Development of Raspberry Pi applied to Real-Time Monitoring of Overall Equipment Effectiveness (OEE)

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Abstract. Overall Equipment Effectiveness (OEE) is a production machine performance measurement system. Performance measurement with OEE consists of three main parameters in the production machine, namely Availability (machine availability time), Performance (number of units produced) and Quality (quality produced). Many OEE monitoring modules are on the market. These modules are still very expensive so most companies are still unable to implement OEE into production machines. In this research, a software called OEEMAX which functions for OEE monitoring has been developed to be installed on Raspberry Pi. OEEMAX was built to be able to run on Raspberry and be able to read inputs from sensors. OEEMAX is also able to communicate with all types of Programmable Logic Control (PLC). The advantage of Raspberry Pi is the price of the module which is very cheap and uses open source operating system. OEEMAX has been successfully developed and applied to Raspberry Pi. It is able to read sensors through general purpose input / output (GPIO) and communicate with PLC using RS-232 protocol. In addition, it is also capable to send OEE data to SQL server.

1. Introduction

Total Preventive Maintenance (TPM) is a management system that has been widely applied. TPM is a management concept for maintenance of overall plant equipment. The purpose of TPM is to improve product quality, reduce abnormal costs, and avoid waste and to prevent engine damage. Prevention of engine damage is done by improving the maintenance system so that it can strengthen manufacturing performance and be able to achieve high quality [1]. The concept of TPM involves production equipment, so that it greatly influences the quality, productivity, cost, inventory, safety, health, and production output.

TPM system requires performance measurements that are appropriate and similar to other world-class management systems. Because one of the achievements of the TPM is to improve equipment efficiency, the measurement of its performance directly influences the availability, efficiency of performance, and quality, and OEE is a tool to fulfill these measurements. Although OEE is a simple indicator, it is still an effective method for analyzing the efficiency of each machine as well as the machine as a whole [2].

Implementing OEE in developing countries, especially in small and medium-sized businesses is considered an important achievement to improve these companies. Small Medium Enterprise (SME) management is very different from large or international companies. Most SMEs do not have a

management system. Even performance measurement is rarely used. These local companies need simple and precise measurement indicators to identify their performance, and OEE is one of the eligible methods. From the literature review, it was identified that OEE is an important factor. OEE is a simple indicator, which helps manufacturers improve equipment performance and reduce ownership costs.

OEE is a metric method of measurement that can be used in TPM applications to keep machines and equipment in ideal conditions by reducing/eliminating six major losses on the production line [3]. OEE measurements are based on three categories that can represent these six major losses. They are average availability, average performance and average quality [4]. Based on the OEE concept developed by Nakajima [5] and also from the SEMI Standard [6], OEE can measure all the losses that exist in manufacturing companies with a high level of trust.

Huang et al. [7] states that OEE can be used by manufacturing companies as a tool to increase productivity. This is because OEE has an ability to identify the root causes of lost production and is able to provide effective solutions to increase productivity. While traditional measurements such as productivity, efficiency and capacity cannot provide comprehensive and detailed information to increase productivity in the manufacturing line.

Muchiri and Pintelon [8] also stated that OEE is an important metric in providing information about the root causes of loss of production time. OEE can be used by manufacturing companies in optimizing production performance without large investments. OEE can also reduce process variation, heavy machine downtime and even improve productivity and performance of workers in the manufacturing area. However, some important steps such as cost and flexibility cannot be measured by OEE. By using the OEE indicator, manufacturing companies can see how effective the use of their production machines is. Basically, the use of OEE aims to maximize the effectiveness of production machines [9, 10].

This paper explained the Raspberry Pi applied to Monitoring Real-Time Overall Equipment Effectiveness (OEE). Raspberry Pi is a credit card sized single board computer developed in the UK by the Raspberry Pi foundation. Raspberry pi has two models namely Model A which has 256MB of RAM, one USB port and no network connection. Model B which has 512MB of RAM, 2 USB ports, and an Ethernet port. This module has a Broadcom BCM2835 system on a chip that includes an ARMl176JZF -S 700 MHz processor, Video Core IV GPU, and SD card. This GPU is able to play back Blu-ray quality, using H.264 at 40MBits / s. It also has a fast 3D core that is accessed using the OpenGL ES2.0 and OpenVG libraries provided. This chip specifically provides HDMI and there is no VGA support.

