Solar Panel Condition Monitoring System based on Wireless Sensor Network

Abhishek Parikh, Farah Pathan, Bhavdipsinh Rathod, Sandeep Shah

***Abstract* - Continuousmonitoring the condition and detecting the faults to ensure the stable power delivery of Solar panel in remote area is our contribution in this paper, this work is part of project. I am working on this project at Optimized Solutions Pvt. Ltd. as a part of curriculum activity in my final year project at Maharaja Sayajirao University. This paper describes the hardware and software implementation for fault detection and continuous monitoring system for solar panel in remote area. This research problem has been stated by engineers working in Solar panel maintenance system. As proposed solution to this wireless sensor node is provided with Voltage sensor, Current sensor, Light sensor, Temperature sensor and Dust sensor and XBeeS2 to implement WSN. Data are being continuously stored and monitored at central station called HUB and through that data are being sent to server via Ethernet. A friendly GUI using Python is implemented to visualize monitoring process and save data on Excel file. The designed system is built and satisfactory results has been obtained.**

***Keywords* - Solar panel, MSP430 micro-controller, Solar panel, fault-detection, Remote monitoring, XBee, Python, Wireless Sensor networks.**

I. INTRODUCTION

As non-renewable energy resources are depleted with time it is necessary to use renewable energy resources like Solar and Wind energy because of its unlimited supply, monetary long-term benefits and environmental friendliness. According to DJ Pandian, principal secretary, energy and petrochemicals department of the state government, they expect around 300 MW of solar power generation capacity to be commissioned in the state before 31st December 2015.

The growth of solar photo-voltaic products in consumer market shows awareness of renewable energy. In order to get maximum benefit and efficiency and to prevent damage it is necessary to monitor the condition of photovoltaic panels continuously[1][2][5].

Though there is very low probability of electrical fault of individual component or total failure of system it is indispensable to monitor and notify the center station to prevent from damage as the cost of components are very much high. Natural cause like lightning strikes, storm, snowfall and heavy rain or even a insect can also damage solar panel and overloading in supply grid can also force power reduction and some times shutdowns also. So it is necessary to monitor each and every smallest fault and report it to central station quickly otherwise it leads to large financial losses. Also it is require to acquire losses due to condition of solar panel. High temperature and dust causes significant power loss and reduce the over all efficiency of Solar panel.

In present industrial scenario PLC and SCADA system are being used to monitor Voltage and Current of Solar panel plant. In this type of monitoring system all the panels are combined and the monitoring system is placed after the inverter. Problem with this type of monitoring system is we can not get each solar panel Voltage and Current of individual solar panel and also we can't detect fault or measure condition of solar panel. PLC system is very much costlier also and once it is wired it is static. So to overcome this problems and as a better alternative solution to this we provide wireless solar panel condition monitoring system that measures electrical parameters of all of the solar panel individually and also it monitors the condition of solar panel continuously. This micro-controller based system is also cost-effective as it dose not requires any extra sensor circuits for voltage and current, also the end node is powered by solar panel so it is versatile solution.

II. PROJECT ARCHITECTURE

For electrical parameter measurement of all the panels it is difficult for engineer to measure them on the field so wireless sensor network is a solution to this.

The Project system architecture divided into two major parts. The first part is wireless sensor node [4] which is connected to each individual solar panel and second part is central computer or HUB which is a computer is connected wirelessly with all devices that displays the data of all panels using GUI [3]. The XBee module connected to node must be in end device or router mode configuration where as the HUB should be in Coordinator mode[12]. Coordinator asks each node to transfer their data and that device responds with acquired data. As that data received by HUB it stores it internally on excel file and forward the data to cloud via internet.

A. Data Acquisition Node

The data acquisition node is made by several sensors that are Voltage sensor, Current sensor, Light sensor, Dust sensor and Temperature sensor. MSP430f6779 micro-controller has seven channel on chip SD-24 bit ADC and 6 channel 10- bit ADC. So at a time three solar panel data can be monitored with it. . So as shown in figure-2 All the sensors are connected to 10 bit ADC and Voltage and Current front-end sensor are connected to Sigma-Delta ADC. Rather than using this type of expensive Voltage and Current sensors to reduce cost We have used simple resistor divider circuit. This circuit vary from panel to panel but it's cost reduce to

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fiftieth part of cost of sensor so that Voltage and Current front-end circuit used instead of separate sensors.

