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International Journal for Modern Trends in Science and Technology, 7(05): 89-95, 2021
Copyright © 2021 International Journal for Modern Trends in Science and Technology
ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0705014
Available online at:http://www.ijmtst.com/vol7issue05.html

Implementation and Optimal Control of DC Microgrid

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To Cite this Article
Ohm Vignesh V & Dr. Latha Mercy E. Implementation and Optimal Control of DC Microgrid. *International Journal for Modern Trends in Science and Technology* 7, 89-95 (2021).

Article Info
Received on 11-April-2021, Revised on 28-April-2021, Accepted on 06-May-2021, Published on 12-May-2021.

ABSTRACT

The degradation of non-renewable energy resources has been increasing widely. The objective of this research is to effectively utilize solar power using DC microgrid technology. Compared with AC microgrids, DC microgrids obtain some advantages and more suitable to access distributed power sources. A methodology "Plug and Play" approach based on the "System of Systems" philosophy controls interconnecting several elements to a DC microgrid. The main aim of this research work is to supply the power to the critical load at any condition. When power availability is less, the non-critical load will be cut down to manage the critical load. In this system, solar array, AC grid (EB), and battery are used as sources and are connected to the buck converter for power conditioning.

KEYWORDS: *Solar PV, DC Microgrid (MG), Buck-Boost converter, Energy Sources, hybrid system.*

I. Introduction

A microgrid is a small-scale power grid that can function independently or in tandem with other grids. Distributed, localized, decentralized, embedded energy generation is the term for using microgrids. The microgrid is referred to as a hybrid microgrid if it can be combined with the area's main power grid. The problem with fossil fuels is that their prices are influenced by economic and political factors. This creates financial uncertainty for businesses and utilities that depend on it as their primary source of electricity. Despite the fact that fuel is widely available anywhere, logistics can be challenging, resulting in higher final costs and increased greenhouse gas (GHG) emissions. The VSC is operated by a leaky least mean mixed norm adaptive power management in the Grid Connected (GC) mode of operation. This control algorithm provides quick operation during the dynamic shift with low oscillations within the expected weight.

Renewable electricity costs have decreased in recent years and are now less expensive than gasoline without any subsidies. Since the end of 2009, solar PV module prices have dropped by about 80%, while wind turbine prices have dropped by 30–40%, raising the implementation of these technologies. Solar and wind power, on the other hand, face a major challenge in terms of intermittency. Batteries are being seen as a solution to the lack of stability of renewable technologies, as they can compensate for their intermittency, thanks to the declining cost of Energy Storage Systems (ESS). Batteries, on the other hand, are also costly and cannot completely compensate for irregular power generation. Most of electrical devices are now operated by AC mains under the current electrical grid. However, as green technology such as solar photovoltaic and wind power become more common in homes, DC microgrids can become a more cost-effective and reliable option.

Solar, EB (grid), and battery sources are operated by relay using a control algorithm that is dependent on the availability and demand of the source. The “plug and play” process is accomplished by simply inserting or removing a source.The loads are divided into two categories in the system,

- Critical load (For example in the hospital operation theatre and ICU)
- Noncritical load (For example veranda, reception, and general rooms)

The key performance desire to turn on the critical load at any time without disrupting the power supply. When solar power (PV panel) is fully charged, it powers all loads and turns on the lights, while the batteries charge. Solar power production is limited during cloudy or rainy seasons, but it must feed power to critical loads while the non-critical load is disconnected from the supply to give power to the critical load. The battery is also a load in this case. The battery charges when the solar and EB (grid) are all turned on. Only critical loads can receive power from the battery. When the battery is fully charged, the trickle charging system is used to keep the battery at its highest charge speed. Since all of the components are DC, the conversion deficiency is minimized.

STRUCTURE OF PAPER

The paper is organized as follows: The paper comprises four section, in which Section II presents the literature review, Section III describe the proposed system and simulation and the block diagram of proposed system hardware, The Simulation model is developed in MATLAB platform and hardware output of the results are discussed in Section VI. Section V describe thefuture scope and conclusion.

