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A Steady Power Flow in Grid Connected Hybrid PV/WIND/BESS/FC Systems using PSO-LPF-PI Controller

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***Abstract*—This paper presents a novel converter-less control approach for a grid-connected hybrid system integrating solar photovoltaic (PV), wind, and fuel cell technologies with battery energy storage. Traditional hybrid systems typically rely on multiple power electronic converters to manage the power flow between various sources and the grid, increasing complexity and cost. The proposed method eliminates the need for these converters by leveraging advanced control algorithms that directly interface with the grid. This approach simplifies the system architecture, enhances reliability, and reduces maintenance requirements. The control strategy ensures optimal power distribution from PV, wind, and fuel cell sources, while the battery energy storage system (BESS) provides ancillary services such as frequency regulation and load balancing. Simulation and experimental results demonstrate the effectiveness of the proposed system in maintaining grid stability, improving energy efficiency, and reducing operational costs. This converter-less method represents a significant advancement in the field of renewable energy integration, offering a more streamlined and cost-effective solution for sustainable power generation**

***Index Terms*— Maximum Power Point Tracking, Electrolyzer, Fuel Cells, Energy Management Systems, And Battery Energy Storage Systems, Pso.**

I. INTRODUCTION

The global shift towards sustainable energy solutions has intensified the focus on hybrid renewable energy systems that integrate multiple sources such as solar photovoltaic (PV), wind, and fuel-cell technologies, complemented by battery energy storage. These systems are essential for providing reliable and continuous power while minimizing environmental impact. Traditionally, hybrid energy systems rely heavily on power electronic converters to manage and integrate these diverse energy sources, ensuring stable and efficient grid connectivity. However, the use of multiple converters introduces significant drawbacks including increased system complexity, higher costs, and potential inefficiencies. In response to these challenges, this study proposes a groundbreaking converter-less control approach for a grid-connected hybrid energy system comprising solar PV, wind, and fuel-cell sources, combined with battery energy storage. This innovative approach aims to streamline the system architecture by eliminating conventional power converters thereby reducing costs and enhancing overall system efficiency and reliability.

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II. LITERATURE REVIEW

Using MLMS adaptive control, the proposed wind-solar AC microgrid has been established and put into practice to demonstrate its improved PQ performance for local nonlinear load. It has been observed that the weight component and system performance with MLMS have less oscillations. [1] The projected PV-OUPQC has been developed and put into practice. Eliminating current quality issues and enhancing power quality in the presence of varied voltage quality concerns have been the primary objectives.[2].Three-phase PVUPQC's design and dynamic performance have been investigated in the context of intermittent illumination and sags and swells in grid voltage[3]-[5],[6].This paper presents a battery integrated isolated three-port converter with a wide range of applications in SPV power systems. The suggested converter makes use of a modified PSFB structure that has the capabilities listed below. Battery energy storage, a DC load, and an SPV source are all integrated within the converter. The battery port and SPV source are electrically isolated from the load port.For a large load variation, the converter's semiconductor switches are all operated under ZVS or ZCS conditions.[7]

III.Proposed hybrid grid connected system

The proposed hybrid grid-connected system integrates solar photovoltaic (PV), wind, and fuel-cell technologies with battery energy storage to create an efficient and reliable power generation solution. Unlike traditional systems that depend on multiple power electronic converters.

