8th International
HYDROGEN
TECHNOLOGIES Congress
12-15 May 2024
Dicle University, Diyarbakır, Türkiye

Energy Management in Microgrids with Hybrid Energy Storage Systems Utilizing Batteries and Proton Exchange Membrane/Fuel Cells

[1]Ömer Faruk Özcan*, [2]Heybet Kılıç, [3]Ömerül Faruk Özgüven

[1]Dicle University, Department of Electric Power and Energy System, Sur,Diyarbakır, 21280, Turkey
[1]Dicle University, Department of Electric Power and Energy System, Sur, Diyarbakır, 21280, Turkey
[3]İnönü University, Engineering Faculty, Electric and Electrical, Battalgazi, Malatya, 44280, Turkey

*E-mail: omerfaruk.ozcan@dicle.edu.tr

I. Introduction

The increasing reliance on renewable energy sources is driving the growth of microgrids, which are designed to facilitate a harmonious interaction between conventional and renewable energy sourcesby Qays (2023). Microgrids consist of distributed generation units, energy storage systems (ESS), and loads that operate either in harmony with the external grid or in self-sufficient island mode. However, the integration of renewable energy sources into microgrids faces technical obstacles due to their intermittent nature, which can cause stability issues such as voltage or frequency fluctuations The battery energy storage system (BESS) is considered the pinnacle of efficiency due to its rapid response characteristics. However, relying solely on BESS for stabilization could lead to operational failures due to capacity limitations. To ensure a harmonious and resilient microgrid ecosystem, innovative control strategies must be developed to facilitate coordinated efforts and effectively distribute load-following responsibilities by Konstantinou (2023).

Recent literature has divided supervisory control and energy management system architectures into two primary groups: model-based control and model-free or soft computing-based control strategies. Model-based control techniques have been proposed to optimize the performance of microgrids, such as regulating voltage on DC and AC busbars, ensuring frequency stabilization in maritime microgrids, and implementing intelligent distributed load-on-load designs by Vandoom (2011).

On the other hand, model-free or soft computing-based control strategies focus on adaptive and intelligent control systems by he (2012). Researchers have proposed smart control methods based on ANFIS and particle swarm optimization, ANFIS-based PID, fuzzy SVPWM-based filters, fuzzy logic-based adaptive droop controllers, hierarchical power management structures, and innovative fuzzy logic controllers for managing power passage between various energy sources.

II. Modeling of Microgrid

Figure 1 illustrates the configuration of a grid-connected hybrid microgrid system with the proposed GWO-TSK-based energy management system.

- Grid-connected hybrid micro-grid system that combines solar PV, wind turbine-based PMSG, a dual-input DC-DC converter, battery energy storage system, hydrogen system, DC load, AC load, and additional components.
- The hybrid renewable energy system's primary energy sources are two- blade wind turbines and photovoltaic (PV) panels (HRES)
- Through the DC bus, power converters are connected to both energy sources using the Maximum Power Point Tracking (MPPT) technique.

The hybrid renewable energy system's primary energy sources are two- blade wind turbines and photovoltaic (PV) panels (HRES).Power converters utilize MPPT control and unidirectional DC/DC converters to extract maximum power from both sources. However, converting the three-phase voltage generated by the wind turbine requires an AC/DC converter (rectifier).

- One system integrates a Proton Exchange Membrane (PEM) fuel cell, hydrogen tanks, and an electrolyzer.

The hydrogen system enhances the stability of HRES and balances energy production with demand. However, it exhibits a slow dynamic response to rapid load fluctuations, necessitating a storage device with fast dynamic response, such as a lead-acid battery.

III. Conclusion

The hybrid system provides three control techniques (strategies I, II, and III) that are responsible for effectively managing energy resources. Under its three-control technique, photovoltaic panels produce electricity when solar radiation is present. PV's DC/DC power converters are controlled by MPPT control in order to optimize the utilization of renewable power sources.

