An IoT Based Smart Solar Photovoltaic Remote Monitoring and Control unit

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An IoT Based Smart Solar Photovoltaic Remote Monitoring and Control unit

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***Abstract*—Using the Internet Of Things Technology for supervising solar photovoltaic power generation can greatly enhance the performance, monitoring and maintenance of the plant. With advancement of technologies the cost of renewable energy equipments is going down globally encouraging large scale solar photovoltaic installations. This massive scale of solar photovoltaic deployment requires sophisticated systems for automation of the plant monitoring remotely using web based interfaces as majority of them are installed in inaccessible locations and thus unable to be monitored from a dedicated location. The discussion in this paper is based on implementation of new cost effective methodology based on IoT to remotely monitor a solar photovoltaic plant for performance evaluation. This will facilitate preventive maintenance, fault detection, historical analysis of the plant in addition to real time monitoring.**

Keywords—M2M ; microcontroller; remote monitoring; GPRS datalogging; IoT; reliable transmission;

I. INTRODUCTION

With advancement of wired and wireless network technologies, internet-connected mobile devices such as smart phones and tablets are now in widespread use. Thus resulting in a new concept, Internet of Things (IoT) [1-2], was introduced and has received attention over the past few years. In general, IoT is actually an information sharing environment where objects in every-day life are connected to wired and wireless networks. Recently, it is used not only for the field of consumer electronics and appliances but also in other various fields such as a smart city, healthcare, smart home, smart car, energy system, and industrial security**.**

At present, the solar photovoltaic (PV) energy is one of the pivotal renewable energy sources. The solar energy is becoming a potential solution towards sustainable energy supply in future. As more and more Rooftop Solar Photovoltaic systems are getting integrated into the existing grid, there is a growing need for monitoring [3] of real time generation data obtained from solar photovoltaic plants so as to optimize the overall performance of the solar power plant and to maintain the grid stability. As local monitoring is not possible for the installer therefore monitoring remotely is essential for every solar power plant. At this juncture harnessing the power of IoT for monitoring solar power plants by using digital technologies and more advanced computational facilities is promising.

Power generation from Solar Photovoltaic plants is variable in nature due to changes in solar irradiance, temperature and other factors. Thus remote monitoring is essential. For developing remote monitoring system for solar photovoltaic power plant, IoT (Internet of Things) approach is taken in this work which actually envisions a near future where everyday objects will be armed with microcontrollers and transceivers for digital communication. The remote monitoring eliminate the hazards associated[4] with the traditional wiring systems and make data measurement and monitoring process much easier and cost effective and IoT based systems take a giant leap towards monitoring by intelligent decision making from web. The decentralized architecture of the remote monitoring systems and its flexibility of deployment make it most suitable for industrial purposes.

In general remote monitoring systems have to fetch, analyze, transmit, manage and feedback the remote information [5], by utilizing the most advanced science and technology field of communication technology and other areas. It also merges comprehensive usage of instrumentation, electronic technology and computer software. Prevalent monitoring PV system approaches present poses some problems like low automaticity and poor real-time. These problems can be averted with an efficient remote environment information monitoring and controlling system. This system should include automatic diagnosis techniques the PV station.

A predictive maintenance which includes localization and definition of related faults and failures in a PV system is very important. In what follows, concentration has been given on the most widely used ones. Remote monitoring and control of PV system based on Zigbee technology [6] is proven inefficient in large scale because it can't face up huge distance.

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Wi-fi technology is also used for remote monitoring and control of PV system for domestic applications. Wi-Fi (IEEE 802.11g) is chosen as it operates at 2.4GHz and offer high data rate of about 54Mbps in contrast to ZigBee (250Kbps). But this solution is suitable for microgrid network architecture.

At present, a number of PV monitoring system have been put into operation .These systems often use wireless public networks such as GSM or other wireless communication networks for data transmission. But there are problems of high operation and maintenance cost which restrict the development of monitoring system and ultimately hinder the process of efficient generation monitoring in real time. This has influenced us to investigate a novel remote monitoring and control of PV system based on IoT[7].

The experimental set up includes solar panels, temperature sensor LM35, voltage transducers, current transducers, SIM900A GPRS module, PIC18F46K22 microcontroller, RS232 interfaces and converters. Programming Codes developed in house are run in MikroC software and hex code is loaded using MPLAB software. The visualization of the collected data in the control station has been done using website designed.
The paper is organized as follows: Section II presents a proposed IoT based solar photovoltaic data logging and monitoring. Section III presents the overall design of the system. Wireless communication is presented in Section IV. Generalized working of the system is shown in Section V. Section VI describes the future work to be done; the paper is concluded in Section VII.

