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Welding station monitoring system using internet of thing (IoT)

Ernie Mazuin Mohd Yusof[1], Mohd Ismail Yusof[2], Rafidah Ali[3], Izzat Hilmi Harjimi[4], Qasidah Kamarul Bahrin[5]
[1,2,4,5]Instrumentation and Control Engineering Section, Universiti Kuala Lumpur, Malaysia
[3]Technical Foundation Section, Universiti Kuala Lumpur, Malaysia

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ABSTRACT

In oil and gas industry, productivity is very important as the industry involves high cost and can be considered as a large-scale industry. Therefore, time and budget should be kept minimal to avoid loss to the oil and gas company. An example of lack of productivity in the industry is there are many complaints in the oil and gas industry that welders do not perform their job on time. Therefore, this project discussed about a system that can be used to monitor these welding stations. This system is important because it can help supervisors track the welding works from afar or anywhere using internet of things (IoT). To achieve that, a system must consist of hardware and software that are capable of connecting to the internet and monitor the welding works. In this project, the hardware chosen were Arduino Uno for data processing, ESP8266 to connect the microcontroller to the internet, voltage sensor to detect the voltage of the welding machine and a website to show the data taken. Other than that, this system was able to warn the welder of overvoltage of the welding machine. Thus, the system solved the problem of welders not performing their job on time. Supervisors were also able to monitor the job of welders to ensure maximum productivity. Based on the testing done on the system, the prototype was able to work as intended. The welding station monitoring system was able to detect welding usage, measure voltage values of welding and send the data to IoT for monitoring.

Corresponding Author:

Ernie Mazuin Mohd Yusof,
Instrumentation and Control Engineering Section,
Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology (MITEC),
Seri Alam, Johor, Malaysia.
Email: erniemazuin@unikl.edu.my

1. INTRODUCTION

There are many types of industries available in the world. According to Kniivilä (2007) [1], there are several types of industries including textile and clothing, leather goods, road vehicles, food and beverages, industrial machinery and oil and gas. Meanwhile, several types of industry in Malaysia include oil and gas, automotive, palm oil, rubber and tin [2]. In the industry, one of the most important things that must be focused on is productivity.

Productivity, in technical term, is the measure of output per unit of input [3]. Productivity involves the efficiency of the usage of labor, resources, capital and many others. Usually, higher productivity shows that the company is able to produce more products with the same resources as compared to company that has lower productivity. Productivity is important in the industry as it can define a company as a whole. Most of the time, productivity involves the rate of work of the workers in a company that can greatly increase profit or revenue if the work rate is fast. Slow work pace will cause delay to the completion of project in any types of organization. The project dateline will not be met and subsequently will incure more operating cost towards the organization.

Welding is one of the processes that can be related to productivity. Welding is very important as most of the works related to the industry involves metal fabrication (Mgonja, 2017) [4]. On the oilrig, complex process such as drilling, extracting and processing of oil and natural gas can be performed. There are many types of oil rig such as fixed platforms, drill ships and floating production systems and most of them are built on steel legs [5]. The process of construction and combining the steel sections mostly involve welding process. Other than that, most equipment in the oil and gas industries are also made up of structural steel. Examples of equipment include pipelines, pressure vessels and oil and gas separators.

Welders are the backbone of oil and gas industry. Within the oil and gas industry, there are many departments such as facilities engineering, production, exploration and drilling. Welders in oil and gas industry can work at two different areas which are onshore and offshore [6]. Offshore welders are welders who work on the oilrig and they are responsible to repair and maintain the structural integrity of the oilrig full time to prevent unexpected catastrophe. This can be done by performing cutting, gouging and welding of the pipelines, rigs, plants and facilities on the plant. Meanwhile, onshore welders are welders who work on repair facilities to fix incoming ship or oilrig to perform fixing work. Thus, due to the nature of the oil and gas industry that requires high commitment and high productivity, welding works need to be done on time and efficiently.

High productivity is important in oil and gas to avoid potential loss, bankruptcy and losing clients. According to PricewaterhouseCoopers (2016) [7], oil and gas is considered as one of the most important industries in Malaysia as it contributed to the second largest exports which contributed up to 20% to the country's gross domestic product (GDP) in the recent years. In a nutshell, productivity is important in any industry especially oil and gas to ensure survivability and to avoid bankruptcy to the company.

There are many problems that have already existed in oil and gas industry such as over time, over budget, political issues and oil price drop (Deloitte, 2014) [8]. The overtime and over budget can be related to the problem that the project has solved which was welders do not perform their task accordingly and not on time. As mentioned earlier, in any industry, productivity is very important as it can be considered as a competitive advantage in today's increasingly changing environment to ensure high revenue and to avoid bankruptcy (Preenen et al., 2017) [9].

In oil and gas industry, supervisor found that it is difficult to monitor the job of the welders as they have other things to handle and welders normally perform their job away from their supervisor's site. Therefore, there is a need for a system that can help the supervisor to monitor the job of welders. Using this system, the supervisor or related personnel were able to observe the runtime of the welding machine on the internet using IOT. Moreover, this system were also able to help welders to perform their job on time, which has ultimately increased the productivity of the company they work in.

