INTEGRATION OF SOLAR PV SYSTEM AND WECS WITH THE GRID AND THE STABILITY OF THE WIND ENERGY CONVERSION SYSTEM

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I. Introduction

Since the demand for energy is increasing at a faster pace than production is decreasing owing to the enormous depletion of fossil fuels, the framework should embrace alternative renewable energy sources to solve the energy challenge. Using renewable energy sources, such as solar and wind power, is the preferred choice. The weather's volatility and the sources' inconsistent availability year-round pose the greatest threat to renewable power generation.

II. Types of Solar PV Systems

Grid-connected (On-grid): These systems are able to take electricity from and contribute to the electrical grid since they are grid-connected. Off-grid (Stand-alone): Relying on batteries to store extra power for later use, these systems are not linked to the grid. Hybrid: Typically, these systems use batteries for backup power and grid connection for additional power; they combine the benefits of both off-grid and grid-connected systems.

Solar PV (Photovoltaic) system

Renewable energy systems that use solar panels to transform sunlight into electricity are known as solar PV (photovoltaic) systems. You may use these systems to power your house, company, or even a large-scale power plant. They consist of solar panels, an inverter, and other electrical components. After that, these PV modules are assembled into an array to generate the necessary amount of power. Even the most basic standalone photovoltaic systems may harness the sun's rays throughout the day and store the energy for use later on when the sun doesn't shine. In smallscale, stand-alone PV systems, the power produced by solar panels or an array is stored in rechargeable batteries.

Wind Energy Conversion System (WECS)

A wind energy conversion system (WECS) may convert the kinetic energy of the wind into mechanical energy, which can then be used to power an electrical generator. Numerous types of wind turbine generators are available, including induction, synchronous, doubly fed, permanent magnet synchronous, and many more. The wind turbine sends the harvested energy to the generator. To maximise the WECS's output, pulse width modulation converters control the generator's rotational speed. To connect the power generated by the generator to the power grid, a pair of inverters—one for the generator and one for the grid—are utilised. Wind farms can be sited onshore or offshore, even in hilly areas. The WECS could be the most exciting DG for future SG.

III. Purpose of Research

The global pursuit of sustainable and low-carbon energy solutions has rendered the grid integration of renewable energy sources, particularly solar photovoltaic (PV) systems and wind energy conversion systems (WECS), essential. The intrinsic intermittent and variable nature of these systems presents significant challenges to grid stability, power quality, and reliability, notwithstanding the environmental and economic advantages they offer. The two most urgent concerns are the interoperability of solar and wind power systems and the stability of Wind Energy Conversion Systems (WECS) during grid outages. Adherence to evolving grid standards, encompassing mandates for voltage regulation, frequency support, and fault ride-through capabilities, is crucial for grid integration, alongside effective power conversion and control methodologies. This study seeks to analyse the impact of concurrently functioning solar photovoltaic and wind systems on overall grid performance, as well as the stability and dynamic behaviour of wind energy conversion systems during grid integration. This study seeks optimised methods to enhance stability, ensure an uninterrupted power supply, and facilitate the transition to a more resilient renewable-based power system by modelling the interaction between hybrid systems and the grid and examining advanced control strategies.

IV. BRIEF REVIEW OF THE WORK ALREADY DONE IN THE FIELD

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Revati & Natarajan (2020) Three distinct methods—mathematical modelling, Simscape modelling, and Matlab coding—demonstrate how precise modelling of solar modules may be accomplished. This study employed a single-diode model of a photovoltaic module for computations, modifying various temperature and solar radiation values to assess the module's performance for its I-V and P-V characteristics.

Zohari Brahman, (2018) A confluence of variables, such as escalating industrialisation, surging energy needs, depleting fossil fuel reserves, and environmental conservation initiatives, has resulted in a heightened dependence on renewable energy sources for electricity generation. Solar and wind energy, among others, may constitute the renewable energy sources of the integrated system. The hybrid system has gained popularity as an energy source in recent decades. A comprehensive and effective approach for power generation has been developed throughout this inquiry. To optimise power generation while avoiding energy production variations, the concept advocates for the integration of wind power, hydropower, and solar photovoltaic (PV) systems.

Ackermann & Söder (2002) offered a preliminary all-encompassing review of wind power integration into power networks, drawing attention to the stability and technical hurdles associated with connecting intermittent renewable sources to the grid.

Sarkar & Bhattacharyya (2012) highlighted the synergistic relationship between solar PV and wind power generation, and explored how hybrid systems may help reduce grid intermittency.

Heier (2014) went over the technical details of integrating WECS into the grid, with an emphasis on the capacity to regulate voltage and frequency as well as to ride out faults, all of which are critical to maintaining grid stability.

Rao et al. (2013) recommended using energy storage and power electronic interfaces to stabilise voltage and frequency after analysing the dynamic stability of grid-connected wind-solar hybrid systems.

Kroposki et al. (2017) highlighted how smart grid technology and improved inverters are crucial for ensuring system dependability and stability even with a large penetration of renewable energy sources.

Muljadi & Butterfield (2005) discussed the impact of various generator types on WECS stability, including synchronous, asynchronous, and DFIGs, and highlighted the significance of reactive power supply and pitch control.

