Smart-Home Automation using IoT-based Sensing and Monitoring Platform

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***Abstract*—In order to help maintain comfortable living conditions within a home, home monitoring and automation are utilized. The standards of human's comfort in homes can be categorized into several types. Among these categories, the most significant ones are the thermal comfort, which is related to temperature and humidity, followed by the visual comfort, related to colors and light, and hygienic comfort, associated with air quality. A system can be set to monitor these parameters to help maintain them within an acceptable range. Additionally, making the house smart is to allow for intelligent automatic executing of several commands after analyzing the collected data. Automation can be accomplished by using the Internet of Things (IoT). This gives the inhabitant accesses to certain data in the house and the ability to control some parameters remotely. This paper presents the complete design of an IoT based sensing and monitoring system for smart home automation. The proposed design uses the EmonCMS platform for collecting and visualizing monitored data and remote controlling of home appliances and devices. The selected platform is very flexible and user-friendly. The sensing of different variables inside the house is conducted using the NodeMCU-ESP8266 microcontroller board, which allows real-time data sensing, processing and uploading/downloading to/from the EmonCMS cloud server.**

Keywords- IoT (Internet of Things), Home Automation System, Sensors Nodes, EMONCMS, Smart Home

I. INTRODUCTION

Developing energy efficiency and renewable energy technologies is becoming a priority and increasing the interest for many countries around the world. Universities have been involved in this technological development through student competitions, which aim at enhancing student awareness. Solar Decathlon is one these competitions which have been running in the United States and other countries around the world. The Solar Decathlon Middle East (SDME) is a newly established competition in the Middle East region that is intended to take place in Dubai in 2018. Qatar University's entry to the SDME 2018 competition has enabled it to form a multidisciplinary of students who will collaborate in the design and construction of a green, smart, portable and affordable solar house. An energy efficient house that is fully monitored and automated using the internet of things (IoT) technologies.

The increase in the popularity of IoT has widely spread to simple in-home applications and everyday tasks. The employment of IoT in homes is for the purpose of energy monitoring and saving while achieving and maintaining a certain level of comfort. Home automation systems using IoT consists of three major parts as shown in Fig. 1. The first part is the sensing and data acquisition part. This is done by placing sensors or devices, also called things, at several locations throughout the home to measure and gather desired information such as temperature, humidity, or lux.

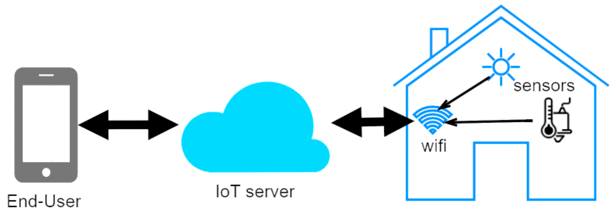

Fig. 1. IoT home monitoring system illustrative diagram

The second part of the system is the data processing. Sensors provide data in raw form. These data are sent to the processor through a mode of transmission, wired connection or wireless. The processor then translates the data into comprehensible values [1]. These values are transmitted to a device to be controlled automatically and/or to a user interface. The last part of IoT automation is the internet. Most systems use a server to upload data after processing, so it can be accessed by the user. The internet also helps to monitor data and manually control devices remotely [2]. By automatically executing several commands, automation systems can help to save time, provide a better quality of life in homes, and save energy.

This paper presents and discusses the design of an IoT-based smart solar house electrical system, using one or more options out of several available methods. The paper is organized into five sections: section 2 presents a short literature review on IoT systems used for home automation; section 3 describes the design methodology; section 4 presents the testing and results; section 5 concludes the paper.

II. LITERATURE REVIEW

This section reviews the typical configuration of home automation system using an IoT platform. Fig. 1Fig. 2 illustrates such a platform which consists mainly of data sensing and acquisition, processing, transmission, and display.

A. Data Sensing and Acquisition

As shown in Fig. 3, to ensure a good comfort level, the typically monitored parameters in houses are temperature, humidity, luminosity, and air quality (i.e. CO_2 and dust levels) [3].

