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Cloud-Based and Secure Smart Home Automation

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Abstract

Smart Home Automation System aims at implementation of automating a house that uses Wi-Fi technology as a network infrastructure connecting its parts to facilitate communication amongst the various devices and sensors to carry out automation of everyday activities. A cloud based web interface enables remote control of the system for manually overriding the automated functionalities. Unlike most available home automation systems in the market, this system is scalable where one server can manage many hardware interface modules(Sensors) as long as the system is connected to the internet. Authentication for users will be implemented, so that only authorised personnel will have access to the house as well as the control interface. The system includes safety features to ensure security. The system supports a wide range of home automation devices along with power management components and security components and aims to provide ease of operation in day to day tasks along with effective energy conservation.

Keywords *–arduino, renewable energy, machine learning, automation, sensors, security*

I. INTRODUCTION

With the increasing need of automation in day to day activities, a feasible solution to implement internet of things devices in home automation suitable for all types of households is not easily possible. This project proposes a solution for an energy efficient automation and ease of control over day to day operations. The automation functions are powered using a renewable energy source, solar power.[9] The involvement of technology enables the users to cut down on power costs by using the devices only when required through smart automation techniques. Taking advantage of the data received from the surroundings through sensors, the system optimizes the functioning of the devices to provide the best possible performance. The system with this specification gives an advantage to the user considering the security aspects of the house. Whether the user is present or not, he/she can control and monitor the status of the house with the help a cloud based and interactive web interface. In

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situations of distress, the system can efficiently detect the event and inform the user and respective authorities about the same.

II. GENERAL DESCRIPTION

A. Overview of the system

An energy efficient home automation system is proposed through this paper. This system is divided into three main components : the hardware interface module, the software communication module and a cloud based user interface module. At the centre of the system is a Arduino Mega 2560 microcontroller [3]. The microcontroller manages all the communication between the connected devices and sensors to implement the automation functionalities. The system provides various different functionalities such as temperature control using fan/air conditioning, automatic light using motion sensors. It also offers utility features such as retractable roofing using rain sensor and operations of garage door, curtains based on suitable sensors. Additionally, the system offers multiple security functionalities like laser trip wire, smoke and fire detection and user authentication using NFC. All of the established functionalities can be manually controlled using a dedicated cloud based web interface. The user can access the the system locally and remotely using a smartphone or a personal computer. The cloud based software system makes it possible to access the system control remotely without needing to have a static IP associated with is which is generally the limitation in case of most households. The integration of advanced software system and hardware modules makes it possible to easily include any additional devices in the system by user without having any technical knowledge of the same.The whole automation system is powered with the help of solar energy. The use of renewablesource of energy adds a sustainable aspect to the project and makes it energy efficient [9]. Home automation has become necessary as the users wish to experience convenience and ease in use of devices. These systems enables the users to have a control over all the major functionalities of the house at the touch of a finger using the smartphones.

B. Existing System

Most of the existing systems have the interface hosted locally on the Arduino module. This poses limitations to overall advancement of the system. Usually, the systems assume that the internet connectivity provided to the Arduino module has a static IP associated with it. However only a limited number of households have a static IP address while the majority of the houses have dynamic IP addresses associated.

