Journal of Engineering Science and Technology
Special Issue on SIET2022, May (2022) 185 - 195

ELECTRICITY OPTIMIZATION OF VENDING MACHINE WITH AUTOMATED RELAY AND ARTIFICIAL INTELLIGENT FOR SMART RETAILING ON INTERNET OF EVERYTHING

GABRIEL YOSUA RANTUNG*, ALVIN YAP CHEE WEI,
SIVA KUMAR SIVANESAN, KRISHNA RAVINCHANDRA

School of Engineering, Asia Pacific University of
Technology and Innovation, Kuala Lumpur, Malaysia
*Corresponding Author: tp047204@mail.apu.edu.my

Abstract

Modern vending machines are designed to meet the consumer's need for quick access to everyday commodities such as food, beverages, and books. Automation is used to carry out purchasing operations such as item selection, payment, and item distribution without the involvement of a human, and this may be done 24 hours a day, seven days a week. Nevertheless, vending machines run continuously and consume the same amount of electricity whether there is a transaction. Although improvements in various sectors during the Industrial Revolution 4.0 (IR4.0), the electrical power of vending machines has yet to be optimised. This study intends to reduce vending machine power consumption by utilizing a camera to identify humans around the vending machine and relays to limit power consumption. Artificial Intelligence (AI) can recognize humans through camera, and this is the Smart Relay's input. Abnormalities such as electrical leakage that consumes more energy can also be discovered. Monitoring is vital for vending operators; therefore, an IoE dashboard is designed to allow monitoring of power utilization and other features. This technique can save up to 50% of a vending machine's electrical power consumption and has low energy waste while retaining the vending machine's capabilities.

Keywords: Artificial intelligence, Internet of everything, Optimization, Smart retailing, Vending machine.

1. Introduction

Vending machines are a contemporary method of selling that includes a detailed automated mechanism from payment to item being given to the client. The vending machine was invented in Alexandria, Ancient Egypt, around 215 BC to dispense holy water in exchange for money [1]. As the world industry progresses to the fourth industrial revolution, or IR4.0, vending machines have accepted this idea by embedding vending machines with IoT, cloud computing, Al, mobile payment, and FinTech, transforming current vending machines into smart vending machines. To execute these functions, a smart vending machine requires electricity to run 24 hours a day, seven days a week.

The operator may use the IoE dashboard to monitor power use, forecast future energy usage based on previously recorded data, and examine the machine electrical part when a power leakage is discovered. This project prioritizes the Internet of Everything (IoE) paradigm over the Internet of Things (IoT) paradigm because the IoE paradigm leverages the IoT. Whereas the IoT is concerned with connecting physical devices collectively, the IoE seeks to enable everything to communicate with just about everything, including both human and computer connections. [2].

2. Literature Review

2.1. Energy optimization relay

A relay is an important element in electrical component circuits for switching and protection. A relay responds to voltage and current to open or close a contact in a circuitry connection. [3] suggested energy optimization by optimizing power grid Energy Efficiency (EE) over many timeslots utilizing Decode-and-Forward (DF) relay nodes. The prototype's purpose is to effectively manage unpredictable arrivals of energy on non-ideal circuit power to enhance energy efficiency. This is accomplished by merging all power allocation on the power source and relay with the sleep mode requirement. The suggested approach employs a source, a DF relay, and a destination, with the source drawing energy from the power grid and the relay harvesting energy from the ambient environment. The input-output channel relationship of the DF relay is stated for the i^{th} timeslot as:

$$Y_{SR}(i) = \sqrt{h_{SR}P_{s,t}(i)x_s(i) + n_R(i)} \quad (1)$$

whereby $i = 1\ldots, N$, $Y_{SR}(i)$ is the signals at the relay, the source-relay power gain channel is denoted by h_{SR}, the transmission power of the source is denoted by $P_{s,t}(i)$, $x_s(i)$ is the signals transmitted from the source, and $n_R(i)$ are additive noises at the relay. The suggested approach distinguishes between active and sleep modes, whereby when the relay gets a signal from the source, it activates active power consumption and when it does not, it enters sleep mode. The EE of this was also enhanced due to the greatest utilisation of the various timeslots via the DF relay.

