

# Implementation and Testing of a Smart DC Micro Grid

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**Abstract**—A DC Micro Grid maintains a DC bus, which feeds connected DC loads. With the increase in usage of Solar, Wind and other renewable power generation requirement of DC Grid is increasing<sup>[1]</sup>. Micro DC Smart Grid is little advanced as it is IoT based for necessary sensing and communication. It Measures, Controls and Logs all the Grid parameters like Bus Voltage, Load Current in cloud. This logged data is very useful for monitoring the generation and consumption, also for maintenance of the Micro DC Smart Grid or for fault identification and analysis. Stored Data in cloud is useful for fault prediction, forecasting and other stability analysis.

One LCD display is available for displaying the data locally. In this paper, design and implementation of a Smart DC Micro Grid is presented to provide sufficient power to the connected DC loads from two different DC Power Generating Systems. The DC Bus is kept at a constant voltage, while different loads and sources are switched on and off to check the stability of the DC Bus. Parameters are monitored remotely over IoT. This type of Micro Grid could be used for disaster management, to power up a small facility temporarily or permanently in Grid Tied and remote Off Grid applications.

**Index Terms**— DC Smart Grid, DC Grid, Smart Grid, IoT, Micro Grid, Smart Micro Grid.

## I. INTRODUCTION

Energy is one of the key essential elements for survival nowadays. Conventional energy sources like fossil fuels are near exhaustion. Different surveys and studies predict that gas reserves will run out in 40 years [3] and coal reserves in 70 years [3]. This scenario leads us to increase in Renewable Energy generation and consumption is highly recommended now a days [2]. The most popular renewable energy sources are Solar Photovoltaic, Solar Thermal, Wind energy, Hydro energy, Tidal energy and geothermal energy [4]. All of these energy sources are totally dependent on geographical and meteorological conditions. Among all other Solar and Wind are the most easy to implement then comes the Hydro Generation [5]. Implementation cost is relatively cheaper in Solar Power than the other two. Thus the PV power generation is expanding rapidly [7]. In PV System the generated power is DC. Some other renewable energy sources also generate DC Power. After generating the power there comes another scenario where this power is needed to be used according to the requirement. For this reason storage of Energy is required [6]. To store the excess generated energy battery is needed which stores Electrical Energy only from DC Source. DC Micro grid could be an easy solution for this type of requirement. On the other hand during disaster management to power up a facility this type of portable micro grid could be very useful.

## II. PROPOSED SYSTEM

Fig. 1 shows the block diagram of the proposed Micro DC Smart Grid. An AVR Micro Controller is used in the center of its control circuit. The system consists of two types of Sensors, one Bus voltage Sensor and three Current Sensors for measuring the Load Current, Current from Supply 1 and Current from Supply 2. The analog signals from these sensors goes to the controller.

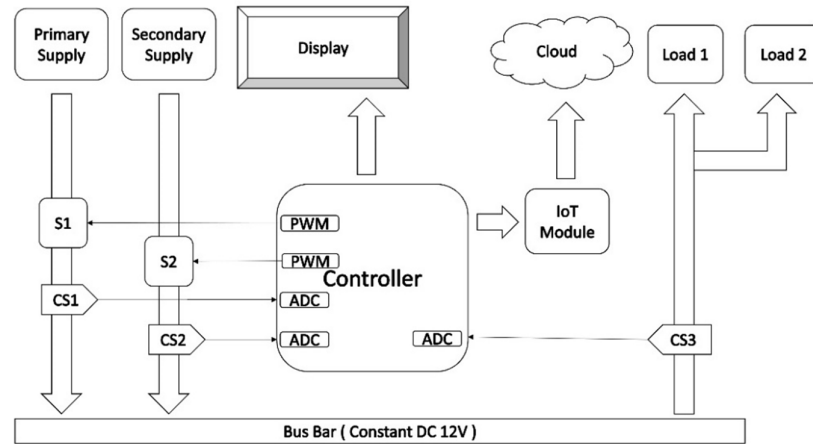


Fig. 1 Block diagram of the proposed system

The built in 10bit ADC of the Micro Controller samples and converts the voltage signal into integer data. This data is then processed and converted to respective current and voltage value and then sent to a LCD Display for real time display. After display the same data is sent to another IoT processor using UART to send this data to the cloud in 18 sec interval. This data could be fetched from the cloud and saved as CSV file. After displaying the data the AVR controller depending upon the value sends some control signal to the MOSFETs. These controls the incoming power to the bus bar thus the voltage of the bus bar. The data obtained from the cloud could be used to draw plot using proper software. Fig. 1 is the block diagram of the Micro DC Smart Grid. The system consists of an AVR microcontroller (ATmega328pu) along with other peripheral circuits. The main objective of the proposed system is to control and maintain the bus voltage to a constant value irrespective of load and let the user monitor the data in the output device as well as using IoT.

