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Technical Overview of WECS in India

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Abstract: *Recently, renewable energy has been particularly important because they seem to be a positive alternative to fossil fuels. In particular, Europe and many other developed countries throughout the world have tried to use wind energy to meet energy needs. The goal of this study is the healthier and more efficient use of wind energy. Increasing the performance of wind energy was suggested by different authors. This paper discuss the various aspect of the wind energy that means their background, and different approach to develop the performance of the wind energy system.*

Keywords: WECS, CSIR, NAL, MNRE, PMSG, CPC, RL, ANN, PQ, etc.

I. INTRODUCTION

Since ancient times, natural wind has been a precious mechanical power source. Today's wind turbines of large capacity are eligible to power the grid as a result of the developments in engineering and technology. Wind power is being used to generate electricity with transformation of mechanical power, which is one of the world's fastest growing electricity generation sources. For at least 3,000 years, people have been using wind power. Wind power was used for the pumping of water or the grinding of grain until the twentieth century. The fluctuating wind energy tends to be disadvantageous in the initial phase of modern industrialization, and therefore fuel fired engines and electrical grid sources that provided a more reliable electricity supply have been replaced. Wind is the flow of air that is normal. The irregular heating of the earth's surface by the sun causes it. Since the surface of the earth is covered by various kinds of soil and water it absorbs solar energy at various rates. The air on top of the soil gets faster over the water during the day than the air. The hotter, heavier air rushes, producing winds over the planet and increasing.

Apart from stressing its increasing importance as a major source of renewable energy, this technical review papers discuss the wind power in India and elsewhere. In the next section here discuss the different approach uses in the wind energy conversion system.

Also discuss additionally energy quality problems produced by Wind Energy Conversion Systems (WECS) on power grid.

II. BACKGROUND OF WECS

In December 1952, wind power development started in India when Manek lal Sankalchand Thacker, a distinguished power engineer, launched an explorative project on wind power in India, together with the Indian Council of Science and Industrial Research (CSIR). In accordance with the CSIR established a wind power subcommittee in the country. Nilakantan's task was to examine the resources available which can be used in combination with the analysis of the economic potential of wind energy. In India, with the help of the Indian Meteorological Department, the Subcommittee has studied and carried out comprehensive surveys of potential wind energy uses and has successfully developed and tested large wood- and-bamboo windmills.

Wind power generation and the Sub-Committee on Wind Energy have already begun constructing twenty wind speed surveillance plants all over India and testing their indigenous windmills, which have a capacity of 6 kW. India was introduced by the West German Government by the Allgaier wind turbine, which began in Porbandar in 1961[1,2]. The Government of India was also considering a proposal for the construction in rural districts of over 20,000 wind power plants that would supply water and power to remotely situated installations.

The CSIR established a wind power division [1] from the 60s to the 80s, and NAL and other Wind Velocity studies continued to develop improved estimates of wind power capacities in India [3] as part of the new National Aeronautical

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Lab (NAL) established in Bangalore in 1960. Wind energy development began in 1986 with the first wind component. These demonstration projects were supported by the Ministry of New and Renewable Energy (MNRE).

The first wind farms in the country to assess wind farms potential in 2011 were Prof. Jami Hossain of TERI University in New Delhi [4]. This was then re-validated by the Lawrence Berkley National Laboratory, United States (LBNL, 2012) as part of independent studies. Consequently, MNRE formed their Potential assessment committee [5] and announced the revision, through the National Institute of Wind Energy (NIWE) of its estimate of wind potential in India from 49,130 MW to 302,000 MW, assessed at a 100 m center [6]. At a height of even 120 m, wind turbines are now installed and the prevailing wind resource is around 120 m or more at the higher hub height.

Also presented an extensive review of modern developments in Wind Energy Conversion Systems (WECS), emphasizing the rapid evolution of turbine technologies, generator configurations, and power-electronic interfaces. Their study highlights the shift from fixed-speed induction generators to advanced variable-speed systems such as DFIG and PMSG, which offer improved efficiency and better grid support. The authors also examine emerging converter topologies and advanced control strategies, particularly those involving model predictive control, fuzzy logic, and AI-based MPPT techniques. Additionally, the review underscores the growing importance of grid integration challenges, including harmonic distortion, voltage instability, and fault-ride-through requirements, especially as wind penetration increases worldwide. According to Mostafa et al., recent trends indicate a move toward intelligent, digitally controlled WECS supported by high-performance

