Smart Home Energy Management System Design with Embedded Electric Vehicle Charging Station Using Renewable Energy Sources

Ahmed Emad AbdUlluh Muhammad, Mahmoud Abdo Muhammad Abd El-Wadood, Ahmed Ibrahim Abdel Rahman Ahmed, Osama Mohamed Mohamed Moawad, Mohamed Hussein Zaki Hussein and Mohamed Tarek Mohamed
Zagazig, Egypt, 20812016100144@eng.zu.edu.eg, mahmoudam2018@gmail.com, ahmedelsabagh5055@gmail.com,

osamamohamed111998@gmail.com, mzaki2495@gmail.com and mohamedtareck95@gmail.com

Supervisor: Mohamed El Sayed Lotfy, Dr
Zagazig, Egypt, Mohamedabozed@zu.edu.eg.

Abstract*– *A novel design for smart home energy management system is presented in this graduation project. Raspberry pi 4 B is used as main controller. The main aim is to control all the home appliances remotely in a secure and emission free methodology. This target is reached using Cayenne which is an IoT platform in addition to building some codes related to some appliances and sensors not supported in Cayenne from scratch. A real three rooms and reception prototype for smart home is implemented. The control methodology consists of sensing temperature, air pressure, and humidity inside the home and depending on that, controlling all the home appliances. Moreover, PIR sensors are implemented and connected to Raspberry pi Cam which allows the owner to check the status of the home as a live stream in case of any motion detected. Door lock is also controlled remotely. Due to COVID 19, a body temperature sensor is used to check visitor temperature in front of the home door. In addition to all of this, the smart home management system controls a charging point for electric vehicle via Raspberry pi. Moreover, disables convenience is considered by using Amazon Echo Dot (Alexa) to control home appliances and the charging point by voice with implementing the associated code for connecting the Raspberry pi with Alexa from scratch. At the end, All the home appliances are fed from a complete off-grid solar system to reach the main target of a sustainable, green, and emission-free smart home.

KEYWORDS: SMART HOME, ENERGY MANAGEMENT, IOT, ELECTRIC VEHICLE, SOLAR SYSTEM, COVID 19.

I. INTRODUCTION

Home Automation [1] is becoming more popular due to the latest developments in hardware which have significantly reduced the cost and improved the capabilities. It is due to the fact that technology around us evolves and the access to needed information is easier than ever.

A “Smart Home” is a part of The Internet of Things (IoT) paradigm and aims to integrate home automation. allowing objects and devices in a home to be connected to the Internet enables users to remotely monitor and control them.
(IoT) is a system that allows devices to be connected and remotely monitored across the Internet. it’s being currently used in various domains such as smart homes, industrial environments, etc. Wireless sensor network technologies integrated into the IoT enable a global interconnection of smart devices with advanced functionalities.

Home Automation Protocols are the language that smart home devices use to communicate with each other. These protocols are classified into wired and wireless, choosing a home automation protocol should have compatibility such as wi-fi, Zigbee, x10, UPB, Z-Wave, KNX and Loxone.

Smart home technology nowadays found in a wide range of household devices, including lighting that can be dimming for saving energy, shutters, and blinds to protect homeowner from suns and noise, HVAC to provide human comfort by regulating heat and moisture, security like smart door locks and security camera, appliances such as (refrigerator, oven, water heater, dishwashers, laundry, and coffee makers).
These smart appliances controlled via application and voice assistance such as Alexa, Siri and Google assistance that depend on artificial intelligence.

Home Energy Management System (HEMs) is defined as a system that inculcates sensors within home devices, via home networks. The hems in majority are developed with a purpose of controlling power utilization, bringing improvement in the performance level of a smart grid, optimizing demands, enabling devices in the residential users, etc. Here hems play the role of a modern energy meter bringing an evolution in the form of low consumption appliances.[2]

Cayenne [3] is an IoT platform for developers, engineers and students can be used in different IoT applications. It makes the IoT development process easier and faster. It has cloud-based web applications as well as mobile apps. It works on raspberry pi, Arduino, and a lora device connected to the internet.
The cayenne platform has features such as customize dashboard with drag and drop widgets, view data stored from devices, remote control IoT projects. There are more home automation platforms to control IoT devices such as Home Assistant, OpenHab and Domoticz.