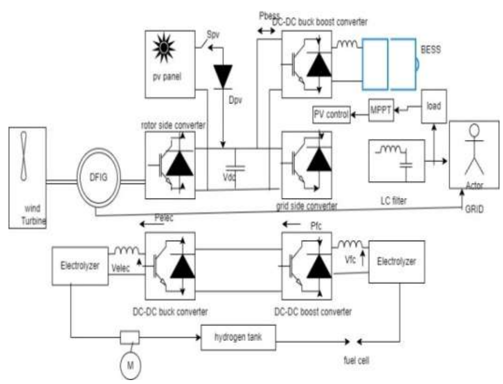

Figure 1. Structure of proposed grid connected hybrid system

A. Photovoltaic Systems

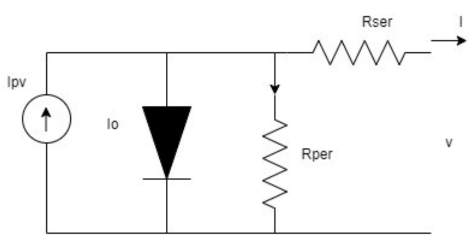

Figure 2. Equivalent circuit of single solar cell

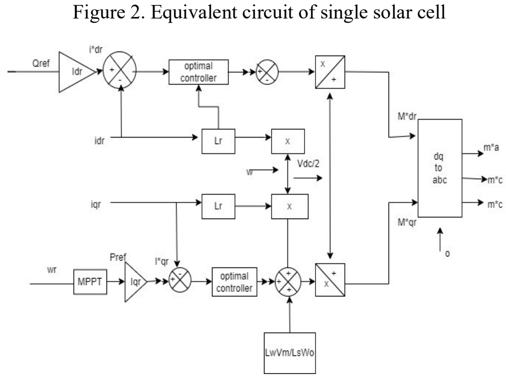

Figure 3. Control Scheme of RSC

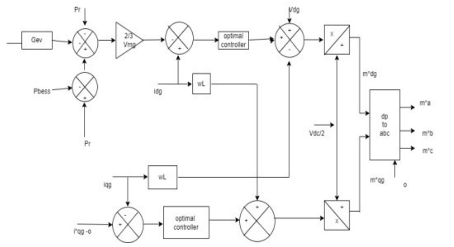

Figure 4. Control scheme of GSC

B. Fuel Cell

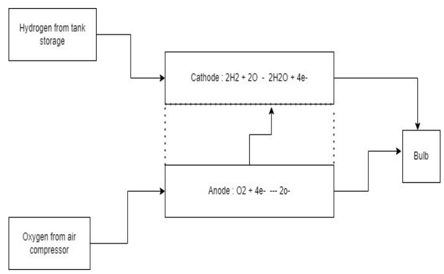

Figure 5. Schematic diagram of the Fuel Cell (SOFC type).

C. Developing an Electrolyzer Model

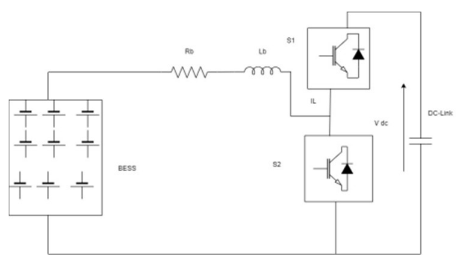

Figure 6. Schematic diagram of DC-DC converter associated with BESS

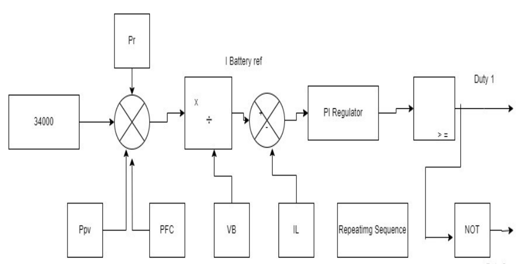

Figure 7. Schematic diagram of control associated with BESS

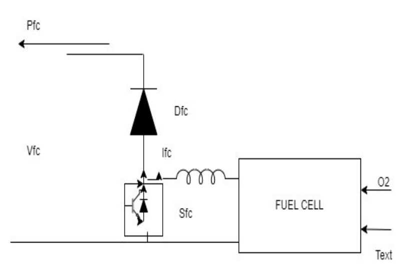

Figure 8. Schematic diagram of DC-DC converter controller incorporated with FC

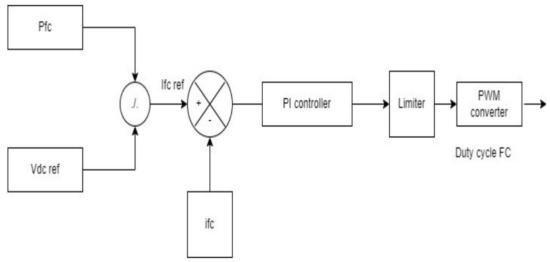

Figure 9. Schematic diagram of control associated with FC.

