DESIGN AND IMPLEMENTATION OF MACHINE LEARNING BASED SMART BUILDING ENERGY MANAGEMENT SYSTEM

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***Abstract*- Energy is that the lifeblood of modern societies. The system uses Internet of Things (IOT) devices to collect real-time data on energy usage and machine learning algorithms to predict future consumption patterns. It proposes the use of Convolution neural networks (CNN) for the design and implementation of a smart home energy management system using IOT and machine learning techniques. This project work aims to develop a machine learning model, method, architecture or appliance to reduce building energy use and emissions using a smart sensor for residential or commercial buildings. An experienced operator can do a good job of adjusting set points and schedule. But no matter how good they are, a human's ability is restricted by the amount of knowledge he or she can process. The system is implemented with a real-time monitoring system and a user interface for remote access. The proposed system has the potential to save energy and reduce energy costs for households while providing real-time feedback to the user. These can be used to accurately estimate the number of occupants in each room using machine learning techniques and this technique can be used to predict future occupancy.**

***Index Terms*: Voltage, Current, IR (Infrared) Sensor, LDR (Light Dependent Resistor) Sensor, Prediction, CNN Algorithm, Raspberry Pi, Temperature, Smart Building, PC (Personal Com- puter), Data Base, Data Analysis.**

I. INTRODUCTION

Smart home energy efficiency improves sustainability, lowers overall carbon footprint, and saves money. Thus, the requirement for intelligent energy management is increasing for both smart homes and smart cities overall. But the absence of inexpensive, simple-to-install, and low- maintenance technologies has partially precluded a large-scale the implementation of such systems. Machine learning based smart energy management system is an innovative approach to reduce energy consumption and improve energy efficiency in residential buildings. This system combines the power of the Internet of Things (IOT) and machine learning to optimize energy usage by monitoring and controlling various electrical devices. The Smart Energy Management System provides several benefits, including reducing energy bills, increasing energy efficiency, and reducing carbon footprint. The system also provides a user-friendly interface that allows users to control their energy consumption and make informed decisions about energy usage based on real-time data.

II. LITERATURE SURVEY

The following papers helped us in choosing the right set of sensors and modules for implementing our proposed model.

[1] Usama Mir, Ubaidt Abbasi, Talha Mir, Summrina Kanwal and Sultan Alamri, In this paper, Energy plays a pivotal role for economic development of a country. A reliable energy source is needed to improve the living standards of people. To achieve such a goal, governments and industries are trying to install a new energy infrastructure called the "Smart Grid". This helps to manage the electricity generation and distribution in an efficient manner. Buildings and other structures are the biggest consumers of electricity. There is a need to reduce the energy consumption so that the resources can be utilized efficiently. Therefore, in this paper, we give a comprehensive state-of-the-art on various recent techniques and solutions which provide energy savings in smart homes and buildings. This includes statistical models, cloud computing based solutions, fog computing and smart metering based architectures, and several other IOT (internet of things) inspired solutions.

