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DC MICROGRID BASED ELECTRIC VEHICLE CHARGING STATION USING IoT

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Abstract— **A rapid production of electric vehicles raises power demand and also puts an additional strain on the public grid through irregular charging management. However, in order to achieve the ultimate purpose of Electric Vehicles like reducing air pollution, lowering dependence on fossil fuels, and greater energy protection, the electrical energy needed to power the EVs must also come from renewable energy sources. Moreover, Batteries are a vital component of Electric Vehicles, to enable Electric Vehicles to become friendly to the DC Microgrid it is essential to monitor and control the charging and discharging status of the battery. In this employment, an IoT-based methodology for controlling the EV charging/discharging method has been proposed. Solar Photovoltaic (PV) power is an easily available and feasible solution among many other renewable energy sources. The goal of this project is to design a charging station that is generated mainly by a Solar PV array. If Solar power is exhausted, then the charging station takes power from the Storage Battery. In the absence of these two sources, the charging station utilizes EB electricity to provide uninterrupted power to the Electric Vehicle (EV) battery. The consumer can access the control for charging and discharging the EV through the Blynk app.**

***Keywords*— Battery Storage, EB, Electric Vehicles, Solar PV Array, IoT.**

I. INTRODUCTION

Over the past few years, Indian cities like Bangalore and Delhi have become extremely susceptible to atmospheric pollution due to the tremendous growth of population and industrialization meanwhile, usage of fossil fuel vehicles also increased rapidly, resulting in an increase in the number of cars on the road [1].

Due to their very low to zero carbon emissions, low noise, great efficiency, and flexibility in grid operation and integration, Electric Vehicles (EVs) are a viable technology for establishing a sustainable transportation sector in the future. With the growing popularity of electric vehicles, the future grid will be overburdened by a huge number of EVs with uncontrolled charging management. The concern is that oil and gas would be unable to meet demand, with sole electricity and different aspects of electric cars as an option. The universe's regular assets are usually used to create renewable commodities. They are entirely derived from nature and that energy is defined as the energy that is much cleaner and derived from renewable sources. They are Solar, Wind, and other renewable energy sources that are regenerated by nature in a restricted manner. Because it wouldn't contaminate the air or water so it is also called sustainable power. Renewable energy supplies are in direct opposition to fuel vehicles because that is generated directly from earth sources which are used far more efficiently than they are restored [2].

Renewable energy supply and electric vehicles have recently gotten a lot of attention in the Microgrid world. Solar Photovoltaic (PV) systems are the most efficient and purest renewable energy source for successful power generation. Solar energy generation has grown increasingly important in electric power applications in recent years. The Solar Photovoltaic (PV) based charging station is a readily accessible and feasible choice among various renewable energy sources. Then Refueling an electric vehicle is several ways easier than refueling a gasoline vehicle. There's no unpleasant smell or mess, no gasoline grades to choose from, and no need to look for a gas station. Electric vehicles can also help the environment, by reducing pollution levels in the air.

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The digitalization of a Charger in Electric Vehicle battery is reliant on grid conditions, EV charging stations are powered by renewable resources and its optimum use decreases charging expenses, and duration, and enhances battery life. PV is the most popular clean energy source,as it can act independently in all DC power applications. On that basis, it is critical to properly control and monitor the charging and discharging of Electric Vehicles to become grid-friendly. The Charging Station is primarily meant to utilize the Solar PV installation, Storage Battery, and then EB (AC Grid) to charge the Electric Vehicle battery using IoT. In any circumstances, when solar energy is insufficient then, battery storage is ready to charge the EV Battery, inadequate power supply from the storage battery, then the charging station intelligently receives electricity from the AC grid using IoT.

