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# Energy Efficient Wireless Performance Monitoring System For Solar Panel

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***Abstract: For a PV array, system monitoring is considered important to analyze the stability and performance. The simple monitoring system involves a data logging system with wired cables for transmitting data. Removing all those drawbacks observed in the existing system this proposed work is designed for the wireless monitoring of photovoltaic cell as a high precision solar array monitoring system. It is planned to measure the basic PV array characteristics like Module Temperature (T), Open Circuit Voltage (Voc), Short Circuit Current (Isc) and wirelessly transmit the data into real time GUI in the computer. The GUI was developed using the PROCESSING software. The commercially available WPAN hardware module ZigBee is used for implementation with API protocol for exchanging information. A sensor node with XBee and a set of analog sensors (eliminating the use of controllers at the sensor node) for measuring current and voltage generated in the PV array has been deployed. A coordinator node with Atmel microcontroller and Xbee connected with a PC to analyze the parameters.***

***Keywords: sensors; wireless monitoring; photovoltaic array; ZigBee;***

## I. INTRODUCTION

### *A. Renewable Energy*

As the global demand for energy rises along with the growing world population, all the countries are insisting more and more emphasis on the development and proper consumption of renewable energy. Among the many sources of renewable energy, solar energy is considered the most promising and reliable energy source. In the light of this, Governments of many countries have provided various incentives to setup solar energy based power plants, to complement the existing power plants which are running on fossil fuels to meet the demand.

In order to ensure stability and reliability of a PV system, a monitoring system is often preferred. As matter of fact, many recent solar energy conversion systems have included monitoring function as an integral part of the systems to ensure its efficiency by collecting the data and analyzing it in a systematic manner.

### *B. Need of the project*

Today the technology moves towards renewable energy source to meet the increasing energy demand. Mainly, solar energy harvesting plays a major role in renewable energy source. A solar farm consists of many solar panel array spread across many acres. To monitor their performance individually is a painstaking task. To eliminate the various drawbacks we provided a solution which is based on the WSN.

## II. LITERATURE REVIEW

Before developing an effective yet low cost monitoring system, a number of previous works, which are related to solar energy monitoring system, have been reviewed and understood.

**TABLE 1: CHARACTERISTICS OF EXISTING MONITORING SYSTEM**

| Work Done By | Data Transfer Mechanism | Parameter | Monitoring Method | Software |
|---|---|---|---|---|
| **Forero(2006)** | Wired : RS232 | Ta,Vpv,Ipv | PC | LabVIEW |
| **Rosiek(2008)** | Wireless : GSM | h,Ta | PC | Not Mentioned |
| **Benghanem (2009)** | Wireless : RF | h,Ta,G | PC | LabVIEW |
| **Benghanem (2010)** | Wireless : RX5002 | Rainfall,h, Ta | Web | LabVIEW |
| **Ayompe (2011)** | Wired : RS485 | Tm,Ta,Epv ,Eac | PC | Not Mentioned |
| **Ranhotigamage (2011)** | Wireless : ZigBee | Ta,Voc,Isc | PC | Not Mentioned |

| | | | | |
|---|---|---|---|---|
| **Wittkopf(2012)** | Wired | Tm,Ta,Vac ,Iac | PC | Matlab |
| **Qingya Fan(2015)** | Wireless : RF | Ta, Vpv, Voc,Isc | PC | VISUAL STUDIO |

Mainly two types of data transferring mechanism are available. They are wired and wireless transferring mechanisms. A Wired transfer mechanism includes RS232 [15][16], RS485[8],PCI bus, Ethernet and wireless transfer mechanism includes RF, GSM[9][10], GPRS, Wi-Fi, Bluetooth, ZigBee[2][4], Satellite. As mentioned earlier, wired systems have their limitations, and are considered less favourable than the wireless option for the monitoring of a solar energy conversion system.

