International Journal of Emerging Engineering Research and Technology
Volume 8, Issue 4, 2020, PP 6-12
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Internet of Things (IoT) for Monitoring and Controlling the Integrated Incubator Using PLC with Raspberry Pi Gateway

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ABSTRACT

Currently, the integrated incubator system uses only the control panel for the purpose of adjusting the parameters and monitoring the temperature or humidity on site. This will cause the inefficient of time, and energy from labor. This project aims to developed integrated main control system using PLC CP1E and raspberry pi as the IoT gateway for transmitting data to the cloud server. The integration including micro controller, sensors for humidity, temperature and dust, and human machine interface (HMI) allow the measured parameter to be monitor an accessed via HMI or through the website. The data can be stored in server database and can be accessed anywhere. Result revealed that this IoT system functioned as designed and improve the hatching process flow.

Keywords: *Internet of Things, PLC, Raspberry pi gateway, Egg incubator, HMI*

INTRODUCTION

Nowadays, various design of manual and automatic egg incubator systems are developed with innovative features. Generally, a conventional incubator system is equipped with the thermostat for heating purpose, manual eggs turning process operated by the workers and the manual monitoring process done by the farmer. In the era of industrial revolution 4.0, these activities are seem to be less efficient especially in term of operation time and labor used.

In the modern and large-scale chicken farmhouse, the farmers need an efficient monitoring and control method that easy to use and time efficient. For this integrated incubator project, researchers used the microcontrollers as the main system controller to control the whole sequence processes in the incubator including egg turning tray, incubation timing, temperature and humidity control. This artificial egg incubator system aims to improve the quantity and quality of hatching process by maintaining the natural incubation method without being affected by weather and enclosed environment.

In the artificial egg incubation systems, incubation settings are the significant factors which affect the hatchability of poultries. Temperature, humidity, ventilation and turning during the incubation period significantly affect the hatchability of fertile eggs and chicks' quality [2]. In the incubation system, the main factor affected the hatching quality is the stability of temperature and humidity. It should be monitored regularly as to ensure the temperature and humidity are stable at predefined level and to ensure the successfulness formation of embryonic fluids in the egg.

In the Fourth Industrial Revolution (IR4.0), the solution for the control and monitoring system of the incubator can be resolved by applies one of the IR4.0 pillar, that is 'Internet Of Things'. The monitoring system based on internet of things enabled the farmer to monitor their incubator operation at any time and from their own device or smart phone. The eggs incubator system with IoT monitoring system are design and developed with combination of CP1E Omron Programmable Logic Controller (PLC) as the main controller with the microcontroller. For communication between incubator and virtual server, its used raspberry pi and node red as the IoT gateway. The system also consist of sensory devices such as thermocouple, digital humidity temperature (DHT) and dust density sensor. The reading of the sensor used as the control parameter and send or store in the server database. The data of the integrated incubator also can be access through the website dashboard or smart phone applications.

METHODOLOGY

The development of Internet of things (IoT) for monitoring and controlling the integrated incubator using PLC with raspberry Pi Gateway consist of five main parts; 1) Sensory devices 2) Controller / Sensor Node 3) Gateway 4) Cloud Server and 5) User database.

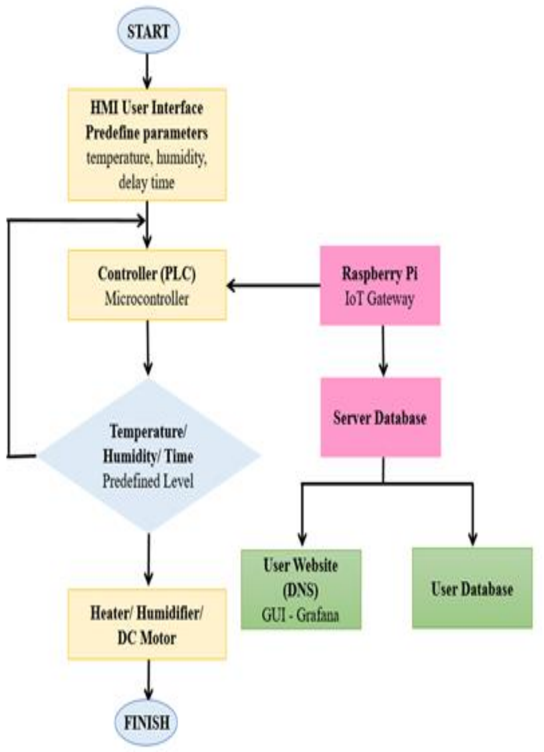

Figure2.1. *Incubator system flow chart*

The main controller for the system is the PLC and serial connection with arduino for the combination input for the temperature, humidity and dust sensor. The controller receive the predefined parameter such as temperature, humidity and tray delay time and consequently generates control action for the heater, humidifier and DC motor. The setting parameters can be access and setting through the Human Machine Interface (HMI) using Omron NB series touch panel.

