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Monitoring and Control of Residential Roof Top Solar PV power plant through IoT

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Abstract--The objective of the proposed work is to collect, analyse and control number of parameters being measured from a residential rooftop solar photo voltaic (PV) power plant and to intimate its performance to the user with the help of arduino and raspberry pi. In order to ensure the stable and reliable operation of a PV system an effective monitoring system is most vital. The monitoring system has to keep track over various indices and fault occurrences. Major aspects of a PV monitoring system are sensors and their working principle, certain data acquisition system and, transmission methods and its storage. Sensors such as Light Dependent Resistor (LDR), Thermistor and Gravity Tilt Module are used to track data from the solar panel and connected to arduino for buffering. Then, data obtained continuously from the solar panel will be transmitted to raspberry pi after arduino. User friendly information is transmitted with the help of raspberry pi. If user desires he can control the PV system via Wi-Fi module in the raspberry pi or through Internet of Things (IoT).

Keywords—photovoltaics (PV), Light Dependent Resistor (LDR), Raspberry Pi, Internet of Things (IoT).

1. Introduction:

Solar power generation is now accepted and growing in our world electricity markets; and it continues to mature both commercially and residentially. As matter of reality, many new solar energy conversion systems have included monitoring function as a integral part of the system to ensure data collection and analysis in systematic matter. Photo voltaic converters are the semi-conductor devices which convert, the part of incidence solar irradiance directly into electrical energy. The most popular photo voltaic converters are thin films and crystalline silicon (Monocrystalline / Polycrystalline). Between these two converters, crystalline solar cell is mostly used for commercial and residential use. Based on the working operation PV system can be functioned in four ways such as: Grid connected PV system, Grid tied with battery backup system, hybrid system and standalone system.

Standalone solar PV systems are also called off-grid PV system. They had their applications in rural household power supply, power supply for communication and lighting and rural central power plants.

For such a system data acquainting continuously is a major problem. In order to find solution for this, Data acquisition systems (DAQs) based on LabVIEW has been implemented for collecting and displaying the electrical parameters of a standalone PV system. In addition to this, global solar radiation can also be calculated with the help of short circuit current [1]. A 11.2kW grid connected solar PV system which is tilted at an angle of 21^{o} on a 25 metre height building has been entirely monitored for different parameters such as PV module efficiency, array yield, final yield, inverter efficiency and performance ratio of a system [2]. Over a period of time, different aspects of PV monitoring systems were proposed and implemented in wide range of literature. A comprehensive review of such PV monitoring evaluation techniques were reviewed with their relative performance[3]. The advent of smart metering huge amount of data is becoming demand for automatic approaches that are robust to deal with controlling equipment. They proposed and introduce a combined method consisting of fitting algorithm and infrared thermography measurement. The results obtained are region specific irradiance characteristics [4]. Various PV monitoring systems are available nowadays in which, the large portion is done on classifications. For example, internet based monitoring can be done servers, GPRS, IP, TCP and so forth; data acquisition monitoring can be done using Power Line Communication (PLC), PIC, reference cell, DAQ of national instruments etc. Review of various monitoring topologies is discussed to get a clear view of both merits and demerits [5].

The performance of a 2.02kW off-grid residential solar PV power plant is predicted using PVSYST simulation software. Data is monitored continuously and its array capture and system losses are analysed for five tracking modes of solar panels; fixed tilted plane, seasonal tilt adjustment, dual axis tacking, horizontal axis tracking and vertical axis tracking. It is obtained that monthly performance ratio is better for fixed tilted plane and minimal for dual axis tracking system [6]. A Zig-bee based wireless monitoring system is developed for online monitoring of a solar PV power plant. Parameters such as PV power output irradiance and temperature are monitored. Auser friendly web application is also developed; through which monitored data can be easily accessible via internet to validate this requirement 1.25kW off-grid connected solar PV system has been considered [7]. Also some recent literature were studied [8]-[23]. This article is organized in such a way as follows:

Section 2: Block diagram
Section 3: Components Description
Section 4: Hardware setup
Section 5: Results and Discussion.

2. Block diagram:

The rated output power of the solar PV panel typically degrades at about 0.5% per year; those too thin film solar panels degrade faster than crystalline panels. As solar panels keeps on aging it might malfunction or increases air particulate matter, which has the effect on contaminating water reservoirs. If the malfunctioning of the solar panel is monitored, it might not lead to dangerous circumstances. Considering the worst case of very high temperature with low irradiance and with high deviating angle, the raspberry pi sends all the three corresponding messages to the user in random, based on the sensing time of the sensors.

