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IMPROVING PERFORMANCE OF AUTONOMOUS DC MICROGRID WITH FUZZY BASED DISTRIBUTED ENERGY STORAGE SYSTEM

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Abstract: This project aims to enhance the performance of autonomous direct current (DC) micro grids using fuzzy-based distributed energy storage systems. The focus is on optimizing the energy storage capacity and discharge rate of the distributed storage systems using fuzzy logic. This approach allows for real-time energy management, better load balancing, and improved system stability and resilience. The project involves modeling and simulation of the microgrid with fuzzy-based energy storage systems, analyzing the results, and comparing them with a microgrid without this technology. The study will also evaluate the impact of the fuzzy-based system on the microgrid's efficiency, reliability, and cost-effectiveness. The findings of this research could contribute to the development of more efficient and reliable DC microgrids, which can help in the transition towards a sustainable energy future. Ultimately, this project aims to advance the understanding and adoption of advanced energy storage technologies in the context of DC microgrids.

KEYWORDS: DC microgrid, Distributed Energy Storage System, Fuel Cell, Stability analysis, Super capacitor

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INTRODUCTION

The need for centralized power generation amidst notable advancements from clean and green power from renewable energy sources (RESs) has seen growing developments worldwide over the past decade. Additionally, development in distributed generation is promising, including one from renewable energy sources. A very flat area for energy transfer improvement persists over enduring thermally accented transmission connections that operate over long distances. Due to regional political matters, the establishment of new transmission corridors is limited in profit to the economic scenario and may need more time to complete. Apart from this, a microgrid is the best solution if the power generation station is far away from the remote location and is more advantageous regarding global economic and fruitful actions due to their distributed generation features. DC Microgrid is becoming increasingly popular and compatible as the penetration of renewable energy sources, loads, and storage devices rise exponentially due to their remarkable simplicity, stability, and effectiveness. In comparison, certain power quality issues specific to AC microgrid, such as frequency modulation, reactive power control, stability issue, and cost-effective solutions in various applications, have no impact on DC Microgrids. In contrast, the intermittent and variable nature of renewable energy sources makes the DC Microgrid system complex. Since of renewable energy sources intermittent nature, stand-alone DC Microgrid banks on energy storage systems to balance the demand inequality and improve the overall power quality and stability. fig.1.1 shows an autonomous DC Microgrid consisting of renewable energy sources, along with PV and wind turbines, Dis, along with fuel Cells and Super Capacitors coupled to common DC bus via power electronic converters.

LITERATURE REVIEW

P. Singh, J. Singh Lather, proposes that This study proposed a novel method based on variable structure control for sharing power between battery and super capacitor (SC) energy storage devices to address

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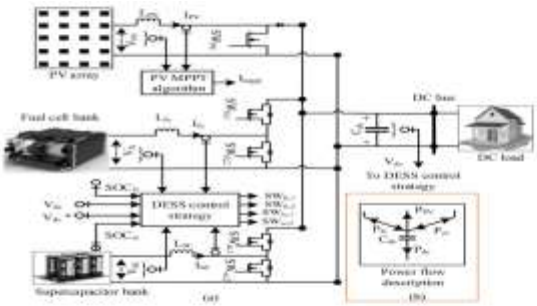
demand-generation disparity and DC bus voltage regulations. It allows for moderate and fast compensations using hybrid energy storage devices, ranging from batteries to fast SCs controlled by battery current error signals. The proposed method using hybrid energy storage devices controlled by proportional integral (PI) and variable-structured controllers enhances DC bus regulations with the reduced stress levels of batteries. Furthermore, redirecting unwaged battery currents toward SCs for fast compensation enhances the lifespan of batteries. The effectiveness of the method has been analyzed using simulations and compared with a conventional control method in terms of peak DC bus voltage deviations. The results were experimentally validated using a real-time hardware-in-loop (HIL) simulator based on a field-programmable gate array.

S. Peyghami, H. Mokhtari, F. Bleiberg, proposes that the advances in power electronics, DC-based power systems, have been used in industrial applications such as data centers, space applications, aircraft , offshore wind farms, electric vehicles , DC home systems , and high-voltage DC transmission systems. To provide such sensitive loads with more reliability, efficiency, and controllability for future power systems, AC microgrid and more recently DC microgrid and smart-grid technologies have been employed.

To obtain stable and optimal operation in DC power systems (microgrids), proper load sharing among different energy units and acceptable voltage regulation across the microgrid is required. This can be achieved by use of a hierarchical power management structure.