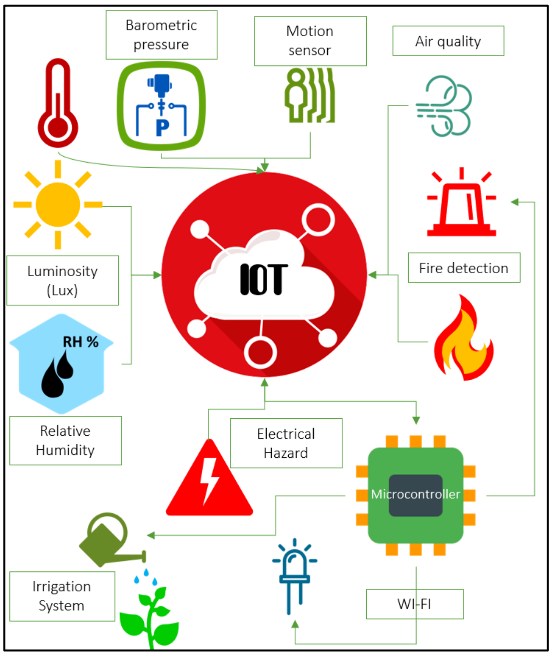

Fig. 2. Typical configuration of a home automation system using the IoT platform

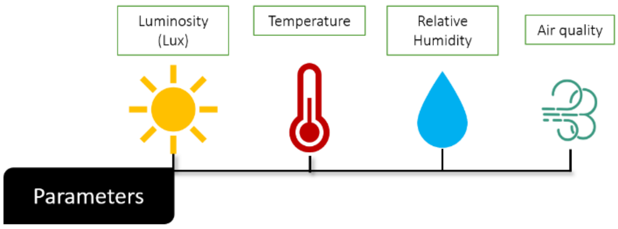

Fig. 3. Measured Parameters in the proposed monitoring system

Usually, the term "Big Data" is often associated with IoT and refers to the large number data collected from a large number of sensors and devices to be processed, which is the case here. In fact, depending on the number of sensors and the measurement-sampling rate, a large number of data might be generated and transmitted through the internet to the cloud server, which should be able to handle such large amount of data communication and archiving.

B. Data Transmission

Transmitting data between devices and controllers is done using one or more communication technologies. These include Bluetooth, ZigBee, Wi-fi, Ethernet or GSM. Bluetooth and ZigBee are commonly used for in-home data transmission and control and provide the link between the sensors and the central processing unit. These data communication technologies are popular because of their low power consumption, and simplicity to implement [4][5]. Furthermore, IoT requires the use of either Wi-fi or Ethernet to connect to the internet. While Ethernet is by far faster than Wi-fi connection, the high data rate is not essential for home automation applications. Additionally, Wi-fi has the advantage of mobility, making it more widespread in most systems. Wi-fi technology consumes more energy than alternatives such as Bluetooth or ZigBee. The power consumption can be reduced by lowering the frequency of data uploading.

C. Data Processing (Microcontroller)

The data collected in a home automation system is usually processed and managed by a microcontroller such as Arduino, Raspberry Pi, and NodeMCU. Raspberry Pi is a small single microcontroller computer. With a higher RAM of 256MB or 512Mb, depending on the model, it can handle more complex tasks than other controllers and used mostly as a central processing unit for multiple devices. Most new models of Raspberry Pi have USB and Ethernet ports, making it easy to upload data to the internet [1][2].

On the other hand, Arduino is a single-board microcontroller that can be simply programmed to execute commands. Arduino comes in a variety of models with onboard flash memory ranging from 32kB to 512kB, and a typically a RAM of 2kB. Evidently, this controller is less powerful than the Raspberry Pi. However, most Arduino models are cheaper, easier to handle, and powerful enough to deal with home automation tasks.

Another option is to use the NodeMCU. It is an Arduino based microcontroller but with the addition of the ESP8266 Wi-Fi chipset. This microcontroller has a memory of 128kB and a 4MB storage. It is mostly used for a single IoT application, or to eliminate the need for a central processing unit. Since each part of the system can upload data to the server individually, this also lowers the complexity of the coding and the connection chain [6]. The biggest advantage of the NodeMCU over the other alternatives is the significantly low price for a controller that can connect to the internet directly using Wi-fi, without the need for any additional peripherals of modules. An issue is that the NodeMCU board has only one analog input, which limits its applications to as single data monitoring system. However, this drawback can be compensated for by using the ASD115, which is an analog to digital converter that has four analog input pins and has a higher conversion resolution of 16-bits.

