

# **Monocrystalline, Polycrystalline and Black Thin Solar Panels Comparison in Terms of Generated Power at Hybrid Power Generation System**

Tolga Özer<sup>1</sup>, Yüksel Oğuz<sup>2</sup>

Department of Electric and Electronic Engineering, Afyon Kocatepe University, Merkez/Afyonkarahisar, Turkey

Department of Electric and Electronic Engineering, Afyon Kocatepe University, Merkez/Afyonkarahisar, Turkey

**ABSTRACT:** As we know energy is the main problem should be resolved in the coming years. So lots of work has been presented about this field. Energy problem should be resolved in the next years. Also development of technology is increased the energy requirements. As a result of these developments lots of works have been studied about this field. For meeting these kinds of energy demands renewable energy can be an alternative solution. Renewable energy usage is increased each passing day at the world. Hybrid power generation systems are used for meeting the energy requirement effectively. Solar panels are mostly preferred for generating energy from renewable energy. In this study, hybrid system is created according to meeting consumer energy demand. These hybrid systems include solar panels, fuel cells, battery and DC loads. Data acquisition system created and solar panels data are gathered with this data acquisition system. Energy flow of the hybrid system was controlled according to taking data. Monocrystalline, polycrystalline and black thin solar panels were used for energy generation. Arduino microcontroller based control system was designed. The transfer of energy flow was performed by relays. As a result of acquiring data from solar panels Monocrystalline, Polycrystalline and Black Thin solar panel powers were compared monthly and totally.

**KEYWORDS:** Renewable Energy, Energy Flow Control, Arduino, Labview

## **I. INTRODUCTION**

From past to present one of the biggest problems of the world is an energy. Energy demand is increasing day by day. Also pollution problem is the important problem of our times with energy problem. To overcome of the these problems alternative renewable energy sources must be considered and have to combined different kinds of energy sources. This kinds of systems are named as a hybrid sources. Hybrid energy sources aims to increase the system efficiency and provide the energy to users without interruption. Our hybrid system is composed of solar panels, fuel cells and batteries. There are three kinds of solar panel which are monocrystalline, polycrystalline and black thin film solar panel. This kinds of hybrid systems have to be controlled for handle the more efficiency from the each of energy sources. So this control process is done with a few numerical values which are taken from sensors. So these programs which I used for data logging process will be introduced.

Proteus is an electrical circuit program which is allow to simulate electrical systems [1]. It includes ISIS and ARES. In the ISIS environment, electronic circuit can be stimulated in detail. Also near of the system design simulation this program is gave an opportunity for handling electrical system PCB (Printed Circuit Board) design and it is named as ARES. Lots of electrical components are can be find in this program with theirs package. This program can be used for educational or commercial aims [2].

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

Arduino is an open-source electronics prototyping platform which offers facilities to makes the applicationseasily. It's a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking analog inputs value from switches or sensors, and controlling physical outputs [3]. The Arduino Mega 2560 board is programmed using the Arduino programming language and the Arduino development environment. Arduino can be used for different kinds of projects as a stand-alone or this controller card and programming environment allows communicating with software running on a computer. Arduino has some advantages for educational, inexpensive when we compare to other systems, open source and extensible software and hardware [4].

LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design development environment platform which is allow to visual programming. LabVIEW provides to collect and save data because of this feature this program can be used as a data acquisition program [5]. Analog and digital data can be acquired flexibly with this program. It is made the programming easier through the visual and object based commands. Labview provides Arduino microcontroller interface environment which is named as LIFA (LabVIEW Interface for Arduino).This addition is make easier data acquisition or control process. Visual and graphical features are providing an advantage for viewing of the acquired data.

