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SUPERVISORY CONTROL STRATEGY USING A COST-EFFECTIVE CONTROLLER FOR THE EFFICIENT SOLAR POWER UTILITY IN A RESIDENTIAL MICRO GRID SYSTEM

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Abstract: In developing nations, load shedding a deliberate interruption of the energy supply to balance demand occurs often. Solar cells rely on sunlight to operate on the photovoltaic effect concept. Our nation receives a plenty of sunlight, which is why solar power plants were built quickly. Currently, solar energy is a popular alternative power source installed in normal middle-class homes. Batteries are used to store surplus energy produced in order to meet future demands. Nevertheless, there are a few issues with the system. These arise when the power source is completely charged as well as the PV output exceeds the load requirement. Solar energy can only be effectively used when there is load shedding. Supervision control and data acquisition, or SCADA, was created by low-developed nations and used to tailor solar field designs. A cost-effective system that is adaptable, dependable, secure, and ready for future expansion was constructed using a combination of software and hardware development techniques.

***Index Terms* -** Supervisory Control System, Microgrid, Load Shedding, Cost effective system .

I. Introduction

Nowadays, there is a growing need for electrical power while the supply of traditional energy sources coal, oil, certain natural gas, etc.is running low. Burning fossil fuels simultaneously has a harmful impact on the environment. to solve the issues and meet the need for the usage of power. Renewable energy sources, such as solar [1], wind, and hydropower, are important. For a constant power source, a microgrid is the best option. In order to function in both grids linked and island mode, a microgrid is a collection of dispersed energy supplies and interconnected loads which can connect and disengage from the main grid. Microgrids have several advantages, including the integration of energy from renewable sources of information, a reduction in distribution and transmission losses, a decrease in problems related to frequent power outages, a lower start-up and maintenance cost [2-4], improved reliability, and ease of protection against extreme weather and natural disasters.

The Govt. of India (GOI) offers 40% subsidies for the installation of solar panels in an effort to increase electricity dependability. India ranks third globally in terms of both production and consumption of energy [5-8]. It still exceeds the requirement. High transmission as well as distribution losses, inadequate power generation, and a dearth of high-quality infrastructure are the causes, the primary disadvantage of grid-connected systems is that they frequently experience power outages and load shedding in addition to lacking a battery backup mechanism for their continuous power supply (UPS).

In addition, rather than grid connectivity and microgrids, the primary necessity in developing nations is electricity reliability [9-11]. These solar-powered microgrids include batteries using an energy storage device as an extra power source. The MPPT (Multipurpose Power Transformer) the controller DC to DC converters, AC to DC chargers, and DC to AC inverter are the parts of a solar inverter. Providing households, a dependable power supply is the supervisory controller's primary goal. These are the characteristics of SCADA: it is more adaptable to use the whole solar energy strategy in a battery and can operate on both a stand-alone and a grid-connected microgrid.

II. THE PROPOSED DESIGN FOR A SOLAR MICROGRID SYSTEM

Combining stand-alone and grid-connected capabilities, the solar microgrid system is also known as a grid-assisted system. By shifting load to the microgrid and maximizing energy distribution, it reduces grid pressure during peak hours. With the use of both types of microgrids, this unidirectional system improves stability and offers broad benefits in sustainability and dependability. Fig. 1 depicts the fundamental layout of the solar connected to the grid system.