[2] R.Mathumitha, Dr.K.Manimala, In this paper, Excessive domestic energy usage is an impediment towards energy efficiency. Developing countries are expected to witness an unprecedented rise in domestic electricity in the forthcoming decades. A large amount of research has been directed towards behavioural change for energy efficiency. Emission of greenhouse gases including CO2 in higher layers of the atmosphere are known as the main cause of global warming phenomena. The attempt to decrease the amount of green- house gases needs significant alteration in human behavior in energy consumption, manufacturing of more environmental friendly products and identifying and mitigating the causes of these undesirable gases. In traditional buildings, households are responsible for continuously monitoring and controlling the installed Heating, Ventilation, and Air Conditioning (HVAC) system. Nowadays, smart buildings are automating this process by automatically tuning HVAC systems according to user preferences in order to improve user satisfaction and optimize energy consumption.
[3] Chrysi K. Metallidout, Kostas E. Psannis, Eugenia Alexandropoulou Egyptiadou, In this paper, The Internet of Energy (IOE) impacts on smart cities' power sector. IOE is an implementation of the Internet of Things technology (IOT) into distributed energy systems and aims to achieve energy efficiency, to avoid energy wasting, and improve environmental conditions. IOE technology includes, among others, utilizing smart sensors and renewable energy integration. Therefore, the IOE is becoming a legal science tool to serve the purpose of a smart city. In this paper, we refer to the reasons that led the European Union to compile Regulations for facilitating transformation of existing cities, starting from existing buildings, into smart buildings. We propose a smart building template that manages the performance of all technical systems through IOT technology with the view of achieving energy efficiency. In addition, in order to improve the certification of existing buildings, as for energy performance, we propose an automated remote, control method supported by cloud interface. This method minimizes time consuming procedures and stores, on a cloud platform the energy performance of each building, for the purpose of drawing conclusion and applying measures
[4] Emmanuel Luj´an, Alejandro Otero, Sebasti´an Valen- zuela, Esteban Mocskos, Luiz Angelo Steffenel and Sergio Nesmachnow, In this paper, describes the Cloud Computing for Smart Energy Management (CC-SEM) project, a research effort focused on building an integrated platform for smart monitoring, controlling, and planning energy consumption and generation in urban scenarios. The project integrates cutting-edge technologies (Big Data analysis, computational intelligence, Internet of Things, High Performance Comput- ing and Cloud Computing), specific hardware for energy monitoring/controlling built within the project and explores their communication. The proposed platform considers the point of view of both citizens and administrators, providing a set of tools for controlling home devices (for end users), planning/simulating scenarios of energy generation (for energy companies and administrators), and shows some advances in communication infrastructure for transmitting the generated data
[5] Alfonso Capozzoli, Marco Savino Piscitelli, Silvio Brandi, Daniele Grassi, Gianfranco Chicco, In this paper,The energy management of buildings currently offers a powerful opportunity to enhance energy efficiency and reduce the mis- match between the actual and expected energy demand, which is often due to an anomalous operation of the equipment and control systems. In this context, the characterization of energy consumption patterns over time is of fundamental importance. This paper proposes a novel methodology for the characteri- zation of energy time series in buildings and the identification of infrequent and unexpected energy patterns. The process is based on an enhanced Symbolic Aggregate approximation (SAX) process, The methodology has been tested on the whole electrical load of buildings for two case studies, and its flexibility and robustness have been confirmed. In order to demonstrate the implications for a preliminary diagnosis, some unexpected trends of the total electrical load have also been discussed in a post-mining phase, using additional datasets related to heating and cooling electrical energy needs.

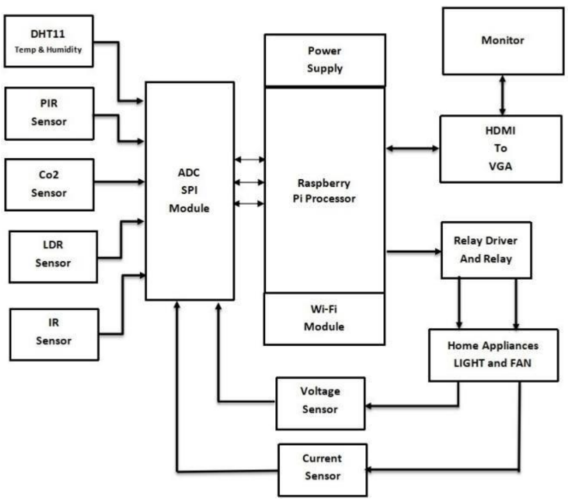


Fig. 1. **Block Diagram of the System**

III. PROPOSED MODEL

The proposed system in this design work is represented in Fig.1, which is shown above with various blocks numbered as follows

Block 1 DTH11 Sensor, is a sensor which used to measure the temperature and humidity of a particular region or object. Block 2 PIR Sensor, that uses infrared light to detect the movement of things, such as people or animals.

Block 3 MQ-2 Sensor, is a sensor monitors the quantity of gases in the air, such as LPG or smoke.

Block 4 LDR Sensor is a type of resistor where the resistance changes in response to the quantity of light hitting its surface. Block 5 IR Sensor, a device that monitors or detects infrared radiation from nearby objects.

Block 6 ADC SPI Module, an electrical integrated circuit that transforms analog signals, such voltages, into binary or digital form, which consists of 1s and 0s.

Block 7 Power Supply, An electrical equipment that provides electricity to an electrical load is called a power supply. A power supply's primary function is to transform electric current from a source into the proper voltage, current, and frequency so that the load may be powered.

Block 8 Raspberry Pi, contained on a single circuit board using ports and general purpose input/output pins that let you experiment with the Internet of Things (IOT) and control electrical components for physical computing.

Block 9 WiFi Module, Microchips with complete TCP/IP stack and micro-controller functionality are utilized in embedded Internet of things applications development.

