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# Enhancing Microgrid Stability with D-STATCOM and Battery-Based Storage

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## Abstract

*Microgrids have gained significant attention as a promising solution for achieving sustainable and resilient energy systems. However, the integration of renewable energy sources (RES) into microgrids introduces challenges related to transient stability. This paper proposes a comprehensive approach to enhance transient stability and improve renewable energy integration in microgrids using a combination of a Distribution Static Compensator (D-STATCOM) and a battery-based storage system. The D-STATCOM provides reactive power compensation and voltage regulation capabilities, while the battery-based storage system offers energy storage and dispatchability. The synergistic operation of these two components addresses the intermittent nature of renewable energy sources and improves the overall performance of the microgrid during transient events. The effectiveness of the proposed approach is evaluated through simulation studies using a representative microgrid model. The suggested MG was designed and simulated in MATLAB. The MG has also been shown to function reliably across a wide range of environmental and loading situations. All use scenarios are covered by the suggested design.*

***Keywords:*** *Microgrid, Transient Stability, Renewable Energy Integration, D-STATCOM.*

## 1. INTRODUCTION

A renewable energy source is one that can be continuously supplied via everyday actions. It gets its many guises from the sun itself or from the planet's underlying heat. Materials and components originating from renewable resources such as sunlight, wind, sea, hydropower, biomass, and bio-powers are all considered part of this notion. Sustainable power source assets are significant openings 9 for energy intensity that exist over extensive geographical regions, in contrast to energy source alternatives that include just a small number of states. Nearly all energy sources were renewable until the advent of the coal era in the nineteenth century. It should come as no surprise that 790,000 years ago, biomass was used to fuel fires as the earliest documented ancient use of renewable energy. Until somewhere between 200,000 and 400,000 years ago [1], people seldom used biomass as fuel for fireplaces.

Using wind power to transport ships across the ocean is one of the first examples of renewable energy use. Ships on the river [2] throughout the era of recorded history are responsible for making this observation, which may be dated back 7,000 years. Primitive renewable energy came from human labor, animal power, water power, windmills used

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for crushing grain, and traditional biomass. A comparison of U.S. energy use from 1900 to 2010 shows that oil and fossil fuels were just as crucial a century ago as wind and solar are now.

Electrical grid engineers have been grappling with the problem of system stability for decades. Stability in a power grid means that it can function normally under most conditions and recover to the point where it is once again dependable after experiencing a disruption. [3]

For a power system to be considered stable, it must be able to provide balancing forces that are equal to or greater than the perturbing forces. If the forces that maintain the machines' synchronization are sufficient to offset the forces that cause disruption, then the system is stable [4].

Instability, on the other hand, is a condition in which synchronization is disrupted or steps are skipped. Planners of electric grids have recognized for some time that considering system stability is essential. Due to the increasing scale and complexity of interconnected systems across vast distances, it is becoming more difficult to keep individual parts of a power grid in sync with one another [5].

Stability problems may be analyzed in three different ways: in a steady state, in a dynamic setting, or in a transitory setting. Steady- state stability is the ability of the electrical grid to return to a state of synchrony after the introduction of small, gradual changes, such as small-scale power modifications. Concerns concerning dynamic stability, which is related to the presence of tiny disturbances that remain over time, arise when automated control systems are introduced [6,7].

The ability of the power grid to maintain synchronization of its timing in the face of a sudden, substantial disturbance is known as its transient stability. Transient stability studies the response of a system to large, sudden perturbations, such as a fault, a line failure, or the application or removal of loads. When it comes to a system's stability, both the size of the disturbance and its starting operating state matter [8]

Several research organizations have conducted considerable studies to evaluate the practicality and benefits of Microgrids, and there are ongoing Microgrid research initiatives underway. Despite widespread familiarity with Microgrids' core ideas, the system's implementation is not often fully recognized [9,10].

The purpose of this paper is to adapt and improve a photovoltaic setup so that it may be used in a micro grid. The requirements of the microgrid and the controls used for the different types of connection inform the selection of wind turbines. The purpose of this work is to evaluate the working hypothesis and to ensure that the findings of this inquiry may give new perspectives that will aid in the modification of standards [11-15].

