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Hybrid Power Generation: Wind and Solar Energy Collaboration: Review

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Abstract: ***The challenge of providing electricity to non-electrified rural areas, while discouraging the extension of traditional electrical grids due to impracticality and environmental concerns, has led to the development of a forward-looking solution: a Solar-Wind Hybrid Power Plant. This innovative system combines solar panels and wind turbines to harness complementary energy sources, ensuring a reliable and uninterrupted power supply. Solar panels capture sunlight during the day, while wind turbines operate continuously, even at night, utilizing wind energy. This integration significantly reduces dependence on fossil fuels, mitigates greenhouse gas emissions, and promotes sustainability. The system's adaptability to various geographical locations and environmental conditions makes it a versatile and scalable solution suitable for both urban and remote areas. In addition to addressing rural energy needs, it contributes significantly to environmental conservation and sustainable development.***

Keywords: Renewable energy, Solar-wind integration, Hybrid system, Energy efficiency, Hybrid power plant

I. INTRODUCTION

The escalating global concerns over climate change and diminishing fossil fuel reserves have amplified the search for sustainable energy solutions. Wind and photovoltaic (PV) systems are vital for meeting the increasing energy needs. However, both face intermittent challenges due to environmental fluctuations.

Utilizing maximum power point tracking (MPPT) algorithms has been suggested to enhance their efficiency and reliability through integration. Current research on hybrid wind/PV power systems involves separate DC/DC boost converters for each energy source operating in parallel during rectification.

A developing approach combines renewable energy sources at the DC-end while upholding MPPT for each source by merging the buck and buck-boost converter, aiming for superior performance.

Current systems address high-frequency current harmonics in wind turbine generators using passive input filters. These harmonics jeopardize the generator's longevity and escalate power loss due to heating.

The proposed multi-input rectifier structure for hybrid wind/solar energy systems aims to overcome these technical challenges. It introduces an innovative method to manage harmonics, striving to surpass the limitations of traditional systems by mitigating high-frequency current harmonics without compromising system efficiency and durability.

II. LITERATURE SURVEY

1) "A Hybrid Model of Vertical Axis Wind Turbine-Solar Power Generation for Highway and Domestic Application" is a Research by *Avinash Bavchakar, P. Ketan N. Chougale, Saloni S. Belanekar, Sushant P. Rane, Nitin B. Sawant* of SSPM'sCoE, Kankavli, Maharashtra, India proposed that the shift to renewables due to declining conventional energy sources. It suggests a hybrid system combining wind and solar energy, meant for highway dividers. This system capitalizes on vehicle motion for wind energy and utilizes solar energy. Both energies charge batteries for highway and home use. By merging wind and solar energy, it powers highways and homes.
2) "Hybrid Power Generation System Using Wind Energy and Solar Energy" by *Ashish S. Ingole, Prof. Bhushan S. Rakhonde* of electrical engineering department, DES's COET, Dhamangaon (RLY) proposed that the shift to renewables due to declining conventional energy sources. It suggests a hybrid system combining wind and solar energy, meant for highway dividers. This system capitalizes on vehicle motion for wind energy and utilizes solar energy. Both energies charge batteries for highway and home use. By merging wind and solar energy, it powers highways and homes.

3) "Hybrid Power Generation System Using Wind Energy and Solar Energy" by *Anil Tekale, Vaibhav Ware, Vishal Devkar, Ganesh Dungahu* of Department of Electrical Engineering, Parikrama Group of Institutions, Kashti, Maharashtra, India proposed that the Renewable energy sources are regarded as the next-generation solution for meeting increasing energy demands and combating the depletion of fossil fuels. Solar, biomass, geothermal, hydroelectric, and wind energy offer significant power generation capabilities. Wind energy can be harnessed through vertical axis turbines (VAWT) or horizontal axis turbines. VAWT's, unlike horizontal turbines, can extract power from wind regardless of its direction, ensuring consistent energy generation. Solar photovoltaic (PV) cells, on the other hand, convert solar radiation into electrical power, making them operational only during daylight hours.

The combined use of these renewable sources in a hybrid system offers potential benefits. This paper aims to explore "Hybrid Power Generation using Solar Cells and Vertical Axis Wind Turbines with Solar Tracking." Leveraging solar tracking and VAWT's, this study emphasizes the advantages of utilizing VAWT's in conjunction with solar energy. VAWT's, particularly of the Savonius type, demonstrate higher torque and lower cut-in speeds, exhibiting improved self-starting capabilities and greater efficiency at lower wind speeds. The focus is on the hybrid power generation by integrating VAWT technology with solar tracking, offering an innovative approach for sustainable energy production.

