Vending Machine Electricity Usage Optimizer Using Automated Relay and AI for Smart Retailing Based on the Concept of Internet of Everything (IOE)

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***Abstract*-Modern vending machines operate to serve the consumer easy-access demand for daily items such as food, drinks, or books. Purchasing processes are carried out via automation from item selection, payment, up to the item dispensing are done without interaction to the human and this can be carried out for 24 hours a day and 7 days a week. However, the vending machines operates for 24/7, consumes the same electrical load regardless of if there is a transaction. Despite the advancements of Industrial Revolution 4.0 (IR4.0) in many sectors, electrical power of vending machine is yet to be optimized. This research aims to optimize vending machine power consumption by using camera to detect human near to the vending machine and relays to control the power usage. Human can be detected via camera via Artificial Intelligence (AI) and this becomes the input to the Smart Relay. Abnormality such as electrical leakage that draws more power can be detected as well. IoE dashboard is developed for vending operator to monitor the power usage, leakage potential, optimization, and prediction of power consumption. The system saves about to 50 percent of electrical power usage in the vending machine and low energy wastage while maintaining the same vending machine capabilities.**

Keywords— Vending Machine Electricity, Automated Relay, AI, Smart Retailing, Internet of Everything (IOE)

I. Introduction

Vending machine is a modern way of retailing that encompasses full automation system from the payment up to the item is dispensed to customer. The invention of vending machine was introduced in 215 Before Christ (BC) in Alexandria, Ancient Egypt to dispense the holy water in exchange of coins (Sibanda, et al., 2020). As the world industry evolves to the fourth industrial revolution or IR4.0, vending machine has adopted this concept by embedding the vending machines with IoT, cloud computing, AI, mobile payment, and FinTech that made modern vending machines as smart vending machine. To perform these capabilities, smart vending machine needs electricity to power up its operation for 24 hours per day in 7 days per week.

As the world industries continue evolving, the problem is that the electricity usage of smart vending machine has not yet been benefitted from this revolution whereby the machine will always be on even whether there is transaction or not. There has not been any Artificial Intelligence (AI)-powered vending machine for the electricity usage. If this idea is made into reality, the AI could unleash the full potential of electricity usage in the vending machine.

Human face recognition has been developed for many purposes such as to unlock smartphone. This could also be implemented for the benefit of the vending machine to detect when someone is approaching that will trigger the machine to be turned onto the full operation.

Another problem with the current smart vending machines is that there is no power leakage detection whereby although the machine seems to run normally, the actual power is higher than the rated power. There are some electrical parts of the vending machine that consumes power more than it is supposed to consume and will increase the likelihood of taking current more from other electrical component in the machine, that will then reduce the lifetime of the machine. Hence, a vending machine electricity usage optimizer using automated relay and AI has to be developed to optimize the electricity usage to reduce the overall electricity usage, high efficiency, and low energy wastage vending machine. Internet of things, or IoT, is one of the biggest advancements made in recent technological times (Abdulla et al., 2020; Al-Gumaei et al., 2018; Eldemerdash et al., 2020; Haziq et al., 2022; Hon et al., 2020; Kalilani et al., 2021; Katemboh et al., 2020; Lakshmanan et al., 2020; Murugiah et al., 2021; Nazrin et al., 2021; Rasheed et al., 2021; Samson et al., 2020; Singh et al., 2021; Yong et al., 2020). Using the IoE dashboard, the operator can monitor the power usage, projected future energy usage based on the previous recorded data, and to check the machine electrical part when there is power leakage detected. This project emphasizes on Internet of Everything (IoE) over Internet of Things (IoT) because IoE paradigm leverages the IoT, whereby IoT is about connecting physical devices altogether, IoE aims to allow everything to communicate with everything including human and computer connections (Iannacci, 2018).

The main challenge for this research is to develop electricity usage optimizer by using automated relay to reduce electrical power usage on the vending machine and AI to detect electrical power leakage. Human detection algorithm is also to be developed to trigger on and off the sleep mode of the vending machine based on the event.

On the fourth industrial revolution, the pace of human technology had been accelerated significantly compared to the other earlier years of human history. For the first time, the technical innovation is brought by an array of new smart tools and interconnected machines. As the technology keep improving, technological advancement such as smart vehicles, intelligent home appliances, and smart retailing through smart vending machine become more common and available to the public. The goal of this project is to help achieve the idea of smart and sustainable society, while improving quality of human lives. Therefore, the aim aim for this project is to optimize the electricity usage of vending machine by using automated relay system and artificial intelligence (AI) that will result directly on 50% electricity usage saving, lower bills for the vending machine operator, high efficiency vending machine, and lower energy wastage.

Relay is an essential component for switching and protection in the circuits of electrical components. Relay reacts to voltage and current with the purpose to open or close the contact in a circuitry connection. Zhao et al. (2018) proposed energy optimization by maximizing the Energy Efficiency (EE) of power grid throughout multiple timeslots by using Decode-and-Forward (DF) relay nodes. The goal of the prototype is to properly handle the random energy arrivals on the non-ideal circuit power to increase the energy efficiency. This is done by combining all power allocation along with the sleep mode criterion on the power source and relay.

It is also very important to consider the capacity of the relay for the project such as the operating time whereby the electricity utilization performance depends very much on it. Purani & Nishant (2016) proposed the relay operating time optimization on an interconnected relay to reduce the relay damage due to fault by reducing the fault clearing time. Also, the project proposed that this prototype can enhance the selectivity of the relays by employing the directional feature.

Another relay power efficiency research was by Ershova et al. (2019) that is intended on improving the long-term vegetable storage microclimate facility that uses low power. To make sure that the agricultural products remain fresh during storage, it is important to control the parameters such as temperature, water level, evaporation index, as well as the in and out air. Maintaining these parameters are not cheap because mainly they are using high electrical power.

The typical example of IoT is to capitalize onto gaining the identity of environment and objects in human lives by the means of internet. Despite of the complex IoT context, IoE paradigm enhances the IoT by transcending the concept of ‘thing’ (Iannacci, 2018). This is because IoE aims to allow everything to communicate with everything, including the human to machine communication, posing more challenges in terms of data exchange volume for control.

