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THE OPTIMIZATION OF GRID INTEGRATION OF RENEWABLE ENERGY SOURCES TO ENHANCE POWER QUALITY

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Abstract:
The integration of renewable energy sources like photovoltaic (PV) solar panels and wind turbines (WT) into the smart grid is highly beneficial due to the inherent advantages of these resources. Solar and wind energy are not only environmentally friendly and sustainable but also widely available and cost-effective. By leveraging the capabilities of the smart grid, which includes advanced communication, control, and automation technologies, the efficiency and reliability of renewable energy systems can be significantly enhanced. This integration supports the transition to a cleaner energy landscape, reduces dependence on fossil fuels, and helps mitigate the impacts of climate change by lowering greenhouse gas emissions. The hybrid system approach, combining both solar and wind energy, further improves energy stability and availability, compensating for the intermittent nature of these renewable sources. This comparative study aims to evaluate the efficiency and effectiveness of these MPPT methods in optimizing the power output from the hybrid renewable energy system. Particle Swarm Optimization (PSO) is known for its robustness and fast convergence, potentially offering superior performance in tracking the maximum power point under varying environmental conditions. On the other hand, the P&O method is simpler and more widely used, but it may not perform as well in rapidly changing conditions. By implementing and simulating these techniques in MATLAB/SIMULINK, the study provides insights into their practical applications and performance metrics, guiding the development of more efficient renewable energy systems.

Key Words - Hybrid system, Photovoltaic system, Wind Power Energy System

I. INTRODUCTION

In other words, energy plays a crucial role in human development and significantly impacts global prosperity. It underpins economic growth, enhances human welfare, and improves the quality of life for nations. However, reliance on conventional energy sources, such as fossil fuels, presents substantial drawbacks. These sources pose serious threats to both current and future ecological balance and safety at local and global levels. Consequently, transitioning to sustainable and renewable energy sources is essential to mitigate these adverse effects, ensuring long-term environmental health and energy security.The depletion of the world's main energy resources is imminent. In an energy-hungry world, renewable energy sources present a superior alternative due to their clean, non-polluting, and eco-friendly nature. These continuous energy forms are abundantly available from natural sources like sunlight, wind, rain, waves, geothermal heat, and tides.Energy produced from natural sources is carbon-free, less polluting, and can effectively replace energy generated from coal and other fossil fuels. This preservation of fossil fuel resources benefits future generations.

II. NEED FOR ELECTRICAL ENERGY

The demand for electrical energy is rapidly increasing. The overuse of conventional sources like coal, petroleum, and oil has led to their drastic depletion and significant environmental impacts, including greenhouse gas emissions that disrupt the ecosystem. Consequently, non-conventional energy sources are crucial for meeting global energy demands. Renewable energy sources, such as solar, wind, hydro, and biomass, are clean, eco-friendly, reliable, and abundantly available in nature.

III. RENEWABLE ENERGY IN INDIA

India is a major player in the global energy market, being the 4^{th} largest electricity consumer and the 3^{rd} largest renewable energy producer. In 2022, 40% of India's energy capacity came from renewable sources, totaling 160 GW out of 400 GW. Ernst & Young's 2021 Renewable Energy Country Attractiveness Index ranked India 3^{rd}, behind the USA and China. For FY2023-24, India plans to issue 50 GW of tenders for wind, solar, and hybrid projects. The country aims for a renewable energy capacity of 500 GW by 2030. Reflecting this commitment, India's installed renewable energy capacity has increased from 94.4 GW in 2021 to 119.1 GW in 2023.