Renewable energy sources, such as solar power, wind power and fuel cell etc., should be used to meet the increasing energy. PV-based power sources are considered a cleaner form of energy generation, photo-voltaic solar energy comes from the conversion of sunlight into electricity.
PV system components consists of solar panel, batteries, inverters, charge controller and blocking diode. PV systems are generally classified according to their functional and operational requirements. The two principal classifications are grid-connected systems and stand-alone systems. PV systems can be designed to provide dc and/or ac power service.

Electric Vehicles it is an electric motor and does not have a diesel engine. there are three main types of electric vehicles: Hybrid Electric Vehicles (HEVS), Plug-In Hybrid Electric Vehicles (PHEVS) and battery electric vehicles (BEV).

Depending on all of that, a real two-layer three rooms and reception wooden home (1.5m * 1m * 0.5m) is implemented in this graduation project. A modern remote smart home energy management system is built using Raspberry pi 4B as main controller. The main target is to sense the vital parameters inside the home and control the home appliances depending on their values. The smart homeowner can check the home status all the time via live stream using Raspberry pi camera. Moreover, a charge point for electric vehicle is implemented and controlled through the main controller. Furthermore, a body temperature sensor is used to check the visitor temperature before entering the home. Disables convenience is considered also by using Amazon Echo Dot (Alexa) with making the required code to connect Alexa with the main controller from scratch. The whole smart home system is fed from a complete off-grid solar system to ensure a sustainable and green electricity source all over the day.

II. METHODOLOGY

A real two-layer wooden protype is implemented as shown in Fig (1). Fig. (2) focuses on the two-layer system to make the wiring system more convenient. The prototype consists of three rooms and reception as shown in Fig. (3). A triangle roof is designed above the prototype as shown in Fig. (4) to fix the solar off-grid system.

Fig. 1 : Wooden prototype.

Fig. 2 : Two-layer system.

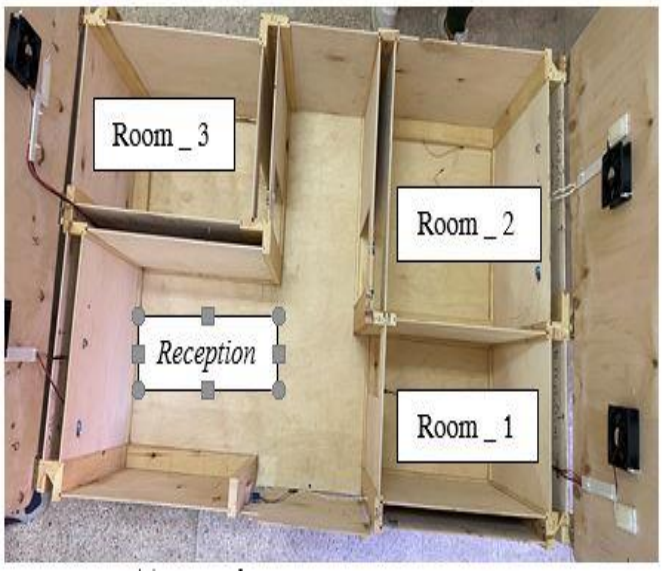

Fig. 3 : Smart home rooms.

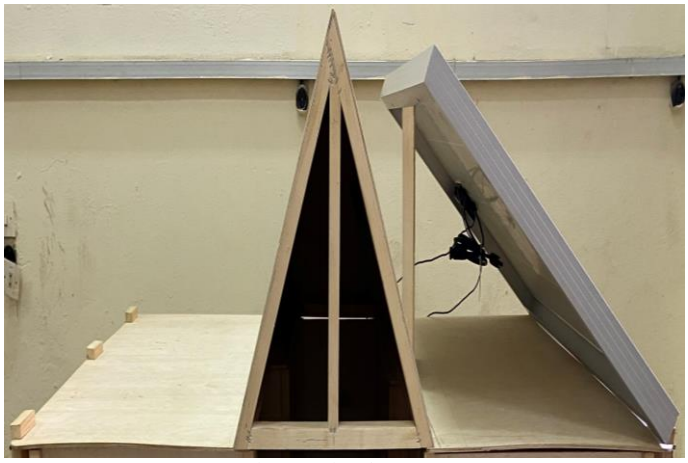

Fig. 4 : Triangle room

Every room is equipped with some sensors like smoke, flame, temperature and air pressure sensors as shown in Fig. (5).

