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Home Energy Management and Monitoring Using Ubidots Platform

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***Abstract*— This paper introduces a practical design for home energy management and monitoring. It has been assumed that the home has a 12 V_{DC} power source and with variable generation power. The virtual house has loads that consisting of four lamps, each with a power of 10 watts and operated on 12V_{DC}. The home can be operated in two modes. The first mode is the grid-tied mode, in which the energy is imported or exported the power to/from the grid depending on whether the home source generation power is greater than or less than its load. The second mode is called the island mode, in which the home depends on its power supply to feed its loads with the required power. The transition between the two operating modes of the home is controlled fully by the Arduino UNO microcontroller according to the main grid status and home status (generation and load demand). The assumption that was set in the designed system is that the maximum current that a home source can supply is 3A. Therefore, when the current that a home needs is more than this value, it imports energy from the main grid and less than that value, it exports energy to the grid. The data of the grid voltage and load current of the home were transferred by the Arduino UNO microcontroller to the Node MCU using RF (HC-12) module. The cases of the main grid and the home power source are monitored in real-time using the Ubidots platform. These cases data raised to the Ubidots platform by using the Wi-Fi- ESP8266 included in the Node MCU board. All cases were tested in practice and the Ubidots platform showed a quick response in updating the data as well as its security.**

***Keywords*— Micro-grid; Power management; Arduino; Internet of Things; Ubidots,**

I. INTRODUCTION

Nowadays, many countries are interested in micro-grid because of being environmentally friendly, supply perfect power quality, increase the efficiency and reliability of the power system [1]. The residential sectors consume a large portion of the energy produced from the national grid in countries (about 29% of the power generated in the USA)[2]. Thus, governments and researchers are decided to find techniques to reduce power consumption and guarantee efficient utilization of energy in the residential sectors and then reduce greenhouse gas emissions[3].

To insert micro-grid in the main power grid, numerous technologies are required. A micro-grid operates in the grid-tied mode during the normal cases and operates in the island mode during abnormal cases (during faults occurrence in the main grid) or in remote regions from an electric grid. Moreover, there are some differences according to operating states like one owner micro-grid operation or competitive operating under an energy market.

Micro-grid running is the best application for information and computer sciences engineers but it is not easy to understand the micro-grid management and operation [4]. Thus, The objective of this paper is the implementation of a simple electric system that clears the concept of the micro-grid operating modes according to the environmental conditions of generation. The prototype system can be operated in two modes, island mode, and grid-tied mode. The operation mode of the system is controlled fully by the Arduino board. The states of the system are monitored and stored by using the Ubidots platform which represents the main contribution of this work.

The remaining sections of this paper as follows: Section II reviews related works. Section III illustrates the block diagram description of the proposed model (the concept of Micro-grid, IoT, Ubidots platform, M2Mcommunication are included). Sections IV introduces a software algorithm. Section V describes the circuit connection of the system. Section VI discusses

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the cases studied. Finally, section VII offers conclusions.

II. RELATED WORK

In this section, some existing literatures review related to the work introduced in this paper will be presented. The researches related to smart home appliances control, management, and monitoring are given. Also, the works that interested in IoT applications, the Ubidots platform, M2M communication, and the smart grid are considered.

Reference [5], designed a control system to manage the power of a smart home that helps the users to minimize the consumption power by the house. The control is performed automatically with the help of sensors that sense human activities. Reference [6] uses the Ubidots platform to monitor smart home conditions with the help of four sensors (Gas, Flame, Sound, and Temperature sensors).