IV. GRID INTEGRATION WITH RENEWABLE ENERGY SOURCES

Grid-connected hybrid wind-solar generation systems are a trending research area today. Wind energy is the most cost-effective form of renewable energy, and photovoltaic (PV) systems offer additional advantages over other renewable sources. Combining solar and wind power creates a highly efficient and reliable method of power generation. This paper primarily focuses on the integration and Maximum Power Point Tracking (MPPT) control technique. The main goal is to maximize power extraction and maintain satisfactory power quality from both varying wind conditions and differing solar irradiation levels on the photovoltaic array. A Particle Swarm Optimization (PSO) based MPPT is employed for the hybrid system to capture maximum power, enhancing the system's stability and efficiency. The proposed model and its control techniques are validated using the MATLAB/SIMULINK environment.The hybrid system utilizing solar and wind energy is suitable for power generation in both rural and urban areas.

V. SYSTEM ILLUSTRATION AND MODELING

Section V of the paper likely discusses the illustration and modeling of the hybrid system, detailing its components, configuration, and how it operates. This section is crucial for understanding the system's design and functionality.In this section, the paper presents a simulation model of the proposed smart grid integrated with a hybrid system. The model includes components such as a wind turbine, photovoltaic array, boost converter with an isolated transformer, asynchronous generator, and double-bridge rectifier. A PSO-based MPPT algorithm is implemented to optimize power generation from both the wind and solar systems. The schematic diagram of the proposed hybrid system is depicted in Figure