This paper has been organized into several sections which are section 1 which provides the background of the project. Basically, this section has explained the origin and the reason why the topic was chosen for the project. This section has also provided in-depth details regarding the project to provide further understanding on the research project. Meanwhile, section 2 includes a review of literature, which is the study of past researches that has been done related to the research project. In writing this section, thorough reading from secondary resources such as journal, article, books, newspaper and website was done. This section has also provided facts based on past researches to further strengthen the data that were used or included in this research project to increase the validity of the research project.

Section 3 focuses on the methodology of the project. This section provides explanation in detail regarding the method used and process flow of the project. Section 4 provides in-depth detail about the experiment and design done for continuous development of the prototype and finally, section 5 is the conclusion of the project, which includes the objectives that have been achieved in this project and the effectiveness of the system for real world use especially in the industry.

2. LITERATURE REVIEW

2.1. Productivity in Oil and Gas Industry

As mentioned earlier by Sauermann (2016) [10], productivity is the measure of output per unit of input. Meanwhile, Jorgenson et al. (2007) [11] stated that the difference between total real output product and total real factor input defines productivity. Productivity is important because historically, consistent productivity has been highly related to development of new technologies such as electricity and steam engine (David, 2010) [12]. Therefore, productivity is very important in businesses especially in high revenue and large-scale business such as oil and gas and there are several importance of productivity in oil and gas industry.

In oil and gas industry, productivity is highly affected by the rise and fall of the oil price [13]. He mentioned that the increase in oil and gas price usually increases employment as well as the company's

needs to produce more oil. Therefore, during this time of high prices of oil, productivity must be increased to reduce the need for more workers to avoid unnecessary spending. Moreover, productivity in oil and gas is also important to allow the company to grow and survive in a business environment that is competitive [14]. Therefore, productivity is important in any industry especially oil and gas industry that is highly competitive.

2.2. Shielded Metal Arc Welding (SMAW)

Also known as stick welding, Shielded Metal Arc Welding (SMAW) is an example of a common type of arc welding which uses a fixed length electrode and an electric power source to join two metals permanently. According to Paul (2013) [15], in many parts of the world especially Latin America and India, SMAW is considered as one of the best types of arc welding process. In arc welding, the heat comes from the production of electric arc between work piece and the electrode. Electric arc is the discharge of luminous electrical through ionized gas between two electrodes. Normally, any arc welding will consist of power supply either AC or DC, welding electrode, electric cables and work piece.

In arc welding, the circuit is completed using the electric arc produced between the work piece and electrode. In this process, oxide and nitride in the atmosphere can contaminate the weld due to the molten metal of the work piece being chemically active and can react to surrounding atmosphere. Moreover, this can deteriorate the mechanical properties of the weld or work piece. Therefore, a shielding gas such as Argon or shielding flux is used to protect the weld pool from atmospheric contamination.

As for SMAW, this process combines two metallic work pieces by producing molten weld pool using energy produced from the welding arc [16]. A shielding flux is used to coat the electrodes and must be of a suitable composition. The flux metal and the electrode metallic core melts together which will form a protecting gas and a slag to protect the weld pool and the arc. The flux supplies some alloying elements to the weld, cleans the metal surface, protects the molten metal from oxidation and stabilizes the arc. The slag formed will be removed after solidification. When performing Shielded Metal Arc welding, all of the CLAMS points must be considered carefully. CLAMS stands for current rating, length of arc, angle of electrode, manipulation of electrode and speed of travel of welding process. To ensure the welding is smooth and flawless, these five points must be carefully implemented. Figure 1 shows the illustration of the working principle of Shielded Metal Arc Welding (SMAW).

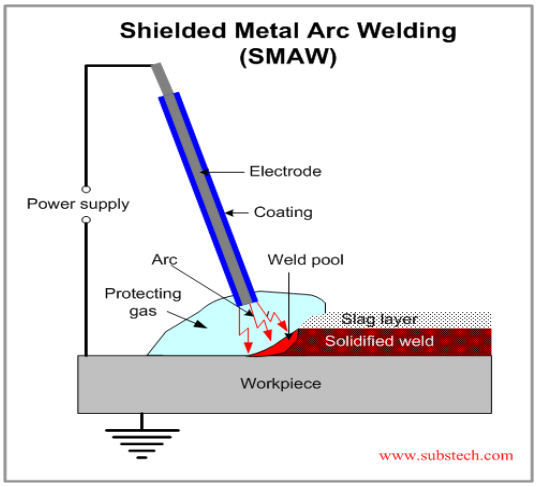

Figure 1. Illustration of shielded metal arc welding (SMAW)

2.3. Effect of Welding Machine Voltage on Welding

In welding, voltage is one of the parameters that is commonly observed to ensure smooth welding process because welding voltage affects the arc length. Although welding voltage has effect on arc length, it has virtually minimal effect on weld penetration compared to other variables such as current and travel speed [17]. When the voltage is increased, the arc length gets longer if it has the same wire speed and when the voltage is decreased, the arc length gets shorter. Figure 2 shows the difference in length of arc and width of cone when using different voltage.