Bansal et al. (2015) investigated control techniques for DFIG-based wind turbines, the most common kind in contemporary WECS, and their function in providing frequency support and fault ride-through—skills essential for maintaining grid stability.

Sharma et al. (2018) used fuzzy logic control and Model Predictive Control (MPC) to ensure the stability of hybrid solar-wind-grid systems by regulating voltage and frequency in real-time, making them more resistant to input fluctuations.

Liserre et al. (2010) paid close attention to the ways in which grid rules change as the percentage of renewable energy sources grows, and how compliance guarantees stable WECS integration and low-voltage ride-through and reactive power support, among other things.

Bhende et al. (2011) met the needs for grid-connected WECS fault detection and fault ridethrough with the use of FACTS devices and sophisticated protection schemes.

Yang et al. (2008) studied hybrid solar-wind systems that are either linked to the grid or operate independently to determine the best size and operating strategy. In the face of resource uncertainty, their research prioritised reducing costs while simultaneously enhancing system dependability.

Khan & Iqbal (2005) demonstrated a MATLAB/Simulink-based dynamic model of a hybrid energy system and examined its operation under varying solar and wind profiles. They brought attention to the fact that reliable output requires maximum power point tracking (MPPT) in real time.

Guo et al. (2014) researched technologies for power electronic converters that are utilised in hybrid renewable systems to integrate with the grid. Research focused on control systems that use inverters to synchronise grids, regulate voltage, and reduce harmonics.

Hossain et al. (2013) assessed the effects of grid integration of wind power on voltage stability and transients, and proposed solutions such as energy storage systems (ESS) and field-activated charge transfer devices (FACTS) to keep the grid resilient.

Blaabjerg et al. (2013) provided a comprehensive analysis of control methods for hybrid solarwind systems, with a focus on conditions characterised by weak grids. Virtual synchronous generators (VSGs) and droop control, which are used for system balance, were introduced in the study.

Chauhan & Saini (2014) put forward a method for analysing the performance of hybrid solarwind systems in real-world scenarios using simulations, and assessed energy management techniques that aid in grid stability.

Ekanayake & Jenkins (2004) examined the fault ride-through (FRT) capacities of several wind turbine types, with a focus on DFIGs, in the event of grid disruptions. According to their research, sophisticated control techniques are crucial for keeping systems stable when failures occur.

Yan et al. (2015) Evaluated the efficacy of low-voltage ride-through (LVRT) components in hybrid systems and recommended improved inverter management algorithms to meet renewable energy integration requirements in the updated grid code.

VI. NOTEWORTHY CONTRIBUTION IN THE FIELD OF PROPOSED WORK

The proposed study would advance renewable energy integration by solving PV/WECS hybrid grid stability's biggest issue. This study focusses on the dynamic interaction of solar and wind sources with the grid to better comprehend hybrid systems in real time than previous studies. The study employed sophisticated control methods including MPPT, FRT, and inverter-based grid synchronisation to increase hybrid system operational reliability. The research also models grid interruptions and load scenarios to assess WECS and solar PV integration resilience, improving power quality, frequency stability, and voltage management. Our study helps utilities and politicians create better, more flexible energy management systems, improving renewable energy dependability and scalability for modern power networks.

VII. PROPOSED METHODOLOGY

This project will build and test a grid-connected PV/WECS hybrid renewable energy system, focussing on WECS stability under diverse operating and fault situations. MATLAB/Simulink will model and simulate a solar PV array with an MPPT controller, a wind turbine generator (either a Permanent Magnet Synchronous Generator or a Doubly Fed Induction Generator), power electronic converters, and a grid interface system. Advanced control algorithms will be employed for PV and wind subsystems to ensure power extraction and grid integration. The WECS will handle reactive and active power flows using pitch angle control and grid-side and rotor-side converters in high winds. The hybrid system will mimic wind speed and solar irradiance changes, demand interruptions, and grid faults including voltage dips and frequency oscillations. We optimised prices and did sensitivity analysis for various renewable energy source combinations using Homer. Researched the solar PV system, wind turbine, generator, battery system, and relevant converters using the manufacturer's data sheet specs. Control parameters are fine-tuned using Genetic Algorithms (GA) to increase system performance. This study develops a methodology for assessing and improving grid-integrated hybrid solar-wind system operational stability.

VIII. EXPECTED OUTCOME

Various distribution networks make up the existing electrical power system, which was constructed in a grid-connected fashion with centralised power generation as the main source to satisfy the required demand. Here, the main power plant is located at the farthest point from the service end, and power is sent there first. Scattered generation has changed the electrical transmission from a circumferential one to one in which the energy stream can be changed or entangled with the fusion reaction, which feeds energy in any direction from the point of connection. Blended wind and solar dispersed generation management has encountered some new obstacles brought forth by distributed generation. Thus, it is critical to design a controller that effectively controls the voltage and frequency fluctuations caused by the hybrid distributed generation system's connection to the utility grid, while simultaneously ensuring the system's robustness by avoiding such fluctuations. Effective implementation is thus within reach, allowing for the preservation of power quality, stability, and reliability.

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