International Academic Institute for Science and Technology

International Academic Journal of Science and Engineering
Vol. 9, No. 3, 2022, pp. 26-30.

ISSN 2454-3896

International Academic Journal of Science and Engineering

www.iaiest.com

Combined Energy Storage and Management Systems for Smart Grid oriented Renewable Energy Optimization

Sunita Lohia [a], Shantanu Dasgupta [b]

[a] *Sunita Lohia, Conversational Interfaces Lab, Surat School of Digital Communication, India.*
[b] *Shantanu Dasgupta, Conversational Interfaces Lab, Surat School of Digital Communication, India.*

Abstract

This study presents an enhanced energy management system (EMS) to minimize energy costs and optimize storage in hybrid solar and wind energy microgrids, incorporating battery storage and grid connectivity. The enhancement of efficiency depends on a parameter known as a contribution factor, which allocates a sufficient quantity of the necessary power from the battery according to the energy price of the primary grid. Various profiles are examined to improve system efficiency. A load shift technique has been incorporated into energy management to optimize energy costs. The system utilizes the efficiency of the components to calculate the energy expenditure precisely. Calculations have been conducted at various load demand rates, demonstrating the advantages of the suggested energy control system over the standard model in reducing energy price, degrading battery costs, and enhancing battery lifespan. The findings indicate that employing a linear profile for the impact of components and transferring load yields daily expenses of $67.3 for fuel and $0.75 for deterioration. These figures indicate a 24.2% reduction in energy expenses and a 90.4% reduction in battery life cost relative to the traditional energy administration system, which does not account for power from the grid or a change in the utilization of battery storage.

Keywords: Energy Storage, Energy Management, Smart Grid, Renewable Energy.

DOI: 10.71086/IAJSE/V9I3/IAJSE0925
Received: 17 June 2022/Revised: 21 July 2022/Accepted: 26 August 2022/Published: 30 September 2022

Introduction

Microgrids, incorporating renewable energy, are crucial in modernizing the electrical system and transitioning from pollutive energy sources (Hirsch et al., 2018). The microgrid can function in grid-connected and islanded styles, enabling a seamless transition between these operational states due to its energy storage capacity. A microgrid is a controllable entity utilizing power electronics conversion devices that can be configured with predictive and scheduling models to adapt to diverse demands in localized areas swiftly, enhancing power supply dependability, reducing distribution expenses, and ensuring continuous power availability (Shahbazi & Khorsandi, 2017). In most mid and small-scale microgrids, energy is generated by sporadic and stochastic sources, including solar photovoltaic (PV) and wind energy (Jones & Olsson, 2017). The load demands and the grid rates fluctuate throughout the day and periods. The various limits and uncertainties render a microgrid a complex system that must be managed as an integrated unit to satisfy demand and attain cost efficiency through connections with the primary grid.

An energy storage-capable microgrid can deliver predictable electrical power and load dependability (Malhotra et al., 2016). In a microgrid, electricity supply from distributed electricity producers and the load demand exhibit significant volatility; the implementation of energy preservation, capable of interfacing with the central electrical system, facilitates power equilibrium between subsequent generations and demand, leading to precise regulation of power transfer across various time scales. Multiple algorithms are being suggested for the operation of microgrids, featuring distinct topologies aimed at optimizing storage utilization and energy expenses (Gomes et al., 2021). An uncomplicated energy administration system was implemented to control the storage of batteries in freestanding wind energy microgrids, taking into account solely the battery's charge level and presuming that the storage supply or absorbs any quantity of power, which is not always feasible.

A comparable Energy Management System (EMS) for a hybrid solar-wind standalone microgrid utilizing identical battery storage estimates was employed (Lee & Cheng, 2016). The particle swarm optimization algorithm was used to maximize the goal functions for the energy administration of a solar power plant with battery storage, considering the energy cost to the primary electrical grid. A suggested EMS employs three tariff levels (minimal, medium-sized, and higher) for the electrical grid and a fixed parameter to measure the loss of electricity. The strategy was employed to maximize the energy expenses for a grid-connected photovoltaic microgrid supplying a constant load. Energy administration was implemented in a bright domestic apartment complex to maximize immediate needs for solar power and current energy prices. This optimization technique employed various choice variables, including energy cost, load, battery life, and bought authority, alongside the Stackelberg game model to identify the ideal solution.

