Design and Implementation of Solar Based Dc Grid using Arduino Uno

M Thirupathaiah

Abstract: ***Renewable Energy Sources (RES) such as Solar Photovoltaic (PV) became more popular over the last decade due to increasing environmental awareness and tax exemption policies on the solar PV systems. Integration of solar PV using various smart load management techniques will boost the efficiency of the overall system by reducing the massive cost of electricity bills. There is a need to find efficient and expert ways to enjoy these RES exclusively. Besides providing the connection between different loads, this system has the ability to collect information and execute control commands for the households by providing continuous observations and information about both load and supply profile, convincing the end user to take preventive measures by switching the auxiliary load to save power. This paper presents implementation of a low cost Solar based DC grid using Arduino. In the proposed system, the node which acts as a microcontroller reads the power consumption by the loads in each unit through current sensor. When the excess amount of power is consumed at particular unit, the controller makes the relay cut off the supply to the loads, which will be continuously displayed through LCD. This DC based power system helps to eliminate the requirement of converters systems, reducing converter cost, power system complexity, improve efficiency and reliability.***

Keywords: Renewable Energy Sources (RES), Solar Panel, Current sensor, Arduino Uno, Relay, LCD Module

I. INTRODUCTION

Solar energy is a clean and renewable power resource and is on its way to high level penetration in the world electricity energy basket. [1] However, there are several challenges associated with solar energy, like intermittency, limited dispatch ability and non-storability. Non-storability in a standalone PV system can be mitigated by incorporating energy storage devices like battery to store the electrical energy produced by solar panel when the sun is shining and to supply power when the sun is not shining. Batteries are, therefore, one of the critical components in the standalone PV system. And often the weakest link in PV systems as it influences the maintenance cost and reliability of the system.[2] The major components in standalone solar PV system are Solar PV panels, batteries and power conditioning devices. The solar PV panels produce DC power which was later on converted to AC using converter devices.

Nowadays, increasing number of devices which use DC, such as laptops, mobile phones and other power electronic devices used in our daily life are being incorporated. Such applications need to convert AC back to DC [3]. This conversion increases the losses and complexity of the power system. This concept is particularly useful for rural and sparsely populated areas where in low voltage DC network can supply electricity generated by solar PV to cater to the load constituting of LED lamps, DC fan, TV and mobile charging stations.

The objective of the proposed work is

- To generate power through an array of solar panels connected each to an individual location and charge the battery through a charging circuit by using the generated power.
- To supply the generated power to the DC loads through the microcontroller that reads the power consumption through the current sensor and displaying it using LCD.
- To differentiate the power consumption between two homes where one home is provided with back up and other without backup through the LCD.

The developed solar based DC grid system for DC loads has been designed for use in Solar Home Systems (SHS) [4]. The individual SHS can be connected to form a low voltage DC micro grid for the remotely located rural population for sustainable provision of electric energy services. Two homes are shown where in the one with backup battery has uninterrupted power supply to the DC loads and the other home without backup battery cuts off the supply to the loads depending on the set units consumption limit in the microcontroller code.

II. BLOCK DIAGRAM

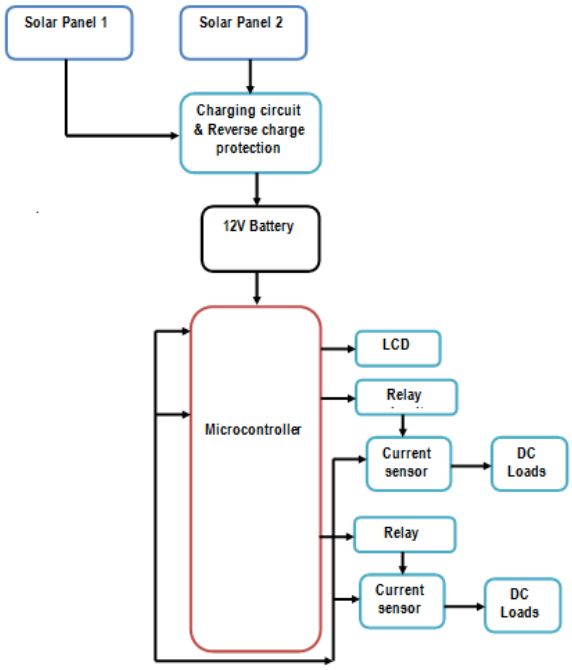

Fig. 1. Block Diagram

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A. Solar Panel

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity. A PV module is a packaged connected assembly of typically 6×10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications[5]. Each module is rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts.