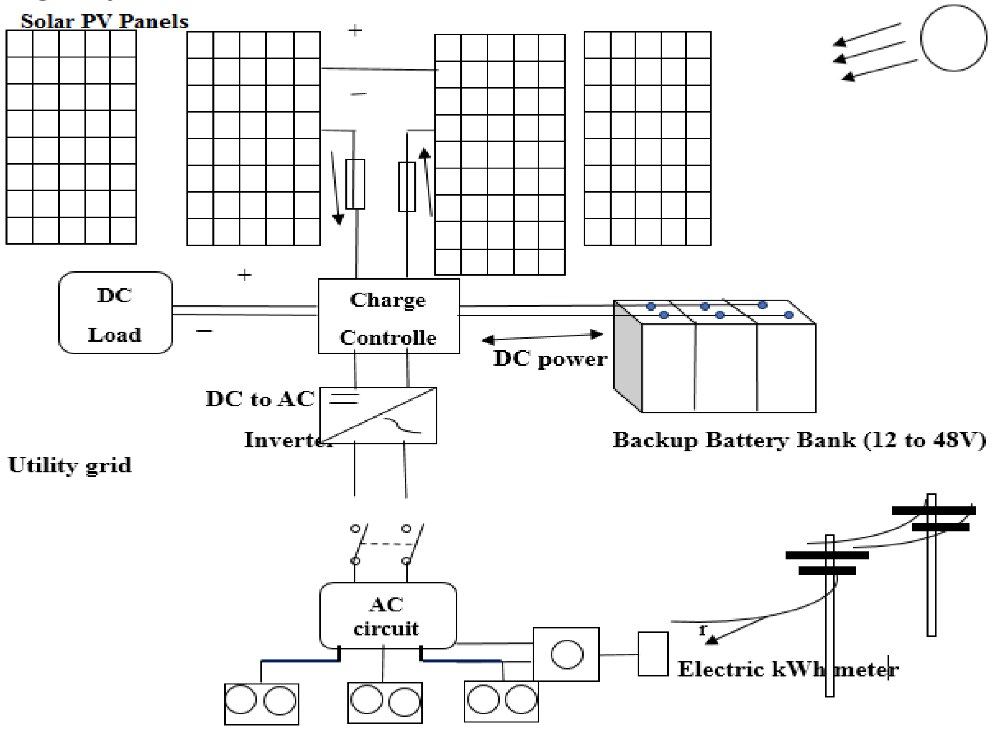

Figure 1. System connected to a solar grid

The house loads are segregated based on ratings in order to use a microgrid system to deliver continuous electrical power to the home load. As can be seen in Fig. 2, loads are categorized into three main categories: heavy loads, regular loads, and important or emergency loads. Room heaters and air conditioners are among the heavier burdens. Fans, washers and dryers, kitchen appliances, lightbulbs, and other low- and moderate-power equipment are examples of typical loads. Electrical grids and photovoltaic microgrid systems power both regular and emergency demands, as seen in Fig. 2.

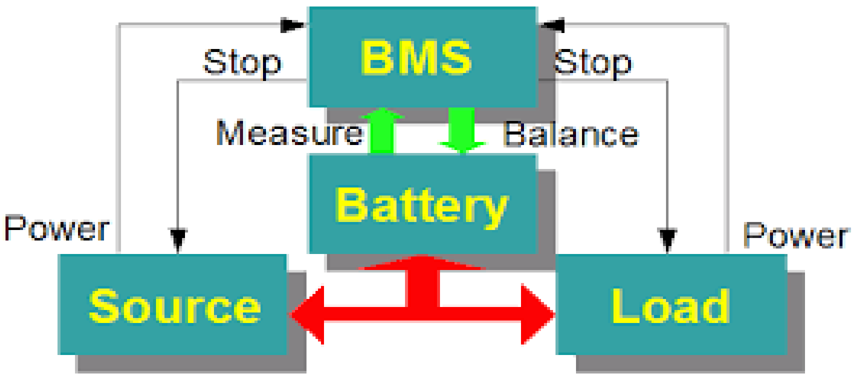

Figure 2. The proposed microgrid system's for home loads

The suggested system's architectural block diagram is shown in Fig. 3. Grid supply, a traditional house inverter (AC to DC & DC to AC converter), solar PV panels, a power purification unit (DC to DC converters), a system for storing energy in batteries (BESS), and various household needs (average and emergency loads) are all included in the proposed system. In order to maximize the power from the solar photovoltaic (PV) modules, the power conditioning device tracks and controls the highest possible electrical created by the photovoltaic system under erratic solar irradiation. The system's cost is optimized and efficiency is increased with the aid of the energy storage system.