III. PROPOSED SYSTEM

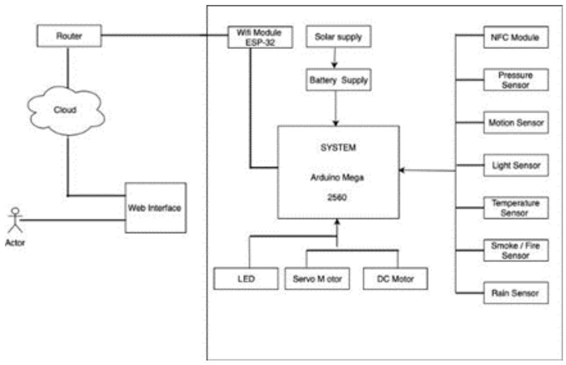

Fig. 1. Block Diagram

The system can function independently without any wired connections due to the use of microcontroller. Efficient use of energy is a very major concern in any developed system. Our proposed system is based on Arduino Mega 2560 microcontroller[3].A dedicated web interface is used to manually control all the functionalities. The system also focuses on security parameters and controlling energy loss by automating the functions according to usage. The surrounding information is recorded by different function-specific sensors to implement the functions accordingly. For authentication of user to enter the house premises, a NFC tag/card is required to be verified at the entrance of the premises. A NFC card reader is installed at the entrance for the user to authenticate [1]. Unless some person is inside the house, the entire system is switched off except the security system and if manually overriden. The illumination of the rooms in the house is governed by detection of motion using PIR (Passive InfraRed) sensors. The PIR motion sensor detects any motion in the room and turns on the light in the respective room. After a specific interval of time the light is switched off when the motion sensor detects that there is no motion. A temperature sensor is used to measure the ambient temperature and control the operation of the fan,AC to maintain a specific temperature range[1].The occurrence of rain is detected using the rain sensor and the retractable roof is used to cover the balcony/terrace so as to prevent any damage from water. The LDR records the light entering the house and controls the operation of the curtains as per the set threshold and specified time range. The garage door is operated using a pressure sensor to detect the presence of car and open the door whenever a car is present and close the door after a set period of time.

An important security feature based on machine learning principles is face recognition. For this KNN (K- Nearest Neighbours) algorithms is used. The algorithm and its supporting functionalities is uploaded on the Raspberry Pi microcontroller. WebCam is attached to the microcontroller which is used to capture the image of the person. When the user reached the front door of the house, the user is required to press a button which will activate the facial recognition system and will be able to get authenticated and enter the house upon authorization [18], [8]. The image captured using the webcam is loaded in the Raspberry Pi and is preprocessed to extract relevant facial features using Haar cascade classifier. Next, a pre-trained KNN classifier is run on the pre processed image which will give an output in binary which is used to authenticate or deauthenticate the user.

Additionally, anti burglary measures are kept in place to prevent any theft using a laser trip wire at all possible entry points in the house. After the house is set in secure mode or when no one is present in the house, a set of lasers are spread across the entry points. Whenever any of the laser is tripped, an alarm is sounded and the owner as well as police is notified using the cloud software.Along with trip wire alarms, PIR motion sensors have also been installed at entrances to detect any kind of suspicious motion in the house at odd hours as a measure to increase security [2], [15]. Furthermore, the system houses a smoke/fire detector which will again notify the owner and the fire department of the town. Most importantly the system ispowered using solar energy which means that it will not add to the electricity usage of the house. Also, a backup battery is in place in case of power failure which is rechargeable using the solar power as well as an external power supply.

IV. LITERATURE SURVEY

An architecture that provides various features for controlling and automating the devices in the house has been pro-posed.Features such as lights, fan, Air Conditioner(AC), Wi-Fi connectivity, Bluetooth connectivity have been included in the system. The NFC card reader has been installed at the entrance door for the user to swipe the card across which automatically controls the lock/unlock state of the door.The NFC card is programmable and in this case it is programmed to control the operations inside the house. Upon detection of suitable conditions through the sensors

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connected to the microcontroller, the functionalities of fan, lights, TV(Television), PC(Personal Computer) etc. can be controlled [1].

An automation to provide security features to the house has been implemented. The TI-CC3200 Launchpad board has been used as the base microcontroller for the implementation with an on-board Wi-Fi shield. The motion sensors detect the motion in the house and whenever a person is detected, the system alerts the user(owner) about the detected motion through an internet based calling feature which is achieved through the Wi-Fi connectivity to the internet facilities. The system depends on the user's discretion to judge whether the person is any intruder or a guest. Using the remote controls, the user can either sound the alarm (if it is an intruder) or switch the lights/fan/AC ON/OFF as per requirement (in case of a guest) [2].