There are lots of scenarios in real life that can make human lives easier with the aid of IoE. Zhihan & Neeraj (2020) proposed a dual-channeling architecture that is defined by the software of wireless sensor on IoE in wireless control of sensors. Because wireless control relies very much on signal, the prototype aims to reduce the signal interference and to transmit better signal for control of IoE application. Wireless Sensor Network (WSN) (Zulkifli et al., 2012), (Abdulla & Ismail, 2013).The prototype uses the Software Definition Network (SDN) that helps to reduce time delay and energy consumption to improve the WSN performance.

Hu, Wang & Yang (2020) proposed IoE control system that incorporates the 6G technology for the IoE control system. Realizing that as the spectrum goes higher will result in even denser network, the energy consumption will be a big hurdle for the IoE technology. The infrastructures that are supporting the IoE such as antenna, network, and the subject device consumes huge amount of energy that the faster the network, the more power will be required to keep the connection run well. Therefore, the project proposes the Distributed Unit (DU) for IoE smart access to increase the efficiency of the system.

Sadu and Arabelli (2018) proposed a monitoring and control system for appliances that uses internet through GSM or Global System for Mobile Communication network to send Short Message Services (SMS) to the authorized personnel. The system was made of an embedded web server with Raspberri Pi, where RASPBERRI PI 11 is the main processor. The wireless sensor network also uses the RASPBERRI PI as the database, while connected to several components such as gas sensor, exhaust fan, relay. Liu (2021) proposed a human motion image detection and tracking method that is based on the Continuously Adaptive Mean Shift (CAMSHIFT) and Gaussian mixture model. The prototype focuses on the recognition of people using the enhanced motion extraction and tracking for both indoor and outdoor environments. Gong et al. (2020) promoted a human recognition system that is based on the aggrandizing of network based on the detected anomaly of human. The goal of the project is to reduce the distraction or noise of the network and the insufficiency of determination of object ability using the Local Distinguishability Aggrandizing Network (LDA-Net).

Caliwag et al. (2020) proposed a Multi-Task Cascade Convolutional Network (MTCCN) that detects human face. The project uses deep learning model using TensorFlow as the foundation library. Zaarane et al. (2020) proposed a distance measurement system using stereo camera. The stereo vision system uses a computer vision that is based on the stereoscopic ranging techniques that is capable of calculating distance. the system uses two cameras that are embedded into one, to give impression of the depth and use of the objects between cameras then compute the distance with high accuracy. Yang et al. (2021) proposed a diagnosis technique for power system protection to avoid cascading damage using machine learning. There were several machine learning methods to identify fault were proposed.

Farhoumandi, Zhou & Shahidehpour (2021) conducted a study to the state-of-the art of machine learning techniques and the potential applications in IoT integrated power system. The study is carried out in reinforcement of data analysis for modern electrical system application such as Electric Vehicles (EVs), Distributed Energy Resources (DERs), smart switches and meters. The study also reviewed the load forecasting and control, by considering the characteristics of load forecasting problems. Kim & Cho (2019) proposed a system called electric energy consumption prediction using deep learning with state explainable autoencoder. A projector specifies an acceptable condition for a particular circumstance, whereas a predictor estimates energy demand from that state. The suggested model forecasts consumption for 15, 30, 45, and 60 minutes, with 60-minute demand being the most recent.

II. SYSTEM IMPLEMENTATION

The proposed methodology for this project consists of four core development phases. Referring to the order of the objectives, the first phase is to design the automated relay system for vending machine. The general block diagram shown in Fig 1. shows the electrical circuit design consisting of five relays, six meters to measure current and voltage, and one microcontroller as the brain for the relays and meters. The black arrows represent the electrical flow direction, red arrows show the power reading from the meters, and blue arrows represent the control flow of the relays. The source of the block diagram is the main power source from the electrical plug. The green color block diagrams represent the meters, blue blocks represent the relays, red blocks represent the electrical loads, and the purple block represents the microcontroller, while the white block diagrams are the existing power equipments of the vending machine.

The types of relays based on the current type are explained on the right-hand side of Fig 1. The "Sleeping Mode" is going to be triggered by the distance of people passing through the front of the vending machine according to the human detection algorithm. The camera will continuously detect the people passing through the vending machine and send the video to the microcontroller to be analyzed.

