Design of DC–DC Converter and Controller for Smart DC Grid and Battery Storage using Arduino

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Abstract - *In India some people are living in village area where national transmission line is not reached till now. The existing electrical grids are not capable of giving electricity to those poor people living in the village. So that renewable energy sources such as photo voltaic panels and wind-generators are the best option for them because of its lower cost and its little maintenance. In this paper a low cost smart DC grid is designed with DC-DC converter and charge controller which is controlled by the Arduino Nano board is proposed. The direct use of on-site renewable energy without conversion to Ac could increase efficiency and reduce the conversion loss. The developed system consist of(i) Buck-boost DC-DC converter using fuzzy logic control (ii) Battery charge controller with Arduino Nano interface (iii) DC net energy meter for power monitoring of DC grid (iv) Wi-Fi module is used for remote surveillance and uploading live data about DC grid and used for studying the health of the battery. The individual solar home can be connected to from a low voltage smart DC grid and the system can be used operate DC load for remotely located village for sustainable provision of electric energy services.*

Key Words: Smart DC grid, DC-DC converter, Charge controller, DC net meter, Arduino Nano, Battery.

1. INTRODUCTION

Today, the world population is drastically increasing, hence the consumption of electrical energy is increasing accordingly. Nearly 1.4 billion people in developing countries still live without access to reliable. In India 31 million people still live in dark. Most of these households without electricity are located in village and near hills that are unconnected to the central electrical grid. The energy generation by fossil fuels has many impact on environment, so that renewable resources of energy especially the photovoltaic energy is considered as the alternative solution to existing fuels due to its low cost, little maintenance and have long life. In order to provide access to electricity to rural population with low energy consumption in remote and off grid areas, a low, voltage DC distribution network where in individual Solar Home Systems (SHS) can be interconnected, is an attractive option [1].Due to the intermittent nature of renewable energy sources, batteries play an important role in load–power balancing in a DC grid. In this paper the Arduino Nano based buck-boost converter and a low cost Arduino Nano based solar powered battery charging system for the SHS and smart DC grid is designed.

2. CONVENTIONAL METHODAND PROPOSED METHOD

The output of most renewable energy generate the DC and must be converted to AC using converter device at appropriate frequency and voltage before it can be use and fed to the local line supply. The use of the power electronics converter increase the complexity and decrease efficiency of the power system. Nowadays most of the electronics devices used in daily life such as laptops, mobile phone, and LED lights use DC. Such application need to convert AC back to DC which increase the loss and complexity of the power system. This concept is useful for rural area where the national grid transmission line not reached. The low voltage DC network can supply electricity generated by solar PV to the load like LED lamp, DC fan, TV and mobile charging stations in rural area. This dc base system eliminate the requirement of converter systems, reducing the cost, power system complexity and improve the efficiency. The buck-boost DC to DC converter used to convert the solar power to desire voltage. The batteries are used as an energy bank to store energy from the solar panel and it is used in night hour. If battery is overcharged or deep discharged for a long duration of time, batteries life span will come down. It is very difficult to recharge battery if a battery goes into deep discharge, since the electrode plates of battery will be fully sulphated, resisting the charging [1]. So the low cost Arduino Nano charge controller is developed to protect from overcharging and deep discharging with LM317. The system has Wi-Fi module which has the capability of logging and storing data for remote surveillance, monitor the DC grid system continuously, maintain the battery, thereby increasing the life of the battery.

3. BLOCK DIAGRAM

The block diagram of the proposed system given in figure 1. It contains a solar panel, DC-DC converter, Arduino Nano interface charge controller, energy meter, battery bank, and load to deliver usable power to end user. The solar panel convert the sunlight to electrical energy. The output voltage of the solar panel is varies continuously depend on sunlight. So that output from solar panel is fed to the DC-DC buck boost converter, which gives the constant output voltage by controlling the duty cycle of MOSFET switch. The duty cycle is varied by PWM from the Arduino Nano board which operate by fuzzy logic algorithm. The charge controller limit the voltage and current for charging the battery by LM317 regulator. The controller also protect the battery from over charging, deep discharging and from abnormal condition. The Arduino Nano control relay in the charge controller to operate when the battery need to charge and interrupt the charging when battery is full. The DC net meter is used measure the in and out power follow of smart DC grid.

