Internet of Energy: A Design to Manage Energy Consumption for Limited Resources Building

Ahmed J. Abid

***Abstract*— This article presents an Internet of thing (IoT) system, which offers a complete energy consumption, monitoring and control. There is a master controller which is a website built with Ajax software to communicate with all the building devices (via a wireless router) which connected to Wi-Fi nodes (ESP8266 nodes) to calculate the consumed energy from each device and compare it with the fluctuated produced energy. The system is designed to keep the consumed energy, lower than the produced energy. This can be achieved by making the user take the decision and divides the building devices into three different priorities (High, Medium and Low). The presented system follows a strategy to reduce the load according to the available power and the device priority.**

***Keywords*— Energy management, Energy consumption, Energy efficiency, Internet of things, ESP8266, Wireless sensor, Renewable energy.**

I. INTRODUCTION

Energy consumption control can be achieved by user awareness of momentary energy consumption. But in case of there is a lack in the produced power specially at the renewable energy sources such as solar or wind, an instant decision must be taken to reduce the power consumption. The Internet of Energy (IoE) provides an innovative concept for power distribution, energy storage, grid monitoring and communication. It will allow units of energy to be transferred when and where it is needed. Especially when there is a lack in the produced power or limited resources. Power consumption monitoring will be performed on all levels, from local individual devices up to national and international level [1]. In a smart grid scenario energy consumption, will be manipulated by a volatile energy price which again is based on the momentary demand (acquired by smart meters) and the available amount of energy and renewable energy production.[2]

As a literature review, in this field, some articles study controlling energy consumption without taking into consideration the limited resources like [3]. Other Authors, offers using smart meters that can give information about the instantaneous energy consumption to the user, thus allowing for identification and elimination of energy wasting devices and for providing hints for optimizing individual energy consumption, or for devices scheduling strategies as in [4], [5] which may affect the quality of life. But the presented design gave the user more options that, the users can give the devices a multi-level of priorities and the system will eliminate the low priority level if required. Devices management in smart home industry visions is a matter of the contradiction between complexity and simplicity, where an expanded range of devices, services and options are marketed as a way to simplify and enhance everyday practices.

A promoted side-benefit is reduced and more efficient energy consumption [6]. Add for that Cloud-based Home Energy Management (HEM) can provide intuitive and automated services that can not only save money and energy but also improve the quality of lives of consumers [7]. ZigBee could be a good solution to manage smart home as in [8], [9], [10], but it could add more cost to the system and it still required a gateway to the cloud. Some researchers also discussed the shading in solar energy sources that causes by passing clouds or in specific months of the year [11], which required an instance response to avoid the lack in the supplied power which may cause a complete shutdown. For that, the presented article discussed the management of the building devices according to their power demand, level of priority, and the available power. It may eliminate some devices when:

- There is a shade in power.
- To decrease the power consumption under a certain level.
- To save the electricity bills without affect the quality of life.
- Avoid total shutdown at the beak load with limited resources.

All that will managed with an intelligence system that will be able to control the whole devices in the building via Wi-Fi networks through ESP8266 nods. In brief, this article is discussed in section II, the system structure. In section III a list of the supported software is listed and discussed. Section IV presents a flowchart that describe how the website manage all devices. Section V describes how the system select the priority mode. The system implementation requirement is described in section VI. In section VII presents the results and discussion, and finally section VIII is conclude the works.

II. SYSTEM STRUCTURE

The system mainly managed based on software and hardware structures, from the software point of view, the system consists of a server and clients. The server could be a desktop computer, laptop, tablet and/or smart phone that can

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manage the website. This server connected to the local clients via wireless router. The presented server can be managing the local network locally or via the cloud. From the hardware point of view, each client is consisting of ESP8266 as an access point. These access points can control a number of devices and monitor a number of sensors and devices status as shown in Fig. 1. Each Node can use as a gateway to reach the node that out of reach the wireless router.