ESP 8266-01 [8]. Module has been used as IoT Module, for sending Data to Cloud. The Current and Voltage sensors are used to make the system a close loop control system. These values are measured by the Controllers 10bit ADC unit. Depending upon the values the PWM Signal from the AVR microcontrollers PWM pin goes to MOSFETs. The 16x2 LCD unit displays the live values of these sensors data. In Fig. 1 S1 and S2 are the switching device (MOSFET). CS1, CS2, CS3 are the Current sensor for measuring the Current from the Primary Power Supply, Current from the Secondary Power Supply and Load Current respectively. The Load Current is the sum of the Current from the Primary Power Supply and Current from the Secondary Power Supply. With increase of voltage in any Power Source the algorithm keeps the bus voltage constant. The whole control system runs on 5V power supply which can be given from external source. Some of the hardwires runs on 3.3V power supply an SMD 3.3 voltage regulator takes 5V as input and supplies power to those hardwires.

## III. SYSTEM ALGORITHM

The system starts keeping Switch 1 and Switch 2 in off mode. Switch 1 has the higher priority Switch 2 comes after that. Once the system starts Switch 1 gradually opens. Controller controls the opening of the Switch by measuring Voltage of the bus. During the process the controller transmits the readings of the Bus Voltage, Load Current, Supply Current 1 and Supply Current 2 to the IoT processor by UART, to process the data. The IoT processor receives the data and prepares it for cloud and sends it to cloud. After sending the data to cloud the controller starts communicating with the Liquid Crystal Display Module, then displays the Voltage and Current data accordingly. Then again checks the voltage of the bus. During the whole cycle if any point Source 1 fails to provide sufficient power to the bus then Switch 2 gradually opens and provides the rest amount of power to the bus and keeps the bus voltage to a constant point. The bus voltage has a lower and upper threshold value. If the

bus voltage falls below the threshold of goes beyond the threshold the controller takes necessary action by changing the PWM signal to Switch 1 and Switch 2 and brings the bus voltage in range.

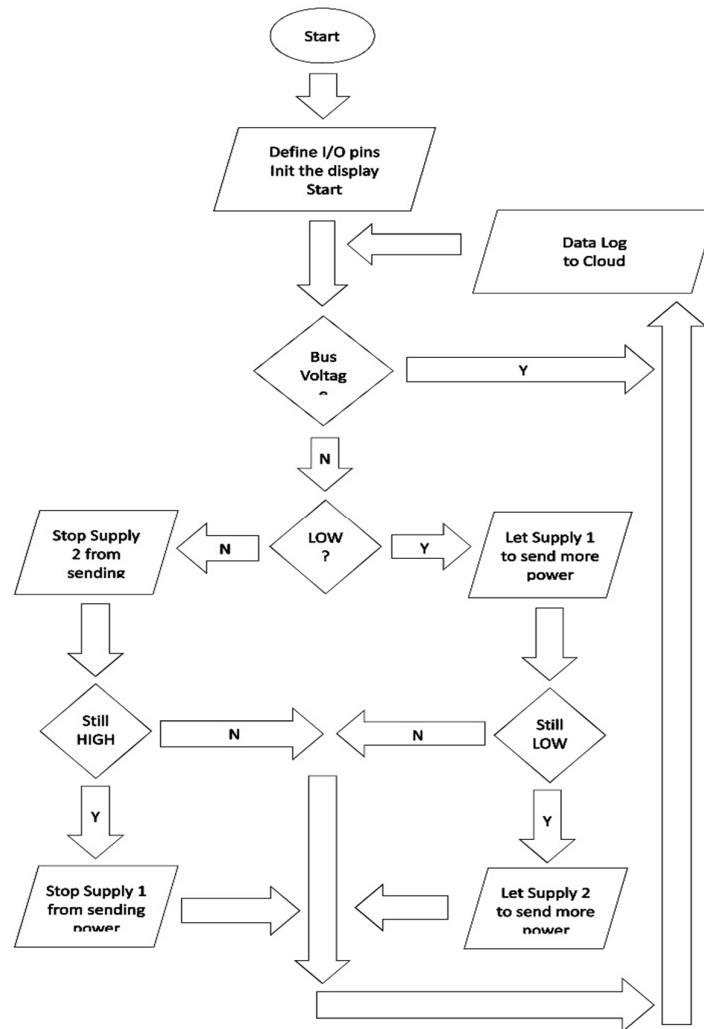


Fig. 2 System Software Flow Diagram

| created_at | entry_id | field1      | field2       | field3            | field4          |
|------------|----------|-------------|--------------|-------------------|-----------------|
| Date_time  |          | Bus Voltage | Load Current | Secondary Current | Primary Current |