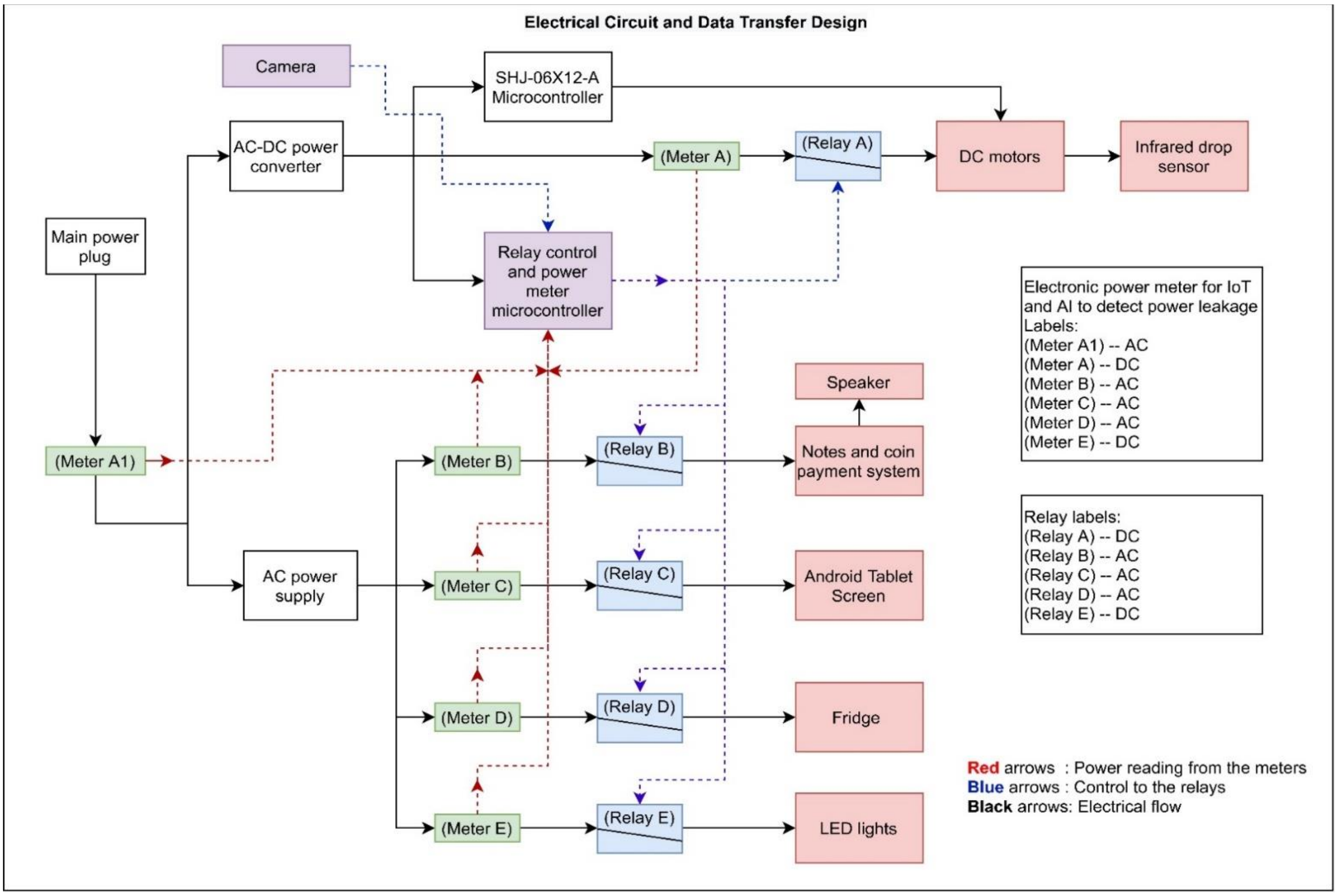

Fig. 1. Electrical circuit and data transfer design

As the flowchart in Fig 2. explained, when the algorithm recognizes people within the range of 3 to 5 meters from the machine, it will turn on 50% of the overall machine power using the set of relays to catch the person's attention towards the machine. Then, when the person is approximated to be 3 meters or less from the machine, it will turn on 100% operation of the machine because at this point, it is assumed that the person is going to be performing transaction on the vending machine. Furthermore, when the algorithm does not detect any human, it will shut the vending machine, reducing the fridge temperature, and leaving necessary components such as the internet-connected microcontroller on. The voltage and current meters will detect the voltage and current for each component every one hour and send the reading to the microcontroller. This is to preliminarily detect the potential of power and current leakage in the machine. As shown in the flowchart in Fig 3., when the voltage and current reading match the rated and trained data, the microcontroller will send signal to the IoE cloud system and display that everything works fine in the machine, meaning that there is no potential power and current leakage that will result in the inefficiency of power usage. However, if there is mismatch of the rated and trained data from the reading, the machine will perform checking that is again based on the trained data of potential electrical problems. Then, it will determine the possible problem and perform self-healing whenever possible and send report to the IoE dashboard that there was a problem, and it has been solved. In case if the machine cannot heal itself, then a report will be sent to the IoE dashboard saying that faulty is detected, power is not being optimized, and further physical checking is required. The goal of this algorithm is to manage any potential energy wastage due to the leakage.

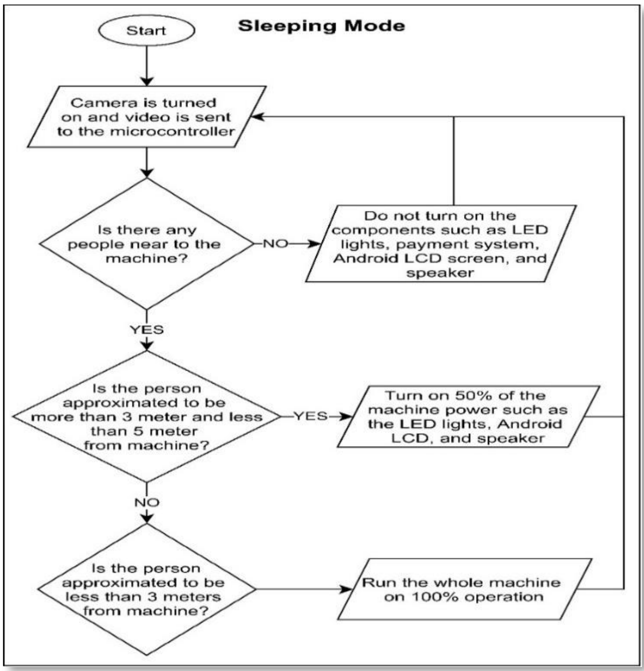

Fig. 2. Flowchart of the sleeping mode

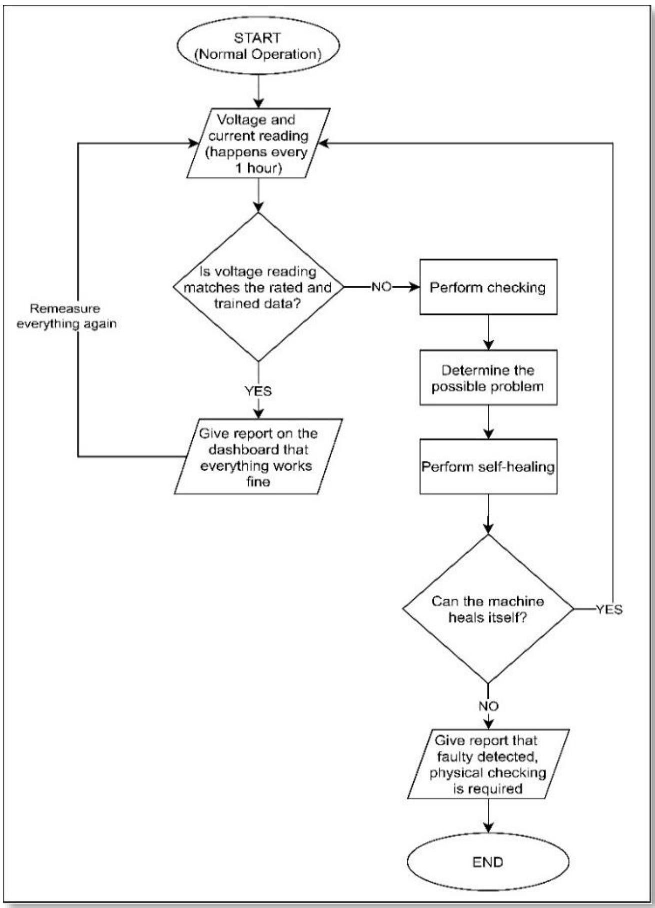

Fig. 3. Flowchart of the power and current leakage detection

Next, Fig 4. describes the block diagram of how the hardware system communicates with the IoE cloud dashboard. As an essential part of this proposed system, the cloud reporting system through IoE dashboard. The goal is to provide a real-time electricity consumption report along with the power optimization using the relay and AI for leakage detection to the vending operator. Introducing this IoE dashboard system is considered user-friendly for the vending operator. This is because as the user of this system, they will just need to open the dashboard and monitor the electrical health status of their vending machine rather than manually assessing it within a period or when faulty has occurred in the first place.