As a result, the arc length defines the size and width of the arc cone. The arc cone will become smaller and more focused as the arc length decreases which results in a weld bead that is narrower and ropy with slight decrease in weld penetration. Meanwhile, when the arc length is increased, the arc cone will

become wider and the arc will be broader. This will result in wider and flatter weld bead that may increase the welding penetration very slightly [18]. In conclusion, the voltage of the welding affects weld bead but not weld penetration. Figure 3 shows the effect of using different voltage rating for welding with the same amperage, travel speed and electrode diameter.

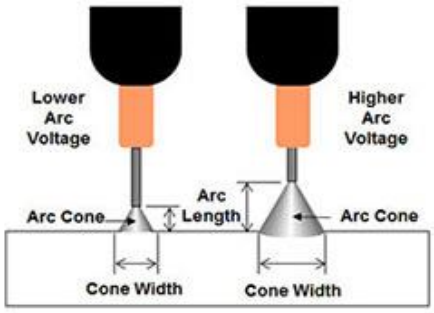

Figure 2. Arc length and arc cone using different voltage

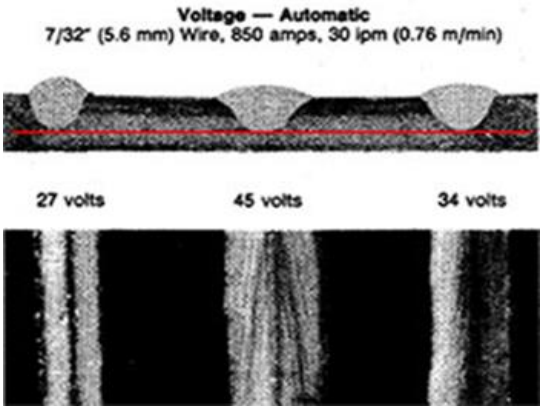

Figure 3. Welding penetration and weld bead shape using different voltage

2.4. Function of Voltage Sensor

A voltage sensor is an important part of an electrical system as it can be used to monitor, measure and determine the supply of voltage of a DC and AC system [19]. Other than for simple voltage measurement, voltage sensors are also used for power failure detection, load sensing, safety switching, temperature control, power demand control and fault detection. The input connected to the voltage sensor is usually voltage from the system while the output can be in many type of signaling forms.

These signaling forms include analog voltage, analog current, audible signals, switches, frequency and even frequency-modulated output. Moreover, some voltage sensors can also perform Pulse Width Modulation, Amplitude Modulation or Frequency Modulation and produce sine or pulse trains as output. According to Chen et al. (2014) [20], the working principle of a voltage sensor is usually based on a voltage divider. There are two common types of voltage sensors, which are capacitive type, and resistive type voltage sensor. Figure 4 shows the schematic of capacitive and resistive type voltage sensor.

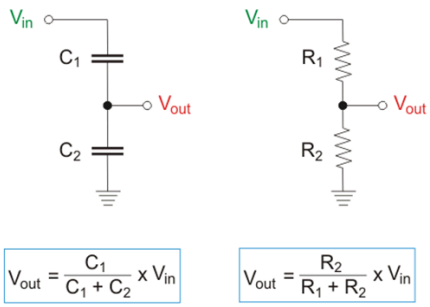

Figure 4. Schematic diagram of capacitive and resistive type voltage sensor

2.5. Overview of Internet of Things (IoT)

Internet of things, commonly known as IoT, is network of physical devices embedded with sensors, actuators, software, electronics and connectivity, which allows these devices to connect and exchange data [21]. In simple words, IoT is a technology used to send and receive sensor data via internet networks [22]. Examples of these physical devices include cars, smartphones and smartwatches. Moreover,

according to Pate and Adegbija (2018) [23], IoT can be referred as a widespread of connected devices that can interact with each other, and collect, translate, and use data to reduce reliance on human intervention.

The best thing about IoT is it allows remote control of devices which results in increase efficiency, accuracy and less human intervention. In businesses, the capability to track and code objects have enabled companies to increase efficiency, speed up their processes, prevent theft, reduce errors and incorporate complex and flexible organizational systems through IoT [24]. With the availability of open wireless technology such as Wi-Fi, Bluetooth and Radio Frequency Identification (RFID), IoT is no longer in its infancy stage and is prepared for mass adoption.

2.6. Website as Monitoring System

The World Wide Web (WWW) is a collection of webpages found on network of computers that are connected through the internet [25]. With network technology improving rapidly and continuously, the WWW continues to grow at an astounding speed as one of the most popular applications [26]. In 1989, an English scientist named Tim Berners-Lee invented the WWW. The WWW is the backbone of the Information Age and is the main tool for people around the globe to communicate and interact on the Internet.