In 2015, MNRE plans to produce wind energy by 60,000 MW by 2022 [7]. Wind power generation had never been linked through the grid by December 2017 in the eastern and northeast regions. No offshore wind farm was operational since December 2017. Since 2015, however, an offshore wind plan has been announced and NIWE is currently building weather stations and LIDARs at some locations. The first offshore wind farm is built in the vicinity of Dhanushkodi in Tamilnadu

III. REVIEW BASED ON WECS

The simulation, optimization, and existing tools to simulate and design self-sufficient hybrid electricity production systems is reviewed in [8]. To describe the various types of defects, their signatures generated and their diagnostic systems in short order is in [9]. Wind Energy Conversion Systems (WECSs) constantly need to reduce operational and maintenance costs. This cost reduction would be most effective if the condition of those systems were continuously monitored. This makes it possible to early detect generator health degeneration, facilitates proactive reactions, minimizes downtimes and maximizes productivity. Wind generators also cannot be accessed because they are located on very high towers, which normally reach a height of 20 m or above. A mathematical modeling and control strategy for small wind turbine systems connected to PMG grid is presented in [10]. The aerodynamic wind turbine uses furling control and the expected dynamics to ensure maximum power production, while the optimal speed of PMG is followed. The optimal speed data promise the greatest power flow into your grid through the controlling of the boost converter output and current through the operating cycle is derived from a novel controller. The proposed modelling and control strategy has been found to be feasible and results are verified by simulation. A novel algorithm for an efficient management in energy of the standalone permanent magnet synchronous generator (PMSG) system of variable wind power conversion, consisting of battery, fuel cell and dump load (i.e., electrolyser). A novel algorithm based upon dc link voltage is presented in [11]. In addition, the output ac voltage of the inverter can be kept constant regardless of the varying speed and load of the wind, by maintaining the dc link voltage at its reference value. In order to balance line voltages at the point of common couples (CPC), an efficient control technique for the inverter based on the Pulse width Modulation (PWM) scheme has been developed. A low-voltage ride-through system for the wind power system (PMSG) for a permanent magnet synchronous generator at the grid voltage slope is presented in [12]. Instead of the grid side converters (GSC), the dc-link voltage is controlled by the generator-side converter. Taking account of the nonlinear relationship between the speed of a generator ωm and the voltage by dc-link Vdc, the dc-link voltage control system is designed by using the liberalizing feedback theory. For maximum power point tracking the GSC controls the Grid's active power. By simulation and experimental results for a reduced scales PMSG wind turbine simulator, the validity of this control algorithm has been verified.

A simple real power control strategy, which augments the MPPT feature of modern WECSs, and is based on rapid torque control as opposed to the traditional pitch-angle control is discussed in [13]. This paper presents the implementation of the proposed control strategy for a direct-drive WECS that employs the permanent-magnet synchronous generator, even though the proposed method can also be extended to other classes of electronically interfaced WECSs. The paper also presents a parameter-tuning procedure for the proposed control strategy. The effectiveness of the proposed control strategy is demonstrated through mathematical analysis and time-domain simulation studies. A high performance permanent magnet synchronous generator-based wind energy conversion system is presented in [14]. In this paper they use medium voltage power converter with diode rectifier, three-level boost (TLB) converter, and a neutral point clamped (NPC) inverter. The TLB generator side converter tracks and balances the dc-link condenser voltages to the max. Outlet, while the net dc-bus voltage and reactive power to the grid is controlled with the NPC grid side converter. A model predictive strategy to control the entire system is proposed in order to predict the future behavior of control variables using the discrete-time models of the proposed electronic power converters. These predictions are evaluated with two independent Cost functions and selected and applied directly for generator and grid-side converters to the switching statuses which minimize these Cost functions. An artificial neural network (ANN)-based reinforcement learning (RL) maximum power point tracking (MPPT) algorithm for permanent-magnet synchronous generator (PMSG)-based variable-speed wind energy conversion systems (WECSs) is presented in [15]. Introduced an advanced hybrid optimization approach for improving the performance of Unified Power Quality Conditioner (UPQC) in grid-connected Wind Energy Conversion Systems (WECS). Their work combines the Enhanced Honey Badger Algorithm (EnHBA) with the Grey Wolf Optimizer (GWO) to create a fast, intelligent, and adaptive control strategy for UPQC. The hybrid controller is designed to minimize total harmonic distortion, enhance voltage regulation, and improve compensation accuracy under rapidly changing wind conditions. The authors demonstrated through MATLAB/Simulink simulations that the optimized UPQC provides superior dynamic response, reduced switching losses, and more efficient power-quality mitigation compared to traditional PI-based and single-algorithm controllers. The study highlights that incorporating nature-inspired optimization techniques significantly enhances the robustness of UPQC, making it more suitable for modern WECS characterized by high variability and increasing grid-code demands [16]. In this paper, diode rectifier, boost converter, neutral point clamped inverter, and L filter are used as the interface between the wind turbine and grid. This topology has abundant features such as simplicity for low- and medium-power wind turbine applications. It is also less costly than back-to-back two-level converters in medium-power applications. The SMC approach demonstrates great performance in complicated nonlinear systems control such as WECS. The proposed control strategy modifies reaching law (RL) of the sliding mode technique to reduce chattering issue and to improve total harmonic distortion property compared to conventional RL SMC.