## 2. METHOD

This study proposes a comprehensive literature assessment of the present electrical environment in the UK, highlighting the primary constraints of the existing network. A unidirectional and vertically integrated grid to address the need for a substantial high voltage transmission network, energy transportation losses of up to 9.1% [16] of total produced power are incurred by this structure based on huge power plants with no optimal geographical placing.

The development of an efficient and sustainable electric power supply system relied heavily on assessing the demand and availability of input sources. One primary approach involved selecting a suitable system, such as renewable energy resources, based on these factors. Once identified, these renewable energy sources were integrated into a Microgrid, along with other resources, to create a comprehensive and resilient power network.

Alongside this integration, energy storage and management systems were implemented to ensure optimal utilization of the generated electricity. These storage systems allowed for the efficient capture and distribution of excess energy, reducing wastage and maximizing overall system performance. In addition, effective energy management strategies were deployed within the microgrids to regulate power flow, prioritize load requirements, and ensure a reliable and stable power supply. These advancements in energy management within microgrids not only promoted sustainability but also contributed to a more resilient and self-sufficient energy infrastructure in the past.A functional power connection between the controllers is made possible by unifying the Shunt and Series FACTS Controllers.

Series FACTS Controllers, although having a much higher power output for a given MVA size, must be constructed to survive static and dynamic overloads, as well as tolerate or bypass short circuit currents [3].

Shunt-connected FACTS Controllers have long been employed in distribution and transmission networks because to their low cost and ease of operation. Most FACTS Controllers with a shunt connection are static shunt compensators like SVC and STATCOM.

Figure 1 shows the block diagram of the proposed model, with control scheme for PWM Inverter. Safeguarding the Electricity Network Today's power transmission networks are feeling the pressure of rising demand and restrictions on building new lines. A system in such a state of stress is more vulnerable to the effects of external disturbances. The findings demonstrate the continued efficacy of FACTS devices in stressing a transmission network to extract maximum performance from its available capabilities while keeping the necessary safety margin.

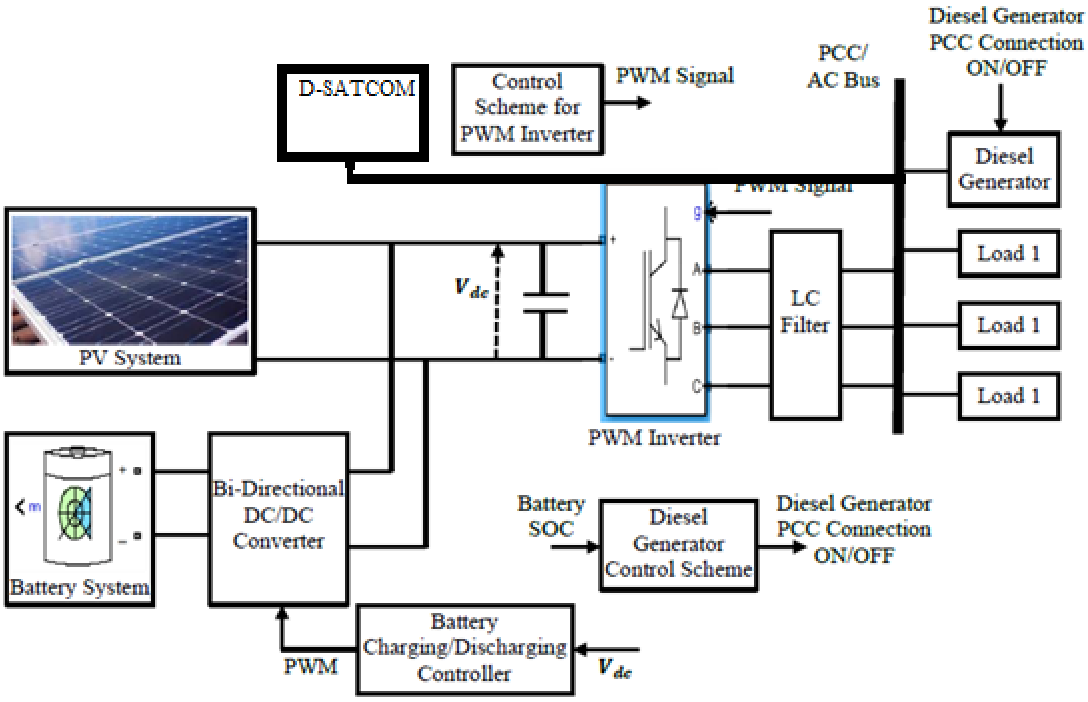

Figure 1: Block Diagram of the proposed 1MW MG

It includes components such as renewable energy sources (like solar panels), energy storage systems (such as batteries), conventional generators, and loads. Creating a representative model is crucial to ensuring that the simulation results are applicable to real-world microgrid scenarios. The simulation results demonstrate the robustness and effectiveness of the methodology across a wide range of operating conditions.