Despite the approach's demonstrated superiority over alternative solution techniques, its execution is intricate due to the necessity of optimizing various cost variables. Photovoltaic systems, energy storage, electric vehicles, and residential loads were simulated for application in the energy control for an apartment complex. Model prediction was employed for efficiency without addressing its execution (Hasan et al., 2017). A comparable system was examined utilizing mixed-integer linear programs to identify the optimization issue. Lyapunov optimization reduced homeowners' storage, power source, and grid system costs. An algorithm, grounded in the concept of queuing, was devised to regulate manageable loads to reduce the operational costs of renewable-powered systems. An optimum day-ahead equipment plan was designed for controlled and uncontrolled workloads in an organized household utilizing hourly pricing. All components of models and restrictions were incorporated into the optimization; its execution lacked specificity (Antonio, 2021). In all the previously stated efforts, the execution of the optimization approaches necessitates a computational burden due to the iterative nature of the search process. The coordination of stored energy and weights was examined using multi-stage improvements to reduce the energy usage of a building's demand.

Proposed Energy Storage and Management Systems

Harmony searching is a robust metaheuristic technique with exceptional exploitation capabilities; it is significantly constrained by the tendency to become ensnared in local optima, known as early convergence, mainly when the initially chosen harmonies are near the local optimal. Hybrid chaos searching (CS)/harmony searching (HS)/simulated annealing (SA) engine is presented to eliminate the constraints of a singular metaheuristic method, enhancing exploration, especially at the onset of execution, to evade local optima.

Thus, to mitigate computational issues such as early convergence, entrapment in local optima, a surplus of control variables, and increased reactivity to the initial value of variables, it is essential to maintain the primary control variables of the method and the diversity of novel approaches throughout the evolutionary process. Integrating simulated heating, harmony searches, and chaotic search methods can enhance solution effectiveness and mitigate computing limitations.

The strategy enhances species diversity to improve the likelihood of achieving an optimal solution. The settings utilized in the SA and CS methods and the criteria for accepting or rejecting solutions render them significantly resistant to entrapment in local optima, diminishing their susceptibility to premature convergence issues.

SA, HS, and CS are integrated to deliver an enhanced optimization tool, resulting in the hybrid method. As a heuristic method, HS emulates the improvisational techniques of artists. The variables used to make decisions for the size issue are discontinuous integers, categorizing this issue as a combinatorial optimization issue. An efficient discrete search method utilizing HS is implemented. The HS approach employed here is the one proposed as a separate HS. Several critical factors influence the speed of convergence of the HS method: the Harmonic Memory Consideration Rate (HMCR), which denotes the choice of rate from the Harmony Memories (HM) and varies from zero to one; the generation spectrum; and the pitched adjusting rate (PAR). HMCR ascertains if the value of a choice variable should be selected from HM. Peak Absorption Ratio (PAR) contributes to regulating local searches. The suitable PAR can efficiently prevent the search from becoming ensnared in a local optimum. A lower PAR is typically favorable for rapidly identifying the local best approach during the initial search phase.

In contrast, a more excellent PAR is beneficial for circumventing the local optimum in the subsequent phase. This work incorporates an evolving modification strategy for PAR into the mixed optimization method. The suitable bandwidth is advantageous in modifying the pace of convergence of the approach for the best answer. In this context, Bandwidth varies constantly with the generated frequency. The method's convergence rate is adjusted with these settings to attain the ideal result. Fig. 1 illustrates the structure of the hybrid process.