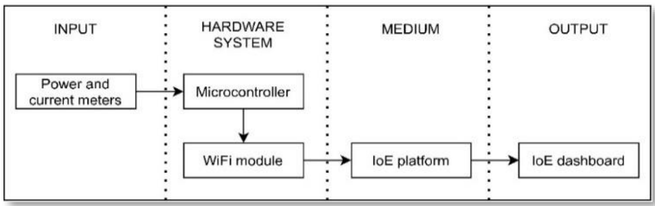

Fig. 4. Hardware system and IoE dashboard integration

Several assumptions have been made for the purpose of narrowing down the scope of this project. According to the components investigation and proposed methodology, this section is created to finalize the ratings of the components along with the measurements.

The first assumption is that the measured values are adjustable, and for development purposes, the system demonstration will use the fixed measurements obtained from the tests. Second assumption is that although the goal of this project is to be implemented in the industry, there will be adjustments performed in the circuitry for the ease of testing and implementation. The overall system will be continuing to improve as the objectives are achieved stage by stage. Last assumption is the external factors that could affect the functionality of relay and sensors such as fatigue or overheating. These factors are relatively difficult to be replicated and subject to manufacturing specifications.

The way current and voltage leakage concept is when current is flowing through the isolation surface on the body of the electrical component (Sofwan et al., 2018). The isolation resistance directly affects the leakage current that the resistance gets greater when the conductor is longer. Therefore, the isolation leak current is found by:

$$I_b = \frac{Vm}{R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

whereby the I_b is the leak current measured in Ampere, Vm is the voltage and R is resistance. The power factor will also be considered to help verify the leakage. Using Phasor current diagram, the formula is:

$$F_P = cos\theta = \frac{P}{V_{rms} \times I_{rms}} = \frac{P}{S} \ldots\ldots\ldots\ldots (2)$$

Whereby the F_P tells the ratio of the apparent power (S) and the real power (P).

Next, the obtained values are going to be tabulated in Fig 5. that shows the draft of the normal and abnormal power usage chart.

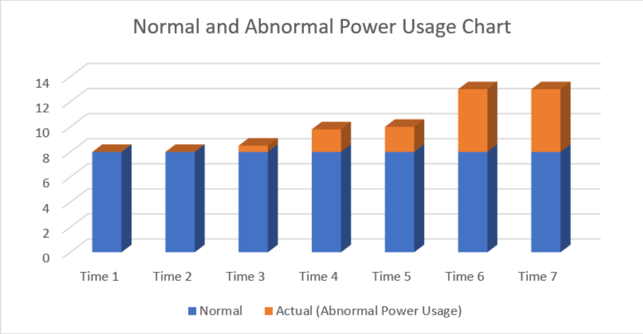

Fig. 5. Normal and abnormal power usage chart

The normal power usage is based on the rated power, while the abnormal power usage is the excessive power readings taken from the meter. Further development and calculations will be done through the cloud algorithm.

An IoE dashboard is to be created for the operator to view the electrical health status of the vending machine. The dashboard will show all the necessary logs which are the power usage log, approximated power usage based on the trend, power enhancement suggestions, modes report, leak status, and options menu. The purpose of this dashboard is to help the operator to monitor and immediately identify whenever there is misbehave of the vending machine electricity. The operator can monitor the status of the vending machine can view the status at anytime and anywhere from their web browser. This will reduce the risks of electrical failure in the machine that will also increase the machine's lifetime.

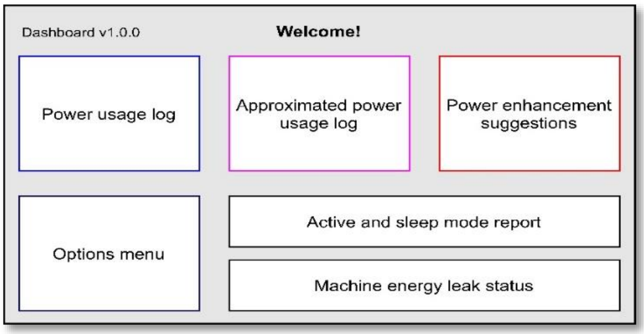

Fig. 6. IoE dashboard draft

Because this application is going to be implemented on the inside of the vending machine, the dimension and size are not a major concern whereby there is large available space for the new components of the vending machine.

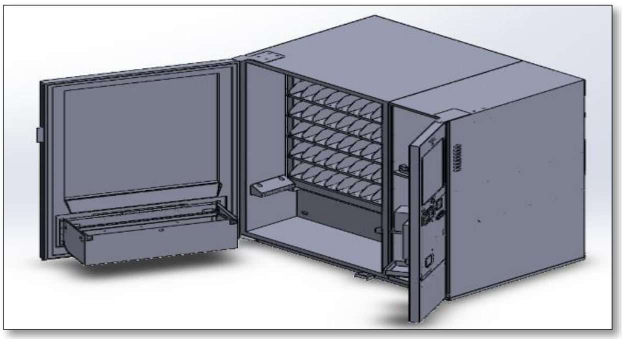

Fig. 7. 3D Model of the vending machine

III. Justification to the Modification Made

There are only few minor changes made and one major change in the final prototype. The major change was the change of Intel Quark D2000 microprocessor to Arduino Uno. Reason behind the change is due to the current unavailability of the microprocessor in the marketplace. This change, however, did not make any significant impact on achieving the aim and objectives of this project. This is because of the fact that Intel Quark D2000 has the exact same architecture and function as Arduino Uno. There are only two differences between them which are the pin numbering and the function. Intel Quark D2000 is commonly used for heavy-duty industrial equipments, while Arduino Uno is for prototype development.