WORKING PRINCIPLE



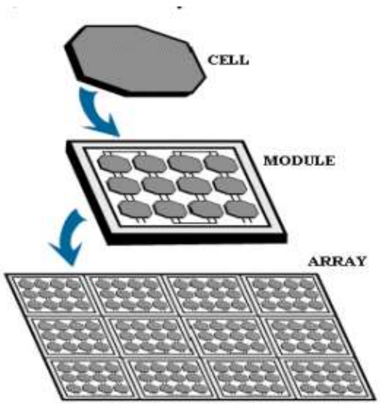
Above figure show the circuit of the total microgrid system. An autonomous DCMG comprising the PV array system, DESS, and DC load is considered in Fig. The DESS devices employ a significant distinct power density and energy density to overcome solar power generation's intermittency. PV system is connected to the DC bus through the boost converter while the FC and the SC are connected to the DC bus through bidirectional DC/DC converters (BDDC). Chiu et al. explained the advantage of the BDDC for fuel cells in terms of a highly efficient and simple circuit. Therefore, in this work, a BDDC for the fuel cell is employed. The mathematical model of a fuel cell (FC) used from Mathworks is executed. In this work, a proton exchange membrane fuel cell (PEMFC) has been employed because of its faster response time than alkaline fuel cell (AFC) Similar to a normal capacitor, the super capacitor also has two parallel plates with a bigger area. But the difference is, the distance between the plates is small. The plates are made up of metals and soaked in electrolytes. The plates are separated by a thin layer called an insulator. When opposite charges are formed on both sides of the insulator, an electric double layer is formed and the plates are charged. Hence the super capacitor is charged and has higher capacitance. These capacitors are used to provide high power and enable high load currents with low resistance. The cost of the super capacitor is high because of its high charging and discharging capacitance.

A fuel cell is an electrochemical device that converts chemical energy from a fuel into electrical energy without combustion. Fuel cells use a chemical reaction between a fuel, such as hydrogen or natural gas, and an oxidant, such as oxygen, to produce electricity, water, and heat. Fuel cells are a promising technology for generating electricity because they are highly efficient, clean, and quiet. Distributed energy storage systems (DESS) refer to a collection of energy storage systems that are located in various locations and are connected to a power grid or a microgrid. These systems can store energy from renewable sources, such as solar or wind power, and release it when needed. DESSs can help reduce the need for expensive infrastructure upgrades, improve grid stability, and increase the integration of renewable energy into the grid. The PV cells are made of semiconductors like silicon when photons from sunlight hit the PV panel electrons are excited from their current molecular orbital. Once excited an electron can either dissipate the energy in the form of heat and return to its orbital or traverse through the cell until it arrives close to an electrode flowing as current through the material to nullify the potential. The materials chemical bond is vital for this operation to work, and in general, the silicon is used in two layers, one layer bonded with boron, the other phosphorus. These layers have different chemical electric charges and subsequently both drive and direct the current of electrons. The combination of solar cells as an array converts solar energy into a usable amount of direct current (DC) electricity.

Fuzzy logic control mainly depends upon the rules formed by the Linguistic variables. Fuzzy logic control is free of complex numerical calculations, unlike other methods. It only uses simple mathematical calculations to control the model. Despite relying on basic mathematical analysis it provides good performance in a control system. Hence, this method is one of the best methods available and also easier one to control a plant. Fuzzy logic control is based on the Fuzzy set theory. In fuzzy set theory, each element has a degree of membership with which it belongs to any particular set. We can say that fuzzy sets are like classical sets without much sharper boundaries. Fuzzy Logic Controller (FLC) is more used when the precision required is moderate and the plant is to be devoid of complex mathematical analysis.

PARTS OF THE SYSTEM

1. PV ARRAY



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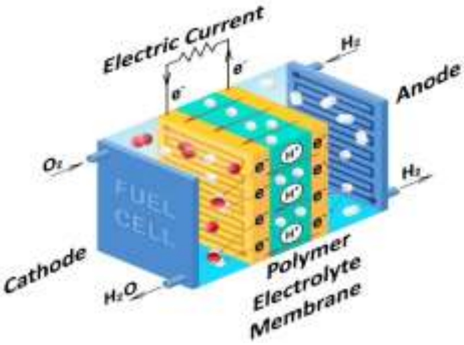
2. FUEL CELL