II. PROPOSED CONCEPTUAL IOT BASED SYSTEM FOR PHOTOVOLTAIC MONITORING

The proposed conceptual system in this work is to monitor the state of a photovoltaic system through an IoT based network in order to control it remotely. The information from the sensors is transmitted via the mobile radio network. A GPRS module is employed to send data to the remote server.
IoT application schematic for the Solar Power Plant is shown in figure 1. The schematic diagram is three layered starting with the sensing layer at bottom which comprises of current sensors, voltage sensors, pyranometer for irradiance measurement and other sensors, this layer also includes microcontroller based data processing of data acquired from the sensors. The microcontroller communicates with wireless module to initiate and transmit data to server.
Layer 2 as envisaged is the network layer where data logging from the plant for real time processing is done which includes database for storage.
Then after the network layer, this processed and stored data is used in the application layer. In this layer sophisticated web based services are designed based on the data collected, processed and stored. Graphical user interfaces will help to monitor the performance of the plant, console will also advice the administrator with decision based on historical data that will significantly reduce the decision making time.

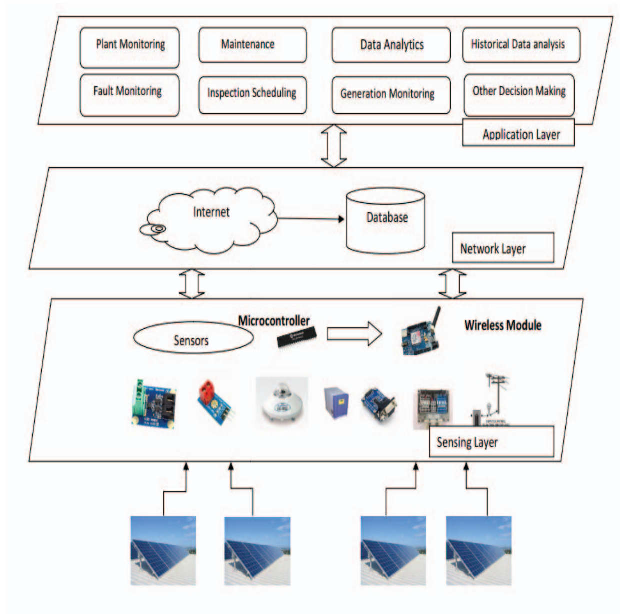

Figure 1 : Proposed IoT Application for Solar Power Plant

By using the IoT based remote monitoring system it will be easier to supervise the overall performance of a solar power plant by a web based approach.

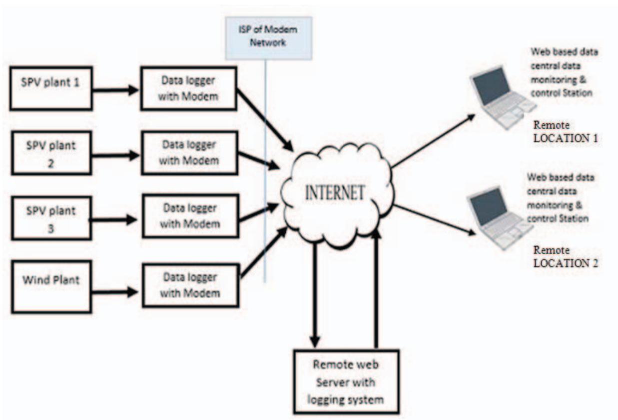

Figure 2: Entire Schematic of the Smart Remote Monitoring System

III. OVERALL SYSTEM DESIGN

A smart data acquisition system as shown in figure 2 for solar power plant is described in this paper. The data acquisition system is capable of acquiring the values for Battery voltage, Battery current, PV voltage, PV current, Grid Voltage, Grid current, Solar insolation and temperature. The PV voltage is sensed by voltage divider circuit, PV current is sensed by using shunt with differential amplifier, Grid Voltage is sensed by potential transformer with precision rectifier, Grid Current is sensed by current transformer with precision rectifier, Battery Voltage is sensed using voltage divider circuit, and Battery Current is sensed by using shunt with differential amplifier. The solar insolation is recorded by using a unit solar cell with precision amplifier. The module temperature is measured by LM35 temperature sensor.

The heart of the data logging unit is a PIC18F46K22 microcontroller, it is an extremely low power advanced RISC microcontroller. The data-logger has a Secure Digital Memory card of 2Gb for storing logged data. Using I2C protocol of the PIC18F46K22 microcontroller the monitored data is being written to MicroSD card for local storage. The sampling rate is 1 scan per second, there are 8 analog inputs, and the channel function and range selection can be done by programming.