The components shown in Fig. 3 that are connected to the proposed controller via dotted lines and act as the controller's inputs are in constant communication with one another. In contrast, the operational command for switches S1 and S2 is sent by the proposed controller's outputs (dash-dot lines). These switches' (S1 and S2) operating goals resemble the plan put forward within (Amr et al., 2018). As a result, switch S1 activates the two operating modes—the economical and dependable modes—while switch S2 permits the house loads to use the battery's stored energy. In terms of economy, the goal is to maximize solar power such that the PV modules waste as little or no energy.

This plan works better in metropolitan areas when load shedding isn't experienced for extended periods of time. On the other hand, extended periods of both planned and unplanned load shedding are typical in rural regions; for this reason, dependable mode performance is more appropriate. When in dependable mode, cells are charged via the grid or a solar PV module, based on which is available to meet load needs during the extended load-shedding hours.

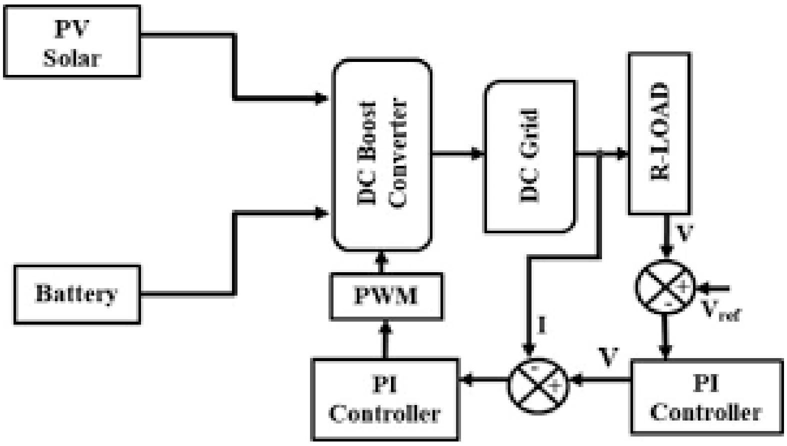

Figure 3. Closed loop microgrid system's architecture

An Arduino Mega 2560 microcontroller is used to carry out the procedure of the suggested control approach. The solar insolation numbers, utility grid access, and battery voltage are all continually monitored by the Arduino. The micro-controller determines the supervisory control strategy for the suggested solar microgrid system based on these inputs. The next section discusses the supervisory oversight algorithm for the suggested system.

III. SUGGESTED SWITCHING LAYOUT AND CONTROLLER DESIGN

For effective solar power usage, the suggested controller, as previously described, uses three input parameters and regulates two output instructions (control signals). The inside of the circuit diagram, shown in Fig. 4, shows how the solar irradiance values, battery voltage, and grid power availability are coupled with the Arduino inputs, enabling effective management over switching state of both S1 and S 2 in the system. The suggested controller, which oversees the changing conditions in S1 and S2 for the effective use of 216 and the harvesting of solar power, includes three input parameters and two output instructions (control signals), as was covered in the previous section. Fig. 4 depicts the suggested controller's internal circuit layout.