Hence, to have information about the performance of a roof top solar power plant, we are using Light Dependent Resistor (LDR), Thermistor and Gravity Tilt Module.

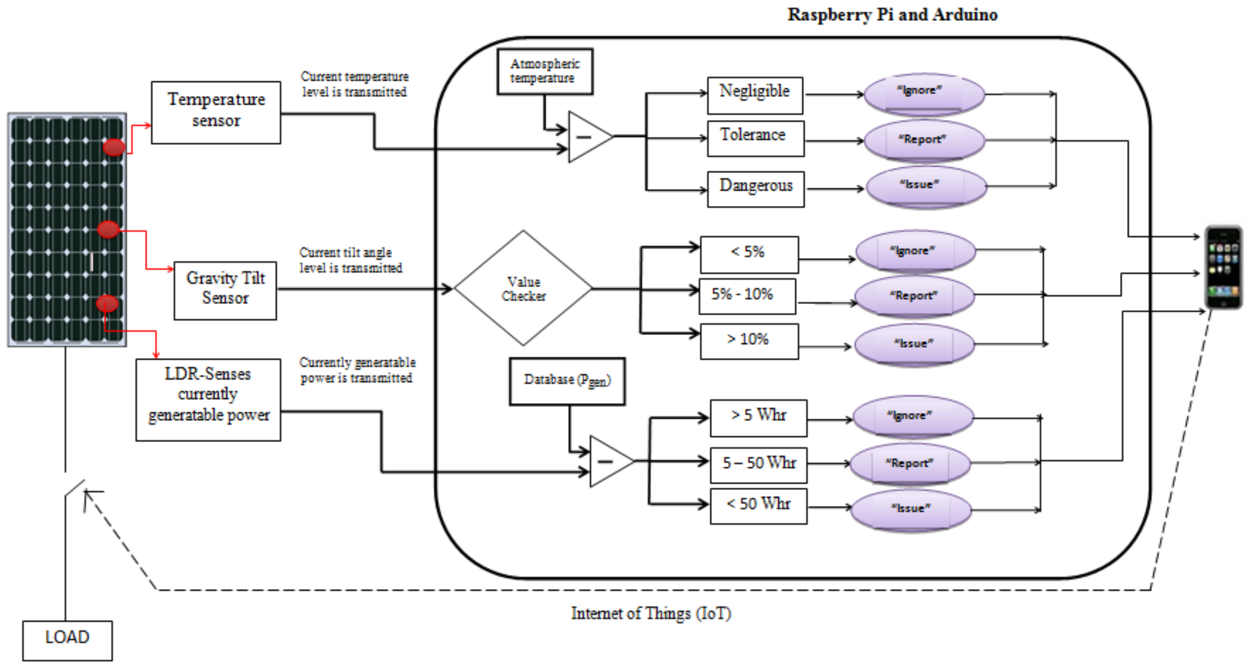


Fig. 1 Block diagram of monitor and control of the residential solar PV power plant

2.1. Temperature sensor (Thermistor):

The temperature of the solar panel is continuously sensed over a period of time and intimated to raspberry pi. On the other hand, atmospheric temperature is sensed and compared within raspberry pi and the difference level is checked for its limit within the category of ignores or report or issue. Based on the value the decision about sending the message to the user is being decided. If a user receivesreporting information, he need not to consider it; if he receives a notification intimating issue, he can disconnect the supply from the solar PV generated power supply and the load through Wi-Fi or IoT.

2.2. Light Dependent Resistor (LDR):

The incident solar irradiance on the solar panel is continuously sensed over a period of time and intimated to raspberry pi after calculating the generatable power with the help of arduino program. The average power generated is taken from the data base. The difference between the average power generated and the generatable power is calculated within the raspberry pi. Based on the percentage of difference value the decision about sending the message to the user is being decided. If a user receives reporting information, he need not to consider it; if he receives a notification intimating issue, he can disconnect the supply from the solar PV generated power supply and the load through Wi-Fi or IoT.

2.3. Gravity Tilt Module:

The angle of the solar panel is continuously sensed over a period of time and intimated to raspberry pi. The angle of deviation from the default angle to the currently sensed angle is calculated within the raspberry pi. The deviated angle is checked for its limit within the category of ignores or report or issue. Based on the value the decision about sending the message to the user is being decided. If a user receives reporting information, he need not to consider it; if he receives a notification intimating issue, he can disconnect the supply from the solar PV generated power supply and the load through Wi-Fi or IoT.

3. Components description:

3.1. Gravity Tilt Sensor:

This sensor acts as a digital tilt switch. The ADXL345 is a small, thin, low power, 3-axis MEMS accelerometer with high resolution (13-bit) measurement at up to +/-16 g. Digital output data is formatted as 16-bit two's complement and is accessible through either an SPI (3- or 4-wire) or I2C digital interface.