II. LITERATURE REVIEW

The consequences of using a microgrid examine the function of a microgrid and explore the factors that contribute to a microgrid's stable activity. The technology of power matching, harmonic suppression, and the stability of electronic cascaded systems are among the considerations. The main constituents that influence the microgrid's stability are power matching technology, harmonic suppression technology, and the stability of electronic cascaded structures, among others [1]. Low-voltage electrical equipment, such as computers and televisions, run on a low DC voltage and thus have conversion circuits built-in. If the conversion circuits are removed, losses may be minimized. However, since the voltages used by the equipment are so low, such as 12v dc, 5v dc, and even lower, dc/dc conversions are required [2]. The technology of power matching, harmonic suppression, and the reliability of electronic cascaded structures, among other things, are major factors that influence the Micro grid's stability [3]. Two major concerns lowered the dc delivery system's stability. One example is the relationship between ac to dc and dc to ac power converters. Filtering and monitoring methods can be used to solve this problem. System grounding is another issue that can be addressed by keeping neutral voltages down in normal conditions and limiting fault currents during fault conditions [4]. The average conversion efficiency of a dc distribution system would be much higher than an ac distribution system when fuel cells or dc generators are used for residential uses [5].

The process of operating a dc microgrid system can be performed autonomously, which increases the system's stability, durability, and maintenance [6]. Voltage drops calculations at various voltage ranges, various safety steps, and a contingency mechanism for stable power supply, among other things, should be analysed and planned for effective use of dc supply in offices and commercial buildings [7]. Hybrid AC/low-voltage DC (LVDC) micro-grid that can operate off-grid and on-grid with a coordinated control system. This microgrid uses AC/DC converters to link the AC and LVDC networks and also allows for plug-and-play converters. [8]. Hybrid microgrids aim to improve interconnection between different distributed and generation systems and the power grid. [9].

In a dc distribution system, power conversion from ac to dc is expected. High efficiency for both ac and dc can be achieved, as well as dc back up energy storage. It is important that there are minimal losses during the conversion from ac to dc, and that dc power applications discharge minimal losses. To have a high-quality interface between an ac and dc voltagesource converter in series with

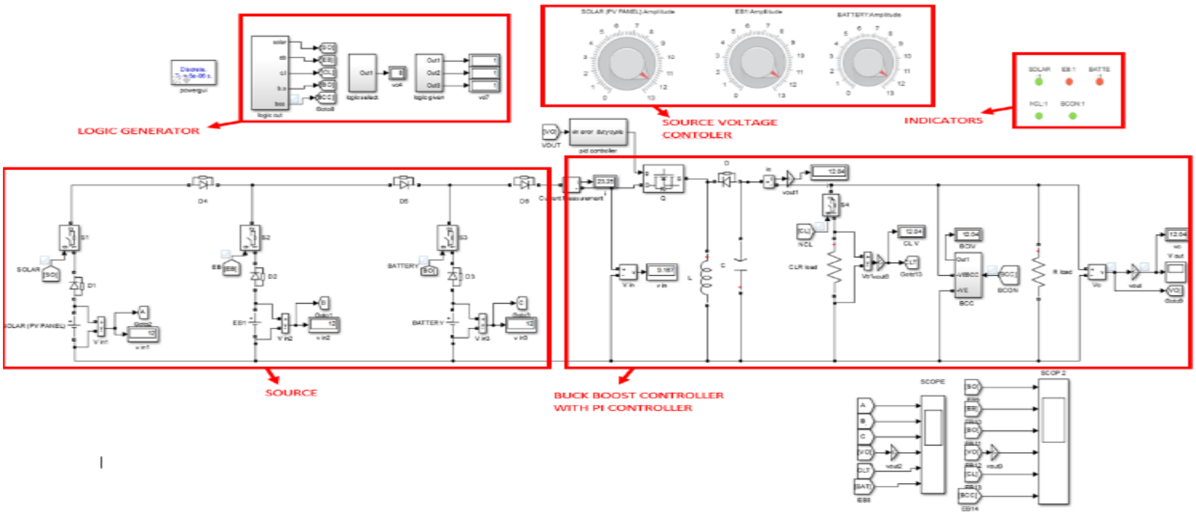

FIGURE 2 Overall Simulation Diagram of Proposed System

a buck converter, DC characteristics are tested for both steady-state and transient states using PSCAD/EMTDC tools. The best conclusion is shown by only calculating the dc capacity. And if the grids malfunction, dc power remains steady [10].

The latest advancements in power electronic technology demonstrate that by supplying dc power to each unit, the reliability of each appliance can be significantly improved while device costs are minimized. Through this, it can be deduced that monthly energy demand can also be minimized [11]. Internal losses, wire losses, and unit losses are all taken into account when comparing DC and 230 voltage AC capacity. As a result, 48V DC is significantly more efficient than 230V AC [12].