The IoT monitoring system for the incubation process is used for monitoring the main incubation parameters during the incubation period. This application involves the IoT gateway; Raspberry Pi which connect the data collected from the controller and sending all the data to a cloud server for storing the time serial databases and records the following information:

- Incubation temperature
- Humidity
- Egg turning position, and
- Air quality

All the recorded data can be accessed using the computer or smart phone via the Graphical User Interface (GUI) from the dashboard using Grafana web dashboard.

System Architecture

To enable communication between the incubator using the PLC and Arduino as the controller that connected to the variables sensor to the Cloud Server. This system is developed based on the common requirements of the gateway and capabilities of each sensor and communication protocols. IoT monitoring system used Raspberry Pi gateway with Node Red programming software to enabled communication between the controllers with their sensors measurements value to the Web Server using Linux Virtual Private Server

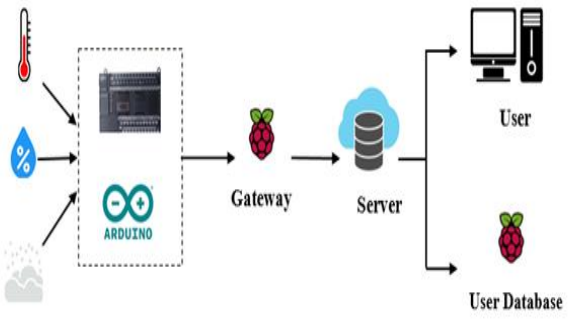

Figure2.2. *IoT communication system architecture*

Sensory Devices

The monitoring system developed is based on measurements of two main parameters, temperature and humidity. The system uses thermocouple for temperature measurement and DHT sensor for humidity measurement. Incubation system also equipped with dust density sensor for sense the dust density in incubator that produced during the incubation period.

Thermocouple

A thermocouple is a sensor that measures temperature. It consists of two different types of metals, joined together at one end. When the junction of the two metals is heated or cooled, a voltage is created that can be correlated back to the temperature [1].

DHT 22

The DHT-22 (also named as AM2302) is a digital-output relative humidity and temperature sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin. Digital temperature humidity sensor DHT has many advantages such as compactness, simple interface, fast response, and cheapness.

Dust Density Sensor

The Optical Dust Sensor is especially effective in detecting very fine particles like cigarette smoke, and is commonly used in air purifier systems. An infrared emitting diode and a phototransistor are diagonally arranged into this device, to allow it to detect the reflected light of dust in air.

Controller (PLC & Arduino) / Sensor Node

Controller is the lowest level of a sensor network, is responsible for gather information from sensors, perform user actions and use communication mechanism to send data to the gateway.

IoT Gateway

In developed system, communication is the main element of IoT, it is important to enable communication between sensory devices and controller to the server. It's also important to enable communication between server and user through GUI interface and accessing database storage. Internet of Things (IoT) envisages overall merging of several "things" while utilizing internet as the backbone of the communication system to establish a smart interaction between people and surrounding objects. Cloud, being the crucial component of IoT, provides valuable application specific services in many application domains [ ].

Figure 2.3 shows the IoT gateway proposed method in this system. Nodes connect to the IoT via a gateway. The nodes themselves (PLC and Arduino) are not IP-based and thus cannot directly connect to the Internet/WAN. Rather, they use wired USB that serially connected to the gateway with a less expensive and less complex mode of connectivity. The gateway maintains an IoT agent for each node that manages all data to and from nodes.

The communication between PLC, Arduino and the gateway raspberry pi using the USB serial connection for stable data transfer. For establish the data communication between Raspberry Pi, PLC, Arduino and Server, we using the Node Red programming methods to interconnect the data. Node Red is a flow-based programming is a way of describing an application's behavior as a network of black-boxes, or "nodes" as they are called in Node-RED. Each node has a well-defined purpose; it is given some data, it does something with that data and then it passes that data on. The network is responsible for the flow of data between the nodes.