II. PROPOSED SYSTEM

A. DC MICROGRID

DC microgrids have gained popularity in recent years due to their low converter costs and ease of control without the need for reactive power. There have been reports of all-electric ships, more-electric aircraft, data centers, and residential complexes, among other applications. The challenge of availability has been evaluated, and so has the question of protection. Because the stability and dynamics of converter-based dc systems differ greatly from those of typical ac systems, researchers have used both linear and nonlinear approaches to analyze dc grid stability. Grid connection, generating sources, load, and Energy Storage System (ESS) are the terminals of the DC microgrid (Fig.1). The autonomous control is entirely based on local detections and the primary characteristics of terminal converters can be incorporated in a "plug and play" and extendable way without the requirement for communications. For autonomous control (Fig.2), a voltage variation-based technique can be used, which does not require any additional communication channels and depends primarily on local voltage monitoring, resulting in higher accuracy and reduced costs.

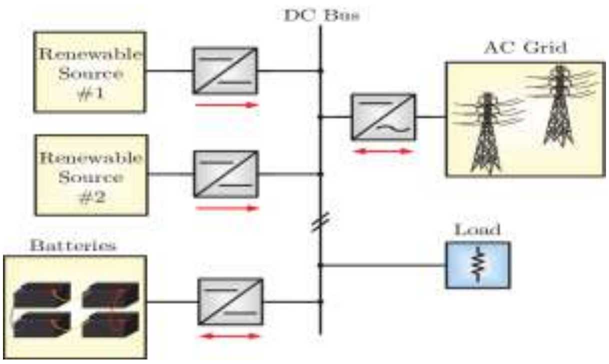

Fig.1 DC microgrid Block Diagram

In this study, voltage variation-based autonomous control technique, droop control is employed here. By considering that the voltage difference between the terminals is negligible, a certain operational voltage range can be specified and partitioned into a number of bands. To achieve power balance, a certain set of terminals is designated to a band that acts as slack terminals.

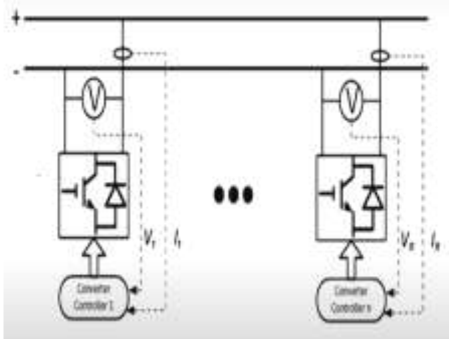

Fig.2 Autonomous control

B. CONTROL STRATEGY

The control strategy of a dc microgrid can be created in accordance with variations in dc voltage since dc voltage can be utilized as a reliable indicator of power-flow conditions. There are various amounts of variance within the working voltage range. Each level has a set of terminals that serve as slack terminals. Although the fundamental approaches are basically the same, the choice of slack terminals varies depending on particular system architecture and necessity. To guarantee that the required amount of power can be supplied at each voltage level, it is also necessary to carefully analyze each slack terminal's power capacity, where V_{dcn} is the normal dc voltage and the dc voltage fluctuation is described as

$$\Delta V_{dc} = V_{dc} - V_{dcn}$$

The coefficients A_1, A_2, A_3,B_1, B_2, and B_3 are given as $-1<A_3<A_2<A_1<0$ and $0<B_1<B_2<B_3<1$ correspondingly. These coefficients determine the voltage variation band for each operation level. The exchange among dc bus voltage variation during the performance and the potential for incorrect switches between various voltage levels during regular consumption and power variation must be taken into account when choosing A_1, A_2, A_3, and B_1, B_2, and B_3.

1) Level 1: Corresponds to Solar photovoltaics (PV)

2)Level 2: Coincides to the Battery Storage, Level 1's primary slack terminal, which transforms into a power terminal and has been unable to maintain the voltage output.

3)Level 3: This level corresponds to the scenario on the AC grid when the system loses the slack terminals while operating at Level 2 due to insufficient power or energy capacity.