An automation system has been depicted that can be controlled with any device that has access to the internet and also has learning capabilities for automation by means of pattern recognition. The system makes use of the Arduino Mega 2560 Microcontroller to send signals to all the appliances that are to be automated with the help of relay switches. It uses a number of sensors to collect data from around the house. This data can be monitored easily with the help of a web server which has been set up by using the ESP8266 Wi-Fi module. In addition to monitoring and controlling the house appliances, the system also has a pattern recognition aspect which records when the owner of the house is using the appliances and performs analysis on time of operation of different appliances and then automates them accordingly [3]

The system has been implemented for smart home automation which can be controlled using an android application as well as a local micro web server. The android application uses a bluetooth shield and the micro web server uses a Wi-fi shield for communication with the Arduino microcontroller. The android application has been built by using the Google-App Inventor Integrated Environment (IDE) and the Java Programming language whereas the web application has been built by using the Adobe Dreamweaver for the interface and PHP, Javascript and Ajax as the programming languages [4].

The system has been built by using Near field Communication (NFC) which can be used for a wide range of security-critical application such as payment or access control. Although such application require secured data transfer, the NFC protocol that are build on top of NFC , such as the NFC data exchange format (NDEF), only provide insufficient security measures. Therefore, implemented security solution are often application specific and to not follow well-establish standards. To facilitate NFC usage in the Internet Of Things (IOT) where millions of devices need to be secured ,an efficient and sufficiently secured NFC-based protocol needs to be developed [5].

A system consisting of using Arduino as a microcontroller in managing and implementing a smart home automation system has been developed. The system is server independent and the user can use a web browser, a smart phone or an IR remote control to control the operations of the devices included in the system. ESP8266 module is used to implement the connectivity mechanism between the devices. 4-channel relay is set in place to operate the actual devices in the home. The software of the system is an android application which requires the user to manually feed the IP address and port of the WiFi module to be able to interact with the system [6].

A system architecture for home automation using RaspBerry Pi as a microcontroller has been proposed. Multiple technologies have been used which involve multi touch smart phones, cloud networking and wireless communication to provide the user with the ability to control various home appliances. Apart from these, a hand help IR remote control is also available to control the devices in the home. The system proposes multiple security features which include fire and smoke detection and cameras for security purposes [7].

V. HARDWARE COMPONENTS

A. ARDUINO MEGA 2560

Fig. 2. Arduino Mega 2560

Arduino is an open source microcontroller platform. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs [4]. Arduino projects can be stand-alone, or they can communicate with software running on your computer. (e.g. Flash, Processin.) The Arduino Uno is interfaced with all the sensors that we are using in the project, the sensors provide the Arduino with input of specific type, upon receiving which the Arduino is programmed to execute a certain list of commands. The discussed modules provide the Arduino with different kind of Input received from different kind of sensor that are integrated with the device.

B. Raspberry Pi 3 Model B

Fig. 3. Raspberry Pi 3 Model B

The Raspberry Pi 3 Model B is the third generation Raspberry Pi. It is a credit-card sized single board computer can be used for many applications and supersedes the previous variants. It has a processor that is about 10 times more powerful than the first-generation Raspberry Pi. It also has wireless LAN and Bluetooth connectivity which makes it an ideal option for most project designs [7].

Raspberry Pi 3 - Model B Features and Technical Specifications :

- 1.2GHz Quad-Core ARM Cortex-A53
- 1GB RAM : helps to run larger and more powerful applications
- 64 Bit CPU
- 4 pole Stereo output and Composite video port
- Full size HDMI
- CSI camera port for connecting the Raspberry Pi camera

• DSI display port for connecting the Raspberry Pi touch screen display

• Micro SD port for data storage

• Micro USB power source

• 40pin extended GPIO to enhance your "real world" project

C. Motor Driver

Fig. 4. L293D Motor Driver

This is a motor driver IC that can drive two motor simultaneously. L293D IC is a dual H-bridge motor driver IC. One H-bridge is capable to drive a dc motor in bidirectional. L293D IC is a current enhancing IC as the output from the sensor is not able to drive motors itself so L293D is used for this purpose. L293D is a 16 pin Dual H-bridge Motor Driver integrated circuit(IC). The L293D uses 5V for its own power and external power source is needed to drive the motors, which can be up to 36V and draw up to 600mA.