This foundation provides the Debian and Arch Linux ARM distribution as well as Python as the main programming language, with support for BBC BASIC, C and Perl. Python was chosen as the main programming language, because it is generally accepted as an easy to learn language and a complete programming language and suitable for real world applications. With the addition of NumPy, SciPy, Matplotlib, IPython, and PyLab, Python can be used for computational mathematics as well as for experimental data analysis or control systems [11].

The recent development of the Raspberry Pi minicomputer has opened up huge potential for computing to be applied in a large number of areas. Because of the unique advantages of the Raspberry Pi system, this technology is very promising to provide solutions in developing countries. This includes but is not limited to educational tools, especially the use of GPIO (General Purpose Input / Output) which enables automatic data acquisition and produces a simple digital control system in manufacturing. The most typical feature of the Raspberry Pi when used for monitoring purposes is the GPIO module, which allows interacting with sensors and actuators [11].

2. System Configuration

Figure 1 explains the system configuration that has been developed. Raspberry Pi has been chosen as the processing unit for the system because of its user-friendly features and economic benefits. Furthermore, the python code algorithm has been developed into the Raspberry Pi and is capable of sending data to the MySQL database. The PLC to be monitored has been connected to the Raspberry Pi using GPIO and PLC input and output. RS232 on the PLC port can be used for communication with HMI or communication with Raspberry pi.

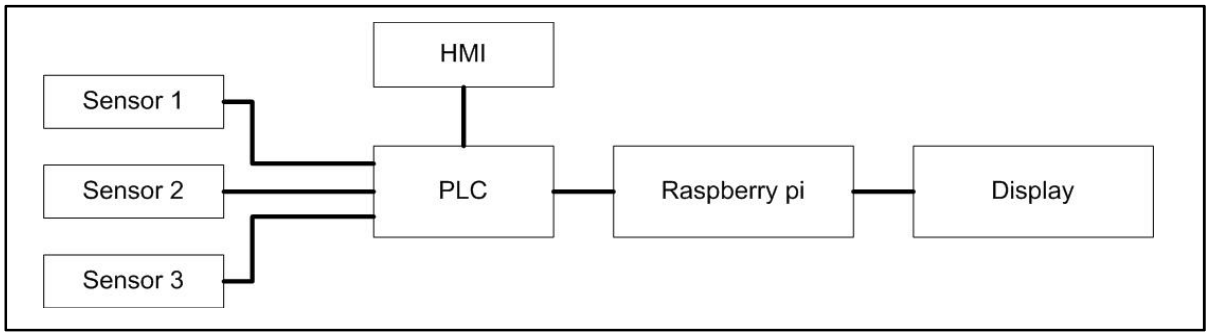


Figure 1. System Configuration

Figure 2 illustrates the modules used in the OEE monitoring experiment via Raspberry pi. A PLC and HMI are installed to represent the actual situation in the industry. The PLC used is Omron CP1L. OMRON CP1L PLC is one of the latest PLC products from Omron .CP1L is a package type PLC available with 10.14, 20, 30, 40 or 60 I/O (input / output). The input output system is in the form of bits. Or better known as PLC type relay because it only reads the input (input) and produces output (output) with logic 1 or 0.

For HMI, the Omron NB7W-TW00B is used. HMI is a Human Machine Interface that connects humans with machines in a plant and is used to display, monitor, and control ongoing processes, timer settings, and parameter settings of machine parameters. In this study, HMI is used as an input to adjust the production cycle time speeds. PLC and HMI communicate using RS232 protocol. The PLC output is connected to the GPIO raspberry using a relay. Relay installation is needed because the PLC works at 24 Volt while Raspberry pi works at 5 Volt. The calculation results of OEE parameters will be directly updated to the MySQL database which is located on an internal Raspberry pi.