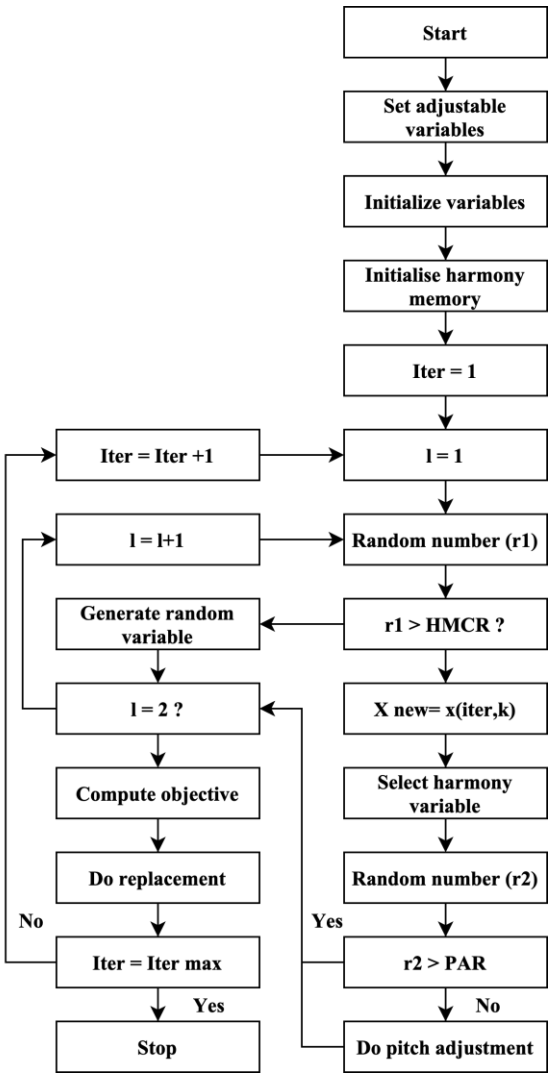


Fig. 1: Flowchart of the Suggested Model

Results and Findings

Fig. 2(a) illustrates that the battery drains continuously during all time slots with the existing EMS. In contrast, discharge happens during high grid pricing time slots with the suggested EMS. This strategy decreases battery power consumption by 71.4% during daylight, enhancing battery longevity. Fig. 2(b) illustrates the power procured from the grid, demonstrating that the grid's power supply is elevated during low-price periods when utilizing the suggested EMS compared to the standard EMS. According to the estimated state of charge depicted in Fig. 2(c), the battery discharges slowly. It remains constant during the low-price time intervals with the suggested energy management system but continues to drain throughout the day with the standard energy management system. It is important to note that the battery deterioration, resulting from the loss of capacity, does not influence the predicted State of Charge (SOC), as everyday use of the battery backup in these instances did not achieve a complete charging or discharging cycle. Extending the operational duration over many cycles will lead to capacity degradation, affecting the condition of the battery store.