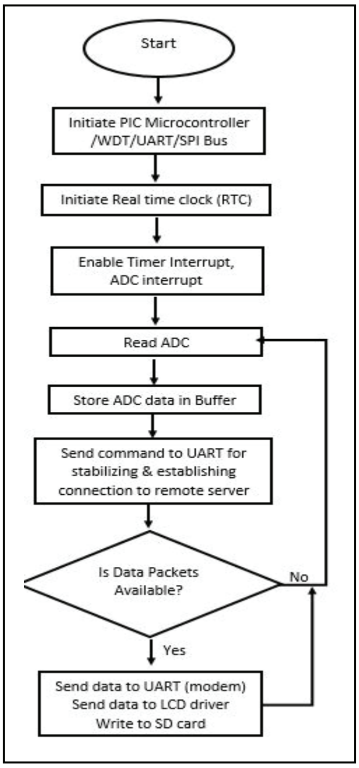

Figure 3: Data logger firmware flowchart

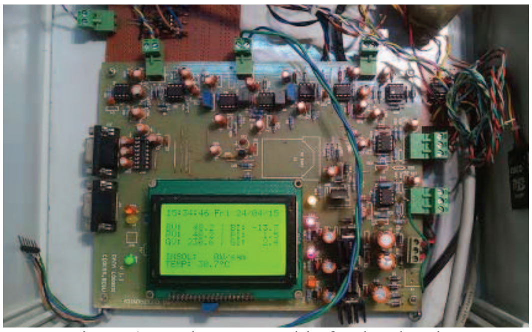

Figure 4: Hardware assembly for data logging

Figure 3 shows the entire flowchart of the firmware development.

The system has RS-232 port for serial data transmission to PC. The data from the data logging unit can also be seen in serial terminal by connecting RS232 cables. 'RealTerm' software is used for serial port monitoring of 'Sourceforge'. A serial to USB converter is used to connect the data logger to the Lab PC.

The system is equipped with a real time clock DS3234 from 'Maxim technologies' for keeping track of the time, thus giving real-time accurate readings from the sensors. This helps in real time Web Based supervision. A hardware assembly for this system is shown in figure 4.

IV. Wireless Transfer Module

'SIM900' is a GSM/GPRS module used for communication between the data logger and the server. This modem as shown in figure 5 is a quad-band GSM/GPRS module with a powerful single-chip processor integrating AMR926EJ-S core manufactured by 'SIMCom Wireless Solutions Ltd'. It delivers GSM/GPRS850/900/1800/1900 MHz performance for voice, SMS and data. It is a low-power consumption module with current consumption as low as 1.0 mA in sleep mode thus it is highly energy efficient. The module is 24 mm x 24 mm x 3 mm and is ideally designed to meet any requirements for Machine2Machine [8] applications .It is interfaced by COM port by using RS232 protocol. It has a GPRS multi-slot class 10/8 and a B-type GPRS mobile station class. Microcontroller is programmed to provide AT[9] commands to control the GSM/GPRS module.

Figure 5: SIM900 GPRS module

V. Working of the System

The major role of data logging system is to send data through the GPRS enabled modem [10]. Modem should perform these commands as soon as it receives them. From the sensing card, variable values are taken as a string. At a particular instance of time, all variable values are taken together as a single string whose length would be less than 150 Bytes. Each value may be separated by comma or spaces. Local RTC is to be incorporated into the controlling system to get a date, time-stamp with the current values.

A) GPRS MODEM:

Modem should be enabled GPRS services as soon as sending the command followed by 'AT'. Target internet protocol and corresponding port is to be given in command. The few commands are necessary for GPRS communication system.

B) TARGET SERVER COMPUTER:

GPRS enabled modem may send the data in ASCII, HEX or Binary format but for making simplicity, the proposed system is designed[11] for sending the ASCII data. The target IP should be static as it helps to make the system simpler. A wired network connection where the public internet protocol is static is recommended for the system.

C) DATA LOGGING SOFTWARE:

A data logging program will be running at target PC where the requested port should be listening mode. ASCII data sent by the GPRS modem will be written there in some text file. User can read the log file to get data.

D) REMOTELY MONITORING FROM SERVER PC:

A standalone web hosting service running on the target PC gives a facility to monitor[12] the live data from anywhere in the world if having an internet connection. Log data file may be directly accessed or the data in the log files may be seen at user-interface webpage. By default, port 80 is used for web server. An HTTP request will come to target PC through port 80 for displaying webpage. Webpage resources should be programmed to 'auto refresh' of data displaying section of webpage at a fixed interval.
TCP/IP data logging software [13] is used for logging real time data from the data acquisition system as shown in Figure 6.

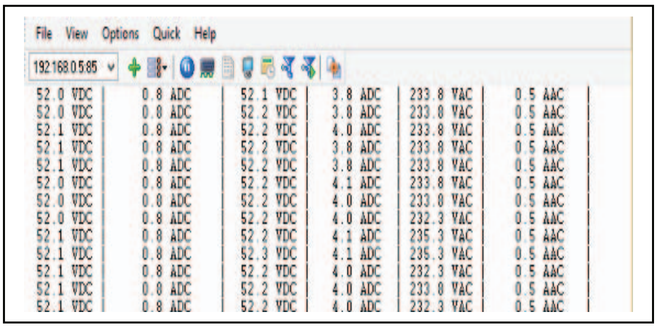

Figure 6: Data getting logged at advanced TCP/IP datalogger

The visualization of the acquired data is seen through a web page.

