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Performance Analysis of a Hybrid Renewable Energy Microgrid through Simulation-Based Evaluation and PLC-Controlled Load Management

As South Africa grapples with ongoing energy shortages and rising demand, hybrid renewable energy microgrids have emerged as an effective and scalable approach for supplying power to off-grid and rural communities. This study, which explores the performance of a hybrid microgrid that integrates photovoltaic (PV) panels, fuel cells, and battery storage systems, plays a crucial role in providing valuable insights for implementing sustainable electrification solutions. The focus is on intelligent load management through Programmable Logic Controllers (PLC). A comprehensive system model was developed using MATLAB/Simulink, incorporating actual Masia Community Development Centre load data. Additionally, HOMER software was utilized for system sizing and optimization, tailored to local resource availability and load requirements. Adopting PLC-based load control strategies significantly improved the system's operational efficiency, responsiveness, and reliability in fluctuating demand conditions. The results underscore the essential role of automation and advanced control techniques in enhancing the effectiveness of hybrid renewable energy systems, providing valuable insights for implementing sustainable electrification solutions in underserved and remote regions throughout South Africa.

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Primary author: RAMALATA, Avhatakali**Co-authors:** TINARWO, David (University of Venda); MULAUDZI, SOPHIE (University of Venda)**Presenter:** RAMALATA, Avhatakali**Session Classification:** Poster Session**Track Classification:** Track F - Applied Physics