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Enhancing Power Quality in Grid Connected Solar - Wind Hybrid Energy System

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ABSTRACT

The Hybrid Renewable Energy Resources (HRERs) will help to generate continuous power supply and energy feed into grid. The hybrid system includes PV array, permanent magnet synchronous generator (PMSG), DC-DC converter, voltage source converter (VSC), ripple filter, and a distribution network. The proposed hybrid system feeds the active power to the distribution system, provides an effective use of solar PV array and wind power. The hybridsystem with MPPT algorithm-based control scheme is used for obtaining the maximum power from the PV and wind scheme to control the switching pulses of the DC-DC buck and boost converter. In addition, it utilizes renewable energy to improve the dynamic response and reduces the burden on the proportional-integral (PI) controller by regulating DC bus voltage. The Renewable energy systems such as photovoltaic (PV) and wind energy systems are widely designed grid connected or autonomous. This is a problem especially in small powerful system due to the restriction on the inverter markets. Inverterswhich are utilized in these kinds of energy systems operate on grid or off grid. A novel power management strategy has been developed by designing a wind-PV hybrid system to operate both as an autonomous system and as a grid-connected system. The inverter used designed to operate both on-grid and off-grid. Due to the continuous demand for energy, gel batteries are used in the hybrid system. The designed Power Management Unit performs measurement from various points in the system and in accordance with this measurement; it provides an effective energy transfer to batteries, loads and grid.

KEYWORDS

Solar PV, Wind, Grid, Power Quality and Harmonics

I. INTRODUCTION

The use of renewable energy sources is rapidly increasing all over the world. The hybrid system includes various components, such as a DC-DC converter, voltage source converter (VSC), and a distribution network, all designed to optimize power output and maintain grid stability. To maximize efficiency, a Maximum Power Point Tracking (MPPT) algorithm is implemented to ensure that the PV array operates at its highest efficiency, while a wind control scheme regulates the switching pulses for the DC-DC converters.

Due to the large population densities in urban areas, world energy sources are consumed in these densely populated areas as expected. Due to the population density in urban areas has been rapidly increasing, It is estimated that by the year 2050, 70% of overall population is going to be living in urban areas and as a result of this, the energy consumption rate is expected to be increased 80% more. Therefore, promoting the usage of small wind-solar system in urban areas has a significant importance. The main problem associated with low power wind solar systems is to shorten amortization period. When this is achieved, then wind solar systems could be more popular in urban areas.

II. LITERATURE SURVEY

A dual-energy generation system for integrated grids proposed in [1]. An optimal grid system configuration is designed using net present cost and cost per unit of energy. Other factors such as the tilt angle of PV array optimization, wind energy, and inverter optimization have also been used for increasing the reliability and stability of the system. Sensitivity analysis has been performed to analyze the effective variations of the capital costs on the developed system economy. The results obtained from the simulations show that the overall costs of generating electricity from diesel systems and non-grid-based systems have been reduced to 20% at 10% annual capacity shortage allowance.

A grid - connected photovoltaic (PV) power system with high voltage gain is proposed, and the steady-state model analysis and the control strategy of the system are presented in [2-4]. For a typical PV array, the output voltage is relatively low, and a high voltage gain is obligatory to realize the grid-connected function. The proposed PV system employs a ZVT- interleaved boost converter with winding-coupled inductors and active-clamp circuits as the first power-processing stage, which can boost a low voltage of the PV array up to a high dc-bus voltage. Two compensation units are added to perform in the system control loops to achieve the low total harmonic distortion and fast dynamic response of the output current. Furthermore, a simple maximum-power-point-tracking method based on power balance is applied in the PV system to reduce the system complexity and cost with a high performance.

An overview of single-phase inverters developed for small distributed power generators discussed in [5-7]. The functions of inverters in distributed power generation (DG) systems include dc–ac conversion, output power quality assurance, various protection mechanisms, and system controls. Unique requirements for small distributed power generation systems include low cost, high efficiency and tolerance for an extremely wide range of input voltage variations. These requirements have driven the inverter development toward simpler topologies and structures, lower component counts, and tighter modular design. Both single-stage and multiple- stage inverters have been developed for power conversion in DG systems. Single-stage inverters offer simple structure and low cost, but sufferfrom a limited range of input voltage variations and are often characterized by compromised system performance. On the other hand, multiple- stage inverters accept a wide range of input voltage variations, but suffer from high cost, complicated structure and low efficiency. Various circuit topologies are presented, compared, and evaluated against the requirements of power decoupling and dual-grounding, the capabilities for grid-connected or/and stand-alone operations, and specific DG applications in their work.

