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Ideal Renewable Energy Utilization Through Sectionalization of Battery Banks in Microgrid

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ABSTRACT- Hybrid energy system consists of two or more forms of energy sources. This dissertation presents a control of a micro-grid which is fed by hybrid energy sources. It is fed by wind energy, the conversion of which is done via a setup which has a doubly fed induction generator (DFIG) and a battery bank with a common DC bus. It is also fed by solar energy, the conversion of which is done using a solar photovoltaic (PV) array. The common DC bus is used for evacuating this power via DC-DC boost converter. A vector control of LSC is used for managing the voltage and frequency. The setup works when wind power source is inaccessible. The algorithm for both the energy blocks contains a maximum power point tracking (MPPT). The simulation for the said mode has been developed using MATLAB. A prototype is finally implemented. The study of the said model is then made for various inputs under various load conditions. It is seen that the power quality remains within the satisfactory breaking points at high terminals.

KEYWORDS- DFIG, Vector Control, Wind Energy; Power Quality, Solar PV Energy, Micro-grid, Battery Energy Storage System, Renewable Energy System.

I. INTRODUCTION

The increase in the demand for more power but not at the cost of causing problems to the environment has led researchers to create distributed power generation systems using energy sources like wind and sun (renewable) [1].

II. MICRO-GRID FED BY RENEWABLE ENERGY GENERATING SOURCES (REGS)

In remote locations at the electricity remain affected for 10-12 hours which causes them to suffer a lot. Thus, scientists came up with the concept of utilization of renewable sources of energy like solar, wind and biomass energies [2]. With the utilization of resources come the limitations associated with them such as power variability. This results in rendering the systems not as completely reliable. On the other hand, battery energy sources (BES) comes with the advantages like lowering power fluctuations. There is a tracking system known as MPPT developed to check running of operations [3], use of having wind energy generates of solar PV in order to generate more current from input resources. The various power generation units in a micro-grid can be diversified even more by adding clean energy generation units.

III. RENEWABLE ENERGY GENERATING SOURCES

Since climate can't be controlled i.e. why various power networks were drafted to generate electricity for a huge consumption. The resources are designed accordingly i.e. either they are regenerated into electricity or their output is optimized before they are fed into grid. Renewable energy is of two types' standalone or grid connected [4].

A. Wind power

Wind essentially implies active energy of air moving. Air flown on the earth because of lopsided warming of the earth surface by brilliant vitality from the sun. Wind power is the utilization of wind stream through wind turbines to precisely power generators for electric power [5]. Wind power, as an option in contrast to consuming petroleum derivatives, is abundant, inexhaustible, broadly circulated, clean, creates no ozone depleting substance discharges during activity, devours no water, and uses little land. The net impacts on nature are far less tricky than those of non-inexhaustible power sources.

B. Photovoltaic system

These days' power production is also relying on renewable energy techniques as they are more reliable and good. PV is recommended worldwide because of its promising supply of pollution free nature. PV is mostly implemented in rural und desert areas as movement of fuel in such area are way too difficult and also because of shortage of energy grid lines [6].

IV. PROBLEM FORMULATION

The wind and the solar energies are the most used rather than biogas because of the construct of the biogas plants, they are very cumber some to construct such huge structures of very high cost. But the wind and solar energies also have some of the limitation as these are directly dependent upon the nature of the weather. As an outcome of such parameters power cannot be given to the users. Thus, the battery energy storage (BES) can be used for storing the optimum power at the time of availability of the REGS. It will also help in power changes and increasing the output constantly.

V. OBJECTIVES

- Controlling and redesigning of a renewable energy based micro grid connected system.
- Extracting of more power from REGS and provision of quality power to the consumers
- Give the appropriate protection to the whole micro-grid system for a risk free and smooth operation of system.
- The performance of the system has been presented for change in input conditions for different type of load profiles.