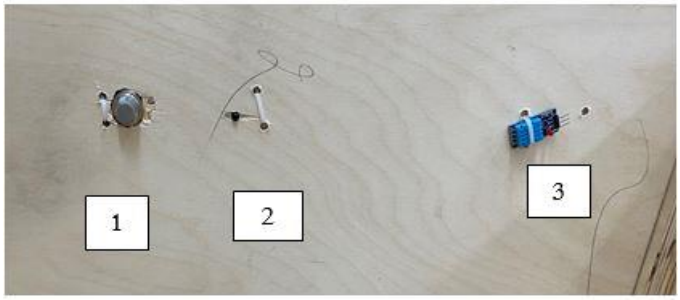

Fig. 5 : (1. Smoke sensor, 2. Flame sensor, 3. Temperature sensor)

Moreover, every room is equipped with some appliances like lamps and fans. Furthermore, PIR sensor is attached near the door of every room to detect the motion as shown in Fig. (6).


Fig. 6 : PIR sensor.

Raspberry pi 4 B with 4G RAM and quad-core processor is used as a central controller for the energy management system as shown in Fig. (7).


Fig. 7 : The main control unit.

A solenoid door lock is used for the main door of the prototype as shown in Fig. (8).


Fig. 8 : Solenoid door lock.

A Raspberry pi camera is implemented to allow the homeowner to observe the home interior remotely all over the day.

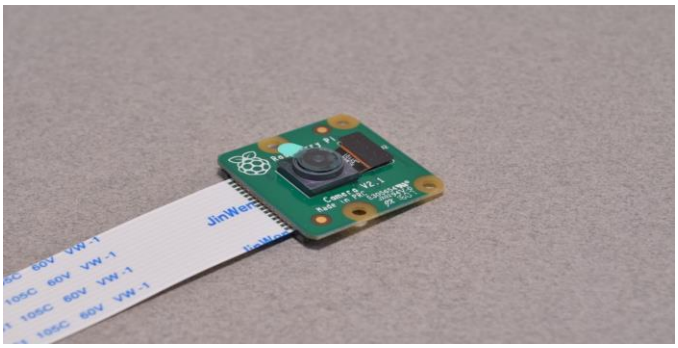
Fig. **:** Raspberry pi Cam.

Due to COVID 19, A touchable body temperature sensor is equipped near the home main door as shown in Fig. (9) to check the visitor temperature. The home visitor will be allowed to enter the home or not depending on the value of his body temperature.

Fig. 9 : Body temperature sensor.

Moreover, a toy electric vehicle is used as shown in Fig. (10) and the associated 5 V charging point is implemented.

Fig. 10 : 5V Electric vehicle

Cayenne as an IoT platform is used to get all the sensors data remotely via connecting the associated sensors with the Raspberry pi GPIO. Furthermore, all the home appliances can be controlled via Cayenne. Controlling the home appliances is done by using two of eight channels relay as shown in Fig. (11). Every relay channel will receive control signal from Raspberry pi. This control signal will be remotely sent from Cayenne to Raspberry pi depending on owner desire, sensors values or pre-designed scenarios in Cayenne as will be discussed in the next section.