The WWW can be accessed using web browser which is able to open and render the content of Web pages. Meanwhile, a web search engine such as Google and Yahoo are software systems intended for information searching on the WWW [27]. The results of the search made are normally shown in line of results and can be a mixture of web sites, images and others. Meanwhile, the WWW is normally seen in the form of web pages. Web pages are mostly documents containing formatted and annotated text using Hypertext Markup Language or also known as HTML. HTML is a computer language that allows creation of websites that can be viewed by people that has access to the Internet.

Apart from texts, web pages can also contain picture, video, audio and other multimedia content to make the website more appealing. To allow the users to navigate through web pages, embedded hyperlinks are used. A group of web pages with the same domain, theme or both combined is what we call a website. A website is flexible and it can be mainly maintained by the publisher, or open-source which allow visitors to edit the content of the website. Websites, are commonly used for information retrieval and exchange, entertainment, commercial, governmental or non-governmental organizational purposes.

Moreover, Pendyala and Figueira (2015) [28] stated that the website is a primary medium for information exchange. To upload the web pages to the Internet, the owner must choose a web hosting service. A web hosting service provider allows the website to be accessible via the WWW by keeping the data on the provider's server. According to Śliwiński et al. (2008) [29], the most popular form of hosting at the moment is free web hosting. However, most free web hosting service will show some advertisements on the user's website.

3. METHODOLOGY

3.1. Research Methodology Structure

In this project, there are six important items in the development of the hardware and software of the prototype. Each of these items played an important role in completing the system in this project. The six items are voltage sensor, LEDs, Arduino Uno, ESP8266 Wi-Fi module, IOT and web pages. The interconnections between these items are shown in Figure 5 in the form of a block diagram.

In this project, the parameter measured was voltage of the welding machine. Therefore, a voltage sensor has been used to measure the voltage flowing through the welding machine wire during usage. Meanwhile, the main microcontroller used in this project was Arduino Uno. The microcontroller acts as a controller to receive the value from the sensors and send the data to IoT.

To send the data to IoT, an internet connection is required. ESP8266 was used to connect the Arduino Uno to the nearby wireless access point. Once the data has been uploaded into the internet, a web page or website is used to display the real-time reading of the current sensor to the user. The following explanation describes the working principle of the whole system:

a) The welding monitoring system is turned on and green LE will light up which shows that the system is active.
b) The voltage sensor will be attached to the welding station to be monitored.
c) The user access the website to view the voltage and usage of the welding machine in real-time.
d) The red LED will light up if voltage exceeds sensor limit value.
e) The user downloads the data in the form of Excel file format if required.

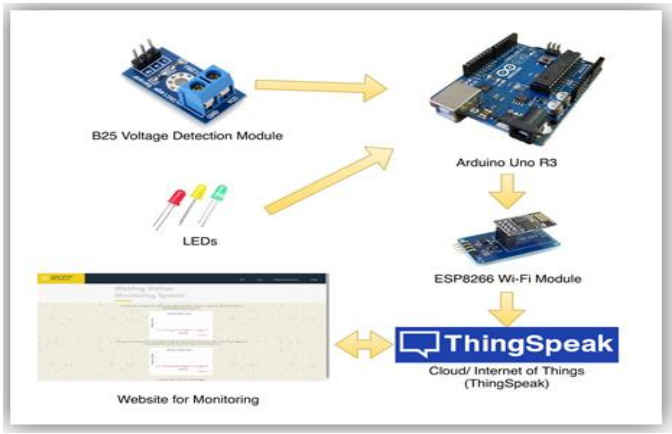

Figure 5. Block diagram of the system

3.2. Project Flowchart

The flow of the whole project can be visualized by using a flow chart since flow chart is commonly used to describe the flow or process of a project. First, the system was turned on to provide power to the system. A green LED lighted up to inform the user that the system was active. Before using the system, the welder has attached the voltage sensor in parallel connection to the positive and negative terminal of the welding machine. In this project, the parameter that is measured was voltage since voltage is one of the sources of heat production for arc welding.

Once the sensor was attached, the welder had started the welding work. A blue LED lights up every time the welder was doing welding to indicate that there was welding being done. Meanwhile, to observe the welding station from afar, the supervisor had accessed the website through a mobile phone or personal computer with internet access using Uniform Resource Locator (URL), since the data were uploaded to the cloud. In monitoring page, he was able monitor the real-time monitoring works by observing the welding status which was in digital '1' and '0' form. The value '1' stands for the welder is currently welding and '0' means that the welder is not doing any welding job. Other than that, the user was also able to observe the voltage of the welding machine to ensure that the voltage was in the range that it should be. The user of the system was also able to export the previous data logging for all welding works by downloading Comma-separated Values (CSV) file in Microsoft Excel format for analysis in later time. Once the monitoring was done, the sensor was disconnected or removed from the welding machine. Figure 6 shows the data logging in the form of CSV file and Figure 7 shows flow chart for the system.