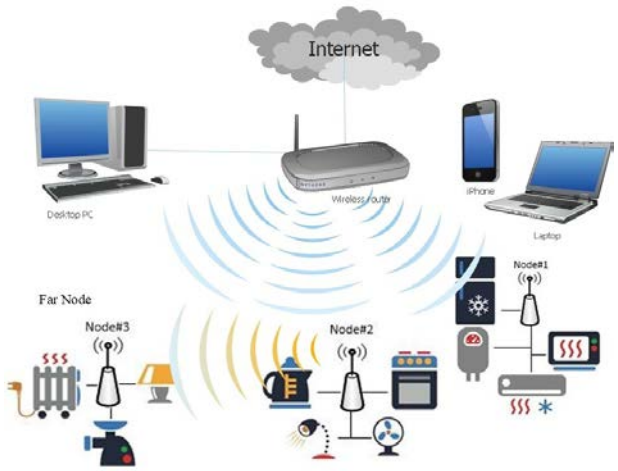


Figure 1. System Structure

III. SUPPORTED SOFTWARE

The web site is designed with the aid of many web design language and Java script to make the user fully controlled and monitoring data of many access point nodes of the devices which is used a Node MCU. A brief list of these software is listed below:

- HTML is an acronym for Hyper Text Markup Language. HTML documents, the foundation of all content appearing on the World Wide Web [12].
- Ajax (Asynchronous JavaScript and XML) encompasses much more than the technologies that make up this catchy acronym [13], [14].
- jQuery is a popular JavaScript library that's designed to simplify the client-side scripting of HTML. As stated on the jQuery website, jQuery is a fast, small, and feature-rich JavaScript library [15], [16].
- CSS (cascading style sheets) to take control of the style of your pages, including the color and size of fonts, the width and color of lines, and the amount of space between items on the page [17].
- Bootstrap is a free and open-source front-end web framework for designing websites and web applications [18], [19].
- Google Charts perfect way to visualize data for website developers with Google.
- Arduino IDE is an open-source makes it easy to write code and upload it to the Arduino boards. This software is used to program the NodeMCU and ESP8266.

IV. SOFTWARE FLOWCHART

The flowchart in Fig.2 is presented the controlling algorithm of the website. As a matter of securing the website, it requested the user name and password to give authority to control the system. If the user name or password is not correct the user will not allowed to control any device. When the user is signed in, the website will start sending request for all the connected nodes and presents the status of each of them. It is also shown the statues of the devices and the readings of attached sensors for each node and keep repeating that every two second to keep the system up to date. Now the user has to select the energy management mode (Manual or Auto), if the Auto mode is selected the system will take care of managing the devices according to the available power AP and the demand power DP, but in case of the user select the manual mode, the level of priority must be selected too.

In both modes, the user has to set the priority level of each device, more info. about how the system manages the devices according them priority is explained in section 5. Level of priority in the AutoMode calculated at this stage, and to do that the website request (AP and DP) from the node that responsible on measuring them.

Measuring the total load achieved by sensing the main current and voltage, but the available power can be set manually by the user to keep the building consumed energy below a certain level, or measure the energy source limitation, for example if the power of building is stand alone with a solar panel source, the available power can be measured to track the maximum power point (MPPT) [20]. Now the system priority level is known, and the user can turn ON or OFF any active device.

V. ENERGY MANAGEMENT MODES

The presented system manages the energy consumption in two modes (manual and auto). In both modes, there are three options (high, medium and low priority). High priority option allows only high priority devices to be an active, medium priority option allows both high and medium priority devices to be an active, and finally low priority option activates all devices.

A. The manual option: in this option, the user manually chooses the group of the devices that should work according to their priorities which selected by the user too.

B. The auto option: in this option system measures the priority level according to deference between available power (AP) and demand power (DP) as in Eq.1. Auto management option can be activated by select Auto from the web. System activates devices, according to their priorities and the load status. Over load status make the system at high mode, critical load status at medium mode, and finally a normal load status at low mode. Figure 3. shows an example for the power status at specific available and demand energy.

I.

$$LoadStatus(AP, LD) = \begin{cases} Overload & LD > 90\%AP \\ CriticalLoad & 80\%AP \leq LD \leq 90\%AP \\ NormalLoad & LD < 80\%AP \end{cases} \quad (1)$$

