Telemetry Monitoring of Solar Panels Using GSM

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Abstract---Solar energy is one of the refine resources of renewable energy these days. Best utilization of this renewable energy source is one of the hot topics in today's research. Solar plants are normally installed in remote areas so they require a remote monitoring system. This research is conducted to develop a remote monitoring system for PV plants to improve their efficiency and productivity.

The monitoring system developed measures the parameters like voltage, current, humidity, temperature and light intensity for a solar panel array. The data collected at the PV plant is send through GSM to the monitoring system main database unit. At main database unit the data is displayed at LCD using GUI human interface. The main database unit is collecting values of above mentioned parameters from 100 different remote sites. The data collected is analyzed at real time and is used for predictive maintenance of PV plants. In predictive maintenance IV curve testing, mechanical inspection, fault in any equipment and its predictive replacement will be done.

Maximum Power Point Tracking (MPPT) method has been studied in detail to improve the efficiency and the productivity of the solar plants. It is an electronic system which set the position of panels in maximum sun light pointing. By applying the MPPT method we can get maximum output throughout the day.

The experimental results of this research shows that by using GSM technology we can have secure and reliable communication between PV plants and monitoring systems. By applying the process of Predictive Maintenance the life of the equipment used in solar panels is enhanced resulting in improved efficiency and productivity.

Keywords— Global system for Mobile (GSM), Remote Monitoring, Arduino Board, Solar Panels, Short Message Service (SMS),

I. INTRODUCTION

Renewable energy resources have a significant importance in today's life due to the depletion of non-renewable energy resources. Efficient use of these renewable energy resources is also in the hot topics of research in today's world of science. Solar energy is one of the main source of renewable energy all across the world. Solar energy is reliable and clean form of energy that is not hazardous to the environment [1]. Solar plants are installed in remote areas where their efficiency is at maximum. For better output and performance of solar plants they should be monitored properly. Lack in monitoring of PV plants leads to the poor power performance [2].

Remote monitoring is one of the major aspect of solar plants installed in remote areas. Remote monitoring is an online technique that is used to transmit real time data from the plant to database unit[3]. This system obtains data then analyse it and Data is collected at the database unit for forecasting and to diagnose any kind of problem in the field equipment. Remote monitoring system uses the advanced science of communication technology, computer sciences, electronic technology and instrumentation.

Till now many techniques of remote monitoring for solar plants are developed. These techniques involves monitoring using wireless network, ZigBee network, Global system for Mobile (GSM) and Ethernet cable network. There are pros and cons of each of the technique. In wireless network there is a huge issue of reliable data transfer and the sensors that are used in this network requires a high power to operate[4]. ZigBee network operates only a small area where signal range is not too far so it does not cover wide range of signals. Moreover, ZigBee network demands high cost and complexity. Ethernet cable network requires a cable for transmission of data so it is limited by geographical constraints[5].

We have selected Global System for Mobile (GSM) network for the remote monitoring of our system. GSM network is reliable channel of transmitting data from one end to the other one. Data transmission using GSM network is also very simple and can be done using a few commands. So, monitoring system using GSM is not very complex. This system does not have any geographical constraints. Due to the availability of Short Message Service (SMS) the cost for data transmission becomes very low. Overall GSM provides us a monitoring system that is wide in signal range, has low cost, highly reliable data delivery, no geographical constraints and less complexity[6].

The outline that we are going to follow in the research paper is: In section II, research methodology for developing this system is described. In section III, literature review or related work on this topic will be discussed. In section IV, Structure of system or system architecture will be described. In section V, system flow chart will be explained. At the end there is a description of experimental results and then conclusion.

II. RELATED WORK

Since solar energy is one of the reliable form of renewable energy so many work has been done for its improvement. Till now many monitoring systems has been developed using different technologies.

Remote monitoring system using wireless technology was developed first. This technology uses sensors that send and transmit data wirelessly. The drawback in this technology was the delay in transmission which makes it vulnerable for failure. Data transmission using wireless sensors is also not highly reliable. Due to non-reliability the data can be lost and this system also acquires much power to operate.