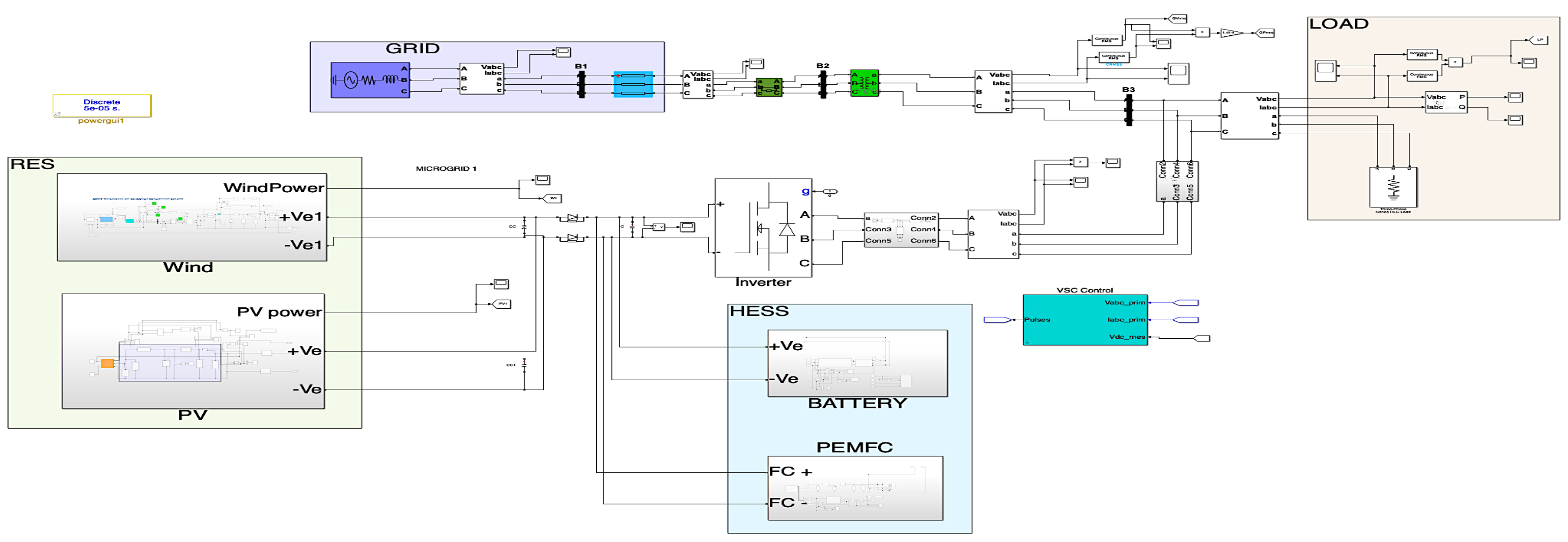

Figure 1. The Configuration of a Grid-connected Hybrid Microgrid System

The controller calculates the power allocation of the battery, the energy output of the fuel cell, and the power consumption of the electrolyzer for hydrogen production, based on the current operating mode. Once the power of each power source is identified, an appropriate control is implemented on the DC/DC converter of each energy source to achieve the desired power.