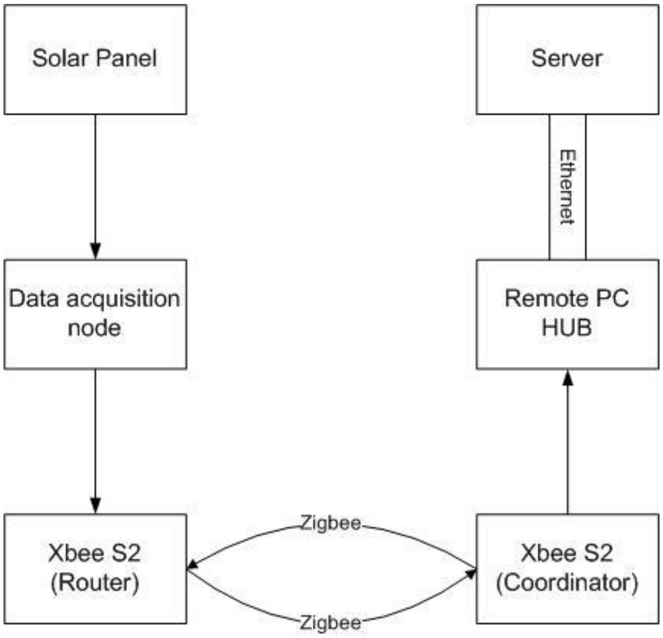

Fig. 1. Project Architecture

At my node design side I will be having three Voltage and three Current front-end circuit to measure electrical parameter. As we get DC Voltage and Current for each panel we can get power that is being consumed by load. MSP430f6779 has on chip RTC so we can get real time data through it[11].

As a power supply of our board we have used Auxiliary power supply which is taken from solar panel itself so my device becomes self powered. Also temperature sensor, light sensor and dust sensor are also powered by solar panel itself so there is no need to supply the power from any other device to node. Now converted data from 10 bit ADC is merged with SD-24 bit ADC and it is combined with current date-time one frame of XBee S2 is made and that frame is sent to UART serially. Our UART baud rate is 9600bps we can make it to higher data rate also. XBee is connected to node via UART communication protocol. We have to set Zigbee communication protocol and than only we can send a data to central station. Transmit frame structure of XBee s2 is shown in figure 3[12]. XBee module works on mesh protocol.

XBee module ensures the data received by central station by receiving acknowledge frame. The node continuously monitors the sensors and electrical parameters of all solar panels but it does not send it until the HUB asks it for. When HUB asks it to send its

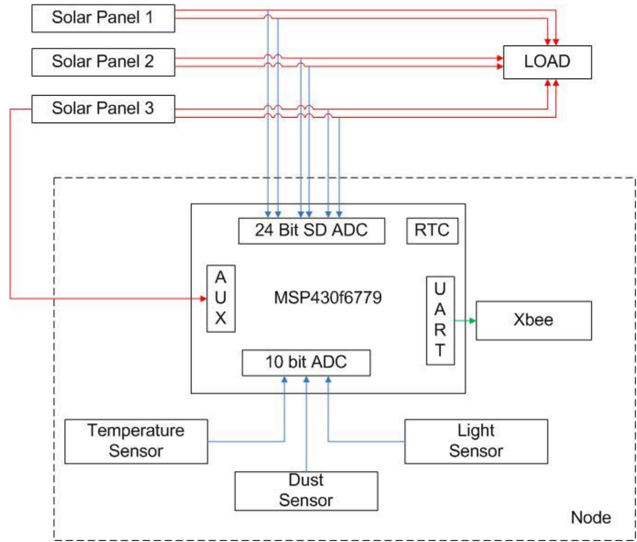

Fig. 2. Node Design

parameters it sends its frame which include data of sensors and panel parameters and current time. We need to attach external coin cell battery with RTC module to keep it on while solar panel is off.

B. Wireless Sensor Network

The frame structure of XBee transmit request frame is shown in figure. Here, RF data contains all the data of node including electrical parameters, sensor data and time also. Option filed contains whether to receive acknowledgment or not. Destination address contains 64 bit of destination physical address which is identical to all other XBee modules. No other XBee can have same physical address. Because of This field of XBee we can ensure that no other nearby device can interfere in our communication. If more than one frame is being sent to other device frame id is provided with it. API identifier specify type of frame. Length specifies the length of our data. If length is lower than 0xFFh value it is stored in LSB only and if more than it MSB and LSB both are used to specifies length of upcoming data. Start delimiter specifies next frame is coming and check-sum is 2's complement of addition of all above fields. XBee module won't send imperfect frames. Any of fields is not matching though data is coming to its UART pins but because of wrong data it discards frame by itself.

