IoT Based Photo- Voltaic Monitoring System

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ABSTRACT

In this fast developing world, keeping track of the essential machines remotely via internet for the industrial and domestic appliance has become important. It estimates that due to industrial 4.0 revolution in 2020 more than 50 billion devices will be connected to the internet leading to the immense requirement of data storage, evaluation and analysis. A dependable remote checking strategy over the on-location technique is constantly alluring with the goal to track essentials and can happen as effectively as could be allowed. This project offers a remote monitoring and controlling system for observing voltage produced from a solar panel and power consumed by load through web-based monitoring to have genuine perception of essential electrical parameters of a running solar panel utilizing promptly accessible assets, which are easier to setup and keep up. Monitoring and controlling achieved using the internet at the remote end so that any protective measures taken in case of faults instantaneously without damaging the interconnected PV (Photovoltaic) system. In the execution of the web-based framework, diversity of sensors. For example, voltage and current sensors utilized to get some basic parameters to display an accurate result of the PV system on a HTML (Hypertext Markup Language) based webpage in ESP32. According to that, data user can control (ON-OFF) attached load to the system through internet over LAN (Local Area Network) as well as WAN (Wide Area Network) with port forwarding. All the data like load currents, battery and solar cell's output voltages and load state are updated on HTML webpage. In case of over current, system is applicable to shut down particular load, which is consuming more current.

Key Words: **Internet of Things, Solar Panel, Remote Monitoring System, Load switching, Sensors.**

1. INTRODUCTION

The renewable energy sources are primary energy alternatives, sunshine and the wind are part of everyday weather elements. Solar cell is the most advanced photon utilization technology in which photovoltaic effects of semiconductors are applied . This project proposes design for hardware as well as software integration of a photovoltaic system. The main objective is to measure various electrical parameters busing different sensors and the real-time data acquired and tracked over HTML based internet web page so that the required protective actions taken on time to prevent damage to the system. The project uses readily available sensors integrated with WiFi (Wireless Fidelity) communication module process together to achieve the task of monitoring at the remote end. The data is then sent to the LAN/WAN using TCP/IP (Transmission Control Protocol/ Internet Protocol) for monitoring on a HTML Web page (Fig.1). For the monitoring and controlling ESP32 as a main controller is used to transmit HTML data over internet through a gateway. ESP32 reads the input from the different analog sensors and represents it on the HTML Web page. It consists of various sensors and circuitry. Hardware and software integrated in this process to achieve the task based on the IoT (Internet of Things).

2. ELECTRICAL SYSTEM

2.1 Micro Controller

ESP32 is a flexible micro controller model that contains WiFi+Bluetooth+BLE and is very robust, flexible. This modules core is the ESP32-D0WDQ6 chip that contains ascendable, adjustable characteristics. The two CPU (Central Processing Unit) cores of this module separately monitored, managed and powered on. The range of its clock frequency is changeable from 80-240 MHz with the help of on board PLL (Phase Lock Loop).The user has the tendency to shut down the main Power/Supply of the CPU and use the low-powered processor to keep track of the condition of the external circuitry consistently and to know whether the analog values are exceeding their limitations or not. The ESP32s model: D0WDQ6 contains distinctive features such as two low-powered Xtensa 32 bit LX6 MCUs and it has built in WiFi (Access Point, Station, Access point and station) and Bluetooth [3].

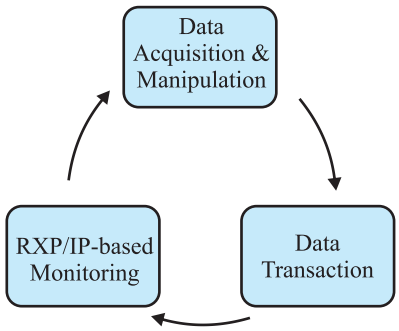

FIG. 1. PROCESS FLOW CHART

2.2 Voltage Sensor

Voltage sensor is just two resistors which are connected in series to work as voltage divider CPU. This configuration is used to measure 25 volts into 3.3 volts through 3.3V 12Bit ADC (Analog to Digital Converter) of ESP32 (Fig.2).