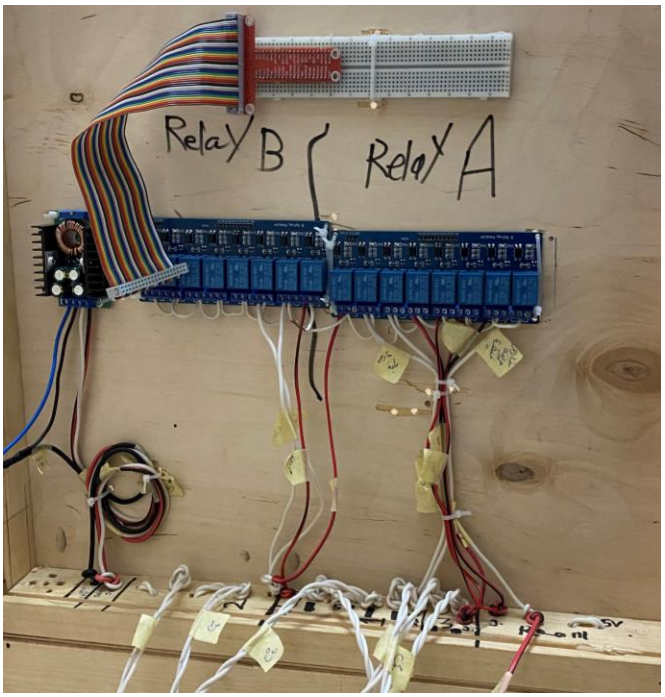

Fig. 11 : A two eight- channels relays.

There are some sensors and appliances that are not compatible with Cayenne. Building the associated codes from scratch is done like DHT11 temperature sensor, smoke, and flame sensors.

Moreover, the code of Raspberry pi Cam is implemented to allow the homeowner to check the home status all over the day.

To improve the disables convenience, Amazon Echo Dot (Alexa) is used as shown in Fig. 12. Alexa is programmed from scratch to control the electric vehicle charging point and one lamp as an example by voice via Raspberry pi.

Fig. 12 : Amazon Echo Dot (Alexa).

The final Cayenne user dashboard is shown in (13). Four Scenarios are built in Cayenne to give more facilities for the homeowner:

1) **First Scenario**: If the visitor body temperature is 36 Celsius, let the home door lock to be opened, otherwise, do not allow the visitor to enter the home.
2) **Second Scenario**: If the PIR sensor outside the home detects any motion, turn on the exterior lamp, otherwise, turn of the exterior lamp.
3) **Third Scenario**: If the temperature inside any room exceeds 28 Celsius, turn on the room fan. Otherwise, turn on the room fan.
4) **Fourth Scenario:** When the home door lock is opened, turn on room 4 lamp (the nearest lamp to the door) otherwise, turn off the room 4 lamp.