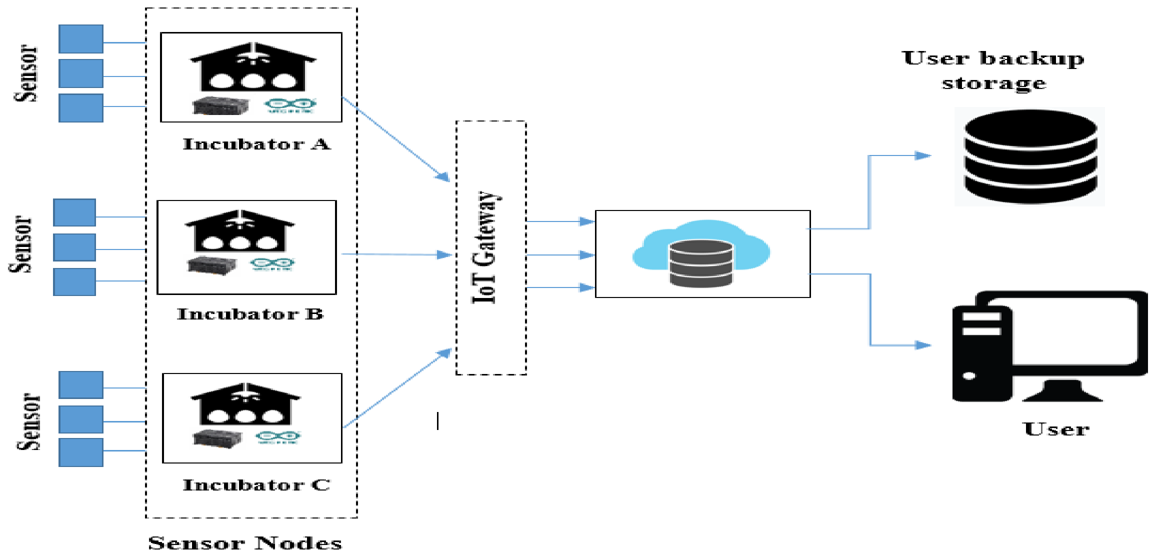

Figure2.3. *IoT communication through gateway*

Raspberry Pi

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse [7]. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games. Raspberry Pi has the ability to interact with the outside world, and has been used in a wide array of digital maker projects.

Node Red

Node-RED is a programming tool for wiring together hardware devices, APIs and online services. Primarily, it is a visual tool designed for the Internet of Things, but it can also be used for other applications to very quickly assemble flows of various services. Node-RED is open source and was originally created by the IBM Emerging Technology organisation. It is included in IBM's Bluemix (a Platform-as-a-Service or PaaS) IoT starter application package. Node-RED can also be deployed separately using the Node.js application. Node-RED enables users to stitch together Web services and hardware by replacing common low-level coding tasks, and this can be done with a visual drag-drop interface. Various components in Node-RED are connected together to create a flow. Most of the code needed is created automatically.

Cloud Server

The cloud is commonly used to refer to several servers connected to the internet that can be leased as part of a software or application service. Cloud-based services can include web hosting, data hosting and sharing, and software or application use. A cloud server is a virtual server (rather than a physical server) running in a cloud computing environment. It is built, hosted and delivered via a cloud computing platform via the internet, and can be accessed remotely. They are also known as virtual servers. Cloud servers have all the software they require to run and can function as independent units.

Time Series Database

A time series database (TSDB) is a database optimized for time-stamped or time series data. Time series data are simply measurements or events that are tracked, monitored, down sampled, and aggregated over time. This could be server metrics, application performance monitoring, network data, sensor data, events, clicks, trades in a market, and many other types of analytics data. In our developed cloud server, it's included the time series database for data storage and combination with Grafana for data visualisation. A time series database is built specifically for handling metrics and events or measurements that are time-stamped. A TSDB is optimized for measuring change over time. Properties that make time series data very different than other data workloads are data lifecycle management, summarization, and large range scans of many records.

Grafana

Grafana is an open source metric analytics and visualization suite. It is most commonly used for visualizing time series data for infrastructure and application analytics but many use it in other domains including industrial sensors, home automation, weather, and process control.