The differential equations of the machine and exciter for the *m* machine, *n* bus system are expressed as follows [13]:

$$\frac{d\delta_i}{dt} = \omega_s \quad \omega_i - 1 \qquad i = 1, 2, \ldots, m \qquad (1)$$

$$\frac{d\omega_i}{dt} = \frac{P_{mi}}{M_i} - \frac{P_{ei}}{M_i} - \frac{D_i(\omega_i - 1)}{M_i} \qquad i = 1, 2, \ldots, m \qquad (2)$$

$$\frac{dE'_{qi}}{dt} = -\frac{E'_{qi}}{T'_{doi}} - \frac{(x_{di} - x'_{di})i_{di}}{T'_{doi}} + \frac{E_{fdi}}{T'_{doi}} \qquad i = 1, 2, \ldots, m \qquad (3)$$

$$\frac{dE_{fdi}}{dt} = -\frac{E_{fdi}}{T_{Ai}} + \frac{K_{Ai}}{T_{Ai}} \quad V_{refi} - V_i \qquad i = 1, 2, \ldots, m \qquad (4)$$

Where:

M is the moment of inertia of the generator rotor.

$P_m$ is the mechanical power input to the generator.

$P_e$ is the electrical power output from the generator.

These equations, when solved together with the power system equations, provide a comprehensive understanding of the dynamic behavior of a synchronous generator connected to an n-bus system. They are vital for stability analysis and control of power systems.

## 3. Simulation Results and Analysis

The suggested MG was simulated using Case 2B's variable load and maximum irradiation value of 60% for the Photo-Voltaic system. This case study illustrates the benefits of the proposed approach in efficiently mitigating load variations. Figure 2 shows the Simulink of the proposed model.

