# Design and Development of Web Server for Solar Panel Performance Monitoring System

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**ABSTRACT**: In Solar Photovoltaic Plants, the traditional method of managing plenty of solar panels is very challenging and inefficient. Since each panel set needs a digital power meter, which is very expensive to use for collecting the data from the panel. To cope with this problem, a standalone monitoring system of solar panels had been proposed, which consists of DC Power Monitoring Node (DPMN), Panel Parameter Monitoring Nodes (PPMN) and an embedded web server. Instead of monitoring PV plants from the installed place which is very complex and time consuming in nature, this proposed system will help users to remotely monitor and access the real-time data via internet. All the parameters from each panel will be sent to the smart analysis database system which was developed and embedded into the web server. Clients can access this webserver for analyzing the performance of the solar plant by using any web browser with specified IP address from anywhere in the world. If the status of the solar panel becomes abnormal, the administrator will receive a message immediately, and necessary steps can be taken. Hence, this system will help the industry in a productive manner.

***KEYWORDS****:* ATmega328, Modbus, Raspberry Pi, RS485, Solar Panel, Web Server.

## I. INTRODUCTION

Solar PV industry is rapidly growing due to huge demand for electrical energy. With increasing installations of solar farms, monitoring, and detection of faults in PV plants has gained ample importance pertaining to the loss caused due to the same. Monitoring and fault detection play an important role in the healthy and optimum functioning of the plant. The work mainly focuses on the study of solar PV systems with in-depth analysis on the DC side of the system and connect it to the web server. The project aims to devise a system that could alert the user in case of any error in the system and efficiently specify the reason of failure and specify the panel. Firstly, it needs to collect data from a set of panels through RS-485 communications, and one side will be Master and another is Slave.

Grid connected PV system needs continuous monitoring because of its installation expenses are too high, if some problem comes user can't be able to monitor the exact fault and day-by-day its efficiency became loose. Perfect monitoring can protect the PV system from preventing the unexpected outcome, it can increase the operational lifetime of the panel also. So, an online monitoring system is an accurate solution for solar PV industry, it can notify user automatically if any problem occurs in the system. As a part of the renewable energy nowadays PV markets are in a most leading stage compared to other renewable sources so without continuous operational monitoring of a PV field it's not possible to improve the systems overall performance efficiency.

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This paper represents a solution to the problem faced by the PV field owner. Section 2 discusses the proposed system regarding monitoring the PV field. Section 3 discusses the hardware part which is required as measurement aspect. Section 4 discusses about the web server development. section 5 discusses results based on experimental setup. And section 6 is about conclusion and future works.

## II. PROPOSED SYSTEM

As studied in literature a lot of work has been done for monitoring a PV system. These systems are all built in industry based and costlier also. But a standalone cheap system has not yet been devised that could recognize and detect the fault of performance during operation of PV fields. Moreover, performance monitoring in real time has not been much considered yet. The complexity of the PV system makes performance monitoring a difficult issue in the solar field. If an accurate user friendly system is developed to maintaining the PV field, large PV fields performance can be monitored and optimal productivity can be achieved. Any defective module causing the problem can be traced immediately and then immediate action can be taken to maintain the system performance. The aim of the project was to develop a cost-effective system that would alert the plant user or register user in case of any error in output and notify the error location. Thereby it helps the user to find the defected module and increase the panels life time of generation of electricity.

