Implementation of Solar Photovoltaic Data Monitoring System

Wai Mar Myint Aung, Yadanar Win, Nay Win Zaw

***Abstract*—Solar Energy is free to use because it is a natural permanent source, which is available in a wide variety of locations in the world. Solar Energy is inexhaustible and pollution free energy, so renewable energy systems are becoming the best way to generate electricity.In this journal, the Photovoltaic (PV) monitoring system, which is developed to know the easy combination of software and hardware.Since the low cost microcontroller used in this project it is very user friendly.Photovoltaic (PV) data monitoring system is designed by using the light sensor, temperature sensor, voltage sensor, and current sensor and Arduino Uno controller. The light intensity is monitored by using an LDR sensor, voltage is monitored by using a voltage sensor module by voltage divider principle, current is monitored by using ACS712 current sensor and temperature is monitored by using temperature sensor (LM35). Reading the photovoltaic cell parameters from the outside world to the microcontroller to do some calculations and all these data are displayed on a 20x4 LCD interfaced to microcontroller. In this system, Proteus ISIS is also used for testing the code of this project before implementing on hardware.The goal of this system is to measure solar panel parameters through multiple sensor data acquisition.**

***Index Terms*—Solar Energy, Solar Photovoltaic, Data Monitoring System, Proteus ISIS**

1) INTRODUCTION

Solar Energy is inexhaustible and pollution free energy. Solar energy resource is the amount of sunlight available to the solar panels to generate electricity. Solar electric technology is developing very quickly; its worldwide use is increasing rapidly as prices of other electric energy sources rise. Today, PV is one of the fastest growing renewable energy technologies and it is expected that it will play a major role in the future global electricity generation. The photovoltaic is the direct conversion of sunlight to electricity. Light striking solar cells is converted into electric energy. This occurs according to a principle called the 'photo-electric effect'. Solar electric devices are also called photovoltaic or PV devices. The technology has spread rapidly throughout the world for both on-grid and off-grid application. Millions of rural off-grid homes are using solar photovoltaic (PV) systems throughout the developed and developing world [1].

The solar photovoltaic systems are installed in different rural areas. The systems (PV) are also situated in dusty, dry and challenging locations. Due to impact of surrounding a system provides variable voltages because are not properly maintained and cleaned daily basis. Thus a system will never provide actual data to the data collector. Change of weatherand sunlight the system will provide changing data information. For smooth, safe, obtaining better performance and timely maintenance, solar (PV) systems should be continuously monitored and evaluated. The aim of this paper is to measure solar panel parameters through multiple sensor data acquisition. In this system different parameters of solar panel like current, voltage, temperature and light intensity are monitored. The goal of this paper is to facilitate common small scale installations with more efficient and cost effective and reliable monitoring system. Finally a centralized monitoring of PV system also reduces the cost of system operation and maintenance.

This journal isorganizedasfollows;at first in Section (I), it presents the introduction of the system. The rest of journal is presented as Section(II) describes the backgroundtheoryandSection(III) presents the experiment of the system. After that Section (IV)discusses circuit test and simulationresults.Thelastsectionshows conclusion for this paper.

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2) BACKGROUND THEORY

Solar (PV) monitoring system is widely used because monitoring and maintenance plays key role in solar power plants. A user of the system would typically want to know what a renewable energy system is generating, the amount of voltage, current, temperature and light intensity readings at specific times of a 24 hour day. In order to implement a successful monitoring system, devices known as sensors need to be used. In this section presents the system design of the Solar Photovoltaic Monitoring System.

1) *Monitoring System of Solar Photovoltaic*

The proposed system is for monitoring of solar photovoltaic using ATmega328 microcontroller integrated directly into current sensor, voltage sensor, temperature sensor, light sensor and power supply. The monitoring system structure of photovoltaic data is shown in Fig. 1.

