Real Time Remote Solar Monitoring System

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Abstract— **The following paper proposes a solar metering system which can be accessed from anywhere for monitoring and analysis of solar setups. It monitors the solar output in real time with ease and therefore any interruption in the system can be immediately monitored. This IOT (Internet of Things) based system is best suited for remote areas where solar systems are setup due to ample availability of solar energy but regular access to the areas is difficult and is not cost efficient. With the demands of renewable and solar energy escalating, this system's demand and usefulness will blatantly increase .The system comprises of Raspberry PI (a Microcontroller based Computer), MCP3008 (Analog to Digital Convertor), DC Voltage Transducer and current shunt. The system has been developed using Virtual Instrument Programming Language LabVIEW.**

Keywords— real time; IOT; remote; Raspberry PI; Transducer; LabVIEW

I. INTRODUCTION

The global problem of greenhouse emissions has been a topic of international debate. The injudicious use of fossil fuels has exploited our conventional energy sources. The cost of fossil fuels has been increasing as the supplies of fossil fuels are getting exhausted. Thus in the present context, the demand for renewable energy has been increasing as it is pollution free and is the only alternative to the fast depleting resources of fossil fuels and other conventional sources of energy. Among the available options of renewable energy sources, solar energy has proven to be the best available source of energy in solar energy rich countries like India because of no fuel cost, low maintenance requirement, and being pollution free. Solar radiation received by India is in the range of 4 to 7 kWh/m^2 /day. This amount of radiation can fulfil the entire energy demand of the country using solar PV technology. . Solar energy generation has huge potential to overcome the problem of energy scarcity caused by the depletion of conventional sources of energy like coal, gas, etc. through the setup of small solar systems such as solar grids, solar water heating systems, solar street lights, etc.

In developing countries like India, there are still many areas that have no access to electricity, majority of the households in such areas depend on the conventional sources for cooking. The country, being located in tropical suburbs, can extensively exploit the abundant sunlight for meeting the energy demands of the nation. As the utility of solar energy increases, the need for its proper monitoring will also be there. Thus, an efficient system needs to be designed to monitor such setups and utilize them to the fullest.

II. SYSTEM DESIGN

The main aim of this system is to monitor and analyse any solar setup ranging from the smallest PV arrays installed for domestic use to the biggest solar farms operating in the world. In the modern scenario when everything is accessible via internet, this system aims to make the data collected from the solar setups accessible through IOT (Internet of Things) platform which will help in the real time monitoring of the data. This system will play a pivotal role in monitoring and analysing the data obtained from PV Arrays setup in remote areas where it is uneconomical and troublesome to get manual metering of data. The system can be represented as:
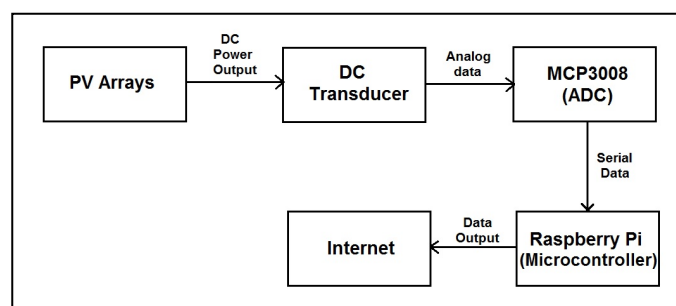

Fig. 1.   Flowchart representing system design

PV Arrays constitute of the arrays of photovoltaic cells. These photovoltaic cells convert the sun's radiation into DC power. The PV Array used for monitoring and testing purposes has 150Wp±3% power, 22.50 V_{oc}, 8.62 I_{sc}. DC Power Output flows from PV Arrays to DC transducer which provides an output DC signal proportional to the input DC signal provided to it in the range of 0-5Volts. The analog data

from the DC transducer is further sent to MCP3008 (Analog to Digital Convertor) which forwards the data received by it to Raspberry PI through SPI (Serial Peripheral Interface). Raspberry PI, which has been programmed through Virtual Instrument programming language LabVIEW, processes this data. Raspberry PI acts as a web server itself and forwards the data to internet. This data, available online, can be thus accessed for monitoring and analysing of solar setup from anywhere. Components used in the system are:

1) *Raspberry Pi:* The Raspberry Pi 2 Model B is a credit card sized single-board computer based on Quad-core ARM Cortex-A7 processor, having 1GB RAM and a clock frequency of 900 MHz. A MicroSD slot is provided for memory purposes. One Ethernet port, one HDMI port, Wi-Fi module and four USB 2.0 ports are provided for connection purposes. For communication with other peripherals, SPI (Serial Peripheral Interface), I²C (Inter Integrated Circuit) or serial communication can be used. Out of the various operating systems available on which Raspberry Pi can be operated, the operating system used in this system is Raspbian Jessie. It has a 40 pin package with 27 GPIO connector pins as well as 3.3V, and GND supply lines.
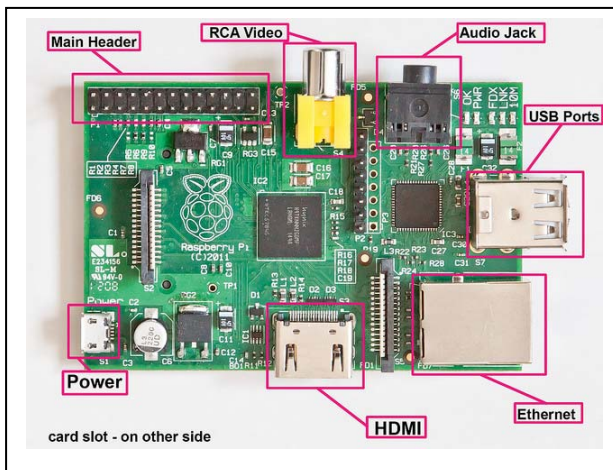

Fig.2. Front view of Raspberry Pi

2) *DC Transducer:* It is a system that converts an available DC input (current or voltage) into the appropriate DC signal which is proportional to the received signal. The DC transducer used in the proposed system has an input voltage range of 0-300V and the converted DC output varies from 0-5V. It can convert an input current ranging from 0-10A into output voltage ranging from 0-5VDC.

3) *Analog to Digital Convertor (MCP3008):* It is a system that converts an analog signal into a digital signal. There are three main steps in this conversion. First, Sampling and Holding in which ADC circuit takes samples from the analog signal from time to time. Second is Quantization in which sampled analog signals are continuously received and are then divided into sub-ranges depending upon the resolution of the ADC. Lastly in Encoding, the analog values

are converted into its corresponding binary code. Resolution of the convertor indicated the number of discrete values it can produce over the range of analog values.
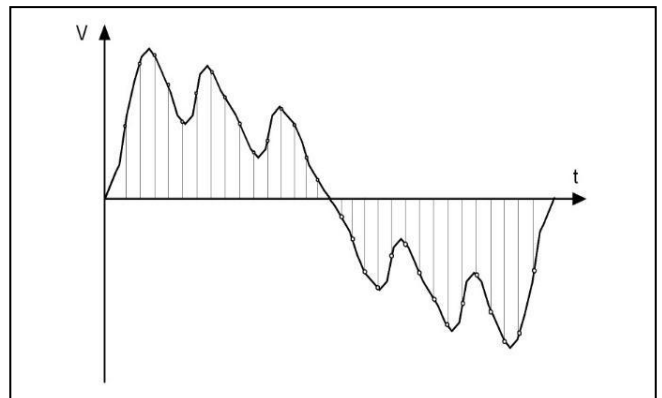