D. Sensors

1. PN532 NFC RFID module

Fig. 5. PN532 NFC RFID module

NFC refers to Near Field Communication. It is a set of standards for devices such as a smartphone or NFC card to establish radio communication which is achieved by touching them together or bringing them in close proximity. This is a short range wireless communication which enables non-contact-point data transfer between the devices [1], [5]. The system uses this module in SPI mode.It is installed at the entrance for the user to authenticate himself/herself.The user can just bring the card close to the NFC module to get himself/herself authenticated.

2. PIR (Passive Infrared) Sensor

Fig. 6. PIR Sensor

The PIR sensor houses a pyro-electric sensor which is covered by a dome-shaped Fresnel lens. The delay and sensitivity of the sensor can be adjusted using the potentiometers available at the base of the sensor. When the presence of a human body is detected in the sensor's range, it provides output 'HIGH' and when no human body is detected, output 'LOW' is given out. This principle is used in the system to detect the presence of a person in the rooms to turn the lights ON/OFF in the respective rooms to optimize the usage and save energy whenever the room is not in use.

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3. LM35 Temperature Sensor

Fig. 7. LM35 Temperature Sensor

The output voltage of LM35 sensor is directly proportional to the temperature (in °Celsius). External calibration is not required for the sensor. The sensor gives precise values with minimum error difference. The sensor is used to measure temperature in the rooms and the operation of the fan/AC is controlled to maintain the temperature in the specified range. As the ambient temperature crosses the threshold, the fan/AC is switched ON and is switched OFF when the temperature returns to the desired temperature range. The system uses the power to drive these devices only when required which helps to save energy.

4. Raindrop Sensor Module

Fig. 8. Raindrop Sensor Module

The sensor has two parts which are separate, the rain board and the control board. A power indicator LED and a potentiometer (to adjust sensitivity) are also available on the board. When the rainwater is collected on the board, paths of parallel resistance are created which are measured via the op amp. More water leads to more resistance and ultimately lower voltage output. Less water or no water shows highest output (5V). The presence of rain is detected by the system using this sensor and the retractable roof is expanded as per the conditions to cover the terrace/balcony area.

5. LDR Light Sensor Module

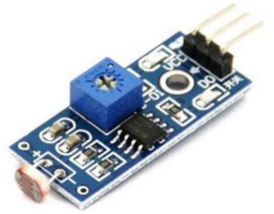

Fig. 9. LDR Light Sensor

The LDR (Light Dependent Resistor) Light Sensor is used to detect or measure ambient light intensity of the surrounding. The sensor gives 'HIGH' output when the light is present and 'LOW' in absence of light. The potentiometer available on the sensor can be used to adjust the sensitivity of the sensor. The intensity of ambient light present inside the house is measured by the sensor. The system controls the status of curtains (closed/open) to optimize the intensity of light entering the house. During specified hours (for example. afternoon hours), the system automatically controls the curtains. This results in a controlled amount of light in the house for a comfortable illumination.

6. Pressure Sensor (Force Sensitive sensor)

Fig. 10. Pressure Sensor

The pressure sensor is used to measure the force exerted on the sensor. It works on the principle that harder the force, lower will be the resistance. This sensor is used by the system to determine whenever a car has approached the garage and when it does, the system automatically opens the garage door for the user to enter and park the car and after a defined time delay, the garage door automatically closes.