Arduino and Labview can be used together different kinds of project. Usually Arduino is used for taking analog data and processing these data and give to the digital outputs according to software which is programmed by user. Taken these data are saved and monitored by means of Labview. When we looked to literature there can be seen Arduino and Labview studies. In [6] developed solar tracking system for obtain the maximum efficiency using Arduino Uno and LabVIEW for real time monitoring. [7] controlled the home automation system remotely with using Arduino. Wireless (Zigbee) technology was used for home automation purposes. [8] used various sensors like infrared sensor, light dependent resistors (LDR), analog potentiometer are used and data was gathered using Arduino microcontroller. DC motor was controlled simultaneously using Pulse Width Modulation. [9] presented innovative laboratory methodology for simulation of microcontroller based virtual kits. Simulation platform by Proteus, LabVIEW, MATLAB and Arduino on a computer easily built all kinds of experiment models. [10] designed and implemented a system which can be able to monitor the school timetable's time slots by controlling the school bell. Arduino microcontroller and Zigbee wireless module was used for control the school bell. LIFA was used for acquiring the data to Labview. [11] presented the practical study of converting manually operated impulse generator to automatic generator. Arduino Board which coded such that the operator has to insert desired impulse voltage through the computer and the rest of the process will be done by the system itself. LabView Simulation tool used for coding purpose using with LIFA.

In this paper, hybrid energy generation system sensor cards are designed with Proteus program. Cards prepared for taking voltage and current data from hybrid energy generation system. Arduino program is used for taking data and programmed as a brain of data logged system. The data calculated process was done with Arduino program. Labview program was used for monitorize data on the screen and saving them in a document. Labview was used for data logging process and explained step by step in this paper. Monocrystalline, Polycrystalline and Black Thin solar panel powers were compared monthly and totally according to acquiring data from solar panels.

## II. HYBRID SYSTEM OVERVIEW

Hybrid energy generation system composed of three groups power sources. Each of group is consist of solar panel, battery, dc load and fuel cell. Three kinds of solar panel used for system. They are respectively monocrystalline, polycrystalline and black thin film solar panel. These solar panels output voltages, efficiencies are different to each other's. Each of hybrid power system groups has 12 Volt, 85 Ah gel batteries and 12 Volt, 20 Watt DC load. All of solar panels powers are 100 Watt. Fuel cell kind is a PEM (Proton Exchange Membrane) type and system feature is 24 Volt, 500 Watt. Hybrid energy generation system block schema is shown at Figure 1.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

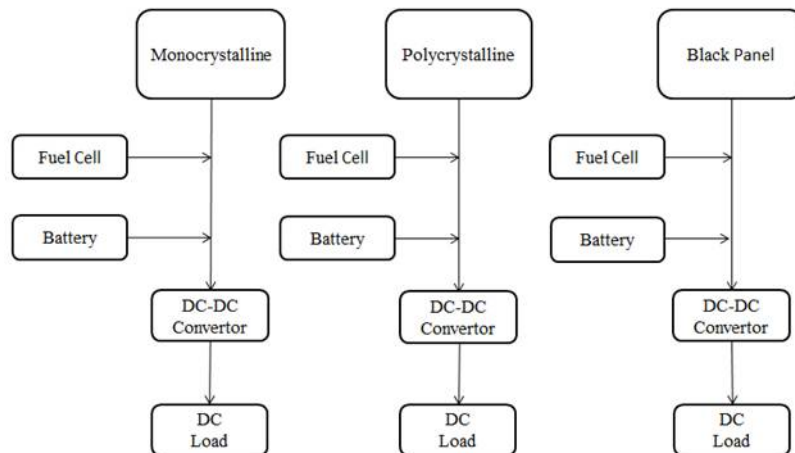


Figure 1. Hybrid Energy Generation System Block Schema

## III. DATA ACQUISITION SYSTEM FOR ENERGY FLOW CONTROL

The schematic of the data acquisition system is presented in Figure 2. Considering small scale applications where accuracy and high speed is not so important, industrial scale DAQ's with high price tag is not necessary. But instead a low cost micro controller like Arduino Mega 2560 is enough to meet the requirement. In this section is composed of card design steps, Arduino and Labview programs software explanations.