The first minor change is that the initial plan is to test the functionality of the overall prototype in the full-body vending machine. However, due to the travel restrictions imposed by the Government, going out to the factory to test it. The solution is to borrow the related electrical and electronic components from the company and do the remaining set of testing at home. The related testing is such as reliability and accuracy testing.

Second minor change is made on the human recognition system. The initial design was to recognize human presence in front of the machine by analyzing human body movements. However, a better solution which is to recognize human faces who are coming towards the vending machine is more efficient as it helps on controlling the relay to turn on machine components only when there is human coming towards the machine. This method helps on optimizing the electricity usage by turning the camera on only when someone is approaching the machine, instead of turning it on every time there is a passerby. On top of that, instead of using meter units, the measurement uses inch for more precise detection on the algorithm.

The camera for human recognition is used to activate the vending machine based on events when people approach the machine and perform transaction. The camera is mounted below the LCD Android screen on the designated place shown in Fig 8 (c) and (d). The algorithm uses Python as the programming language.

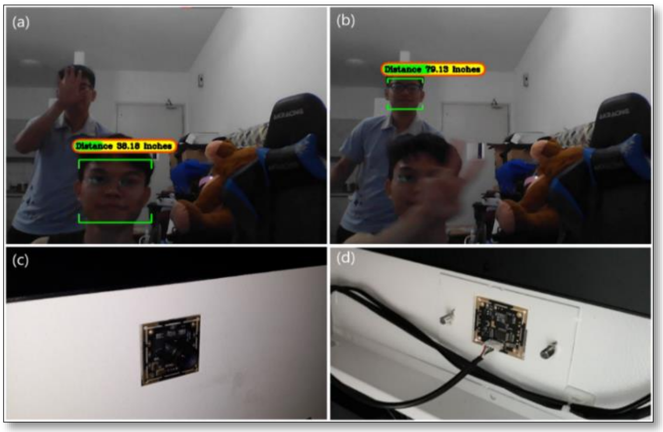

Fig. 8. Human face detection and distance measurement

Figs 9 and 10 show the code snippets of the algorithm implemented for the facial recognition and distance measurement. On Fig 9., the algorithm is to measure the essential variables such as the measurement of distance from camera lens to the object, which is the face. The algorithm predicts the known distance and width, then the color pixels are then determined as a part of the pixilation measurement. Then, the '.xml' file will be executed and analyze the measurements.

```
import cv2
# variables
# distance from camera to object(face) measured
Known_distance = 76.2  # centimeter
# width of face in the real world or Object Plane
Known_width = 14.3  # centimeter
# Colors
GREEN = (0, 255, 0)
RED = (0, 0, 255)
WHITE = (255, 255, 255)
fonts = cv2.FONT_HERSHEY_COMPLEX
cap = cv2.VideoCapture(1)
# face detector object
face_detector = cv2.CascadeClassifier("haarcascade_frontalface_default.xml")
# focal length finder function
```

Fig. 9. Variables import.

On Fig 10., the algorithm is to plot the image analysis result on the computer monitor. It shows the focal length and face data such as the approximated distance.

```
def FocalLength(measured_distance, real_width, width_in_rf_image):
    focal_length = (width_in_rf_image * measured_distance) / real_width
    return focal_length
# distance estimation function


def Distance_finder(Focal_Length, real_face_width, face_width_in_frame):
    distance = (real_face_width * Focal_Length)/face_width_in_frame
    return distance

def face_data(image):
    face_width = 0
    gray_image = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
    faces = face_detector.detectMultiScale(gray_image, 1.3, 5)
    for (x, y, h, w) in faces:
        cv2.rectangle(image, (x, y), (x+w, y+h), WHITE, 1)
        face_width = w
    return face_width
```

Fig. 10. Plot algorithm

The test was performed for 6 hours for day and 6 hours for night. In average, 107.3MB computing memory power which is very large as well as 0.1MBps disk capacity. And it consumes 54.8% memory power when it detects face, whereby cache is a consideration factor. Fig 11. shows the overall connection of the existing electrical connection and the new electrical connection with the relays.