Nahas et al. [4] proposed a Smart Power-Voltage Relay (SPV-Relay) based on localised measurements to safeguard DC microgrids utilising the rate of power (*dP*) and rate of voltage (*dP*) mapped in the *dP-dV* profile. The suggested voltage-power relationship with the load analogy is characterised as follows, independent of the source:

$$P = K \times V^{\propto} \quad (2)$$

where K represents the constant and $V^{\propto}$ represents the voltage sensitivity parameter. For the constant power source, regardless of voltage, the parameter will always be 0. The suggested system was tested using a variety of power sources, including stored battery power. As a consequence of the low number of controlled energy switches, this system can increase electric service resiliency, improve service dependability, and cut costs by 50%.

Ershova et al. [5] conducted another relay power efficiency study with the goal of developing the long-term vegetable storage microclimate facility that utilises little power. It is critical to maintain parameters such as temperature, water level, evaporation index, and in and out air to ensure that agricultural goods remain fresh throughout storage. The prototype was tested for 24 hours during a 72-hour period, with the power switching of the relays controlling the storage facility settings. Although the 24-hour testing was regarded effective in getting the system to run, it is advised that extended periods of testing be undertaken to analyse the overall system's dependability. Further research into the long-period activation control of the relay is also recommended in order to meet the specifications of an industrial-readiness system.

2.2. The internet of everything control system

The most common use of IoT is to leverage on obtaining the identification of surroundings and items in human lives via the internet. Despite the complexity of the IoT setting, the IoE paradigm improves IoT by transcending the idea of 'thing' [2]. This is due to the IoE's goal of allowing everything to connect with everything, including human-machine communication, which poses additional hurdles in terms of data interchange volume for control. There are several real-world instances in which IoE may make human existence simpler. Lv and Kumar [6] presented a dual-channeling architecture defined by wireless sensor software on IoE in sensor wireless control. The sensor's data is analyzed using fog and edge computing, and wireless network connection quality is measured by transmission energy consumption and packet loss rate.

2.3. Image processing for human detection

Liu [7] proposed using the Continuously Adaptive Mean Shift (CAMSHIFT) and Gaussian mixture model to identify and track human motion in photographs. By utilising improved motion extraction and tracking, the prototype focuses on people identification in both indoor and outdoor environments. Gong et al. [8] advocated for a human identification system based on network expansion based on recognised human anomalies. The project's purpose is to use the Local Distinguishability Aggrandizing Network (LDA-Net) to eliminate network distraction and inadequacy in determining object ability. Caliwag et al. [9] presented a Multi-Task Cascade Convolutional Network (MICCN) for human face detection. The project employs a deep learning model, with TensorFlow serving as the foundation library. Zaarane et al. [10] suggested a stereo camera-based distance measuring system. The stereo vision system employs computer vision algorithms based on stereoscopic range techniques to calculate distance. Tian et al. [11] suggested an adaptive ensemble model technique with broad application, capable of dealing with prediction situations at many energy and temporal dimensions. The project considers external elements that influence energy use patterns, such as weather conditions, energy system performance, occupancy, and user behaviour.

2.4. AI for power leakage detection and power consumption prediction

Yang et al. [12] presented a machine learning-based diagnosis approach for power system safety to avert cascading harm. Several machine learning algorithms for identifying defect were presented. Farhoumandi et al. [13] investigated the current state of machine learning algorithms and their prospective uses in IoT integrated power systems. This research is being undertaken to better analyse the current electrical system applications, where this data will be contributed to the data analysis of the overall electrical system. The characteristics of load prediction is taken in consideration as part of the study to control and overcome the challenge of load prediction. Moreover, the results were assessed to other researchers' applications in terms of mean absolute percentage error (MAPE) and teaching-learning based optimization algorithm (TLBO). A prediction system based on deep learning was proposed for an electric power consumption was proposed by Kim and Cho [14].