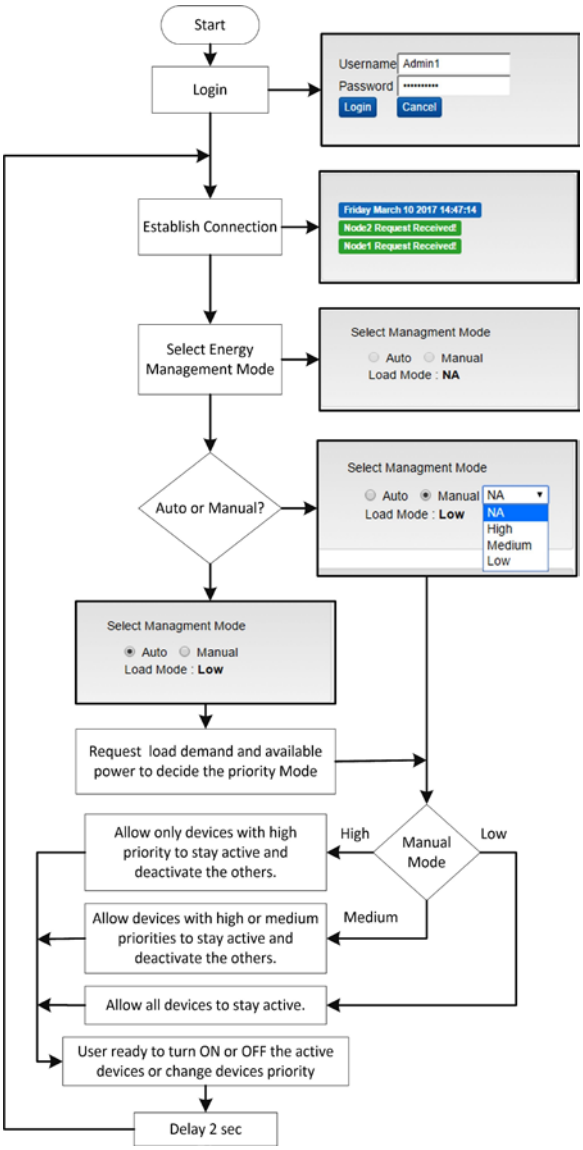


Figure 2. Website Flowchart

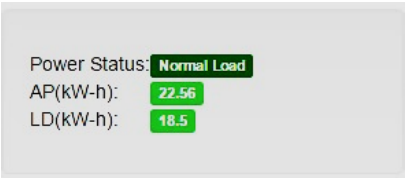


Figure 3. Power status, AP, and LD example

VI. PHYSICAL DESIGN

The presented system can handle many nodes as much as the Wi-Fi router can handle, but it is tested to manage only three. Nodes must use a static internet protocol (IP) to avoid IP conflicts, this can be achieved easily by using a fix IPs in the Wi-Fi router according to the devices MAC address. Figure 4. shows how to manage these two nodes which have two local IPs (192.168.50.136) and (192.168.50.138). Node1 controls four buttons with different IDs and priorities, but Node2 controls only two devices, but it is import to know that number of nodes and connected devices is a matter of the design requirement. The presented access point nodes main unit is ESP8266 ESP-01 or ESP-12 according to the node connecting devices number.

The ESP8266 is a low-cost Wi-Fi chip with full TCP/IP stack and MCU capability, *Espressif* Systems. For the small node, which control two devices ON and OFF, ESP8266 ESP-01 (see in Fig.5a and Fig.5b) is enough, but for the nodes that need to control more than two or need to read an analog sensor, its required to use ESP8266 ESP-12 as NodeMCU.

ESP8266 ESP-01 needs to programed using FTDI board and with help of Arduino IDE. This *FTDI* card connected as shown in the Fig. 6. The system adopts this electronic card as shown in Fig.7 and it is work perfectly.

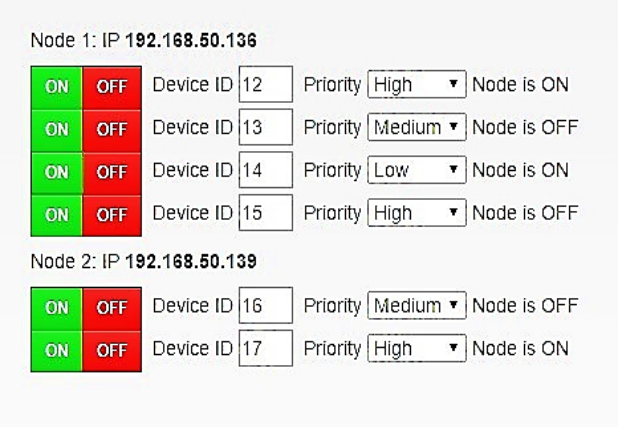
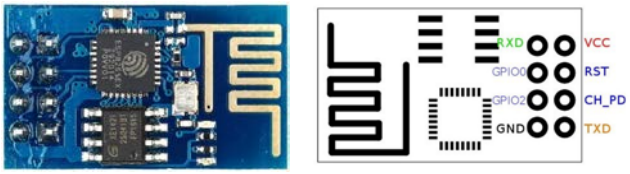


Figure 4. Device Manager



(a) Model (b) Pin out

Figure 5. ESP8266 ESP-01.