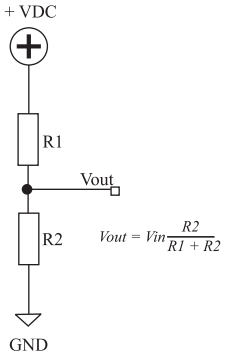

FIG. 2. VOLTAGE DIVIDER AS A VOLTAGE SENSOR
*R1 = 10K, R2 = 1.5K (VOUT = VIN * (R2/(R1+R2)))*

2.3 Current Sensor

The ACS712 is AC or DC current sensor that provides economical and precise solutions for industrial, commercial and communications system, it can be used for load detection and management switched-mode power supplies, motor control and over current fault protection (Fig. 3) [4] .

"Hall-Effect" principle used to convert current into voltages in ACS712. EMF produced as the current starts flowing through the wire then EMF converted by this sensor into voltage.

ACS712 is available in different variants like 5A, 20A and 30A. 20A variant used in this project and it is connected in series with electrical loads to measure current consumption of the load with ADC of the micro controller (Fig. 5).

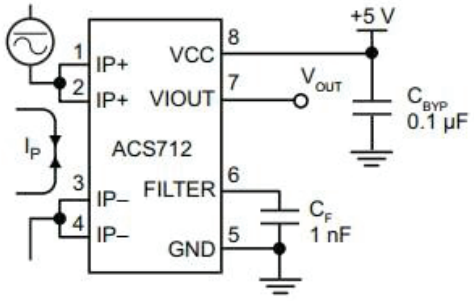

FIG. 3. CURRENT SENSOR ACS712

2.4 Photo-Voltaic Cell

Initially PV solar cells were thin silicon wafers that used to transform sunlight energy into electrical energy . These days the PV technology based on the principle of electron hole creation in each cell composes of two different layers (p-type and n-type materials) of a semiconductor material (Fig.4).

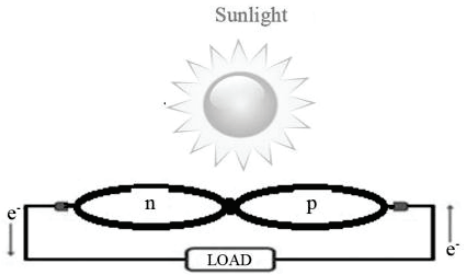

FIG. 4. THE P-N JUNCTION OF SOLAR CELL WITH THELOAD [3]

The core function of the solar panel in this research paper is to convert the solar radiations into electrical energy by means of PVs, which further used to charge the battery. Apart from the connection of the solar panel to the battery charger and also connected to a voltage sensor, which measures the reading of obtained voltages and read it with ESP32 to further monitor energy production.

3. IMPLEMENTATION

3.1 Hardware

The paper discusses about selection of sensors as well as design of sensor circuitry that used in project according to the feasibility, requirement, range and availability. Initial analysis and testing of sensors was done by ESP-32. Sensors data further integrated with firmware in ESP-32, which used calculations, formulas, and data manipulation techniques applied for scaling and desired output. The sensors include current sensor and voltage sensors (Fig.5).

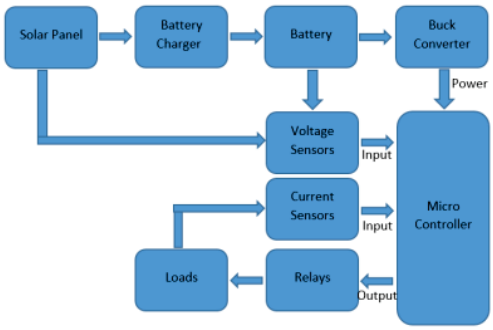

FIG. 5. BLOCK DIAGRAM SHOWS HOW THIS SYSTEM IS POWERED UP AND WORKING

In this system, there are two-voltage sensor one for monitoring solar panel's output voltage and second one for monitoring battery's voltage [7]. After the battery there is a buck converter which is used to step down voltages from 12-5V so the whole circuit can work properly. The max output voltages of ESP32's pins are 3.3V so to operate the relays that are operating the load connected. There are also some types of relay, which are

directly operate able with ESP32 like 3V SSR (Solid State Relays). After relay, there is a current sensor which is attached in series with load to measure the current (Fig.6).