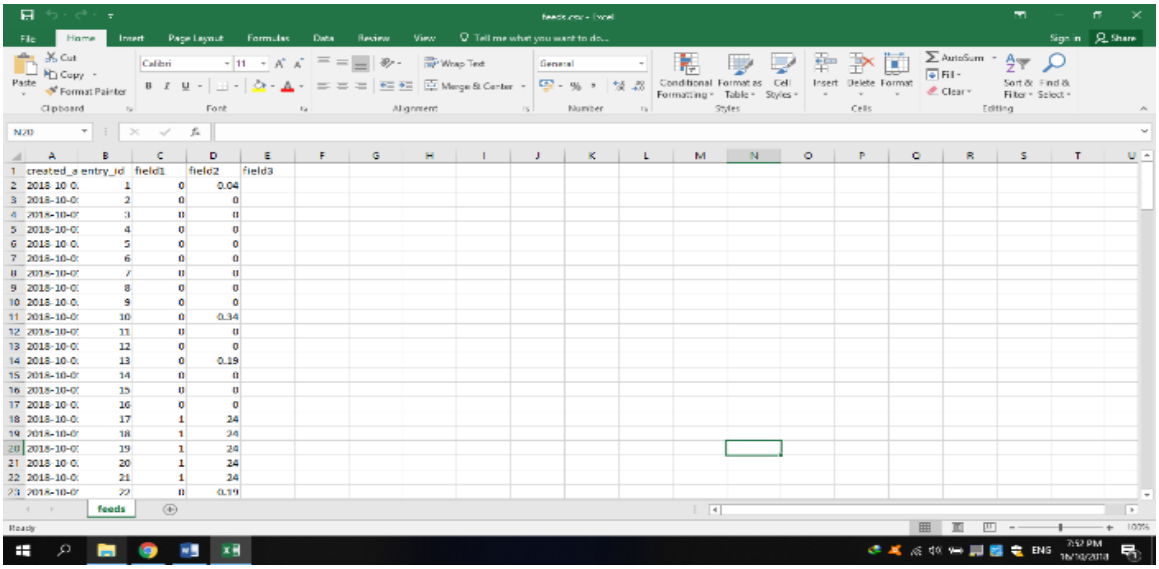

Figure 6. Data logging in the form of CSV file

3.3. Circuit Diagram

Before the development of the prototype, a circuit diagram was designed and developed to ensure smooth development of the system. This is because a circuit diagram acts as a guide for the user during the development phase. Due to lack of focus or human error, a circuit design can help prevent wrong wiring which may cause short circuit or the electronic component to be broken. The software used to draw a circuit diagram was Fritzing software, which is an open-source tool for design of electronic circuit.

From the circuit diagram as shown in Figure 8, there are three LEDs used which are green, red and blue. The green LED, which was used to indicate that the system is turned on, is supplied with 3.3 V power supply from the Arduino Uno and protected with 100 Ohms to reduce current flow that may fry the LED. Meanwhile, the blue and red LED were connected to digital pin 8 and 9 on the Arduino Uno and protected with 220 Ohms resistor. The ESP8266 Wi-Fi module with ESP-01 adapter was connected to digital pin 2, digital pin 3, 5 V power supply and ground on Arduino Uno. Digital pins were used for the Wi-Fi module because the connection is based on serial communication with the Arduino Uno.