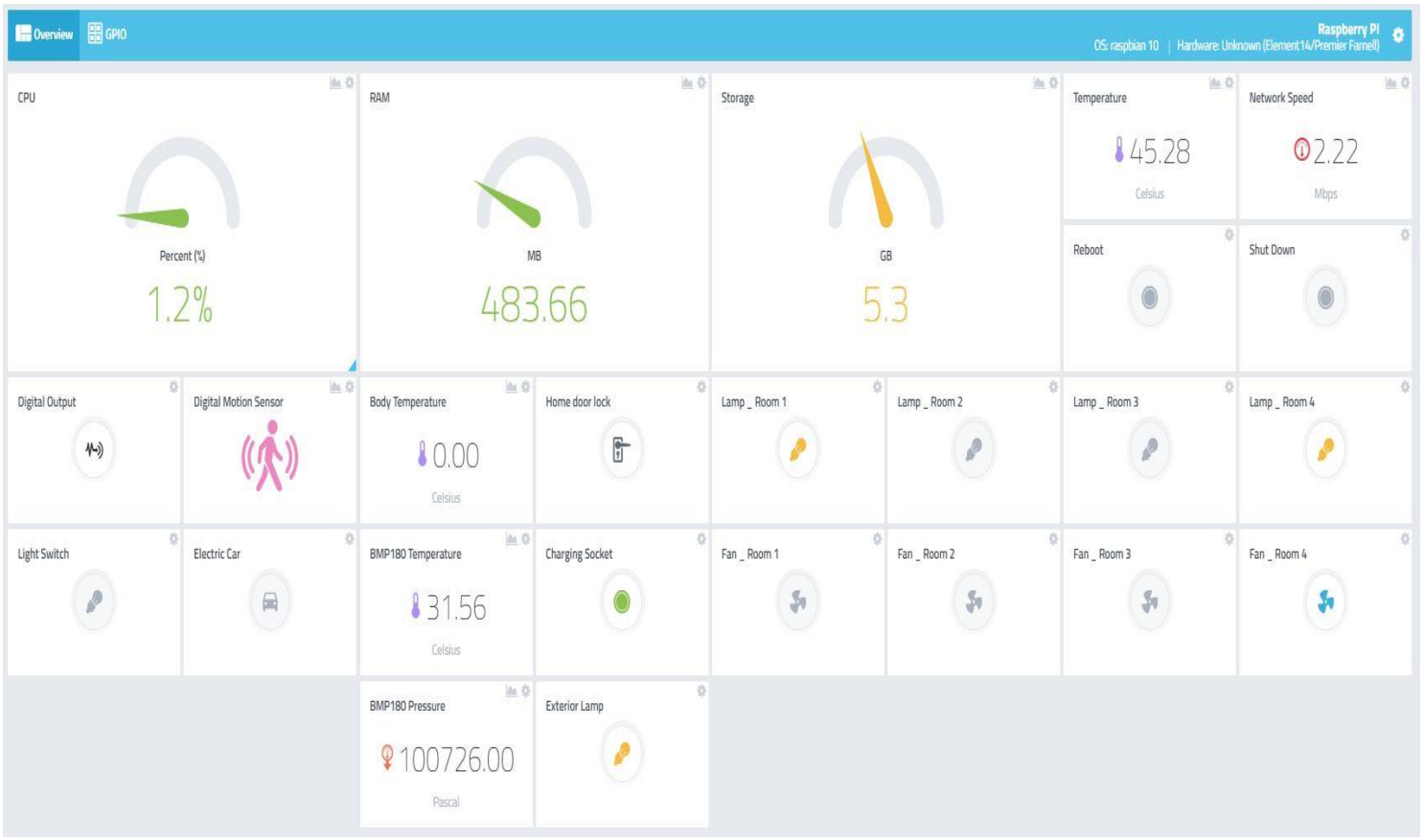

Fig. 13 : Cayenne dashboard

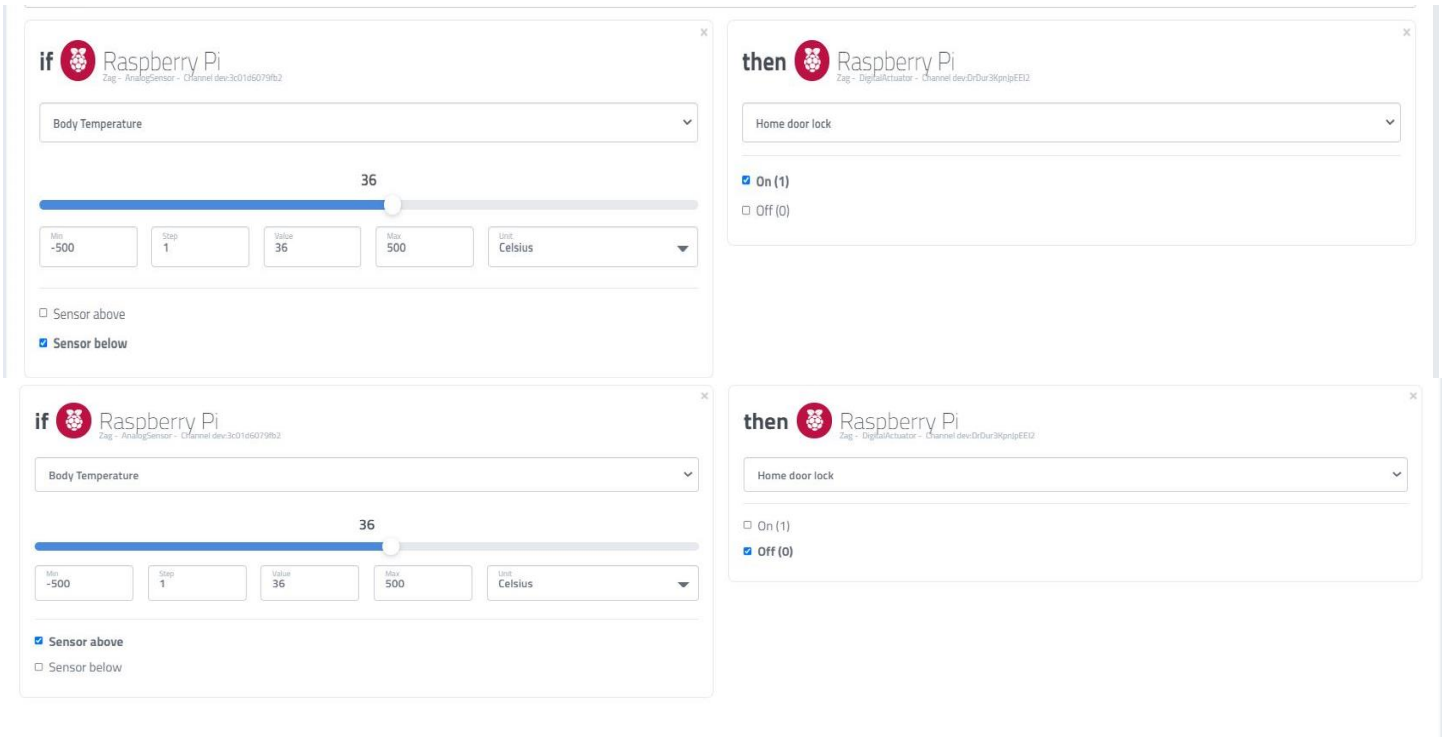

Fig. : First Scenario

A complete off-grid solar system is designed and implemented to feed the smart home with sustainable, green, and emission-free electricity all over the day. The off-grid solar system consists of:

a) A 100-Watt Photovoltaic panel (Shown in Fig. 14).
b) A 12 V, 12 Ah Lead-Acid battery with 10A solar controller to ensure 12 V power supply (shown in Fig. 15).

Fig. 14 : 100-watt solar panel.

Fig. 15 : Lead-Acid Battery with solar controller.

All the home appliances (Lamps, fans, and door lock) are chosen to work on 12V. That is why all these appliances are directly fed from the solar controller. A DC-DC converter is used to step down the voltage from 12V to 5V required for Raspberry pi 4, electric vehicle charging point, and some sensors. The shape of the DC-DC converter is shown in Fig. (16). Other sensors that need 3.3 V are fed directly from Raspberry pi.