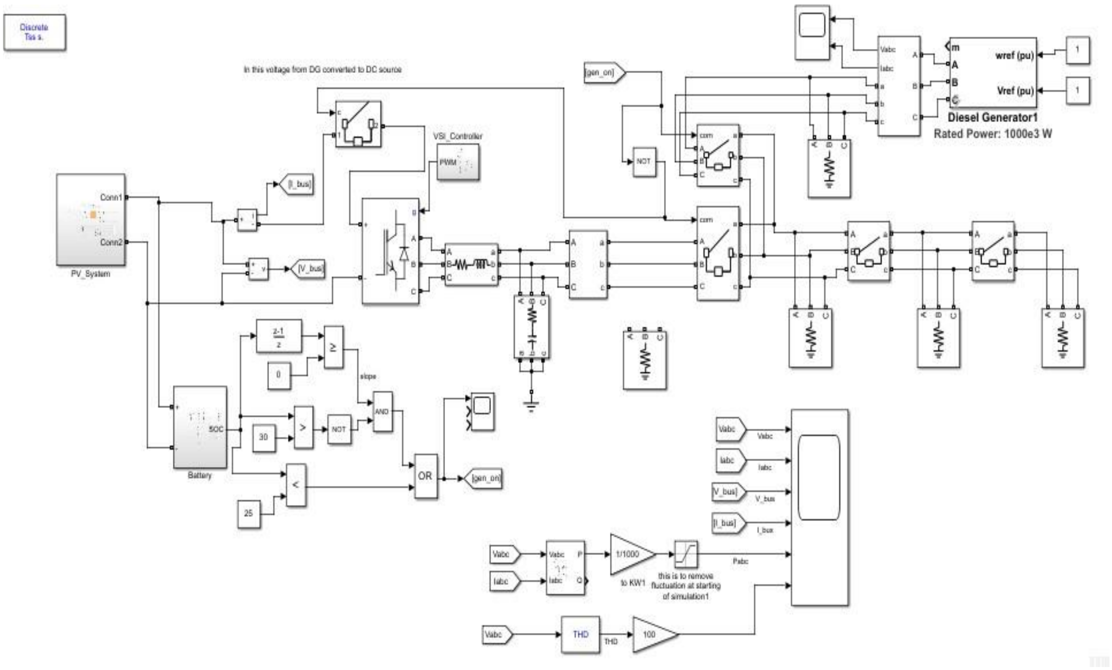

Figure 2: Simulink model of small energy microgrid 1 MW

During the course of this simulation study figure 3, a load of 400 kilowatts (kW) was linked to the MG and its power was increased from zero to one second in increments of one. When compared to MG, the load that is applied at 1 second and 2 seconds is 400 kilowatts more. Therefore, the total load over MG was 800KW during the first 1-2 seconds of the simulation, and for the next 1-3 seconds, the total load over MG was 1-3 seconds [17,18].

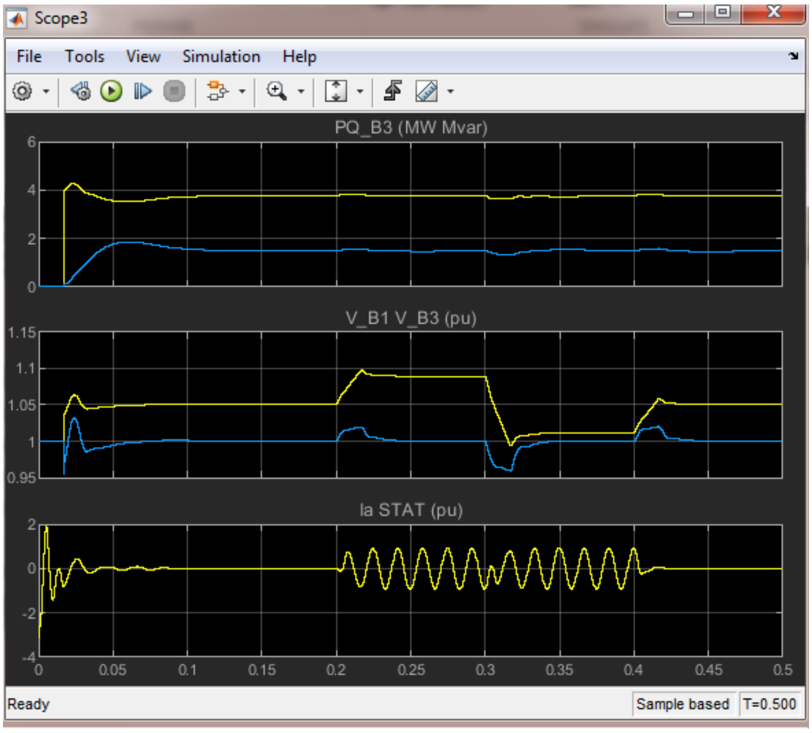

Figure 3: Output Wave form of Voltage Inv and Voltage Vap

Various weather conditions limit the electricity generation of solar panels, which is one of the hurdles for photovoltaics. In this case, the investigation demonstrated the performance of the recommended MG across a variety of meteorological situations. For the simulation training, the load request was kept constant at 800 Kilowatt. We used a time-varying irradiance profile applied to the solar panels to mimic weather conditions. Under typical conditions, solar panels generate the most electricity with a full light of 1000 W/m2. The solar panels' irradiance profile shown in Fig. 4