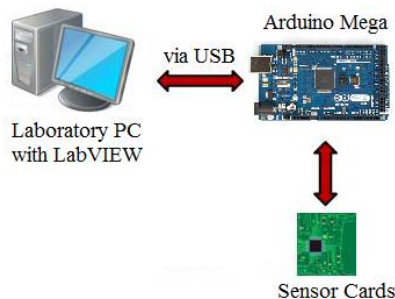


Figure 2. Arduino and Labview Data Acquisition System

### Card Design

In this step electronic circuit cards were designed as a sensor cards. There are three sensor cards and each of card belongs to respectively Monocrystalline, Polycrystalline and Black thin film solar panel hybrid power system groups. Two kinds of sensor were used to sensor cards. They were voltage and current sensors. Voltage sensors were created by voltage divider circuit as shown Figure-3 [12]. Voltage divider is a linear circuit which divides input voltage into an output voltage with a specific ratio. As a current sensor ACS-712 was used for measuring the current. Current sensor working principle is based on Hall Effect event. From -30 A to +30 A current values can be measured with this sensor. Proteus program was used for these sensor cards design and circuit components placements. Current sensor package was modeled in the Proteus. These cards main purpose is taking the current and voltage measurement values from the sources of hybrid systems by means of Arduino card. There are 16 analog inputs with three sensor cards.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

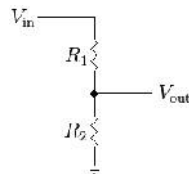


Figure 3. Voltage divider circuit

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in} \quad (1)$$

### Arduino Microcontroller and Software

Arduino Mega 2560 microcontroller card is used in measuring system. Resolution of the Arduino Mega is 10 bit. It serves to from 0 to 1024 ADC number. If 5 Volt is applied to analog inputs 1024 ADC number value is obtained. Arduino Mega has 16 analog inputs and 54 digital outputs. It can be supplied with USB connection cable or external power source. For the data communication USB connection is used. But Arduino Mega microcontroller card is based of RS-232 communication. RS-232 communication is converted to USB on the Arduino Mega card.

In Arduino software 16 analog inputs variables are defined and taken. ADC sensor values determined to taken average of fifty sensor input values. ADC sensor values converted real voltage or current value. All sensor card outputs calibrated particularly. Coefficient of analog ADC values determined separately for taking more accurate results. These data are sent as a string type from the Arduino card [13]. This process gets advantage to microcontroller for decreasing runtime and it can be affected Arduino speed. Arduino software logic steps can be seen at Figure 4.

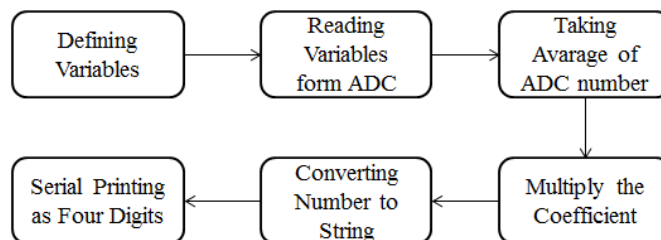


Figure 4. Arduino Software Programming Logic

### Labview Software

The Labview software was composed of two main program block. The first block is related with taking serial data from the Arduino and second block includes the recording operation of the received data. Received data is taken string data type from the Arduino card and this string type data is converted as anumeric data type. These data are saved as a txt. file extension with data's date and clock. Figure-5 is shown that Labview software processing flow.

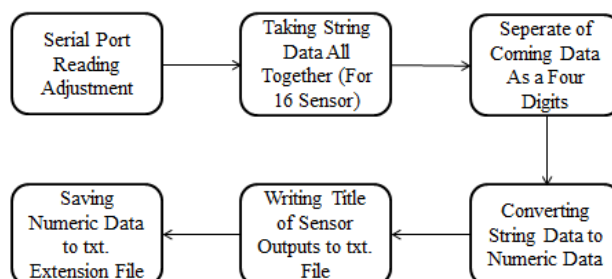


Figure 5. Labview Software Processing Flow

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

## IV. WORKING PRINCIPLE OF DATA ACQUISITION SYSTEM

Voltage and current sensors are used to sensing the real voltage and current values. Voltage sensor decreases the input voltage applicable level to Arduino analog inputs. The maximum voltage value of Arduino analog input has to be 5 V. If applied voltage is 5V then ADC section gives 1024 ADC number in theoretical. In practice this value can be different. So each sensor outputs have to be controlled in calibration stage. Taken 5 V from the voltage outputs sensor cards is mean 60 V. There is a coefficient number and it was chosen 12. Maximum voltage level is determined as 60 V according to black solar panel maximum output voltage value from the from the product catalog. The coming signal voltage is detected with this method.

