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IOT: Improved Home Energy Control System Based on Consumer Behavior

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***Abstract*— the merge of urbanisation in Indonesia results in a sharp increase in household energy consumption. The increasing household energy consumption is mostly caused by unwanted usage of electrical energy. The purpose of this paper is to design an improved smart home electricity management system based on consumer behavior which will help household occupant to control the usage of electricity automatic using sensor and manual using a smartphone. The sensor used in the system are a motion sensor, temperature sensor, sound sensor, and light sensor also wireless technology is used for controlling electricity outside of the home using a smartphone. The proposed system has multiple benefits of saving electricity bill of the house and keep the owner of the house updated about home security with the ability to control the home appliances and reduce electrical energy consumption.**

Keywords*— *Electrical Management System; IOT, Control System, Smart Home

I. INTRODUCTION

In our lives, electrical energy plays an important role in supporting daily activities. Population growth and technological advances have an impact on increasing energy needs. The application of IOT to smart home energy management systems has developed very quickly and can answer various problems related to energy savings in the household and city environment [1]. The smart home energy management system is used to control various energies such as water, electricity, and gas. This paper will focus on the efficiency of electrical energy in households. Some functions of the smart home energy management system that can be used include monitoring electrical energy, controlling electrical energy automatically and manually, and optimising the use of electrical energy. This paper focuses on the method of controlling the system, the method of implementing sensors and the application of system design as needed. The purpose of this study is to develop the design of implementing smart home system management energy in terms of behavior or habits of occupants based on IOT and are expected to be able to provide solutions in building an optimal smart home electrical management.

II. CURRENT STUDIES

A. Internet of Things

Internet of things is broadly defined by an object or device capable of transmitting data to the internet without the need for interaction from humans. IoT itself consists of several layers or layers. Layers on IoT include perception layer, network layer, a middleware layer, application layer, and business layer. To be able to transmit data via the internet, at least you have radio frequency identification RFID, wireless sensor network (WSN) and cloud computing [2]. IoT can be implemented in various sectors, including smart home, smart traffic-system, smart grid and many more [3].

B. Literature Review

From the studies that have been done by previous researchers regarding energy management in the smart home, many of the researchers conducted different frameworks to get optimal results. Some of them are energy control systems with the utilization of smart power sockets with centralized control functions using zigbee communication protocol [4], minimizing energy use by using wireless smart sockets without using sensors [5], smart home control systems using Coordinator-based Zigbee networking [6], monitoring energy use using distributed optimization algorithm [7], the use of motion sensors for energy savings and security systems in monitoring the entry of residents in the kitchen [8], monitoring energy use and optimizing energy using multi-sensors [9][15], energy control by looking at the amount of energy consumption in each equipment using a smart controller [10], the use of sensors in energy control based on the habits of the occupants of the house [11], a prototype system using a PIC18F458 microcontroller and several sensors in energy control [12], demand and scheduling of electricity supply based on intelligent network conditions, electricity generation capacity and household electricity consumption [13], IoT implementation in homes using lightweight photovoltaic (PV) electrical systems [14], application of smart appliances in determining or choosing energy sources to be used such as PV, Wind Turbine, Grid and Storage Battery [16], Infrared use in controlling equipment and using Zigbee communication systems [17], as well as off-line control of electrical energy in smart homes [18].

This paper proposes the design of a home electrical energy management system, which is based on consumer behavior by integrating microcontroller with several sensors like PIR sensor, light – dependent sensor, sound sensor, and humidity. The designed system will give full control of all home electrical appliances automatic and manually.

C. *The novelty of the Smart Home Energy Management System*

Based on the results of the previous literature review. We will try to develop a framework that has been done before by implementing four sensors, two device control systems, and a control system based on occupant activities. The implementation of the framework will be tested using building prototype design and determining the use of different sensors on each device according to the function of the room and its effectiveness.

III. Purpose Home Energy Management System

The purpose of implementing IoT on smart home electrical management is to help increase the effectiveness of energy use, especially electrical energy. But to build an IoT-based smart home energy management system, several main points must be considered including the hardware used, the different architectural designs for each building, and what type of control will be implemented in the system as well as the electrical installation.