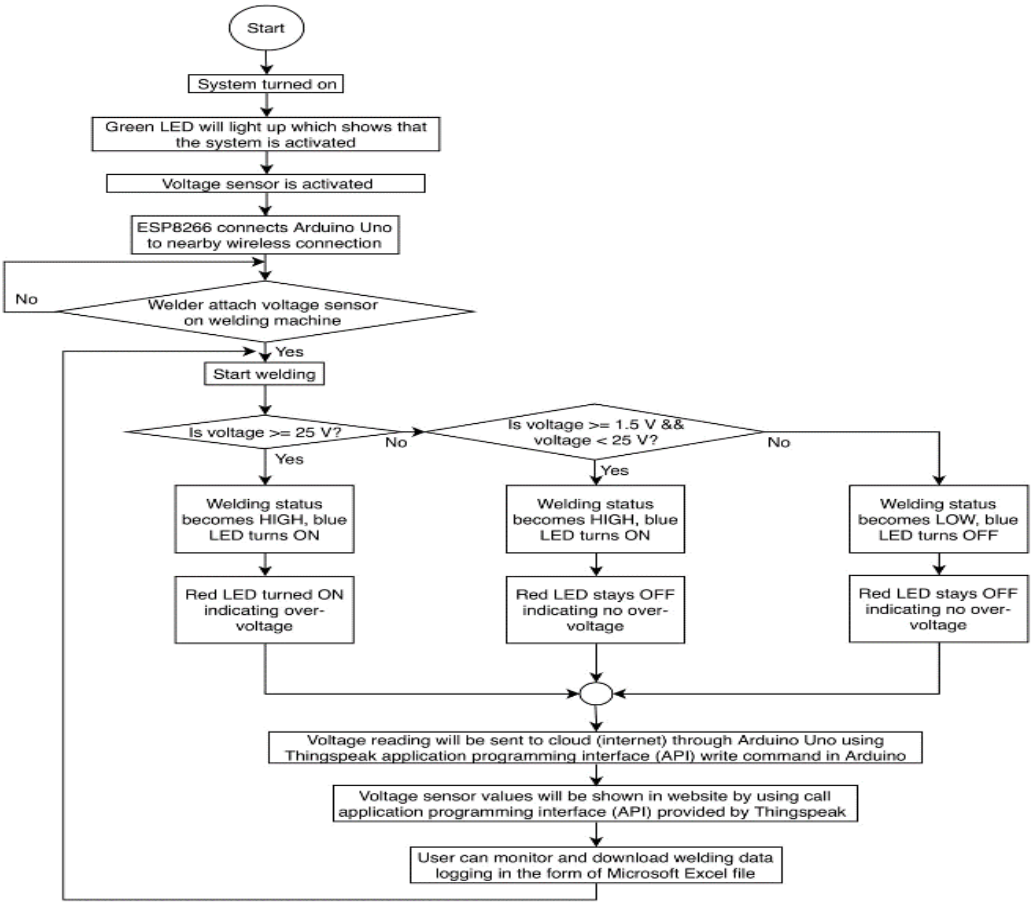

Figure 7. Overall system flow chart

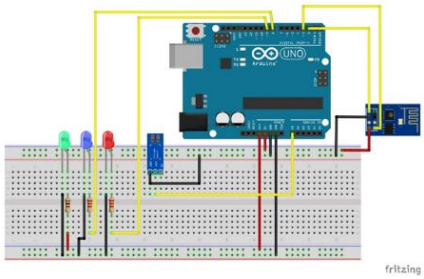

Figure 8. Circuit diagram design for welding station monitoring system

3.4. Prototype Design

Figure 9 presents the prototype design of the system. These two components which are smart device and the welding monitoring system hardware are vital for this system to work. Basically, the user needs to connect to the internet via a smart device such as a laptop to monitor the welding machine in order to utilize IOT technology. It can be observed as well that the hardware also has LED indicators to indicate the condition of the system such as power status (green LED), welding status (blue LED) and over-voltage alarm (red LED).

Figure 9. Prototype design

4. RESULT AND DISCUSSION

4.1. Development of Website for Monitoring System

In this system, a website was used to monitor the welding works. The main programming language used to create the website was Hypertext Mark-up Language (HTML) which is a common language used in creating a website. Other than monitoring page in the website, there are also pages that gives information regarding the project as well as the person that should be contacted regarding the project. Basically, the main page of the website briefly describes the project to ease the user to understand more about the project. Figure 10 shows the welcome page of the website for the system.

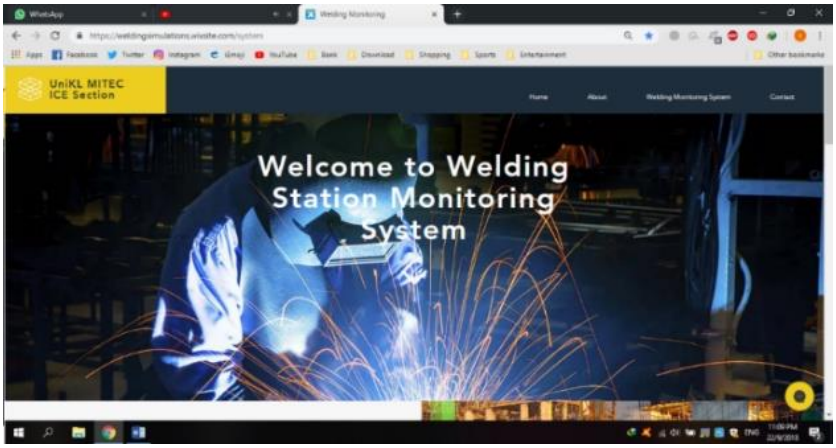

Figure 10. Main Page of the Website

As for the data of the sensors shown in the website, the data were shown in the form of two graphs, which are usage graph and voltage reading graph. The usage graph shown data in the form of digital '1' and '0', which translates '1' for currently welding and '0' for idling. Meanwhile, the voltage reading graph showed the voltage of the welding machine. Both of the graphs were in real-time as long as the system was turned on. Once the system was turned off, the graphs have stopped at the latest data that was sent by the system. Moreover, the data can also be interpreted by downloading the excel file that records the reading of the sensors and usage with timestamp. Meanwhile, Figure 11 shows the section of the page where the monitoring is done.