Figure 2. Modules in OEE monitoring

3. Control Algorithm

OEE can display 3 categories, namely availability, performance and quality [12]. Availability and Performance can be used to evaluate the capacity and performance of production machines and Quality can evaluate product quality. Based on the six major losses measured by OEE [10], the formula for calculating OEE, availability (A), performance (P) and quality level (Q) is as follows:

$$OEE = A \times P \times Q \quad (1)$$

$$\text{Availability (A)} = \text{Running time (h)} / \text{Planned Production Time (h)} \times 100 \quad (2)$$

$$\text{Performance (P)} = \text{Ideal Cycle Time (h)} \times \text{Total Count} / \text{Running Time (h)} \quad (3)$$

$$\text{Quality (Q)} = \text{Good Count} / \text{Total Count} \times 100 \quad (4)$$

Running time (h) is the duration of time in hours at which the machine is operating normally without stopping caused by the engine. Planned Production Time (h) is a production plan or schedule, for example, in one day the production will operate for 8 hours. Ideal Cycle Time is the fastest time needed by a machine to produce a good product. While the Total Count is the number of products produced in a certain period of time. Good Count is the number of good products produced by a machine.

Figure 3 shows the OEE MAX input output process. In making the algorithm, there are several input parameters that must be taken into account including shift start, shift end, planned downtime, unplanned downtime, total parts produced, ideal cycle time, and total scrap. While the output parameters that will be displayed are capacity, total produced, performance, quality, availability and OEE.

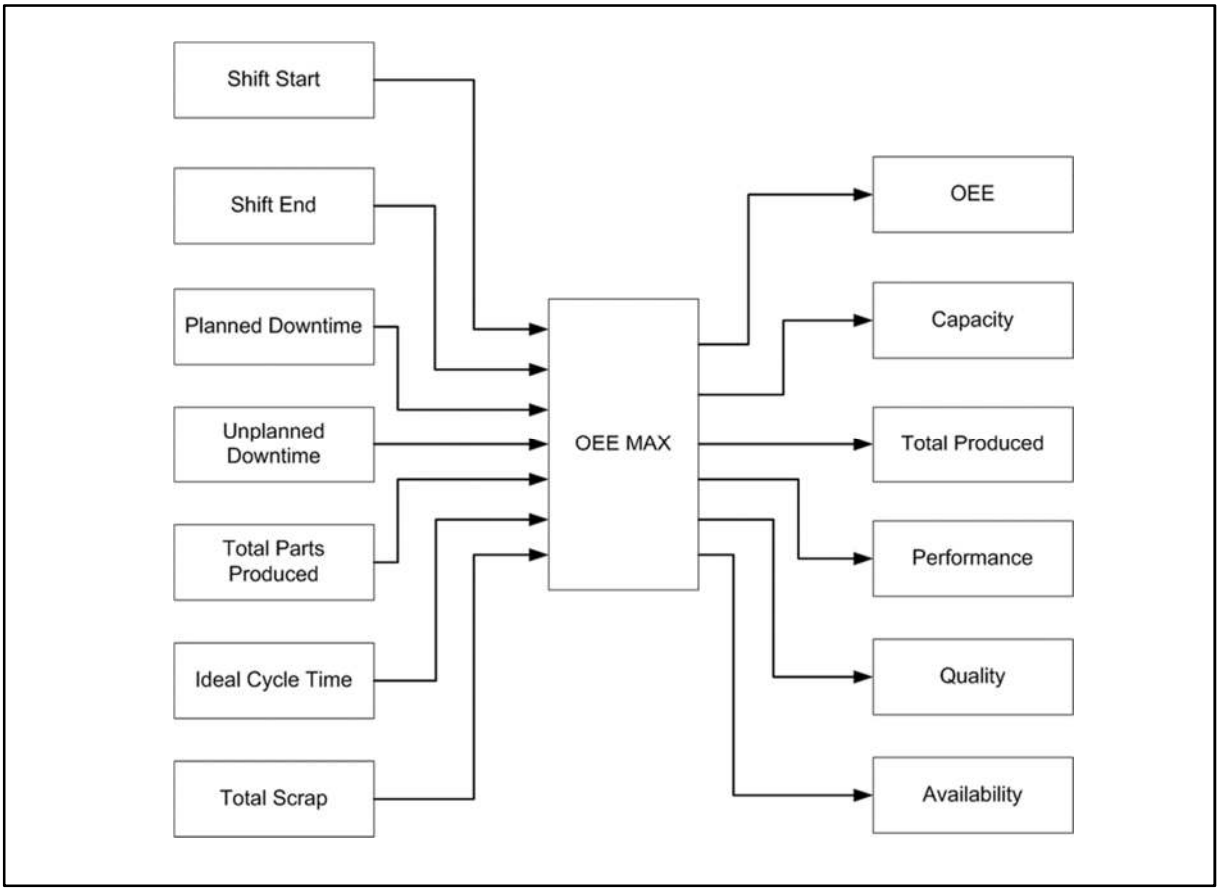
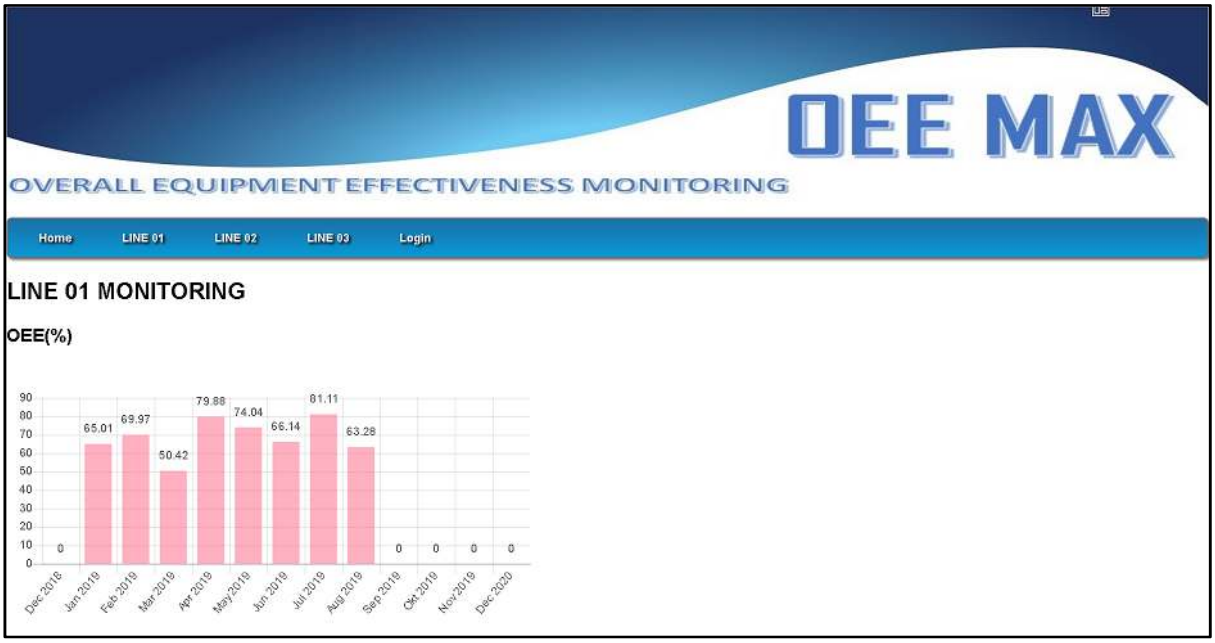


