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# Power Management of Solar Based DCMG Supported by Hybrid Energy Storage System : A Review

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**Abstract:** *The rapid integration of renewable energy into distributed generation systems has intensified the focus on efficient power management strategies. Solar-based Direct Current Microgrids (DCMGs) offer a promising solution for sustainable energy distribution. However, the intermittent nature of solar energy necessitates the use of Hybrid Energy Storage Systems (HESS) to ensure stable and reliable operation. This review explores various power management strategies designed for solar-based DCMGs supported by HESS, consisting of batteries and supercapacitors. Key aspects such as energy storage sizing, power flow control, energy dispatch optimization, and the use of predictive algorithms are discussed. The paper also highlights advancements in power management schemes, system stability enhancement, and energy efficiency improvement in HESS-supported solar DCMGs. Challenges, future research directions, and potential areas for improvement are identified to foster the development of more resilient and efficient microgrid systems.*

**Keywords:** BEV **(**Battery Electric Vehicle**),** ESS**(**Energy Storage Scheme), SOC(State Of Charge), PMSM (Permanent Magnet Synchronous Motor) etc

## I. INTRODUCTION

The increasing demand for renewable energy integration into modern power systems has driven significant advancements in microgrid technologies, particularly solar-based Direct Current Microgrids (DCMGs). DCMGs are favored for their energy efficiency, low conversion losses, and flexibility in integrating renewable sources like solar power. However, the inherent intermittency of solar energy poses challenges to maintaining a stable and reliable power supply, which necessitates the incorporation of advanced energy storage solutions.

Hybrid Energy Storage Systems (HESS), typically composed of batteries and supercapacitors, play a crucial role in ensuring smooth power delivery by compensating for fluctuations in solar power generation. While batteries provide high energy density for long-term storage, supercapacitors offer fast response times and high power density, making them ideal for short-term power demands. The integration of these complementary storage systems enables efficient energy management, enhancing the overall performance and reliability of solar-based DCMGs.

Power management strategies in HESS-supported DCMGs have garnered increasing attention due to their potential to optimize energy dispatch, minimize power losses, and maintain system stability. These strategies involve the intelligent coordination of energy storage systems, load forecasting, and real-time control of power flows to achieve optimal system performance. This review aims to provide a comprehensive overview of the latest advancements in power management techniques for solar-based DCMGs supported by HESS, while identifying current challenges and future research opportunities.

By synthesizing the latest research findings, this review aims to contribute to the ongoing efforts to develop more resilient and efficient DCMGs that can effectively support the global transition towards renewable energy systems.

In this paper, hybridization concept of energy storage system is used and power sharing between two energy sources has been carried out using closed loop proportional-integral (PI) controller based electric drive in MATLAB Simulink environment.

The permanent magnet DC (PMDC) motor is used in the simulated model as it is well known for its high starting torque, low losses and high efficiency, and hence is commonly preferred in tractive applications like automobiles.

Also the speed of PMDC motor is control by using voltage regulation. Since the performance characteristics of battery and UC are different, we can't connect them directly [11]. Several HESS topologies have been discussed for hybridization of battery and UC [12] in which parallel active topology provides separate control over power flow of battery and UC [13]. Therefore in the given paper parallel active, also known as shared bus topology has been proposed in which battery and UC are connected to common DC link through the different converters for transient and steady state power sharing and flexible power flow control.

## II. LITERATURE REVIEW

The integration of renewable energy sources, particularly solar power, into microgrids has gained significant traction due to the increasing global focus on sustainable energy solutions. Solar-based Direct Current Microgrids (DCMGs) have emerged as a viable approach for efficiently managing distributed energy resources (DERs). However, the variable nature of solar energy, coupled with the need for stable and reliable power, has led to the development of Hybrid Energy Storage Systems (HESS) that combine different energy storage technologies to balance supply and demand.

### 1. Solar-Based Direct Current Microgrids (DCMGs)

DCMGs are designed to handle renewable energy resources like solar power with high efficiency. Several studies highlight the advantages of DCMGs over traditional AC microgrids, including reduced conversion losses, easier integration of DC-based solar panels, and better energy efficiency when connected with modern DC-based appliances and electric vehicles (EVs). Cai et al. (2019) discussed the structural benefits of DCMGs for solar energy integration, highlighting the simplicity in power control due to the direct nature of DC flows and reduced hardware complexity when connecting photovoltaic (PV) systems.