3.1.1. Operation:

The ADXL345 has special sensing abilities. The single and double tap sensing detects when a single, or two simultaneous, acceleration events occur. Activity and inactivity sensing detect the presence or lack of motion. Free-fall sensing compares the acceleration on all axes with the threshold value to know if the device is falling. All thresholds levels that trigger the activity, free-fall, and single tap or double tap events are user-set levels.

These functions can also be mapped to one of two interrupt output pins. An integrated, patent pending 32-level first in, first out (FIFO) buffer can be used to store data to minimize host processor intervention. The ADXL345 is well suited to measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion or shock. Its high resolution (4 mg/LSB) enables measurement of inclination changes less than 1.0°. Furthermore, low power modes enable intelligent motion-based power management with threshold sensing and active acceleration measurement at extremely low power dissipation.

3.1.2. Features:

- Supply Voltage : 2.0 - 3.6 VDC
- Ultra Low Power : As low as 23 uA in measurement mode, 0.1uA in standby mode at 2.5V
- Communication : SPI or I2C

3.2. Light Dependent Resistor (LDR) Sensor:

An LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits. The resistance of an LDR for Daylight is 5000Ω and for Dark is 20000000Ω.The output pin for digital output interface is DO, a small plate(0 and 1) and for analog output interface is AO, a small board.

3.2.1. Operation:

Photosensitive resistor module most sensitive to environmental light intensity is generally used to detect the ambient brightness and light intensity. Module light conditions or light intensity reach the set threshold; DO port output high, when the external ambient light intensity exceeds a set threshold, the module D0 output low. Digital output D0 directly connected to the MCU, and detects high or low TTL, thereby detecting ambient light intensity changes; Digital output module DO can directly drive the relay module, which can be composed of a photoelectric switch; Analog output module AO and AD modules can be connected through the AD converter, you can get a more accurate light intensity value.

3.2.2. Features:

- Operating voltage 3.3V-5V
- Can detect ambient brightness and light intensity
- Adjustable sensitivity (via blue digital potentiometer adjustment)
- Output Type
  - Analog voltage output -A0
  - Digital switching outputs (0 and 1) -D0
- With fixed bolt hole for easy installation
- Power indicator (red) and the digital switch output indicator (green)

3.3. Thermistor:

A thermistor is a type of resistor whose resistance is dependent on temperature, more so than in standard resistors. The thermistors are in the form of beads, rods and discs.

3.3.1. Operation:

The thermal resistance of the module is very sensitive to the ambient temperature, generally used to detect the ambient temperature. Through the adjustment of the potentiometer , we can change the temperature detection threshold (ie, temperature control value).If necessary to control the ambient temperature to 50 degrees , the module in the corresponding ambient temperature, DO output is HIGH level falls below the set temperature value, the output is high , the green light does not shine.DO output can be directlyconnected with the microcontroller through the microcontroller to detect high and low, thereby detecting the ambient temperature changes.DO outputs can directly drive the relay module , which can be composed of a thermostat to control the operating temperature of related equipment can also be connected to the fan used to heat and other. The detection range of the module's temperature 20-80 °C .This module can also be replaced with a wire temperature sensor for water temperature, water tank controlled.

3.3.2. Features:

- Working voltage : 3.3V-5V
- Driving ability : more than 15mA.
- Output format : Digital switching output (0 and 1)
- PCB size : 3.2cm x 1.4cm
- It provides good sensitivity

3.4. Raspberry Pi:

Raspberry Pi is a low-cost, credit-card sized computer that plugs to a computer monitor or TV, and uses standard keyboard and mouse. The Raspberry Pi is contained on a single circuit board. The computer runs entirely on open-source software. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python.

3.4.1. Operation:

An SD card is inserted into the slot on the board acts as the hard drive for the Raspberry Pi. It is powered by USB and the video output can be hooked up to a traditional RCA TV set, a more modern monitor, or even a TV using the HDMI port. This gives you all of the basic abilities of a normal computer. It also has an extremely low power consumption of about 3 watts

3.4.2. Features:

- SoC : Broadcom BCM2837
- CPU : 4× ARM Cortex-A53, 1.2GHz
- GPU : Broadcom VideoCore IV
- RAM : 1GB LPDDR2 (900 MHz)
- Networking : 10/100 Ethernet, 2.4GHz 802.11n wireless
- Bluetooth : Bluetooth 4.1 Classic, Bluetooth Low Energy
- Storage : microSD
- GPIO : 40-pin header and populated

3.5. Arduino:

The Arduino Uno is a open source microcontroller board based on the ATmega328 chip. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2Atmega8U2 up to version R2 programmed as a USB-to-serial converter. While the Arduino UNO can be powered via the USB connection or with an external power supply, the power source is selected automatically.