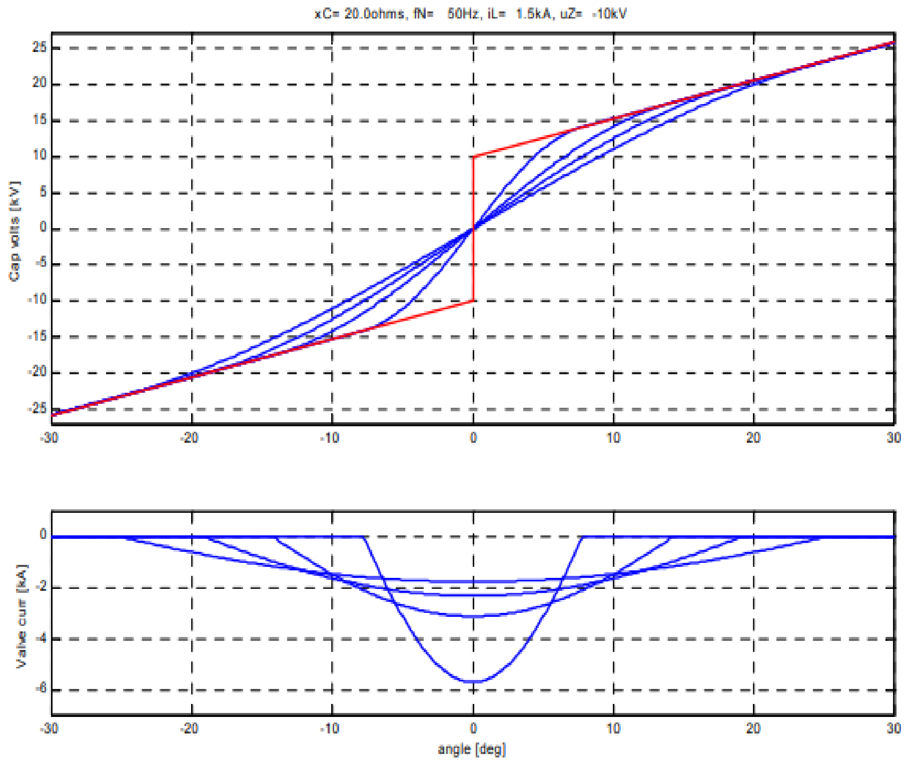

Figure 4: Capacitive mode voltage inversions, and infinite.

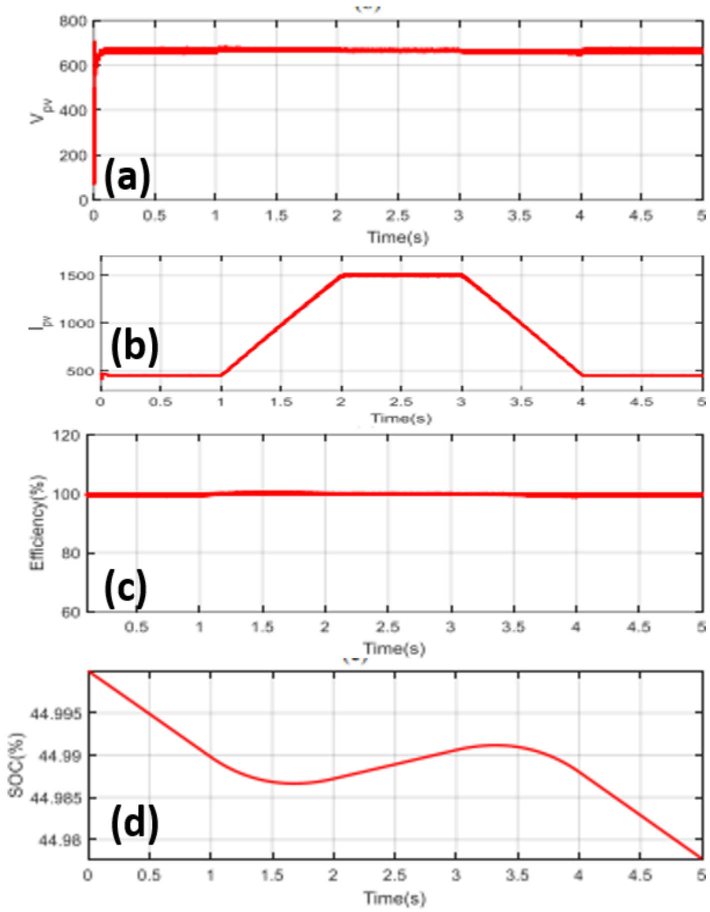

Figure 4: Simulation results of viltage, current and efficiency across time

Figure 5(a) shows the average voltage across the PV system, which is a steady 665V throughout the experiment. Figure 5(b) displays the current in the PV system, whereas Figure 5(c) shows the overall efficiency of the system throughout the simulation. The SOC of the battery system is shown in Figure 5(d), demonstrating that the battery charging/unloading controller is functioning properly.

PV power is inadequate to serve the load when the irradiance is 300W/m2, thus the battery system kicks in to provide the remainder. The SOC curve shows that the SOC decreases throughout this period, and the batteries start to deplete. The SOC battery starts to curve from discharging to charging when the PV structure begins providing enough power to operate the loads during the evolution phase of irradiation from 300W/m2 to 1000W/m2 [19-20].