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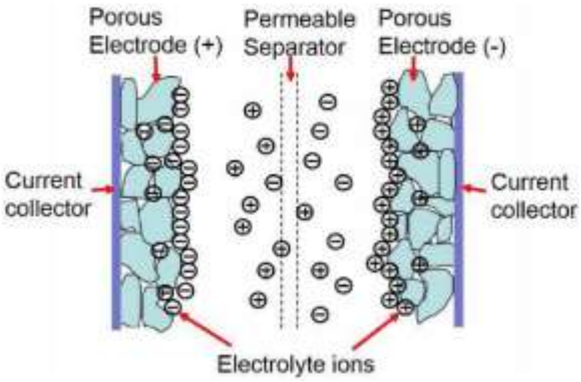
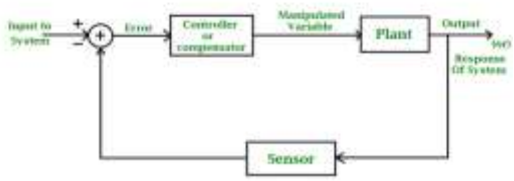
3. SUPER CAPACITOR



A super capacitor also called as ultra-capacitor or a high-capacity capacitor or double-layer electrolytic capacitor that can store large amounts of energy nearly 10 to 100 times more energy when compared to the electrolytic capacitors. It is widely preferred than batteries because of its faster charging capacity and faster delivery of energy. It has more charging and discharging cycles than rechargeable batteries. These are developed in modern times for industrial and economic benefits. The capacitance of this capacitor is also measured in Farad’s (F). The main advantage of this capacitor is its efficiency and high-energy storage capacity.

4. FUZZY LOGIC CONTROLLER



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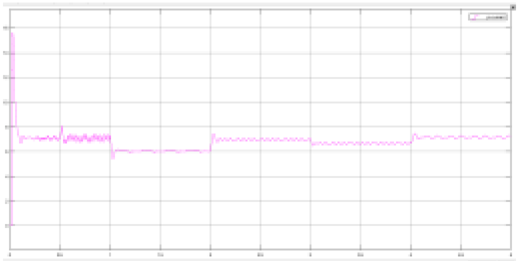
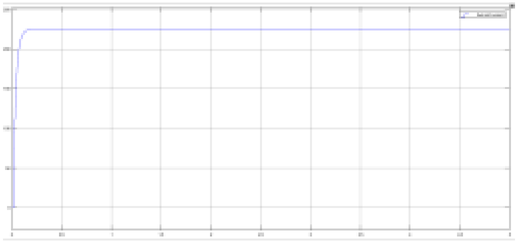
OUTPUT WAVEFORMS

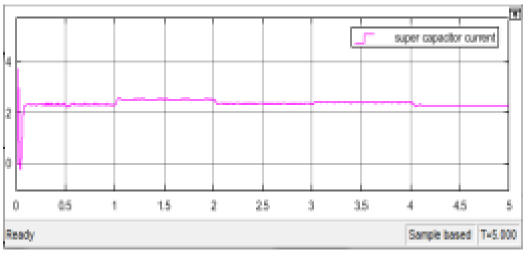
1. PV CURRENT



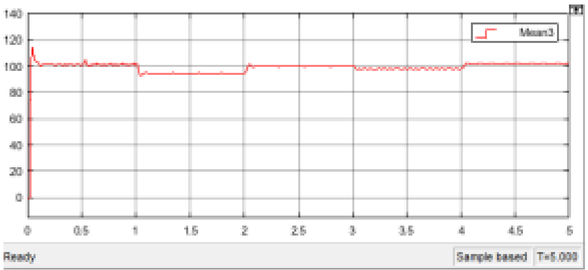
2. FUEL CELL CURRENT



3. SUPER CAPACITOR CURRENT



4. Vdc



ADVANTAGES

1. More efficiency.
2. Less harmonics.
3. It increases stability of the system.

DISADVANTAGES

1. It requires more cost.
2. It requires skilled person to operate.

CONCLUSION

In conclusion, this project has demonstrated the effectiveness of fuzzy-based distributed energy storage systems in improving the performance of autonomous DC microgrids. The results of the modeling and simulation studies have shown that the use of fuzzy logic can optimize the energy storage capacity and discharge rate of the distributed storage systems, leading to better energy management and load balancing. The implementation of this technology can also reduce the need for frequent battery replacements, leading to cost savings and improved system reliability. Moreover, the study has shown that the fuzzy-based system can enhance the stability and resilience of the microgrid, making it more capable of withstanding power disturbances. Overall, this project has contributed to the development of more efficient and reliable DC microgrids, which can help to support the transition towards a sustainable energy future. The findings of this research have important implications for the design and operation of future energy systems, and can inform the development of more advanced energy storage technologies for DC microgrids.

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