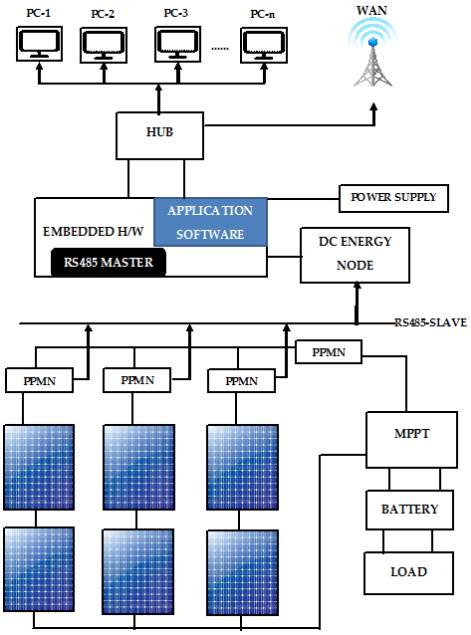



**Figure 1:** Functional block diagram of solar PV performance monitoring system

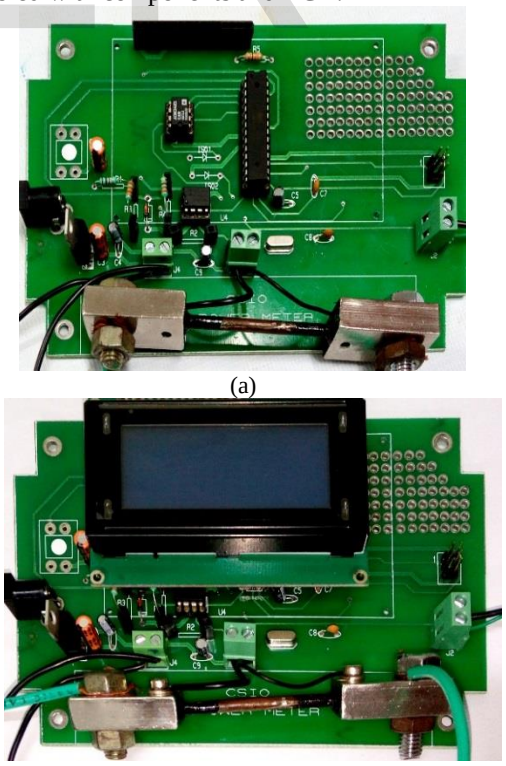
Fig. 1 shows the overall block diagram of PV field performance monitoring system which is based on Embedded web server. The DPMN is built with ATmega328 microcontroller for measuring the overall fields Voltage, Current, Power and Energy which has RS485 connectivity with the web server through Modbus protocol. The pre-developed PPMN consists of ATmega328 microcontroller for each panel parameters monitoring like Panel Voltage, Current, Irradiation level and Temperature which has RS485 connectivity and Modbus protocol also. The efficiency of each solar panel is monitored by PPMN interfaced with it. The parameters such as input, output, and losses are monitored by each PPMN node of the corresponding panel. All the PPMN nodes are networked with the DPMN and DPMN is connected with the web-server via RS485 communication standard. The Raspberry Pi board will act as a Modbus master. Each PPMN node will act as Modbus slave with unique id ranging from 1 to 255, since the Slave ID uses unsigned char variable to store the Slave ID. The Raspberry Pi board with pre-assigned IP-ADDRESS can be accessed from anywhere in the world with internet connection. When the IP address is typed in a web-browser, the developed dynamic web pages which is stored in the memory of Raspberry Pi Board is displayed. This page will show the analysis graph of PV field parameters with the help of DC Power Monitoring Node which connected to it. When the user enters in that server all the parameters data of each panel will be displayed in a table and after every seconds table will be updated automatically. The parameters are updated in real time with MODBUS MASTER polling all the slaves connected to it in periodic interval. If some node is not alive, it will be also displayed. Thus, with this Raspberry Pi board user can monitor the efficiency and other vital parameters of a solar panels condition from anywhere in the world.

## III. HARDWARE IMPLEMENTATION

For monitoring the performance of the PV field, it is very important to measure some electrical parameters like voltage, current, temperature, irradiance, etc. It is essential to develop a hardware for measuring all those parameters with accuracy so that user can monitor easily if any faults occur in the PV field. And one more hardware had been fabricated for a standalone web server.

