IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 20, Issue 6 Ser. I (Nov. – Dec. 2025), PP 48-53
www.iosrjournals.org

Design and Implementation of a Hierarchical Control System for Managing the Integration and Operation of Super Capacitors and Micro Sources within a DC Micro Grid Island

M. Kalainesan[1], Dr. S. Vijayaraj[2]

[1.] Ph.D. Scholar, Department of Electrical and Electronics Engineering, School of Engineering, Vels Institute of Science Technology and Advanced Studies Chennai-117

[2.] Assistant Professor, Department of and Electrical and Electronics Engineering School of Engineering Vels Institute of Science Technology and Advanced Studies Chennai-117.

Abstract: *In this paper, to design and implementation of a hierarchical control system for managing the integration and operation of super capacitors and micro sources within a DC micro grid island, aiming to enhance the grid's stability, reliability, and efficiency while optimizing energy management and ensuring seamless transition between grid-connected and islanded modes. This control architecture typically involves multiple layers, such as primary, secondary, and tertiary control, each responsible for specific functions like voltage regulation, frequency control, and power sharing among micro sources.*

Key word: Battery, Voltage Regulator, Buck-Boost Converter, Relay, Arduino, Voltage Regulator, LCD Display, Labview,

----

Date of Submission: 12-11-2025 Date of Acceptance: 23-11-2025

I. Introduction

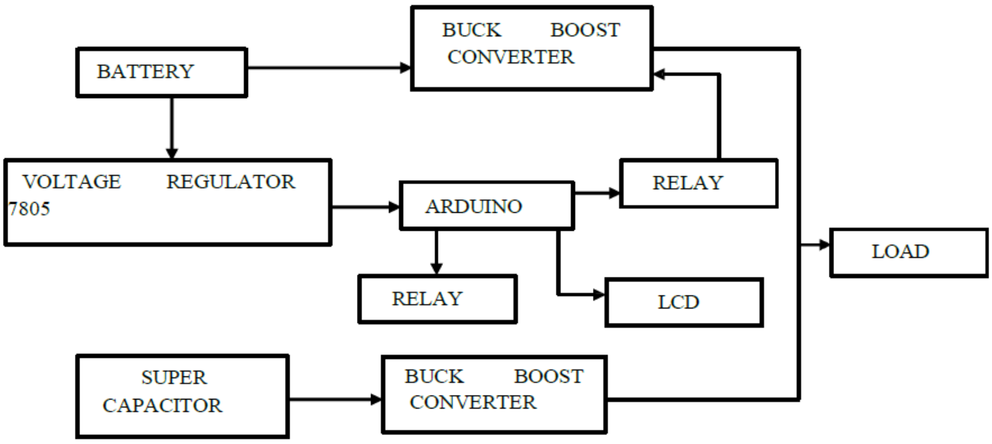
Now a days, not easy to keep and monitoring using super capacitors in DC Micro Grid Island, the increasing adoption of renewable energy sources, coupled with advancements in energy storage technologies, has spurred the development of micro grids as a viable solution for decentralized power generation and distribution. Among the various types of micro grids, islanded DC micro rids have garnered significant attention due to their potential for providing reliable and efficient electricity supply in remote or off-grid areas. These micro grids operate independently of the main grid, relying on a combination of renewable energy sources and energy storage systems to meet local demand. However, the effective control and management of these complex systems pose significant challenges partiScularly, in ensuring grid stability and optimal utilization of resources.

The Super capacitors have emerged as promising energy storage devices in micro grid applications due to their high-power density, fast response times, and long cycle life. Their ability to store and release energy rapidly makes them well-suited for addressing transient power imbalances and smoothing out fluctuations in renewable energy generation. Additionally, the integration of various micro sources such as photovoltaic arrays, wind turbines, and battery storage systems provides further flexibility and resilience to the micro grid operation. However, coordinating the operation of super capacitors and micro sources in islanded DC micro grids requires sophisticated control strategies to optimize energy flow and ensure system stability.