3. Methodology

The following parameters govern the design methodology:

3.1. Sleeping mode

According to the human detecting algorithm, the "Sleeping Mode" will be activated based on the disparity of the persons passing across vending machine. The camera will identify persons going by the vending machine on a constant basis and feed the footage to the microcontroller for analysis. Figure 1 demonstrates that when the algorithm identifies humans within three to five meters of the machine. To bring the person's attention to the machine, it will activate 50% of the total machine power through a series of relays.

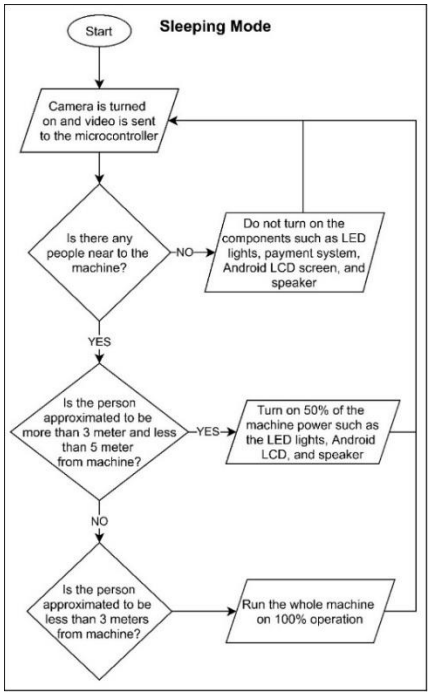

Fig. 1. Sleeping mode flowchart.

3.2. Current leakage detection

The current and voltage measurements for each component are measured and collected every hour, then the information is sent to the microcontroller. The reason for voltage and current data collection is to prevent any leakage current in the system. Furthermore, the current and voltage measured ratings are checked with rated or trained data before being sent to the IoE cloud system through a signal generated by the microcontroller. As a result, it will signal that the vending machine is in excellent working order and that there is no leakage current in the machine. Otherwise, wasteful power usage would occur, and a report on the vending machine's issue would be sent (see Fig. 2).

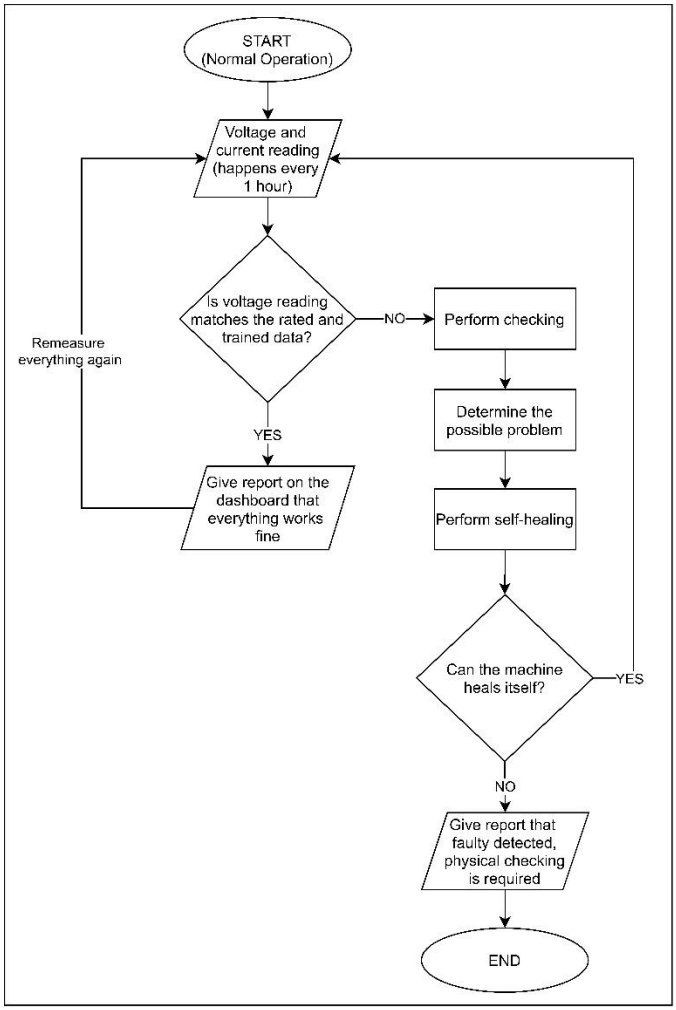

Fig. 2. Flowchart for detecting power and current leaks.