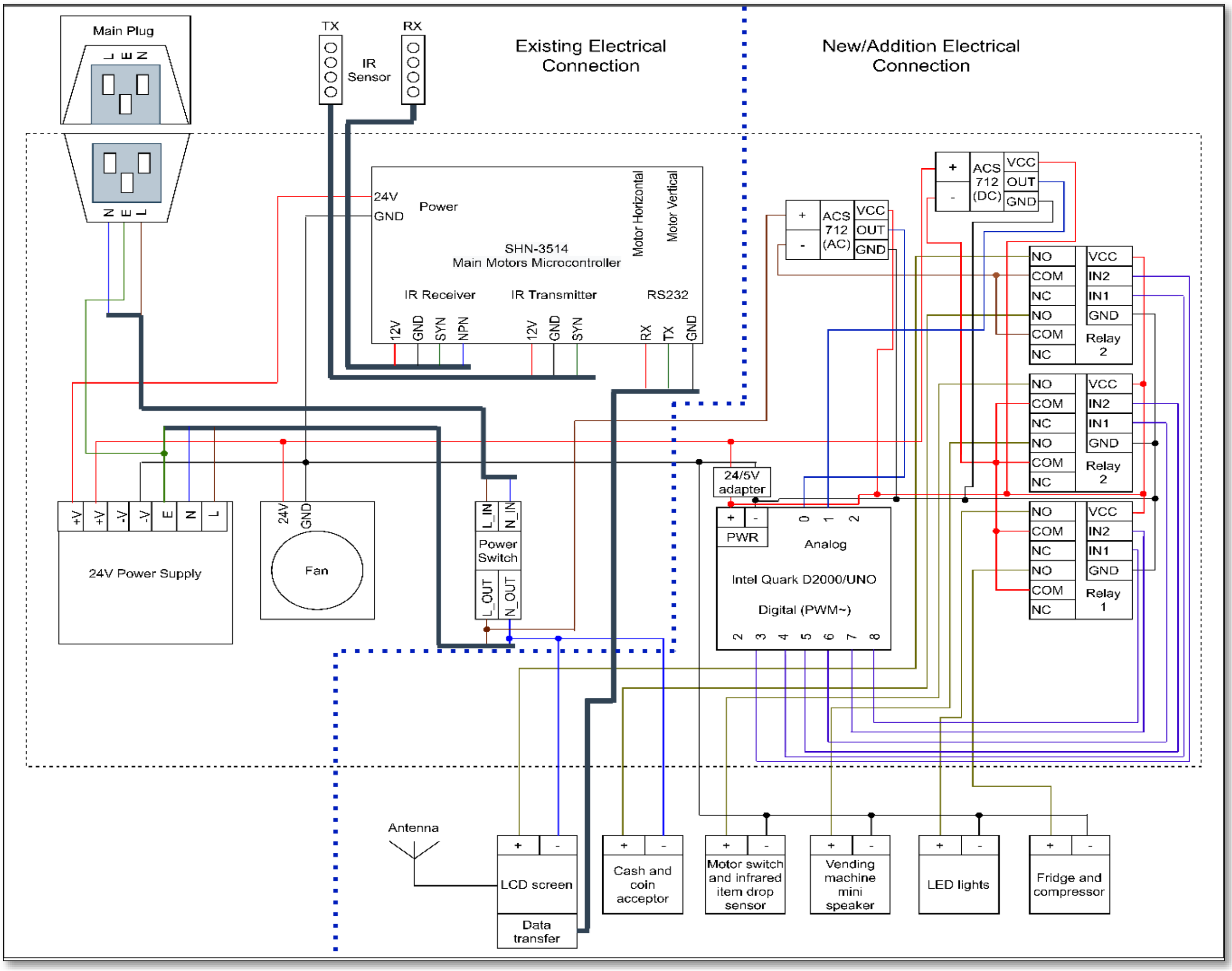

Fig. 11. Wiring schematic diagram

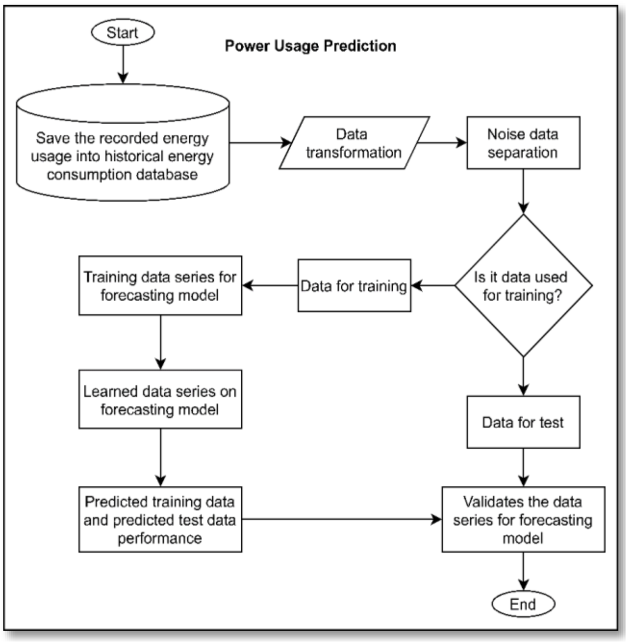

Fig. 12. Power usage prediction flowchart

Similar to the facial detection and distance measurement algorithm, the leakage detection and energy optimization uses Python as the programming language. The difference is that this application requires 'pandas' as a software library because it provides flexible and open-source data analysis and manipulation tool for Python. On top of that, 'numpy' is also added to the workspace to perform large and multi-dimensional arrays for mathematical calculations. The import of the 'panda' and 'numpy' functions to the program is shown in Fig 13.