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7. Laser Module and Receiver

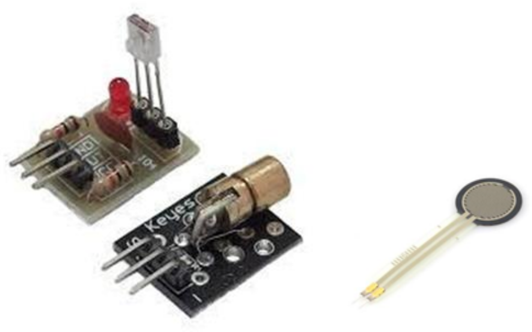

Fig. 11. Laser Module and Receiver

The KY-008 Laser module is used to emit a laser beam, the detector senses the presence of laser and gives digital output.

This module is used to detect the tripping of the beam for theft detection and sound the alarm.

VI. SOFTWARE DESCRIPTION

The software used for the system is divided into two components. The software code run on the Arduino board being the first one and the cloud based application platform being the second one. Arduino Studio is being used for implementing the logic of the system and managing their operation. This code is directly uploaded into the Arduino board which acts as a mediator between the sensors, devices and the user interface hosted on the cloud. All the automation features of each sensors are individually fed into the board. These include automatic lighting, temperature control and security features.

An ESP32 WiFi module is connected to the Arduino to interface with the cloud platform. The ESP32 module hosts a local web server which will serve as an API (Applicaton Programming Interface) to the cloud interface. The API will contain options for manually overriding each functionality and also to change settings involving security. The local web server will periodicallly ping the cloud platform to listen for any remote requests.

The cloud platform is a web application which can be accessed remotely using any smart devices including personal computers and smart phones. Authentication using username and password is required to access the functionalities of the cloud platform and interact with the system. Users can operate the entire system manually from the platform remotely as well as locally. Using the platform, the owner of the system can add or remove any user from accessing the system as well as add or remove any NFC card authorization.When the theft detection system is activated, the cloud platform will be notified first if any security intrusion is detected or an alarm is set off. It will then perform any necessary actions as instructed by the owner. Additionally, functionalities to be able to add or remove faces for authorisation is provided in the user interface. The platform will train the model for the new face and upload it into the RaspBerry Pi device database. The official IDLE 3 is used to write the program for face recognition in Raspberry Pi board. The user needs to login using valid credentials on the web interface.

Fig. 12. shows the login page of the web interface which includes two fields, username and password. The authorised users can login using their respective credentials. Fig. 13. shows the control interface which includes the devices and respective control switches.

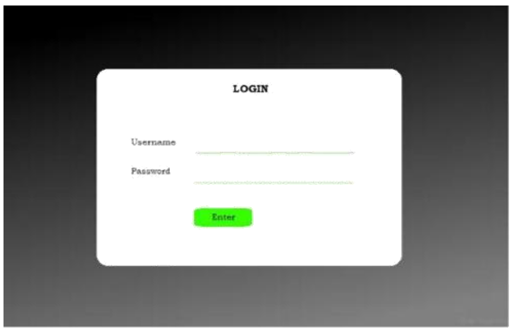

Fig. 12. Login UI

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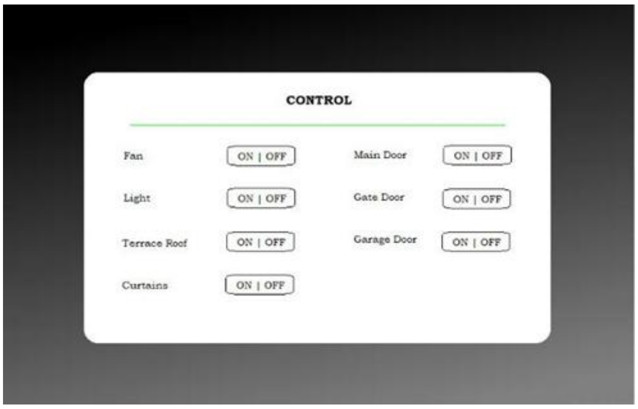

Fig. 13. Control UI

VII. HARDWAREIMPLEMENTATION

A. IoT devices and sensors for automation:

A prototype model depicting the complete home automation system is built with the help of various IoT devices and sensors such as temperature sensor (LM35), pressure sensor, light sensor (LDR), smoke/ fire sensor, ultrasonic sensor, NFC/RFID reader, rain sensor, motion sensor etc. These sensors are connected to the Arduino Mega 2560 micro-controller and have been installed at various places in the prototype model according to their functioning with respect to the automation.