III. PROPOSED SYSTEM

Schematic Diagram of Proposed DC Microgrid as shown in figure 1. In this proposed work, renewable energy is utilized efficiently. Here the DC to DC converter is used to maintain the stability of the system. Depend on source availability the load is divided into the critical and non-critical load. In all the situations the uninterrupted supply is given to the critical load continuously. When the source availability is minimum the non-critical loads are cut down to maintain the uninterrupted supply for the critical load. The storage system is also used to maintain uninterrupted supply in the critical load. When the excess energy is available from the renewable source, the batteries in the storage system will be charged.

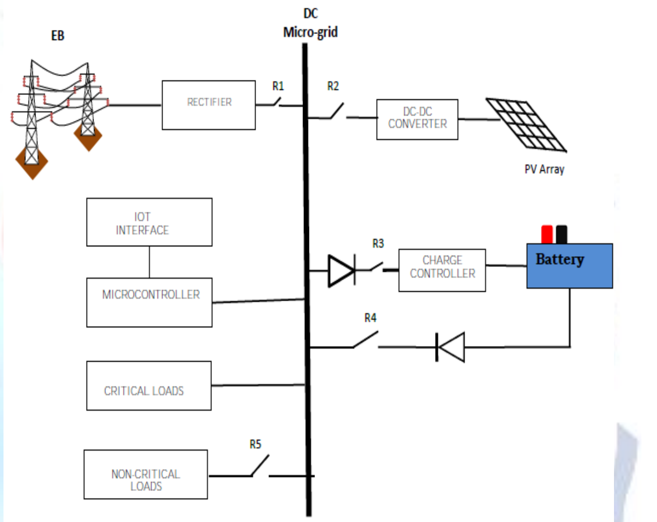

FIGURE 1 Schematic Diagram of Proposed DCMicrogrid

Sources are solar, EB (grid) and battery and are controlled by relay using control algorithm depending upon the source availability and demand. “Plug and play” operation is done by easily adding source or removing source. Overall simulation diagram of proposed system shown in figure 2.

The logic controller controls the relay depending upon the source availability. It consists of three blocks; Logic generator unit, Logic select unit, Relay selection logic. In logic generator circuit shown, in figure 3 input voltage from source and the reference voltage is compared and output is generator. From (000) to (111) is given to logic select to make logic out**,** the output of the generate is as follows,

If, V_{ref}> Vin →1; If, V_{ref}< Vin → 0

In this way 3 outputs from 3 sources are either one or zero.The output from the logic generate has 3 varying outputs therefore Here we have 3 inputs, therefor totally 8 conditions, each condition should be programmed.

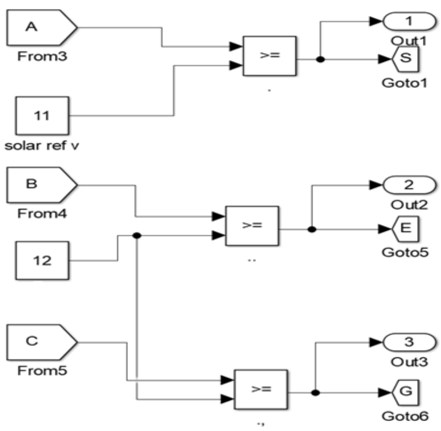

FIGURE 3 Logic Generate Simulation

Depending upon the condition, the output is selected. In relay selection logic the output from the logic select is decoded. It should have multiport switch with 8 points. which is relates to1 to 8 values of the output from the logic select. when any one of the values is selected, the corresponding relay should be activated. which decide the selection of five relay. correspond to eb, solar, battery charging/ discharging state and non-critical load. The critical load should be ON when EB (grid) and solar at full power to carry both loads. When solar only gives power, critical load is ON and when the non-critical load is off. When battery is ON the non-critical load is off. The whole system is controlled by Voltage Variation Based Autonomous Control strategy therefore the Non-critical load off (when solar on time) below 11.5V. Non-critical load subsystem shows in figure 4.

The battery charge control unitcontrols the battery charging and discharging control unit. when solar is with full power out condition, the battery is charging. when both sources are off condition, the battery gives power to the critical load.

Buck boost converter is used to step up or step down the output voltage from the sources. The buck boost converter is designed to for 240 watts. Boost converter is controlled by PI controller.