Current sensor is ACS-712 can sense current from -30A to +30A. Sensor has to supply with 5 V. At 0 A sensor output gives 2.5 V. If current increases towards to positive direction, output voltage decreases from 2.5 V to 0.5 V or if this event occurs opposite then sensor's output voltage is decrease from 0 V to -2.5 V value. While 30 A current is passing through the current sensor, sensor output voltage decrease to 0.5 V. At -30 A this voltage value will be done 4.5 V. Change of maximum and minimum voltage value can stem from the inlet side of the load or solar panels cable. Also if the cable connection of current sensor inlet changes at the 30 A sensor output voltage can be measured 4.5 V. The cables from the power sources are entered to the sensor cards. And voltage and current values senses by means of these cards. And sensor cards outputs are transferred to Arduino card analog inputs separately. These voltage values are interpreted with Arduino software and real measured values are sent to Labview with serial communication. Data are taken with USB cable. All sensors outputs values are sent only one byte size as a string data type. These taken data are converted to numerical data in Labview software. And each of data is saved to txt. extension file with their received time and date. Herewith data acquisition system created.

## V. EXPERIMENTAL RESULTS AND DISCUSSION

There are three kinds of solar panels which are monocrystalline, polycrystalline and black thin used for hybrid energy generation system. Data was taken Afyonkarahisar city of Turkey between the 1 May 2014 and 30 April 2015. According to taken data from hybrid energy generation system total generated energy and the energy generated by each solar panel is calculated. Power value was changed according to months. The main reason of this changingsunshine duration and intensity of radiation varies throughout the year. Also power is changed right proportion with sunshine duration and intensity of radiation. These results are demonstrated as a graphical form

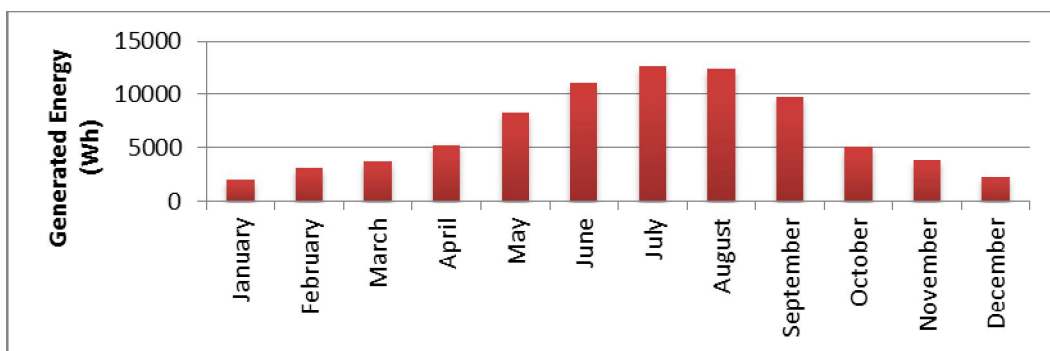


Figure 6. Black Thin Solar Panel Monthly Generated Energy

Generated energy is given monthly at Figure 6 by black thin solar panel. Maximum energy generation was obtained on July as nearly 12500 Watt-hour (Wh). Also minimum energy generation was achieved on January month as nearly 2000 Wh