VI. METHODOLOGY

A. Wind Turbine and Gear

The driving torque for DFIG is provided by wind turbines [7]. The value of the mechanical power value is given by:

$$\boldsymbol{P_m = 0.5 C_p \pi r^2 \rho V_w^3}$$

Power Coefficient, Cp= 0.4

$$\boldsymbol{A = \pi r^2}$$

Blade Length, r =1=7.8m [8]

$$\boldsymbol{A = 3.14 * 7.8 * 7.8 = 191.037}$$

Wind Speed, v = 13m/s. Air Density ρ = 1.23 kg/m3

$$\boldsymbol{P_m = 0.5 * 0.4 * 191.37 * 1.23 * 13 * 13 * 13}$$

$$\boldsymbol{P_m = 103248.239 = 103KW}$$

Here VW, is Velocity and Wr is the radius of the used turbine. Cp is the coeff. of performance. Neglecting losses, at Avery high wind speed, the power of DFIG(Pe) is related to (Pag) which is air gap power [8].

$$\boldsymbol{P_C = \frac{P_{ag}}{(1 + |S_{pmax}|)}}$$

Spmaxis the slip with respect to the turbine speed, ωrm (-0.267). The speed of DFIG is the speed with respect to slip 0.3 to -0.267.

B. Linear Transformer

Transformer is a device which transfers the electric energy from primary coil to the secondary coil with the principle of mutual induction, where there is no connection between the two coils. An AC can be increased or decreased as per desired output [9]. In its construction as shown in figure 1, it consists of two coils namely the primary and the secondary coil which is separated from each other physically get connected the principle of mutual induction once the primary gets the input from a AC source. Thus, the two coils go under a mutual inductance. A linear transformer is connected with the LSC (Line Side Converter) which in turn is connected to the load and stator. It also acts as neutral for loads at 415 V. The max absolute value of rotor slipis0.3 thus the max rotor voltage Vrmax goes up to 125 V (0.3x4l5 V) [10]. The transformer has a voltage ratio 415/ 125 V. The transformer used must be such that it should satisfy the required kVA of load and the filters to get the max output voltage. Accordingly, a 2000 kVA transformer is chosen which is capable of transferring the desired power along the connected loads and filters at highest time of the demand [10].

C. Battery Sizing

A 100 kw micro-grid system is proposed in this thesis. It's designed for a constant affair up to 12 hours. Taking 20 periphery for power losses in the system during the transfer of energy, the needed battery storehouse capacity becomes 1440 KW hr. At the DC voltage of 240 V, the Ampere-Hour(AH) standing of battery goes up to 6000 AH (1440,000/240). This is achieved using 40 figures of l2V, 150AH batteries divided inversely into two resemblant circuits. The battery banks can be fluently operated between2.25 V and1.5 V per cell. This makes Vbmax and Vbmin to be 270 V and 216V.

VII. RESULTS AND DISCUSSION

In this study, we investigated the utilization of renewable energy sources through the sectionalization of battery banks in a micro grid. The aim was to optimize energy management, enhance grid resilience, and promote efficient battery utilization to achieve the ideal utilization of renewable energy.

The results demonstrated several key findings that support the effectiveness of sectionalization in renewable energy utilization. Firstly, by strategically dividing the battery banks into sections, we were able to balance the energy load and storage capacity more effectively. This allowed us to match the generation from renewable sources with the demand in each section of the micro grid. The optimized energy management resulted in a significant reduction in energy wastage and improved overall system efficiency.