4. Program Design

These factors guide the program's design.

4.1. Camera for human recognition

The person recognition camera is used to activate the vending machine depending on events such as individuals approaching the machine and performing transactions. The camera is installed beneath the LCD Android panel in the chosen location. Python is the programming language used in the algorithm.

4.2. Microcontrollers, relays, and sensors

The relay is the mechanism that regulates the electric flow to the electrical components in the vending machine that need to be maximised. The basic role for a relay is to switch on and off the component depending on the programmed event and time. But it was discovered the vending machine can use it as an overcurrent protection if excessive current, short circuit, or power failure occurs. Since, the vending machine requires both AC and DC power to operate, therefore there were two types of relays used. The maximum rating for the relay in AC and DC were 250V/10A and 30V/10A respectively. The display screen and cash payment mechanism including coins used AC whilst motors, LED lights, and speakers used DC power. Thus, the relays work both in AC and DC conditions without any other constraints.

4.3. Machine learning for electrical energy usage prediction

In order to predict the power consumption of the system, the machine learning model requires supervision to allow an efficient prediction to be modelled. The prediction can only be effective, reliable, and accurate if large amounts of data is collected, which can then be used in Microsoft Azure Machine Learning platform [15]. The collected data is then uploaded, a selection of the features is implemented into the algorithm, which will then familiarise with the data environment. In order to perform data partitioning, it is split into two groups which is training and testing.

4.4. AI algorithm for detecting leaks and optimizing energy

The leakage detection and energy optimization method, like the facial detection and distance measuring algorithms, is written in Python. This application requires the use of 'pandas' as a library, which offers a diverse environment. In addition, the Python-based open-source data analysis and manipulation software are also additional feature of the library. Furthermore, 'numpy' is introduced to the workspace in order to execute big and arrays with many dimensions for mathematical operations. Thus, 'panda' and 'numpy' libraries have been added to the programme.

4.5. IoE dashboard implementation

Following the collection of all data, an IoE dashboard is developed to provide the vending operator with a smooth machine power monitoring experience, as illustrated in Fig. 3. In an interactive fashion, the dashboard will give statistics and notifications such as power consumption status, power usage log, power enhancement log, uptime, and other essential factors. This form of monitoring enables the vending operator to keep track of several vending machines at the same time. The dashboard also shows and informs the operator if anything is wrong with the vending machine, such as high consumption or a short circuit.

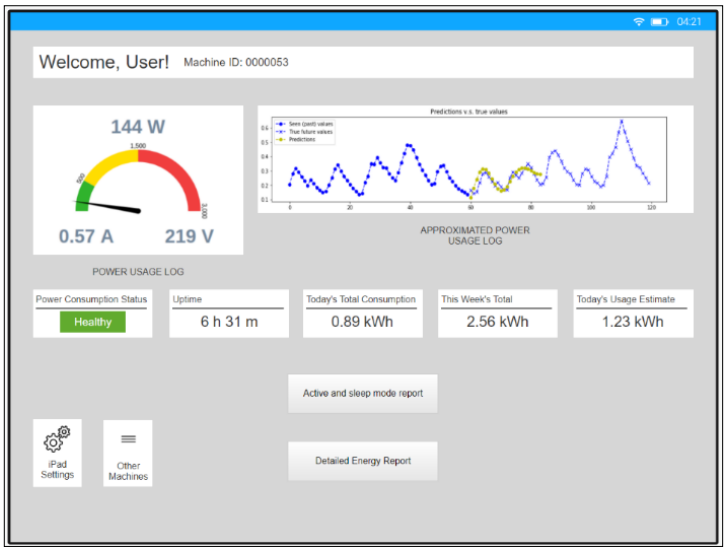

Fig. 3. Dashboard for IoE on iPad.