The data sensors send to the Ubidots Platform using the Arduino UNO board with help RFID. the work is designed and implemented to take prompt action by alerting the smartphone of any unusual situation with no effort from a human. n [7] development of a simple home automation system for controlling various devices and monitoring from anywhere in the world was proposed. The technique includes Raspberry Pi and the webserver. The Raspberry Pi and Arduino incorporated with Nrf modules for monitoring home status appliances, and the readings were transferred to the webserver. When any threat is detected, a message or alarm is sent to the mobile. Performance analysis of various protocols (MQTT,HTTP and CoAP) was estimated employing visualization. Reference [8] suggests smart home implementation by combining the Internet of Things with network and cloud computing services. The ESP8266 WiFi module was used to load all sensor data to the cloud. The cloud services enable measuring home states, monitoring home appliances, and regulating home access. In [9] an energy management system for a residential home (or nano-grid) was developed. This nano-grid is able to control and schedule the main loads such as heating, air conditioning lighting...etc. UNO microcontroller equipped with a WiFi module was used to test and validate the MQTT protocol for connecting devices in a home environment. Reference [10] uses the internet of things (IoT) to manage the demand side of three microgrids every one includes two solar panels, wind unit, batteries, and loads. For optimal management and economic operation for the three microgrids, Arduino microcontroller with IoT Ubidots cloud was applied. The load request to the end-user was covered with low cost and high reliability from available sources in the system.

III. BLOCK DIAGRAM DESCRIPTION OF PROPOSED MODEL

The block diagram of the proposed system is shown in Fig. 1. The system is consists of the main electric grid and a home that has its own power source (usually PV panels). The home contains the Arduino board to manage the load as well as to control the transition between the operation mode of the home (Island mode or grid-tied mode). The home is connected to the main grid and can export power if there is the available extra power in it or import power from the grid when the generating power in the home is insufficient or unavailable.

The home is communicating wirelessly with the Node MCU by radio frequency (RF) that was attached to the Arduino board. The information cases of the home and the electric grid are sending to the Ubidots platform via WiFi-ESP8266 included in the Node MCU board. Thus the data can be monitored from anywhere by using a laptop or smartphone. The following subsections contain the topics related to the system design:

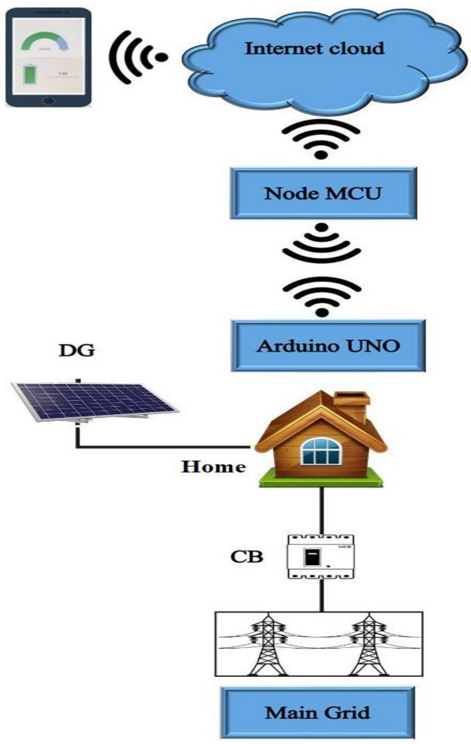

Fig. 1. Block Diagram of Proposed Model

A. *Microgrid Concept*

The concepts of the microgrid are varied and there is still no common concept for it. However, it can be defined generally as a relatively small scale localized power grid, that comprises a controllable load, a group of distributed

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generation (DG), and distributed storage devices (DS). Microgrid usually includes a communication system that links all parts of the microgrid. It transfers and monitors the data gathered from all microgrid components to ensure optimal management and control. Microgrids can be applied to single consumers, such as sports stadiums; neighbourhood Microgrids with multiple customers, such as campuses[1].

Figure 2 illustrates a local microgrid configuration [4]. All microgrid DG's deliver energy to local consumers like residential and commercial buildings, factories, and offices. The main grid is tied with microgrid at the PCC to purchase energy if there is no sufficient energy produced from local DGs of the microgrid and to sell energy back to the main grid when there is extra power generated. When a disturbance occurs in the main grid, microgrid disconnected and it operates in the islanded mode. In this case, only the necessary loads remain at work when insufficient generation in the microgrid.