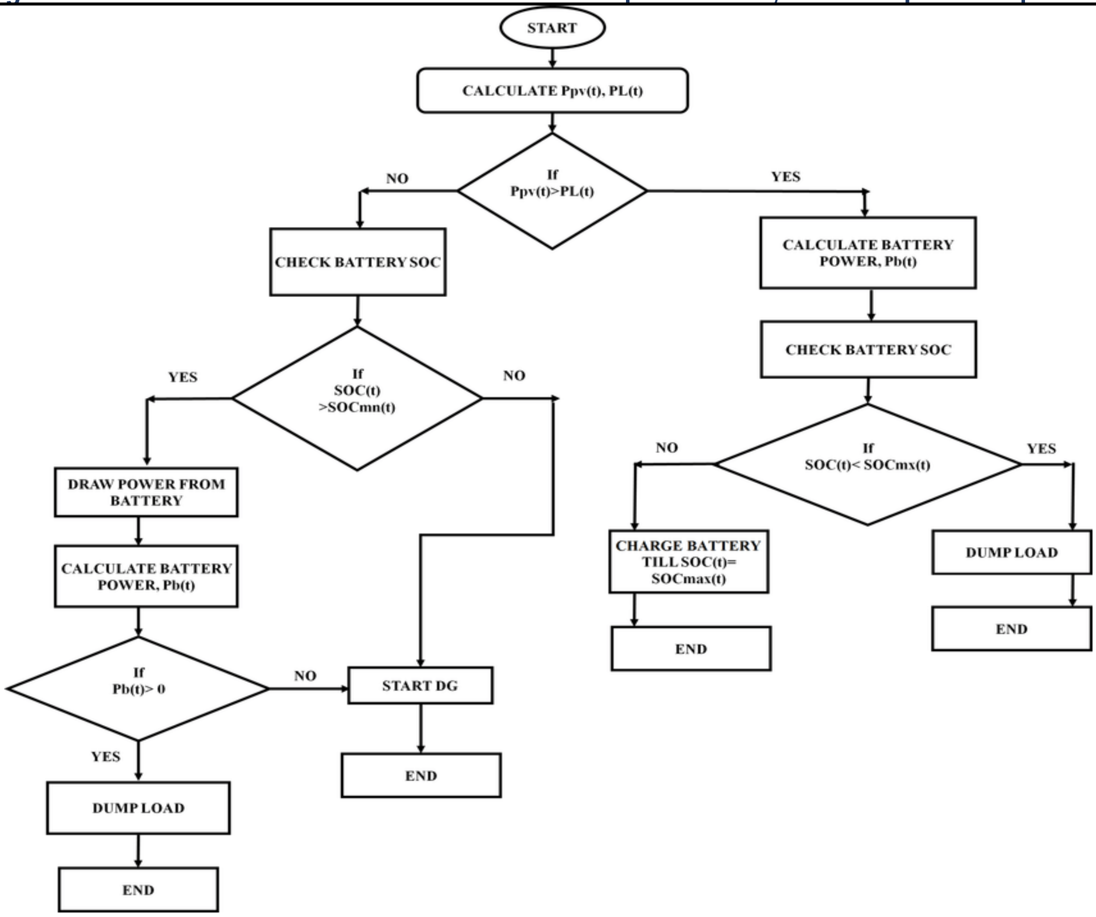

Figure 4. Microgrid control system loads' flowchart

Pins A9, A12, and A13 of the Arduino Mega 2560 are used to link pin 218 to the three input variables battery electricity, electrical grid access, and solar irradiance value. To get the battery voltage (VB) into the 5 V range (the Arduino working voltage range), a potential divider is used to scale it down. The adapter (AC-to-DC converter) provides the grid with the input signal. When energy from the grid is available, the adapter 221 recognizes it and changes the 230-volt AC voltage to a 5 V DC signal. The Arduino will register a high voltage (logic 1) when grid power is available. In contrast, "logic 0" will be shown by the zero-adapter voltage throughout the load shifting 223 period. With the support of the LDR sensor, solar energy input is provided. The Arduino receives the insolation level data that the LDR sensor continually measures.

The voltage drops at pin A13, or the 220 Ω resistor, fluctuates in accordance with variations in the insolation level. The source signal at A13 becomes strong, otherwise low, if the insolation exceeds a certain threshold level (300 W/m2). But the photovoltaic (PV) system charges the battery whenever S1 and S2 are high. The DC-to-AC converter provides the loads with power from both the solar PV and the batteries. A flowchart presented in Fig.4 also aids in illuminating the specific controlling algorithm of the suggested microgrid system.