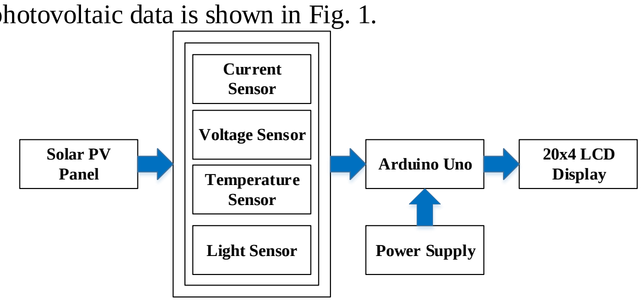

Figure 1.The monitoring system structure of photovoltaic data

2) *Arduino Uno*

Arduino is an open source electronics platform or board which can be easily programmed, erased and reprogrammed at any instant of time. Introduced in 2005 the Arduino platform was designed to provide an inexpensive and easy way for hobbyists, students and professionals to create devices that interact with their environment using sensors and actuators. The Arduino IDE provides a simplified integrated platform which can run on regular personal computers and allows users to write programs for Arduino using C or C++. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button[2].

3) *Sensors*

A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human readable and usable form.

A. ACS712 Hall Effect-Based Linear Current Sensor

ACS712 current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current. To get the solar current the main component used is the ACS712 sensor from Allegro Micro Systems to measure the current as shown in Fig. 2. ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems [3]. The device is not intended for wide applications but is usually used in motor control, load detection and management, switch-mode power supplies, and overcurrent fault protection.

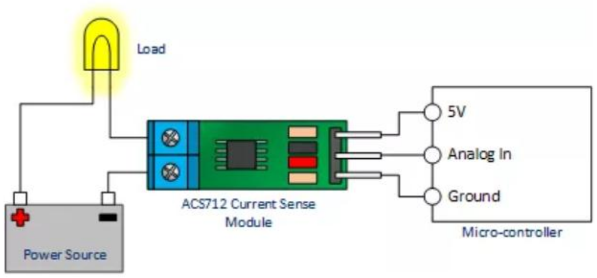

Figure 2.ACS712 Current Sensor[3]

One of the current sensors circuit is IC ACS712-30A-T circuit, this circuit is used to detect the large current flowing on PV module. ACS712-30A sensor can be used to measure AC current and DC current. This sensor can measure the positive current and negative current between -30A to 30A.This sensor needs power supply of 5V. For 30A model, the value that links the proportionality of output voltage and input current measurements is sensitivity which has a typical value of 66mV/A. ACS712 DC current measurement formula is shown in (1).

Current=(Arduino measured analog reading−AcsOffset)/Sensitivity(1)

Where, AcsOffset is normal voltage output at VIOUT pin when no current is flowing through the circuit. Arduino measured analog reading is analog signal value read and converted to actual voltage from the analog channel to which ACS712 output is connected. Sensitivity is ACS712 change in current representing 1Ampere.

B. *Voltage Detection Sensor Module 25V*

Sensors are basically a device which can sense or identify and react to certain types of electrical or some optical signals. Implementation of voltage sensor and current sensor techniques has become an excellent choice to the conventional current and voltage measurement methods. Advantages of sensors over conventional measuring techniques:

- Small in weight and size
- Personnel safety is high
- Degree of accuracy is very high
- It is non-saturable
- Wide dynamic range
- Eco-friendly, etc.

A voltage sensor can in fact determine, monitor and can measure the supply of voltage. Applications of voltage sensor are power failure detection, load sensing, safety switching, temperature control, power demand control and fault detection etc.