Block 10 Voltage Sensor, An object's voltage levels can be calculated and tracked using a voltage sensor.

Block 11 Current Sensor, instrument intended to measure and identify electric current passing through a circuit or a wire. Block 12 Home Appliances, device that helps with chores around the house like Light, fan to predict the power usage. Block 13 Relay driver and Relay, simplest electro mechanical switch. A relay does the same thing as a standard switch only it utilizes an electrical signal to operate an electromagnet instead of a manual switch. Another circuit is connected or disconnected by this magnetic in turn.

Block 14 HDMI to VGA Converter, cheaper cable that connects an HDMI signal from a computer to a VGA connection on an older display.

Block 15 PC, is a multi-purpose microcomputer designed to be operated directly by the end user. It's used to monitor the results get by the designed system as a database and data analysis.

IV. WORKING

The entire operation of the proposed system can be broken down into the following modules

a) Voltage Sensor connected with ADC SPI Module is used to monitor, calculate and determine the voltage supply.

b) Current Sensor is connected with ADC SPI Module is used to measure the flow of electric current and based on their usage.

c) Step-down Transformer is connected with the power supply board to reduce the voltage of an Ac power supply.

d) DTH 11 Sensor is connected with ADC SPI Module to measure the Temperature and Humidity.

e) PIR Sensor is connected with ADC SPI Module to find the ideal of detecting the human presence.

f) MQ2 gas Sensor is connected with ADC SPI Module to detect the gas leaks and prevent potential hazards.

g) LDR Sensor is connected with ADC SPI Module to indicate the presence or absence of light and to measure the light intensity.

h) IR Sensor is connected with ADC SPI Module to detect and measure the presence of an object in a given area.

i) ADC SPI Module is connected with the Raspberry Pi 3 to convert the continuous voltage value (Analog) to binary value (Digital).

j) Raspberry Pi processor is connected with the WiFi module to transmit WiFi signals to PC and power supply to convert electric current from a source to the correct voltage, current, and frequency to power the load.

k) Both the Voltage and Current Sensor is connected with the Home Appliances to get the desired output.

l) Relays connected with raspberry pi and home appliances is used to protect the electrical system and to minimize the damage to the equipment connected in the system due to over currents/voltages.

m) HDMI to VGA converter connected with Raspberry Pi is used to convert Digital signal (HDMI) to Analog signal (VGA) to the monitor to display the outputs.

n) We can get the desired outputs by VNC Viewer a remote access software to our PC (Personal Laptop) to avoid the connectivity of HDMI to VGA Converter. Now the outputs receiving from all sensors will be displayed in the Personal Computer as data base and also as data analysis for current and voltage usage in the different seasons. This is how the entire system works.

Figure 2 depicts the proposed system's flowchart. The flowchart begins when the system gets on all the sensors that are implemented in the design will starting detecting and sends the data to the Raspberry Pi Platform using the CNN Machine learning Algorithm from the Home appliances. The measured outputs will display to PC through a VNC viewer to receive the monitored data as data base and data analysis with power usage of the both current and voltage in different seasons.

V. COMPONENTS SPECIFICATION

A. Raspberry Pi 3b+

The Raspberry Pi is a credit card-sized computer that can link to a wide range of sensors and modules, including LCD screens, servos, and motors. It is a low-cost, low-power single-board computer the size of a credit card.

B. AC Voltage Sensor

A voltage sensor is a type of sensor that is used to measure and track an object's voltage. This sensor takes voltage as its input and outputs switches, analog voltage, current, or audio signals for output.