A. *Hardware parts*

- *Microcontroller:* In the process of building an energy saving system, Arduino Microcontroller will be used. The function of the Arduino microcontroller itself is as the center of control and processing of analog data from the captured sensor. In the energy saving system which will later be built, a microcontroller will be placed in a position close to other electrical control panels in the house.
- *Sensor:* In implementing the energy saving system, sensors that will be used on a device are determined based on their usefulness and the location of the sensor itself. The following are some of the sensors used:
    - *PIR sensor*: The PIR sensor works by reading the movements of an object based on a certain range of distances [19]. The range of motion readings from an object that can be captured by the PIR KC7783R sensor [20]. Based on the distance range of the motion sensor used, determining the position of the sensor placement in building a system to save electricity must be able to reach every corner of the room.
    - *Light-dependent sensor (LDR):* The Light Sensor or LDR sensor works based on the amount of light received. In this paper, light sensors are used to control outdoor lights [19].
    - *Sound sensor:* The sound sensor works to capture sound signals and forward data to the microcontroller. The function of the sound sensor in this paper aims to control the bedroom lights.
    - *Humidity sensor:* Temperature sensors or Humidity sensors are used to see changes in temperature or room temperature. In its application, the temperature sensor is used in the bedroom to control the air conditioning (AC) device.
- *Relay:* Relays are scalars or electrical switches. Relays can replace currents up to 10 Amps at 30 V DC or 220 V AC. In this paper, the relay plays an important role as an electrical switch that can be operated with a logic function and will be connected to any home electronic device with 220V voltage.

B. *The methodology of Smart Home Electrical Management System*

The following are the methods that will be used in implementing the Smart Home Electrical Management System:

- The design of the system to be built is based on the extent and function of the room for determining the use of a suitable sensor, the electrical installation used to determine the position of the micro-controller board and the design of the SHEMS architecture and the control function of each device. System control is based on occupants' habits by utilising automated systems and manual control. A controlling system can be done using a smartphone application connected via iCloud [2].
- System control is automatically carried out using sensors that are connected to each device.

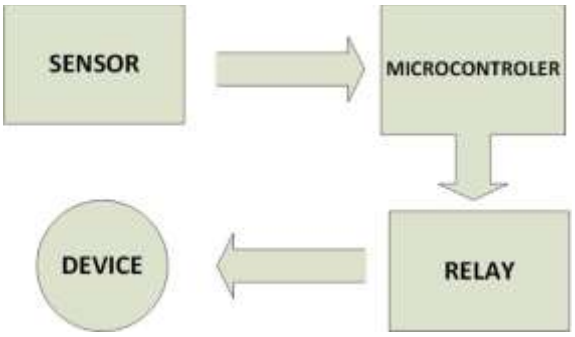

Figure 1: Automatic control system

The system will receive Sensor and microcontroller reading data to determine the condition value. When the system receives analog data sent by the sensor according to the value of the specified condition, the device will automatically ON / OFF.

- Manually controlling the system by using a smartphone as a remote device.

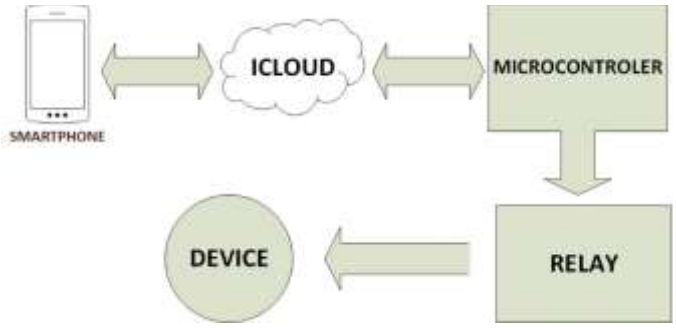

Figure 2: Manual control system

- Controlling the system can be selected according to the user's wishes based on activity mode.

  In the system control function, there are three modes used to control home appliances. The first is a "sleep" mode. The working mechanism of the system in sleep mode is as follows: every equipment in the bedroom such as Lamp KT-1, Lamp KT-2, Lamp KT-3, AC KT-1, AC KT-3, AC KT-3 will turn off and automat function the system also won't work other than on the porch lights. The second is the "Leaving Home" mode. The mechanism of the system in leaving home mode is as follows: all electronic equipment in the house will die except certain electronic equipment that does require electricity to stay alive, for example, a refrigerator. The installation of the electricity network in this mode must be made separately. So that when leaving home mode, the system control line only works on the specified path. For the distribution of electrical installation lines that use SHEMS controls and those that do not use SHEMS control can be seen in figure 5. The third is the "Day" mode. The working mechanism of the system in Day mode is as follows: occupants can control every home appliance that uses the SHEMS control function through two control functions namely manually control by using the smartphone as a system control panel and control function automatically by utilising the role of the sensor installed on each home appliance according to their respective functions. Examples of applying the "Day" mode: Lamp KT-1, Lamp KT-2, Lamp KT-3 Lamp KT-1, Lamp RT-1 can be manually controlled, and the sensor automaton function will still work. For example, lamp KT-1 gets an ON command from the Smartphone control panel, and the light will turn on. When the lamp gets an OFF command from the Smartphone control panel and the motion sensor on the lamp reads the movement of the lamp will also automatically turn on. For how multi-control works can be seen in figure 6.