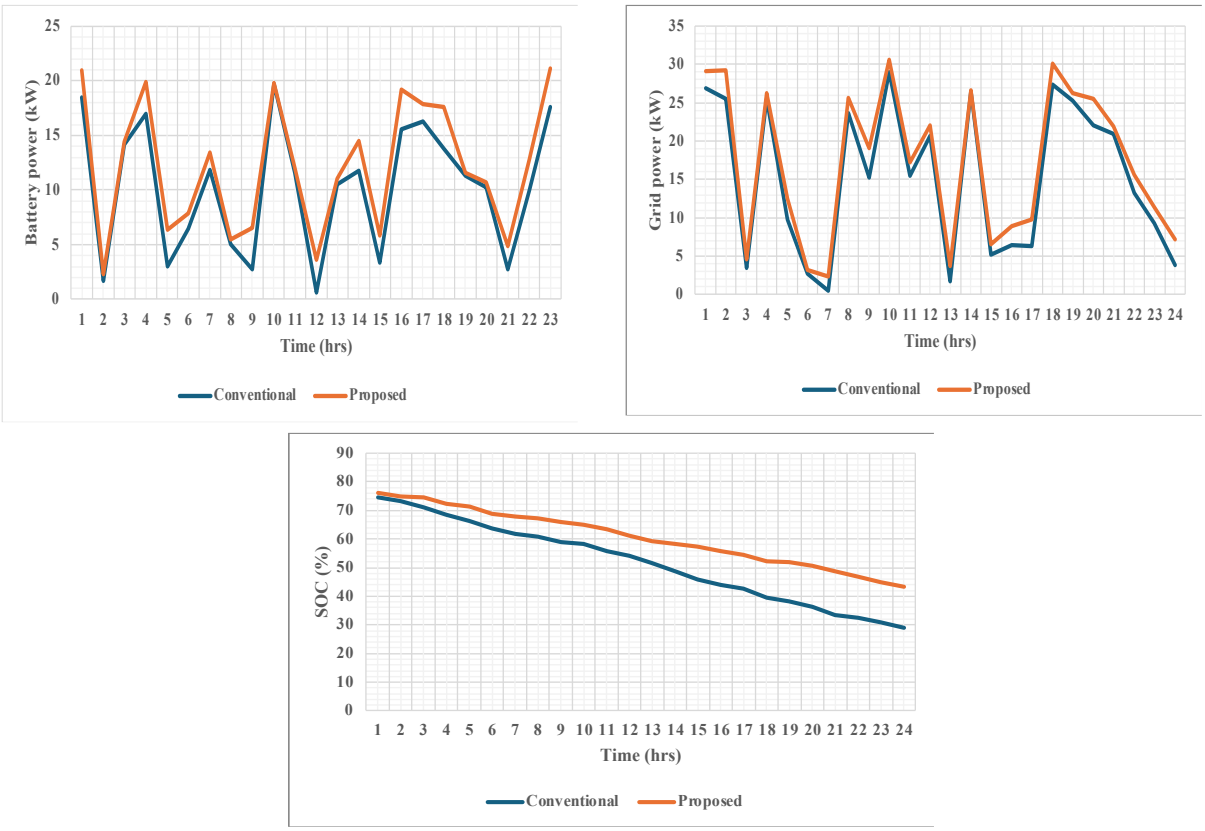


Fig. 2(a): Battery Power, 2(b): Grid Power and 2(c): SOC Analysis

Conclusion

The present research introduced a system to manage energy for hybrid solar and wind power systems, incorporating a battery storage technology to improve energy costs and storage efficiency. The optimization methods incorporate a contribution factor that diminishes energy consumption and storage use to extend battery longevity. The optimal configuration for this variable is linearly correlated with the grid price. Load shifting enhances the system's efficiency by reducing energy costs. The results indicate that the suggested EMS diminishes battery contributions and operational volatility throughout the day. It reduces the expenses associated with battery depreciation. The algorithm's construction is straightforward and entails a minimal computational load relative to the improvement derived from the iterative search for the ideal solution. Future endeavors encompass examining a microgrid's monthly and annual operations by modifying the contribution aspect to incorporate complete battery phases, optimizing the lifecycle and minimizing degradation costs, integrating Electric Vehicles (EVs), and enhancing the power management framework for a network of microgrids.

References

Hirsch, A., Parag, Y., & Guerrero, J. (2018). Microgrids: A review of technologies, key drivers, and outstanding issues. *Renewable and sustainable Energy reviews*, *90*, 402-411. https://doi.org/10.1016/j.rser.2018.03.040

Shahbazi, M., & Khorsandi, A. (2017). Power electronic converters in microgrid applications. In *Microgrid* (pp. 281-309). Butterworth-Heinemann. https://doi.org/10.1016/B978-0-08-101753-1.00010-3

Jones, L. E., & Olsson, G. (2017). Solar photovoltaic and wind energy providing water. *Global Challenges*, *1*(5), 1600022. https://doi.org/10.1002/gch2.201600022

Malhotra, A., Battke, B., Beuse, M., Stephan, A., & Schmidt, T. (2016). Use cases for stationary battery technologies: A review of the literature and existing projects. *Renewable and Sustainable Energy Reviews*, *56*, 705-721. https://doi.org/10.1016/j.rser.2015.11.085

Gomes, J. G., Xu, H. J., Yang, Q., & Zhao, C. Y. (2021). An optimization study on a typical renewable microgrid energy system with energy storage. *Energy*, *234*, 121210. https://doi.org/10.1016/j.energy.2021.121210

Lee, D., & Cheng, C. C. (2016). Energy savings by energy management systems: A review. *Renewable and Sustainable Energy Reviews*, *56*, 760-777. https://doi.org/10.1016/j.rser.2015.11.067

Hasan, K. S., Antonio, J. K., & Radhakrishnan, S. (2017). A model-driven approach for predicting and analysing the execution efficiency of multi-core processing. *International Journal of Computational Science and Engineering*, *14*(2), 105-125. https://doi.org/10.1504/IJCSE.2017.082877

Antonio, C. (2021). Sequential model based optimization of partially defined functions under unknown constraints. *Journal of Global Optimization*, *79*(2), 281-303. https://doi.org/10.1007/s10898-019-00860-4