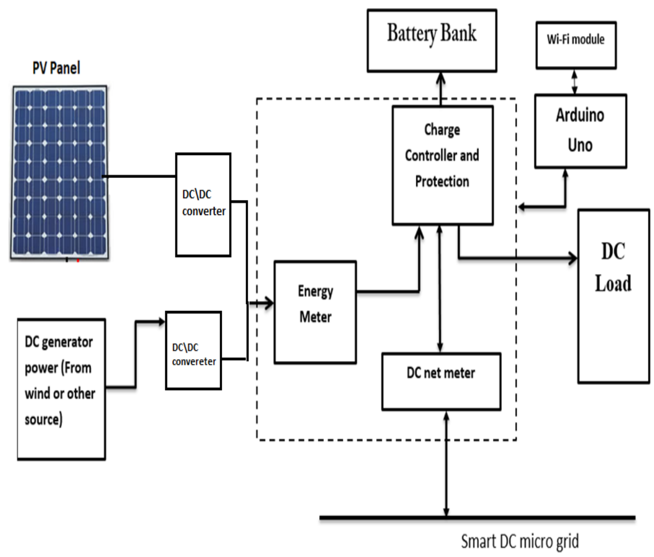

Fig -1: Block diagram of the system

3.1. BUCK-BOOST DC\DC CONVERTER

Figure 2 shows the buck-boost converter with controller. The buck-boost converter is used to convert the higher or lower Dc input voltage from the solar panel to constant DC output voltage. The duty cycle of the converter is varied by the PWM from the Arduino Nano.

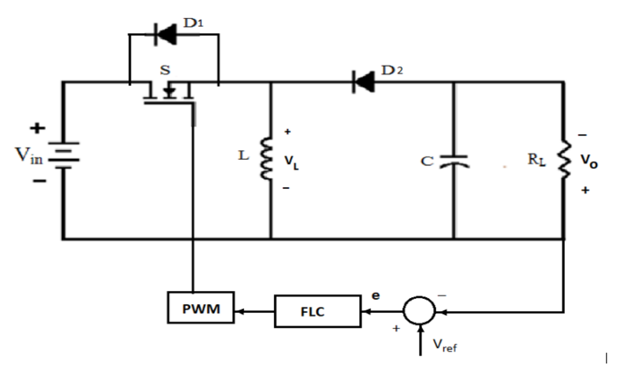

Fig -2: Buck-boost DC/DC converter system

Table -1: Parameters of converter

Parameter	Value
Inductance	10 mH
Capacitance	30 mF
Switching Frequency	1 kHz
Output voltage	15 V

The circuit equation are given below.

1. The dc voltage transfer function of the buck–boost converter is

$$M_v = \frac{v_0}{v_s} = -\frac{D}{1-D}$$

2. The value of the inductor is determine by

$$L = \frac{R(1-D)^2}{2f}$$

3. The value of capacitor is determine by

$$\frac{\Delta v_0}{v_0} = \frac{DT}{RC}$$

3.2. CHARGE CONTROLLER

The charge controller designed is used to protect battery from overcharging, over discharging and from abnormal condition. When the battery becomes fully charged the charge controller limits the current supplied by the source to the battery to protect from heating. When the battery reaches full state of charge the controller enter into float made, which maintain the battery voltage 13.6V.In this controller LM317 ICs are used, one used to control the voltage and the other used to limit the current. Here the IC2 is used to control the current and IC3 is used to control the voltage to the battery. The Arduino get the voltage and current value from the converter with help voltage divider and current measurement circuit, with the help of that it calculated the power. Figure 3 shows the charge controller circuit.

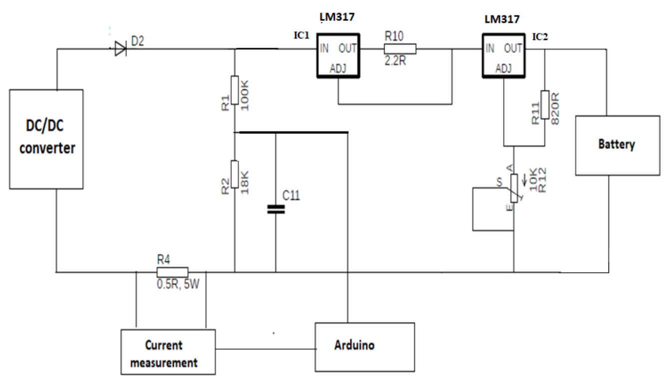

Fig -3: charge controller circuit diagram for battery

a. Current Limiter Circuit:

The LM317 current limiter circuit limit the current based on the resistance value R1, by selecting the resistor R1 the current can be adjust to required limit.