### *A. DC Power Monitoring Node*

The proposed DC power monitoring node is developed for measuring the electrical energy consumed by multiple loads that are connected to PV fields. The DPMN is ideal for measuring the drop of voltage across DC current shunt, input voltage and observing Current, Voltage, Power and Energy. A voltage divider arrangement had been used to measure the panel voltages. The resistor values were selected such a way that the maximum panel voltage corresponds to a maximum output voltage of 5V. Since the voltage divider was connected in parallel across the panel, the values in the range of kilo ohms are selected so that minimal current will flow through the measurement circuit. Here positive side of the voltage divider is connected to the positive side of the panel, and negative side of the voltage divider is connected with the negative part of the load. Current measurement is another important parameter in PV field to monitor the panel activity. The measurement of current has to be done accurately; there are several dedicated sensors are available like Hall-Effect current sensor (ACS712) and DC shunt. Here low-value shunt resistor had been used with one Instrumentation Amplifier (AD623AN) which has the sensitivity of 1.5 mV/A where the Hall-Effect sensor have the sensitivity of 180 mV/A. Fig.2 is showing the printed circuit board of DPMN, assembled with components and LCD.



(a)

(b)

**Figure 2:** (a) DC power Monitoring Node Assembled on PCB (b) DC power Monitoring Node Assembled on PCB with LCD

Here ATmega328P had been used as a microcontroller for collecting data from panels through connected sensors like voltage sensor and current sensor. Voltage divider had been used here for voltage measurement and shunt with AD623AN for sensing the current across the load and source. All collected data pass through the microcontroller and send in receiver side via RS485 transceiver using Modbus communication. Fig. 3. (a) shows the flow chart of slave part which is a DC power monitoring node.

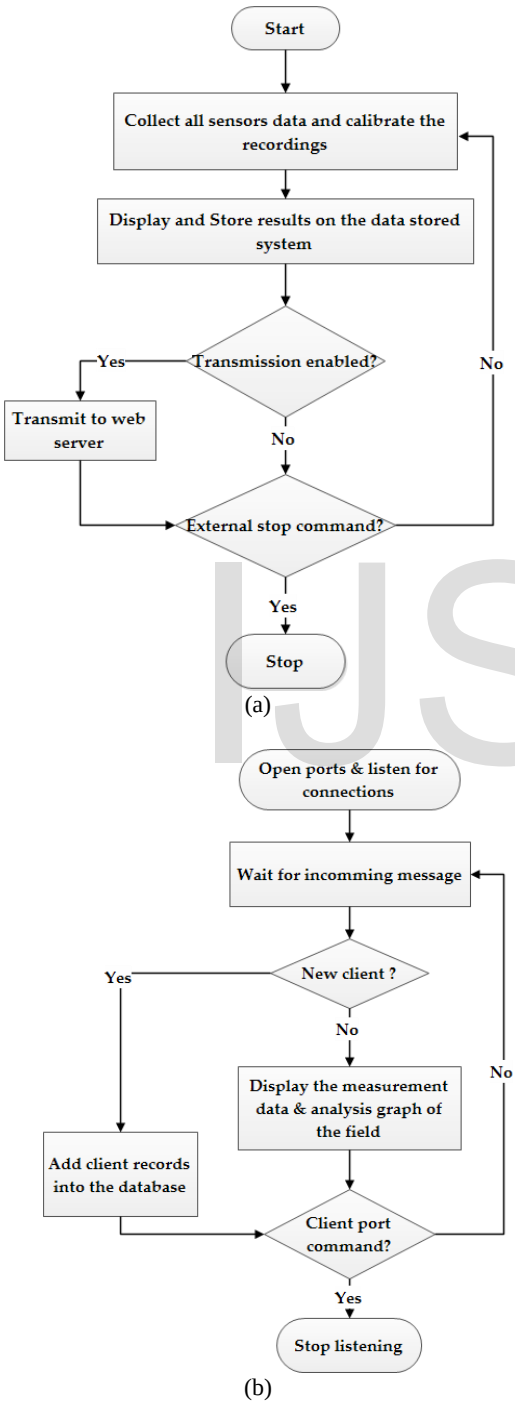



**Figure 3:** (a) Flow Chart of Slave Side Connection, (b) Flow Chart of Master Side Connection

### *B. Fabricated Standalone Web Server*

A standalone web server is a portable web server which consists of an embedded web hardware (Raspberry Pi), Power Supply, Ethernet Connection, Display Module, Keypad Activity and Modbus Communication. Figure 4. shows the overall block diagram of the solar panel to end user.