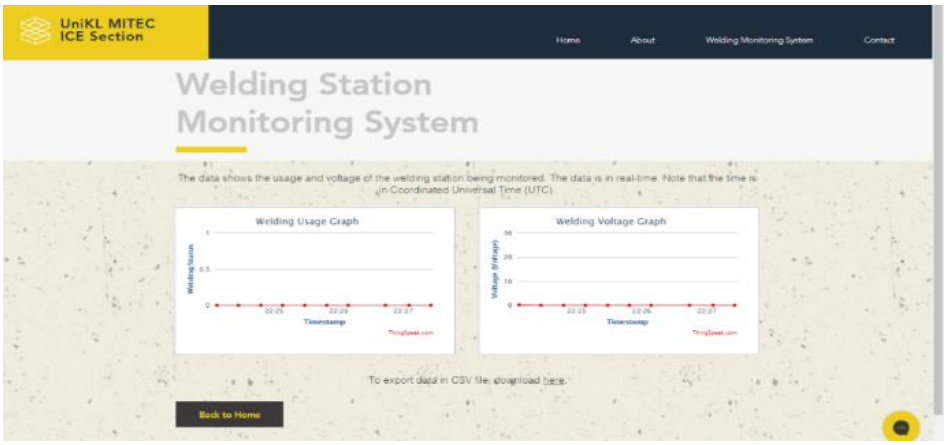

Figure 11. The page used for monitoring works

4.2. Comparison between Different Types of Probe

In this system, there were two types of probe used to measure voltage of the welding machine, which were multimeter and voltage sensor for Arduino. Both of these probes work on different principle. The multimeter working principle is based on a shunt resistance, measuring the voltage developed across it. Meanwhile, the voltage sensor for Arduino works similar to a voltage divider. Therefore, due to different working principle, the difference in the two sets of data were expected. A graph was plotted based on both sets of data on the same graph to observe the trend of the data. Figure 12 shows the graph of readings from different probes.

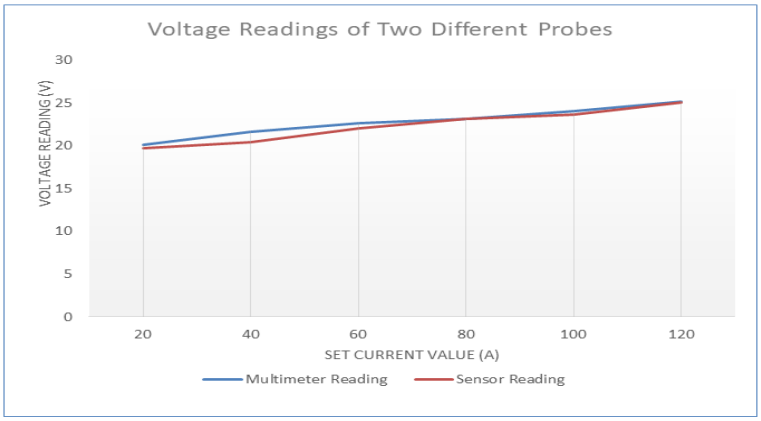

Figure 12. Graph of voltage readings of two different probes

Based on the data that were collected, it can be seen that different types of probe used have given different readings. This is simply because there were many external factors that can contribute to the differentiation of probe values. These external factors can arise when the probe is exposed to a certain environment. The external factors that can cause disturbance to the readings are:

A. Application Variables

The first external factor is application variables such as barometric pressure, overpressure, specific gravity, obstructions, shock, vibration and temperature. In this experiment, the most obvious application variable was temperature. This is because the temperature inside the workshop or welding area was extremely hot. This might cause disturbance to the sensor data since the data were sent through wires that are sensitive towards temperature [30].

B. Lack of Proper Installation

Second factor includes lack of proper installation such as improper wiring, unsuitable wire and incorrect parameters. The wiring of the system might not be at optimum since there were many jumper wire used. This might cause voltage drop across the circuit, which resulted in unreliable reading [31].

C. Natural Drift

Natural drift can come from wear and tear as well as rust in wires since the system was exposed to extreme conditions [32].

4.3. Collection of Voltage Reading from Internet Cloud

In this section, the results collected were in the form of CSV file, which is an Excel file type. This excel file was downloaded in the website used for monitoring. Inside the CSV file, there are four columns shown which were time stamp, entry number, welding usage and voltage reading. The time stamps were in coordinated universal time (UTC). Figure 13 shows the data logging in the form of CSV file.

Then, the data logging were interpreted in the form of graph, which shows the usage of the welding machine of UniKL MITEC students in welding workshop. The data logging were taken for three days, which were on Monday, Tuesday and Wednesday dated on 1st of October to 3rd of October in 2018. These days were chosen because these are the days where most classes are usually conducted. Figure 14 shows the welding usage of a welding machine in UniKL MITEC.