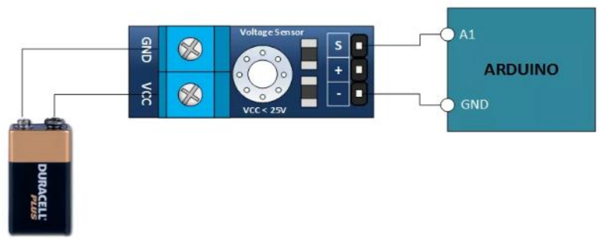

Figure 3.Voltage Sensor Circuit [4]

Fig. 3shows the voltage sensor circuit. This voltage sensor is very simple and it can measure DC voltage from 0-25V. It consist of only two resistors (R1= 30000Ω, R2= 7500Ω). This sensor is actually a voltage divider circuit which is a very common circuit that takes a higher voltage and converts it to lower one by using a pair of resistors. The formula for calculating the output voltage is based on Ohm's Law [4].

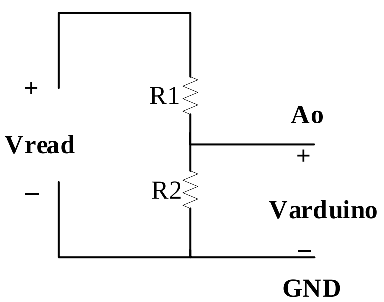

Figure 4.Voltage Divider Circuit

As presented in fig. 4, the input voltage can be calculated by using voltage divider rule. Arduino AVR chip has 10 bit A/D converter, so this module simulation resolution is 0.00489V (5V/1023). The DC voltage measurement formula is shown in (2).

From figure (4),

$$Vread = \frac{5}{1023} \times sensorValue \times \frac{(R1+R2)}{R2} \quad (2)$$

Where, sensorValue is the analog output of voltage divider.

C. *Temperature Sensor (LM35)*

In general, a temperature sensor is a device which is designed specifically to measure the hotness or coldness of an object. LM35 is a temperature sensor from National Semiconductor that has a high accuracy. LM35 is a precision integrated-circuit temperature device with an output voltage linearly proportional to the Celsius (Centigrade) temperature. The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, the temperature can be measured more accurately than with a thermistor. It also possess low self-heating and does not cause more than 0.1°C temperature rise in still air. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every °C rise/fall in ambient temperature, i.e., its scale factor is 0.01V/°C [5]. Output pin can be directly connected to an analog (ADC) input. Analog inputs on the microcontroller has a 10-bit resolution, which can provide output 2^10 = 1024 discrete values. Precision centigrade temperature sensor (LM35) temperature measurement formula is shown in (3).

Temperature = reading from ADC * (5/1023) *100 (3)

D. *Light Dependent Resistor (LDR)*

A photoresistor or light-dependent resistor (LDR) or photocell is a light-controlled variable resistor which is a one type of resistor whose resistance varies depending on the amount of light falling on its surface. The resistance of a photoresistor decrease with increasing incident light intensity; in other words, it exhibits photoconductivity. A photoresistor can be applied in light-sensitive detector circuits, and light-activated and dark-activated switching circuits [6]. A photoresistor is made up of semiconductor materials having high resistance. LDR's are light dependent devices whose resistance is decreased when light falls on them and that is increased in the dark. In the dark, a photoresistor can have a resistance as high as several mega-ohms (M Ω), while in the light, a photoresistor can have a resistance as low as a few hundred ohms. This property helps the LDR to be used as a light sensor. It can detect the amount of light falling on it and thus can predict days and nights. These resistors are often used in many circuits where it is required to sense the presence of light. LDRs are cheap and are readily available in many size and shapes. They need very small power and voltage for its operation.

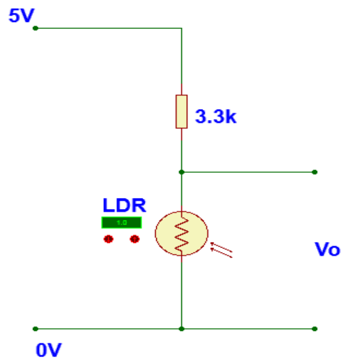

Figure 5.Light Sensor (LDR) Circuit

Light Sensor (LDR) circuit is shown in fig. 5. The relationship between the resistance R_L (LDR) and light intensity Lux for a typical LDR is shown in (4)

$$R_{LDR} = \frac{500}{Lux} \quad (4)$$

If the LDR connected to 5V through a 3.3k Ω resistor, using the voltage divider rule, the output voltage of LDR is shown in (5).