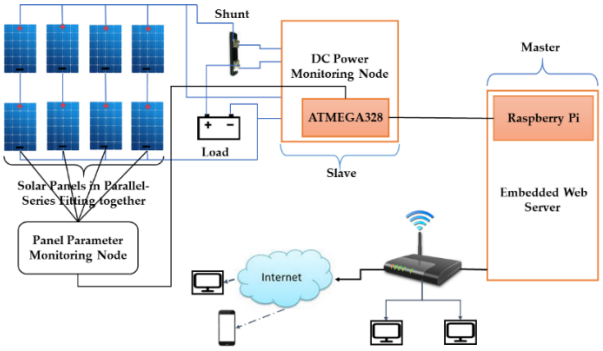



**Figure 4:** Energy Node to Web Server Block Diagram

Hardware had been fabricated for a standalone web server which will be connected to a router via Ethernet connection. The user sitting on the same network or whoever is connected to the Internet can access the web server via a particular static IP address. The user has to know only the address of the server. This web server will show the connected panels status and some analysis graph related to voltage, current, power, and energy. It is a portable web server which is consist of an embedded web hardware (Raspberry Pi), Power Supply, Ethernet Connection, Display Module, Keypad Activity and Modbus Communication. Fig. 5 shows the block diagram of standalone web server.

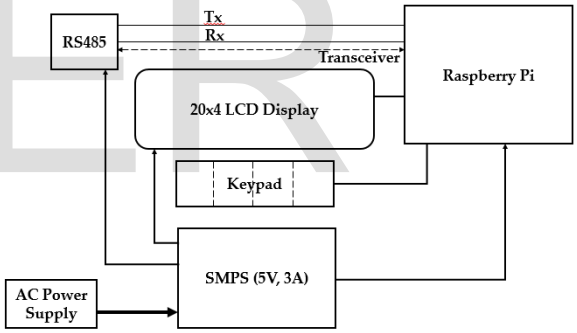



**Figure 5:** Block Diagram of Fabricated Standalone Web Server

## IV. WEB SERVER DEVELOPMENT

### A. *Raspberry Pi as a Web Server*

Here Raspberry Pi had been used as a local web server which is host two to three lightweight HTML pages. This page is generally about PV fields performance analysis. Raspberry Pi is cheaper than other embedded hardware, and it is consuming less power also so for testing it is quite good. It has Ethernet connectivity also which is connected to world wide web through the router. In the market, many Embedded hardware is there but they all are too expensive compared to the Raspberry Pi, and many unnecessary features are there which user is never going to use also, so it's not worthy of buying this.

For dealing with the real-time data the Raspberry Pi is very useful as a device for collecting these data from the DPMN or various sensors. A web server is a good way to access that information, which can be call a dedicated network device. Ideally this is an identical product which is combination of hardware and software. To access this Raspberry Pi based web server remotely a static IP address

had been used otherwise if we use Dynamic IP (i.t. denoted by DHCP) we may not access the Pi every time after removing it from network because DHCP automatically allocate the Pi with a new IP address. A lightweight server (LAMP) had been configured with Raspberry Pi which will act as a web server.

B. ***Database Creation***

For an Intelligent monitoring system, an efficient database is required which will maintain all the parameters based on user requirements. Using of database system increases a lot of flexibility for operating a real application like a monitoring system. To records all the parameters from an installed PV field, a database had been created with the help of MySQL, which is a specific brand of server. And phpMyAdmin had been used as a server tool to access the database on MySQL servers. Two table had been created, one for registered user details and another for measured parameters. User table is interfaced with user-login web page and main analysis page is fetched with database parameters table. Fig. 6(b) shows the backend connectivity between database and user page.