C. HUB Design

HUB is nothing but a Zigbee to Ethernet gateway with GUI. In HUB design application is made on high level python language. GUI and back-end process flow both are made on python. In which XBee S2 coordinator is connected to HUB or central CPU which asks each and every node one by one to send their data by theirs

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destination address.

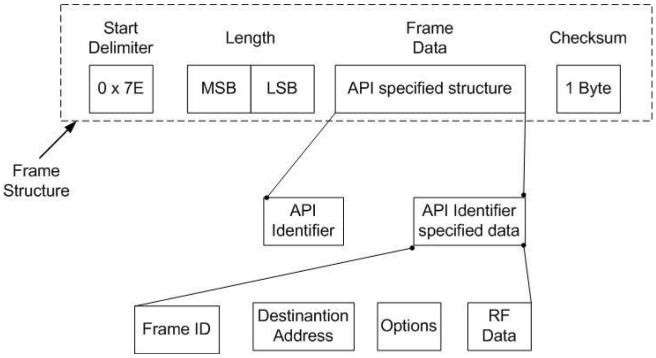


Fig. 3. Frame structure of XBee transmit request

Once the node receives the request to send it sends its data to coordinator by coordinator's destination address. As coordinator receives data it decode the real time frame and than it takes useful data from it and display it to GUI as well as store in Excel sheet and forward it to server via Ethernet. HUB should be powered continuously once HUB's power is down our whole system stops sending and receiving data as there is no other coordinator.

GUI and excel file having logged data is shown in figure 4 and 5 respectively. First column represents voltage of each channel second is current and third is power. Here maximum power in whole day is also stored as shown in figure 5 which shows maximum power delivered during the whole day. The physical hardware design of node is shown in figure 6 and HUB in figure 7. At node side 50W bulb is taken as DC load over here.

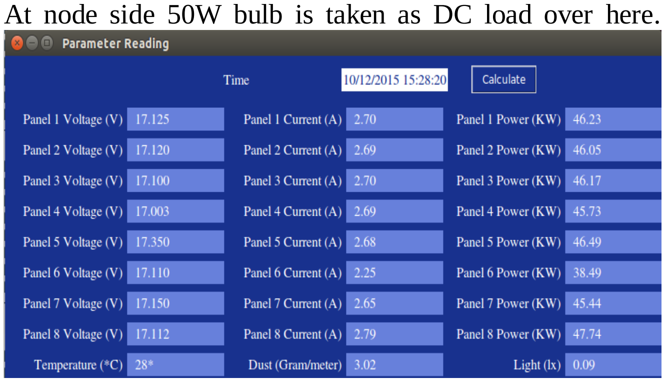
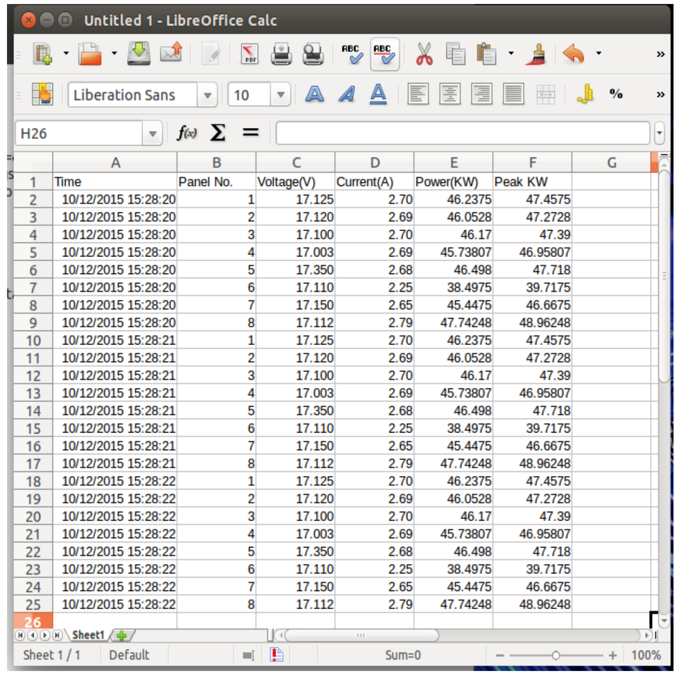


Fig 4. GUI of HUB made using python

LDR(Light dependent resistor) or photo-resistor is used to detect the light intensity. It is used to correlate the efficiency of solar panel. Light is measured in terms of Luminescence and if solar panel is not generating the voltage and current efficiently that means solar panel is degraded.