5. System Implementation

The entire system is made up of two parts: hardware components and a software cloud system. Figure 4 depicts the overall implemented system flowchart. As a result, integrating these components necessitates the use of a web-based platform such as Google Firebase or Amazon Web Services (AWS). Because it is free for prototype testing projects, this project makes use of Google Firebase and because its 'Realtime Database' is quicker than AWS, which requires credit card payment and lacks a real-time database All measurement findings and computer analyses are loaded into the iPad application for the final study target, It is about the power use reporting system that sends data straight to the cloud via the IoE dashboard. The software displays useful factors such as power usage log, estimated power usage log, power consumption status, uptime, and current energy consumption, as well as notifications to the vending operator.

6. Results and Analysis

A number of tests are run on both the hardware and software systems to measure overall system performance and use dependability.

6.1. Camera human recognition and distance measurement test

Figure 5 demonstrates that during the daytime test, has an average discrepancy with periods where the camera could not identify the face displayed as "0.00". Meanwhile, when the average computation removes five occasions where the camera could not recognize a face, the average difference becomes 3.7 inches. As a result, the camera and algorithm used to distinguish human faces have an overall error rate of 9%. According to the graph, the system is more reliable when the human distance from the camera is roughly 82 inches, while it under measures or over measures distances more than or less than 82 inches, respectively.

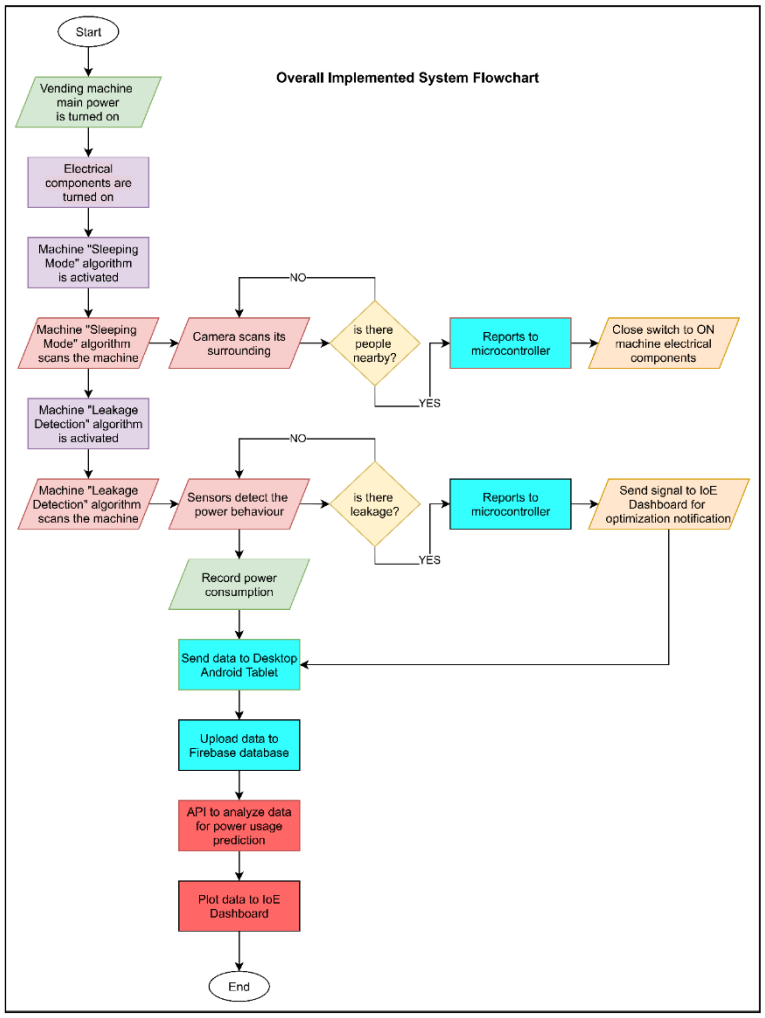

Fig. 4. Overall system flowchart.