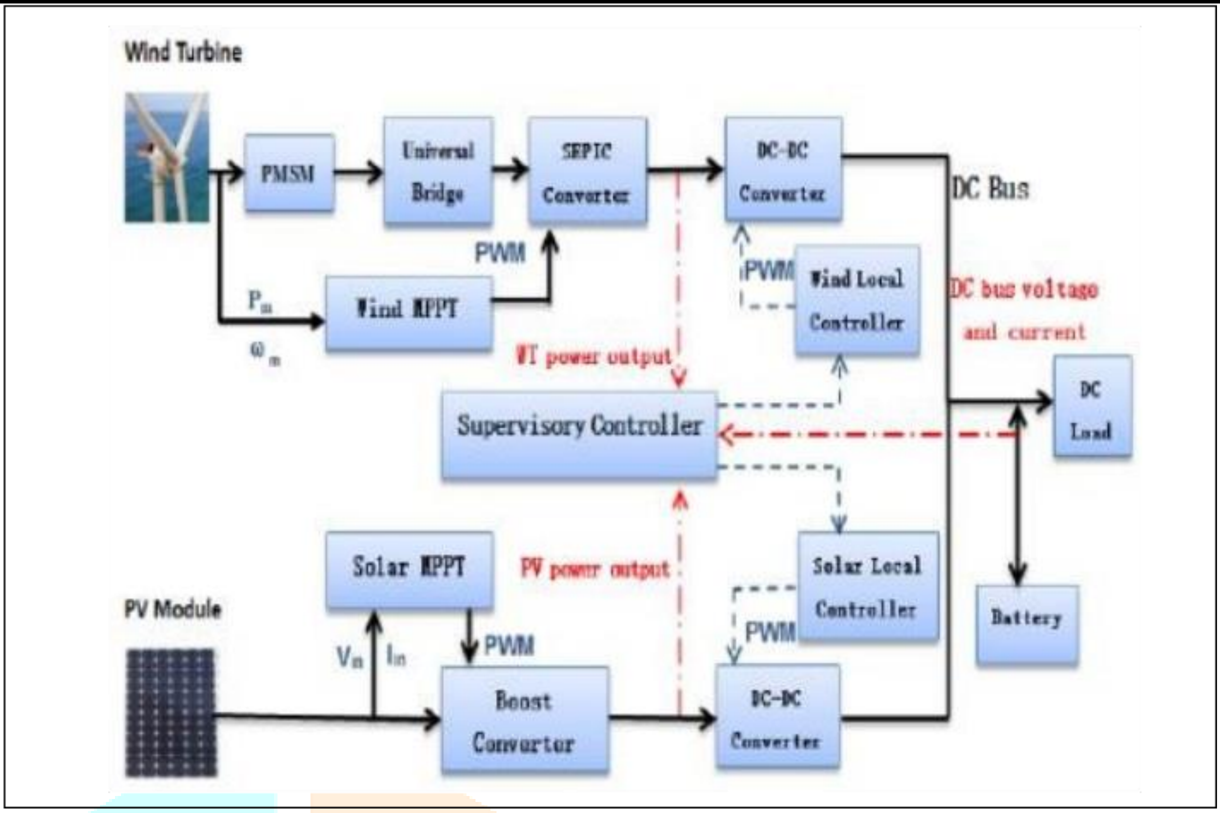


Fig- 1Complete diagram of system

Components of the System

The overall system is composed of some basic elements

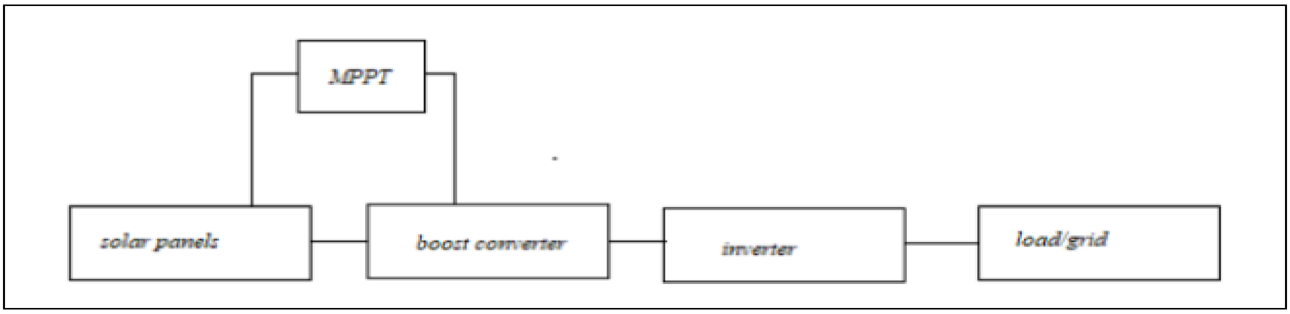
- PV Module
- Boost Converter
- Maximum Power Point Tracking System
- DC-DC Converter
- Battery
- Buck Converter
- Inverter
- Wind Turbine Modeling
- Wind Turbine Generator
- Rectifire

MAJOR PARTS OF SYSTEM

PV SYSTEM

Solar panels serve as the conduit for converting energy into either heat or electricity. These panels are crafted using semiconductor materials, primarily silicon. When sunlight strikes the surface of these cells, it is absorbed. Fundamentally, solar cells operate akin to diodes, with a PN junction formed within the material. As sunlight interacts with the material’s surface, energy absorption occurs, enabling electrons to move freely. Indeed, the flow of electrons generated by the movement results in the production of electric current. This process is based on the principle known as the photoelectric effect. Solar panels are constructed by assembling photovoltaic (PV) cells. These PV cells are interconnected to form PV modules, and subsequently, these modules are further linked together to create the desired PV panels or arrays.

PV cells typically come in configurations of 36 or 96 cells per module. Depending on the load requirements, these cells are connected in either series or parallel combinations. Similarly, the modules are also interconnected in series or parallel configurations. When aiming for higher output voltage, PV cells are arranged in series, while for increased output current, they are arranged in parallel. Initially, in a solar panel, the cells are connected in series to achieve the desired voltage, and these strings are then connected in parallel to achieve the desired current.