LM35 temperature sensor is interfaced with it MSP430. As photovoltaic panel's current is depended upon a temperature and it is degraded by following formula

$$I_0 = qA\frac{Dn_i^2}{LN_D} \quad (1)$$


Untitled 1 - LibreOffice Calc

	A	B	C	D	E	F
1	Time	Panel No.	Voltage(V)	Current(A)	Power(KW)	Peak KW
2	10/12/2015 15:28:20	1	17.125	2.70	46.2375	47.4575
3	10/12/2015 15:28:20	2	17.120	2.69	46.0528	47.2728
4	10/12/2015 15:28:20	3	17.100	2.70	46.17	47.39
5	10/12/2015 15:28:20	4	17.003	2.69	45.73807	46.95807
6	10/12/2015 15:28:20	5	17.350	2.68	46.498	47.718
7	10/12/2015 15:28:20	6	17.110	2.25	38.4975	39.7175
8	10/12/2015 15:28:20	7	17.150	2.65	45.4475	46.6675
9	10/12/2015 15:28:20	8	17.112	2.79	47.74248	48.96248
10	10/12/2015 15:28:21	1	17.125	2.70	46.2375	47.4575
11	10/12/2015 15:28:21	2	17.120	2.69	46.0528	47.2728
12	10/12/2015 15:28:21	3	17.100	2.70	46.17	47.39
13	10/12/2015 15:28:21	4	17.003	2.69	45.73807	46.95807
14	10/12/2015 15:28:21	5	17.350	2.68	46.498	47.718
15	10/12/2015 15:28:21	6	17.110	2.25	38.4975	39.7175
16	10/12/2015 15:28:21	7	17.150	2.65	45.4475	46.6675
17	10/12/2015 15:28:21	8	17.112	2.79	47.74248	48.96248
18	10/12/2015 15:28:22	1	17.125	2.70	46.2375	47.4575
19	10/12/2015 15:28:22	2	17.120	2.69	46.0528	47.2728
20	10/12/2015 15:28:22	3	17.100	2.70	46.17	47.39
21	10/12/2015 15:28:22	4	17.003	2.69	45.73807	46.95807
22	10/12/2015 15:28:22	5	17.350	2.68	46.498	47.718
23	10/12/2015 15:28:22	6	17.110	2.25	38.4975	39.7175
24	10/12/2015 15:28:22	7	17.150	2.65	45.4475	46.6675
25	10/12/2015 15:28:22	8	17.112	2.79	47.74248	48.96248
26						

Sheet 1 / 1 Default Sum=0 100%

Fig. 5. Data logged in Excel sheet

So that above 25*C approximately 0.5% per *C current is reduced and so at 45*C approximately 10% current reduces.

Here we have used GP2Y1010AU0F as a dust sensor. Heavy dust also reduces the efficiency of photovoltaic panel approximately by 8% to 10%. So to give cleaning notification dust sensor is interfaced with MSP430

Figure 7 shows HUB design on PC which is connected to XBee module using USB to RS232 converter. The baud-rate of XBee here is 9600bps.

HUB receives XBee frame and manipulates it and keep useful data and save it to excel sheet as well as show instantaneous data to GUI. It also transmits data to server using Ethernet.

Server is the device which stores the data continuously and retrieve back when they are needed. For current use we have used Google sheets as our server.

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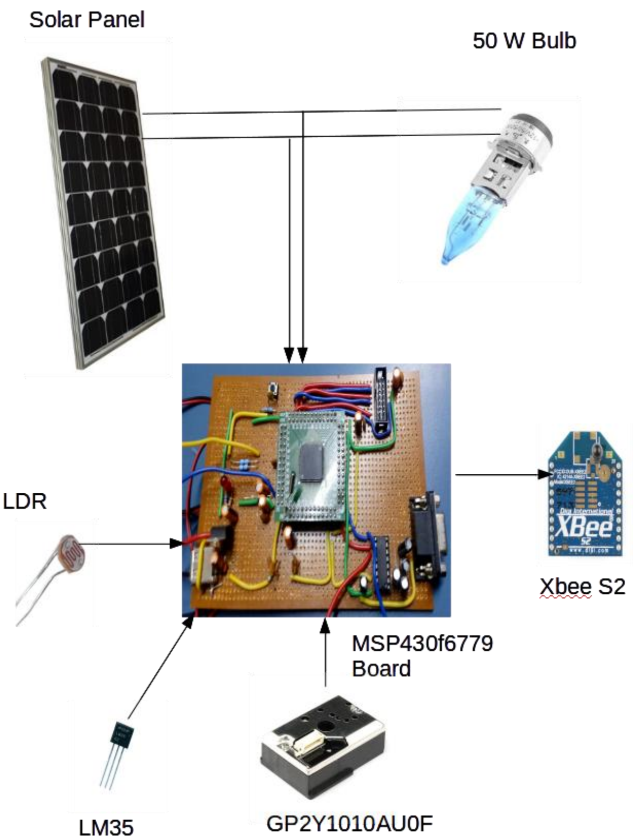