ZigBee is also one of the technology that is used for remote monitoring. Major drawback in this technology was its short range. This system is only capable of monitoring within a small range. The transmission rate for ZigBee network is also not very high and system using ZigBee network involves much more complexity[7].

Another way for monitoring remote sites is using internet. The problem with internet also involves the reliable delivery of data from one end to the other end. Also network cables involves the geographical constraints. Lack of support of internet in cut off sites has limited that method[8].

Wi-Fi technology can be used for sending data from one end to the other end. Data transmission rate for Wi-Fi is much higher than ZigBee and also the system is not very complex. The only limitation involved in this method is its range and this system can be applied at micro grid level[9].

III. RESEARCH METHODOLOGY

This research is conducted in a sequential manner. We have followed a specific pattern to perform our work. First of all the solar plant is installed in the remote area. The plant is installed in the remote area due to the specific requirements. The sunlight in certain remote areas has a very high intensity which is much feasible for our system. The sites where these solar plants are installed re normally cut off sites away from urban areas. Due to this they require continuous monitoring for their proper working and best efficiency.

Remotely monitoring that plant is one the best economic and efficient way. There are too many wireless techniques for remotely monitoring. We studied all of them and find out GSM is one the best way for monitoring as it has distinct advantages. The problems with other systems are mentioned earlier in this paper due to which we gave preferences to the GSM technique.

The parameters that are required for monitoring a solar plant properly are voltage, current, power, light intensity, temperature and humidity. Voltage, current and power are parameters related power generation. The voltages that are produced from the solar panels are stored in batteries. A voltage and current sensing circuitry is installed there to measure the voltages and the current from the battery.

Temperature measurement is the important parameter to measure in order to know about the output voltages from the panel. As solar intensity is directly proportional to the temperature so when the temperature is high in the remote region then it means we will have the good output from our solar plant [10].

Light intensity is required to measure amount of sun light faced by the solar panels to generate output. We also measure region where the maximum light is falling. When we know the region in our remote site where maximum light is falling solar panels are faced towards that region. This gives us the maximum output voltages from the same number of panels throughout the day.[11]

Humidity of the remote site is also measured in order to know about the weather conditions properly. As efficiency of a solar plant is much dependent on the weather in that region so it is good to know every parameter of it. As humidity in the air effects the solar light so output of the solar plant is also effected but the humidity present in the air. Also it is important to measure the humidity because it effects the maintenance of our system. A greater humidity in the air will require more maintenance of solar panel arrays than in the normal conditions [12].

Maximum Power Point tracking is also done in this research. In maximum power point tracking the position of the solar panels is such that they face the maximum of the light from the sun. In this technique the solar plant gives the maximum output voltages it is capable of. By this tracking technique we can obtain maximum output from the panels throughout the day [13].

IV. SYSTEM ARCHITECTURE

The system architecture have sensors for all the parameters that we have to measure. Parameters that we have to be measure are voltage, current, humidity, light intensity and temperature. All the data collected from different sensors is sent to the microcontroller. Microcontroller is the main part of system's hardware design. Analog to Digital Converter (ADC) is used to convert analogue data to digital for further processing. Control circuit is also used to shut down system in any case of failure. After receiving and processing of data it is displayed on LCD.

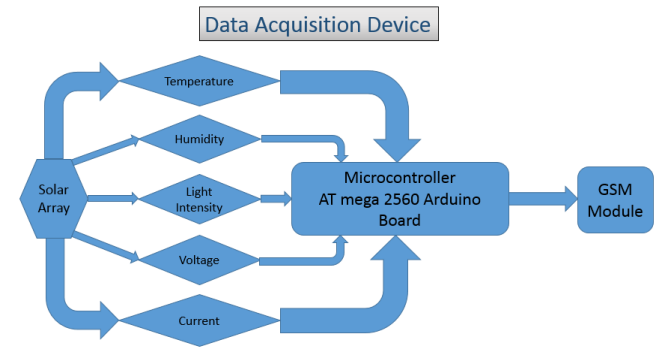


Figure 1. Data Acquisition Device

Voltages of solar panels array are monitored using Arduino board (at mega microcontroller). Dc voltages generated

depending upon light intensity. ADC of Arduino used to measure voltages and display on LCD.
Current value depend on the load (i.e. Battery). In this project we use max 4080 (FASA) IC for current measure. It give 50mv output per ampere. The circuit of current sensing is designed for measuring a current of 50A. Analog voltages from the current sensor circuitry are converted into the digital form and are then displayed on LCD.