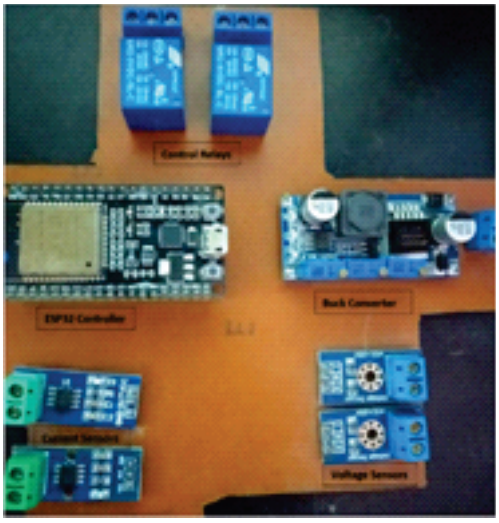

FIG. 6. HARDWARE PCB

3.2 Software

Main software algorithm given in Fig.7 in which micro controller initialize all required pins like analog input pins for voltage and current sensors and digital output pins (Relays). Micro controller's Wi-Fi in station mode and establish connection with Wi-Fi network to access Internet to send sensor data and receive appliance control command data through Internet on specified IP and port so client can easily access the web page [7].

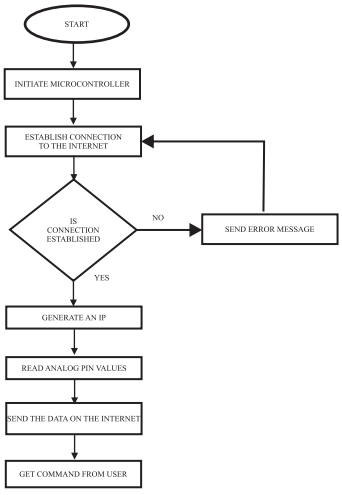

FIG. 7. ALGORITHM REPRESENTATION OF THE SYSTEM

When ESP32 connected to Wi-Fi modem then it will only be access able on LAN so to access it on WAN by the use of the phenomena called port forwarding. Port forwarding is a pure networking technique; it transmits all the incoming data to a specified port. It enables the ability of a device to send information to a specified gateway on the subnet mask of the router that can be accessed anywhere if the IP address and subnet mask of the known devices (Fig. 8). There is another way to access ESP32 over WAN there are some websites which provides online clouds for ESP32 like ThingSpeak, Ask Sensors, AWS (Amazon Web Services) IoTCloud and many more.

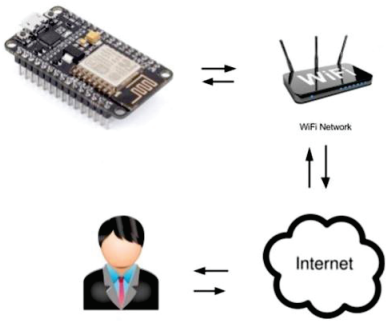

FIG. 8. CONNECTION WITH INTERNET AND USER.

4. TEST RESULT

The Testing cycle is very important for a project before release or any research done on it. Generally, a testing cycle is a trail, error, improve. Repeat scenario, where you repeatedly check your project (Fig. 9) So that no miscalculations can be found on the later stages. Once a project passes all the stages of trial and error it considered ready to research upon, and gladly our project has passed successfully through all the stages.

Initial testing of the web page over WAN (port 27016) (Fig. 9) and this test was without sensors so controller through random values over web page.