II. Design and Methodology

A .Block diagram

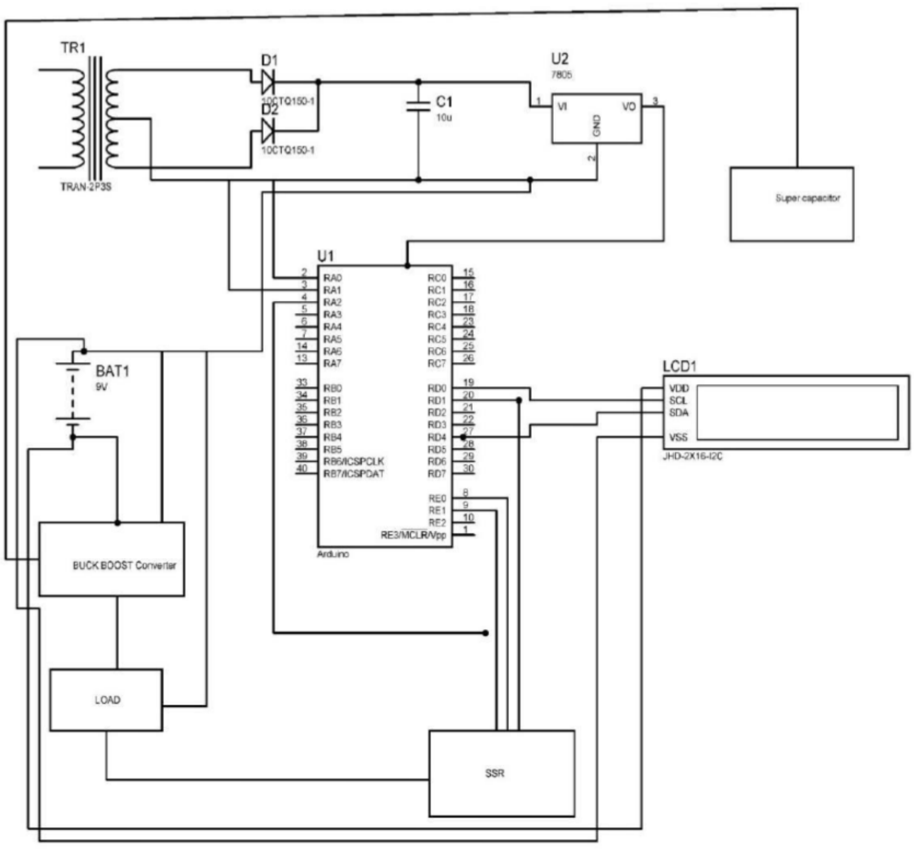
In this block diagram which consists of battery, supercapacitor, voltage regulator, Arduino, relay, LCD, buck boost converter, load. The battery is connected with the buck boost converter and also super capacitor is connected with buck boost converter the two- power source commonly connected with the load. Based upon the required voltage the buck boost converter either the voltage will be buck or boost the voltage. The Arduino is used to generate the gate signal which is present in the buck boost converter.



This paper hierarchical control system for the components within the islanded DC micro grid aims to optimize energy management, enhance system stability, and ensure efficient operation under varying conditions. At the core of the system lies an Arduino microcontroller unit (MCU) programmed to oversee the hierarchical control architecture. The MCU acts as the central supervisory controller, orchestrating the interaction between the various components to achieve optimal system performance.

The battery serves as a primary energy storage device within the micro grid, providing backup power during periods of low renewable energy generation or high demand. The voltage regulator 7805 maintains a stable output voltage for powering the control electronics, ensuring reliable operation of the control system. A buck-boost converter is employed to efficiently regulate the voltage level within the micro grid, adapting to fluctuations in renewable energy generation and load demand .Relays are utilized for switching between different power sources and loads, enabling seamless transitions and effective management of energy flow. An LCD display provides real-time monitoring of system parameters such as voltage, current, and energy levels, allowing for easy visualization and assessment of system performance.