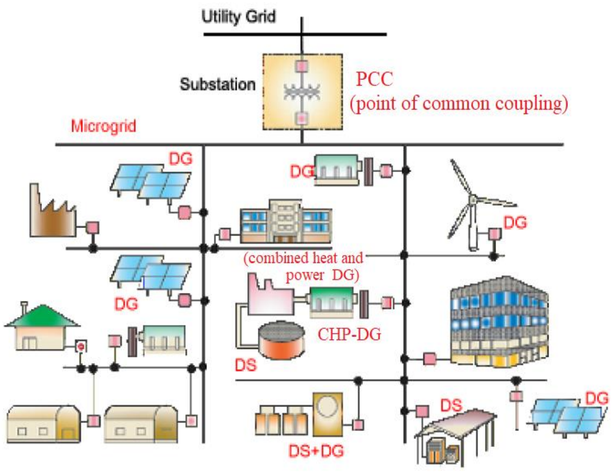

Fig. 2. Microgrid Configuration [4]

A. Smart Energy Home

smart energy home (SEH) is an essential part of smart cities. It plays an important role in the move towards SG. It can be described as a ”nano grid” as it can contain generation, distribution, and loads. the ability of homes is developed to supply surplus power back to the grid. This interaction between homes and the grid is important for improving the performance of residential neighbourhoods because it increases the efficiency and reliability of the systems [3].

B. Internet of Things (IoT)

IoT means a network of a huge number of devices having sensors and can connect with the internet to facilitate the exchange of products and services around the world[3]. IoT permits control and monitors on devices remotely across the internet network by the smartphone, creating an improvement in the efficiency, accuracy, and economic benefits as well as reducing human effort [10].

C. Ubidots Platform

IoT platform that will be employed in this work is Ubidots. This platform used to transmit and receive the data of sensors to the cloud from any smartphone or laptop linked with the internet, and turn it into beneficial information. Ubidots platform used here since it has many benefits such as[10]:

i- Optimize computation, visualization, and recovery of the IoT data storage.

ii- Has a simple GUI, easy to use.

D. Machine to Machine (M2M) communication

M2M Communications is the independent interaction of a huge number of sensing, processing, and action without human intervention [11]. M2M communications considered an important part of the IoT [12]. Also, it is considered a building block for the smart electric grid as a way of implementing a wide-ranging monitoring and control network. To exchange data between machine to machine, there is a need for communication protocols. The communication system designed in this work offers the following communications protocols:

i- Two IoT protocols, Message Queuing Telemetry Transport (MQTT) and Hypertext Transfer Protocol (HTTP),

ii- Serial communication protocols.

Figure 3 represented the whole communication system of the proposed system. The sensors data (current and voltage) are collected to read by the Arduino UNO board and then these data send wirelessly to the Nod MCU by RF (HC-12). The exchanging data between Arduino and Node MCU in a sequential manner over the communication channel [13]. With the help of WiFi included in the Node MCU, the data are sent to the MQTT Broker where all data about the home and the main grid are collected and stored. The Web server receives updates from the MQTT Broker and writes them to a database. The network users get all data from the Web server.

IV. SOFTWARE ALGORITHM

The software is divided into two main parts. The first part relates to the control side. In which, the Arduino microcontroller was programmed to manage the loads and control the operation mode of the home. The second is related to the communication side. In which, the exchange of information through the system's local network was managed and connect the system with the internet cloud to monitor the data remotely. Figure 4 shows the flowchart of the software program where the data processing was involved.