IV. SIMULATION TEST OF THE PROVIDED CONTROLLER AND RESULTS

Before developing the hardware configuration, the suggested control method is evaluated on a simulation platform. MATLAB®/Simulink is used to create the simulation model for the suggested control method. Fig. 5 presents the suggested Simulink model. The controller receives three input signals, VB, M, and S, as was covered in the preceding section. Vb1, the battery voltage level, is set at 26 V. The Simulink model has the switching control method programmed, as shown in Table 1. The controller's time-varying input variables are depicted in Fig. 5. The battery's charging and discharging characteristics are depicted in Fig. 5 by the profile of VB. The mains supply availability period (M = 1) and load shedding period (M = 0) are represented by the input values, respectively. In a similar vein, S = 0 & S = 1 denote, respectively, the solar radiation level ranging from zero to 300 W/m2. The suggested controller supplies S1 and S2 with switching command signals under various input conditions in accordance with the guidelines specified and displayed in Table 1. displays the controller's output command signals to S1 and S2. A possible scenario for the control's rule-based implementation

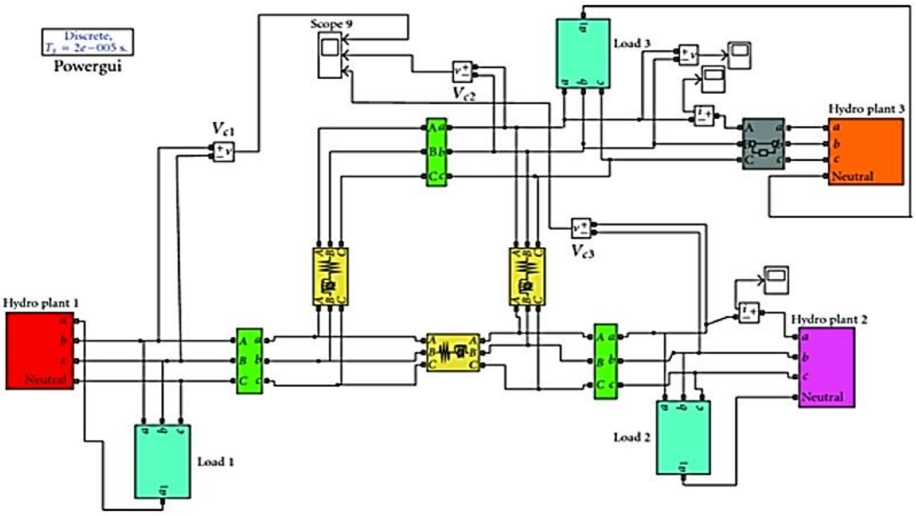

Figure 5. The suggested controller's Simulink model

At a particular point t > 5 Hour (Fig. 6), the technique is explained. The provided values are M = 0, S = 0, and VB = 25 V shortly following t = 5 hours. Based on Table 1, the suggested switching rule indicates that S1 = 0 and S2 = 1 should be the controller output.

Table 1. displays the suggested rule-based controller switching algorithm

Voltage, V_B	$V_B \leq 23.7$ V				23.7 V < $V_B \leq V_{b1}$				$V_{b1} < V_B \leq 28$ V				$V_B > 28$ V			
Mains, M	$M = 0$		$M = 1$		$M = 0$		$M = 1$		$M = 0$		$M = 1$		$M = 0$		$M = 1$	
Solar insolation, S	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Control output to S_1	0	0	1	1	0	0	1	1	0	0	1	0	0	0	0	0
Control output to S_2	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1

In Fig. 6, the simulation result, the same outputs are obtained shortly after t = 5 hours. The results are determined to meet the rules listed in Table 1 over the whole 24-hour period, based on similar observations. This indicates that the mathematical system is operating in accordance with the suggested rule-based control approach.