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
from datetime import datetime, timedelta
import tensorflow as tf
import keras
from keras.layers import Input
from tensorflow.python.framework import ops
import math
from keras.callbacks import EarlyStopping
from keras import optimizers
```

Fig. 13. Leakage detection input variables

After all data are collected, an IoE dashboard is created to give a seamless machine power monitoring experience for the vending operator. The dashboard is to interactively show the data and necessary notifications such as power consumption status, power usage log, power enhancement log, uptime, and other important metrics. Using this approach of monitoring, the vending operator can monitor many vending machines simultaneously from the tip of their hands. The dashboard also functions to display and notifies operator when there is something potentially wrong on the vending machine such as overpower consumption and in case of short circuit.

The dashboard was built based on the 'LocalHost' integration that is used on the Firebase. The LocalHost is used to access the network services that is currently running on the host through the Firebase loopback network interface. Fig 14. shows the LocalHost that replaces webpage link.

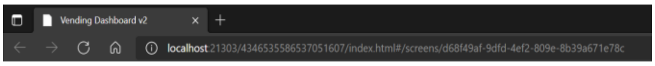

Fig. 14. LocalHost implementation

IV. INTEGRATED SYSTEM COMPONENTS AND WORKFLOW

The overall system consists of two parts which are the hardware components and software cloud system. Therefore, the integration of these components requires an internet platform such as Google Firebase and Amazon Web Services (AWS). This project uses Google Firebase as it is free for prototype testing projects and it is faster using its 'Realtime Database', as compared to AWS which requires credit card payment and does not provide a real-time database.

The location represented is Singapore instead of Malaysia because the server for Southeast Asia region is based in Singapore. The diagram of the combined detailed hardware and software components are shown in Fig 15. Meanwhile, the overall implemented system flowchart shown in Fig 16. shows how the entire system operates from the start to the end.

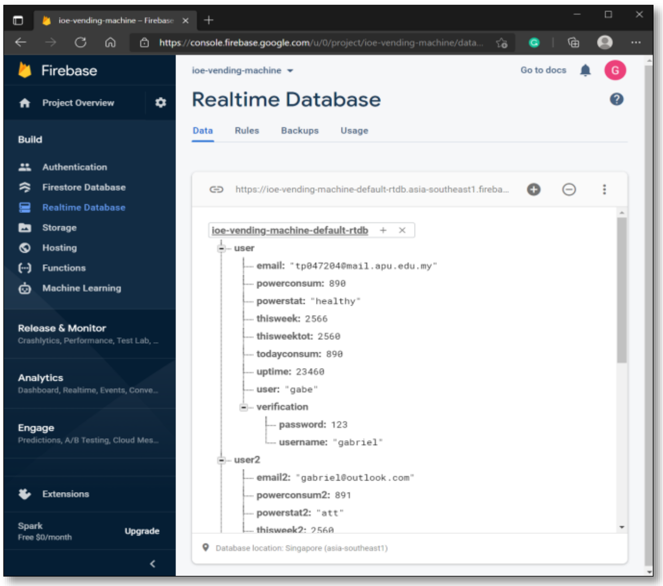

Fig. 15. Firebase Realtime Database backend

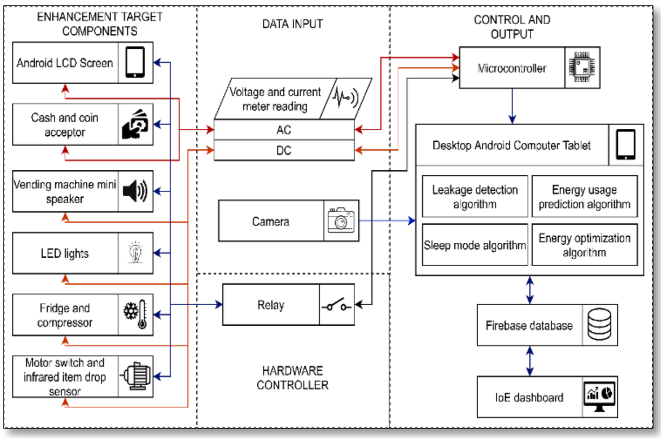

Fig. 16. Combined hardware and software system block diagram

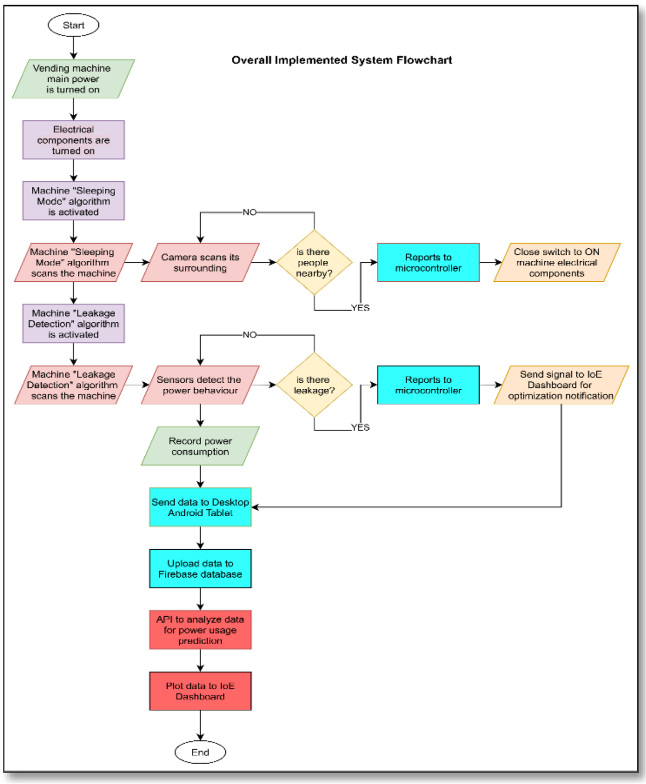

Fig. 17. Overall system flowchart

V. HARDWARE AND SOFTWARE RESULTS

The final design fulfils the objectives of this project. For the camera and human detection system, Fig 18. shows the physical placement of the camera on the vending machine, while Fig 19. shows where the camera is placed on the machine through 3D illustration.

Fig. 18. Camera placement on the vending machine

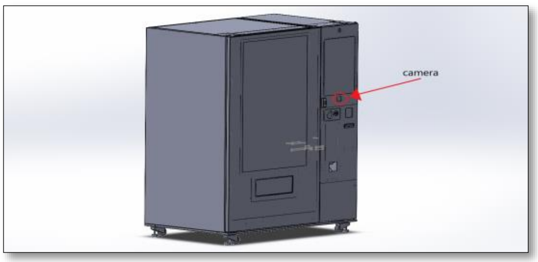

Fig. 19. 3D design of camera position on the vending machine

Next, the remaining hardware components such as relays and sensors to detect leakage are placed as shown in Fig 20. The components are then integrated and hid under the protective electrical box inside of the vending machine available space. This is done to ensure safety when the components are turned on. The electrical box is then mounted inside the machine and locked with screws. Fig 21. shows how the hardware connections look like when the machine is turned on and is in operation. The lights and external indicators show that the machine is running on 240V.

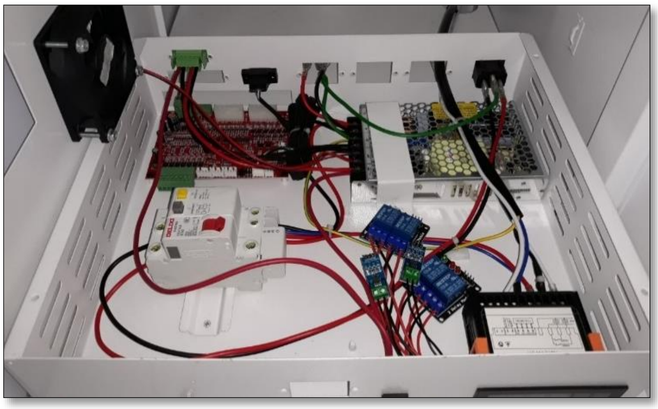

Fig. 20. Electrical wiring components

Fig. 21. Electrical components when machine is running.

Fig 22. shows the electricity prediction chart that is going to be plotted on the IoE cloud dashboard. It shows the prediction versus true values for the operation of 120 minutes.

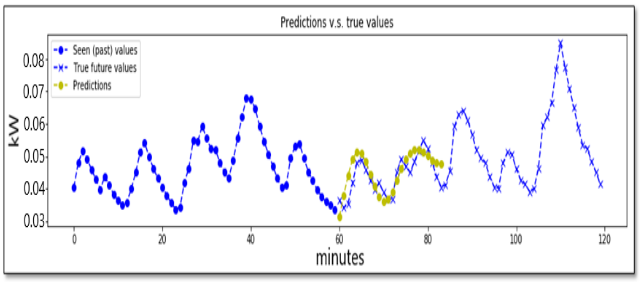

Fig. 22. Electricity prediction

For the last research objective which is about the electricity usage reporting system directly to the cloud through IoE dashboard, all measurement results as well as computing analysis are placed into the iPad application. The app shows the valuable variables such as power usage log, approximated power usage log, power consumption status, uptime, as well as present energy consumption and notifications to the vending operator.

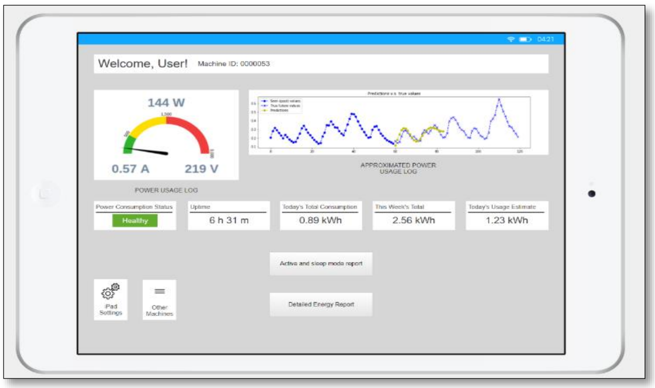

Fig. 23. IoE dashboard on iPad

VI. Testing of the Proposed Design

A. *Camera Human Distance Reliability Test*