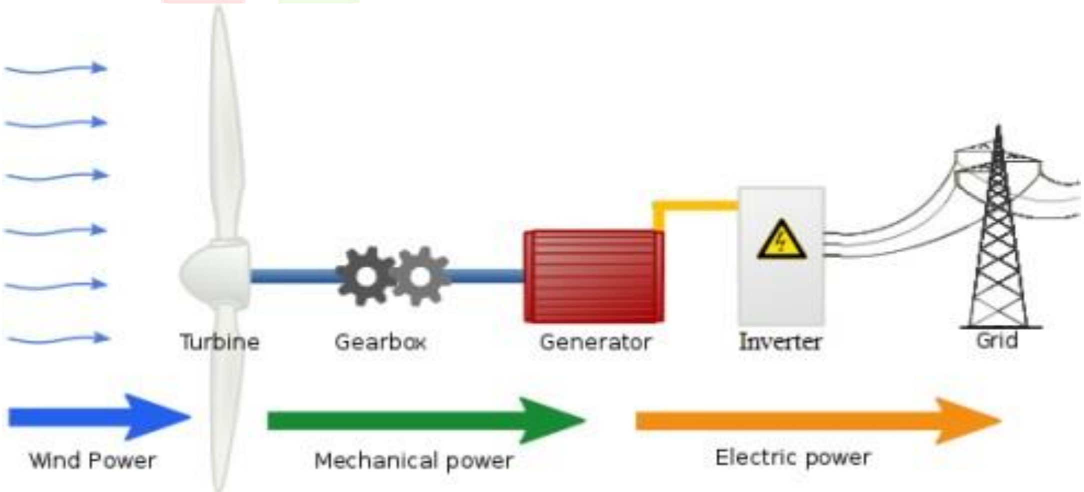


Block Diagram of PV Solar System

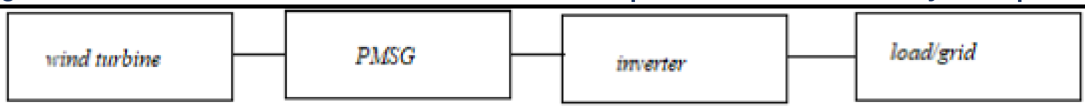
WIND ENERGY SYSTEM

Wind energy stands out as one of the most promising renewable energy sources to address the world's increasing energy needs. It's environmentally friendly and offers a clean energy solution. Wind, simply put, is the motion of air. Wind turbines harness the kinetic energy from the wind and convert it into mechanical energy. The mechanical energy extracted from wind turbines is then transformed into electrical energy through generators. Various types of generators are utilized for wind energy generation, with the most common being the permanent magnet synchronous generator (PMSG) and induction generators (IG).

Permanent magnet synchronous generators (PMSGs) utilize permanent magnets to establish the excitation field, rather than relying on excitation coils. This configuration is widely favored for commercial electricity generation purposes. Indeed, these generators are referred to as synchronous generators because the speed of the rotor always synchronizes with the frequency of the electrical supply. In high-power applications, permanent magnet synchronous generators (PMSGs) are often preferred due to their low cost and maintenance requirements. They also eliminate the need for a separate DC power supply for excitation, resulting in higher efficiency.



Wind Energy System



Block Diagram of Wind Enerrgy Sysytem

HYBRID ENERGY SYSTEM

Solar energy is primarily available during the daytime, while wind energy is accessible both day and night. Interestingly, wind intensity tends to be higher at night. This complementary nature ensures that either solar or wind power supply is available throughout the day and night, providing continuous energy generation. Indeed, solar energy is more abundant and beneficial during the summer months, while wind energy proves advantageous during winter due to windier conditions. Consequently, integrating renewable energy sources offers enhanced performance and reliability compared to standalone systems throughout various cycles of the power generation system.

Hybrid energy systems strive to integrate solar and wind energy with grid connections and advanced control techniques to maximize power generation. One significant advantage of coupling these power generation units to the grid is that in case of shutdowns in solar or wind production, the grid can serve as a backup source, ensuring continuous energy supply.In simpler terms, hybrid power generation combines renewable energy sources like solar and wind to address fluctuations in energy production, resulting in more stable and efficient output. This approach helps store excess energy in the grid to meet demand when needed.