Humidity and temperature are measured using Dht11 sensor. It is four pin sensor two for power and one for digital data. We interface this sensor with our controller and measure both quantity and display on LCD.3 to 5 volts power and I/O. Measurement range of sensor is 10-90% RH and 0-50 degree Celsius[14].

For the Measurement of light Intensity we have used Light Dependent Resistor (LDR).
Light Intensity is measured in lux and output is displayed on LCD.

We design battery charger of 12v and 1A. Both voltage and current can vary according to the need of charging. Tl494 IC is used to design battery charger.

All parameters which are measured and then display on LCD are transmitted through GSM. Model SIM 908 were used in this project. SIM908 module is a Quad-Band GSM/GPRS module. This GSM module combines GPS technology which can be used for different purposes such as for satellite navigation. Operates in 850, 900, 1800 and 1900 MHz supply voltages ranges 3.0 to 4.5v[15]. AT commands will be used to operate the GSM modem. Mode for usage of GSM modem in this research will be text mode.

At mega 2560 Arduino board is used as microcontroller. Data from the sensors is sent to the analog pins of controller and the digital value against the analog data is displayed on LCD. This board contains USB port so it can be directly connected to the computer using this port.

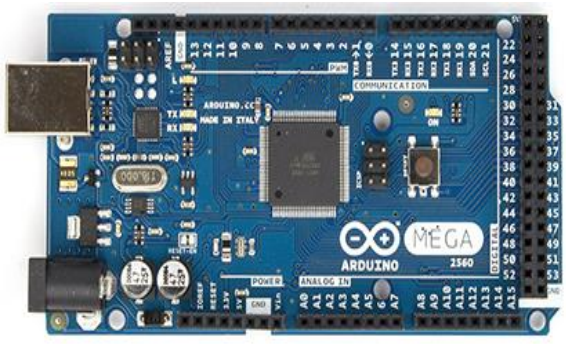
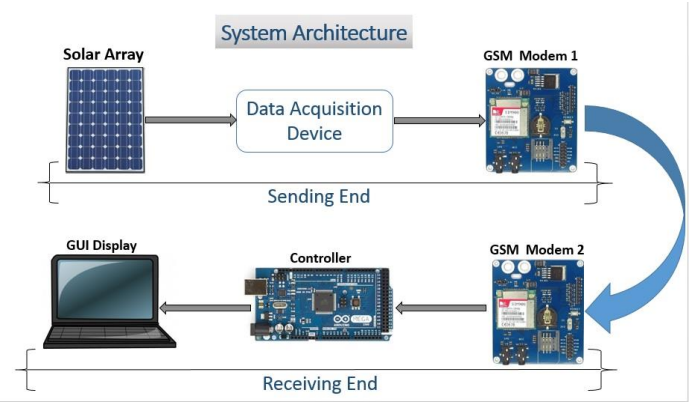


Figure 2. AT mega 2560 Arduino Board

A. Hardware Design



In hardware design the main part of the system is the solar panel array and the central monitoring system. The sensors are combined to form a hardware architecture of the system.

1) Solar Panels Voltages Detection Circuit: Solar panel output voltages are dependent on light intensity of sun facing the solar panels. On a particular intensity the solar panel voltages and current are depend upon on the load connected with it. Let say load is battery so the internal resistance of battery will describe the module voltages. By testing we know the maximum output voltage of panel. By using ADC with setting reference voltages we measure panel voltages. In our microcontroller we have 5v reference ADC. We connect output voltage with divider to detect voltage with reference ADC value.

