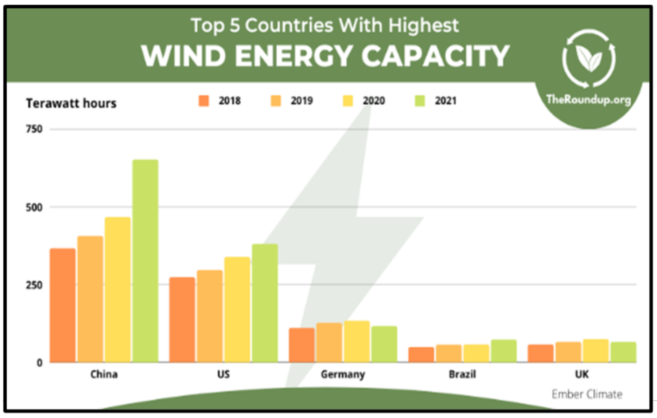

Fig. 4.2: Top 5 countries with wind energy capacity

farms and also contain the largest amount of wind energy capacity as well. Among the top 5 countries, China ranked in the first position, and in the year 2021, almost 750 terawatt hours of energy will be produced in China by using the wind forces in the wind farm as well.

5. Conclusion. By summarizing all the information thus it can be concluded that the concerned project contains all the information about the wind farms and the strategy used by the wind farms in order to conserve the wind and transform them in order to generate the electrical energy. It has been observed that different strategies, different technology, different instruments, and different techniques that are used for conserving the wind forces and further utilized for producing electrical energy are illustrated in this project. Moreover, different challenging situations faced by wind farms are also described as well. This challenging situation lowers the efficiency of the wind farms and as a result of this scenario, the production rate of generating the electrical energy becomes low. the study also highlights the challenges that wind farms face, which can diminish their efficiency and consequently impact the rate of electrical energy generation. Addressing these challenges and continuing to refine wind energy technologies are imperative steps in the journey towards a greener and more sustainable energy future. It underscores the global shift towards wind energy and emphasizes the importance of overcoming challenges to further enhance the efficiency and effectiveness of wind farm operations. As the world seeks to reduce carbon emissions and bolster its commitment to renewable energy, the role of wind farms in achieving these objectives remains pivotal.

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