Fig.3. Sampling of analog signals by ADC

The resolution determines the magnitude of quantization error and therefore determines the maximum possible average signal to noise ratio for an ideal ADC without the use of oversampling. The minimum change in voltage required to guarantee a change in output code level is called the Least Significant Bit (LSB) voltage. The resolution Q of the ADC is equal to the LSB voltage. Normally, the number of voltage intervals is given by:

$$N=2^M \qquad (1)$$

where *M* is the ADC's resolution in bits. The ADC used in this system, MCP3008, is a successive approximation 10-bit ADC with on board sample and hold circuitry. It is programmable to provide four pseudo differential input pairs or eight single-ended inputs. Communication with the device is accomplished using a simple serial interface compatible with the SPI protocol. It is capable of conversion rates of up to 200ksps. The device operates under a broad voltage range of 2.7V to 5.5V. MCP3008 is offered in 16-pin PDIP and SOIC packages.
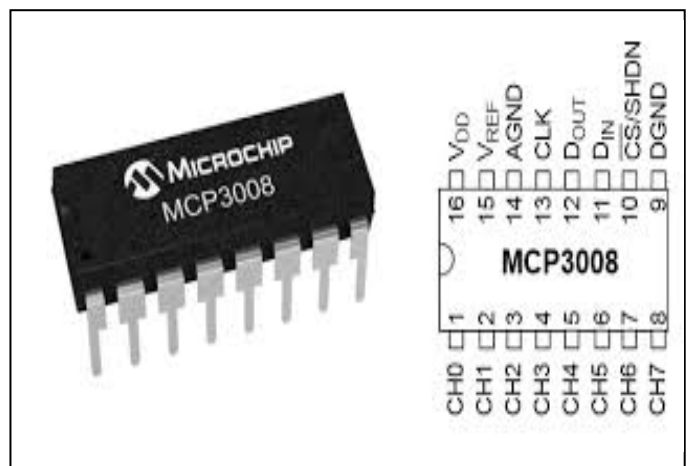

Fig.4.   MCP3008 (Analog to Digital Converter)

III. Circuitry

DC power obtained from the solar setup is fed to the transducer which sends two voltage signals to the ADC (0-5V) each corresponding to the voltage and current values of the DC power. These two analog voltages are read by ADC on its two differential channels 0 and 1 for voltage and current respectively. The converted digital voltage values are sent to Raspberry Pi through SPI with the following connections:

TABLE I.   CONNECTIONS BETWEEN RASPBERRY PI AND MCP3008

| Raspberry Pi	MCP3008 (ADC)	Raspberry Pi	MCP3008 (ADC)
MISO	D_{OUT}	5V	V_{DD}
MOSI	D_{IN}	5V	V_{REF}
I/O Pin	CS/SHDN	GND	AGND
GND	DGND	SCLK	CLK

Figure 4 shows the circuit diagram of the system. SPI uses four lines for communication- Clock, MISO, MOSI and CS (Chip Select). The clock line keeps both Raspberry Pi and ADC in synchronization while the data line (CS/SHDN) transfers the voltage values (data). The clock is an oscillating signal that tells the Raspberry Pi exactly when to sample the bits on the data line. The master (Raspberry Pi) sends a bit on the MOSI (Master Out Slave In) line and the slave (ADC) reads it, while the slave sends a bit on the MISO (Master In Slave Out) line and the master reads it. After the proper connection of Master and Slave, the data transfer between the two takes place.