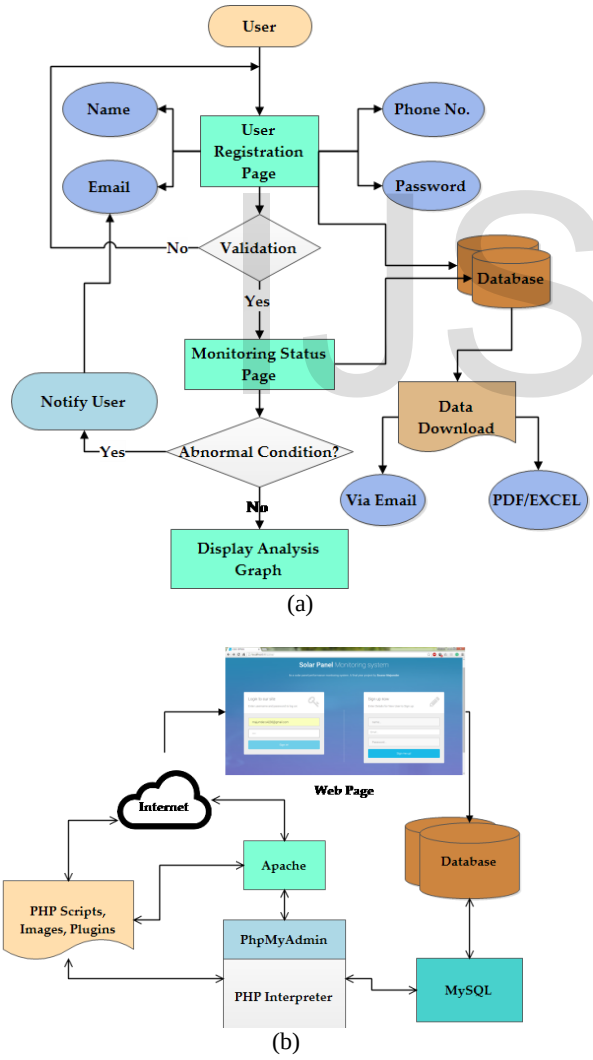



**Figure 6:** (a) Flow Chart of Functional Web Server, (b) Backend Connectivity between Database and Webpage

C. ***Web Page Development***

A webpage is a document or information about something which is written in Hypertext Mark-up Language (HTML), and accessible worldwide through the Internet by a specific URL address. A website is consisting of these type of web pages. For a dynamic connection between database and web page PHP script had been used [24,25]. It is a medium through which user can access the information, here for the PV field performance monitoring system several web pages had been developed which will show the status of a 600W PV field. Fig. 6(a) shows the functional web server flow chart of PV fields performance monitoring system.

D. ***DPMN to Web Page***

Connect a web page to the database several procedures need to be followed; here MySQL had been used as a relation database management system which is based on structured query language (SQL). MySQL is associated with several web-based platforms that use Linux as an operating system, as a web server Apache was used and for object oriented script PHP was used. Figure 4.20 shows the overall connectivity of database to a web page. Apache is an open source web server and now a day 60% of all websites on the internet are using it. A real time application like PV field monitoring system, a dynamic web application is required, so PHP had been used here for simultaneously update the database and fetching those data with several users at the same time. As a PHP interpreter, PhpMyAdmin tool had been used, and it is connected with the Apache-based server and MySQL in a bidirectional way. Apache web server is for hosting all hosted files, web pages, images and all data which are for online activity, client whoever seating in online can access these hosted files, information via IP address of the hosted web server [22].