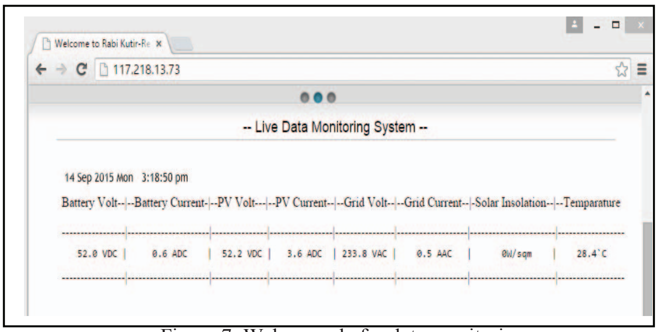

Figure 7: Web console for data monitoring

Figure 7 shows Real time data of the Solar Power Plant in the Web Based user interface.

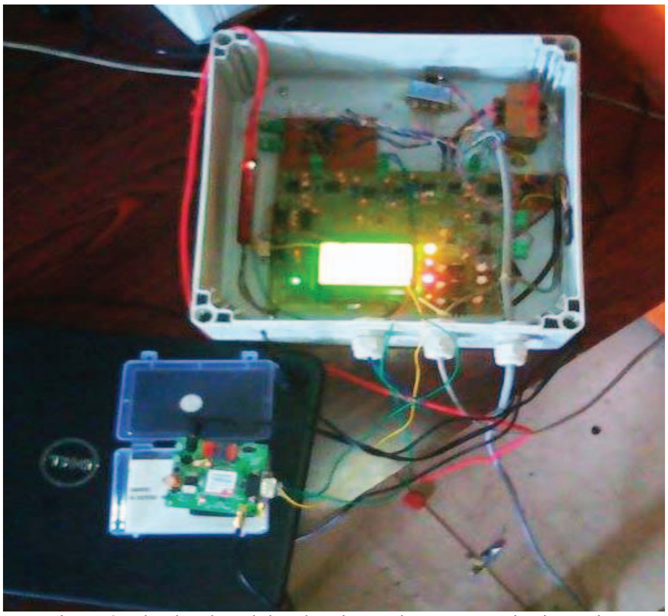

Figure 8: The developed data logging and remote monitoring unit

The entire data logging and monitoring unit is shown in Figure 8, the module for wireless transmission is also shown.

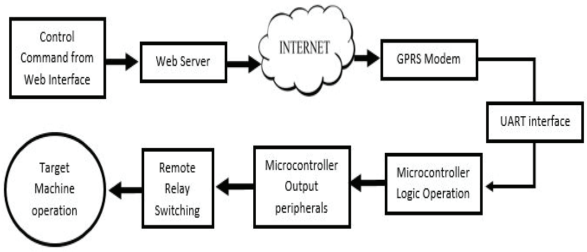

Figure 9: Envisioned Web Based remote controlling

The remote controlling of the plant equipment can be done in future by the visualized schematic as shown in Figure 9.

VI. FUTURE WORK

The uniqueness of the proposed system is that it will be easier to monitor the performance of a solar power plant in a holistic level .The IoT based system will populate dedicated web server based database with real time data of the plant parameters , that will enhance the decision making process of the concerned authority. The generation monitoring, fault detection of the plants in real time will be visible in the web console [14-15]. Large scale grid integration of the solar power plants will require huge data analytics for decision making.

The data populated about generation, irradiance profile, ambient temperature of a plant in database can be used for historical analysis. This approach has to be modified in future by using sophisticated database technologies and equipped with much more embedded intelligence for faster data processing and computation.

This system can be further equipped with GPS modules for tracking plant locations when deployed in large numbers that will further enhance the operation and maintenance of the plants in real time.

VII. CONCLUSION

Use of IoT for monitoring of a solar power plant is an important step as day by day renewable energy sources are getting integrated into utility grid. Thus automation and intellectualization of solar power plant monitoring will enhance future decision making process for large scale solar power plant and grid integration of such plants. In this paper we proposed an IoT based remote monitoring system for solar power plant, the approach is studied, implemented and successfully achieved the remote transmission of data to a server for supervision. IoT based remote monitoring will improve energy efficiency[16] of the system by making use of low power consuming advanced wireless modules thereby reducing the carbon foot print. Web Console based interface will significantly reduce time of manual supervision and aid in the process of scheduling task of plant management. A provision of advance remotely manage the Solar PV plants of various operations like remote shutdown, remote management is to be incorporate with this system later.

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