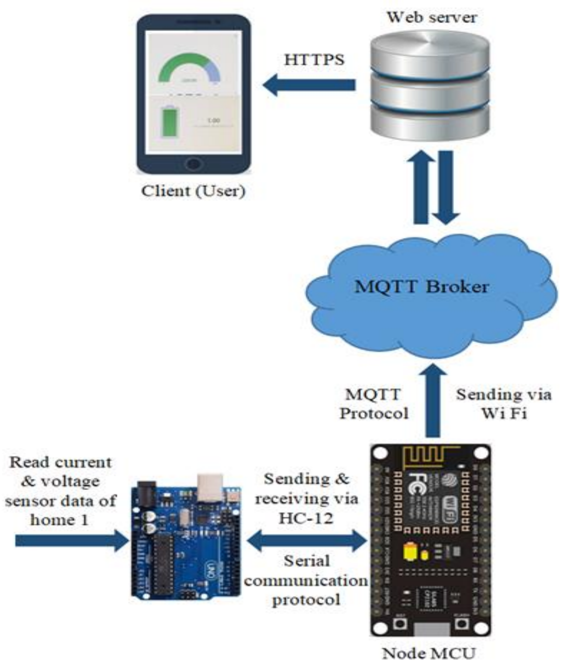

Fig. 3. Proposed System Communication Architecture

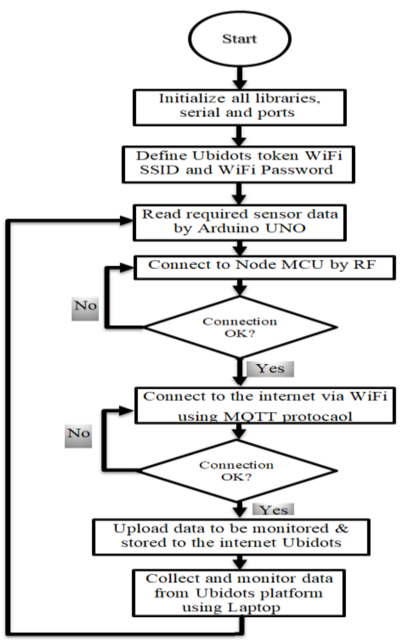

Fig. 4. Flowchart of the Software Program

V. CIRCUIT CONNECTION

The complete circuit of the system designed in this work is shown in Fig. 5 which will be displayed at the end of the this article. The connection parts of the circuit can be summarized as follows:

The main electric grid signal is connected to the analog input pin (A0) of the Arduino microcontroller after step down the voltage by transformer and voltage divider. This voltage signal is used to detect the availability of the grid or not. The current sensor (ACS712) senses the current drawing from the total load of the home and this signal is sent to the analog pin (A1). This current signal determined whether the power consumed by the home greater or less the generation power.

The (LCD 20*4) used to display the output of the microcontroller, which refers to all statuses for the source of the home and main grid. It connects with pins (A4 & A5) of Arduino by I2C communication serial protocol, where SDA (Serial Data) pin connected to A4 pin and SCL (serial clock) pin connected to A5 pin. Arduino digital output pins (2, 3, 4, 5,6,7,8, and 9) are connected with an 8-channel relay module, where it used to ON/OFF power of the loads.

RF-HC-12 module, which exchanges data between home and Node MCU about their load's condition and operating mode wirelessly, is connected to (TX, RX) pins of the Arduino. All parts of the circuit (C.S, RF, LCD, and relay coil) are powered by an Arduino Uno board power supply. Figure 6 shows the image of the practical components and connection of the circuit.

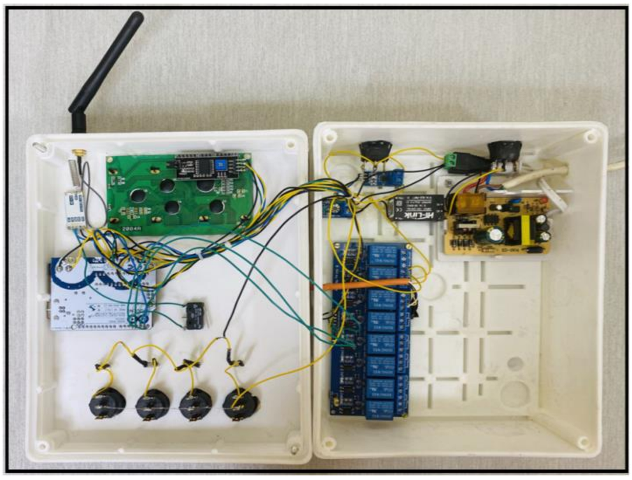

Fig. 6. Image of the Inner Connection of the Circuit.

The controller Node MCU is used to connect the system with the Ubidots platform by its WiFi for establishing remote monitoring continuously with a laptop or smartphone. Node MCU board is connected with the RF-HC-12 with serial ports (TX, RX) as given in Fig. 7. This

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connection is made by using a logic level converter, which contains 3.3V & 5V where ESP8266 operated with 3.3V and HC-12 operated with 5V. The image of the Node MCU circuit connection is given in Fig. 8.