Fig. 3 Data format for CSV file in cloud

#### IV. RESULTS AND DISCUSSION

The results obtained are depicted in Fig. 4. Fig. 4 demonstrates the CSV Data from the cloud. Fig. 5 indicates the Bus Voltage gradually increasing at starting and steady during running condition while the load changing occurs. Fig. 6 indicates the Load Current at different loads. Fig. 7 shows the Current from Primary Supply supplying the maximum current to the Load, Fig. 8 Shows the Current from Secondary Supply providing current when Primary Supply fails to provide sufficient power to maintain the bus voltage. The load current is always the sum of Current from Primary Source and Current from the Secondary Source.

Fig. 9 indicates that the voltage is still same while Fig. 10 shows load current became twice. From Fig. 11 and Fig. 12 it can be seen that the Primary current is higher than the secondary current, from Fig. 15 - Fig. 16 Fig. 19 - Fig. 20 it can be seen that the Primary current is always higher than the secondary current.

From the value of bus voltages in the Fig. 5, Fig. 9, Fig. 13, Fig. 17 and the value of load current in Fig. 6, Fig. 10, Fig. 14, Fig. 18 it is shown that the Bus Voltage remains constant irrespective of the load. This sample data was recorded on 21<sup>st</sup> of April 2020.

| created_at              | entry_id | field1      | field2       | field3            | field4          |
|-------------------------|----------|-------------|--------------|-------------------|-----------------|
| Date_time               |          | Bus Voltage | Load Current | Secondary Current | Primary Current |
| 2020-04-21 13:24:00 IST | 438      | 12.15299    | 0.45873      | 0.02483           | 0.4364          |
| 2020-04-21 13:28:38 IST | 453      | 12.12393    | 0.88143      | 0.30385           | 0.54045         |
| 2020-04-21 13:30:11 IST | 458      | 12.12898    | 1.39566      | 0.63782           | 0.72779         |
| 2020-04-21 13:31:44 IST | 463      | 12.04432    | 1.23844      | 0.54069           | 0.64459         |