The NFC/RFID module is installed at the entrance of the premises for protected entry only to authorized users i.e. the owners of the house. For authorization purpose an NFC chip has been used which contains a particular Hex value. This hex value is used for authorization of a person entering the house. If the hex value matches with the value associated to an owner's card then only the person will be granted entry to the premises. For additional security and authorization, a face recognition system has been set up at the entrance of the house with the help of Raspberry Pi 3b computer. The Raspberry Pi system makes use of the haar cascade algorithm to detect faces of the owners and then sends a signal to the Arduino to open the main door to the house if the face matches.The model has been trained for face detection and its precision improves with each cycle of training.A camera has been connected to the Raspberry Pi computer to capture faces that will be matched with the ones in the database to carry out the recognition process.The precision of recognition also improves everytime a face is successfully identified.

A pressure sensor has been installed at a suitable distance in front of the garage door. It is a force sensitive pressure sensor that will recognize that a car is standing right in front of the door. When the force parameter is met, the garage door will automatically open for the car that is to be parked inside the garage. A temperature sensor has been installed to monitor the surrounding temperature and automate the fan to maintain the temperature inside the house. If the temperature goes above a particular threshold then the fan will automatically turn on. A smoke/fire sensor has been installed to detect fire emergencies. The owner of the house will be notified immediately in case of a fire. In case of real-life implementation these are mostlyinstalled in the kitchen as kitchen is the area where a fire or a fire like event is most likely to happen. A light sensor has been installed at appropriate places in the prototype so that it can sense the amount of light entering the house. If the illumination is below the set threshold, then the curtains of the room will open automatically so that the proper amount of light enters the house. The rain sensor will detect rainfall and the automated roof will slide over the terrace to protect it from the rain. The motion sensor has been installed for two purposes i.e. automation of lights and intrusion detection in the house. For automatic lights, PIR motion sensors have been installed in at proper places in the house where it will detect motion whenever lights are required to be turned on. Moreover, motion sensors have also been installed at entrances in the house for

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intrusion detection against any attempt of theft, burglary or breach. Also,foradditional security trip wire alarms have been set up using the laser sensor module at all possible entrances.With the help of these security features, any attempt to breach the house can be easily detected and the authorities can be informed immediately. All mechanical tasks such as opening of doors and sliding the roof will be performed with the help of multiple DC and servo motors. These motors will receive signals to perform the tasks from the Arduino micro-controller. Each and every device has been connected to the Arduino mega micro-controller with their corresponding digital or analog pins via jumper cables in the prototype model. The prototype model can work without relay modules but a life size automation of this scale cannot work without the use of relay modules. The Arduino board has been connected to a Wi-fi module (ESP32) which will receive responses from a cloud based interactive web interface for manually controlling all the hardware implementation.

B. Solar power integration (Powering the Arduino with solar energy)

Fig. 14. Solar Module

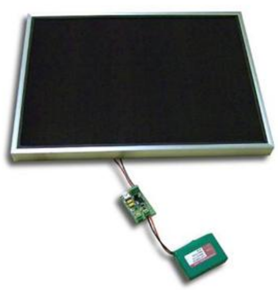

Fig. 15. Solar Setup

Solar is a form of renewable and sustainable energy. Use of solar panels to power the Arduino system adds an aspect of energy efficiency to the project[9]. The world is in dire need of saving energy and hence making use of sustainable energy is always beneficial. [20]

The following components are required for the solar setup:

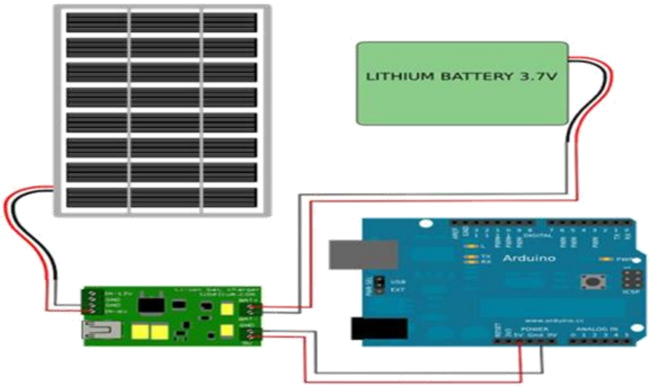

Fig. 16. Solar Circuit Diagram

1) Solar module for Arduino

2) Li-ion rechargeable battery

3) Solar panel

The solar module for Arduino is a board that acts as a charger for the Li-ion battery and a DC to DC converter that supplies the 5 volts required by the Arduino. This module has been used for the solar setup. It has connectors for the battery input, the converted 5V DC output, two solar panel connectors (6V and 12 V) and a mini-USB port for charging the battery with any external power supply if required. The module also consists of a charger IC in order to drive the charging current into the rechargeable battery. The charger IC is capable of producing a 280mA output charging current to the battery and a voltage of about 4.2V. There is also a converter IC to provide the 5V output and a number of capacitors as preventive measures against noise. The connections for the setup are fairly simple and straightforward. The battery is connected to the battery input of the solar

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module and 5V output is connected to the Arduino VCC and GND. A solar panel consisting of 6V cells is suitable for accumulating enough energy to recharge the battery. The 6V solar panel is connected to the corresponding 6V input connector on the solar board. With this setup and enough exposure to sunlight, the solar panel is capable of charging the battery which is used to power the Arduino micro-controller and all the sensors connected to it via the solar module.

C. RESULTS AND CALCULATIONS

The characteristics of output power of a solar power are calculated when kept static at a fixed angle.

Fill Factor :

$FF=(V_{mp} * I_{mp})/(V_{oc} * I_{sc})$ (1)

The fill factor is a measure used to determine the quality of the solar cell. It is calculated by comparing the maximum power and the theoretical power as an output at the open circuit voltage and short circuit current together.

$$Pmax = V_{oc} * I_{sc} *FF \quad (2)$$

The maximum power output obtained from the photo-voltaic cell can be calculated using equation(2).

$$n= (V_{oc}* I_{sc} *FF) /P_{in} (3)$$

Maximum possible efficiency of the solar panel at a given fill factor is calculated using equation (3).

Where,

FF - Fill factor

V_{oc} -Opencircuitvoltage

I_{sc}- Shortcircuitvoltage

n-Efficiency

V_{oc}= 11.23V

I_{sc} = 0.38A
V_{oc} * Isc = VA
V_{mp} = 9.22V
Imp = 0.33A
FF=0.712
Pmax = 3.04
n = 30.4 Percent

Battery Specifications :

Type : Li-ion

Capacity : 2600 mAh

Voltage : 3.7V

Assuming an average of 10W power is required to recharge the battery,5 hours will be required to charge the battery using the solar panel.

VIII. CONCLUSION

In this project, a low cost and energy efficient smart home automation system using Arduino and cloud-based user interface is proposed and implemented. The architecture uses a cloud-based web server for remote access as well as a local web server to act as API which uses Wi-Fi 802.11n standard as a medium of communication. Any smart device with the capabilities to access internet can be used to access the user interface. Solar panels are placed at suitable locations to utilize the unconventional source of energy from the sun to power the rechargeable batteries and run the system.

LIST OF FIGURES

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IX. FUTURE SCOPE

Internet of things has immense applications. We plan to scale up the use of solar energy supply to power all the devices in addition to the currently powered board. The machine learning model can be used to recognize the patters of the use of devices by the user to learn and apply those for providing a more personalized user experience.

X. ACKNOWLEDGMENT

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