III. COMPONENTS

This "Hybrid Power Generation: Wind and Solar Energy Collaboration" contains various components for the proper working and better performance are as follows:

1) Solar Panel
2) Dc Motor
3) Step Up Gearbox
4) Solar Charge Controller
5) Battery
6) Inverter

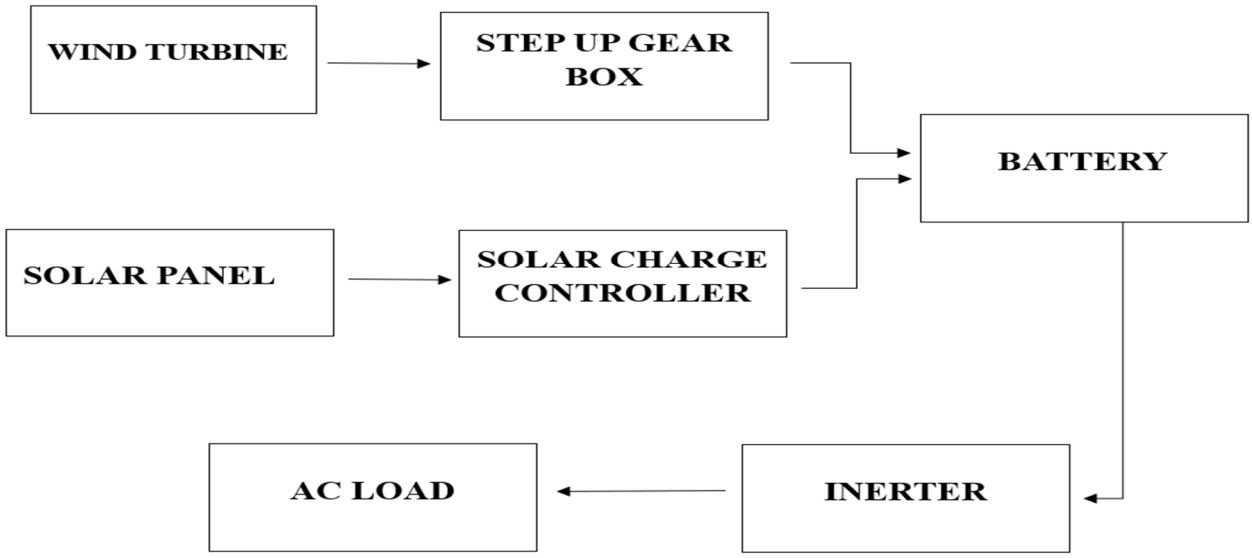

Fig 1: - Block Diagram Representation of Hybrid Power Working

IV. WORKING

Solar-Wind Hybrid Systems for Electrical Power Generation: A Technical Overview

The exponential growth in technology has significantly increased the demand for electric power, necessitating innovative techniques for power generation. This surge in demand has also fuelled interest in renewable energy sources to mitigate pollution and preserve non-renewable resources like coal and petroleum. Among the renewable options, solar and wind energy are prominent, and their hybrid combination offers an effective solution for power generation.

Solar-wind hybrid systems integrate solar panels and small wind turbine generators to produce electricity. While typically of smaller capacities ranging from 1 kW to 10 kW, these systems play a crucial role in decentralized power generation. Understanding the individual workings of solar and wind energy systems provides insight into the dynamics of these hybrid systems.

1) *Solar Energy System:* Solar energy systems utilize solar panels for power generation. These systems convert solar energy into electrical power using photovoltaic cells. The solar panel output is measured in watts or kilowatts, varying in design and capacity, ranging from 5 watts to higher ratings. However, their output is influenced by factors such as climate, sunlight intensity, and orientation to the sun. Properly maintained, solar panels typically have a lifespan of 25 years and require efficient placement, often facing east at a 45-degree angle for optimal performance.
2) *Wind Energy System:* Wind turbine generators harness wind power to produce electricity. These systems consist of blades that rotate when exposed to wind, driving a generator to produce electrical power. Wind energy systems are known for their variability and require consistent wind flow for efficient operation.
3) *Solar-Wind Hybrid System:* The solar-wind hybrid system integrates solar panels and wind turbines to generate electricity. This combination offers advantages such as a more consistent power supply by utilizing both solar and wind resources. Such systems commonly include a configuration with solar panels, wind turbines, and a battery for storing excess energy, providing reliability in power supply.