IV. LabVIEW Program

Raspberry Pi processes the data received from Analog to Digital Converter (ADC) on the LabVIEW platform. The Virtual Instrument (Figure 5 and Figure 6) used for the processing of data can be analysed in four parts. The first part is used for the configuration of the ADC in which either of the two Single ended or Differential configurations is used for input by using *Single-Diff Select* block. *Channel Select* block selects one of the four differential channels or one of the eight single-ended channels available on the ADC. According to the configuration used, a 10 bit-code is placed on the MOSI pin of MCP3008. The second part constitutes of SPI configuration and Chip Select configuration. SPI configuration focuses on setting the frequency of communication between Raspberry Pi and ADC. Chip Select configuration sets the GPIO pin which will receive the data from the ADC. In the third part, connection of LabVIEW to Raspberry Pi is made with the help of blocks available in the Linx library. Linx Open, Linx SPI Write/Read and Linx Close are the major blocks used for the purpose. The fourth part constitutes of blocks which decodes the 10-bit data into readable voltage value according to the pre-feeded resolution of the ADC. In the last part, the readable voltage value is plotted on a graph and the data is made global and forwarded to the web service for making it accessible online. Another VI, managing web services, will be running in the background which will forward the readable value of voltage to the web server. This value can either be accessed from an Android app or directly from a web page online.
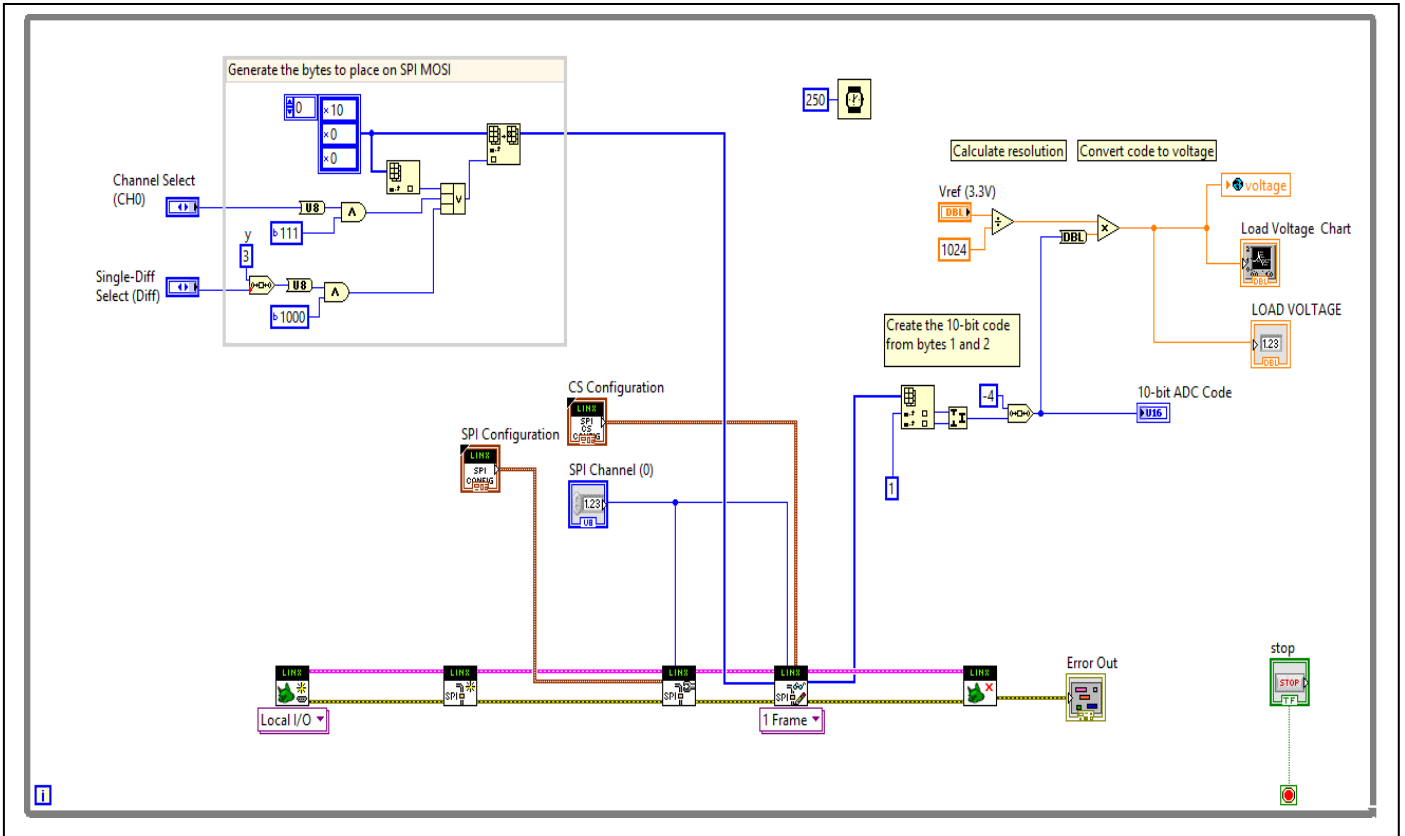
Fig. 5. Circuit Diagram of the system