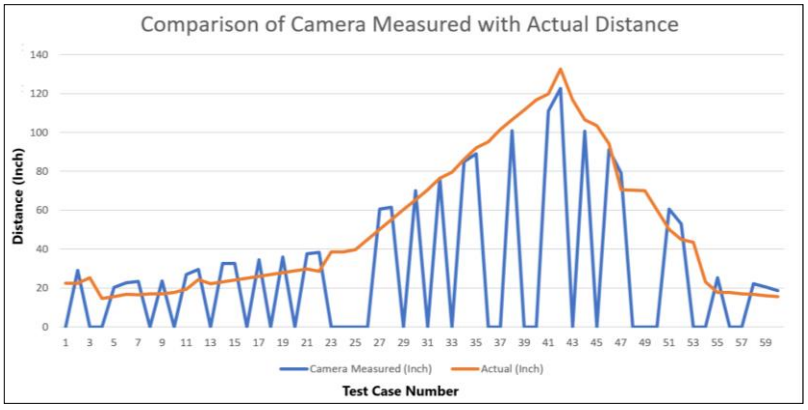

Fig. 5. Comparison of camera measurement with actual distance after sunset.

6.2. IoE relay trial run

Relay IoE testing is performed on the vending machine's electrical components. This test has two objectives. First, it ensures that the relay receives the correct instruction from the cloud-controlled microcontroller and that the relay executes the correct command. Next, it ensures that the microcontroller can control all six relays independently. The testing requires no extra components or circuitry, such as a bridge rectifier or a regulator. This is due to the fact that the relays utilised in this project include photoelectric isolation, anti-electronic interference, and optocouplers.

The data used for the relay IoE trial run is not yet connected to the camera for usability testing because this test is covered in the IoE dashboard integration and overall power efficiency tests. According to the trial run test, for the first day there were 14 transactions that occurred, second day a total of 24 transactions, and third day a total of 11 transactions. Throughout this test, the occurrences of switching ON and OFF for each relay had at to be least 49 times. Four relays failed to switch on throughout the 50 times the test was done as shown in Table 1. This results in a 92% accuracy. The four failures occur just as the system is ready to start up. This is thought to be related to an electrical component's first start fault after the system has been placed to sleep for several hours. However, after the system is restarted, the relays resume regular operation.

Table 1. Accuracy percentage for relay activation.

$$Acurracy = \frac{|System\ Output - Expected\ Output|}{Expected\ Output} \times 100\%$$

$$Acurracy = \frac{|4 - 50|}{50} \times 100\% = 92\%$$

Tests Performed	50
Number of times relay failed to activate	4
Accuracy	92%

6.3. Evaluation of overall electrical energy efficiency

This test will examine the entire power efficiency that this project proposes, which is to save about half of the power utilised prior to implementing this method, as shown in Fig. 6.

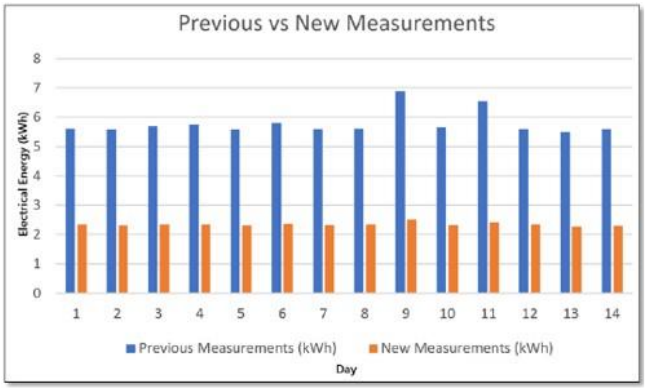

Fig. 6. Previous and new system measurements are compared.

Based on the test cases, the average transaction for certain days close to almost 14/day, some days the transactions are below the average, such as two last days 13 and 14 respectively. Sometimes for certain days, the transactions numbers are significantly higher than the average, for example day 9 and 11. Both the days recorded the highest of 39 and 24, respectively. Therefore, this shows that during low transaction days, the energy consumptions will be similar to average and power savings will be typical. In addition, when the transaction rate is higher than the usual, the percentage of energy saved would be higher. For example, is when the transaction is a back-to-back type, where customers purchase more than one item at the same time. Because the vending machine's electrical parts demand greater initial power when powered on, the more consumers who buy at once, the more energy the system may save.