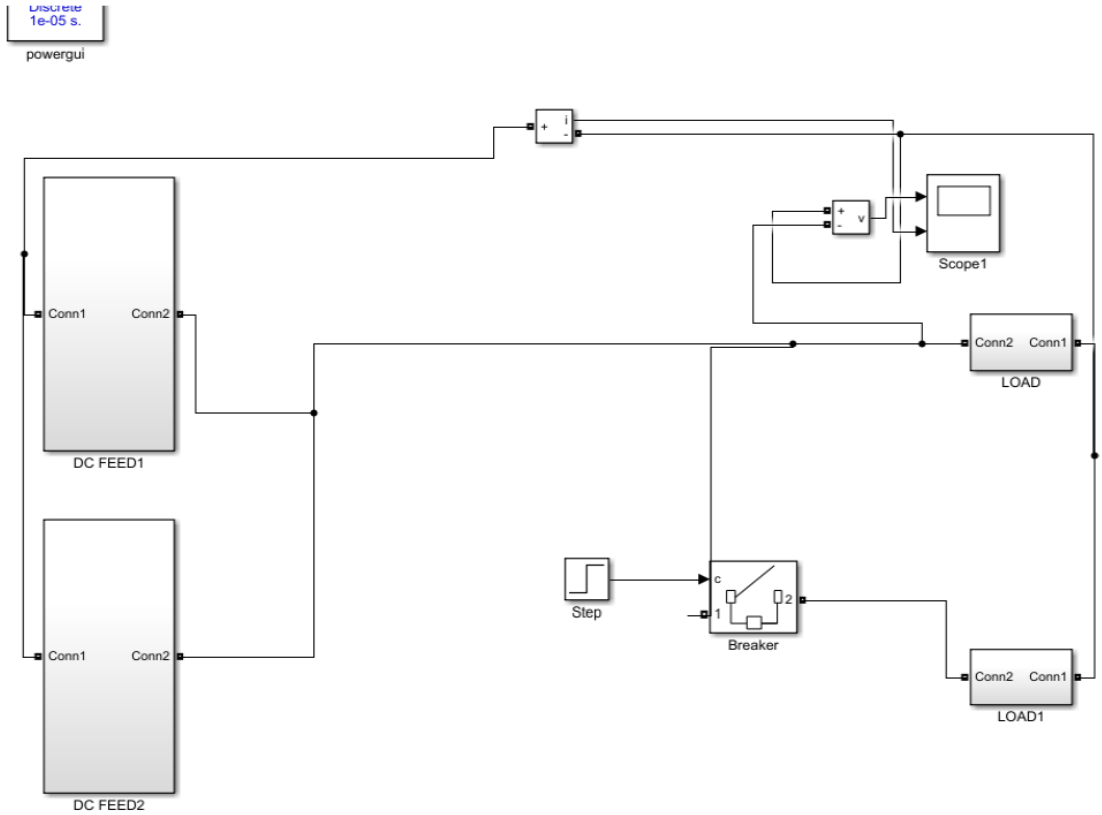
III-Circuit Diagram:



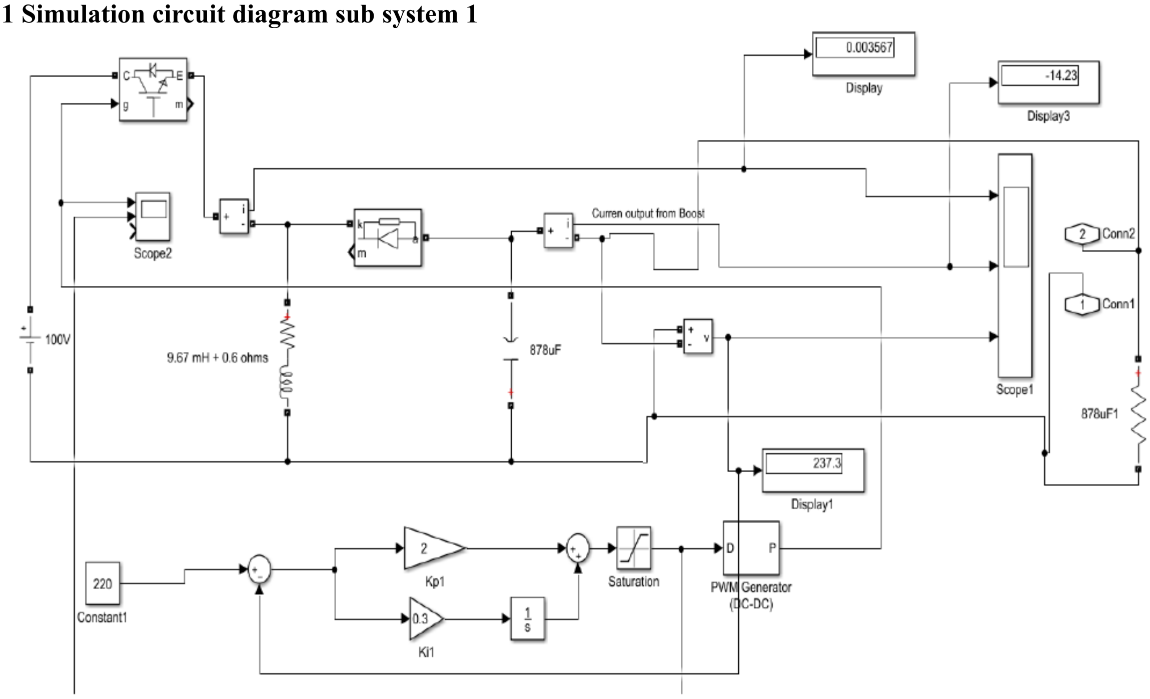
In this circuit diagram which shows the connection to implement in the hardware part of our project which is super capacitor and micro sources in islanded dc micro grid. In response to these challenges, this paper proposes a hierarchical control framework tailored specifically for the coordinated operation of super capacitors and micro sources in islanded DC micro grids. The hierarchical architecture encompasses multiple control layers, each addressing specific control objectives and functionalities. At the top level, a global supervisory control oversees the overall system operation and coordinates the interaction between super capacitors and micro sources. Lower-level local control loops are responsible for regulating individual components, including super capacitors and various micro sources, to ensure efficient energy management and adherence to system constraints.

The hierarchical control strategy aims to enhance the resilience, reliability, and efficiency of islanded DC micro grids by dynamically managing energy flow and distribution. By leveraging the complementary characteristics of super capacitors and micro sources, the proposed control framework optimizes system performance while mitigating the impact of renewable energy intermittency and load fluctuations. Through simulation studies and analysis, the effectiveness and robustness of the hierarchical control strategy will be evaluated, providing insights into its potential for practical implementation and advancing the state-of-the-art in micro grid control and management.

IV- Simulation Diagram:

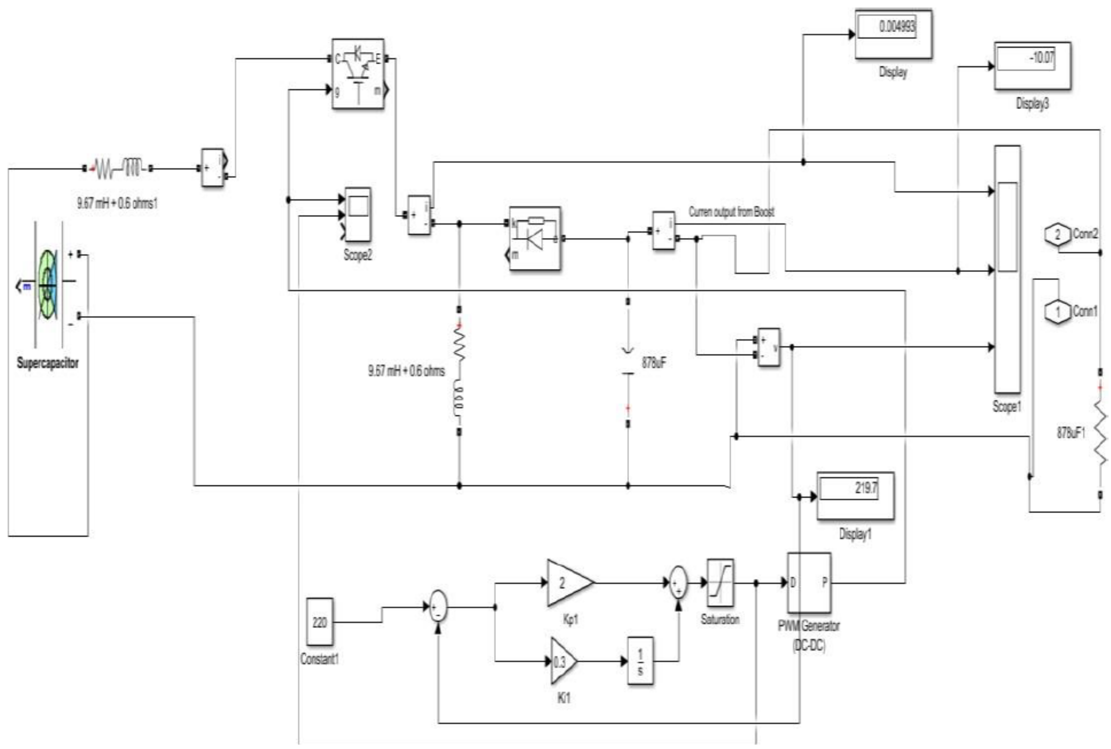


3.1 Simulation circuit diagram sub system 1



In this paper the Simulation circuit diagram it consists of two subsystem both are connected in parallel that consider as islanded dc micro grid which connected with two loads (load, load1). The load 1 work after 3sec that set-in step. The breaker is connected with load for protection from overvoltage. A simulation is a model that mimics the operation of an existing or proposed system, providing evidence for decision-making by being able to test different scenarios or process changes.