D. Data Display & User Interface

The interaction between the user and the system can be done in several ways. One option is to use an application. There are many simple means to create a mobile or a web-based app to display data, even with a limited knowledge of programming. Another control option is through mobile GSM where the user can send commands in codes by SMS to the microcontroller. This control method requires a special GSM module added to the circuit. This method can also be applied using emails [7].

III. Proposed Solar House Monitoring System Design

As mentioned earlier, the monitored parameters in homes are selected to ensure a smart, efficient and comfortable living conditions. Therefore, one hub is made to measure temperature, humidity, light intensity, proximity, and CO_2 levels. This hub can be placed in each room of the house, and preferably at a high level above the ground and below the ceiling. Collected data can be processed and used to control smart devices such as smart LEDs and A/Cs.

The schematics of the proposed design configuration is shown in Fig. 4. It comprises mainly sensors, processor, user interface, and data communication and transmission links.

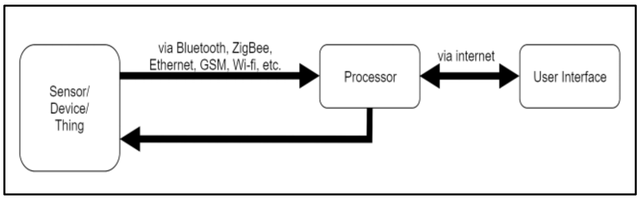

Fig. 4. Schematic of proposed home automation system using IoT

A. Sensors

The design began with the temperature and humidity sensors. The LM35 temperature sensor was selected for temperature sensing and the HIH4000 for humidity sensing. The reason behind these selections was their smaller sizes compared with the other sensors such as DHT22, as well as their lower prices.

The LM35 temperature sensor schematic connection diagram is shown in Fig. 5. There is a linear relationship between the output voltage and the sensed temperature in centigrade.

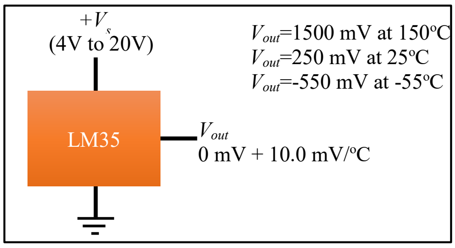

Fig. 5. Basic connection diagram of centigrade LM35 temperature sensor (+2ºC to +150ºC)

The connection and circuit diagram of the humidity sensor is shown in Fig. 6. The output voltage is connected to the analog input of the microcontroller.

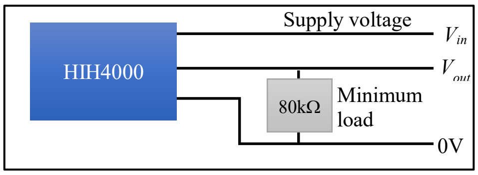

Fig. 6. Humidity sensor connection diagram

There a linear relationship between the output voltage and the actual humidity of the atmosphere. These are related by (1), which is retrieved from the datasheet of the sensor.

$$V_{out} = (0.0062 * Humidity_{relative} + 0.16)V_{in} \qquad (1)$$

This sensor has a good measurement range that is suitable for the home environment.

For the room luminosity measurement, a Light Dependent Resistor (LDR) is used. Compared to other alternatives such as the photodiode, the LDR is smaller and cheaper. As can be seen in Fig. 7, the output voltage is obtained using voltage division and then converted directly into lux.

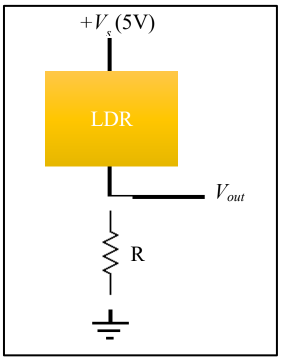

Fig. 7. Basic connection diagram LDR

the value of the resistor is chosen to be 5kΩ and the relation between the resistance of the LDR and output voltage is defined as in equation(2).

$$V_o = V_s\left(\frac{R}{R_{LDR}+R}\right) \qquad (2)$$

A circuit was designed to include all the mentioned sensors, as shown in Fig. 8. All sensors were enclosed into a specially designed enclosure that was built using a 3D printer as shown in Fig. 9. The enclosure is used as the weather station hub and includes also the NodeMCU, the ASD115, and a backup battery.