In the proposed system, two 3W, 6V, 0.5A solar panels have been used to generate electrical energy that is used to charge the rechargeable batteries. The characteristics of the solar panel used are:

Maximum Power (P max) - 3 W
Voltage at Maximum Power (V_{mp}) - 6 V
Current at Maximum Power (I_{mp}) - 0.5 A
Open Circuit Voltage (V_{oc}) - 7.2 V

B. Battery

In this system, four 12 Volt 1.2 Ah Sealed Lead Acid rechargeable batteries are used for one home and two 12 Volt 1.2 Ah Sealed Lead Acid Rechargeable batteries for other home are used which are charged from the solar panels [6]. The characteristics of the battery are:

Battery - F1 Terminal
Voltage: 12 Volt
Capacity: 1.2 Ah
Type: Sealed Lead Acid Battery
Length: 3.82''

C. Current sensor

In this system, two ACS712 Current sensor modules - 20A have been used through which the microcontroller reads the power consumption for two homes. The specifications of current sensor used:

Supply voltage: 4.5 V ~ 5.5 V
DC Current range: -20 A ~ 20 A
Sensitivity: 100 mV/A.

D. Aurdino Uno

The Arduino Uno is an open-source microcontroller board based on the Microchip Atmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards and other circuits. The board has 14 digital I/O pins, 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. Each pin can provide or receive 20mA as the recommended operating condition and has an internal pull-up resistor of 20-50K ohm. A maximum of 40mA must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller. The Uno's 6 analog inputs, labeled A0 through A5; each provides 10 bits of resolution.

Technical Specifications:

Microcontroller: ATmega328P-8bit AVR family
Operating voltage: 5 V
Input Voltage Limits: 6 - 20 V

The microcontroller reads the power consumption through the current sensor and when the excess amount of power is consumed at particular unit, the controller makes the relay cut off the supply to the loads accordingly to two homes depending on the source code given to microcontroller.

E. Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. In this system, a two-channel relay module for home1 and single channel relay module for home2 have been used. For Home A, the two relays incorporated in the relay module are powered by Arduino and input is given from the digital pin of the Arduino. Relays cut off the power supply to the DC loads from the battery when it exceeds the power consumption limit for home A and home B set in the source code of microcontroller.

F. LCD Module

The LCD runs in four bit data mode but generally the data from LCD can be in eight bit or four bit data mode, in order to reduce the program size four bit data and the four data pins (D4-D7) are used to read and write the data to the LCD. The power consumption is displayed through LCD for both the homes in units and also for home1 with backup battery the transition from primary to secondary battery can be observed in the LCD.

G. DC Loads

Two DC motors have been used as DC loads represented as DC fans i.e., one DC motor for home1 and other DC motor for home B respectively. For home1 with back up battery the connected DC motor receives uninterrupted supply by transition through the 2-channel relay module from primary battery to back up battery according to the set power consumption limit in the microcontroller which reads the power consumption from the current sensor. For home B without back up battery the connected DC motor runs only until the set number of units in the microcontroller is consumed and supply is cut off by the single channel relay module.

III. METHODOLOGY

In order to implement a low cost solar based DC grid using Arduino, two homes with DC loads running on DC power supplied by the solar panels are used for demonstration. For practical purpose any number of such homes can be connected in parallel to form a DC grid [7].

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The DC based power system helps to eliminate the requirement of converters systems, reducing converter cost, power system complexity, improve efficiency and reliability. This concept is particularly useful for rural and sparsely populated areas where in low voltage DC network can supply electricity generated by solar PV [8]-[9] to cater to the load constituting of LED lamps, DC fan, TV and mobile charging stations. To differentiate the battery requirement, two homes are implemented in such a way that one home is provided with a backup battery whereas the other home is not provided with it. A total of six 12 Volt 1.2 Ah sealed lead acid rechargeable batteries in a pair of two i.e. 3 battery pairs with their respective anodes and cathodes connected to each other are used. So these can be considered as three batteries out of which battery1 and battery 2 are connected in home A and battery3 in home B. These batteries are charged by the solar power generated from the two 3W, 6V and 0.5A solar panels through the charging circuit.

A PCB is designed which constitutes the charging circuit for two homes i.e. the PCB has two different circuits one circuit with three connectors for home A and other with two connectors for home B. The charging circuit also contains two LEDs, one led for home A and other for home B, which are used as an indication when energy from the solar panels is transferred to the batteries i.e. when charging of the batteries takes place. Also, two p-n junction diodes are provided for the reverse charge protection of batteries which means the energy from the solar panels should be directed to the batteries but the backup voltage in the batteries should not be directed back to the solar panels. The flow of power should be unidirectional which is from solar panels to the batteries, for this purpose a diode is used in the charging circuit of each of home A and home B.