The simulation will show how effective battery controllers are at keeping dc-link tension constant by keeping the reference value of link tension constant throughout the simulation. Power transfer from and to the battery arrangement as it depict the average voltage and load current over an extended period of time. Instantaneous load power whereas THD over the load B in converted voltage.

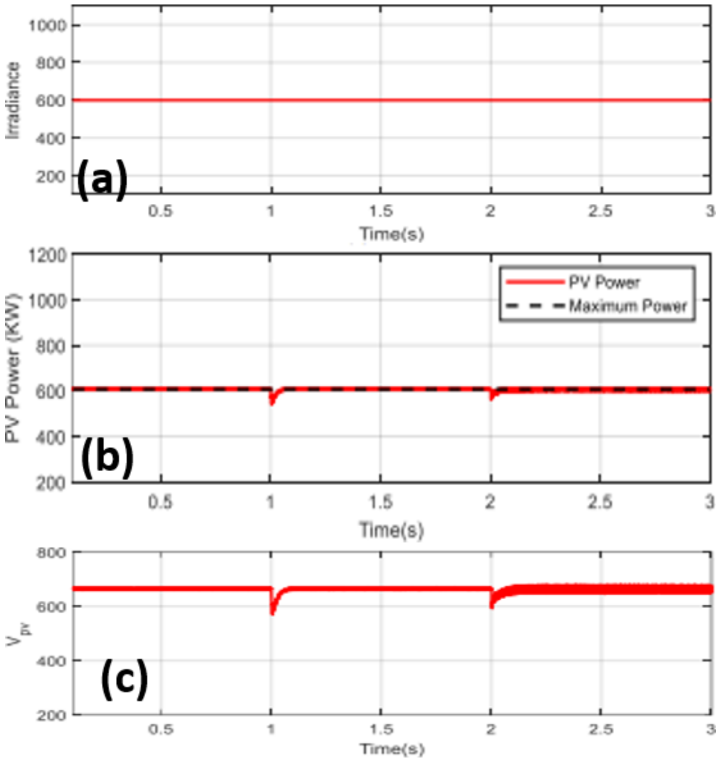

Figure 5: Output Wave form of Voltage Inv and Voltage Vap

Scenario 2 has a constant irradiation of 600W/m2, as shown in Figure 7(a) throughout the simulation period. The PV system's maximum output is seen in Figure 4.6. combined with the maximum power output that the PV system is capable of producing (b). The dc connection (c) voltage is shown in Fig. 7 to be equal to the PV system voltage. There is some voltage fluctuation when the load is rapidly increased at 1s and 2s. The dc-link voltage has returned to 665V because of the work of the battery charge/discharge controller. The consistent current consumption may be attributed to the constant power output from the PV system. A comparable scenario. A PV system's efficiency is shown in Fig. 6 (c). The battery charging and discharging rates were shown graphically as a SOC battery.

Without DSTATCOM: In a power system, during a fault or disturbance, voltage and current levels can deviate from their normal values. This can lead to instability, especially in situations where there's a sudden change in load or a fault in the system. Without a

DSTATCOM, the system may struggle to maintain stable voltage levels and could lead to voltage collapse or instability.

With DSTATCOM: A DSTATCOM is a power electronic device that can quickly control the voltage and current in a distribution system. It can provide or absorb reactive power as needed, helping to maintain voltage levels within an acceptable range during disturbances. When a fault or disturbance occurs, the DSTATCOM can inject or absorb reactive power to support the grid, reducing voltage fluctuations and improving stability.

## 5. CONCLUSION

This paper aimed to design and simulates an islanded 1MG microgrid (MG) system for the army and group. A 1MW photovoltaic system powered the proposed MG to reduce its environmental effect. After the PV system failed due to weather, a battery system was built to keep the dc-link voltage at 665V and power these capacities [21-23].

Two case studies proved the effectiveness and operation of the proposed MG: (1) with diverse PV system weather conditions and (2) with varying MG loads. The simulation reveals that the suggested method reduces the influence of variable irradiance while effectively satisfying load demand. A diesel generator was also meant to power important loads and provide backup power in case of unexpected weather. The system maintained the dc-link voltage at the orientation value throughout the simulation, and the THD was below 5%.