3.5.1. Operation:

Arduino's processor basically uses the Harvard architecture where the program code and program data have separate memory. It consists of two memories- Program memory and the data memory. The code is stored in the flash program memory, whereas the data is stored in the data memory. The Atmega328 has 32 KB of flash memory for storing code (of which 0.5 KB is used for the boot loader), 2 KB of SRAM and 1 KB of EEPROM and operates with a clock speed of 16MHz. Arduino Uno consists of 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

3.5.2. Features:

- Microcontroller : ATmega328.
- Operating Voltage : 5V.
- Input Voltage : 7-12V.
- Digital I/O Pins : 14 (of which 6 provide PWM output).
- Analog Input Pins : 6.
- DC Current : 40mA.
- Flash Memory : 32 KB.
- SRAM : 2 KB.
- EEPROM : 1 KB.
- Clock Speed : 16 MHz.

3.6. Relay:

A relay can be defined as a switch. Switches are generally used to close or open the circuit manually.Relay is also a switch that connects or disconnects two circuits. But instead of manual operation a relay is applied with electrical signal, which in turn connects or disconnects another circuit. According to the notification received, the user by self can trip the load from the solar panel manually or the load is tripped off from the panel automatically with the help of a relay. Thus, relay is an automatic switch which disconnects the load automatically at critical situations.

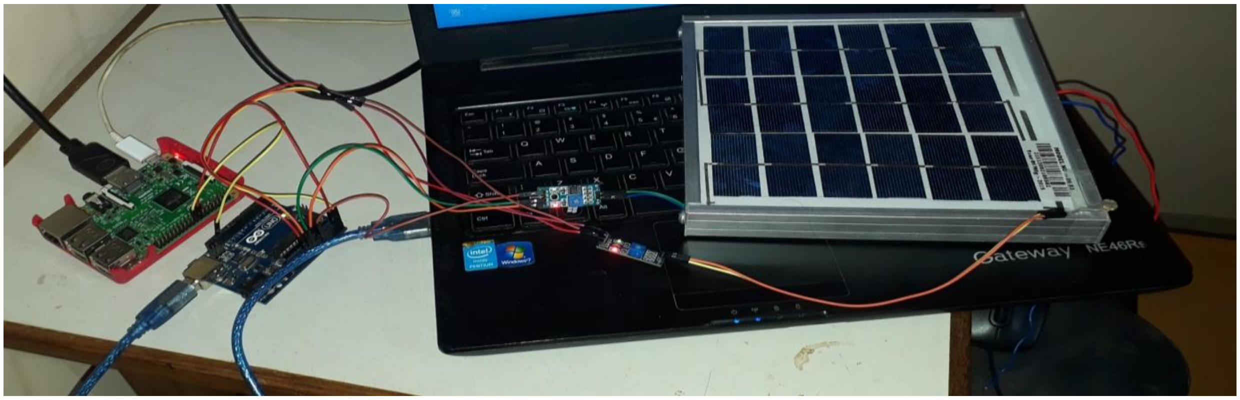
3.6.1. Operation:

Relay works on the principle of electromagnetic induction.When the electromagnet is applied with some current it induces a magnetic field around it. In the relay Copper coil and the iron core acts as electromagnet. When the coil is applied with DC current it starts attracting the contact. When the supply is removed it retrieves back to the original position.

3.6.2. Features:

- Control : DC or AC signals
- Load : AC 220V
- Driver current : 15 - 20mA
- Output Indication : LED
- PCB Size : 5 x 3.8 x 1.7cm

4. Hardware:



5. Results and discussion:

i. The temperature of the panel is sensed by the temperature sensor. If the read temperature exceeds 65^{o}, then the user receives the message as “Issue”. At the same time, the load is also cut off from the solar panel automatically using a relay.

ii. The lux value for the irradiance is read using lux meter. It is converted into irradiance by multiplying it by 0.0929. The maximum current generated is calculated and it is mapped with the irradiance. The generatable power is also calculated and this data is stored in the database. The current irradiance level is sensed using LDR (Light Dependent Resistor) sensor. The generated power is calculated from the irradiance level. Thus the difference of generated power and generatble power is calculated. If the difference is more, then the user receives “Issue” message.

iii. The gravity tilt angle sensor senses the angle of deviation from the default angle. The angle of deviation have the tolerance value of 10%, above which is intimated to the user as “Issue” message.

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