The effectiveness of the proposed control strategy is explored by simulation study on a 4-kW wind turbine, and then verified by experimental tests for a 2-kW setup.

A survey on important electrical engineering aspects for PMSG-based megawatt-level wind energy conversion systems (WECSs) is discussed in [17]. A comprehensive analysis on power converter topologies for wind turbines (WTs), grid integration of wind farms, digital control schemes, fault-ride- through compliance methods, and future trends is presented. The updated market share, technology trends, WT products information, in-depth technical analysis, and promising research works highlighted in this study will help the reader to understand the state-of-the-art and emerging technologies for PMSG-based WECS. Frequency response strategies for the PMSG-based WECS are explored, and an enhanced frequency response strategy is investigated to regulate the RAPS system frequency jointly with the integrated ultra capacitors is presented in [18]. The proposed short-term frequency response strategy utilizes a virtual inertial technique along with the supplementary droop control. Suboptimal power-point-tracking is also implemented at the PMSG to improve the active power reserve. The enhanced frequency response strategy can regulate the RAPS system frequency while alleviating high rate-of- change-of-power, and thus stresses on both the conventional generator and PMSG under frequency disturbances. Proposed control strategies are validated by both simulations and experiments.

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IV. PROBLEM ASSOCIATE IN WECS

Naturally, as most renewable energy sources, wind energy is a fluctuating source. Consequently, the power plant has a distinct function in comparison with traditional power generation units. As the wind changes, the active power of WTs changes and so which leads to a voltage fluctuation. This can lead to the so-called flicker. Harmonic emissions are, furthermore, seen as a power quality issue in the presence of power electronics for contemporary variable speed wind turbines. Therefore, WTs are typically connected to the grid at a distance from central load or conventional generation of terminals. This leads businesses to show reluctance to introduce unpredictable behavior into this type of power and analyze the related aspects of power performance. Due to the large proportion of the wind power in the grid, power systems operators have additional difficulties, since it is necessary to ensure that a reliable and consistent grid system is in place. So long so small or single wind turbines are installed in the power system, it does not impact and is easy to integrate the wind power network. Nevertheless, it is difficult to ensure grid inclusion without problems if a considerably high degree of wind penetration is obtained and traditional power production units are substituted. WT's should therefore be able to display the same behavior in the event of grid failure as confidential generator units. Therefore, it becomes clear how wind power affects the power system and needs to be addressed.

With regard to the value of the WT power performance and the need for a reliable and replicable record of wind turbine power quality characteristics, various guidelines, such as the IEC 61400-21, have been released. These guidelines provide us with a typical process for evaluating the power quality of the wind turbine required for network-connected functions. The various power value variables are included in different categories, depending on the time frame of the study. In addition, grid codes are added by power system operators for those countries with enormous amount of wind power and they define the required capacity of wind turbines for faults which are well recognized as fault-travel connections. We concentrate mostly on how to improve the wind turbine controller and the safety of the turbine so that even in the case of grid failures, the wind turbines are connected to the network.

What needs to be addressed is how wind power contributes to the reliability of electricity and how it impacts the sustainability of the power system. Through various published research on this subject the WTs embedded through distribution networks have been found to have various impacts on the operations in these networks.

V. CONCLUSION

Recently, the value of renewable energy was especially high as it seems to be a positive alternative to fossil fuels. There are many developed countries worldwide have been seeking to use wind energy to fulfill energy requirements in particular. The goal of this paper is to make the use of wind energy safer and more efficient. Various authors proposed increasing the efficiency of wind energy. The paper addresses the different aspects of wind energy and the different approaches to wind energy system efficiency. Also discuss the basic problem associated in the wind energy conversion system with integration of the grid.

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