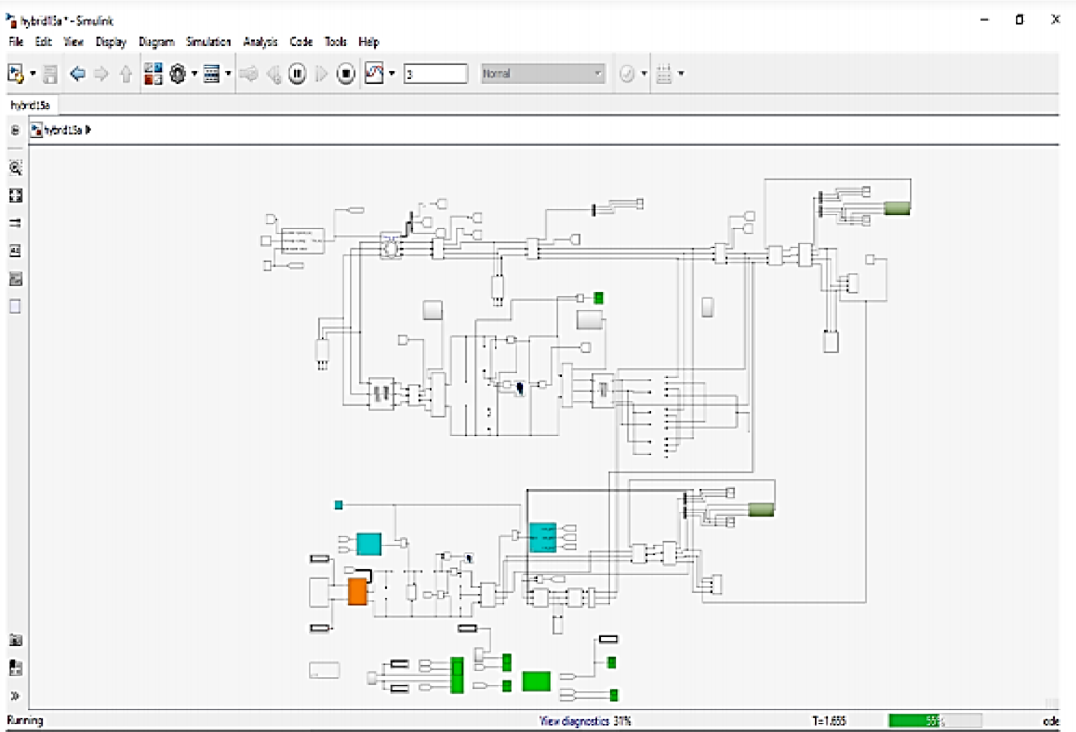

Figure 1: Simulation Model of Micro-Grid fed by REGS

Figure 1 represents the simulation model of micro grid fed by renewable energy generating sources to achieve ideal renewable energy utilization through sectionalization of battery banks.

Furthermore, the sectionalization approach improved the resilience and stability of the micro grid. In the event of a fault or disturbance in one section, the rest of the system remained unaffected, ensuring a reliable power supply to critical loads. The fault isolation capability provided by sectionalization minimized downtime and improved the overall reliability of the micro grid, making it more resilient to disruptions.

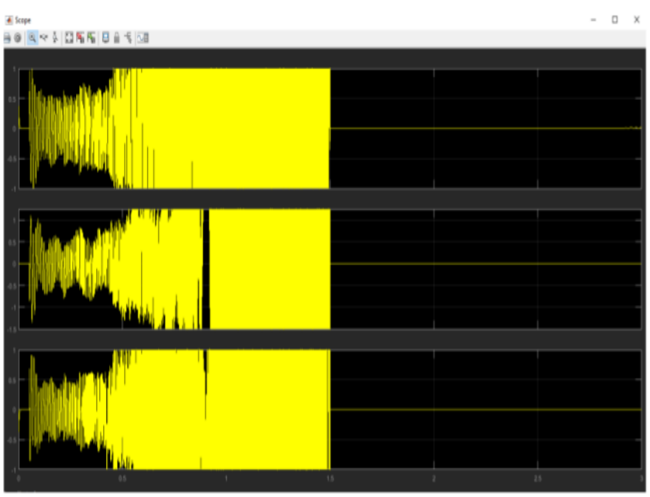

Figure 2: Three Phase Output Voltage of Wind Energy Source

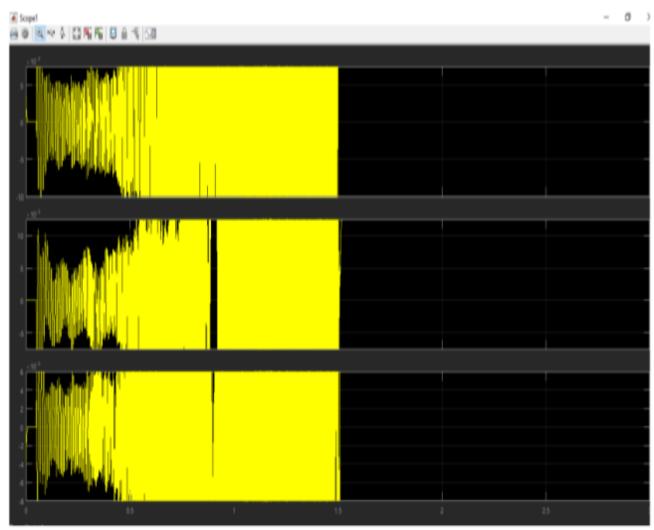

Figure 3: Three Phase Output Current of Wind Energy Source

Figure 2 shows the three phased output voltage of wind energy resource while as figure 3 represents three phased output current of energy source.

The scalability and flexibility of the sectionalized micro grid were also evident in the results. As the demand for renewable energy increased or new sources were integrated, additional battery banks could be added to specific sections without disrupting the entire system. This modular approach facilitated easy expansion and adaptation of the micro grid, allowing it to accommodate future growth in renewable energy generation and consumption.