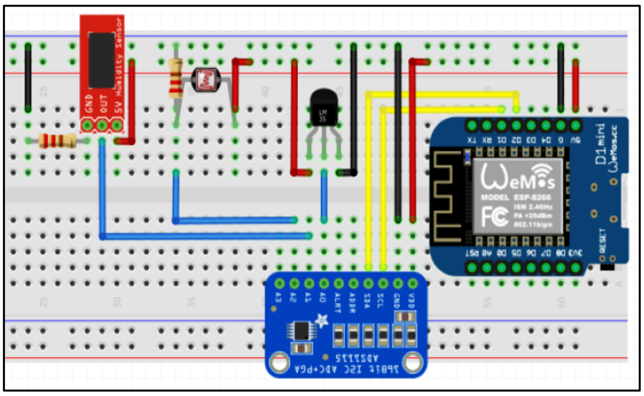

Fig. 8. Circuit design of the weather monitoring hub

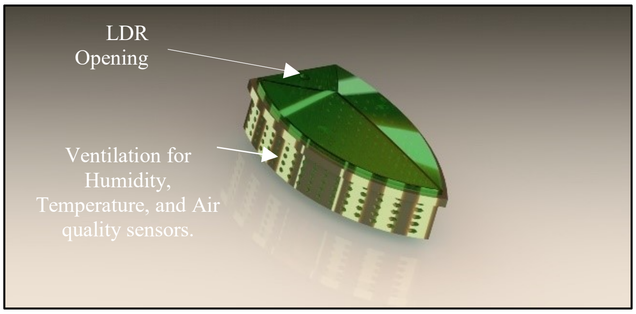

Fig. 9. Design of the weather monitoring hub case

B. IoT

Acquiring data from each node is done using the NodeMCU. The data acquired from all the sensors are continuously uploaded and stored on the EmonCMS platform. The EmonCMS is an IoT cloud server used for logging the data, with an option to display it using dashboards that can be easily designed and adapted to the needs of the user. It is an open-source server that is compatible with several preset hardware modules; such as emonPi and emonTx, and with the option to set up any external nodes or sensors to upload data to it. This is done by using a provided personal API key to the code of the controller. This platform was selected because it was found the most suitable for this project. Additionally, an application is created to get and display the monitored parameters from the server, and to apply the needed control of the devices [8][9]. In fact, Blynk is used as a mean to display selected monitored data for the users on their mobile phones and tablets. Blynk is an app for IoT applications. It is easy to program with simple codes and the interface is configurable through the app itself. The main advantage of using Blynk is its mobility between platforms and ability to connect to multiple microcontrollers, which are distinguished through authentication tokens.

C. Automatic Solar Panel cleaning system (ASPCS)

Since the solar house is supposed to be fully powered from solar PV panels, and because the total available area on the rooftop of the house may not be sufficient to accommodate all needed panels, it is suggested to add a number of solar panels on the façades and above the windows and doors, as shown in Fig. 10.


Fig. 10. Side PV panels used as shades to the Garage

Some of the solar panels will be placed on the facades on top of the windows; thus, providing shade for the windows facing the southern hemisphere. However, there is a serious problem of dust accumulation, which affect the performance of the PV panels and requires their frequent cleaning. Since the panels are placed on the façades and are not easily accessible for cleaning, it is important to consider an automatic cleaning system of accumulated dust using a sliding cover and brush mechanism as shown in Fig. 11. Notice that the sliding mechanism is fixed on two-rail system that uses a horizontal, or diagonal, thread connected to a Brushless DC motor through a mechanical coupling.