IV. Interfacing of Control System

This paper will use a 9m x 8m building prototype by applying four sensors as an automation system and an alternative manual control device. The process of implementing sensors in each room can be seen in Figure 4. In Figure 5 is the Design Architecture System where each sensor has a role in carrying out the relay function as a switch to each device, and for manual functions, the control system will take orders from smartphones connected to the microcontroller to execute commands to each relay connected to each device in the house.

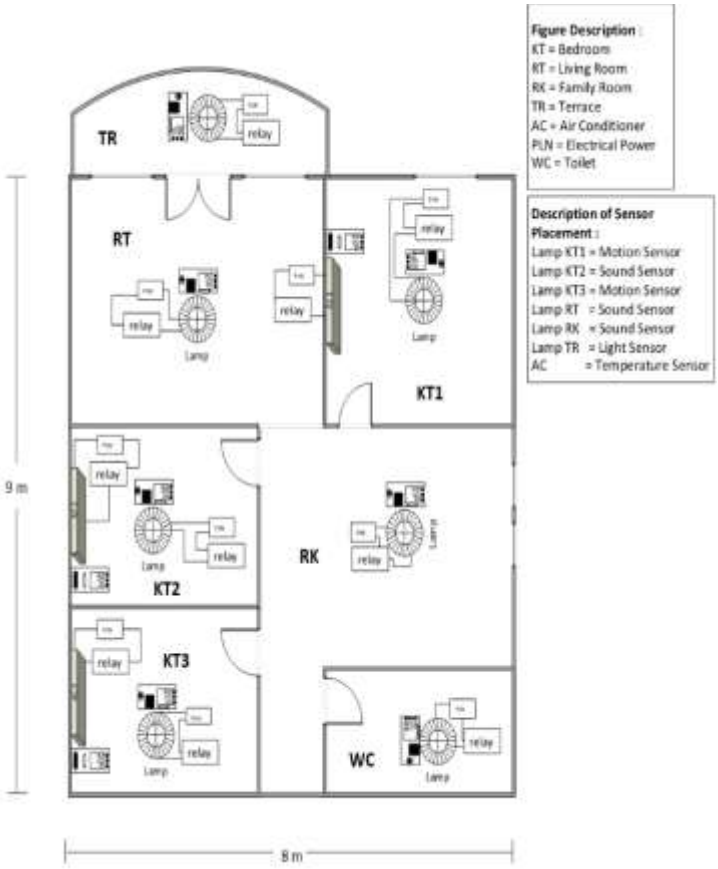

Figure 4: House plan and sensor implementation

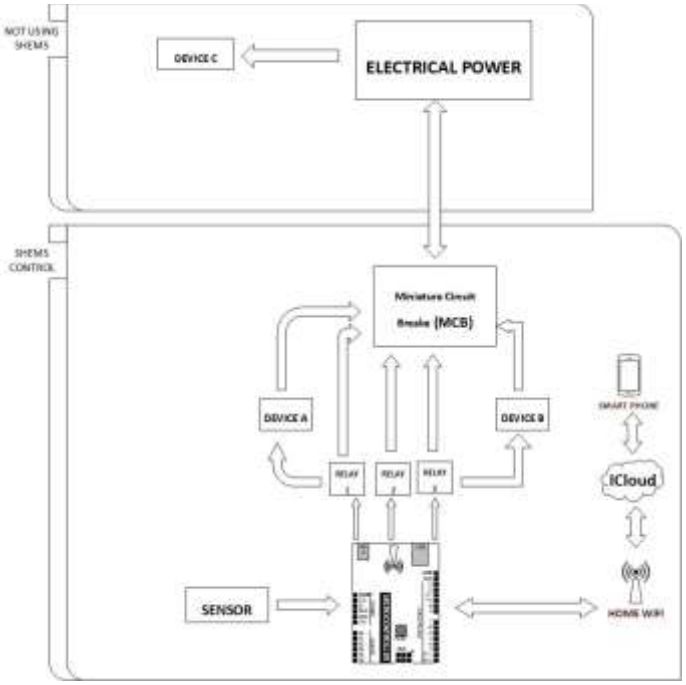

Figure 5: Architecture System Design

V. Result and Discussion

In this section will be explained about the work process system on a home prototype. In Figure 5, the function of the sensor used as an automation system and the application of manual control as an alternative control, while in the actual application of the building prototype there are 6 rooms with three bedrooms, one living room, one family room, and one bathroom. In the building prototype, the implementation of the sensor is based on the needs and habits of the occupants of the house. In the living room and family room, the sensor used is a sound sensor. The reason for the use of sound sensors in the living room and family room is based on the traffic factor movement of the occupants of the house. If applied using other sensors, for example, motion sensors, it is considered not optimal. Because if in the space where the traffic of the occupants is high, the lights will automatically turn on continuously by the movements that are read. If the lights keep burning when there is a movement, the power of the electrical energy consumed will be even greater. So the implementation of a sound sensor makes it possible to apply it to spaces where traffic is high. In this case, the sound sensor is placed to control the lights in the living room and family room.

The implementation of sensors in the bedroom depends on the comfort or habits of the occupants of the house. In prototypes, in bedrooms, one and three are used motion sensors, while bedrooms two are used sound sensors. Two different sensors applied to three bedrooms are based on the needs of the occupants of the house. In this case, for example, there is one room from the homeowner who wants the room lights to stay on according to the habit of sleeping without turning off the lights. As easy as in the other two rooms, the motion sensor will work when it detects movement. Another condition is that if the sensor does not get