RESULT AND DISCUSSION

The incubator system that has developed is using the CP1E PLC type as the main controller for more durability and lower cost compared to the new PLC with built-in Internet access capabilities and data logging. PLC connected in series with Raspberry Pi as the low cost IoT gateway for the data transfer to the cloud server. Temperature and Humidity measurement used Thermocouple and DHT 22 sensor for more accurate and precisely data. Influx Db time series database used for data storage at the server. Data visualization or dashboard can be access through the website with our own DNS anytime and anywhere. System also equipped with user backup storage using Raspberry pi. Figure 3.2 shows the complete assembled system between PLC, Arduino and Raspberry Pi.

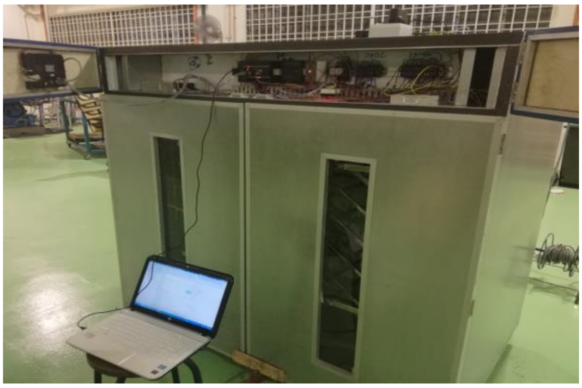

Figure3.1. *Incubator systems that has been developed*

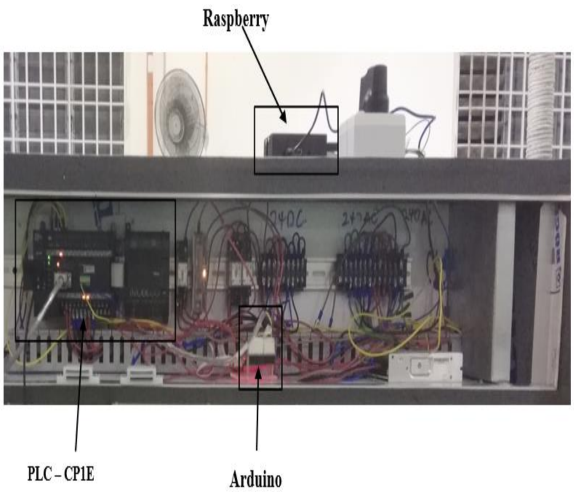

Figure3.2. *Assembled incubator system*

Grafana Dashboard – Graphical User Interface (GUI)

Figure 3.3 shows an information that can be seen by user through website. For the developed system we used combination of Time Series database and Grafana included in cloud server for data storage and visualization. Data from the Sensor Node will send and update to the server through the Raspberry Pi IoT Gateway with a maximum frequency of five seconds per cycle. Data visualization can be displayed using various widgets on Grafana dashboard graphics such as gauge, graph and table. The system has been tested and found that the measured parameter (temperature, Humidity and Dust Density) data has been successfully sent to the server synchronous with the display data on the HMI.