$$V_o = 5 \times \frac{R_{LDR}}{R_{LDR} + 3.3} \quad (5)$$

Light intensity measurement formula is shown in (6).

$$Lux = \frac{\frac{2500}{V_o} - 500}{3.3} \quad (6)$$

4) *Liquid Crystal Display (LCD)*

LCD stands for liquid crystal display, is an electronic device which is used for data display. LCDs are preferable over seven segments and LEDs as they can easily represent data in form of alphabets, characters, numbers or animations. LCDs are very easy to program and make your work quite attractive and simple. Numerous types of LCDs are available in market such as 16x2, 16x4, 20x2, 20x4, graphical LCDs (128x64) etc.. In this paper, 20x4 LCD display is used to display the values of the measured parameters.

3) EXPERIMENTS OF SYSTEM

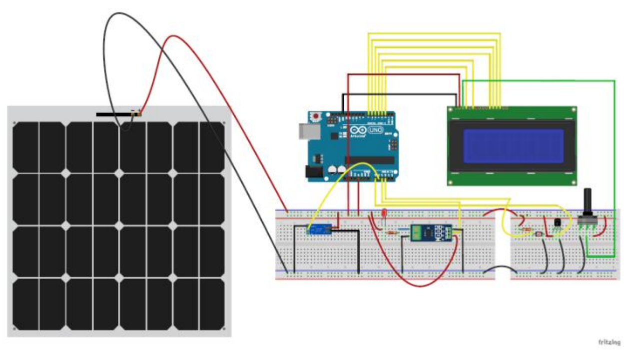

Figure 6.Complete Connection Diagram of Proposed System

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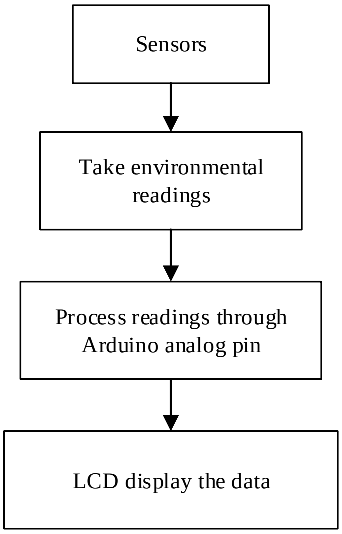


Figure 7.Work flow of the system

1) *Proposed Monitoring System for Solar PV System*

Fig. 7 represents the process of proposed system. The work flow of the solar photovoltaic monitoring system is presented in the form of step below:
Step 1: The first step is solar parameters such as current, voltage, temperature and light intensity will give an indication of the environment in which the solar system is operating in.
Step 2: In this step read current, voltage, temperature and light value from microcontroller ADC and calculate for these parameters values to actual values.
Step 3: The final step is 20x4 LCD display all parameters outputs from Arduino microcontroller.