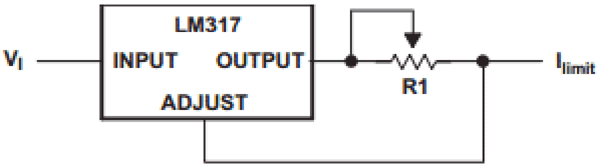

Fig -4: Current limiter

The formulae to calculate the output current is

$$I_{out} = \frac{1 \cdot 25}{R_1}$$

b. Voltage Regulator Circuit:

In LM317 voltage regulator the output voltage is decided by the resistor values R1 and R2, the resistor R2 is used as a variable resistor to control the output voltage.

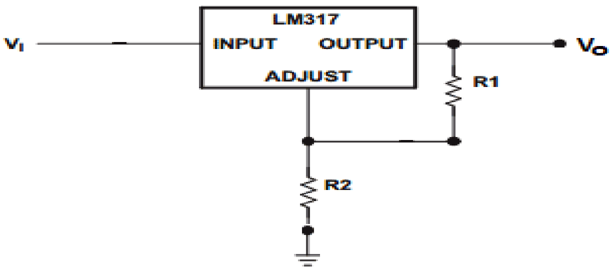

Fig -5: Voltage regulator

The formulae to calculate the output voltage is

$$v_{out} = 1 \cdot 25\left(1 + \frac{R_2}{R_1}\right)$$

The charge controller can operate in one of the following state:

i. Bulk: When the battery voltage is very low the maximum constant amount of current is fed into the battery [3]. As the battery is being charged up, the voltage of the battery increases gradually.

ii. Absorption: When the battery is nearly to the full state of charge, the regulator hold the voltage constant [3]. This is to avoid over-heating and over-gassing the battery. The current level is slowly decrease as the battery becomes more fully charged.

iii. Float state: When the battery is fully recharged, the charging voltage is reduced to prevent further heating or gassing of the battery.

iv. Off State: When no power is generated by the solar panels the charger goes into off state.

3.3. DC NET METER

Net metering is a solar incentive that allows you to store energy in the electric grid. When your solar panels produce excess power, that energy is sent to the grid and in exchange you can pull from the grid when your system is under-producing like during nighttime. Figure 6 shows the DC net meter [4].

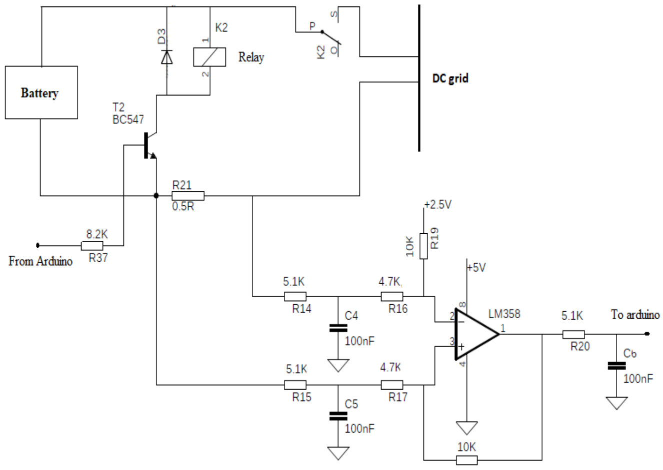

Fig -6: DC net meter

DC net meter measure the amount of power flows from source to DC grid and measure the amount power flows from DC grid to Battery. The op-amp measure the current in the circuit with the help of shunt resistor.

4. INTERFACING OF CONTROLLER WITH WI-FI MODULE

ESP8266 is Wi-Fi enabled system on chip (SoC)module developed by Espressif system. It is mostlyused for development of IoT (Internet of Things)embedded applications. ESP8266 module comes with preprogrammed with a firmware.

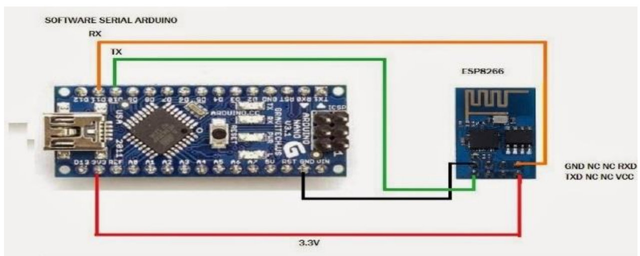

Fig -7: Interfacing of WI-FI module with Arduino

It helps to gather informatiom about the solar panel, energy produce by it, and battery details. The information about the energy consumption and energy produced by solar can be send to the user mobile phone. The IOT helps in better maintenance of the smart DC grid.

5. SIMULATION AND RESULT

The simulation of the charge controller and DC net meter is done using the Proteus. Figure 8 shows illustrated the simulation using Proteus. The solar panel is replace by DC voltage source of 15 V and the current limit the current to 1A and voltage regulator gives the 13.6V to the battery. When the battery is fully charged the controller reduce the current to the battery and maintain the battery in float state.