Calculation for buck boost converter;

$L = V_s*D/\Delta I*f_s$ (1)

$C = I_o*D/\Delta V*f_s$ (2)

$D = V_o/Vi + V_o$ (3)

$D = 0.333$; $L = 126mH$; $C = 44\mu F$;

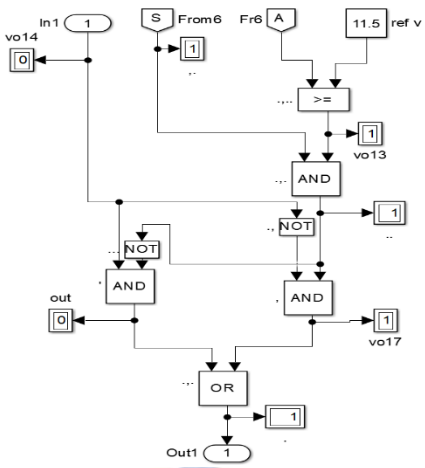

FIGURE 4 Non-Critical Load Control Subsystem

3.1 Design of Pi Controller

Output power equals to the sum of proportion and integral coefficients. The higher the proportion coefficient, the less the output power at the same control error. PI control provides zero control error and is insensitive to interference of the measurement channel. The PI control disadvantage is slow reaction to disturbances. To adjust the PI controller, first set the integration time equal to zero, and the maximum for proportion time. Then, by decreasing the coefficient of proportionality, achieve periodic oscillations in the system. Close to the optimum value of the coefficient of proportionality is twice higher than that at which any hesitation, and close to the optimum value of the integration time constant - is 20% less than the oscillation period.

3.2 Working conditions

The table 1 shows the overall working condition of proposed system. In the existing three sources of system the PV source is gets a priority. When the three sources are available at the same time, depends on priority level the solar PV is feed power in to critical load and also a non-critical load. In this condition the excess power of PV is feed into energy storage system (like Battery). When the PV source gives moderate output power, it satisfies the critical load only. In this condition the non-critical load is switched off and charging of battery is stopped. When the PV source output power is very low, EB starts to feed the power to critical load and also a non-critical load. In the absence of PV power, the charging of battery is stopped. In the absence of power from both EB and PV the battery will manage the critical load. In this condition charging of battery is stopped and non-critical loads are disconnected.

TABLE 1 Overall Working Conditions

CONDITIONS	Source Conditions	NON-CRITICAL Loads conditions
P_{solar} with full power out > P_{EB}	EB OFF, Battery charging, Solar give power to load	ON
P_{solar} with low power out > P_{EB} (with apl. conditions)	EB OFF, Battery not charging, Solar give power to load	OFF
P_{solar} < P_{EB}	EB ON, Battery not charging give power to load	ON
P_{solar}, P_{EB} < $P_{Battery}$	EB OFF, Solar off, Battery not charging, Battery give power to load	OFF

3.3 Block Diagram of Proposed System Hardware

Proposed block diagram of DC microgrid is shown in the figure 5.For the intent of regulating the source, measuring the source and load voltage. It's achieved by taking voltage readings. The voltage

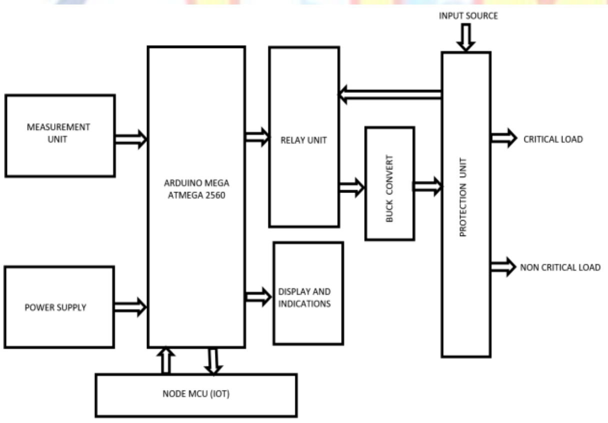

FIGURE 5 Block Diagram of Proposed DC Microgrid

divider system is used to calculate the voltage. Analog inputs on microcontrollers can be used to calculate DC voltage between 0 and 5V. By creating a voltage divider with two resistors, the range over which the Microcontroller can test voltage can be extended. The voltage divider reduces the voltage being tested to a range that the Microcontroller analog inputs can handle. The real voltage being determined is then calculated using code from the Microcontroller sketch. This enables the measurement of voltages greater than 5V. Equitation (4) and (5) is use calculate the source voltage.