Understanding the individual components and dynamics of solar and wind energy systems helps in comprehending the working principles of a solar-wind hybrid system. These hybrid systems provide a reliable and sustainable solution for electricity generation, contributing to a greener and more diversified energy landscape.

By optimizing the use of renewable sources, solar-wind hybrid systems pave the way for a more sustainable and efficient future in power generation, mitigating environmental impact while meeting the increasing demand for electric power.

From the graph shown below, the wind power generation is high compared to other renewable sources but by combining it with the solar energy system the output can be maximize.

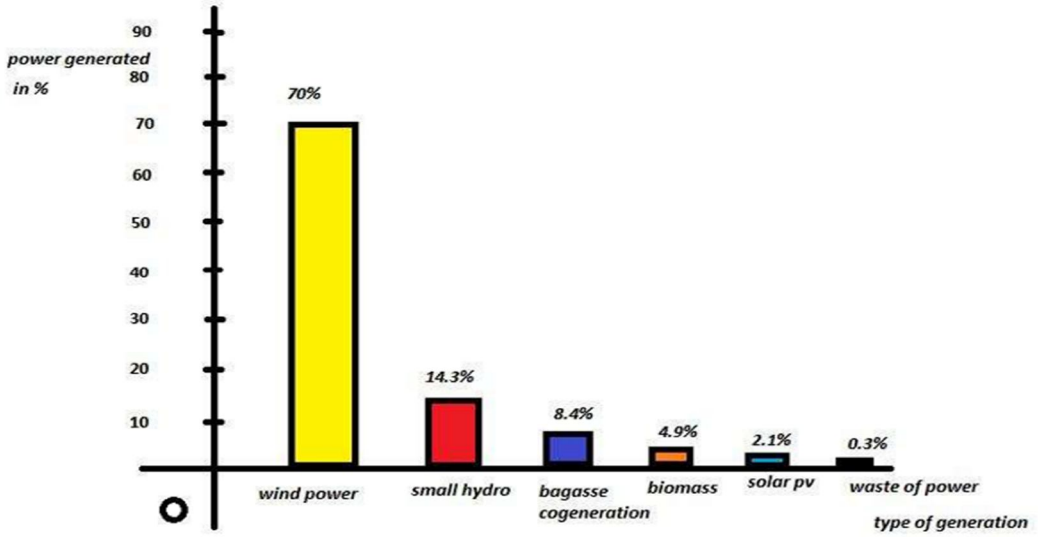

Fig 2: - Graphical re-presentation of renewable energy power generation in %

V. CONCLUSION

Reaching non-electrified rural areas through grid extension isn't economically viable or encouraged by major stakeholders. Conventional solutions like fuel genset-based systems are diminishing due to rising oil prices and their adverse impacts on users and the environment. To drive rural development sustainably, infrastructure investments need cost-effective, reliable tools.

Renewable energy sources stand out as the most feasible option for supplying electricity to remote or off-grid areas. They contribute significantly to economic, environmental, and social goals by ensuring energy security, reducing greenhouse gases, and creating local employment, thus improving overall living conditions.

Hybrid systems emerge as the optimal choice to provide high-quality energy services to rural areas at minimal cost, offering maximum social and environmental benefits. Opting for renewable energy allows developing countries to stabilize CO2 emissions even with increased consumption due to economic growth.

VI. FUTURE SCOPE

The concept of hybrid power generation has a vast scope for future development. Some of the area that can explore further are: -

1) Enhanced Reliability: By combining solar and wind power, these systems can operate more consistently, as wind and sunlight availability often complement each other. When one source might be less available, the other could be more abundant, ensuring a more stable energy supply.

2) Increased Energy Production: By harnessing both solar and wind energy, hybrid plants can generate more electricity compared to single-source systems. This versatility allows for a more continuous and potentially increased power output.

3) Better Land Utilization: Combining solar panels and wind turbines in the same area optimizes land use, especially in regions where space is limited. This integrated approach maximizes energy generation from a single location.