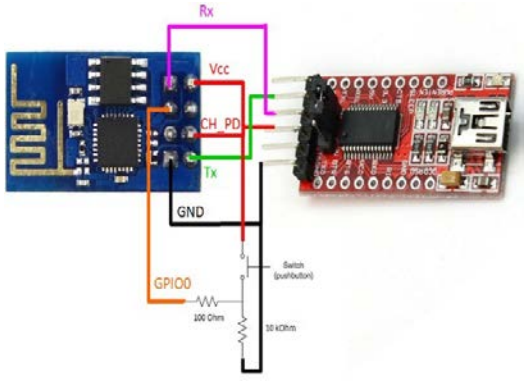


Figure 6: ESP8266 ESP-01 Programming Adapter

The system also required a wireless router which can cover all the building. This router required to let the computer communicate with all the nodes. In case of big or multi store building that cannot be cover with one router, it possible to using more routers or make the ESP8266 work as a gateway to repeat the Wi-Fi signal [21] and cover the whole building as adopted in this design. It is also required more electronic components to drive the device by the node. These components include (ULN2003A, relays, LEDs, resistors) as in Fig. 8, a 12V power supply, and OLED which is an optional.

Figure 7: The Implemented ESP8266 ESP-01 Adapter

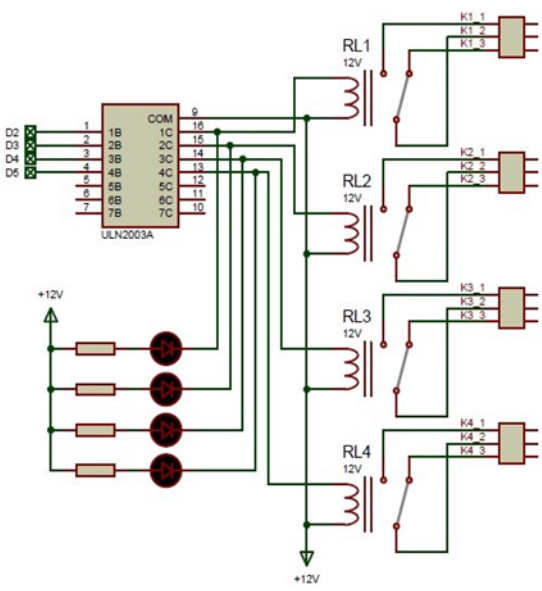


Figure 8. Devices Drive circuitry

VII. System Circuitry

The system is implemented, tested and worked as planned. The website is work as shown in Fig.9. For testing the website, the *ManualMode* activated by selecting the *ManualMode* and the system priority level set to be *High*. Then the priority of each device has been set as shown in Fig. 10. Since the energy management mode is High, so it is obvious that at Node 1 (device 13, Medium Priority), (device 14, Low Priority), and at Node 2 (device 16, Medium Priority) are deactivated and turned OFF by sending a request for these nodes to turn them OFF. The website is programed to send periodically request for each node to read the statues of each device and that is so important in case if the website is refreshed. It's also reads all the available sensors and graphic them on the website, for example the website display the available power and the demand load, which measured from a node that responsible on measuring these data as shown in Fig.11.

Time and date is displayed at the left top corner of the website, and this will be used as time-stamp to save all the statues, readings, and the events that happen periodically and as required. As mentioned before in section 6 the system use ESP8266 ESP-01 and ESP-12 and according to the building's requirements. Fig.12 shows a prototype for one of the node that measure, display, and send the available power and the load demand of the system. It also used to control the around device as required.

The two LEDs represent two devices for the hardware simulation purpose. The OLED used to display any required data, here it used to display the measure data and local time. Snapshots are taken for the displayed data such as, local time in Fig.13a, power demand in Fig.13b, available power in Fig.13c.