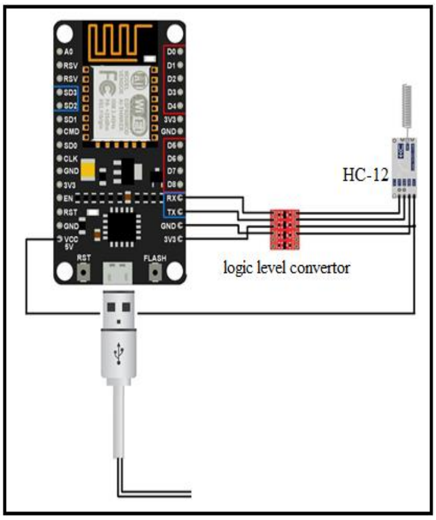

Fig. 7. Circuit Diagram Connection of the Node MCU

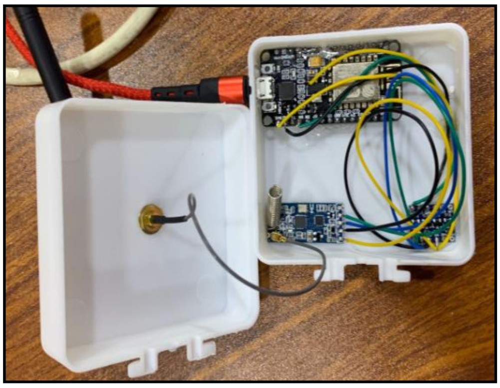

Fig. 8. Pictorial Image of the Node MCU Circuit

VI. RESULTS ANALYSIS OF THE CAESE STUDIED

The final design of the practical circuit of the system is shown in Fig. 9. In the system, four lamps were used in the home to represent the load. Each lamp has 10 watts power with a DC voltage of 12 volts. The performance of the system was verified within moving from one operating mode to another automatically by reducing and increasing the load (Change the number of lamps that are working) to interpret the change in the load during the day. The system flowchart is shown in Fig.10. According to the flowchart, the following three cases will be studied.

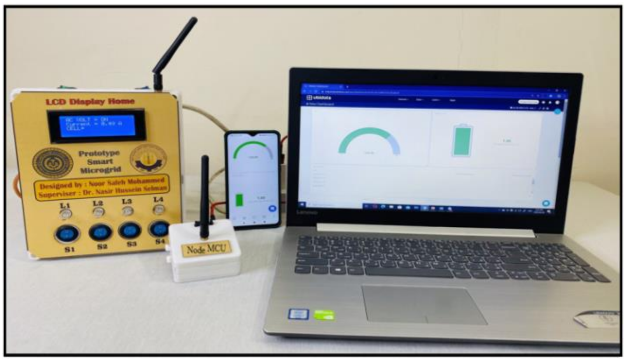

Fig. 9. Image of the Final Design

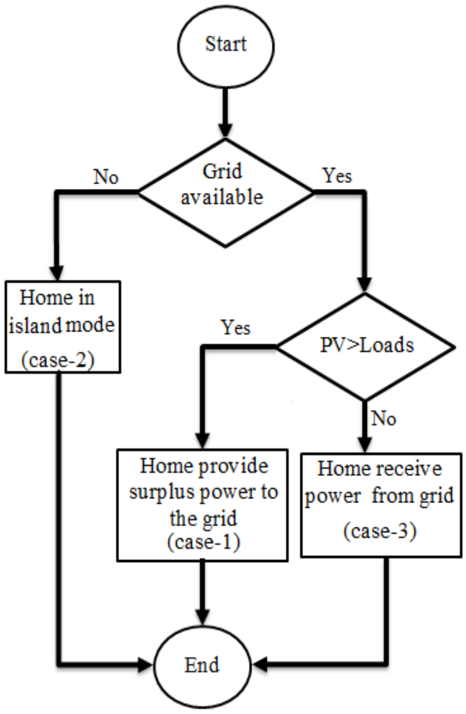

Fig. 10. Flowchart of the Home Energy Management

A. *Grid available and home generated power* > load

In this case, the grid is present and the home generates power greater than the total home load (load current less than 2.5A). The screen picture of the LCD display is shown in Fig. 11. Table-I illustrates the meaning of the symbols appearing on the LCD display.