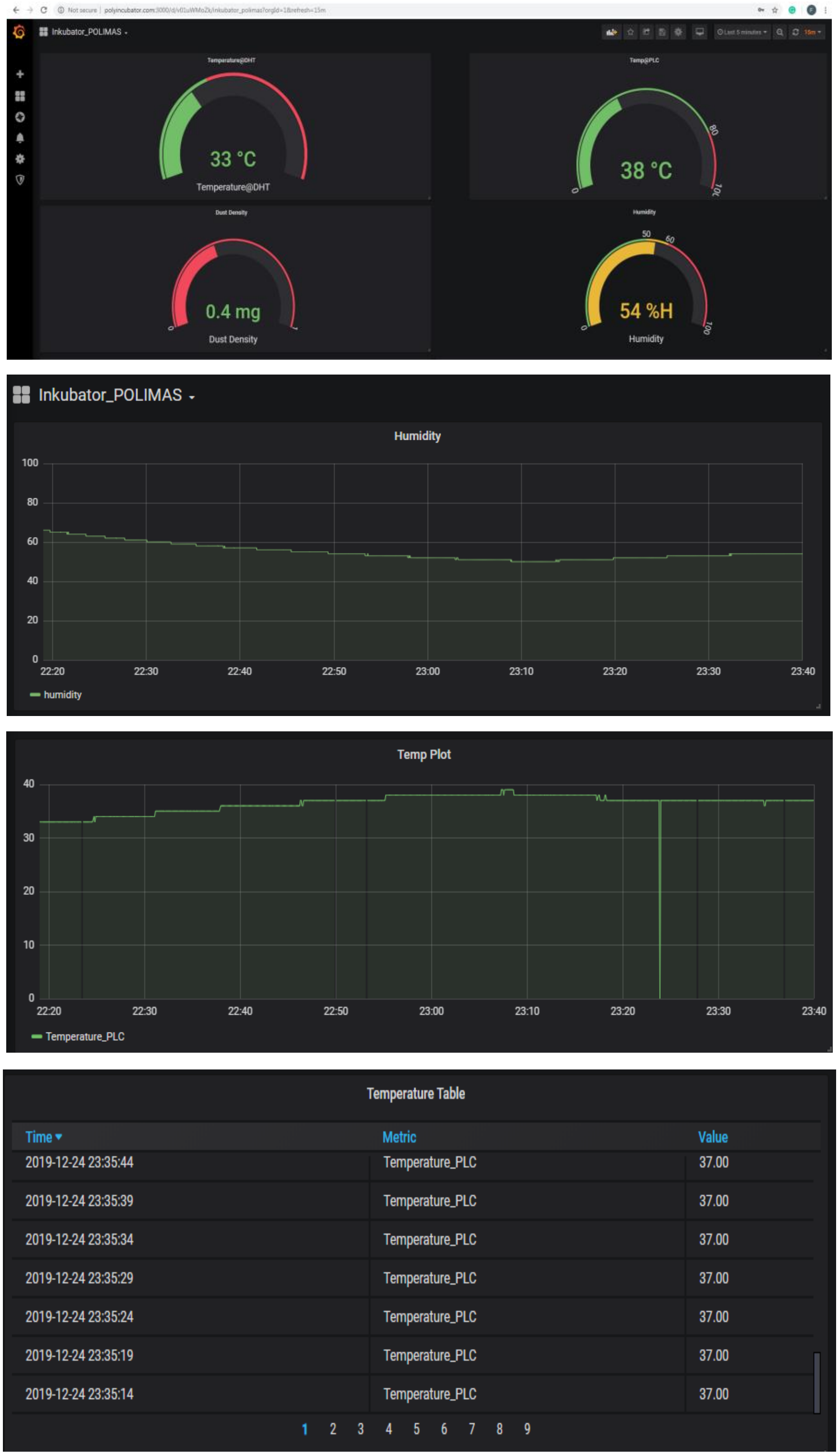

Figure3.3. *Data visualization on dashboard*

Figure3.4. *Data displayed on the HMI*

Node Red Flow

Figure 3.5 and 3.6 show the flow programming in Node Red serial data transfer from Arduino and PLC to the Raspberry Pi. Data was successfully sent to the raspberry pi.