VIII. Result and Discussion

To test the system, some featured devices have been selected as listed in Table.1 with their consumed load in Watt. Device load can be fixed or slightly variable according to its specification and statues, for that the system uses a power sensor, as shown in Fig.14, to measure the instantaneous consumed power for each device. The system mainly supplied with AC power source via three parallel circuit breakers with current rates equals to (3A, 5A, and 8A) only for testing purpose. Every circuit breaker has its own indication which connected to the system via node 3 which is responsible on main consumed power calculation. When the 3 amperes circuit breaker is ON, the system considers the available power is ≈ 528W, same thing with 5A and 8A circuit breakers but the available power will be ≈880W and ≈1408W respectively. These available powers calculated based on eq. 2 with taking into consideration the voltage (V) is 220 V_{AC} and power factor cos(θ) is ≈ 0.8.

$$Active\ Power\ (W) = V * I * \cos(\vartheta) \qquad (2)$$

The system is response perfectly when the available power changed without exceed the rated current of the circuit breaker. Also, we can notice from Table. 2 that, the high priority total load is 320W, the high and medium load together is equal to 770W, and finally the total load is 1780W. So three scenarios should be taken into consideration in the testing. The first scenario when the available power is 528W which is > 320W and < 770W which means that it can keep only the high priority load activated.

The second scenario is when the available power is 880W which is > 770W and < 1780W which means that it can keep both the high and medium priority load activated. The third scenario is when the available power is 1408W which is less than the total load (1780W), so the system will not activate the low priority unless the available power is increased, or the load is decreased less than the expected, or the user change the devices priority.