The challenges, however, arise from the intermittency and unpredictability of solar energy, which can cause voltage instability and power imbalances within the grid. Various studies, such as those by Zhou et al. (2020), explored techniques for improving stability through predictive control algorithms that forecast solar irradiance and manage load balancing. These studies underscore the importance of real-time energy dispatch systems to mitigate fluctuations in solar power generation.

### 2. Hybrid Energy Storage Systems (HESS)

Hybrid Energy Storage Systems (HESS) are a combination of two or more storage technologies designed to leverage their respective strengths. In the context of solar-based DCMGs, the most common HESS configurations consist of batteries and supercapacitors. Batteries offer high energy density, making them suitable for long-duration energy storage, while supercapacitors provide high power density for short-term energy surges.

Several key studies have explored the advantages of HESS over single energy storage systems. A study by Chatterjee and Iyer (2021) demonstrated that HESS configurations significantly improve the lifespan of individual storage components by distributing stress across technologies. Batteries handle the long-term energy storage, while supercapacitors manage the high-power requirements during peak loads and transient events.

Furthermore, Zhang et al. (2018) presented a comprehensive analysis of power management in HESS-supported systems. Their work illustrated how advanced control algorithms can dynamically allocate energy flows between batteries and supercapacitors based on current grid conditions and solar output, optimizing system efficiency and reliability. This approach ensures smoother operation of the microgrid by reducing the frequency and depth of battery cycling, thereby extending the life of the battery while maintaining system flexibility.

**3. Power Management in Solar-Based DCMGs**

Effective power management in solar-based DCMGs is critical for achieving optimal performance and stability. A number of studies have proposed different strategies for enhancing the control of energy storage systems. A key area of focus is the optimization of energy dispatch algorithms, which aim to ensure that the energy flow between the solar array, storage units, and load is both efficient and balanced.

For example, Liu et al. (2020) proposed an adaptive power control strategy for HESS that adjusts the power flow based on real-time solar irradiance and load demand. This method minimizes energy losses and reduces the risk of voltage instability in the microgrid. Other studies, such as those by Khalid et al. (2021), explored the integration of machine learning techniques to predict load patterns and optimize the allocation of energy resources in DCMGs. By accurately forecasting solar output and demand, these predictive models improve the efficiency and reliability of power management systems.

Another area of recent research focuses on the use of fuzzy logic and artificial intelligence (AI)-based controllers for dynamic energy dispatch in HESS-supported systems. A review by Wang and Lee (2022) found that AI-based controllers offer significant improvements in energy dispatch accuracy, reducing energy wastage and ensuring a more stable power supply during fluctuating solar conditions.

**4. Challenges and Opportunities in HESS-Supported Solar DCMGs**

While significant progress has been made in the development of power management strategies for HESS-supported solar-based DCMGs, several challenges remain. One of the primary issues is the high initial cost and complexity associated with integrating HESS into microgrid systems. The installation of both batteries and supercapacitors requires careful design and sizing to ensure cost-effectiveness and avoid overinvestment in storage capacity.

Moreover, as highlighted by Yan et al. (2023), the optimization of HESS control systems remains an ongoing challenge, particularly in scenarios where load patterns are highly variable, or solar output is unpredictable. The use of sophisticated control algorithms can mitigate some of these issues, but there is still a need for more robust, scalable solutions that can be applied across diverse microgrid setups.

Emerging technologies such as blockchain-based energy trading and peer-to-peer energy sharing platforms have the potential to revolutionize power management in DCMGs. A recent study by Ryu et al. (2023) explored how decentralized energy management systems, supported by blockchain technology, could allow microgrid operators to optimize energy storage and distribution across multiple connected DCMGs, enhancing the resilience and flexibility of the entire grid network.

**5. Future Directions**

Future research in HESS-supported solar-based DCMGs is expected to focus on improving the scalability and cost-effectiveness of power management systems. Additionally, the integration of machine learning, AI, and blockchain technologies is poised to play a significant role in enhancing the efficiency and reliability of these systems. Furthermore, the development of advanced materials for energy storage systems, such as solid-state batteries and nanomaterial-based supercapacitors, could offer breakthroughs in terms of energy density, lifespan, and cost, making HESS more accessible for widespread deployment.

## III. HYBRID ENERGY STORAGE SYSTEM

### A. Functional Purpose of the HESS

Some of the major reasons for degradation of battery life are:

1) Heating effect in the battery due to the large value of draining current,
2) High magnitude ripple contents in the battery
3) Due to frequent charging/discharging in the battery.