Figure 3. System Hardware Design

2) Current Sensing Circuit: Current sensing is one of the most important parameter in system to measure. The photovoltaic cell and battery both have charge and discharge mode in PV power generation system[16]. To protect battery from excessive charge and discharge we sense current.

In this research paper we use max 4048 for sensing current. Block diagram is shown in figure

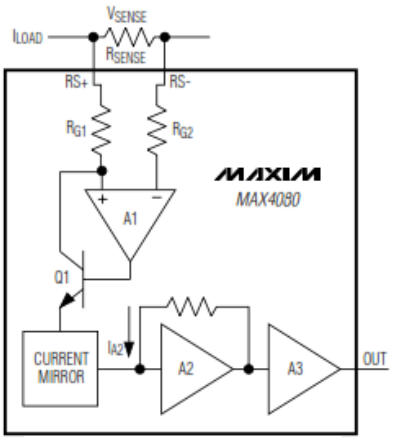


Figure 4. Max 4048 Current Sensor

Current through load flow across sense resistor creates sense voltages. Internally at negative terminal have high impedance cause the RG2 current zero. Open loop gain force non-inverting input voltage equal to inverting voltage. Amplifier A2 used to convert current into voltage and send through amplifier A3.

3) Humidity and Temperature sensing: Temperature is also an important parameter to monitor in solar panel system. As the performance of panels is also depend on the temperature. As the light intensity cause of change the output charging power of the battery. PV cell temperature increases 1°C, the efficiency of battery down about 0.45% and the life of it will come down. Both temperature and humidity measure using digital sensor. Low relative humidity between 69% and 75% favour increase in output current from solar panels. Output voltage also increased with decrease in relative humidity but stabilized between relative humidity values of 70% and 75% values[17].

4) Luminous intensity detection circuit: Light intensity is the important parameter to measure for good output voltages. For fixed light intensity to be faced, panels should move according to the sun position. In a fixed position panels light intensity varying cause varying output voltages. We use 5mm LDR (light dependent resistor) with a series resistor to measure light intensity. DC 5v constant voltage apply to resistors and measure intensity according analog divider voltage using ADC.

5) Sun Tracking Circuit: To get the maximum output throughout the day we have designed the sun tracking circuitry. This circuitry is used to track sun maximum light intensity throughout the day. This will aligned the panels with sun to get maximum efficient output. For sun tracking we require light detection circuit and motors attached with panels to rotate it as the sun is rotating. For light detection we use LDR (Light dependent resistor) whose resistance vary with varying light intensity. It may be NTC or PTC .The solar tracker can be used for several application such as solar cells, solar day-lighting system and solar thermal arrays.

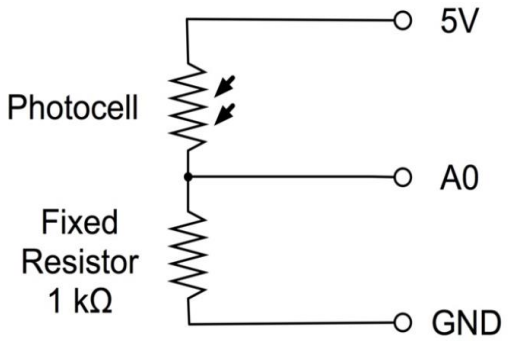


Figure 5. Sun tracking Circuitry

B. Central Control and Monitoring System

The basic purpose to establish the central control and monitoring system is to develop a system for connecting technology to the humans. It is basically a GUI interface for the human. It acts both as a monitoring unit and a command center. The values gathered from the solar plants are monitored in the central unit and for taking any action a command can also be send.

For central control and monitoring a system is installed in order to measure different parameters from solar plant. The central monitoring system is installed in Islamabad. The system saves all the information received from the different remote sites where solar plant is installed. LabVIEW is used as a software for monitoring the different parameters. All the parameters are monitored by the software and are displayed on LCD.

The monitoring system is getting all the values real time and all the communication is happening in real time. The main objective of the central monitoring and controlling system is to analyze the values of different parameters. The values are displayed in graphs for the ease to analyze them.