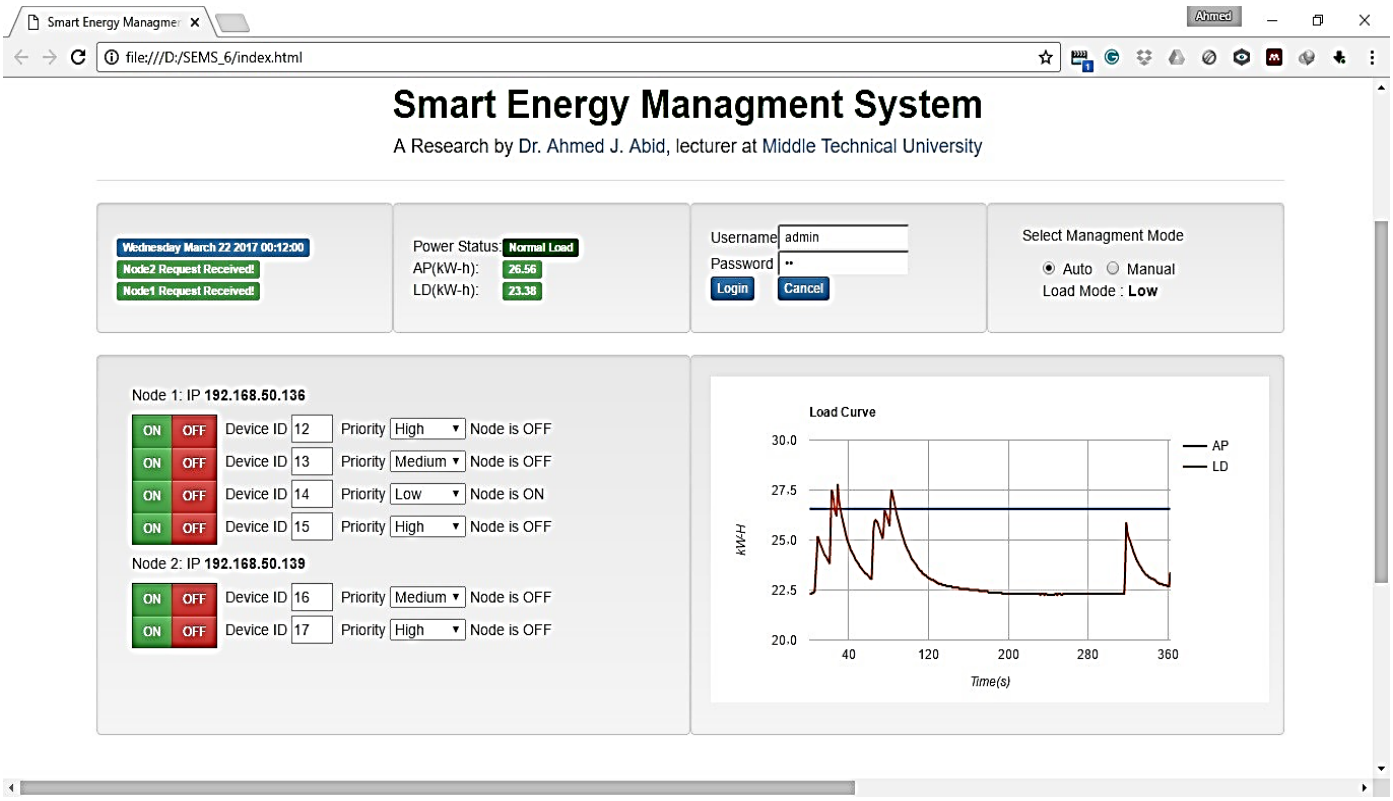


Figure 9: The Designed Website

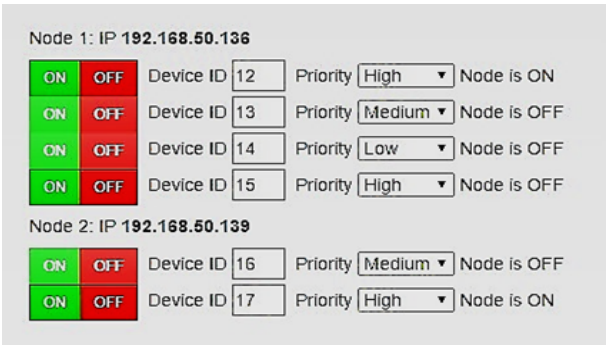


Figure 10: Devices activation response for High Level Manual Mode

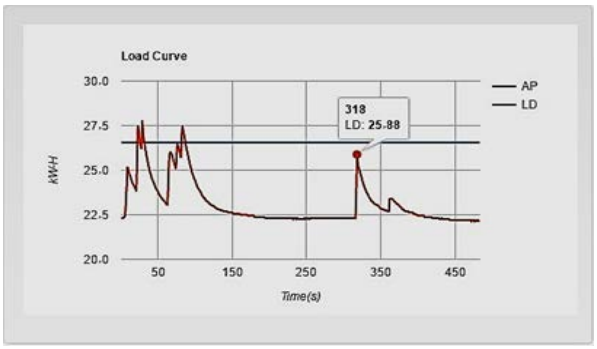


Figure 11: Monitoring of the Available Power and Load Demand

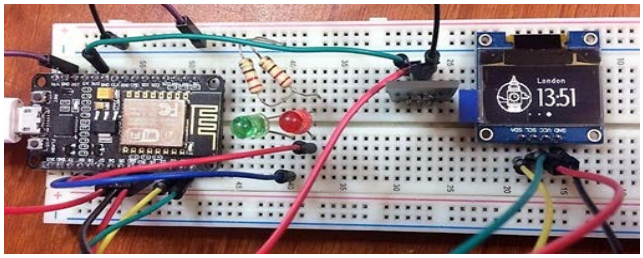


Figure 12: Prototype for ESP8266 ESP-12 Node

(a) (b) (c)

Figure 13: OLED Screen Presentation for Node 2. (a) Local Time, (b) Power Demand, (c) Available Power

Table 1: Selected Devices for Testing Purpose

Device Name	Load (W)	Priority	Node	ID
Ceiling Fan	35	High	1	12
Television	150	Medium	1	13
Iron	1100	Low	1	14
Refrigerator	225	High	1	15
Water pump	300	Medium	2	16
Light bulb	60	High	2	17
Total Load	1870			

Table 2: Load Analysis

Mode	*Load (W)*	*Available Load (W)*
High Priority	320	528
High + Medium Priority	770	880
High + Medium+ Low Priority	1780	1408

Figure 14. AC Power Sensing Device

IX. CONCLUSION

Internet of Energy is how to manage your energy consumption with limited resources without affect the quality of life as much as possible. The proposed system presents a low cost, reliable, efficient way to manage the power consumption for a Wi-Fi covered building with wireless router with a decision-making system based on web design. The system offers fast response to recover the load shading caused by many reasons in the renewable energy source [22], power limited resources, or to save the consumption under a certain level to save the electricity bills.

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