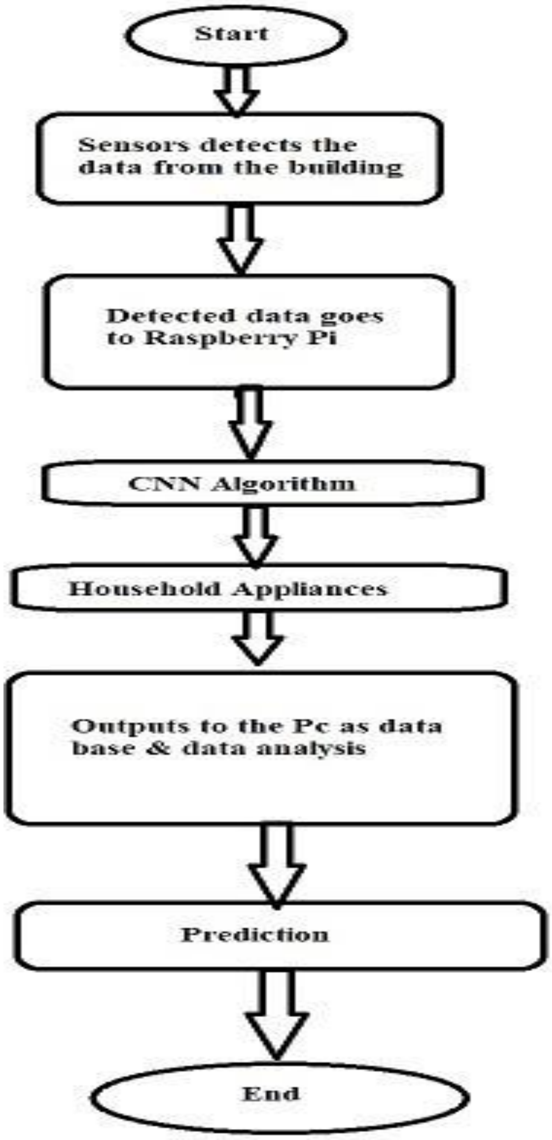


Fig. 2. **Flow chart of the system**

C. DTH11 Sensor

DTH11 Sensor is a low cost sensor which is used to measure the temperature and humidity of the surroundings.

D. Current Sensor

The current sensor monitors and converts current to provide an output voltage in intended area.

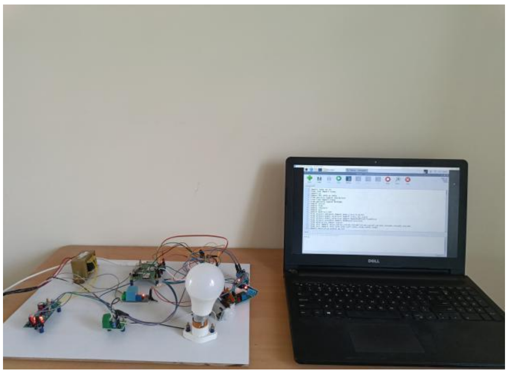


Fig. 3. **Entire Setup of the System**

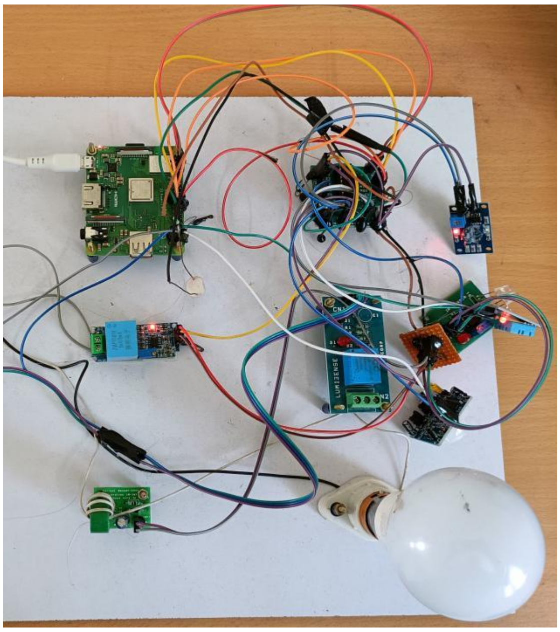


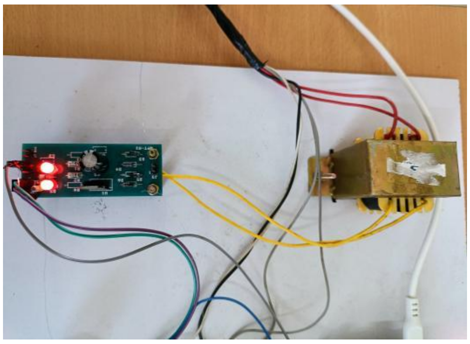
Fig. 4. **Interfacing Raspberry Pi with voltage, Current, LDR, IR, MQ-2 and PIR Sensors**

E. ***IR (Infrared) Sensor***

An IR sensor is a basic electrical equipment that produces and detects infrared radiation in order to locate specific items or barriers within its range.

F. ***LDR (Light Dependent Resistor) Sensor***

It is a device designed to detect light. It has a (changing) resistance that changes depending on the amount of light falling on it. They are used in numerous consumer items to measure light intensity.