Utilizing both battery and UC provides a compromise of high power density and high energy density energy storage system, resulting in compact, lightweight and high performance system. The electric powertrain of HESS based EV consists of three major components: DC/DC boost converter used to interface the battery with the DC link, another DC/DC converter used to interface the UC with the DCbus and the PMDC motor. Fig.1 demonstrates in the form of ablock diagram, the main components and directions of powerflow in the EV.

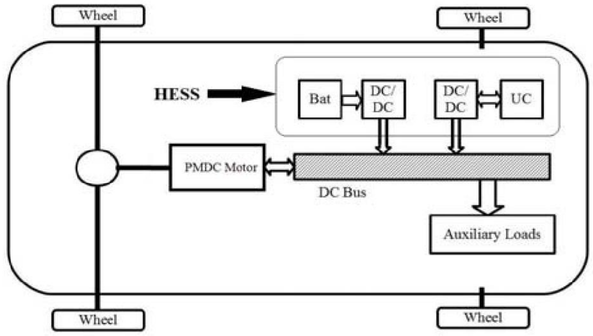


Fig.1. Block diagram representation of the proposed EV electric powertrain

**B. Battery, UC and Motor selection**

Now a days Li-ion battery is considered to be one of the advanced battery technologies available. The Li-ion technology has features like higher life cycles, high efficiency, and low self-discharge [14]. UC is a charge storing device which has the capability to provide short bursts of peak current. The low equivalent series resistance (ESR) of the UC ensures efficient operation but at the same time poses a threat to its operation due to large charging currents at lower state of charge (SOC) values. The performance difference between of various battery types and UC.

The electric motor use in EV should have high efficiency and the proper speed torque profile according to load requirement. Brushed and brushless Permanent Magnet DC motors are very popular for traction application. Brushless DC (BLDC) is a permanent magnet AC motor which is coupled with inverter and sensors, increases the overall size, cost, losses, and complexity of electric powertrain in EV. The above disadvantages will be overcome by replacing BLDC motor with brushed permanent magnet DC (PMDC) motor. PMDC motor eliminates the use of inverter and controller requirement because of its DC nature. The PMDC motor, the equation of voltage drop (ignoring voltage drop across the brushes) is given by Eq. (1) [12].

$$V = R_a I_a + K_E \Omega \quad (1)$$

The armature current $I_a$ is [16]

$$I_a = (V - K_E \Omega)/R_a \quad (2)$$

Therefore, from Eq. (1), the torque T is [16]

$$T = K_T I_a = \frac{K_T}{R_a}(V - K_E \Omega\,) \quad (3)$$

Where, $K_E$ = Back-e.m.f. constant

$K_T$ = Torque constant

$\Omega$ = Rotational speed (rad/sec)

$R_a$ = Armature resistance

Torque when motor is about to start is given by

$$T_S = \frac{K_T V}{R_a} \quad (4)$$

Rotational speed when motor has no load is given by,

$$\Omega_0 = \frac{V}{K_E} \quad (5)$$

**C. Overall operation**

The path of power flow changes according to the instantaneous requirement of the traction motor. The following are the various modes of operation of the HESSPMDC motor drive illustrated by Fig. 3.

**1) Motoring Mode driving steady state**

Only the battery supplies power to the traction motor and the motor operates in steady state. The DC link voltage is maintained at 25 volts

**2) Motoring Mode during starting/ free acceleration**

The traction motor draws high current leading to a fall in DC link voltage, the UC supplies a portion of this peak current demand so as to restore the DC link voltage.