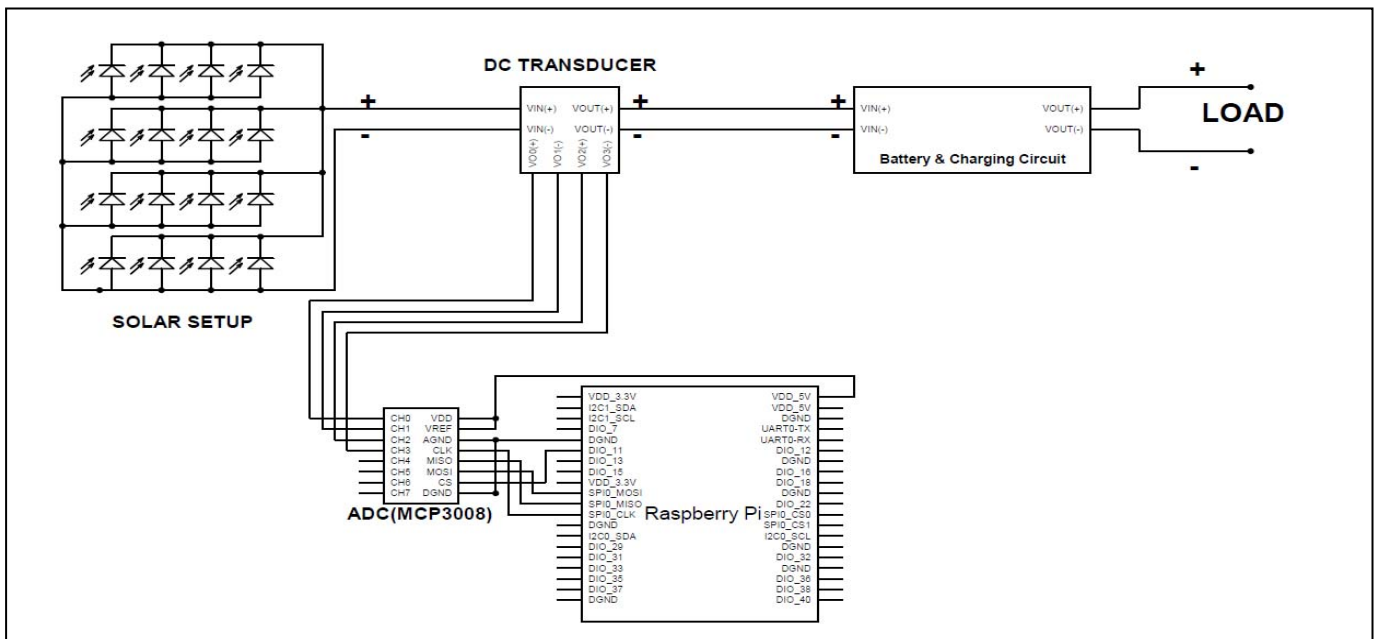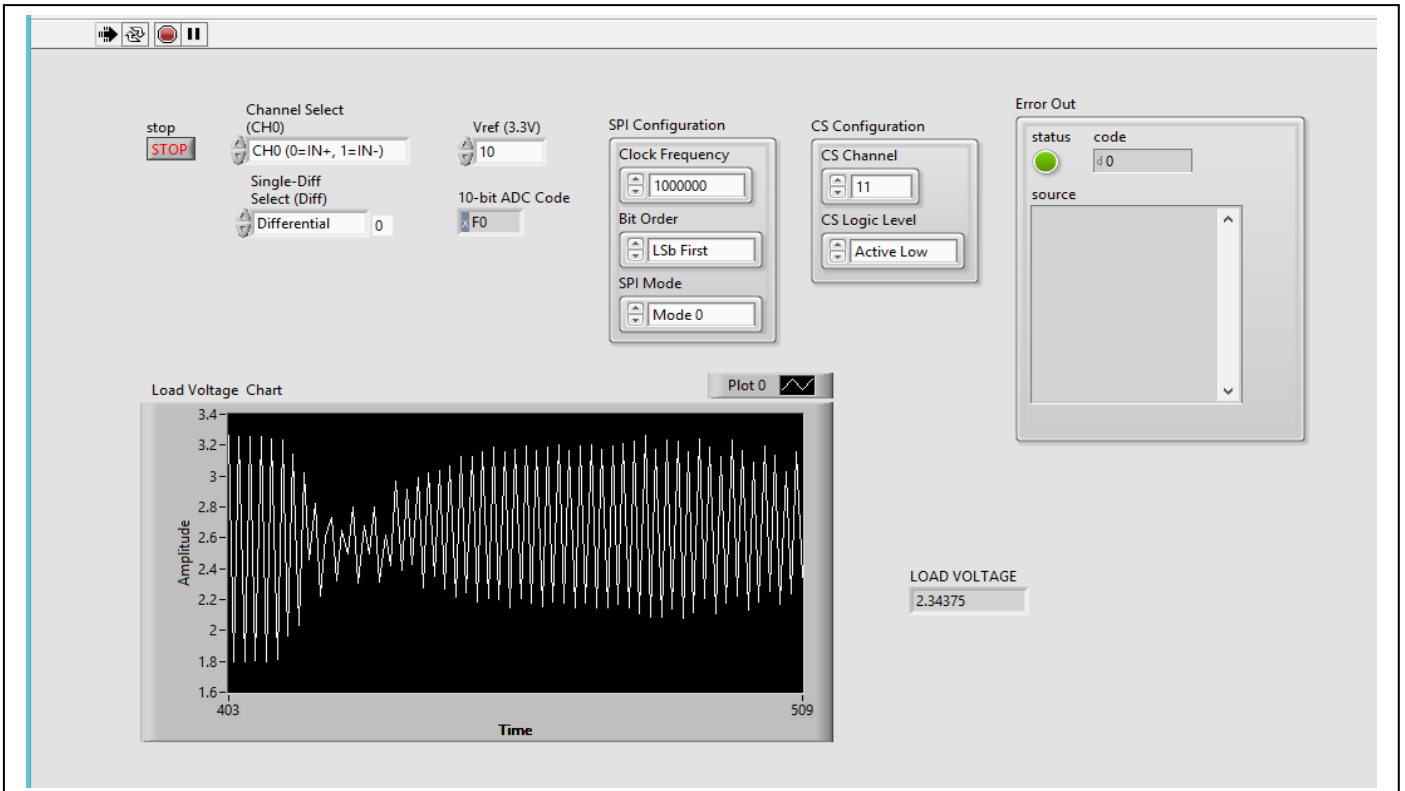
Fig. 6. Block Diagram in LabVIEW

Fig.7. Front Panel in LabVIEW

V. CONCLUSION

The solar monitoring and analysing system proposed in this paper can provide an excellent means for data transmission and it is easy to install, stable and reliable to work. It can collect the power, voltage and current obtained from solar setup and display it online, making it accessible from anywhere .It can calculate the energy generated by the solar setup in a period of time. Degradation of solar cells can also be known through the data collected. It can also help in load optimization and help in the growth of solar technology in India. It can also be used to monitor the conventional energy systems presently used in households, industries, etc.

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