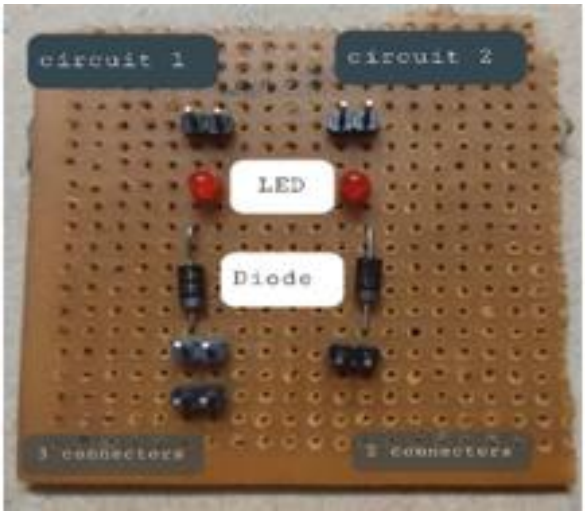

Fig. 2. PCB Board for charging circuit

The initial two connectors in the first and second circuits of PCB, placed behind the LEDs are used for connecting the solar panels simultaneously for home A and home B. The two connectors in the first circuit placed ahead of diode in home A are used for connecting the battery 1 and battery 2 (backup battery) whereas in case of home B the connector placed ahead of diode in second circuit is used for connecting the battery 3.

A. Functioning of Arduino

As the power consumption here is in terms of analog values and the ADC (i.e., analog to digital converter) of Arduino UNO can be used to convert the analog values to digital values and also for using the inbuilt LCD display libraries.

For prototype Arduino UNO is powered by a battery but the charging and discharging currents of battery leads to fluctuations which in turn causes improper functioning of the program code. So, a DC adaptor is used to power the Arduino UNO with 12 volts DC and this adaptor is used only for proper program functionality. Home A contains battery 1, battery 2 and load A whereas Home B containing battery 3 and load B as main components.

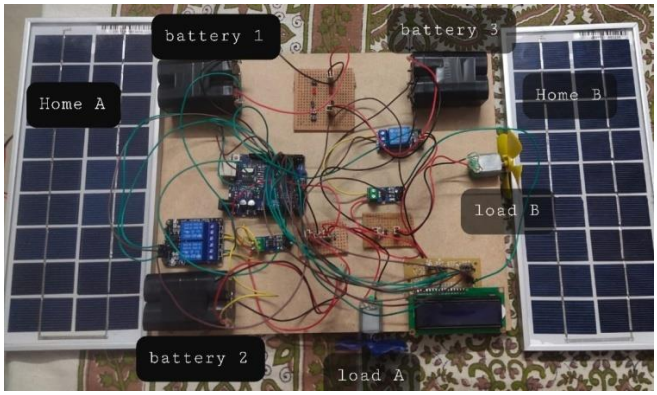

Fig. 3. Prototype model

B. Home A

Initially, load A runs on the battery 1 when the power limit of the battery is exceeded the load A is shifted to the battery 2 i.e backup battery. In this case, it has been set as ten pulses equivalent to one unit and the maximum units consumption limit for each battery to three units. When three units limit of battery 1 is reached, load A automatically shifts to the battery 2, so it acts as an uninterrupted power supply to the load and for demonstration purpose the battery 2 also limited to maximum power consumption of three units after which the supply to load is cut off. For transition of load A from battery 1 to battery 2, a two channel relay module is used and here the relay1 and relay 2 are connected respectively to battery 1 & battery 2.The input to this two channel relay module is given by the microcontroller i.e. the microcontroller reads the analog values from the sensor and when the unit consumption limit is exceeded it cuts off the supply to the relay. So initially the load A runs on battery 1 and when the microcontroller observes that the three units of battery 1 are consumed relay 1 is turned off and relay 2 is turned on which shifts the load A to battery 2.The load A continues to run on the battery 2 until the three units of battery 2 are also consumed which is observed by the microcontroller, after which the supply to the load A is cut off and the current sensor cannot send the values anymore to the microcontroller. Therefore, it can be concluded that the relay receives the input from microcontroller and output is given to the battery.

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C. Home B

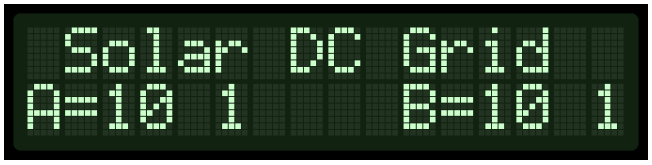
For home B, the load B runs on the battery 3 and when the power limit of the battery is exceeded the supply to the load is cut off i.e. load is not shifted because of the absence of back up battery. When the three unit limit of battery 3 is reached the supply to load B is cut off. For the purpose of disconnecting the supply to load here a single channel relay module is used which is connected to the battery 3.The input to this single channel relay module is given by the microcontroller i.e. the microcontroller reads the analog values from the current sensor and when the unit consumption limit is exceeded it disconnects the battery 3 thereby disconnecting the supply to load B as the current sensor cannot give any readings to the microcontroller thereafter.