The top three rows display three possible input values for the three input variables: solar insolation (S), mains supply (M), and battery voltage (VB). Lead-acid batteries with a voltage of 12 V are utilized in the suggested hardware system. Battery University (2019) reports that each battery contains six cells, with a voltage ranging from 2.25 Volts to 2.45 V per cell. 14.4 V may be achieved while charging only a single 12 volt battery. According to Ananda-Rao et al. (2016), an inverter's 24 V DC-DC bus is powered by two batteries linked in series. This battery possesses to be charged all the way up to 28.8 V. The 234-maximum voltage of the battery VB is therefore determined to be 28.8. Classifications. M = 1 and M = 0 stand for electrical grid availability and blackout, respectively. In the input of the control instruction to the Arduino, solar insolation beyond a certain threshold (300 W/m2) is assumed to be S = 1, otherwise S = 0.

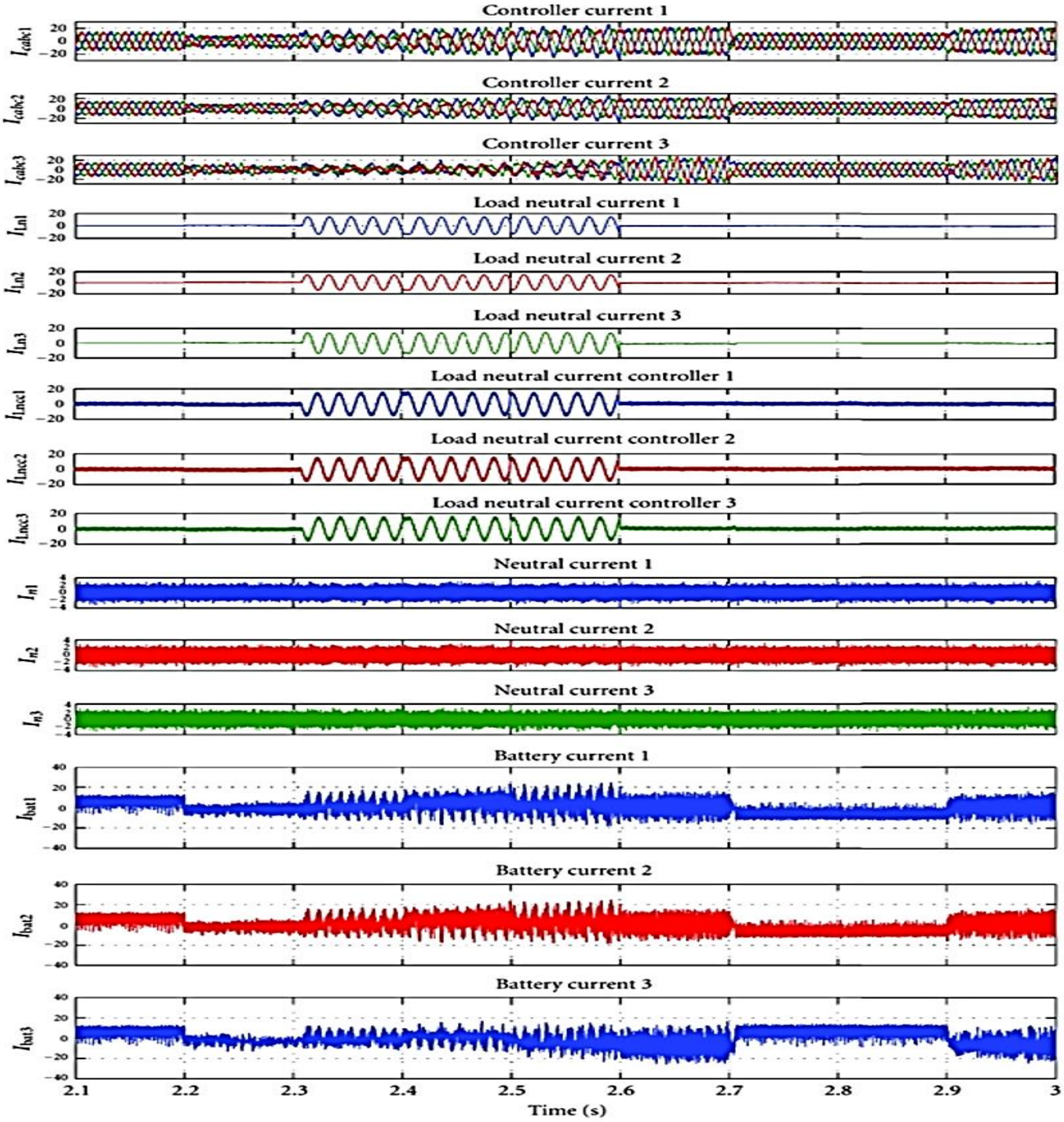

Figure 6. Performance of microgrid under proposed controller

VB is a measure of the battery's state-of-charge (SOC) that is indirectly employed in the proposed approach; Fig. 6 shows the link between the two. Table 1's first row displays the electrical voltage divisions in VB. Fig. 7 shows that the VB has been separated into four groups based on SOC levels, with 10% and 97.2% of SOC representing the two extremes. We consider a voltage below 23.7 V to be the initial stage of VB.

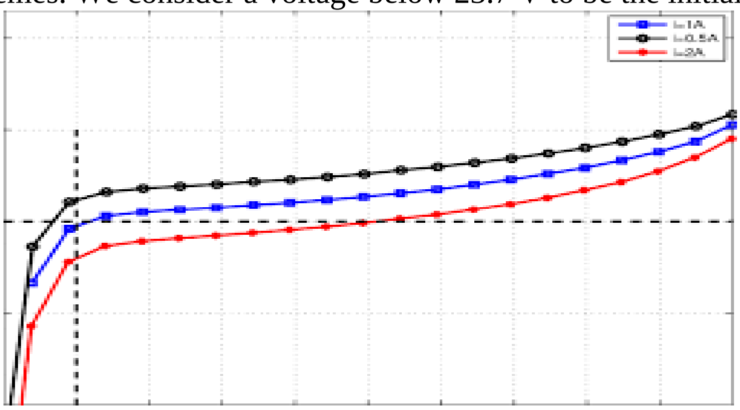

Figure 7. The voltage curve of the battery in relation to its state of charge