- By using GSM which provides reliable service with accuracy of data transmission and also exhibit low retransmission rate and low total data loss rate of approximately 2.73% and 0.66% respectively. One of the main drawbacks of GSM is that the user needs to pay for the data transmission service. [5]
- On the other hand, RF data transmission was quite a popular mean of wireless data transfer. Radio communication has the possibility of sending and receiving a huge amount of information at a low cost of transmission, and it is also a good alternative in remote area which does not have telephone lines. Its main disadvantage is the difficulty in obtaining permission for the transmission frequency and the high price of its installation.
- Similar to the RF, ZigBee also provides wireless communication stack which based on the IEEE 802.15.4 standard develop-fed by IEEE and ZigBee alliance. It has low data transmission rate compared to Wi-Fi but it provides nodes connectivity up to 65,536 and the range is of about 1.5 Km outdoor (clear line of sight). (Sung & Hsu, 2011)
- For the sake of readily available values there are many options for creating a GUI. Few such methods with the help of a PC are the web-based system[12], visual studio[20], Matlab [15] and LabVIEW [19].

## III. SYSTEM OVERVIEW

The proposed system consists of XBee modules, Arduino Uno R3 and Arduino IDE for programing and retrieving data. Wireless communication is achieved through XBee along with the sensors distributed in the PV array.

The task of router nodes is to collect the physical parameters of PV array, i.e. temperature, current and voltage from the sensors, and then send the data to the coordinator node via XBee module.

The task of the coordinator node is to receive the data whenever available or as when requested. The task of GUI is to receive, store and display the data, judge working status of PV array and give alarm when PV array works abnormally.

### *A.* ***Sensors used***

*1) Temperature sensor LM35*

*a)* Operates at 4 to 30 volts

*b)* Linear: + 10.0 mV/°C scale factor

*c)* Operates at: 4 to 30 volts

*d)* self-heating: 0.08°C in still air

*e)* Nonlinearity: ±1⁄4°C typical

*f)* impedance output: 0.1 W for 1 mA load

*2) Current sensor ACS712*

*a)* Bandwidth: 80 kHz

*b)* single supply operation: 5.0 V

*c)* internal conductor resistance: 1.2 mΩ

*d)* output sensitivity: 66 to 185 mV/A

*3)* ***Voltage sensor***

It is a simple voltage divider network which ranges between 0-25V and it contains 3 pins of which 2 pins are for output (S) and ground (GND).

*4)* ***Voltage Divider Network***

Voltage divider network is used to reduce down the voltage produced from the sensor. As the output voltage produced by the sensor is in the range of 0-5V and it has to be scaled down to 0-1.2V because it is in range that can be detected by the XBee module.

### ***Router Node***

The router node is a device which connects to sensors, converts the sensor data, and then broadcasts the data to the coordinator node. It consists of XBee radio communication module, voltage divider circuit and a power supply module. All the configuration to XBee is done with XCTU interface.

The role of a micro-controller is avoided in this router node an the sensor values are directly given to the XBee transceiver for transmission and the

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build-in Analog to Digital Converter is used to convert the analogy signal to digital values

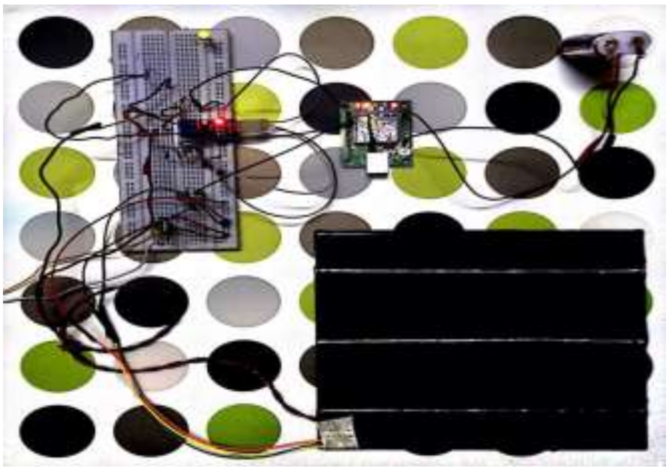

**Figure 1: Photographical View Of Designed Router Node**

### B. *Cordinator Node*

In this node the data received by the transceiver is sent to the Arduino micro controller for processing the data and further sent to the processing interface. The Arduino is powered via USB cable connected to the PC and further XBee module is supplied with 3.3V from the board.