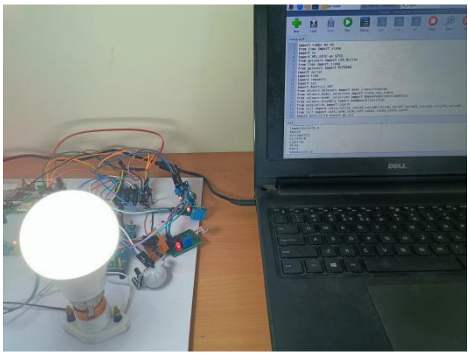


Fig. 5. **Interfacing Transformer With Power Supply**

Fig. 6. **Sending Sensors Data to Raspberry Pi OS Platform**

G. ***MQ-2 Gas Sensor***

An electrical sensor intended to measure the airborne concentrations of different gases.

H. PIR (Passive Infrared) Sensor

A device that uses infrared radiation from hot things to detect motion and heat. PIR sensors are used for things like turning on cameras or lights when someone walks into a room.

I. Step-down Transformer

Step-down transformers are used to join transmission networks with varying voltages. They reduce the voltage level from high to lower value.

J. Two Relay Board

A relay board is a computer board featuring a variety of relays and switches. These boards have input and output terminals and are intended to control voltage supply.

K. WiFi Module

A device that is a fully integrated wireless communications product. It has an application host processor and a WiFi chip, which allow for WiFi transmission and receiving. It is capable of broadcasting WiFi signals to smart devices, like phones and laptops, by plugging into a network. It is employed in the creation of Internet of Things (IOT) end-point applications.

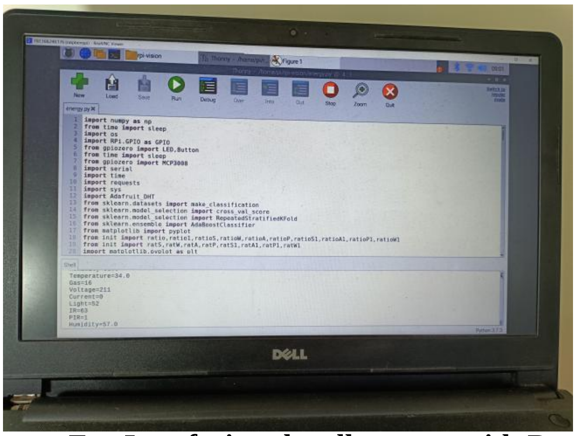


Fig. 7. **Outputs For Interfacing the all sensors with Raspberry Pi**

L. (ADC) Analog to Digital Converter

A circuit known as an analog to digital converter transforms an analog continuous voltage value into a digital binary value that can be interpreted by a digital device and utilized for digital computation. Analog (continuous, infinitely variable) signals are converted to digital (discrete-time, discrete- amplitude) signals by use of ADC. Converting conditioned analog signals into a stream of digital data so that the data acquisition system can process them for display, storage, and analysis is the primary function of the ADC inside a data acquisition system. ADC facilitate communication between digital logic circuits such as Arduino, Raspberry Pi, and circuits controlled by microprocessors and the outside world.

M. HDMI to VGA Converter

The device lets users convert a VGA signal from an HDMI stream. It is used to link VGA displays—including older monitors or projectors—that lack HDMI inputs to HDMI devices, like laptops, game consoles, or media players. By acting as a link between the various video format, the adapter enables smooth device interoperability. Moreover, an integrated chip set that transforms the digital HDMI stream into an analog VGA signal is included.

N. Power Supply Board

A power supply board is a circuit board that retains the power supplied via sub circuits. It is the source of power or battery for the systems of any electronic device and circuit board.

O. Personal Computer(PC)

PC were used to show the monitored values in both data base and data analysis.

Fig. 8. **Outputs of Data base and data analysis for current and voltage usage in the different seasons**

VI. RESULT ANALYSIS

This project mainly focused on reducing the usage of energy, predicting future consumption and automating the building. The significant part of making a building smart is that we can reduce the overheads and rectify an issue so that it doesn't occur again. It becomes tedious to solve the problems that are repetitive and this can save human labor and also guesswork can be avoided. Sensors are essential to monitor each system and collect data. This data help us to decide the allocation of resources and energy lost in every room. This Smart Building Management system is created by using IOT and Machine learning.