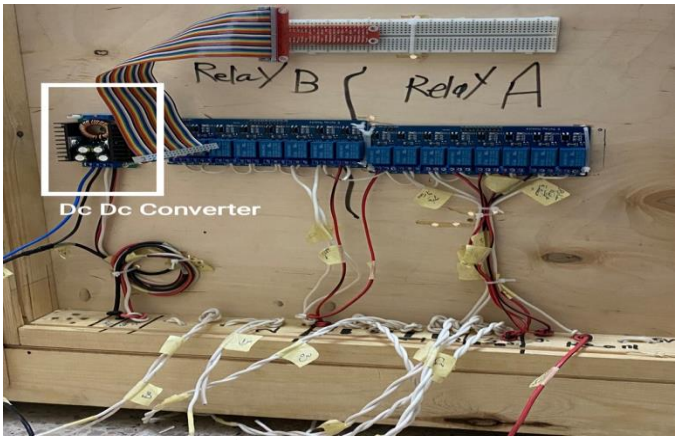

Fig. 16 : DC-DC converter.

III. CONCLUSIONS

A real smart home energy management control scheme is presented in this graduation project. The homeowner will have the ability to control all the home appliances remotely via dashboard. Moreover, homeowner can check the security status inside the home all over the day. Raspberry pi 4 B is used as main controller. Furthermore, a touchable body temperature sensor is implemented near the home main door to check visitor temperature during COVID-19 interval. A charging point for electric vehicle is implemented and controlled via Raspberry pi 4. Amazon Echo Dot (Alexa) is used to control the electric vehicle charging point and home appliances by voice to fulfill the disables convenience. The whole smart home is fed from a complete off-grid solar system to ensure sustainable and emission-free power supply all over the day.

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