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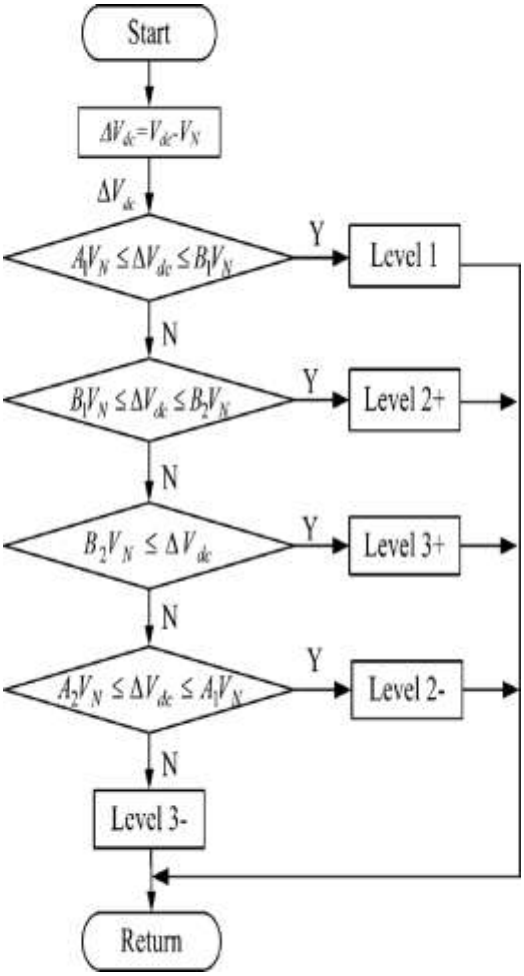

Fig. 3 Flowchart of switching between different dc voltage levels

C. SWITCHING LOGICS

According to the switching logic in Table.1, if there is no power source from solar (0) or battery storage (0), or EB (0), the battery could not take power from any of the three sources. Whether any of the sources seem to have a power supply, such as solar (1) then, the charging station would use solar power to charge the EV battery.

Photovoltaic energy that is not used will indeed be stored in a storage battery. Whenever the sun is really not streaming or perhaps the temperature is foggy, the charging station focuses on the storage battery for electricity. If solar and battery storage run out of electricity, the charging station will switch to the EB/AC network to charge the EV Battery.

Table-1 Switching Logics to Charge/Discharge the EV Battery

INPUT			OUTPUT		
SOLAR PV	**BS**	**EB/AC GRID**	**DIS. (YES/NO)**	**EV (Cha.)**	**EV (Dis.)**
0	0	0	0	0	0
0	0	0	1	0	1
0	0	1	0	1	0
0	0	1	1	1	0
0	1	0	0	1	0
0	1	0	1	1	0
0	1	1	0	1	0
0	1	1	1	1	0
1	0	0	0	1	0
1	0	0	1	1	0
1	0	1	0	1	0
1	0	1	1	1	0
1	1	0	0	1	0
1	1	0	1	1	0
1	1	1	0	1	0
1	1	1	1	1	0

D. BLOCK DIAGRAM

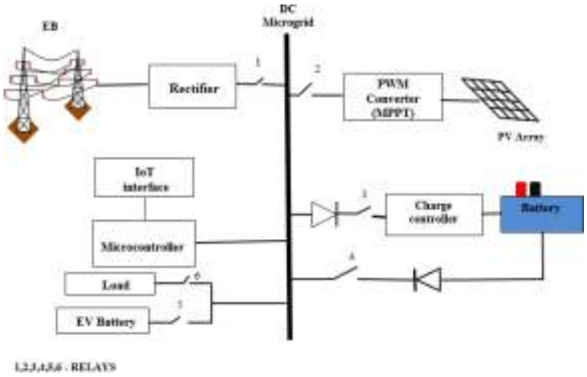

Fig.4 Proposed System Configuration

E. CONTROLLER

The Charging Station of an Electric Vehicle is entirely controlled by IoT which consists of ESP8266, Arduino Nano, OLED display, 8-Channel relay, and Rectifier.