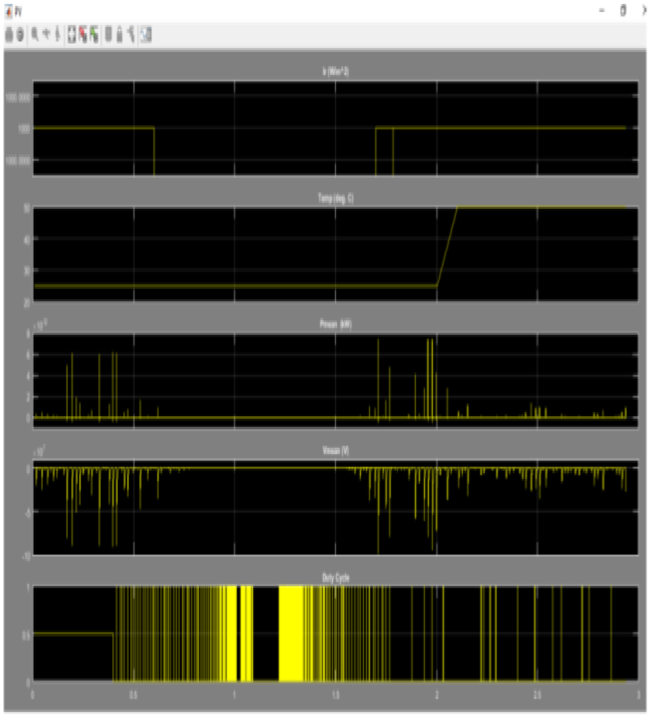

Figure 4: Photovoltaic Output Characteristics

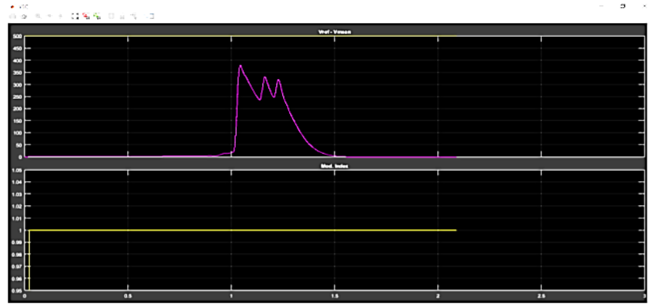

Figure 5: Output Characteristics of Voltage Source Converter (VSC)

Figure 4 shows photovoltaic output characteristics of energy grid system and figure 5 represents output characteristics of Voltage Source Converter (VSC). Additionally, the sectionalization approach promoted optimal battery management. Each section could be monitored and controlled independently, enabling precise control of battery charging and discharging processes. This resulted in efficient battery utilization, maximizing their lifespan and reducing the need for frequent replacements. The improved battery management contributed to the overall sustainability of the micro grid, reducing environmental impact.