Fig. 4 Data in Cloud

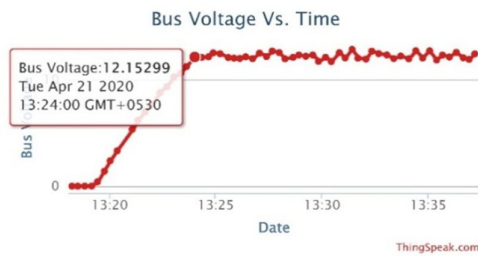


Fig. 5 Bus Voltage on 21/Apr/2020@13:24:00

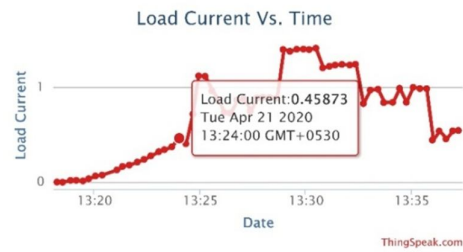


Fig. 6 Load Current on 21/Apr/2020@13:24:00

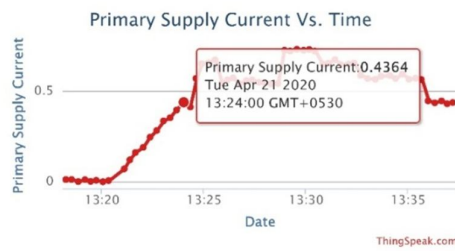


Fig. 7 Current from Source 1 on 21/Apr/2020@13:24:00



Fig. 8 Current from Source 2 on 21/Apr/2020@13:24:00

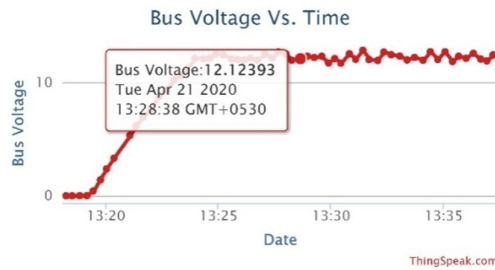


Fig. 9 Bus Voltage on 21/Apr/2020@13:28:38



Fig. 10 Load Current on 21/Apr/2020@13:28:38



Fig. 11 Current from Source 1 on 21/Apr/2020@13:28:38



Fig. 12 Current from Source 2 on 21/Apr/2020@13:28:38

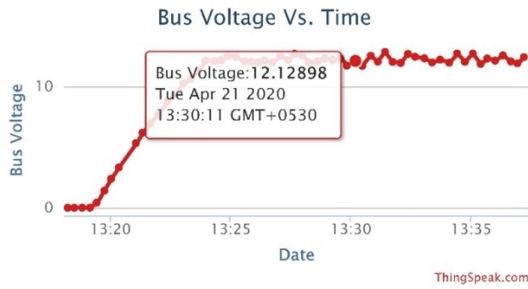


Fig. 13 Bus Voltage on 21/Apr/2020@13:30:11

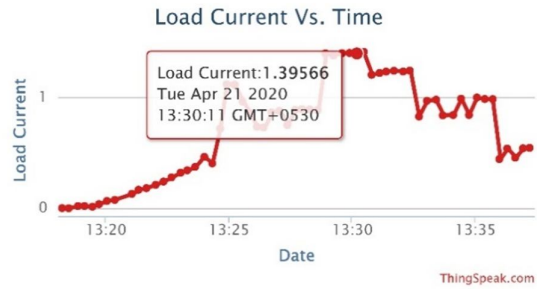


Fig. 14 Load Current on 21/Apr/2020@13:30:11



Fig. 15 Current from Source 1 on 21/Apr/2020@13:30:11



Fig. 16 Current from Source 2 on 21/Apr/2020@13:30:11

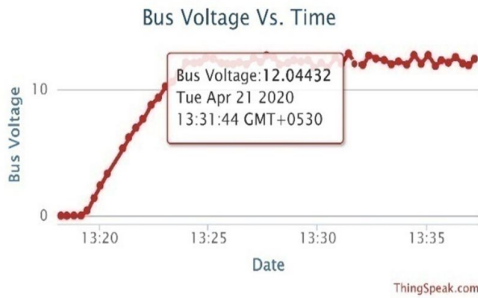


Fig. 17 Bus Voltage on 21/Apr/2020@13:31:44

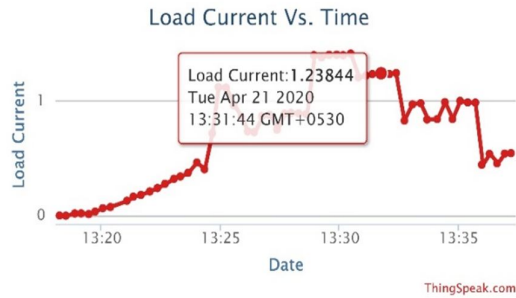


Fig. 18 Load Current on 21/Apr/2020@13:31:44

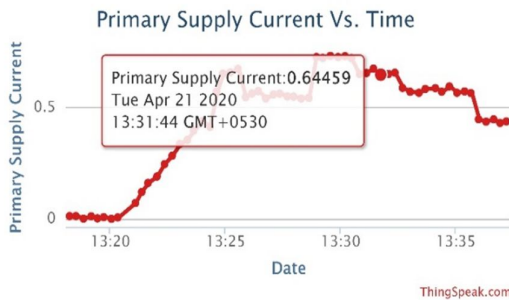


Fig. 19 Current from Source 1 on 21/Apr/2020@13:31:44



Fig. 20 Current from Source 2 on 21/Apr/2020@13:31:44

From the result we can easily see that if the primary supply fails to feed the requirement, secondary supply starts to supply power, for maintaining the bus voltage. Machine Learning could be implemented for fault prediction. To achieve that the historical data from the data logging system would be fed to the computation module to produce a linear regression model. This model then take live data to analyze and identify the situation where any instability of the system is occurring. So that whenever such situation arises the device would predict future fault possibilities generate alarm as well as may take some precaution to avoid such circumstance.

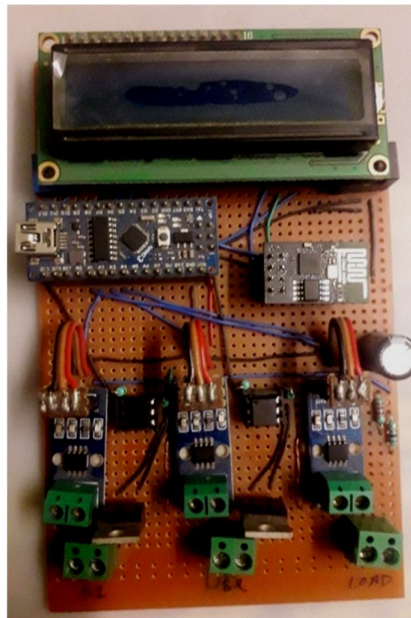


Fig. 21 Hardware setup

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