Fig. 6. Hardware design of Node

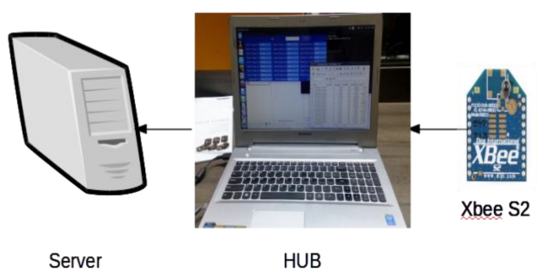

Fig. 7. Design of HUB

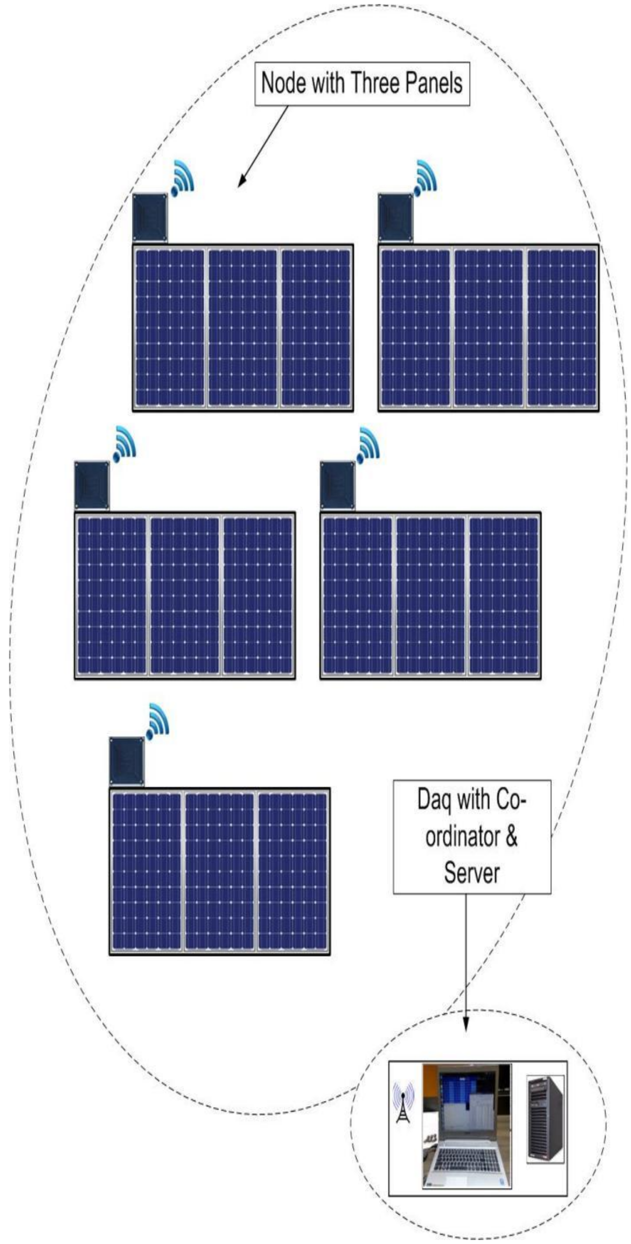

Fig. 8. WSN System Architecture

III. CONCLUSION

In this work we have studied how to access a set of solar panel at remote area with using WSN. Continuous monitoring solar plant is prime requirement of industry. Specified hardware and software is been made for the continuous monitoring purpose. In the prospective work the better GUI design and to make better human machine interface. Also there will be some difficulties in real environment when there is more then hundreds of PV panels.

IV. ACKNOWLEDGMENT

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