As described earlier that the system is also a command center unit so in case of any emergency it can send command for the operation. If central unit receives some data that is not according to the usual one and can damage our solar plant the command center sends a command to shut down that particular solar plant. It also shows at the LabVIEW interface that in which portion the system is facing any failure. When a command is sent by the central unit to particular solar plant which is facing any failure it acts according to the command. When the solar plant is shut down and the operator at solar plant detects the problem in the specified area it sends an indication to the command unit. That indication is displayed on the LabVIEW interface and the operator at the command center is able to know that the problem in that specific solar plant is resolved.

Central control and monitoring system enables us to monitor any system installed in any remote area without being there. It saves us the labor work and also the facility to do the required work in more comfortable place.

C. Maximum Power Point Tracking

Maximum Power Point Tracking is usually abbreviated as MPPT. In this tracking technique panel produces maximum output which they are capable of. It is totally an electronic system which set the position of panels in maximum sun light pointing. There is advantage of getting maximum output throughout the day. There are different methods for tracking maximum power point are[18]:

1) *Perturb and observe method:* In this first method the controller adjusts the panel voltages by changing the position of the panel slightly. And note output is increasing or decreasing if the output is increasing it slightly adjust the panel until it get no longer maximum output. And perturb starts in reverse direction. But the output graph is varying. It is

observed that there is some power loss because of its moving functionality and is also fail to get maximum output at fast varying output condition. But still this method is very popular and simple [19].

2) *Incremental Conductance Method:* In this method the panel is adjusted by the controller as incremental changes in array current and voltages to predict voltage change. This method use comparison of incremental conductance to array conductance. When there comparison are same it is maximum power point.

3) *Current Sweep Method:* This method uses I-V characteristics curve to predict where the maximum output is. It updates the curve from time to time and adjust the panel according to the curve to maximum peak point.

4) *Constant Voltage method:* In this method we try to maintain the output voltages of the solar plant at a constant value by any means. The ratio between the maximum power point tracking voltages and the open voltages is kept constant for achieving the maximum output from the solar plant.

In our research we have used the first method for maximum power point tracking. In the perturb and observe method we have the output voltages from the panel. These voltages are varied a little bit and then the power is calculated at some varying voltages. When we have the power at some varying voltages we compare the values power at different output voltages. If the value of the power is increasing in a particular manner by adjusting the voltages in particular direction then the voltages are again adjusted in that manner until the maximum power point is achieved [20].

This method is named perturb and observe because we change the voltages from the solar panel and observe the power due to that change. This method is not purely perfect to get the maximum power point but it is used most commonly due to its simplicity.

D. Software Design

In Software design we have used the C programming language to program the microcontroller. The microcontroller is then interfaced with the GSM module. GSM uses AT commands for its operation. Few AT commands that are used for specific operations are[21]:

- AT = Initialize Modem
- AT+CMGF=1 = Set Modem in text Mode
- AT+CNMI = New Message Indicator
- AT+CMGS = Send Message
- AT+CMGR = Read Message
- AT+CMGD = Delete Message

These are the few commands for SIM908 modem which will do our task.

For the purpose of GUI human interface C# tool is used. C# program is interfaced with the Arduino board. The data collected from the sensors is converted into digital form by Arduino board. This digital data is then serially transmitted towards the computer. For serial communication USB port connected to the Arduino board is used.

V. SYSTEM FLOW CHART

The system that is developed for this research has two parts. The sending part and the receiving part.

At the sending side first of all data is collected from the sensors in the analog form. Data from each sensor is collected separately and is sent to the separate analog pins of Arduino board. After the data has been received from each sensor it is then processed in the microcontroller. Data is converted from the analog to digital form in the processing. The measured values from the sensors are then displayed on the LCD. LCD is connected to the digital pins of the Arduino board. As the digital data is displayed on LCD it is also sent towards the GSM modem (send) for transmission to the receiving end. The processed data is sent to the GSM module after a specific interval of time.

At the receiving side of the system data is received by GSM modem (receive). The received data is directly transferred to the PC where it is displayed using LabVIEW interface. The LabVIEW interface shows all the measured values, the analysis of the value and their graphs. There is an indication on GUI human interface in case of any failure in the Solar panel plant. The data collected is stored at real time on receiving side. The communication between both ends (the solar plant and the central monitoring system) is happening on a real time basis.