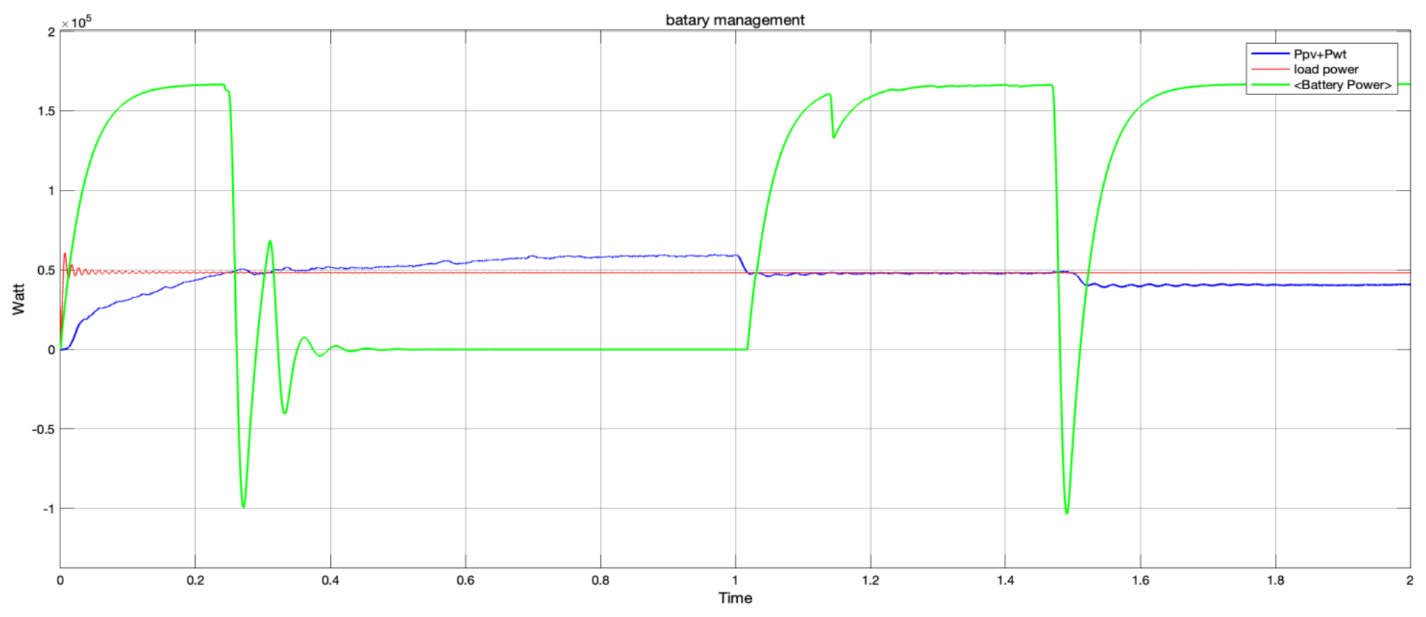

Figure 2. Simulation Results of Energy Management

Simulation result illustrates in figure 2, this strategy uses a battery or fuel cell to provide power to meet the load if P < 0, with an additional power source determined based on the battery State of Charge (SOC) and hydrogen tank level. If the SOC of the battery is greater than 40% and the hydrogen tank level is less than 20%, the battery system provides the necessary power. If the SOC of the fuel cell is less than 40% and the hydrogen tank level is less than 20%, the fuel cell provides the necessary power to meet the total load demand. If the output power of the FC is higher than the power deficit, the excess power is utilized by the battery.If P > 0, the battery operates at maximum power, and the remaining power is used to charge the battery. If the battery's SOC is less than 40% and the hydrogen tank level is greater than 20%, it is used to replace the current power battery.

References

Qays, M.O., Ahmad, I., Habibi, D., Aziz, A., & Mahmoud, T. (2023). System strength shortfall challenges for renewable energy-based power systems: A review. Renewable and Sustainable Energy Reviews.

Konstantinou, T., & Hatziargyriou, N.D. (2023). Day-Ahead Parametric Probabilistic Forecasting of Wind and Solar Power Generation Using Bounded Probability Distributions and Hybrid Neural Networks. IEEE Transactions on Sustainable Energy, 14, 2109-2120.

He, J. and Li, Y. (2012). An enhanced microgrid load demand sharing strategy. IEEE Transactions on Power Electronics, 27(9), 3984-3995.

Vandoorn, T., Meersman, B., Degroote, L., Renders, B., & Vandevelde, L. (2011). A control strategy for islanded microgrids with dc-link voltage control. Ieee Transactions on Power Delivery, 26(2), 703-713. https://doi.org/10.1109/tpwrd.2010.2095044