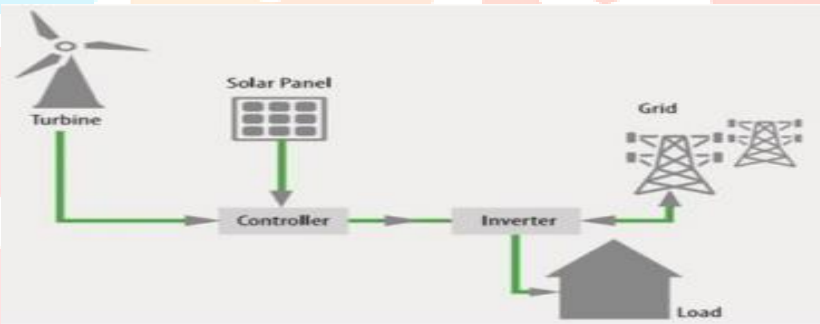
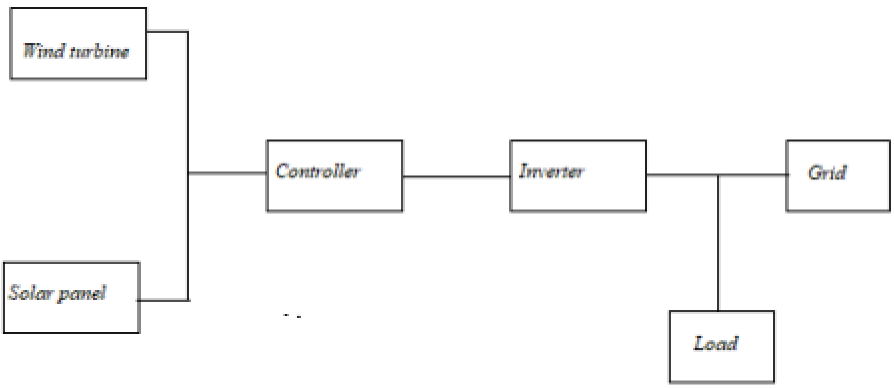
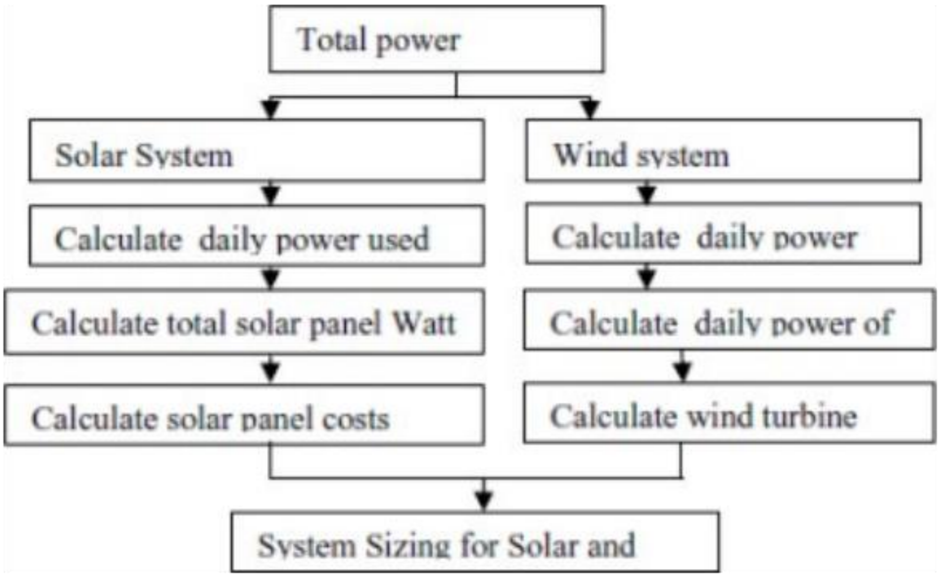


Fig 7.1 Schematic Diagram of Hybrid Solar-Wind Energy

Hybrid Energy System



Block Diagram of Hybrid Energy system



ADVANTAGES

1. Improved Power Quality:

   - Voltage Stability: Integration of RES can help stabilize voltage levels, reducing fluctuations and improving overall power quality.