movement or occupy the room in the sleeping room, the system will automatically turn off the room's lights. For the AC sensor used is a temperature sensor where the system will turn on the air conditioner if the temperature in the room reaches the level of the boundary settings that the occupants of the house want. The sensor used for outdoor lights is a light sensor that will automatically turn on when the amount of light received by the sensor is small.

The alternative control function used is a manual control system. The process of combining the two control systems uses a dual switch model where the system will perform the ON switch function on the relay if one of the command conditions in the system automation or the manual system instructs the ON function on the device. Table III and figure 6 is an example of applying the OR function to a dual control switch:

TABLE I. Double Switch Logic With OR Function

Automat	Manual	Device
0	0	OFF
0	1	ON
1	0	ON
1	1	ON

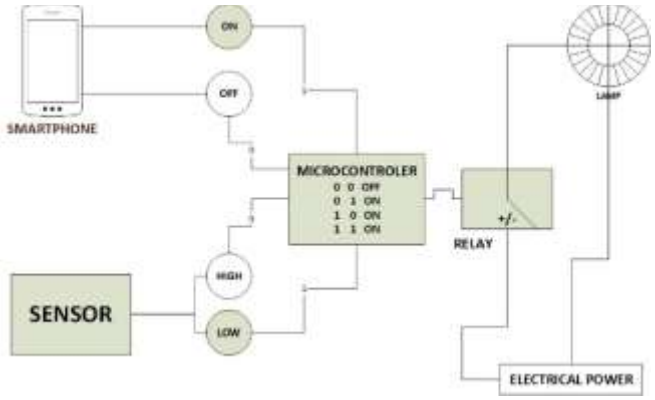

Figure 6: Single home appliances with two control functions

In this paper, the operation of the system also uses "Mode". An example of one way of working "Leaving Home Mode" can be seen in Figure 5. In the picture relay, two will automatically run the switch OFF function when Leaving Home Mode is turned on. Relay 2 will decide all the electricity flow of each device in the house except for certain devices whose electrical installation lines are made separate because of the reason for the electricity needs 24 hours. For relay 3 has a role as a switch to manually control every other device that does not use the system automation.

Figure 7: Smart Phone Application Prototype design

Figure 7 is a prototype design application for smartphones. The start page is the login page. The second page is an automatic control page with the function "mode", and the choice of rooms to be controlled manually. The last page is a manual control page for each device in the selected room.

VI. Conclusion

In this paper, the architectures of smart home energy management system are presented and explained in term of structure, communication between the main component of the system and technology used. The use of multi-sensor in the design of this system gives the system the ability to control home appliances automatic or manually. With this in hand, the home occupant now is capable of controlling home appliances and save the consumption of electrical energy. The proposed framework can be expanded to consist of more than one house regardless of the size and number of the home appliance to be controlled.

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