## V. RESULT AND DISCUSSIONS

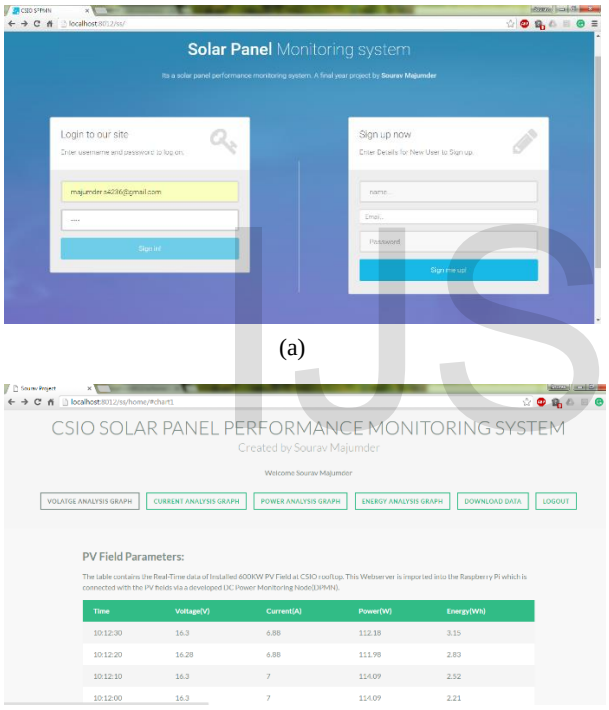
A DC powered room had been made in CSIO which is connected with a 600W PV field. This photovoltaic panels all are installed on the rooftop of CSIO. Total 8 numbers of 75W panels are connected in parallel-series connection. For testing purpose based on available load 4 panels were connected in parallel, and this power source is connected to the approximate 100W of the load in a room. This loads are connected with panels via a switch box and in series DC power monitoring node is connected to measure all the power and energy parameters. is for specification of the installed panel and PV array. Table 1 shows the specification of the installed setup.

**Table 1:** Specification of Installed Solar panels

| Parameters | 75W Solar Panel | 300W PV Field | 600W PV Field |
|---|---|---|---|
| Open Circuit Voltage ($V_{OC}$) | 21.5 V | 21.5 V | 43 V |
| Short Circuit Current ($I_{SC}$) | 4.8 A | 19.2 A | 19.2 A |
| Voltage at Maximum Power Point ($V_{mp}$) | 17.2 V | 17.2 V | 34.4 V |
| Current at Maximum Power Point ($I_{mp}$) | 4.36 A | 17.44 A | 17.44 A |

| | | | |
|---|---|---|---|
| Maximum Power ($P_{mp}$) | 75 W | 300 W | 600 W |
| Connection | - | Parallel | Parallel-Series |

Fig. 7 shows the developed registration page and PV field analysis page. For viewing the status of a monitoring system user have to register first, for that user need to know the IP address of web server which is connected to the fields. If the user types the address in their web browsers, the first page will be registration page which is consists of two form one for new users and another for the login of registered users. In this page user have to provide their Name, Email, Password and Contact number for the record purpose. Registered user gets the status via registered email if any error comes in the system. This is the first page of the web server if the user provides all the details correctly then only a status page will come otherwise it will show some error because PHP validation function had been attached to it.

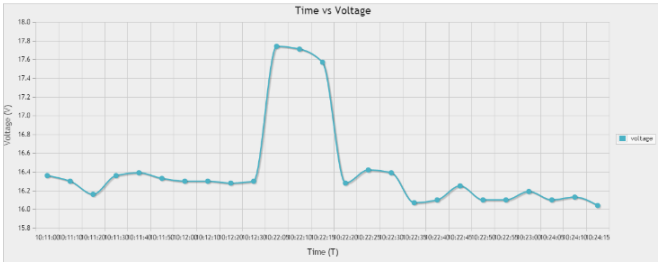



(a)

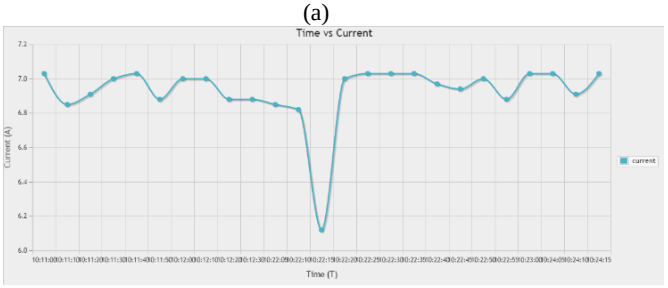
(b)