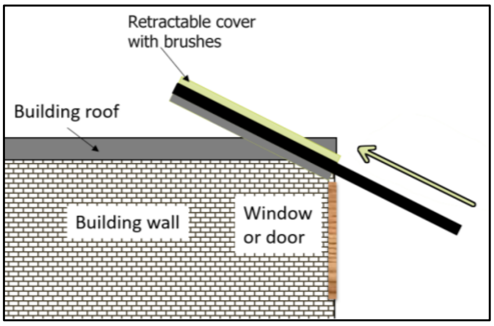

Fig. 11. ASPCS principle of operation

The system acts also as cover at night to protect panels from moisture as to ease the process of cleaning in the morning and protect the panels from sticky mud (cement) that is usually the harshest difficulty that faces any solar-based power system in the Middle East [10]. The proposed system is controlled through the same IoT platform using the NodeMCU that links directly with the EmonCMS platform. The NodeMCU acquires and process real time data of lux, dust perception, temperature, …etc., and sends them to the EmonCMS server. Based on the collected data, it can decide whether to cover the panels or not. The system can be also remotely controlled by the user and can be stopped or powered up at any time using and Blynk app as a preliminary platform for the cleaning system. as shown in Fig. 12.

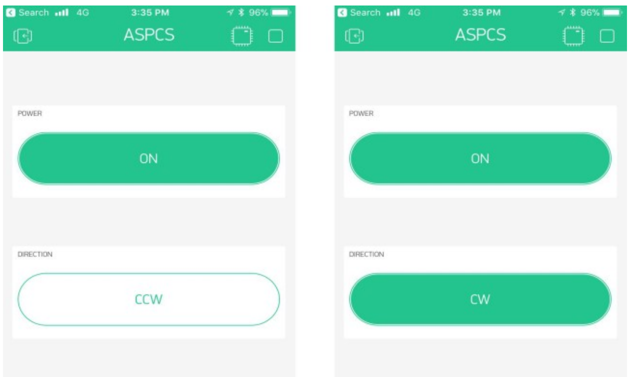

Fig. 12. ASPCS app on Blynk app

IV. IMPLEMENTATION, TESTING AND RESULTS

The proposed design of the Solar House monitoring system that is used for controlling the house energy efficient while maintaining the minimum required comfort-of-living conditions is implemented as shown in Fig. 13. While the sensors placed inside and around the house continuously collect data, the information should be accessible at all times and uploaded every few minutes to the cloud server for display, processing, and archiving. A test was made to ensure that the data is uploaded to the IoT EmonCMS cloud server, and it is plotted over a desired period of time.

Results provided in Fig. 14 show the recorded values of temperature, humidity, and illuminance that are logged by the EmonCMS input nodes. Additionally, these values are recorded and displayed over time through a data-viewing dashboard in the EmonCMS, as shown in Fig. 15. Furthermore, Fig. 16 shows the data displayed for the user on a Blynk app that was designed for this purpose.

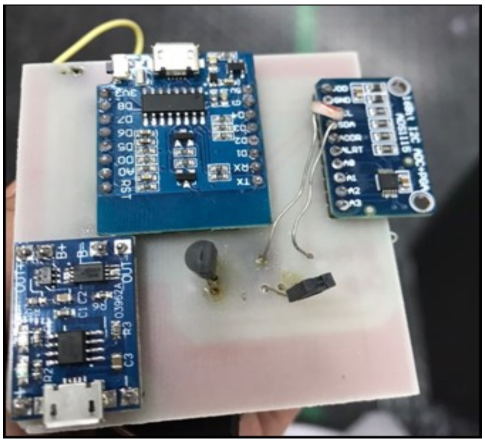

Fig. 13. Implemented Monitoring Circuit

Inputs

Node:	Key	Name	last updated	value
1	1	Temperature 1	2s ago	23.84
1	2	Humidity 1	2s ago	49.5
1	3	Lux 1	2s ago	233

Fig. 14. Uploaded data uploaded and logged on the EmonCMS

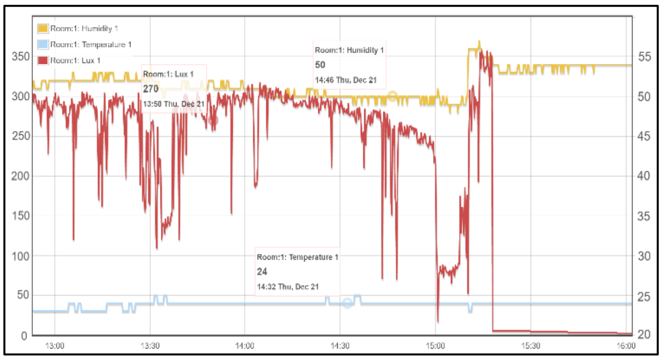

Fig. 15. Example of temperature, humidity (scale on right) and lux (scale on left) readings over a period of time (3 hours)