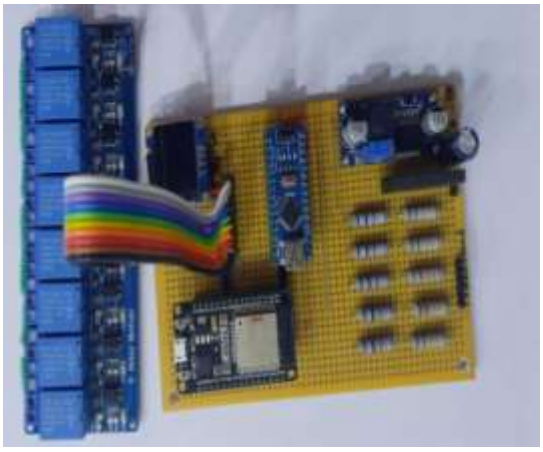

Fig.5 Controller of Charging Station

F. VOLTAGE DIVIDER

In order to measure voltages greater than 5V, the voltage divider concept is used to measure higher voltages. 100k ohm and 10k ohm resistors are used to measure up to 50V.

$V_{in} = 12V$, $R_1 = 100k\Omega$, $R_2 = 10k\Omega$

$V_{out} = (Vin*R_2)/(R_1+R_2)$

$V_{out} = (12*10000) / (100000/10000)$

V_{out} = 1.090 V (from Voltage divider)

$V = V_{out} / (R_2 / (R_1 + R_2))$

By using the above formula, we can obtain the original value

$V = 1.090 / (10000 / (100000+10000))$

V=12V

G. EV CHARGING STATION LITHIUM-ION BATTERY

A Lithium-ion battery is a type of rechargeable battery that makes use of charged particles of lithium to convert chemical energy into electrical energy used in electric vehicles and several portable electronics. A lithium battery consists of an anode of lithium, dissolved as ions into carbon. The cathode material is made up of Lithium liberating compounds typically the three electro-active oxide materials. (i.e.) Lithium Cobalt-oxide ($LiCoO_2$), Lithium Manganese-oxide ($LiMn_2O_4$), and Lithium Nickel-oxide ($LiNiO_2$).

III. EXPERIMENT AND RESULTS

H. ASSIGNING RELAYS

In this work, Eight-channel relays are used to switch three separate sources for charging and discharging the electric vehicles. The relays that have been assigned are as follows:

- ❖ Relay1: Solar
- ❖ Relay2: EB
- ❖ Relay3: Battery (Discharging)
- ❖ Relay4: Battery (Charging)
- ❖ Relay5: EV
- ❖ Relay6: Load

IOT CONTROLLED RELAY:

- ❖ Relay7: Load
- ❖ Relay8: EV Battery

IoT-controlled relays are controlled by the user through the Blynk app. Electric Vehicle charging station gets charged based on different modes. Configure a data stream in the Blynk app for observing the voltage variation levels from source inputs such as Solar Photovoltaics, Battery(storage), and Electricity Board/AC grid. Charging Station ON indicates the Vehicle to Grid condition and the user can only control the discharge process through the Blynk app (Fig.9).

I. MODE 1

In Mode 1, (Fig.10) the charging station will be using Solar power to charge the battery once it has been entirely discharged. In this case, the battery will receive electricity from the solar panel and the status will be depicted as Solar ON. Meanwhile, this condition will be displayed on Smartphones via the Blynk server, allowing users to track the status of the EV Charging Station battery.

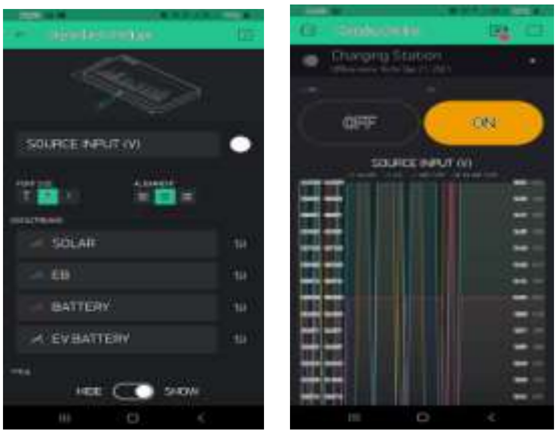

Fig.9 Different DataStream dashboards for charging EV Battery

Fig.10 MODE 1

Fig.11 MODE 2

Fig.12 MODE 3

Fig.13 MODE 4

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J. MODE 2

In Mode 2, (Fig.11) if Solar power is insufficient to charge the electric vehicle due to unforeseen factors such as cloudy weather or wet seasons then the charging station will move on to the next source. (i.e.) when there is excess electricity in PV during a day, it will be saved in the storage battery. On that note, the battery in the Electric Vehicle Charging Station (EVCS) intelligently recharges from the Storage Battery. The status of charging from the storage battery will be depicted as Battery ON both in OLED Display and on Smartphones.