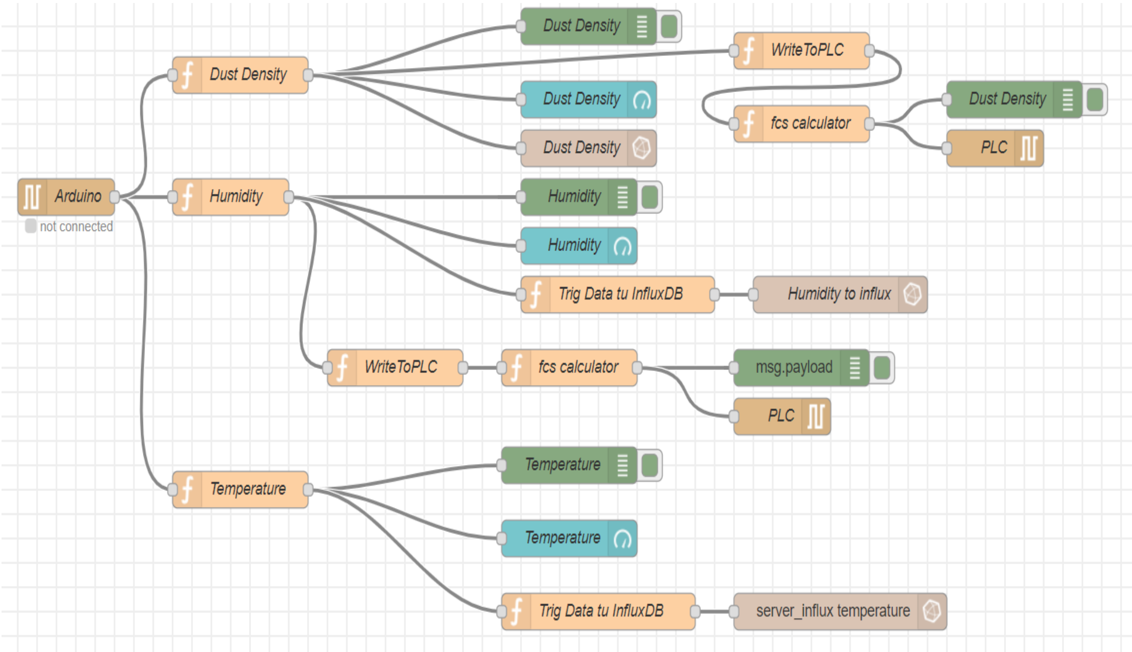

Figure3.5. *Arduino serial data flow to PLC and Influx Db*

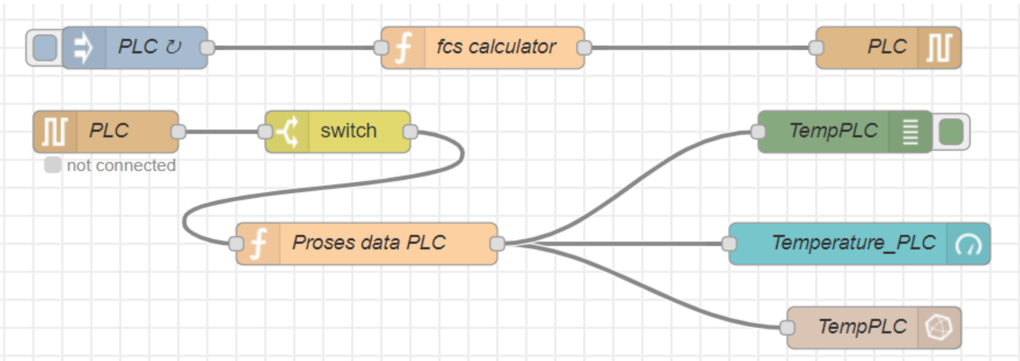

Figure3.6. *PLC serial data flow to Influx Db*

CONCLUSION

Controlling eggs incubator using PLC and monitoring the system through the Raspberry Pi gateway to the website of the cloud server has succeed. This monitoring system enables breeders to monitor incubator operations at all times and wherever they are. It helps breeders to ensure their incubator in good operation condition without having to do regular manual monitoring to the incubator. Its also facilitates breeders or researchers to record incubator operating data automatically during the incubation process for data storage or research purposes. Using website application as graphical user interfaces (GUI) through Grafana Dashboard gives an easiness to use this system because it can be accessed through internet browser from various devices such as smart phone, desktop computer and others.

References

[1] Omega Engineering 2019 .Thermocouples. Available from: https://www.thermocoupleinfo .com/

[2] Harb, S. K., Y. A. Habbib, A. M. Kassem, And A. El Raies, "Energy Consumption for Poultry Egg Incubator to Suituit Small Farmer," Egypt Journal for Agricultural Research, vol. 88, no. 1, pp. 193 -210, 2010.

[3] Gusti Putu Sena Sila Adnyana,I. Nyoman Piarsa, Kadek Sua Wibawa. 2018. Internet of Things: Control and Monitoring System of Chicken Eggs Incubator Using Raspberry Pi. International Journal of Internet of Things 7(1), 16-21.

[4] Andre Gloria, Francisco Cercas, Nuno Souto. 2017. Design and Implement of an IoT gateway to create smart environments. The 8th International Conference on Ambient System, Networks and Technologies, 568-575.

[5] Guohong Li, Wenjing Zhang, Yi Zhang. 2014. A design of the IOT Gateway for Agricultureal Greenhouse. Sensor & Transdusers, Vol 172, Issue 6 June 2014, pp. 75-80.

[6] Frimpong Kyeremeh, Forson Peprah. 2017. Design and Construction of an Arduino Micro controller-based Egg Incubator. International Journal of Computer Application, 0975-8887.

[7] C. Bell, Beginning Sensor Networks with Arduino and Raspberry Pi, 1st Edition, Apress, 2013.

Citation: *Izhar Ahmad, Faizal Ahmad, Mohd Khairul Domadi, Mohamad Norizham Hamzah, Junaidah Ramli, "Internet of Things (IoT) for Monitoring and Controlling the Integrated Incubator Using PLC with Raspberry Pi Gateway", International Journal of Emerging Engineering Research and Technology, 8(4), 2020, pp. 6-12.*