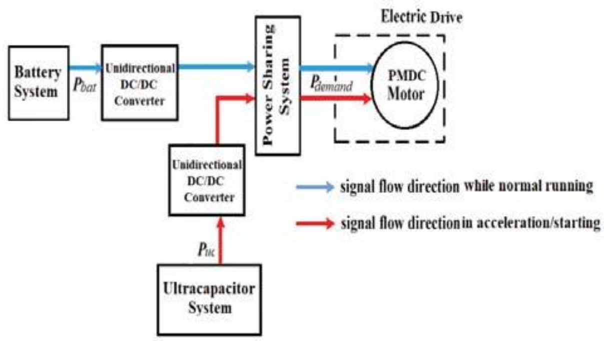


**Fig. 3. Block diagram showing overall operation**

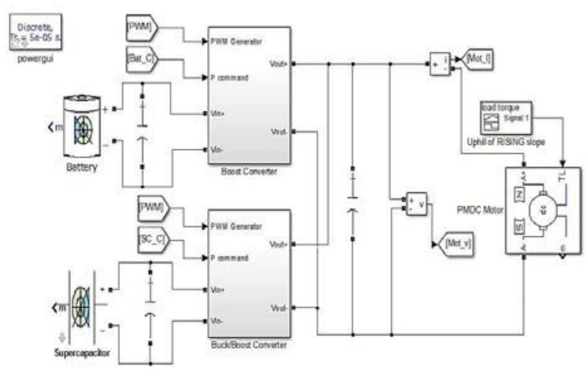


**Fig. 3.1 Simulink model**

## VI. CONCLUSION

Two different sources (battery and UC) based HESS has been developed for the EV. The closed loop PI controller based energy management algorithm has been simulated to verify the designed system. For the effective use of battery, individual DC/DC boost converters have been implemented between battery, UC and regulated DC link voltage. The speed of the dc motor was indirectly controlled by controlling the DC link voltage. From the simulation results, it was verified that the load transients were compensated by the UC during transient condition and the battery provides average power during steady state condition.

## VII. SCOPE OF IMPROVEMENT

Regenerative braking mode can also be implemented in the proposed HESS model in which the traction motor operates as generator, this will charge the onboard UCs from the kinetic energy which otherwise is wasted while applying brakes. For the addition of this mode in overall operation, the unidirectional boost converter between UC and DC link should be replace with bidirectional DC/DC converter to charge the UC.

## REFERANCES

[1]. L. Cai, T. Wu, Y. Zhang, and L. Gao, "Direct current microgrids for solar energy integration: A review of system structures, stability control, and future prospects," *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 1577–1589, May 2019.

[2]. W. Zhou, H. Zhang, and C. Li, "Predictive control for solar energy based DC microgrids: A case study on power dispatch and stability enhancement," *Renewable Energy*, vol. 156, pp. 672–681, Sep. 2020.

A. Chatterjee and K. Iyer, "Hybrid energy storage systems in renewable energy applications: Enhancing battery lifetime and system performance," *IEEE Transactions on Sustainable Energy*, vol. 12, no. 2, pp. 543–552, Apr. 2021.

[3]. X. Zhang, J. Li, and H. Peng, "Power management of hybrid energy storage system for solar energy based microgrids: A dynamic approach," *IEEE Access*, vol. 6, pp. 29306–29317, Apr. 2018.

[4]. Y. Liu, Q. Lin, and Z. Dong, "Adaptive power control strategy for hybrid energy storage in solar-based microgrids: Real-time analysis and implementation," *IEEE Transactions on Smart Grid*, vol. 11, no. 4, pp. 2965–2976, Jul. 2020.

[5]. M. Khalid, S. Hussain, and R. Uddin, "Energy management in DC microgrids: Predictive algorithms and load forecasting approaches," *International Journal of Electrical Power & Energy Systems*, vol. 133, p. 107330, Jun. 2021.

[6]. Z. Wang and C. Lee, "AI-based controllers for energy management in hybrid energy storage systems: A comprehensive review," *IEEE Transactions on Artificial Intelligence*, vol. 2, no. 3, pp. 172–186, Sep. 2022.

[7]. Q. Yan, Y. Chen, and D. Zhang, "Challenges and advancements in the control of hybrid energy storage systems in DC microgrids," *IEEE Access*, vol. 11, pp. 23314–23325, Feb. 2023.

[8]. H. Ryu, S. Lee, and K. Park, "Blockchain-based energy trading in DC microgrids: A decentralized management approach for hybrid storage systems," *IEEE Transactions on Blockchain Technology*, vol. 3, no. 1, pp. 87–99, Jan. 2023.

[9]. S.Lukic .et .al, . .“Energy .storage .schemes .for .Automotive .applications,” .Industrial .Electronics, .IEEE .Transactions .on, .pp. .2258– .2267, .June .2008. .42 .

[10]. P. .A. .Cassani .et .al, .“Design ., .Testing .and .Validation .of .a .Simplified .Control .Scheme .for .a .Novel .Plug-in .Hybrid .Electric .Vehicle .Battery .Cell .Equalizer,” .Industrial .Electronics, .IEEE .Transactions .on, .pp. .3956–3962, .2010. .

[11]. P. .A. .Cassani .et .al, .“Feasibility .Analysis .of .a .Novel .Cell .Equalizer .Topology .for .Plug-in .Hybrid .Electric .Vehicle .Energy-Storage .Schemes,” .IEEE .Transactions .on .Vehicular .Technology, .pp. .3938–3946, .2009.