Efficiency evaluation comparative for twomultileveltopologiesarebeinggenerallyused in grid connected transformer less applications.An analysis of power losses distribution in the semiconductors providing information to develop a good thermal design of the converter is included in efficiency evaluation [8-12]. Two of the most important characteristics in grid connected converters, such as the leakage currents which appear between the stray capacitances and the ground path and the efficiency are focused in proposed work. For the evaluation it is assume that the overall DC link is fixed to the desired voltage value and the capacitor voltages are balanced, the grid for which topologies are selected connected through an ideal L filter for active power injection to the grid. In presentation for both the cases, the proposed modulation strategy is based in the Simulation level Shifted the overall DC link is fixed to the desired voltage value and the capacitor voltages are balanced.

A soft-switched, isolated bi-directional dc/dc converter developed at Oak Ridge National Laboratory for FCPEV applications. The converter employs dual half-bridges interconnected with an isolation transformer to minimize the number of switching devices and their associated gate drive requirements. Snubber capacitors including the parasitic capacitance of the switching devices and the transformer leakage inductance are utilized to achieve zero-voltage switching (ZVS). Therefore, no extra resonant components are required for ZVS, further reducing component count. The inherent soft – switching capability and the low component count of the converter allows high power density, efficient power conversion, and compact packaging. A prototype rated at 1.6 kW was built and successfully tested. Experimental results confirmed soft-switching operation and an average model-based analysis [13-16].

III. PROPOSED SYSTEM

3.1. EXISTING SYSTEM

The increased penetration of distributed generation (DG) units on the electrical grid systems, the renewable energy sources (RESs) including photovoltaic (PV) systems and wind energy systems have been widely used in the distributed power systems in the past decades. The DG units play an important role in reducing pollution, decreasing power transmission losses and improving local utilization of RESs, which becomes a strong support for the large-scalepower grid. However, DG units may also bring challenges to the distribution network such as inverse power flow, voltage deviations andvoltage fluctuations. When a number of DG units are clustered together, they can form a micro grid (MG) that solves the problems caused by high penetration of DG units' success fully and makes the large-scale application of DG systems possible. The main drawbacks are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low.

3.2. PROPOSED SYSTEM

The Enhancing Power Quality in Grid-Connected Solar-Wind Hybrid Energy System focuses on integrating solar and wind energy sources efficiently while addressing power quality issues. This hybrid system utilizes Maximum PowerPoint Tracking (MPPT) to optimize energy generation from both sources and ensuresseamless integration with the grid. To enhance power quality, advanced techniques such as voltage and frequency regulation, harmonic reduction, and reactive power compensation are implemented using a Unified Power Quality Conditioner (UPQC). The Energy Storage System (ESS), such as batteries or super capacitors, is integrated to smooth power fluctuations and improve grid stability. Smart grid synchronization is achieved using a Phase-Locked Loop (PLL), ensuring efficient power transfer without voltage sags or swells.

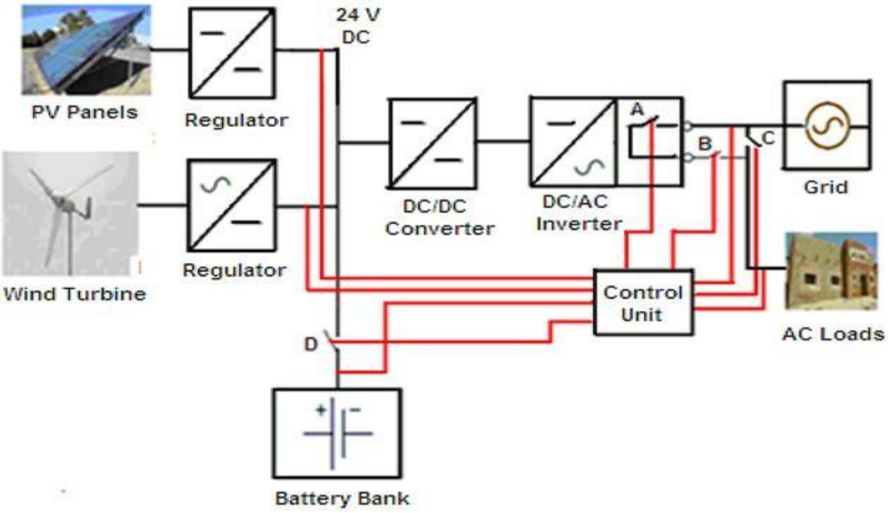

Figure 1. Proposed Block Diagram

The grid-connected solar-wind hybrid energy system not only improves power quality but also enhances the reliability and efficiency of renewable energy integration into the grid. By incorporating real-time monitoring and intelligent control strategies, the system can dynamically adjust power flow, ensuring stability even under varying load conditions. The use of Flexible AC Transmission Systems (FACTS) devices further aids in reducing transmission losses andimproving overall grid performance.