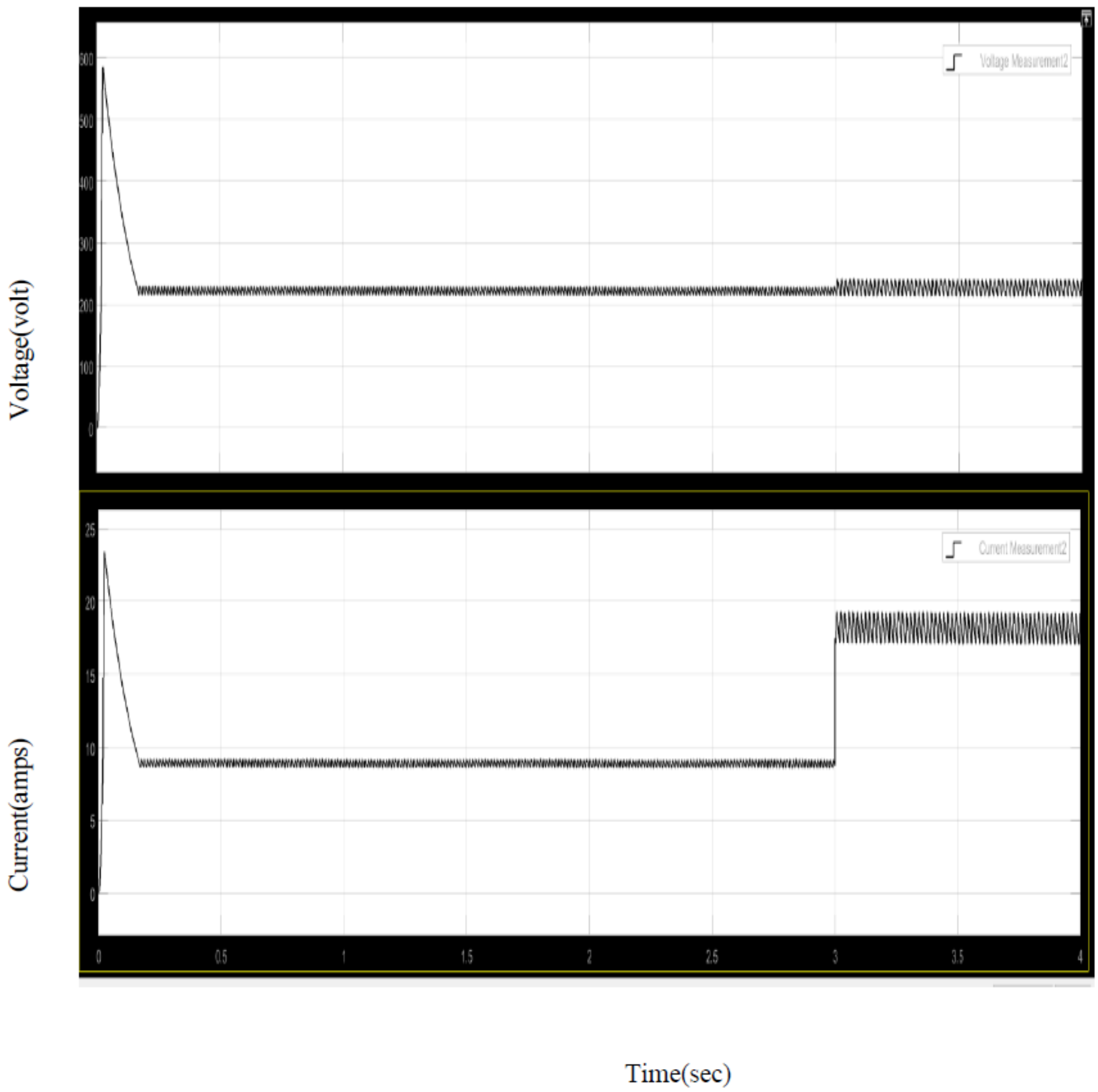
3.2 Simulation circuit diagram sub system 2



The Subsystem 2 is battery source that connected with fly back buck-boost converter. From battery side the voltage 100v and reference voltage 200v, as per load demand the converter buck or boost the voltage, the display shows normal current, boosted voltage and current through voltage and current measurement.

In this paper the super capacitor that connected with fly back buck-boost converter. From battery side the voltage 100v and we set as reference voltage 200v, as per load demand the buck or boost converter either buck or boost the voltage and display shows normal current, boosted voltage and current through voltage measurement and current measurement. Here we are using the logic controller to compare the normal output voltage with reference voltage and decides the function either buck or boost the voltage.

IV. Simulation Result



A Simulation result shows in Fig 3.4 the output of the simulation represents graphically which is plotted normal current vs time, boost current vs time and boost voltage vs time the variation of voltage in load shows in 3sec.

V. Conclusion

In conclusion, the hierarchical control framework proposed for the coordinated operation of super capacitors and micro sources in islanded DC microgrids represents a significant advancement in the field of micro grid control and management. Through the hierarchical architecture, which encompasses global supervisory control and lower- level local control loops, the proposed system optimizes energy management, enhances system stability, In and ensures efficient operation under varying conditions. By dynamically coordinating the interaction between super capacitors, micro sources, and other components such as batteries, voltage regulators, and buck-boost converters, the hierarchical control system maximizes energy efficiency, minimizes losses, and improves grid resilience.

The integration of super capacitors into the micro grid provides rapid response capabilities to mitigate transient power imbalances and enhance grid stability, while the inclusion of diverse microsources ensures flexibility and reliability in energy generation. Through simulation studies and experimental validation, the effectiveness and robustness of the proposed hierarchical control system have been demonstrated, highlighting its potential for practical implementation in real-world micro grid applications.