4) CIRCUIT TEST AND SIMULATION RESULTS

1) *Proteus Simulation Results*

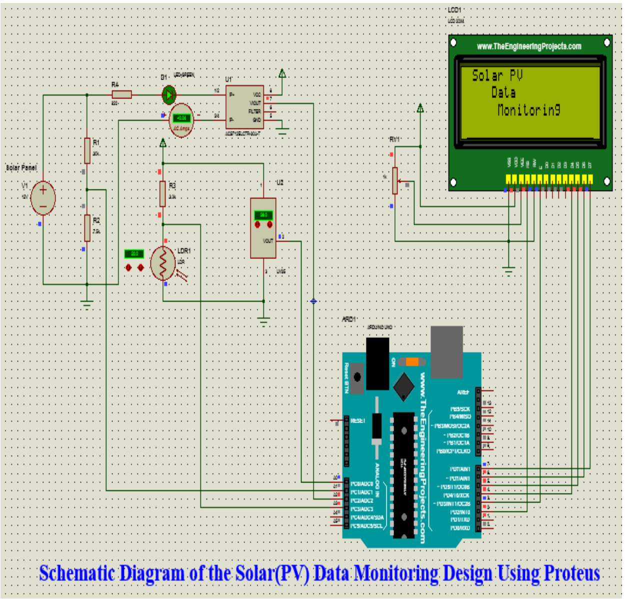


Figure 8.Overall Schematic Diagram of Solar (PV) Data Monitoring System

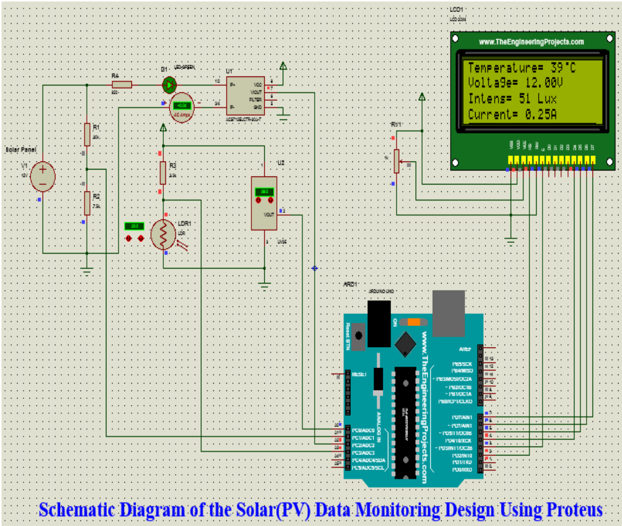


Figure 9.Solar (PV) Data Measurement Results

Fig. 8 and Fig. 9 shown the overall schematic diagram of solar (PV) data monitoring system and its measurement results that have been develop by using Proteus 8. In this simulation circuit, the power generated from the solar panel is 12V approximately.