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

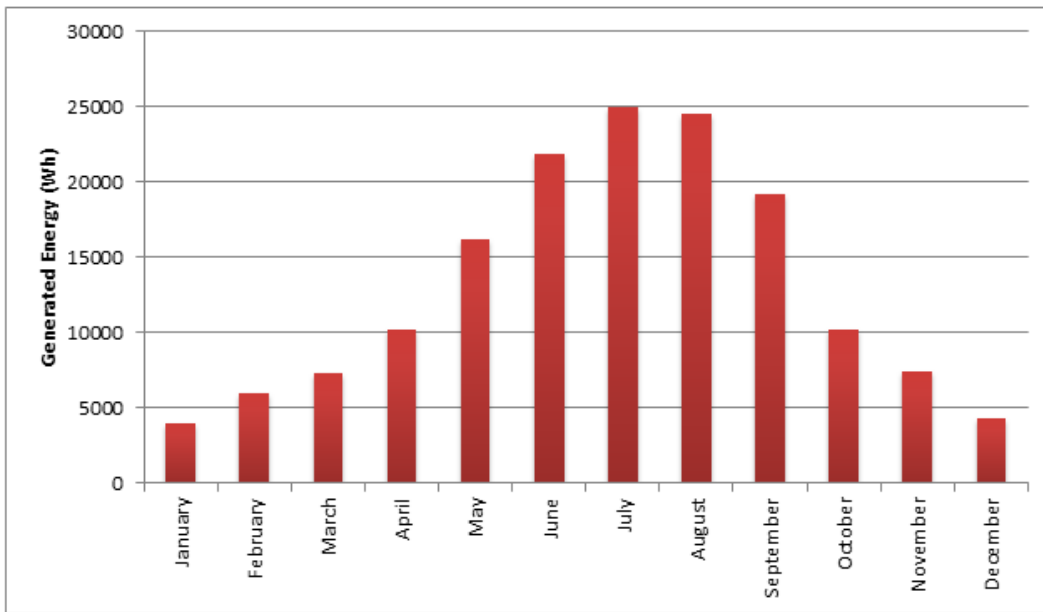


Figure 7. Monocrystalline Solar Panel Monthly Generated Energy

Generated energy is given monthly at Figure 7 by monocrystalline solar panel. Maximum energy generation was obtained on July as nearly 25000 Wh. Also minimum energy generation was achieved on January month as nearly 4000 Wh.

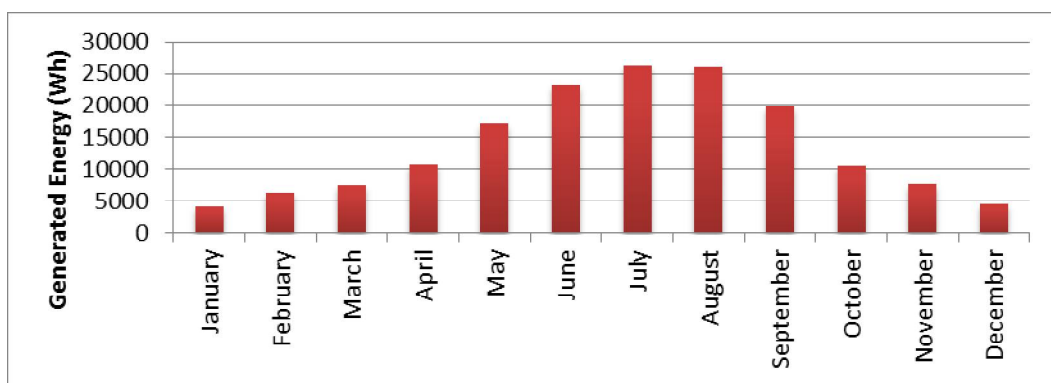


Figure 8. Polycrystalline Solar Panel Monthly Generated Energy

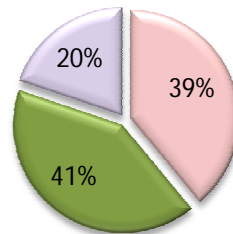
Generated energy is given monthly at Figure 8 by polycrystalline solar panel. Maximum energy generation was obtained on July as nearly 26000 Wh. Also minimum energy generation was achieved on January month as nearly 4200 Wh.



# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017



MONOCRYSTALLINE POLYCRYSTALLINE BLACK THIN

Figure 9. Share of Each Solar Panel on Total Generated Energy

Total energy generation was obtained nearly 396000 Wh. The share of the total energy produced each of solar panel is given at Figure 9. Monocrystalline solar panel was generated 39 percent of total energy, polycrystalline solar panel 41 percent of total energy and black thin solar panel was generated 20 percent of total energy generation.