Figure 3. MAX OEE Input Output Process

4. Performance Evaluation

To display the results of OEE calculations and diagrams, a website was developed using PHP and MySQL. This web system is able to display OEE data every month very accurately. The company owners can observe the status of OEE from month to month whether declining or increasing. Figure 4 shows an OEE MAX display that is capable of displaying data and OEE status. Production display which is displayed through the web, will provide production data directly to all workers. All data is saved to the database for further analysis.

By using a web browser, PC, Smartphone etc., users can access from any location and view OEE MAX displays including graphs, activity, and user history. In addition to basic KPI displays, data logs, and direct production data charts, OEE MAX can also automatically send emails to designated employees, if something urgent requires their immediate attention. For example, if the production level drops to a critical level, send a message to the production manager so that he can immediately investigate. Or if certain machines in the production line fail, send a message to the maintenance team and tell them which tools are needed to resolve the issue.



Gambar 4. OEE display

5. Conclusion

In this highly developed era, where directly or indirectly, everything depends on computing and information technology, Raspberry Pi proved to be an intelligent, economical and efficient platform for implementing OEE monitoring systems. This paper provides a basic application of the OEE monitoring system using Raspberry Pi which can be easily implemented and used efficiently.

Acknowledgement

The authors wish to express their sincere thanks to the Ministry of Research, Technology and Higher Education, Indonesia and Sekolah Tinggi Teknologi Muhammadiyah Cileungsi, for support and carry out this work.

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