4) Cost-Effectiveness: Advances in technology and economies of scale are making these hybrid systems more cost-effective. They benefit from shared infrastructure and operational costs, making them potentially more affordable in the long term.

5) Environmental Benefits: Utilizing renewable energy sources reduces greenhouse gas emissions and reliance on fossil fuels, contributing to a more sustainable and eco-friendly energy solution.

6) Technological Advancements: Ongoing technological innovations and research in the field of renewable energy are likely to improve the efficiency and effectiveness of hybrid power plants, making them even more viable in the future.

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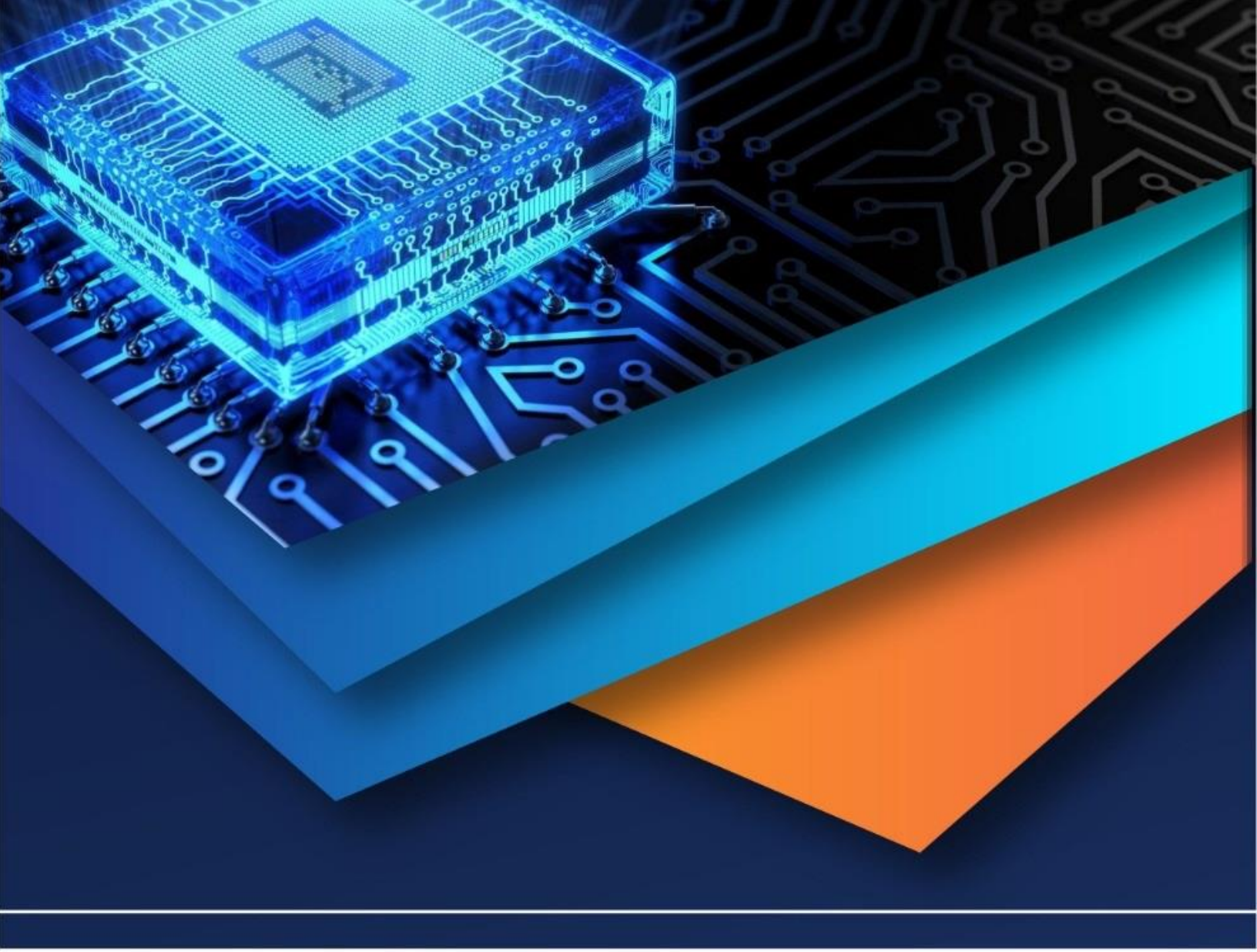

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