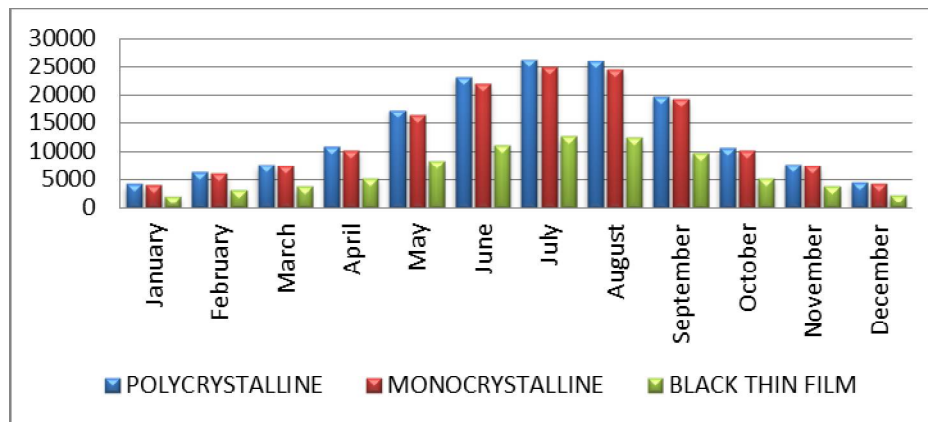


Figure 10. Solar Panels Comparison of Energy Production

Three kinds of solar panel monthly generated energy comparison is demonstrated at Figure 10. As seen the Figure 10 the most energy production is obtained by polycrystalline solar panel.

## VI.CONCLUSION

The energy produced from the solar panel is associated with mainly sunshine duration, intensity of radiation and efficiency of panels. According the results it has seen that generated energy varies month to month because of changing sunshine duration and intensity of radiation. In summer months for the three solar panels generated energy values reached maximum level. Normally when efficiency values are comparing between three solar panels monocrystalline solar panel has highest efficiency. So maximum energy generation is expected to be by monocrystalline solar panel. But according to data polycrystalline solar panel has maximum energy generation. At total generated energy polycrystalline panel have produced two percent more energy according to monocrystalline. Black thin solar panel which has lowest efficiency value was generated lowest energy.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

## REFERENCES

- [1] L. W. Bo Su, «Application of Proteus Virtual System Modelling (VSM) in Teaching of,» International Conference on E-Health Networking, Digital Ecosystems and Technologies, 2010.
- [2] G. J. Ding Yanchuang, «LED Display Screen Design and Proteus Simulation,» IEEE, 2010.
- [3] B. S. Y. C. S.-m. Z. E. L. Chun Yina, «Fractional-order adaptive minimum energy cognitive lighting control strategy for the hybrid lighting system,» Energy and Buildings, 2015.
- [4] R. I. L. A. C. D. Calinoiu, «Arduino and LabVIEW in Educational,» IEEE, 2014.
- [5] B. Mihura, LabVIEW for Data Acquisition, Prentice Hall, 2001.
- [6] K. S. P. R. C. M. K. N. R. K P J Pradeep, «Development of Dual-Axis Solar Tracking using Arduino with Lab,» International Journal of Engineering Trends and Technology (IJETT), p. Volume17 Number7, 2014.
- [7] M. G. S. M. R. K. A. K. Kim Baraka, «Low cost Arduino/Android-based Energy-Efficient Home Automation System with,» 2013.
- [8] D. P. K. Naveenkumar, «Low Cost Data Acquisition and Control,» International Journal of Science and Research (IJSR), p. Volume 2 Issue 2, 2013.
- [9] P. V. M. S. D. S. S. S. Kendre, «Developing Experimental Platforms Using CommonSoftware Tools For Enhancing Technical Skills of Electronics Engineering Students in Microcontrollers,» IEEE, 2013.
- [10] J. Habiaryemye, «Labview Based Remote Controlled Automatic & Manual Bell For Boarding and Day Schools,» The International Journal Of Engineering And Science (IJES), pp. Volume 2, Issue 7, Pages 96-102, 2013.
- [11] H. U. B. Talha Iqbal, «Control System Design to Automate 100KV,» International Journal of Scientific & Engineering Research, pp. Volume 5, Issue 4, 2014.
- [12] Diunduh, «Voltage Divider,» [http://en.wikipedia.org/wiki/Voltage\\_divider](http://en.wikipedia.org/wiki/Voltage_divider), 08 March 2015.
- [13] M. Margolis, Arduino Cookbook, O'Reilly Media, 2011.
- [14] P. S. D. Anusha, «Appliance Remote Control Using Arduino,» International Journal of Latest Trends in Engineering and Technology, 2013.