D. MODE 3

In Mode 3, (Fig.12) if the Storage Battery is insufficient to charge the electric vehicle, then the charging station will move on to the next source AC grid or Electricity Board. Moreover, the battery in the Electric Vehicle Charging Station (EVCS) automatically takes from the AC grid. Meanwhile, Smartphones and OLED Displays are used to display the status of charging fromthe Electricity Board. This condition is used for backup or anyemergency situations.

E. MODE 4

In Mode 4: When the battery of the Electric Vehicle Charging Station (EVCS) is fully charged, then it will not take power from any sources. Meanwhile, the above status of the battery will be displayed on the OLED Display as All OFF (allsources are off), and the charging station is primarily designed to receive power first from solar, then it will be displayed as SOLAR 0.0V(Fig.13).

F. MODE 5

When an EV charging station is completely charged, whether power interruption occurs for any reason or when there is a sudden need for any emergency places like hospitals, etc then the DC microgrid can able to deliver electricity from the EV charging station, it will supply power back to the grid within a certain range. Here, (Fig.14) an LED stands for the microgrid's return power supply from the EV charging station.

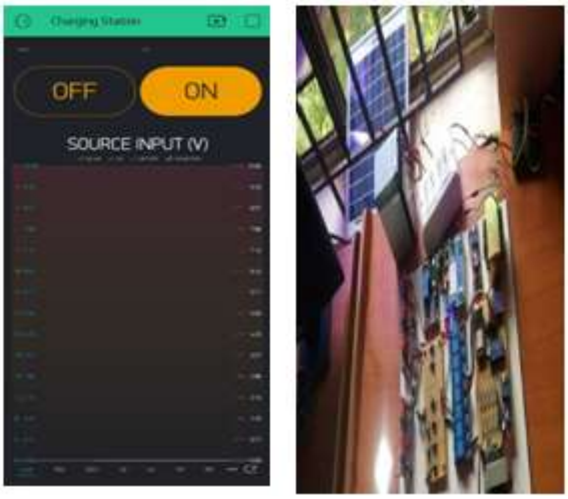

Fig.14 EV CS Discharges to Grid (V2G)


Fig.15 Entire Hardware Setup

Table -2 Experiment Result

Sources	Outcomes
Solar	11.9946 V
Storage Battery	9.5911V
EB/AC grid	10.8103V

Table 2 shows the voltages of the proposed method with various sources to charge the Electric Vehicle Charging Station.

IV. CONCLUSION

The high demand for Electric Vehicles on the road will require a massive infrastructure for transmission and distribution in the power grid. The charging station has been designed in this work to meet various requests of Electric vehicle owners. The future form of transportation is drawn by the integration of renewable energy and electric vehicles. On that basis, the monitoring and control of the Electric Vehicle charging station are critical for its efficient use. The voltage variation levels with the different terminals were controlled using an Autonomous Control Strategy of DC Microgrid. Developed an IoT-based approach for dealing with the EV charging and discharging process that does not require a human supervision body to regulate the process. Through the Blynk app on smartphones, the user can control the process of charging and dischargingthe EV Charging Station. In the future, the Battery Management System (BMS) estimates the State of Charge (SoC) and State of Health (SoH) of the battery to improve its safety and performance. The charging station will perform the Vehicle to Vehicle (V2V) power transfer and the user needs to decide which path to take and where and how much to charge/discharge its battery at the charging stations in a chosen path such that its journey can be accomplished with the minimum monetary costand time delay.

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