	A	B	C	D
1	created_a	entry_id	field1	field2
2	2018-10-0	1	0	0.04
3	2018-10-0	2	0	0
4	2018-10-0	3	0	0
5	2018-10-0	4	0	0
6	2018-10-0	5	0	0
7	2018-10-0	6	0	0
8	2018-10-0	7	0	0
9	2018-10-0	8	0	0
10	2018-10-0	9	0	0

Figure 13. Data logging in the form of CSV file

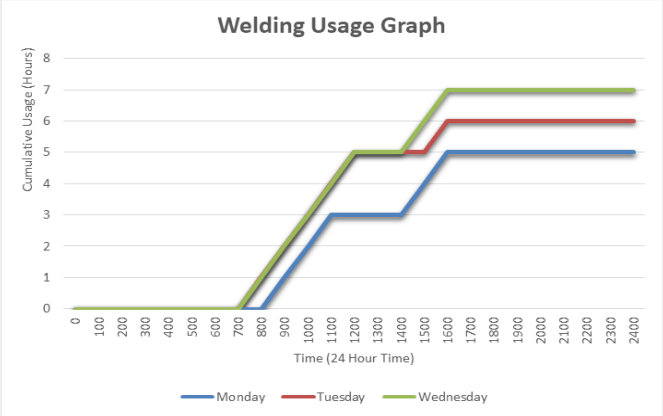

Figure 14. Welding usage graph of a welding machine from three days

Based on the graph, it can be concluded that the usage of the welding machine has increased day by day. This is due to the week was ending and students needed to finish their work quickly. The productivity of the usage of welding machine has also increased as the week progressed. However, there is usually no trend in welding usage since the usage is mostly random based on on-going projects or task that were given to the students by lecturers. Based on this data logging, that the third objective, which is to collect voltage reading from internet cloud, was successful since the data were able to be collected from internet cloud from interpretation.

5. CONCLUSION

Based on the testing done on the system, the prototype was able to work as intended. The welding station monitoring system was able to detect welding usage, measure voltage values of welding and send the data to IOT for monitoring. A B25 voltage sensor module was used to measure voltage reading of welding machine and Arduino Uno was used to process the data that were sent to IoT using ESP8266 Wi-Fi module. The user was also able to interpret the data and monitor the data in real-time using a website. However, small drift in accuracy was expected when using the system as external factor such as application variables, lack of proper installation and natural drift should be take into account when using the system. Thus, the objectives of the research project which were to integrate Arduino Uno and IoT for the purpose of monitoring and controlling welding jobs, to measure the voltage in arc welding machine using voltage sensor and to collect the reading of voltage from the internet cloud are achieved. Moreover, there were several problems encountered during the development of the prototype such as broken sensor and improper circuit connection. In a nutshell, supervisors were able to use the system to monitor welding works, which has been proven to increase the productivity of welding works in the industry as it can help to ease the job of monitoring done by supervisors.

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BIOGRAPHIES OF AUTHORS

Ernie Mazuin Mohd Yusof received her B. Eng. in Computer and Information Systems Engineering from the International Islamic University Malaysia (IIUM) in 1999. She earned MSc in Computer Science from the Universiti Teknologi Malaysia (UTM). She is currently pursuing her Doctor Philosophy in UTM. She was holding a Senior Engineer post in electronics manufacturing company. She is currently a lecturer in Instrumentation & Control Engineering section, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology (UniKL MITEC). Her research interests cover business intelligence, manufacturing data visualization, Supply Chain Management and Internet of Thing (IoT). Her current project is 'Business Intelligence Implementation in Manufacturing'.

Mohd Ismail Yusof Othman received his B. ET in Mechatronics from Universiti Kuala Lumpur, Malaysia France Institute (UniKL MFI). Then he earned PhD in Automatic Control & Systems Engineering from University of Sheffield, United Kingdom. He is currently a Senior Lecturer in Instrumentation & Control Engineering section, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology (UniKL MITEC). His research interests are in control system with application in robotic, slam sensor fusion single and multi cooperation robot mobile platform for rescue, inspection and exploration application.

Rafidah Ali received her B. Mathematics from Universiti Institut Teknologi Mara (UITM). Then she earned Master of Mathematics from Universiti Teknologi Malaysia (UTM). She is currently pursuing her Doctor of Philosophy in UTM, specializing in forecasting hybrid learning machines model, wavelet and empirical mode decomposition methods. She is currently a lecturer in Technical Foundation section, Malaysian Institute of Industrial Technology (UniKL MITEC). Her research interests are in mathematics and statistics focusing on forecasting and modelling.

Izzat Hilmi Harjimi received his BET in Instrumentation and Control Engineering from Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology (UniKL MITEC). He is currently working as Instrument and Control Trainee at Petronas Carigali Sdn. Bhd., Malaysia Asset, Sarawak Operation (SK-Oil), under the department of Instrumentation and Control (Oil and Gas (Upstream)). His research interests are in instrumentation and control in oil and gas field and internet of thing.

Qasidah Kamarul Baharin is currently pursuing her BET in Instrumentation and Control Engineering from Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology (UniKL MITEC). She is currently doing her research project on Solar Energy Generating System (SEGS) in UniKL MITEC. Her research interests are in instrumentation and control specialized in renewable energy generating system and internet of thing.