- Improved MGs, a range of electrical and electronic devices, may help create intelligent networks, the future of conventional systems. Customers and utilities want greater freedom, therefore the distributed paradigm is growing [24].
- DC Microsystems studies more properties than AC systems. Energy management drives MG control in the central controller. It is less reliable than the decentralized control strategy. This requires meeting worldwide standards for voltage management, ear detection, transient levels, and more.
- The system's control technique must provide object dependability, safety, and interoperability. Many control algorithms—centralized, decentralized, and distributed—meet worldwide standards. AC microsystems need frequency and voltage management. Two controllers needed. This control uses hierarchical or monitoring unit data and control methods. Keep the system running. DC microphone controllers use a single device instead of two (frequency and voltage) in AC microphone controllers.
- Despite this, there are still obstacles to overcome because of the rapid dynamics and short reaction time of DG or distributed energy, the inherent imbalances of MG, the limited energy storage capacity and lack of inertia, and the huge numbers [25].
- Depending on the application and integration environment, the study may expand on the scenarios and topologies of connected AC/DC HMGs and allow dynamic evaluations of different combinations of AC/DC HMGs (market circumstances, regulatory conditions, DG Possibility of departmental integration, etc.). In addition, the scenarios and topologies of linked AC/DC HMGs may be used as the basis for developing new AC/DC HMGs.

Novelity

By facilitating the integration of renewable energy sources and ensuring their stable operation, this approach contributes to environmental sustainability. Microgrids with D-STATCOM and battery-based storage enable higher utilization of clean energy, reducing dependency on fossil fuels and mitigating greenhouse gas emissions. The combination of D-STATCOM and battery-based storage allows for sophisticated energy management strategies. These systems can intelligently balance the supply and demand, store excess energy during peak generation periods, and discharge stored energy during high demand, optimizing the microgrid's overall performance and efficiency.

Ensuring stability within such systems is challenging due to the intermittent nature of renewable energy sources. The use of D-STATCOM and batteries addresses this challenge by providing real-time compensation for voltage imbalances and fluctuations, thereby enhancing the overall stability of the microgrid. The incorporation of D-STATCOM and battery-based storage not only improves stability but also enhances the resilience and reliability of microgrids. Microgrids with these advanced technologies are better equipped to handle sudden changes in load or generation, ensuring continuous power supply even during transient disturbances or grid faults.

## References

[1] D P Kothari, I J Nagrath, and R K Saket. Modern power system analysis. Tata McGraw-Hill Education, New Delhi, India, 2021.

[2] Ahmadali Khatibzadeh, Mohammadreza Besmi, Aminollah Mahabadi, and Mahmoud Reza Haghifam. Multi-agent-based controller for voltage enhancement in ac/dc hybrid microgrid using energy storages. Energies, 10(2):169, 2017.

[3] Tiezhou Wu, Fanchao Ye, Yuehong Su, Yubo Wang, and Saffa Riffat. Coordinated control strategy of dc microgrid with hybrid energy storage system to smooth power output fluctuation. International Journal of LowCarbon Technologies, 15(1):46–54, 2020.

[4] Rahman Saidur, EA Abdelaziz, Ayhan Demirbas, MS Hossain, and Saad Mekhilef. A review on biomass as a fuel for boilers. Renewable and sustainable energy reviews, 15(5):2262–2289, 2011.

[5] Saad Mekhilef, Rahman Saidur, and Azadeh Safari. Comparative study of different fuel cell technologies. Renewable and Sustainable Energy Reviews, 16(1):981–989, 2012.

[6] Quentin Tabart, Ionel Vechiu, Aitor Etxeberria, and Seddik Bacha. Hybrid energy storage system microgrids integration for power quality improvement using four-leg three-level npc inverter and second-order sliding mode control. IEEE Transactions on Industrial Electronics, 65(1):424–435, 2017.

[7] Kumari Sarita, Sachin Kumar, Aanchal Singh S Vardhan, Rajvikram Madurai Elavarasan, RK Saket, GM Shafiullah, and Eklas Hossain. Power enhancement with grid stabilization of renewable energybased generation system using UPQC-FLC-EVA technique. IEEE Access, 8:207443–207464, 2020.

[8] Jaynendra Kumar, Anshul Agarwal, and Nitin Singh. Design, operation and control of a vast dc microgrid for integration of renewable energy sources. Renewable Energy Focus, 34:17–36, 2020.