Additionally, fault detection and self-healing mechanisms can be integrated to enhance the resilience of the system against grid disturbances. The combination of advanced control algorithms, energy storage, and smart grid technology ensures minimal power interruptions and better voltage regulation. With growing energy demands and the push for sustainable solutions, the implementation of this hybrid system can significantly contribute to reducing carbon emissions and promoting a cleaner, more efficient power network.

The use of renewable energy sources is rapidly increasing all over the world. New investments in renewable energy have reached 260 billion dollars world. Even though the world economic crisis has been affecting the world economy since 2008, significant investments in renewable energy have continued. When new investments are evaluated on a sartorial basis, it is seen that investments in the field of wind and solar systems have been in the forefront. Today, more than half of the world population has been living in urban areas. Due to the large population densities in urban areas, world energy sources are consumed in these densely populated areas as expected. By thereason of 60–80% of world energy has been consumed in urban areas, 75% of CO_2 emission occurs through these areas. Due to the population densityinurbanareashasbeenrapidlyincreasing, It is estimated that by the year 2050, 70% of overall population is going to be living in urban areas and as a result of this, the energy consumption rate is expected to be increased 80% more. Therefore, promoting the usage of small wind-solar system in urban areas has a significant importance. The main problem associated with low power wind solar systems is to shorten amortization period. When this is achieved, then wind solar systems could be more popular in urban areas.

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IV. RESULT AND DISCUSSION

4.1 SIMULATION RESULT

The voltage and current challenges, solar energy can be integrated into the grid more efficiently, ensuring a reliable and sustainable energy supply.

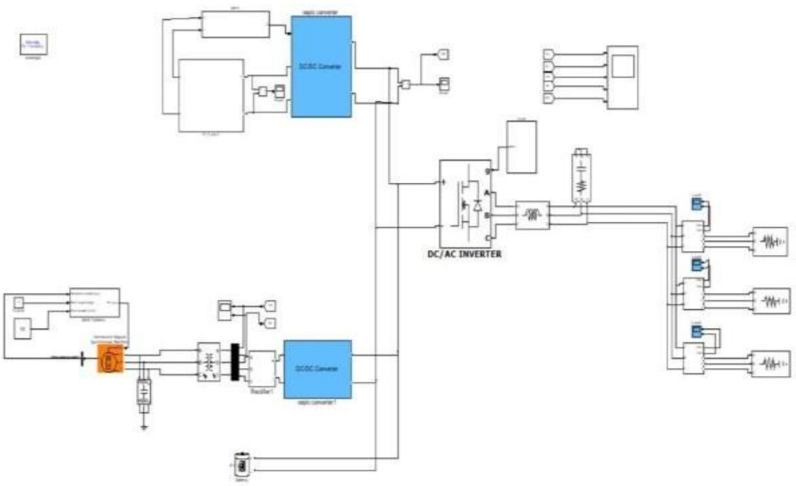

Figure 2. Simulation Diagram

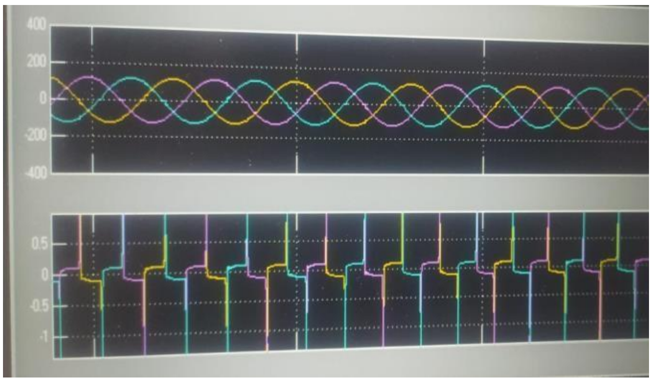

Figure 3: Voltage and Current for Wind

By understanding and addressing voltage and current challenges, wind energy can be integrated into the grid more efficiently, ensuring a reliable and sustainable energy supply.