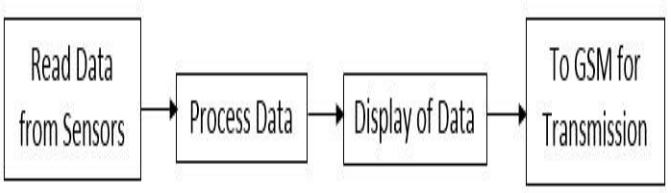


Figure 6. Sending Side (Block Diagram)

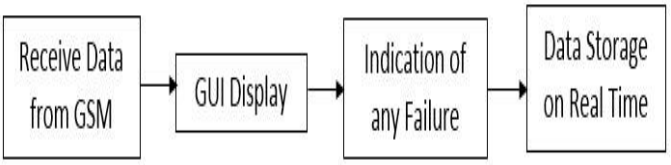


Figure 7. Receiving Side (Block Diagram)

VI. EXPERIMENTAL RESULTS

The results of the research shows the voltage in Volts, current in Ampere, temperature in Celsius, light intensity in candela and humidity in % on GUI display. There is a separate graph for the power calculation of the system on GUI display. The graphs and the analysis of the results shows that when the

temperature of the remote side is not very hot and there is much humidity in the air then less voltages are generated.

When the temperature of panel is maximum at noon time maximum voltages are generated. Short current of the panel arrays also goes to its maximum value during that time of the day. At this time of the day batteries that are connected to the solar arrays are fully charged. In the morning and at the time of sun set the temperature begins to drop. As the temperature of the panel arrays drops the voltages and the current also begins to drop.

When the battery connected to the solar array is fully charged then the solar panel system automatically shut down itself. When the batteries are used the voltage across the battery is dropped then the system turns on and start to charge the battery.

At day time when the load on the system is much higher than the solar energy can provide then batteries cannot provide full load of electricity. At that time there have to be another source of electricity for backup support. During night there is minimum load but also the solar energy is not there to charge the batteries. When at late night batteries are fully used the system automatically turns itself on and charge the batteries for the usage on next day.

This is the problem that is due to the small number of batteries and less solar panel arrays. If our solar plant has greater number of batteries and solar arrays then this problem can be minimized,

The monitoring system gathers the data from different remote sites at specific intervals of time. This monitoring system is designed to respond in any case of failure and emergency. The results shows that in case of any emergency on any remote site the monitoring system sends the command to the system for emergency shutdown. When the system that is facing any kind of failure is shutdown it sends a command signal back to monitoring system indicating that the task has been done.

Figure 8. GUI display of Central Monitoring System

The above figure shows the central monitoring system that is developed using C# tool. It displays the temperature, voltage, current, power, light intensity, and humidity at real time.

VII. CONCLUSION

In this research paper telemetry monitoring of solar panels is discussed. This system makes it easy to monitor different sites at a time remotely. From the results of experiment it can be concluded that the telemetry monitoring system designed on the bases of GSM is working properly in all conditions. GSM is preferred over other techniques due to its highly reliable data transmission and its cost. Moreover the complexity of the system using GSM is also reduced. Techniques using wireless sensors, internet and ZigBee technology have limitations. These limitations involve data loss, more complexity, short range for transmission of data, unavailability of some technology at remote sites and complex architecture of the system.

GSM technology is available all across the country so it removes the problem of unavailability of technology at remote site. Cost of SMS in Pakistan is 0.80 paisa/SMS and the packages available for SMS reduce that cost to 20 paisa/SMS. So, the facility of Short Message Service (SMS) in GSM makes it a low cost system as compared to others. The results of the experiment depicts that the monitoring system operates well under the severe weather conditions without any data loss and transmission delay. Data received at central monitoring system which is displayed at the GUI is stored real time. This system shut down itself in any case of failure or emergency condition. So, the core conclusion of this research is that by using GSM technology we can obtain an efficient transmission of data and secure communication at both sending and receiving ends.

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