[9] James T Reilly. From microgrids to aggregators of distributed energy resourcesthe microgrid controller and distributed energy management systems. The Electricity Journal, 32(5):30–34, 2019.

[10] Snigdha Sharma, Lokesh Varshney, Rajvikram Madurai Elavarasan, Akanksha Singh S Vardhan, Aanchal Singh S Vardhan, RK Saket, Umashankar Subramaniam, and Eklas Hossain. Performance enhancement of pv system configurations under partial shading conditions using ms method. IEEE Access, 9:56630–56644, 2021.

[11] Jaynendra Kumar, Anshul Agarwal, and Nitin Singh. Design, operation and control of a vast dc microgrid for integration of renewable energy sources. Renewable Energy Focus, 34:17–36, 2020.

[12] James T Reilly. From microgrids to aggregators of distributed energy resources. the microgrid controller and distributed energy management systems. The Electricity Journal, 32(5):30–34, 2019.

[13] Umer Akram, Muhammad Khalid, and Saifullah Shafiq. Optimal sizing of a wind/solar/battery hybrid grid-connected microgrid system. IET Renewable Power Generation, 12(1):72–80, 2017.

[14] Ranjay Singh, Ramesh C Bansal, Arvind R Singh, and Raj Naidoo. Multiobjective optimization of hybrid renewable energy system using reformed electric system cascade analysis for islanding and grid connected modes of operation. IEEE Access, 6:47332–47354, 2018.

[15] Adam Hirsch, Yael Parag, and Josep Guerrero. Microgrids: A review of technologies, key drivers, and outstanding issues. Renewable and sustainable Energy reviews, 90:402–411, 2018.

[16] MD IBRAHIM ADHAM. Optimal planning of nuclear-renewable microhybrid energy system by particle swarm optimization. IEEE Access, 8:181049–181073, 2018.

[17] Sachin Kumar, RK Saket, Dharmendra Kumar Dheer, JensBo HolmNielsen, and P Sanjeevikumar. Reliability enhancement of electrical power system including impacts of renewable energy sources: a comprehensive review. IET Generation, Transmission & Distribution, 14(10):1799–1815, 2020.

[18] G Soundarya, R Sitharthan, CK Sundarabalan, C Balasundar, D Karthikaikannan, and Jayant Sharma. Design and modeling of hybrid dc/ac microgrid with manifold renewable energy sources. IEEE Canadian Journal of Electrical and Computer Engineering, 44(2):130–135, 2021.

[19] Jingjing Huang, Jianfang Xiao, Changyun Wen, Peng Wang, and Aimin Zhang. Implementation of bidirectional resonant dc transformer in hybrid ac/dc micro-grid. IEEE Transactions on Smart Grid, 10(2):1532–1542, 2017.

[20] Sachin Kumar, Kumari Sarita, Akanksha Singh S Vardhan, Rajvikram Madurai Elavarasan, RK Saket, and Narottam Das. Reliability assessment of wind-solar pv integrated distribution system using electrical loss minimization technique. Energies, 13(21):5631, 2020.

[21] Vallem VVSN Murty and Ashwani Kumar. Optimal energy management and techno-economic analysis in microgrid with hybrid renewable energy sources. Journal of Modern Power Systems and Clean Energy, 8(5):929– 940, 2020.

[22] Umer Akram, Muhammad Khalid, and Saifullah Shafiq. An innovative hybrid wind-solar and battery-supercapacitor microgrid system—development and optimization. IEEE access, 5:25897–25912, 2017. [23] Xianglong Liu, Youbo Liu, Junyong Liu, Yue Xiang, and Xiaodong Yuan. Optimal planning of ac-dc hybrid transmission and distributed energy resource system: Review and prospects. CSEE Journal of Power and Energy Systems, 5(3):409–422, 2019.

[23] PC Sekhar and Sukumar Mishra. Storage free smart energy management for frequency control in a diesel-pv-fuel cell-based hybrid ac microgrid. IEEE transactions on neural networks and learning systems, 27(8):1657– 1671, 2015.

[24] Mohamed A Eltawil. Zhengmingzhao,“. MPPT techniques for photovoltaic applications. Newable and Sustainable Energy Reviews, 25:793– 813, 2013.

[25] Mohamed A Eltawil. Zhengmingzhao,“. MPPT techniques for photovoltaic applications. Newable and Sustainable Energy Reviews, 25:793– 813, 2013.