**Figure 7:** (a) User Registration Page, (b) PV Field Parameters Analysis Page

After successfully login user can access the main page, which is consists of data table and some real time analysis graph. Based on these figures, field owner can take the decision and if any error comes on these plots user can easily maintain the error if the action is minor. These figures will generate plots consistently by appending the data to it in continuous motion. Here JavaScript had been used for making these graphs and for plotting this graph dynamic web page was developed by PHP script [21,22]. Four individual analysis graph is implemented, these are Fig. 8(a) shows the time vs. measured voltage graph, Fig. 8(b) is regarding time vs. current graph, Fig. 8(c) is about time vs. power and Fig. 8(d) is for time vs. consumed energy graph. Suddenly the changes in the peak of all these graphs are because of due to the disconnecting and reconnecting the loads.




(a)

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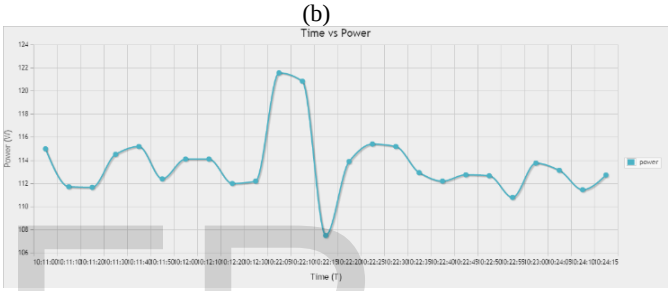


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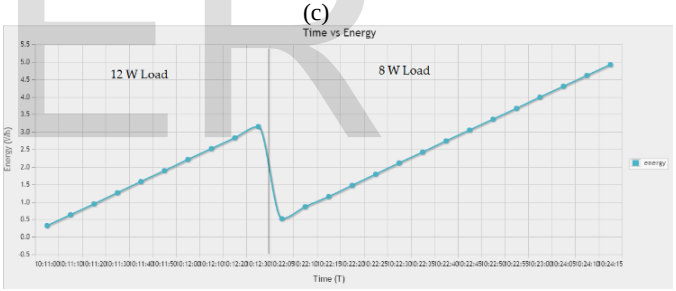


(d)

**Figure 8:** Web View of Analysis Graphs (a) Time Vs. Voltage, (b) Time Vs. Current, (c) Time Vs. Power, (d) Time Vs. Energy

## VI. Conclusion and Future Work

Solar PV field monitoring is thus identified as an important feature to be implemented in every PV farm. This could enable the user to identify faults and access the performance of the PV system from any remote location. During this project, a DC power monitoring node had been developed. The pre-developed panel parameter monitoring node (PPMN) continuously collects data from the real field and transfers it to the web interface. For collecting or analysis the data, a standalone web server hardware also developed to monitor the PV fields behaviour. If any abnormal behaviour occurs during the operation, the system sends an alert message to the registered user or owner for resolve the problem. Dynamic pages had been developed for updating the real time fields data into the database and projecting the analysis graph in online. This thesis described the development of a low cost and flexible PV monitoring system. The online monitoring station

developed relies on the measurements done by the DC power monitoring node which is connected with the PV field and no other additional hardware is required. The main advantages of the devised monitoring system are cost effective, flexible and potential for implementation in PV farms. Though it is more complicated to handle such real times data, here a web server had been developed which is very light weighted, and after every time stamp database getting updated and fetch those data to the web page automatically at the same time.

To adequately protect PV arrays from any hazards suitable technology must be developed to detect the exact fault of the systems which will show the fault location also. In this thesis, monitoring and error analysis of data part has been done, but several things need to add with it for making the system more accurate for a large PV system. Now everything is cloud based, so if the system synchronizes the data to the cloud which is called smart analysis database system it will be useful for the future purpose.

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