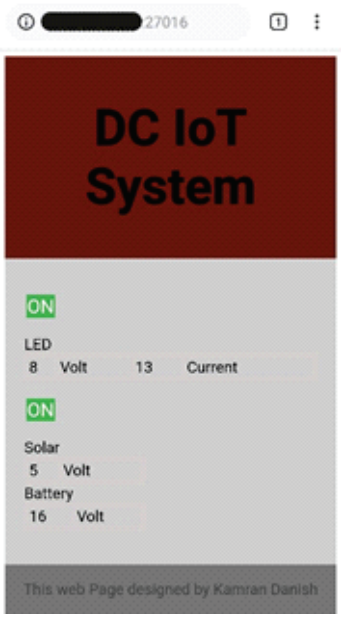

FIG. 9. HTML WEBPAGE ACCESSED ON SMART PHONE OVER WAN

Final result of the system which is displaying all the results and it can also control the appliances or equipment which are attached with hardware (Fig. 10) (Loads are off). Fig.10 also displaying battery and solar panel voltage on webpage.

FIG. 10. HTML WEB PAGE OVER WAN

5. CONCLUSION

This research based on monitoring and controlling DC electric appliances and voltage sources (battery and solar panel) through internet. Whole system depend on simple resistor based voltage divider as a voltage sensor, ACS712 as current sensor and low cost, locally available micro controller ESP32.

6. FUTURE WORK

In future, it could use to measure electric unit consumed by user and store data on cloud so user can easily see the graph of power or units consumed. It can also use to monitor AC power with small changes in the system hardware.

This system based on ESP32 that has built-in Bluetooth and WiFi hotspot or Access Point that can be used in areas where WiFi network is not available.

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REFERENCES

[1] Sen, Z., "Solar Energy in Progress and Future Research Trends", Department of Meteorology, Faculty of Aeronautics and Astrobautics, Istanbul Technical University Turkey; February, 2004.

[2] Kumar, P., and Pati, U.C., "IoT Based Monitoring and Control of Appliances for Smart Home", Proceedings of IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology, May, 2016.

[3] Espressif Systems, "ESP32 2.4 GHz Wi-Fi and Bluetooth Combo Chip", ESP32 Datasheet, May, 2017.

[4] Allegro, "Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor", ACS712 Datasheet, January, 2020 [AC712-DS, Rev.10]

[5] Kurde, A., and Kulkarni, V.S., "IOT Based Smart Power Metering", International Journal of Scientific & Research Publications, Volume 6, Issue 9, September, 2016.

[6] Sharma, S., Jain, K.K., and Sharma, A., "Solar Cells: In Research and Applications - A Review", Materials Sciences & Applications, Volume 6, No. 12, December, 2015.

[7] Altabatabaie, K.F., and Hama, K.D., "Remote Automation System Control Using Arduino Board", International Journal of Latest Trends in Engineering and Technology, Volume 8, Issue 3, pp. 161-167, June, 2017.

[8] Allafi , I., and Iqbal , T., "Design and Implementation of a Low Cost Web Server Using ESP32 for Real-Time Photovoltaic System Monitoring", IEEE Conference on Electrical Power & Energy, Saskatoon, Canada, February, 2018.

[9] Chandra, A.A., Lee, Y., Kim, B.M., Maeng, S.Y., Park, S.H., and Lee, S.R., "Review on Sensor Cloud and its Integration with Arduino Based Sensor Network", International Conference on Information Technology Convergence & Security, Macao, China, January, 2014.

[10] Kalaitzakis, K., Koutroulis, E., and Vlachos, V., "Development of a Data Acquisition System for Remote Monitoring of Renewable Energy System", Measurement, Volume 34, Issue 2, pp. 75-83, September, 3003.

[11] Roberts, J.R., Jimenez, C., and Ghosseiri, N., "Solar Energy, Engineering Experimentation Lab Report", December 2, 2004.

[12] Mwogeza, M., and Fragaki, K., "Feasibility Studyfor School Renewable Energy Supply", M.Sc. Thesis, New and Renewable Energy, Durham University, August, 2009.