$$Vout = (Vin*R2) / (R1+R2) \quad (4)$$

$$V = vout / (R2/(R1+R2)) \quad (5)$$

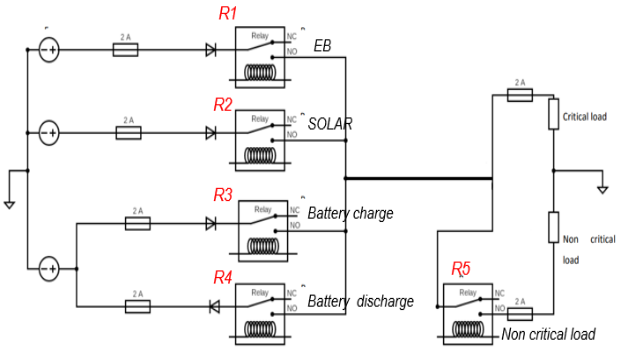

FIGURE 6 Relay Connection Diagram of proposed DC Microgrid

The DC microgrid is supplied by the following three sources in the desired priority order. They are EB, solar (PV panel), battery. The sources are controlled by relays is shown in figure 6. When solar is under rated voltage, both critical and non-critical loads are supplied by solar power under R2 closed condition When there occurs reduction in sunlight intensity, the solar line voltage drops within a certain limit and under this condition, non-critical loads are disconnected. If the limit is crossed, R2 is de-energized, DC grid line is supplied with Electricity board power via relayR1. And on including EB, both loads are connected to the grid. On the failure of EB supply, R1 is turned off and backup power is supplied to only critical loads via relay R4. The battery is charged in ON conditions of maximum solar condition. The critical and non-critical loads are controlled by relays R5. Relay control Signal from the microcontroller is fed to an optocoupler, to protect the microcontroller from the relay's back emf. Then, the signal from the optocoupler is fed to the

NPN transistor base to control the relay. A diode is in parallel with the relay. The use of a diode in a relay circuit prevents huge voltage spikes from arising when the power supply is disconnected (flyback or freewheeling diode). LED is placed in parallel with the relay forindication.The output current carrying capacity of an optocoupler is low.

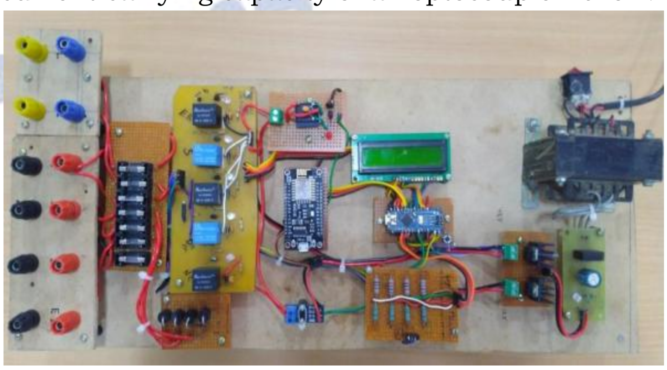

FIGURE 8 Overall Hardware

Therefore, the transistor is used to amplify the signal. A protection diode is used in the circuit that allows the flow of current in the forward direction, because the current will not flow in the reverse direction. It protects the components which are responsive to the flow of current through them in the wrong direction. Also, another reason to build it this way is the limitations of a diode in reverse biased.

V. RESULTS AND DISCUSSION

The output waveform of simulation results Depend upon source availability/priority, the source and load were selected. It is clearly mention in the figure 10. EB and Solar is ON condition, When Solar give power to both load and battery is charging.

FIGURE 9 Overall Hardware with Source and Load Connected

When, Solar ON and EB is OFF condition. When, Solar gives power to both loads, Battery is charging. Solar and EB is OFF condition. When, the Battery gives power to critical load only. Non-critical load is in OFF condition.

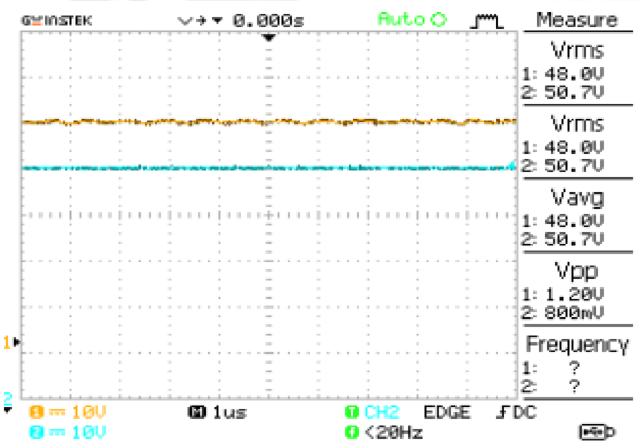

FIGURE 11 Solar and EB ON Condition for hardware

EB and Solar is ON condition, When Solar give power to both load and battery is charging. It is shown in figure 11.