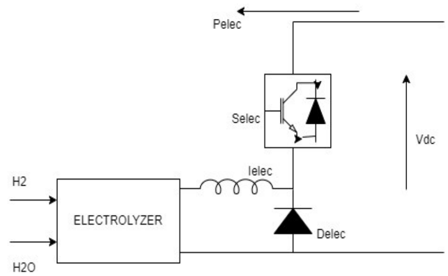

Figure 10. Schematic diagram of Electrolyzer with buck converter

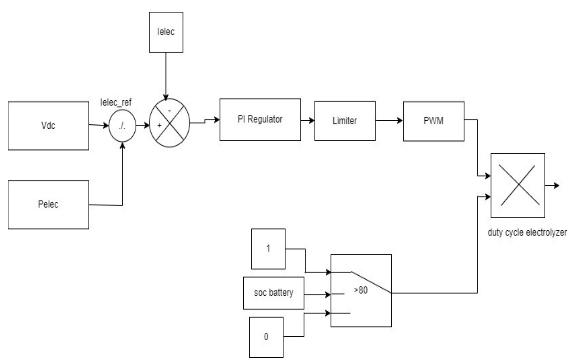

Figure 11. Schematic diagram of Electrolyzer control

IV. SIMULATION AND RESULTS

The FC and Electrolyzer are added to the WTG-DFIG, PV, and BESS systems in this study, which shows how they are integrated into a hybrid grid system. The hybrid grid-connected system has been implemented, and the recommended system's electricity is controlled using MATLAB's Simulink environment. A simulation of the system was conducted with different loads and environmental factors. This demonstrates how the hybrid system affects the efficiency and quality of the energy that is needed or injected.

Figure 13. PV Power Output w.r.t to Time (Mw)

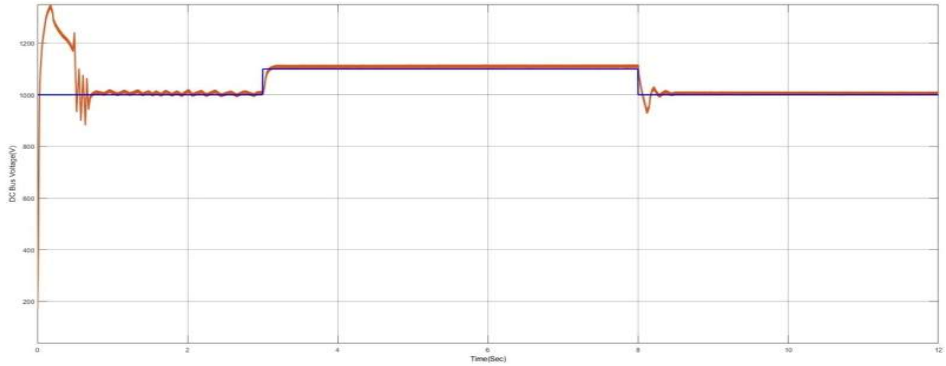

Figure 14. Dc Bus Voltage w.r.t to Time (V).

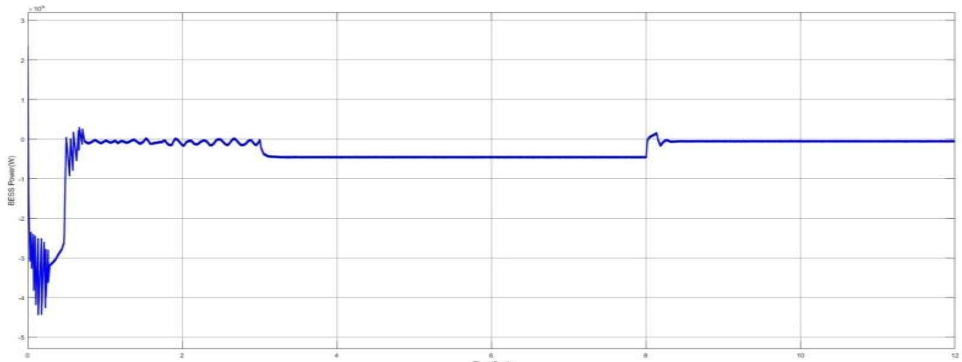

Figure 15. Bess Discharging Power w.r.t to Time (Kw).

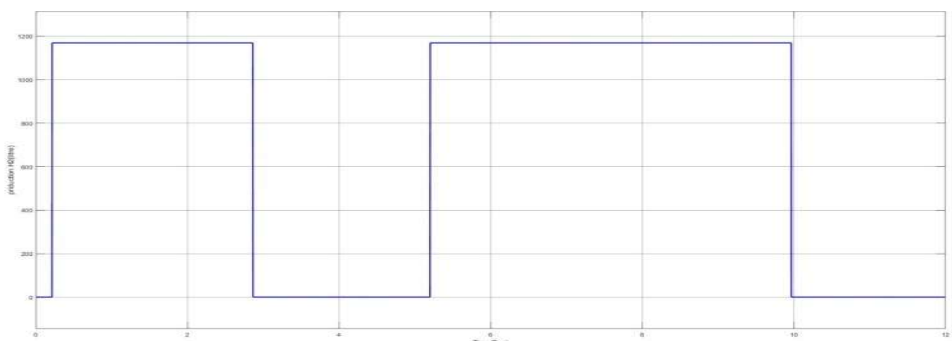

Figure 16.H_2 Production w.r.t To Time (Litre).