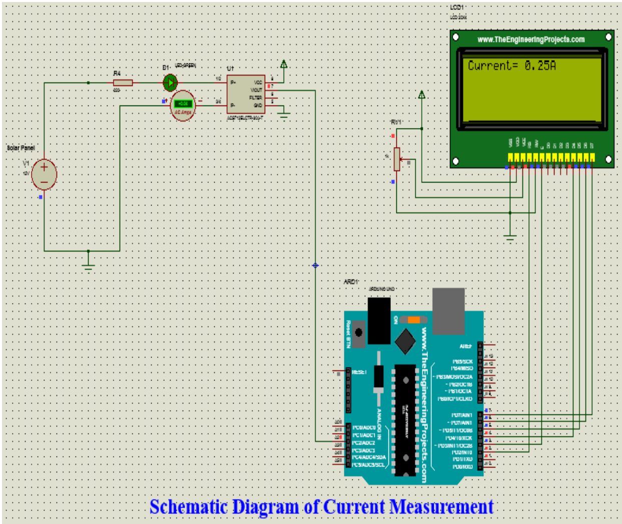


Figure 10.Simulation results for current

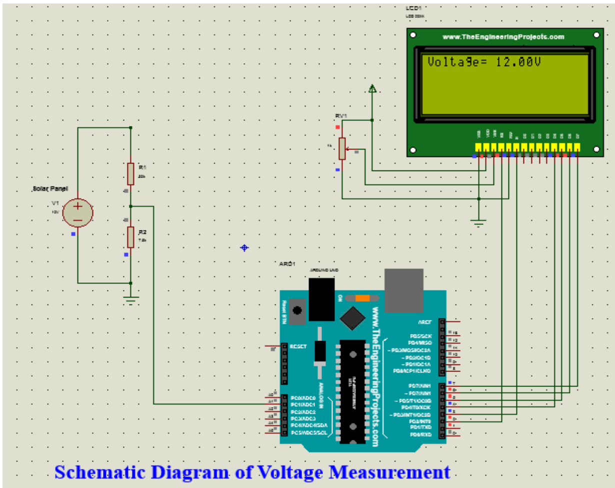


Figure 11.Simulation results for voltage

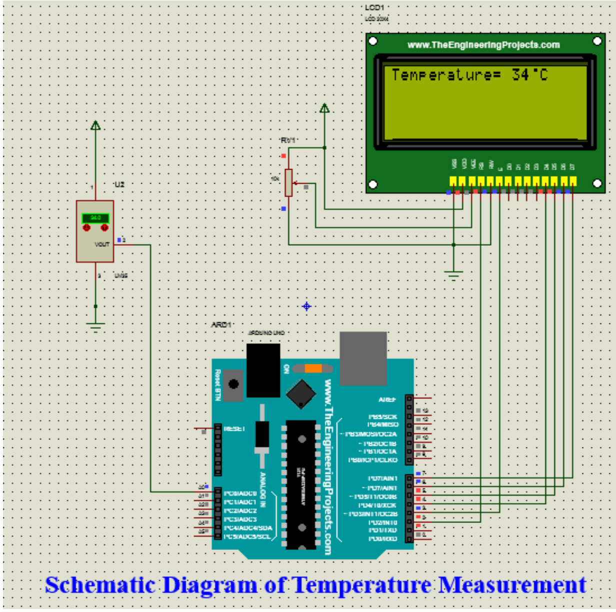


Figure 12.Simulation results for Temperature

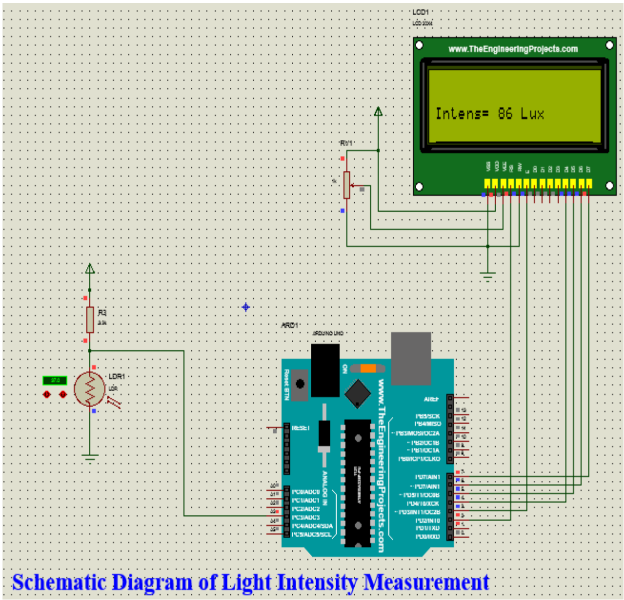
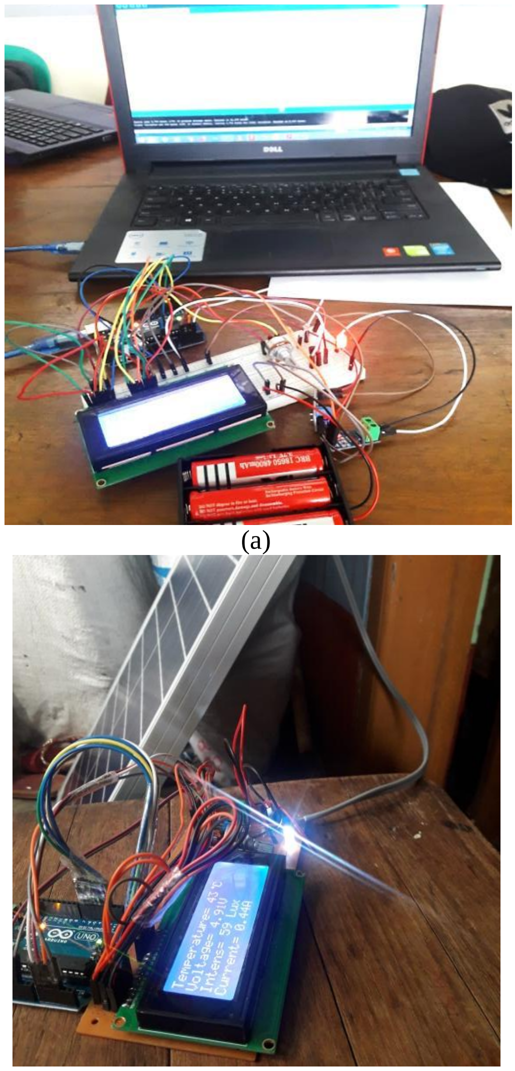