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Fig. 11. Print Screen of the State of the Grid and Home for Case-A

Table-I: Summary Results LCD Displays of the Home with Grid for Case-A

Case A: Grid available and home generated power > load		
Item state	**Symbol signal**	**Meaning**
State of Grid (AC VOLT)	ON	Grid available
Signal sending from home	A	Home export power to the main grid
feeding of home loads	CELL *	Home loads are fed from the home's source and there is surplus power in the home.

Figure 12 shows the results that uploaded to the Ubidots platform which represents home power and grid status. The battery represents the state of DC generated power of the home where they appeared fully charged in this case to indicate the availability of additional energy. Also, the main electric grid is present on the Ubidots platform.

Fig. 12. Ubidots Data of the Home and Grid of Case-A

B. Grid not available

This case discusses if the main grid is not available and the home operates in Island mode. Figure 13 shows the print screen of the LCD of this case. Table-II illustrates the meaning of the symbols that appear on the LCDs of the home.

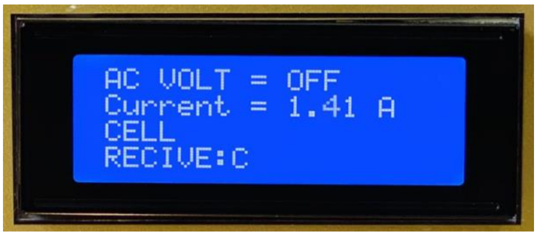

Fig. 13. Print Screen of the State of the Grid and Home for Case-B

Table-II Summary Results LCD Displays of the Home with Grid for Case-B

Case B: Grid is not available (Island mode)		
Item state	**Symbol signal**	**Meaning**
State of Grid (AC VOLT)	OFF	Grid unavailable
Signal sending from home	C	Home operate in Island mode
feeding of home loads	CELL	Home loads are fed from its sources only.

Figure 14 shows the results uploaded to the Ubidots platform for home power and grid status. From the figure, we note that the home power is available and represented by a full battery and the grid is not available.

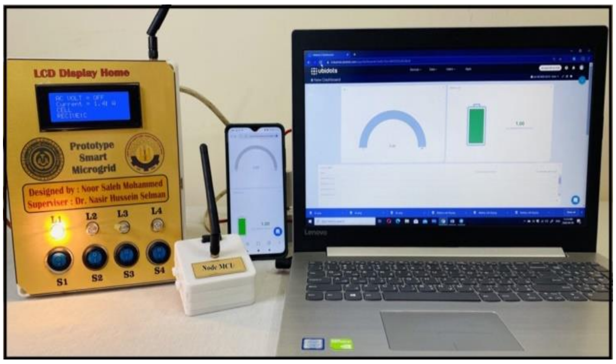

Fig. 14. Ubidots Data of the Home and Grid of Case-B

C. Grid available and home generated power < load

In this case, the home-generated power not enough to cover the total loads (current 4.27A). Therefore, home imports power from the main grid. Figure 15 shows the print screen of the LCD of this case. Table-III illustrates the meaning of the symbols that appear on the LCDs of the home.

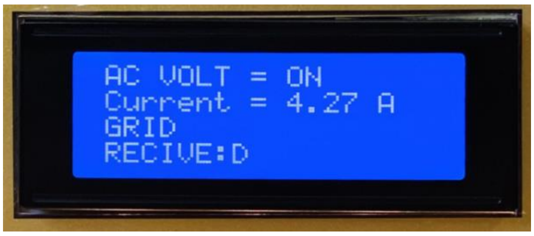

Fig. 15. Print Screen of the State of the Grid and Home for Case-C

Table-III Summary Results LCD Displays of the Home with Grid for Case-C

Case C: Grid is not available (Island mode)		
Item state	**Symbol signal**	**Meaning**
State of Grid (AC VOLT)	ON	Grid available
Signal sending from home	D	Home import power from the grid
feeding of home loads	GRID	Home loads are fed from the grid

Figure 16 shows the results that uploaded to the Ubidots platform for home power and grid status. From the figure, we note that the grid is available while the power generated from the home is few and represented by a battery with a little charge.