EB is ON condition, Solar is OFF/ low level condition, when both source in ON condition and battery is not charging it is shown in figure 12. All sources in OFF condition, when each load is OFF condition. It is shown in figure 13.

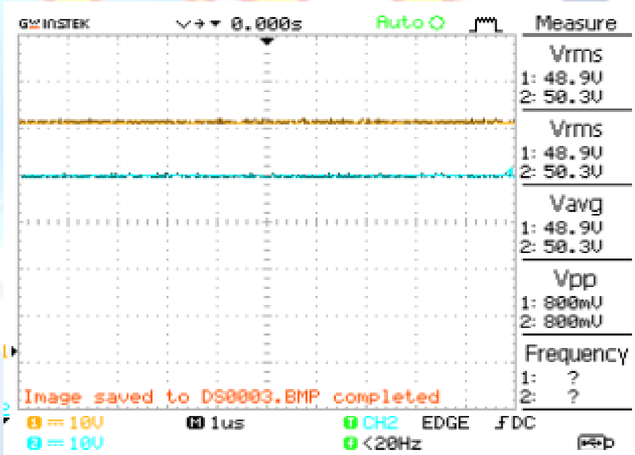

FIGURE 12 EB ON Condition for hardware

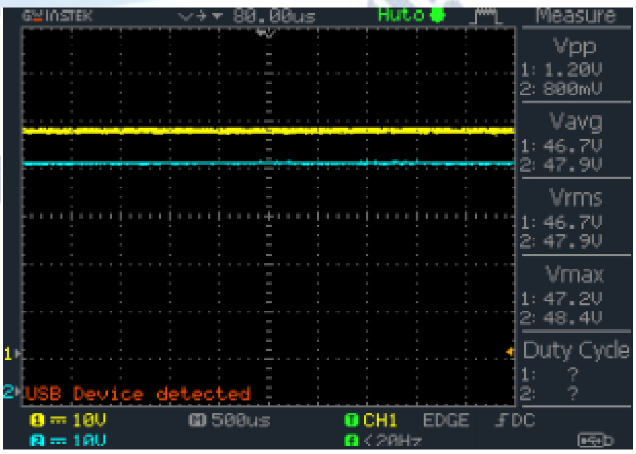

FIGURE 13 All Source Off Condition for hardware

The table 2 show the comparation between simulation and hardware result. Various condition the readings are taken and take readings.

TABLE 2: Comparison Results of Simulation and Hardware Results

SOURCE VOLTAGE (V)	SUMULATIO N RESULTS (V)	PRATICAL OUTPUT (V)
54/SOLAR,48/EB,48/ BATTERY (charging)	48.9	48.3
52/SOLAR,0/EB,51/ BATTERY	48	48
47/SOLAR,48/EB,51/ BATTERY	48	48.6
0/SOLAR,0/EB,51/ BATTERY (discharging)	48.1	48.2
47.5/SOLAR,48/EB, 51/BATTERY	48	48

VI. FUTURE SCOPE AND CONCLUSION

In view of the entire electric power system's economic performance, including power transmission and distribution. PV generation with low working rates should be deployed in the demand region in a distributed manner. Based on this concept, we suggested the DC microgrid system as a solution for large-scale PV generation and power flow stabilization in commercial grids. We performed an experiment using a DC microgrid device with a battery to demonstrate the system's main strategy, matching power supply and demand. The DC microgrid system's operational viability was demonstrated in this research. We will evolve this method into a realistic implementation and increase its economic performance in response to social needs and patterns. The key goal is to provide power to vital loads under any circumstance. To reduce power consumption by removing non-essential items. Since all of the components are dc, the conversion loss is minimized. The ac to dc conversion is responsible for nearly 30–40% of the deficit. The conversion failure is minimized when all appliances are powered by DC. Using an IOT application, you can track and power the dc microgrid in any palace at any time. To monitor and perform IOT operations in real-time.

Renewable electricity generation has been steadily growing in recent years. PV has a major effect on electricity production by using clean energy sources. The PV's DC output will be converted to AC by the power electronic converter. As a result, the converter will experience voltage drops and poor power efficiency. This can be corrected using a DC microgrid and smart loads such as BLDC motors and LEDs, among other things. As a result, we can make better use of PV energy by lowering conversion losses. We will use the most electricity in the future by installing PV standalone systems with smart loads in industrial buildings, hospitals, and schools.

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