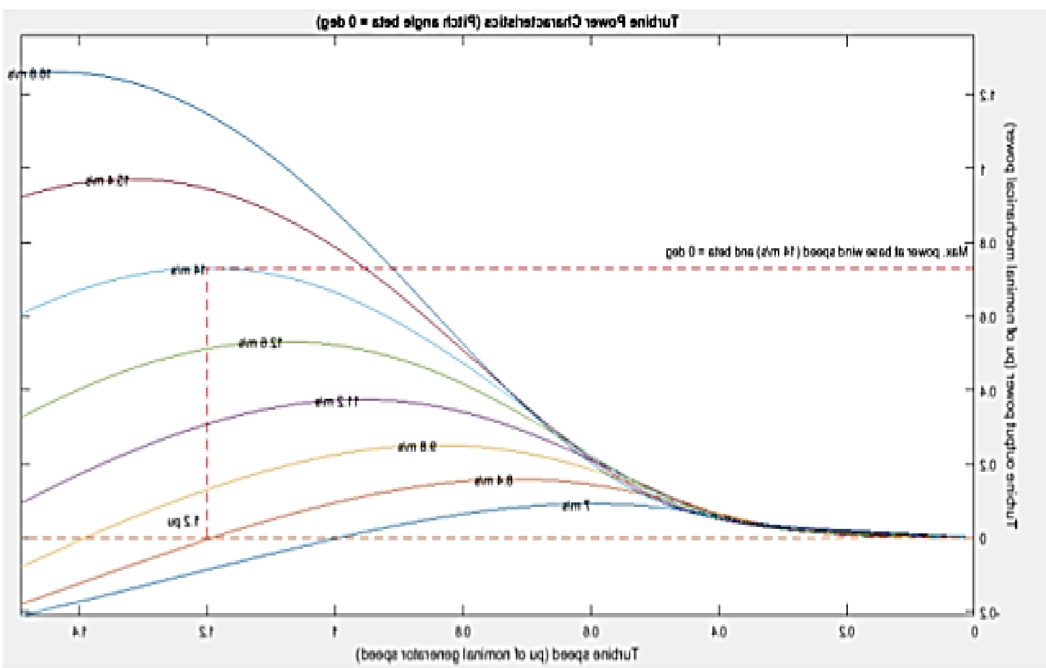

Figure 6: Speed and Output Power Characteristics of Wind Turbine

The results of this study highlight the potential of sectionalization in achieving the ideal utilization of renewable energy in micro grids. By optimizing energy management, enhancing grid resilience, supporting scalability, and promoting efficient battery utilization, the sectionalized micro grid offers a promising solution for transitioning towards a sustainable energy future.

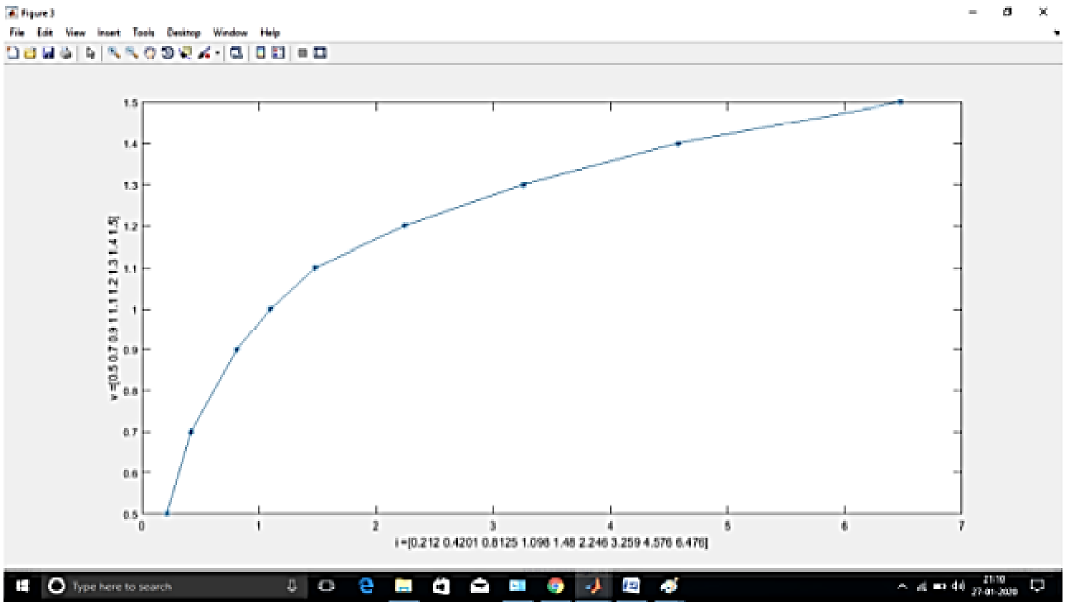

Figure 7: V-I Characteristics of Doubly Fed Induction Generator

However, it is important to note that the effectiveness of sectionalization may depend on various factors, including the specific characteristics of the micro grid, the renewable energy sources being utilized, and the energy demand patterns. Figure 6 shows speed and output power characteristics of wind turbine while as figure 7 depicts the graph showing voltage vs. current characteristics of doubly fed induction generator.

Further research and real-world implementations are necessary to validate the results and explore potential challenges and limitations associated with sectionalization.