Human recognition and distance measurement are one of the key components on making the energy saving to run well because they are the only way to recognize human that is approaching the vending machine. The camera acquires the light reflections and compare turn them into pixels that are then used to analyze human faces. The aim of this test is to examine the reliability of the camera and algorithm to recognize two components which are the human and the approximate distance from the machine. As there is only one camera used for this system, the distance measurement relies heavily on the pixel matching between two image frames that is recognized by the camera CMOS sensor. The camera is placed in front of the machine under the Android screen where people can easily be seen from the machine face. Fig 18. shows the camera model that is used in to recognize face and approximate distance. The camera has 60 degrees of visibility as shown in Fig 24. The camera is then placed slightly above the middle of the vending machine, right below the Android screen where the buyers will go to select their item shown in Fig 19. This way, the camera can easily recognize human face and measure distance accurately.

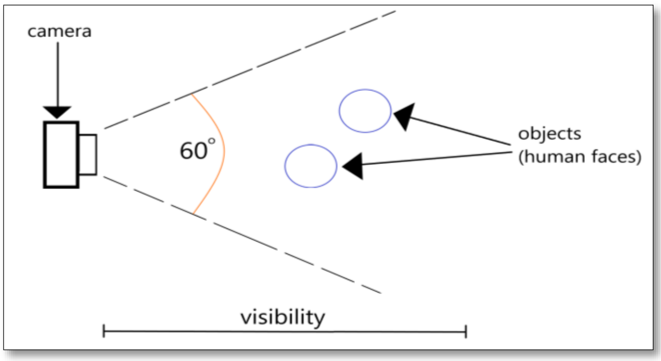

Fig. 24. Bird's eye view of the camera angle

The data recorded are the camera analysis results and manual or physical measurements. The test is done for 60 times on daytime and after sunset to determine accuracy from various distance and height within the camera degree of visibility. The test results are recorded in following tables that compare the camera-measured distance and the actual distance. The several test cases are performed to know the system accuracy and reliability where there is plenty amount of light on daytime, while lighting is quite limited during after the sun sets.

On the test performed during the daytime, it is shown that the average difference is 1.353 inches from the actual measurement includes times when the camera did not detect face shown as "0.00". Meanwhile, when the average calculation excludes five times when the camera could not detect face as "0.00", the average difference became 3.7 inches. Therefore, in average, the camera and algorithm to recognize human face has error rate of 9% overall. The data visualization of the daytime human face camera and algorithm is shown in Fig 25. Based on the chart, the system is more reliable when the human distance is at around 82 inches from the camera, while it undermeasures distances above 82 inches and over measures distances below 82 inches.

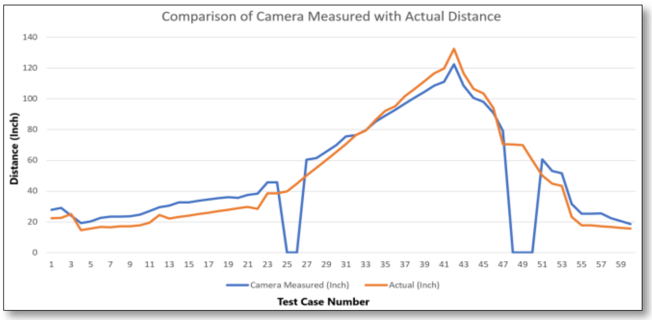

Fig. 25. Comparison of camera measurement and actual distance during daytime

Meanwhile, for the test performed at times after sunset, it is shown that the average difference is 23.184 inches from the actual measurement includes times when the camera did not detect face, shown as "0.00". When the average calculation excludes five times when the camera could not detect face as "0.00", the average difference became 4.381 inches. Therefore, in average, the camera and algorithm to recognize human face has error rate of 38.097% overall. The data visualization of the post-sunset human face camera and algorithm is shown in Fig 26. Based on the chart, the system is quite similar with the test performed during daytime where it is more reliable when the human distance is at around 82 inches from the camera and undermeasures distances above 82 inches and over measures distances below 82 inches. The difference is that the post-sunset test result has more "0.00".

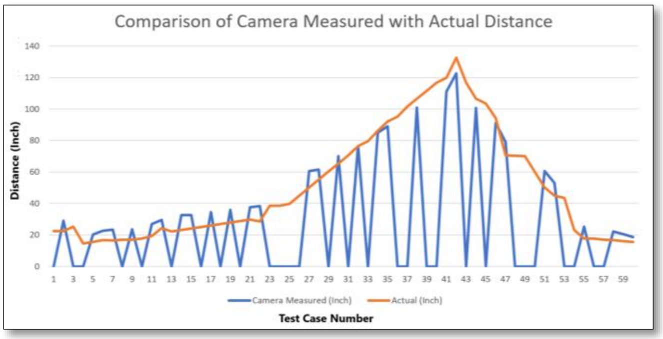

Fig. 26. Comparison of camera measurement and actual distance after sunset

Comparing camera performance during daytime versus after sunset, it is clear that the camera is more reliable on daytime, while it is less reliable on post-sunset period that it could not recognize human face at some times. As the camera depends on lighting, there are cases where the camera cannot detect anything especially after the sun sets.

While the test during daytime is reliable, there is still a small percentage of error that is still acceptable. This error happens when different views or distances are tested on the camera analysis and expected to happen – this phenomenon is called as floating error as the measurement error between the detected distances and actual distances are small (Pang, 2014).

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