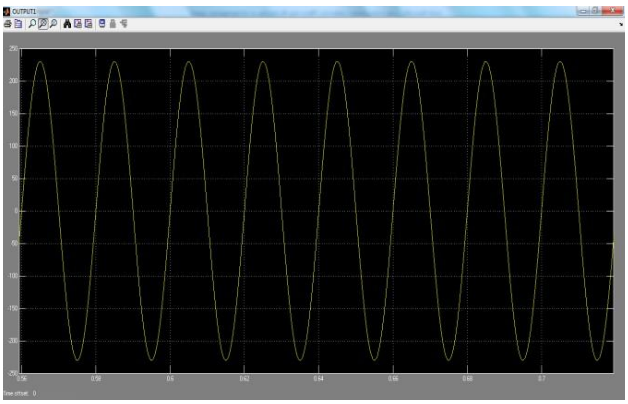

Figure 4: AC output Voltage

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In wind and solar energy systems, the AC output voltage is typically produced by Inverters (in solar systems), Generators (in wind turbines), Power electronic converters (in wind and solar systems). These devices convert the DC power generatedbytherenewableenergysourceintoAC power that can be fed into the grid or used by electrical loads**.**

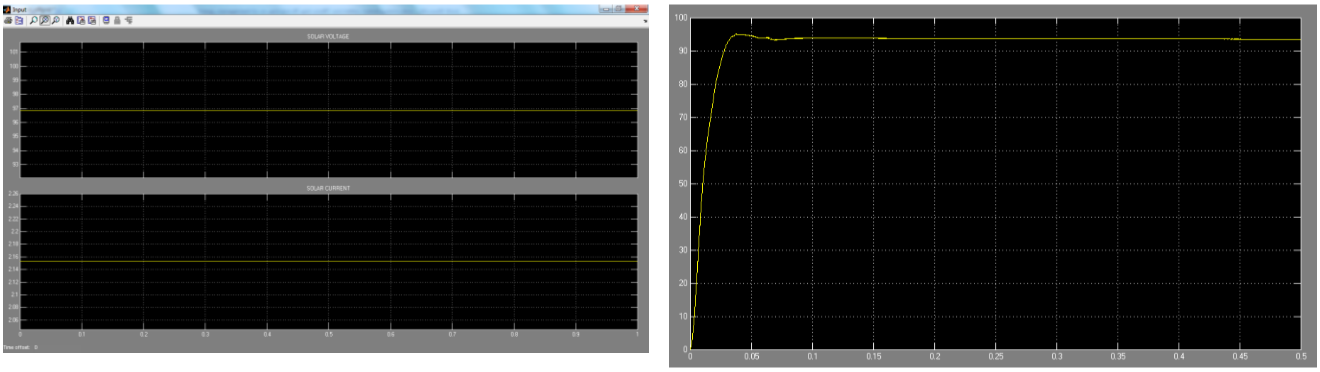

Figure 5. Voltage and Current for Solar

4.2 HARDWARE RESULT

The successful operation of a 230-watt bulb without any issues demonstrated the system's stability and reliability. Throughout the testing phase, there was no lag, no high voltage or low voltage fluctuations, and no damage to any device. The system effectively managed voltage regulation, ensuring a steady and stable power supply. Advanced power electronics, including MPPT controllers, inverters, and STATCOM, played a crucial role in maintaining proper synchronization with the grid while minimizing harmonic distortions.

Figure 6. Hybrid Energy System

The power quality enhancement techniques ensured that the system operated efficiently, delivering clean and stable electricity to the load without any disturbances. These results confirm that the hybrid energy system is well-designed for safe and reliable operation, making it a sustainable and effective solution for renewable energy integration into the grid.

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V. CONCLUSION

The effectiveness of advanced power electronic converters and control strategies in enhancing power quality in grid-connected solar- wind hybrid energy systems. The proposed system effectively mitigated voltage fluctuations, harmonic distortion, and frequency deviations, ensuring a stable and reliable power supply. The results showed that the hybrid system with optimized power electronic converters and control algorithmsachieved. Voltage regulation are improved (±2% deviation), Reduced total harmonic distortion (THD<3%), Enhanced frequency stability (±0.5 Hz deviation), Increased power factor (>0.95) and Reduced grid support requirements.

These improvements enable a higher penetration of renewable energy sources in the grid, reducing green house gas emissions and promoting energy future the grid- connected solar-wind hybrid energy system, the successful operation of a 230-watt bulb demonstrated the system's capability to provide stable and reliable power. The solar panels and wind turbine efficiently generated electricity, which was regulated and converted through MPPT controllers, rectifiers, and inverters. Throughout the testing phase, there was no lag, no high voltage or low voltage fluctuations, and no damage to any device. These results confirm that the hybrid energy system is well-designed for safe and reliable operation, making it effective solution for renewable energy integration into the grid.

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