Arduino is used to interface between XBee coordinator node and PC. The XBee module is configured to API mode so that the data enclosed in packet is ripped and data is extracted by the Arduino and send the data to the required application. The PC is connected to the coordinator node which acts as a base station collects the data from the Arduino and channels the data to the required application.

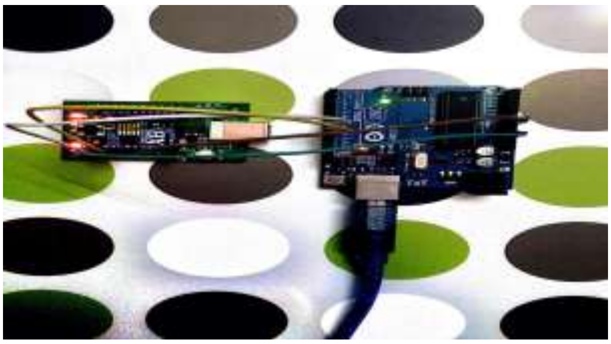

**Figure 2: Photographical View Of Designed Coordinator Node**

## IV. IMPLMENTATION

### A. *Preparing the Router Node*

*1)* Select a router XBee you've labelled with an"R" and place it into the XBee Explorer.

*2)* Plug the XBee Explorer into your computer.

*3)* Run the XCTU program and click on ADD DEVICES or DISCOVER DEVICES to find the radio modules connected to the computer.

**Figure 3: X-CTU Interface**

*4)* Select the appropriate serial port, and double click on them to open their properties.

*5)* Click on 'Update the firmware' to change the firmware to Router AT, select the newest version of firmware and click update

*6)* Enter your PAN ID. Make sure it's the same for both router and coordinator node.

*7)* Enter the coordinator's serial address as the destination address for the router node.

*8)* Select I/O settings. Configure the number of required I/O pins as ADC.

*9)* Click on 'write the setting to the radio module' button to write the setting to the radio module.

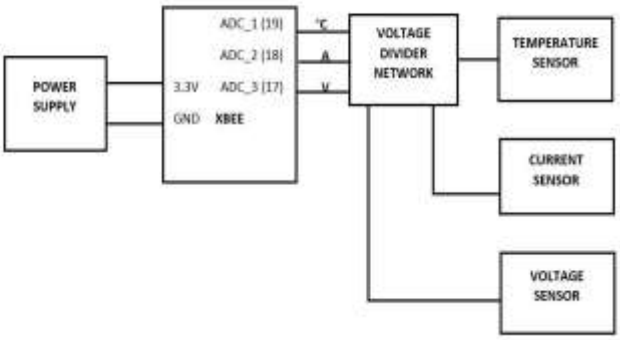


**Figure 4: Router Block Diagram**

### B. *Preparing the Coordinator Node*

*1)* Plug the XBee Explorer into your computer.

*2)* Run the XCTU program and click on ADD DEVICES or DISCOVER DEVICES to find the radio modules connected to the computer.

*3)* Select the appropriate serial port, and double click on them to open their properties.

*4)* Click on 'Update the firmware' to change the firmware to Router AT, select the newest version of firmware and click update.

*5)* Enter your PAN ID. Make sure it's the same for both router and coordinator node.

*6)* The destination address in the node can be defined as '0000'.

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*7)* Configure the API Enable to 2 and write the settings.

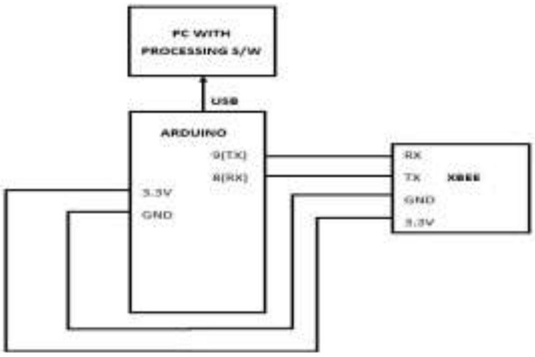



**Figure 5: Coordinator Block Diagram**

### *C. Algorithm*

*1)* The router XBee is configured to send data from the sensor with the sampling interval for about every 1 second.