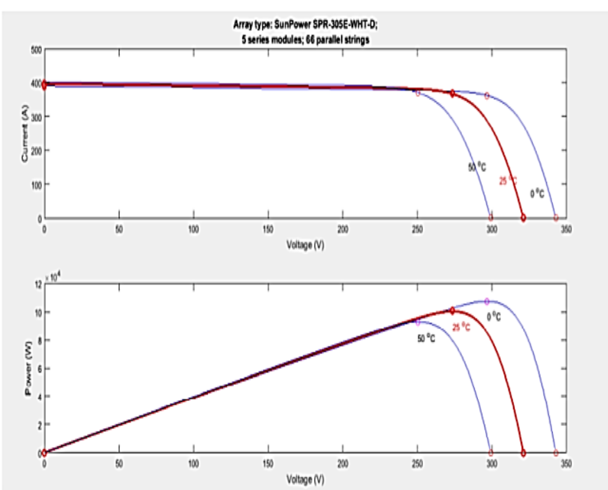

Figure 8: V-I and Power Vs Voltage Characteristics of Solar Plate

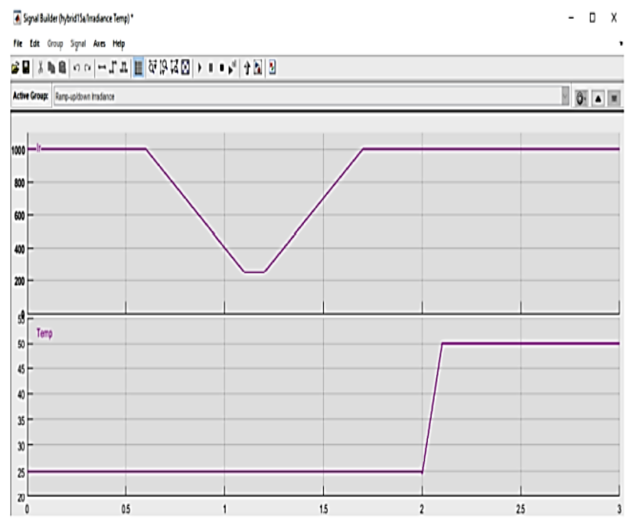

Figure 9: Irradiance vs. Time and Temperature Characteristics of Solar Plate

The results of this study demonstrate that the sectionalization of battery banks in a micro grid can effectively enhance renewable energy utilization. Figure 8 shows graph depicting V-I and power vs. voltage characteristics of solar plate, and figure 9 represents time and temperature vs. irradiance characteristics of solar plate.

The optimized energy management, improved grid resilience, scalability, and efficient battery utilization achieved through sectionalization contribute to the ideal utilization of renewable energy sources. This research provides valuable insights for the design and implementation of micro grids, supporting the transition towards a sustainable and reliable energy infrastructure.

VIII. CONCLUSION

Sectionalization of battery banks in a micro grid offers an ideal solution for effectively utilizing renewable energy sources. It optimizes energy management, enhances grid resilience, supports scalability, and promotes efficient battery utilization. By embracing this approach, we can create a sustainable and reliable energy infrastructure that harnesses the full potential of renewable resources, paving the way for a greener and more sustainable future.

One of the key advantages of sectionalization is the enhanced energy management it enables. By distributing the battery banks across different sections of the micro grid, we can effectively balance the energy load and storage capacity. This allows us to match the generation from renewable sources, such as solar or wind power, with the demand in each section of the micro grid. By doing so, we minimize energy wastage and maximize the overall efficiency of the system. This approach allows us to make the most of the intermittent nature of renewable energy sources and ensures that the clean energy generated is efficiently utilized.

Sectionalization also plays a vital role in improving the resilience and stability of the micro grid. By dividing the system into sections with their own battery banks, we can isolate any potential faults or disturbances, preventing them from affecting the entire system. In the event of a fault or a failure in one section, the other sections can continue to operate normally, minimizing downtime and ensuring a reliable power supply to critical loads. This fault isolation capability enhances the overall reliability and robustness of the micro grid, making it more resistant to disruptions and improving the quality of power delivery.

Furthermore, sectionalization offers significant benefits in terms of scalability and flexibility. As the demand for renewable energy grows or additional sources are integrated into the micro grid, new battery banks can be added to specific sections without disrupting the entire system. This modular approach enables the micro grid infrastructure to be easily expanded and adapted to changing energy needs. It provides a scalable framework that can accommodate future growth in renewable energy generation and consumption.

Additionally, sectionalization promotes optimal battery management. Each section can be monitored and controlled independently, allowing for precise control and optimization of battery charging and discharging processes. This ensures that the batteries are utilized efficiently, extending their lifespan and reducing the need for frequent replacements. By maximizing the performance and longevity of battery banks, we minimize their environmental impact and contribute to the overall sustainability of the micro grid.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest

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