IV. TESTING AND RESULTS

The results can be analysed through the readings displays on LCD. Here, Home A and Home B are represented as A and B respectively. As the power consumption limit set for each battery is three units and each unit constitutes ten pulses the number of pulses and corresponding units consumed are displayed on LCD for both Home A and Home B.

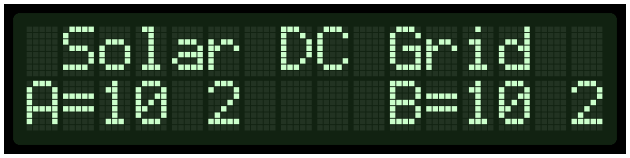
Case (i)

When the load A of home A runs on battery 1 and load B of home B runs on battery 3 and one unit is consumed by both the loads i.e. first ten pulses equivalent to one unit.



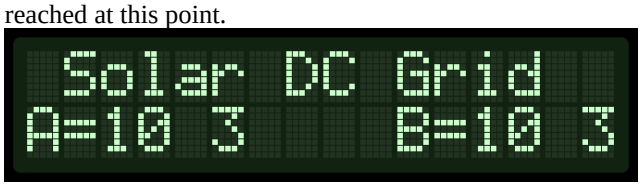
Case (ii)

When the load A of home A runs on battery 1 and load B of home B runs on battery 3 and two units are consumed by both the loads i.e. first ten along with next ten pulses equivalent to two units.



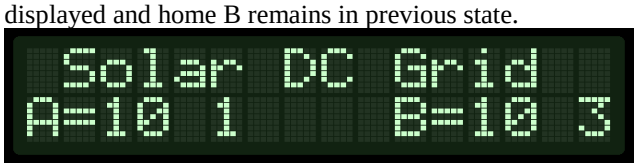
Case (iii)

When the load A of home A runs on battery 1 and load B of home B runs on battery 3 and three units are consumed by both the loads i.e. first ten, second ten and next ten pulses equivalent to three units. So, the maximum power consumption limit for both battery 1 and battery 3 has been reached at this point.



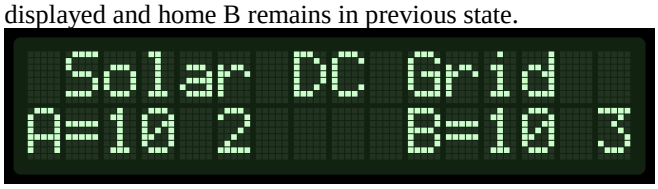
Case (iv)

The maximum unit consumption limit of three units for both battery 1 and battery 3 has been reached at this point. But as home A has a backup battery the load A is shifted from battery 1 to battery 2 by switching using a two-channel relay module whereas for home B without the backup battery the supply to load B is cut off. Now on the LCD for home A first ten pulses equivalent to one unit of battery 2 consumed is displayed and home B remains in previous state.



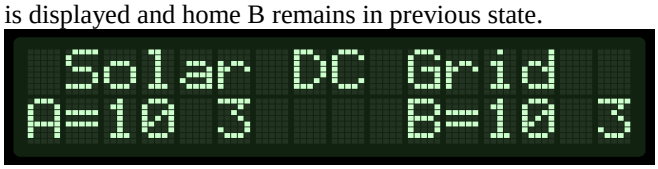
Case (v)

In this case, load A runs on battery 2 and supply to load B is cut off. Now on the LCD for home A first ten and second ten pulses equivalent to two units of battery 2 consumed is displayed and home B remains in previous state.



Case (vi)

In this case, load A runs on battery 2 and supply to load B is cut off. Now on the LCD for home A first ten, second ten and next ten pulses equivalent to three units of battery 2 consumed is displayed and home B remains in previous state.



V. CONCLUSION

The prototype has been developed by integrating features of all the hardware components used. Presence of every module has been reasoned out and placed carefully thus contributing to the best working of the unit. Secondly, using highly advanced IC's and with the help of growing technology it has been successfully implemented.

The developed solar based DC grid system for DC loads (DC lighting i.e. LEDs, DC gadgets like laptops, telephones, satellite TV controllers etc.) has been designed for use in Solar Home Systems (SHS). The individual SHS can be connected to form a low voltage DC micro grid for the remotely located rural population for sustainable provision of electric energy services. This DC based power system helps to eliminate the requirement of converters systems, reducing converter cost, power system complexity, improve efficiency and reliability.

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