   - Frequency Regulation: Advanced control systems and energy storage can help maintain a stable frequency, essential for power quality.

2. Reduced Greenhouse Gas Emissions**:

   - Cleaner Energy: By integrating more RES, the reliance on fossil fuels is reduced, leading to lower carbon emissions and a smaller carbon footprint.

3. Energy Security:

   - Diversification of Energy Sources : Utilizing a mix of renewable sources (solar, wind, hydro, etc.) can reduce dependency on a single energy source and improve energy security.

4. Cost Savings:

   - Reduced Operational Costs: Over time, the operational costs of RES are lower than traditional power plants, as they do not require fuel.

   - Lower Maintenance Costs: Renewable energy systems often have lower maintenance costs compared to conventional power plants.

DISADVANTAGES

1. Intermittency and Variability:
   a. Unpredictable Output: Renewable sources like solar and wind are intermittent and can vary, which can challenge grid stability and power quality.
2. High Initial Investment :
   a. Capital Costs: The initial setup costs for renewable energy infrastructure, including generation and grid integration, are high.
3. Grid Infrastructure Challenges:
   a. Upgrades Needed: Existing grid infrastructure may require significant upgrades to accommodate RES, including advanced metering, control systems, and storage solutions.
   b. Complex Integration: The technical complexity of integrating diverse RES into the grid can pose challenges.
4. Energy Storage Requirements:
   a. Need for Storage: To manage the intermittency of RES, significant investments in energy storage systems (such as batteries) are required, which can be costly and technologically demanding.

VI. RESULT & CONCLUSION

Project aims to focus on the study of a hybrid PV-Wind power generation system for a grid connected application using the Matlab/Simulink software. Estimation of the solar irradiance and wind speed data in the parts of Akluj was done as a reference to prove the feasibility and with the availability of energy it is possible to propose and develop a model. Annually Akluj is well exposed to sun's radiation which is approximately 7 hours of sunshine a day.

In smart grid applications, a PSO based MPPT wind-PV hybrid system is proposed. The output from
the solar system is depends on solar irradiation this leads to discontinuity of supply to the load takes place. To overcome this problem the wind turbine system will come into operation to satisfy the load. The PSO based MPPT technique is implemented for tracking the maximum power point of photovoltaic and wind system. The simulation results of the PSO based MPPT algorithm is compared with P&O based MPPT technique. The nature of the presented model is inspected thoroughly under the set of conditions to operate the system. The entire proposed model with controlling techniques have been implemented in MATLAB/SIMULINK environment.

VII. REFERENCES

1. ”IEEE Std 1547-2018: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces”. This standard provides guidelines for the integration of distributed energy resources, including renewable energy systems, into the grid.

2. International Energy Agency (IEA) Reports: The IEA publishes reports on renewable energy integration, which often include discussions on optimizing power quality. An example is the “Renewables 2020: Analysis and forecast to 2025” report.

3. ”Grid integration of large-capacity Renewable Energy sources and use of large-capacity Electrical Energy Storage” by Xiao Lu et al., published in the IEEE Transactions on Industrial Electronics. This paper discusses the challenges and strategies for integrating large-scale renewable energy sources into the grid and the role of energy storage in enhancing power quality.

4. ”A review of power quality problems and solutions in electrical power system ” by S. Kumar and S. V. Singh, published in the International Journal of Engineering Science Invention. This article reviews various power quality issues and their solutions, including those related to renewable energy integration.

5. Optimization of Renewable Energy Integration into the Smart Grid” by various authors, presented at the IEEE Power & Energy Society General Meeting. These proceedings often include case studies and methodologies for optimizing renewable energy integration.