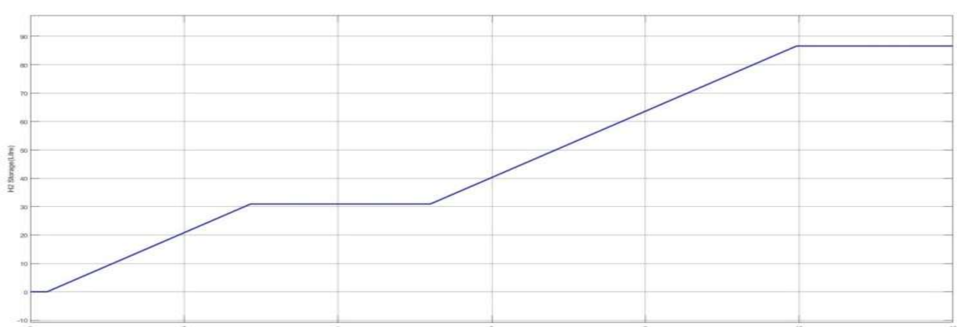

Figure 17.H2 Storage w.r.t To Time (Litre).

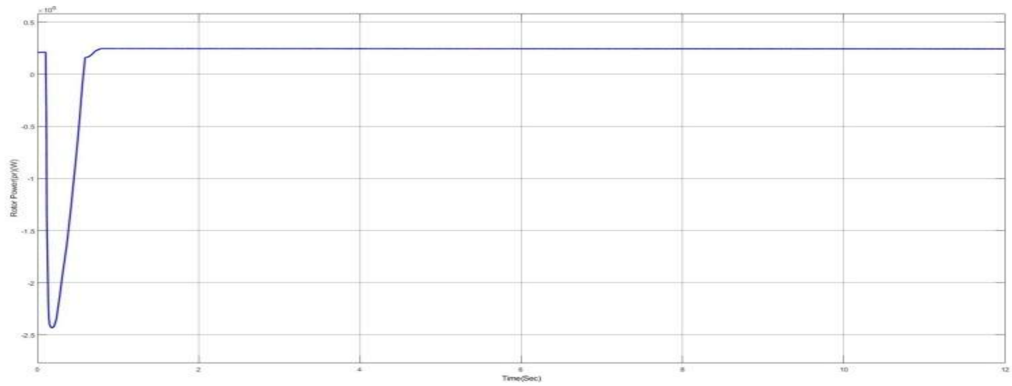

Figure 18. Rotor (Pr) power (W) w.r.t To Time

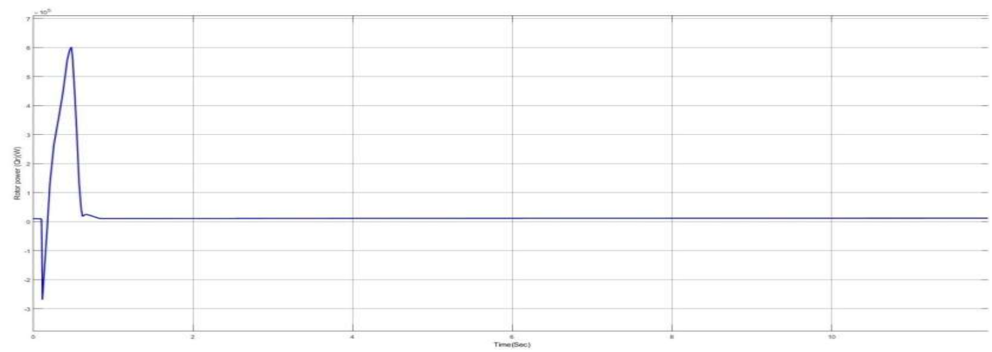

Figure 19. Rotor (Qr power (W) w.r.t To Time

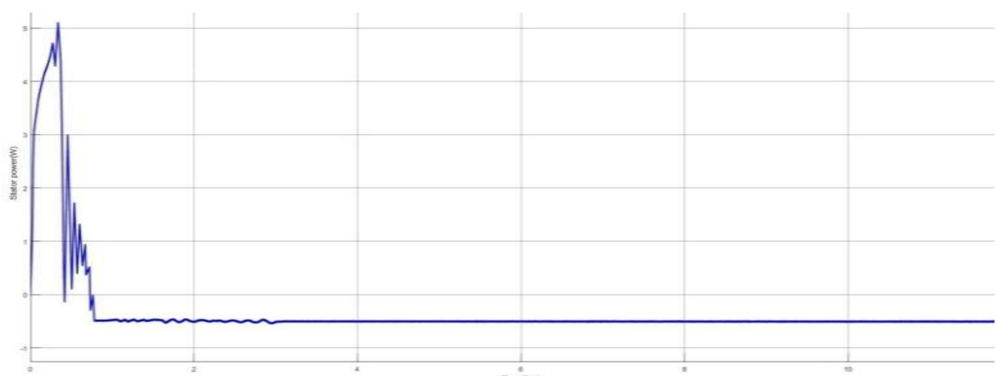

Figure 20. Stator (Ps) power (W) w.r.t To Time

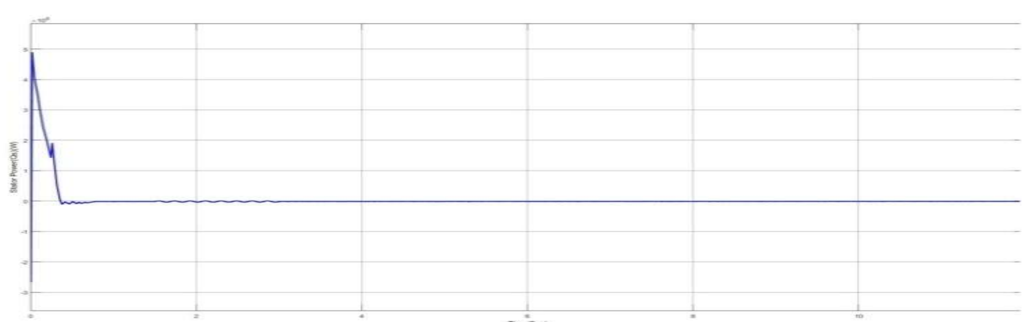

Figure 21. Stator (Qs) power (W) w.r.t To Time

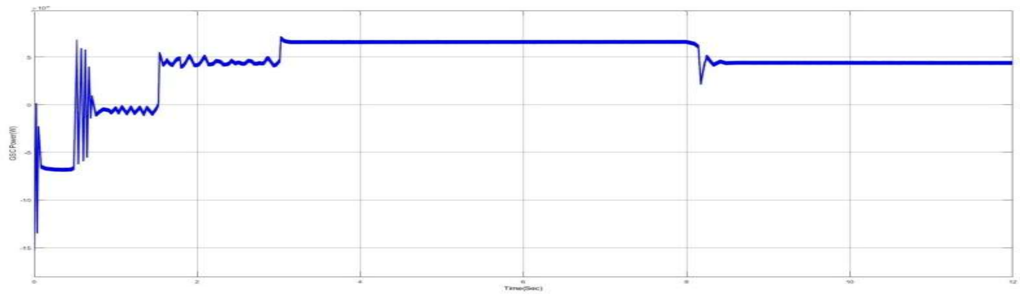

Figure 22. PGSC power (W) w.r.t To Time

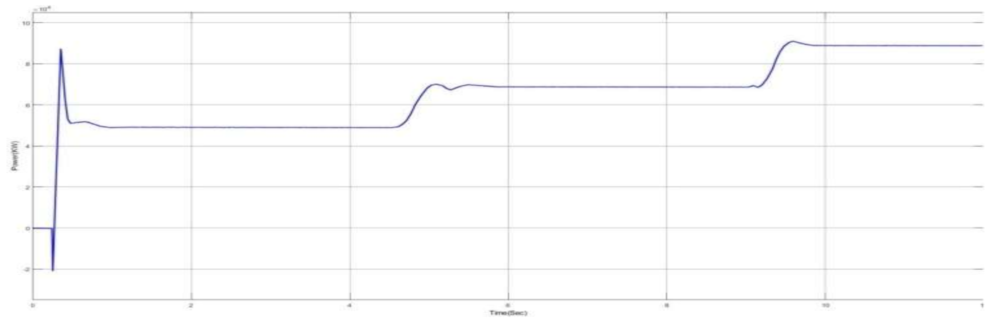

Figure 27. Comparative analysis of proposed hybrid and conventional power system

VI. CONCLUSION

The novel converter-less solar PV control approach for a grid-connected hybrid PV/Wind/Fuel-Cell system combined with battery energy storage significantly enhances the efficiency, cost-effectiveness, and reliability of renewable energy systems. By eliminating the need for conventional converters, the system reduces energy losses, lowers initial and maintenance costs, and simplifies the overall design, leading to fewer points of failure. This innovative approach allows for seamless integration of multiple renewable energy sources, providing flexible and stable power management. It is highly scalable and adaptable making it suitable for various applications and contributing to environmental sustainability by supporting cleaner energy sources. Overall, this converter-less approach represents a major advancement in hybrid renewable energy systems, addressing critical challenges and paving the way for more efficient and reliable energy solutions.,

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