Figure 13.Simulation results for intensity

The results of PV parameters testing and measurement results are shown in fig. 10,11,12,13. As presented in fig.10, ACS712 current sensor is used to sense the direct current (DC) flowing through solar panel. The current data was obtained from analog pin A2 and fig. 11shows the output voltage of solar panel is connected to analog pin A1 of Arduino and convert that in digital and display result on LCD. As shown in fig. 12 interfacing of temperature sensor LM35 with Arduino in Proteus ISIS.LM35 is connected to Arduino Uno microcontroller. The Vcc pin of LM35 is connected to +5V of Arduino board. Science LM35 generates analogue value at its output pin that's why this output pin is connected to A0 pin of Arduino board. And the last pin is connected to the GND pin of Arduino board.

As shown in fig. 13 LDR sensor interfacing with Arduino in Proteus. In this figure, we are using a 3.3k ohm resistor and a LDR connected with each other and middle point is used as output. Proteus is very handy software and is used for circuit and PCB designing. It is also used for circuit and programming testing. Note that the same Arduino code used in Proteus is used in the experiment, and this is the benefit of using Proteus in simulation instead of PSIM and Matlab Simulink, because by using PSIM and Matlab we must again write the code of our algorithm once we start the experiment. Another benefit is that if our system is tested by using Proteus and it gives good performance, it will probably give the same result in the experiment, because we use the same components and Arduino code in simulation and experiment [7].

2) *Experimental measurement results*



(a)

(b)

Figure 10.Hardware configuration setup

The above fig. 10(a) shows hardware implementation and fig.10(b) shows the output results of temperature, voltage, light intensity and current value. Hardware configuration setup includes solar panel, temperature sensor, voltage sensor, current sensor, and light sensor and Arduino microcontroller. When we switch on the system first current sensor and voltage sensor gets power from solar panel and other sensors gets power from Arduino. The open-source Arduino Integrated Development Environment or Arduino software (IDE) is used in system for upload the code on to board. It manipulatesthe whole source code uploaded to the board, prints the desired data on serial monitor and also prints the executed commands on the LCD. Currentsensor, temperature sensor (LM35), light sensor sensesparameters and voltage sensor gives voltage values of panel to Arduino board. The microcontroller will read the ADC data values and all four parameters current, voltage, temperature, light values are sent LCD display.

5) CONCLUSION

Photovoltaic (PV) data monitoring system design and simulation results is presented in this paper. We have presented work on design and development of solar panel parameter reading using Arduino for environmental monitoring, the node is enough to provide information about environment parameters such as temperature, current, voltage and light intensity. This system is cost effective. Implementing renewable energy technologies is one recommended way of reducing the environmental impact. Because of solar energy is abundant, free and readily available source of energy. Solar cells are clean sources of energy with no harmful emissions of greenhouse gases. This system can monitor solar panel parameters related to solar power plant operation and maintenance with the help of multiple sensors. Appropriate monitoring improves efficiency of plant and operating conditions. This system can be further enhanced, by using the results of this current system, i.e. the monitoring values obtained are helpful in predicting the future values of the parameters considered.

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