7. Conclusion

The goal of this research is to find solutions to energy optimization, one of the world's most difficult and important problems. The goal is to find a large-scale solution to a minor problem. The worldwide energy use may be improved by using this technology to optimise the currently installed vending machines. This study has demonstrated that it is feasible to achieve this goal using current and emerging technologies, such as artificial intelligence (AI) to detect human presence and forecast potential future energy consumption, and internet of everything (IoE) to connect a sizable number of vending machines through an easily accessible dashboard. Making intelligent and environmentally friendly vending machines wouldn't be a thing of the past.

Acknowledgments

The authors would like to acknowledge Asia Pacific University of Technology and Innovation, as well as Vechnology Sdn Bhd, for contributing finances and property to the system's development via a Research and Development Grant.

References

1. Sibanda, V.; Munetsi, L.; Mpofu, K.; Murena, E.; and Trimble, J. (2020). Design of a high-tech vending machine. *Procedia CIRP*, 91(1), 678-683.
2. Iannacci, J. (2018). Internet of things (IoT); internet of everything (IoE); tactile internet; 5G - A (not so evanescent) unifying vision empowered by EH-MEMS (energy harvesting MEMS) and RF-MEMS (radio frequency MEMS). *Sensors and Actuators A: Physical*, 272, 187-198
3. Zhao, M.; Deng, D.; Zhou, W.; and Fan, L. (2018). Non- renewable energy efficiency optimization in energy harvesting relay-assisted system. *Physical Communication*, 29, 183-190.
4. Nahas, E.W.; Mansour, D.-E.A.; El-Ghany, H.A.A.; and Eissa, M.M. (2020). Developing a smart power-voltage relay (SPV-Relay) with no communication system for DC microgrids. *Electric Power Systems Research*, 187.
5. Ershova, I.; Vasilyev, A.; Poruchikov, D.; and Ershov, M. (2019). Electrical relay-pulse regulator of heat-exchanging equipment for energy obtaining of water-ice phase transition. *Proceedings of the International Conference on Intelligent Computing and Optimization*. Koh Samui, Thailand.

6. Lv, Z.; and Kumar, N. (2020). Software defined solutions for sensors in 6G/IoE. *Computer Communications*, 153, 42-47.
7. Liu, Y. (2021). Human motion image detection and tracking method based on gaussian mixture model and CAMSHIFT. *Microprocessors and Microsystems*, 82.
8. Gong, M.; Zeng, H.; Xie, Y.; Li, H.; and Tang. Z. (2020). Local distinguishability aggrandizing network for human anomaly. *Neural Networks*, 122, 364-373.
9. Caliwag, E.M.F.; Caliwag, A.; Morocho-Cayamcela, M.E.; and Lim, W. (2020). Thermal Camera Face Detection and Alignment Using MICNN. *Proceedings of the KICS Summer Conference 2020*. Pyeongchang, Republic of Korea, 319-321.
10. Zaarane, A.; Slimani, I.; Okaishi, W.; Atouf, I.; and Hamdoun, A. (2020). Distance measurement system for autonomous vehicles using stereo camera. Array, 5.
11. Tian, J.; Li, K.; and Xue, W. (2021). An adaptive ensemble predictive strategy for multiple scale electrical energy usages forecasting. *Sustainable Cities and Society*, 66.
12. Yang, H.; Liu, X.; Zhang, D.; Chen, T.; Li, C.; and Huang, W. (2021). Machine learning for power system protection and control. *The Electricity Journal*, 34(1).
13. Farhoumandi, M.; Zhou, Q.; and Shahidehpour, M. (2021). A review of machine learning applications in IoT-integrated modern power system. *The Electricity Journal*, 34(1).
14. Kim, J.-Y.; and Cho, S.-B. (2019). Electric energy consumption prediction by deep learning with state explainable autoencoder. *Energies*, 12(4).
15. Shapi, M.K.M.; Ramli, N.A.; and Awalin, L.J. (2021). Energy consumption prediction by using machine learning for smart building: case study in Malaysia. *Development in the Built Environment*, 5.