VII. FUTURE SCOPE

As this system designed for the current and voltage prediction in a day to manage the energy of the household appliances as a smart building system, it cannot store all the monitored data in PC. May be in future we should find solution to store all the monitored values as a data sheet records to know the variations.

VIII. CONCLUSION

In our Proposed system, we are using the voltage and current sensors to predict the usage in the building, Temperature, Gas, IR, PIR, LDR sensors are also act as a smart system for a smart building. The trained model is obtained from the input features with tuned CNN parameters. Based on the data analysis, the daily routine and occupancy pattern of a building is known. This is helpful for Predicting the buildings by finding the voltage and current used in a day and control of electrical appliances in building using relay, switches in future. As a smart system management it also detects the Temperature, Humidity, light intensity, human presence and absence, gas leaks and presence of an object in the area. Thus our smart building saves energy automatically without human intervention.

IX. ACKNOWLEDGMENT

I want to honor my Companion, Prof J L Mazher Iqbal, challenges. His patient sweats forced me to revise this design. I would like to express my gratitude to my institute, Vel Tech Rangarajan Dr.Sagunthala R and D Institute Of Science and Technology (Deemed to be University), for giving me the opportunity to work on the design.

REFERENCES:

1. Mir, Usama, et al. "Energy management in smart buildings and homes: current approaches, a hypothetical solution, and open issues and chal- lenges." IEEE Access 9 (2021): 94132-94148.
2. Mazlan, N., et al. "A smart building energy management using internet of things (IoT) and machine learning." Test. Eng. Manag 83 (2020): 8083-8090.
3. Metallidou, Chrysi K., Kostas E. Psannis, and Eugenia Alexandropoulou Egyptiadou. "Energy efficiency in smart buildings: IoT approaches." IEEE Access 8 (2020): 63679-63699.
4. Luj´an, Emmanuel, et al. "Cloud computing for smart energy manage- ment (CC-SEM project)." Smart Cities: First Ibero-American Congress, ICSC-CITIES 2018, Soria, Spain, September 26–27, 2018, Revised Selected Papers 1. Springer International Publishing, 2019.
5. Capozzoli, Alfonso, et al. "Automated load pattern learning and anomaly detection for enhancing energy management in smart buildings." Energy 157 (2018): 336-352.
6. Pathak, Nilavra, et al. "Forecasting gas usage for big buildings using generalized additive models and deep learning." 2018 IEEE International Conference on Smart Computing (SMARTCOMP). IEEE, 2018
7. Javaid, Nadeem, et al. "A survey of home energy management systems in future smart grid communications." 2013 eighth international conference on broadband and wireless computing, communication and applications.

IEEE, 2013.

8. Casado-Vara, Roberto, et al. ”Improving temperature control in smart buildings based in IoT network slicing technique.” 2019 IEEE Global communications conference (GLOBECOM). IEEE, 2019.
9. Jahn, Marco, et al. ”The energy aware smart home.” 2010 5th interna- tional conference on future information technology. IEEE, 2010.
10. Alves, An´ıbal A., et al. ”Development of an internet of things system for smart home hvac monitoring and control.” Sustainable Energy for Smart Cities: First EAI International Conference, SESC 2019, Braga, Portugal, December 4–6, 2019, Proceedings 1. Springer International Publishing, 2020.
11. Deligiannis, Paraskevas, Stelios Koutroubinas, and George Koronias. ”Predicting energy consumption through machine learning using a smart- metering architecture.” IEEE Potentials 38.2 (2019): 29-34.
12. Basit, Abdul, Guftaar Ahmad Sardar Sidhu, Anzar Mahmood, and Feifei Gao. ”Efficient and autonomous energy management techniques for the future smart homes.” IEEE Transactions on Smart Grid 8, no. 2 (2015): 917-926.
13. Ungku Amirulddin, U. A., et al. ”Development of a WiFi smart socket and mobile application for energy consumption monitoring.” Advances in Electronics Engineering: Proceedings of the ICCEE 2019, Kuala Lumpur, Malaysia. Springer Singapore, 2020.
14. Mourshed, Muhammad Waseem Ahmad Monjur. ”Building energy me- tering and environmental monitoring.” Pulse 125.185 (2016): 150-265.
15. Zhang, Xiangyu, Manisa Pipattanasomporn, Tao Chen, and Saifur Rahman. ”An IoT-based thermal model learning framework for smart buildings.” IEEE Internet of Things Journal 7, no. 1 (2019): 518-527.