*2)* The coordinator XBee (Base Station) receives the data from the router node and sends the data to PC with the staring of the header "H" to identify it as a data frame.

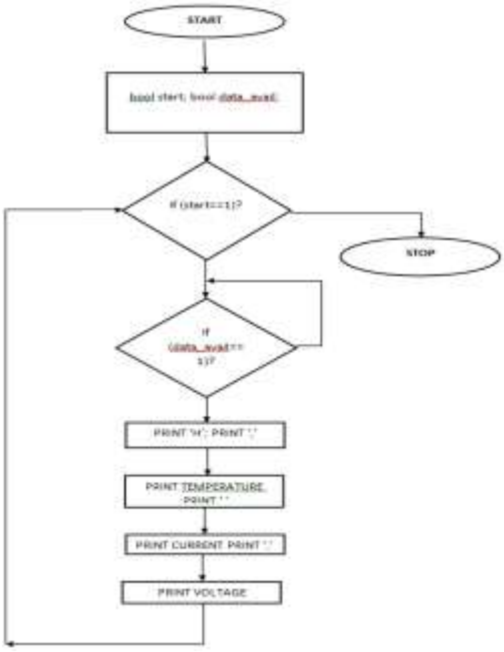
*3)* In PC side, the PROCESSING software is opened with the data logger.

*4)* When the START button is clicked it begins to collect the data is split in to corresponding data and the data is logged in to excel worksheet as .csv file.

*5)* When the STOP button is clicked the file is closed and the data is stored in the PC.

*6)* The file can now be used various purposes such as analysis etc.

### *D. Flowchart*




## V. RESULTS AND DISCUSSION

Certain results are observed from this project with comparison to other projects and research. Most of the research includes microcontroller as the end device whereas the system designed for this project removes the need of microcontroller as a controller part resulting in simple hardware design and lesser power consumption. Moreover by using the ZigBee the cyclic sleep modes are implemented which also contributes to reduce the power consumption.

Figure 5 depicts the analysis of the parameters for measured temperature, current and voltage at different time intervals. The plot in figure 6 indicates the data logged directly from the solar panel into the computer that is obtained from the .csv file, which stores all the values received.

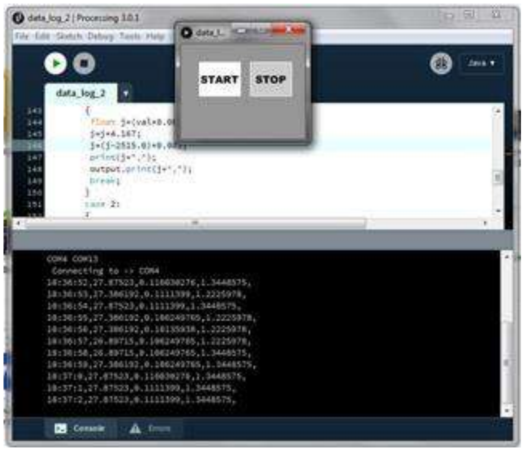



**Figure 6: Gui Created Using Processing Software**

**Figure 7: .Csv File Showing Logged Data**

Implemented results show that the system is able to work with good performance. Based on the results obtained, the developed system has provided an effective solution for wireless monitoring for the stand-alone solar energy generation system. While the system here is designed specifically to accommodate a 5 W stand-alone PV system, the design concept here is completely scalable, and can be made applicable for larger or smaller PV systems.

## VI. CONCLUSION AND FURTHER ENHANCEMENT

The implementation of a wireless monitoring system for PV array is presented. Details on the whole process of the implementation (i.e. system structure design, hardware and software design) have been covered.

In order to increase the efficiency and further reducing the cost and complexity of the system, there are still two more proposed works

- The work exhibits the possibility of eliminating the controller part even in the coordinator node and still performing the XBee API format in the similar way.
- Developing a hanging robot that moves from one PV panel to another carrying the sensors and transceiver with it, measures the parameter of each individual node one at a time and transmitting its corresponding data.

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