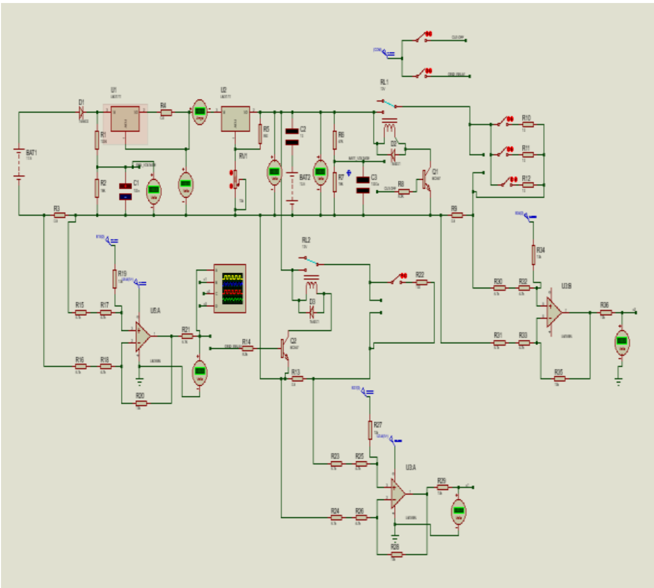

Fig -8: Simulation of controller and DC net meter

The current measurement using op-amp gives voltage greater then 2.5V to the Arduino. DC net meter measure the power flow to grid.

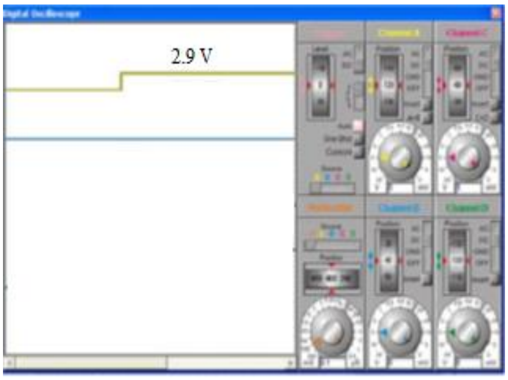

Fig -9: Current measurement of Net meter

6. EXPERIMENTAL RESULT

Hardware has been set up in order to experimentally test the performance of the newly developed system. 50 W solar panel is used as a source to system and it gives nearly 17V. Figure 10 shows the hardware setup.

Fig -10: Hardware setup of system

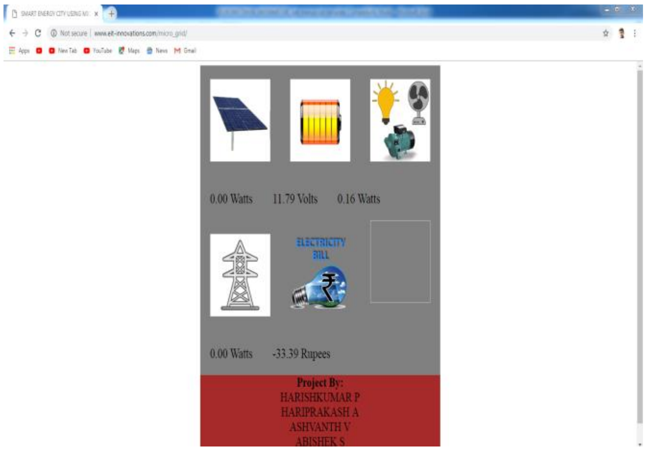

Fig -11: Web page of system

The converter gives the constant output voltage of 15V to the charge controller. The controller gives the voltage of 13.6V and current of 1A to the battery. The excess of energy is given to the DC grid, which is tested by connecting another battery. The display show the power generate by the panel, battery charge percent, power flow in and out of DC grid and load power. The Wi-Fi module send the complete detail about the system to the web page which is shown in figure 11.

7. CONCLUSION

In this paper the low cost converter and Arduino Nano based charge controller for smart low voltage DC grid is designed and developed. The individual solar home can connect together to from the low voltage DC grid system for DC load. Direct use of locally generated electricity at a low voltage helps to reduce the transmission loss and conversion loss. The charging of the battery is controlled by the Lm317 and

Arduino Nano which protect battery from overcharging and over discharging. The voltage and current of battery and solar panel is continuously monitor by energy meter. DC net meter monitor the power flow in the DC grid. LCD display and Wi-Fi module are used for data logging and it can also be used for remote surveillance of the system.

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