Fig. 16. Ubidots Data of the Home and Grid of Case-C

VII. CONCLUSIONS

In this paper, a prototype electric system is practically designed. It has been assumed that this system consists of a home contains a DC source (12 V) and a controller (Arduino UNO). The home can operate in grid-tied mode and island mode according to the generation power of the home and availability of the main grid. Four lamps were used in the home to represent the load. Each lamp has 10 watts power with a DC voltage of 12 volts. The performance of the designed system was verified within moving from one operating mode to another automatically by reducing and increasing the load (Change the number of lamps that are working). With the help of the RF module linked with the Arduino board, the data send wirelessly to the Node MCU board. These data include the grid status (availability or not) which senses by voltage sensor and DC power source of the home that senses by a current sensor. The Ubirdots platform was used to monitor the data remotely. These data uploaded to the Ubirdots cloud by Node MCU using WiFi-ESP8266-01 included in it. The data that was uploaded to the Ubidots platform was according to the existing sensors in the system and can be increased to include other useful data in the future work. Also, the system can be developed by adding other virtual houses and using one of the optimization methods to find the optimal management of the system.

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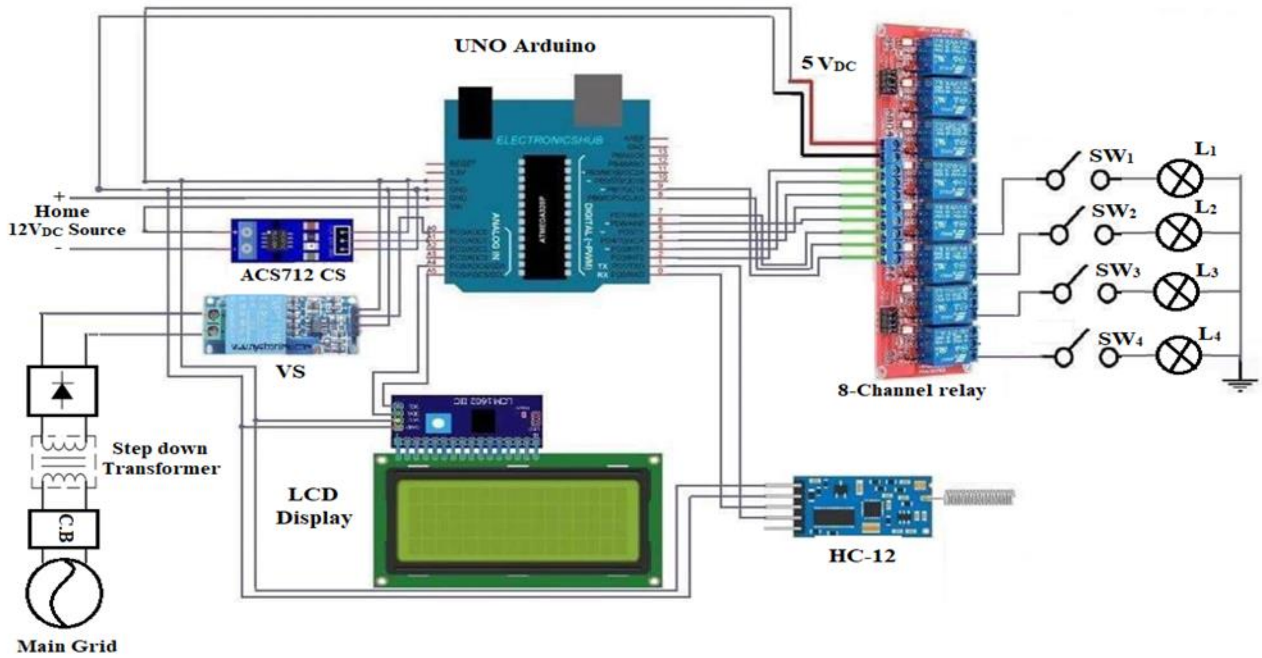

Fig. 5. Complete Circuit Diagram Connection of the System