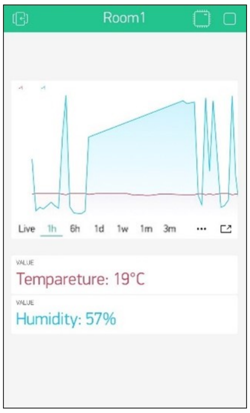

Fig. 16. Temperature and humidity readings displayed using Blynk app

All the recorded data was checked, benchmarked, and validated with data measured at the same time using other conventional and calibrated meters in the labs.

The automatic solar panel cleaning system was built and set up for testing, as shown in Fig. 17.

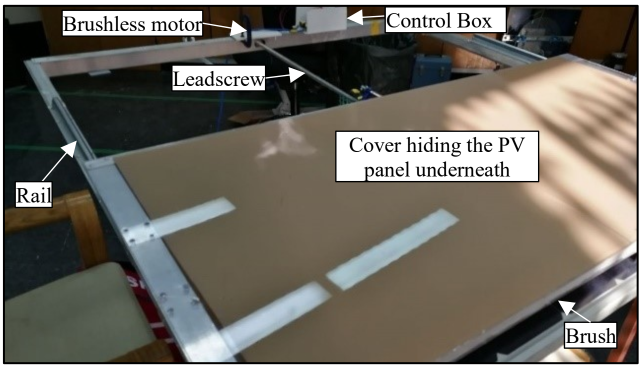

Fig. 17. ASPCS constructed prototype

The cover and brush are moved together using a 24V DC brushless motor, along a leadscrew. The power of the control system can be taken directly from the PV panel micro-inverter output. The system is designed with an LDR to detect light intensity. This way, the cover with the brush at its edge, would move “in” each morning and “out” each evening to clean the PV panel and uncover and cover it accordingly.

The control system through IoT was also implemented and tested. The NodeMCU controller reads periodically one digit command value from one of the EmonCMS nodes. Based on the acquired value (0 or 1) the NodeMCU send a command to the motor controller to open or close the panel cover. In fact, a zero value means that the panel cover must be closed and a unity value means the opposite.

Since the IoT system is in constant need for internet connectivity to access and view data, it is suggested that, in the future, copies of uploaded data be saved to local memory storage (e.g. SD Card). This can allow for physically accessing data in cases of emergencies or other called-for situations.

Besides, aiming at making the House even smarter, one can think of enabling it to learn, develop and grow with people living in the house. This can be achieved by implementing advanced artificial intelligence that can learn to adjust to certain member of the family's behavior.

Moreover, it can be used for advanced security measures, elderly health monitoring, fall detection, head counting, face ID ...etc. the possibilities are limitless when it comes to artificial intelligence [11]. Thus, the next step would be to create a smart automated house that can grow, adapt, and evolve. The way to do that is by using RNN (Recurrent Neural networks) aided by the renewed interest in Long Short-Term Memory (LSTM) variation which provides solution to many machine learning problems that involve processing a sequential data, along with image processing that can detect objects in 3D scene with high accuracy [10][12].

V. CONCLUSION

This paper presented a simple and flexible design for solar house monitoring and automation. The selected platform is the EmonCMS that uses a cloud server to collect data from sensor nodes using the IoT principle. Collected data can be displayed, archived or processed and used to control devices in the house. The NodeMCU combined with the ESP2866 was used as the main processing unit that collects the data from the sensors, processes it and then uploads it to the EmonCMS cloud server. The NodeMCU can also read data and commands from the same server and control switching devices. This constitutes a complete smart-home monitoring and automation system that is based on the IoT technology.

The proposed design of the smart solar home is very flexible and can be easily expanded and applied to larger buildings by increasing the number of sensors, measured parameters, and control devices. More functionality and smartness could be also added to the existing system for making the house automation system grow, adapt, and evolve by itself using advanced artificial intelligence.

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