According to Dhundhara et al. (2018), this threshold was chosen because to the battery's low state of charge (SOC). Under 23.7 V, only urgent loads are permitted to draw power from the battery pack in order to prevent a deep drain scenario. Between 23.7 V and Vb1, there is the second voltage level. The level Vb1 is chosen based on the electric power supply's characteristics and requirements. While Vb1 can be set at the top limit (28 V) in rural regions, it can be picked near the lower threshold of VB (23.7 Volt) in urban areas. Thus, it is possible to attain both the inexpensive mode (urban example) and the dependable mode (rural case) in this way. Vb1 and VB max—that is, Vb1 ≤ VB < 28 V and VB > 28 V represent the third and fourth.

V. CONCLUSION

The present study provides a supervisory control strategy for a microgrid system powered by solar energy with the goal of storing and using solar energy as efficiently as possible while giving residential loads a steady supply of electricity. Three input variables are used to apply the suggested control strategy: the voltage of the battery, grid availability, and an absence of sufficient solar irradiation. The suggested control algorithm modifies the microgrid system's switching mechanism to provide effective power management depending on each of these input parameters. Additionally, the suggested control mechanism is effectively developed and put into practice.

Testing of the proposed structure is done by testing the closed-loop system's experimental setup across a variety of voltages. When both solar and grid power are available, the findings show how fully to utilize solar energy. Additionally, in the worst-case scenario when both power-generating sources are unavailable the suggested microgrid control method offers a dependable power supply to the loads.

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