References

1. Ali, Z. Terriche, Y. Abbas, S. Z. Hassan, M. A. Sadiq, M. Su, C.-L. and Guerrero, J. M. (2021)''Fault management in DC microgrids: A review of challenges, countermeasures, and future research trends,'' IEEE Access, vol. 9, pp. 128032–128054
2. Bhargavi, K. M. Jayalakshmi, N. S. Gaonkar, D. N. Shrivastava, A. and Jadoun, V. K. (2021) ''A comprehensive review on control techniques for power management of isolated DC microgrid system operation,'' IEEE Access, vol. 9, pp. 32196–32228
3. Cabrane, Z. Ouassaid, M. and Maaroufi, M. (2017)''Battery and supercapacitor for photovoltaic energy storage: A fuzzy logic management,'' IET Renew. Power Gener., vol. 11, no. 8, pp. 1157– 1165
4. Dong, M. Li, L. Nie, Y. Song, D. and Yang, J. (2019) ''Stability analysis of a novel distributed secondary control considering communication delay in DC microgrids,'' IEEE Trans. Smart Grid, vol. 10, no. 6, pp. 6690–6700,
5. El-Bidairia, K. S. Nguyen, H. D. Jayasinghe, S. D. G. Mahmoud, T. S. and Penesis, I. (2018) ''A hybrid energy management and battery size optimization for standalone microgrids: A case study for Flinders island, Australia,'' Energy Convers. Manage., vol. 175, pp. 192–212
6. Kewat, S. Singh, B. and Hussain, I. (2018)Power Gener., vol. 12, no. 4, pp. 391–398
7. Liu, Z. Luo, Y. Zhuo, R. and Jin, X. (2018)''Distributed reinforcement learning to coordinate current sharing and voltage restoration for islanded DC microgrid,'' J. Modern Power Syst. Clean Energy, vol. 6, no. 2, pp. 364–374
8. Li, Y. Xu, Z. Xiong, L.Song, G. Zhang, J. Qi, D.and Yang, H. (2019)''A cascading power sharing control for microgrid embedded with wind and solar generation,'' Renew. Energy, vol. 132, pp. 846–860
9. Lopez, G. L. Schacht Rodriguez, R. Alvarado, V. M. Gomez- Aguilar, J. F. Mota, J. E. and Sandoval, C. (2017)''Hybrid PEMFC- supercapacitor system: Modeling and energy management in energetic macroscopic representation,'' Appl. Energy, vol. 205, pp. 1478–1494
10. Mahmood, H. Michaelson, D. and Jiang, J. ''A power management strategy for PV/battery hybrid systems in islanded microgrids, (2019)'' IEEE J. Emerg. Sel. Topics Power Electron., vol. 2, no. 4, pp. 870–882
11. Mehdi, M. Kim, C.-H. and Saad, M. (2020) ''Robust centralized control for DC islanded microgrid considering communication network delay,'' IEEE Access, vol. 8, pp. 77765–77778
12. Pavković, D. Lobrović, M. Hrgetić, M. and Komljenović, A. (2017)''A design of cascade control system and adaptive load compensator for battery/ultracapacitor hybrid energy storage-based direct current microgrid,'' Energy Convers. Manage., vol. 114, pp. 154–167
13. Sandoval, C. Alvarado, V. M. Carmona, J.-C. Lopez, G. L. and Gomez-Aguilar, J. F. (2018) ''Energy management control strategy to improve the FC/SC dynamic behavior on hybrid electric vehicles: A frequency based distribution,'' Renew. Energy, vol. 105, pp. 407–418
14. Sebastián, R. (2019)''Application of a battery energy storage for frequency regulation and peak shaving in a wind diesel power system,'' IET Gener., Transmiss. Distrib., vol. 10, no. 3, pp. 764– 770