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Proposing a Training Model on Energy Management of Compressed Air Systems with Artificial Intelligence of Things

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Abstract: Technology 4.0 in the industry focuses on effective energy saving. There is an increase in the need for industrial worker training, especially in compressed air systems, air kept under more significant pressure than atmospheric pressure. It is an important medium for the transfer of energy in industrial processes. However, the new technology of energy management systems to enhance performance has yet to be widespread. Owing to the learning material for training is expensive. It is also not possible to simulate the operation of a comprehensive system. The employees lack an understanding of the big picture, causing problems in learning and lacking practical skills. Especially new employees may need more knowledge and experience and have operation errors or problem-solving skills. In this study, we proposed a training model consisting of a compressed air systems training kit based on the Artificial Intelligence of Things (AIoT), and the energy-saving scenarios consist of 1) controlling the compressed air pressure fed to the air cylinder while being subjected to loads of different sizes. 2) controlling the compressed air pressure supplied to the air cylinder while operating the air cylinder without load. 3) controlling the compressed air supplied to the machine while it is stopped. In addition, we use an outcome-based approach to drive training activities. The results show that the training model can simulate the process of energy management systems of compressed air systems and show it on the dashboard. It can be implemented in employee or engineer practical training in the future.

Keywords: energy management systems, training kit, AIoT, engineering education

1. Introduction

Nowadays, industrial manufacturing and companies increasingly recognize the financial and reputational benefits of meeting sustainable targets concerning waste and excessive energy consumption (Abela et al., 2020). Although compressed air in the industry is an important yet overlooked energy carrier. However, in the industrial sector, compressed air systems are one primary energy consumer, accounting for around 10% of the electricity consumed in the European Union and China, while the US, Malaysia, and South Africa account for 9% of total energy consumption (Bonfá et al., 2019; Eras et al.,2020) Therefore, reducing CAS energy consumption is crucial to meet the energy efficiency goals (Benedetti et al., 2019).

Compressed Air Systems (CAS) provide a significant improvement opportunity for energy saving. CAS refers to air kept under more significant pressure than atmospheric pressure. It is an important medium for the transfer of energy in industrial processes.

Many studies attempt to propose a methodology to develop the energy management of CAS. For example, Thabet et al. (2020) proposed real-time sensing and machine learning to increase CAS efficiency with algorithms that automate the detection of energy inefficiencies and make decisions regarding suitable troubleshooting procedures will be created. Sanders et al. (2020) proposed new intelligent techniques to save energy in compressed air systems with real-time ambient sensing via Artificial Intelligence and Knowledge Management to automatically improve efficiency in energy intensive manufacturing.

This paper uses Artificial Intelligence of Things (AIoT) technology to develop the energy management of compressed air systems training model. AIoT will reduce energy consumption in compressors by considering real-time circumstances and predicted needs. Sensor data will deliver real-time performance information, interpret the data, and then act automatically.

This training course focuses on new technology that will be applied to save energy in industrial manufacturing. Therefore, we proposed a training model consisting of a compressed air systems training kit based on the Artificial Intelligence of Things (AIoT) and the energy-saving scenarios to align the outcome-based approach.

2. Related work

2.1 Training course of a compressed air system

For the industrial sector, CAS is necessary to offer versatility, reliability, and ease of use in various industrial applications. It is a cost-effective and efficient solution for powering tools, controlling processes, and facilitating numerous manufacturing and operational tasks. CAS is a network that generates energy from gas molecules being transported through and activating an engine or rotor. It uses natural air that is all around us that we inhale and exhale. The system uses compressed gas molecules to create sufficient pressure, which pushes through the rest of the circuit. Therefore, the concept of training is shown in Table 1.

Table 1. *The training concepts of leaning outcomes*

Concepts	***Leaning outcomes***
1. Management of industrial compressed air systems	Understand the management compressed air systems
2. Programmable logic controller (PLC)	Use PLC to control hardware.
3. Ladder programming	Write Ladder logic programming with PLC.
4. Pneumatic cylinders	Write programming to control pneumatic cylinders.
5. Photoelectric sensor	Apply a photoelectric sensor to detect an object.
6. Vision inspection systems	Apply a vision inspection system to track an object.
7. Electro Pneumatic control	Write program control Electro Pneumatic control
8. Vacuum grippers control	Use Vacuum grippers to pick and plate the workpiece.
9. Artificial Intelligence	Apply Artificial Intelligence to save energy
10. Dashboard	Display information on the dashboard

2.2 Artificial Intelligence of Things (AIoT)

Artificial Intelligence of Things (AIoT) refers to integrating artificial intelligence (AI) technologies with Internet of Things (IoT) devices and systems. AIoT combines the power of AI algorithms and data analytics with IoT devices' connectivity and sensor capabilities to enable intelligent decision-making, automation, and advanced functionalities (Hu et al., 2021; Xian et al., 2023). Many studies attempt to present AIoT applications in many fields. For example, El Himer et al. (2022) present applications of AIoT technology to manage and save energy in renewable energy sources such as solar and wind. Shi (2021) presented AIoT as a new technology for developing innovative, low-cost, reliable monitoring systems for smart home applications.

3. Training Model on Energy Management of Compressed Air Systems

3.1 Proposed Training model

In this study, we designed a training model focusing on industrial employee practice training. A training course should have a hands-on activity that can operate related work. To understand the engineering problem of saving energy, we design the training model to perform the activities and appropriately prepare devices or materials based on a conceptual framework, as shown in Figure 1.

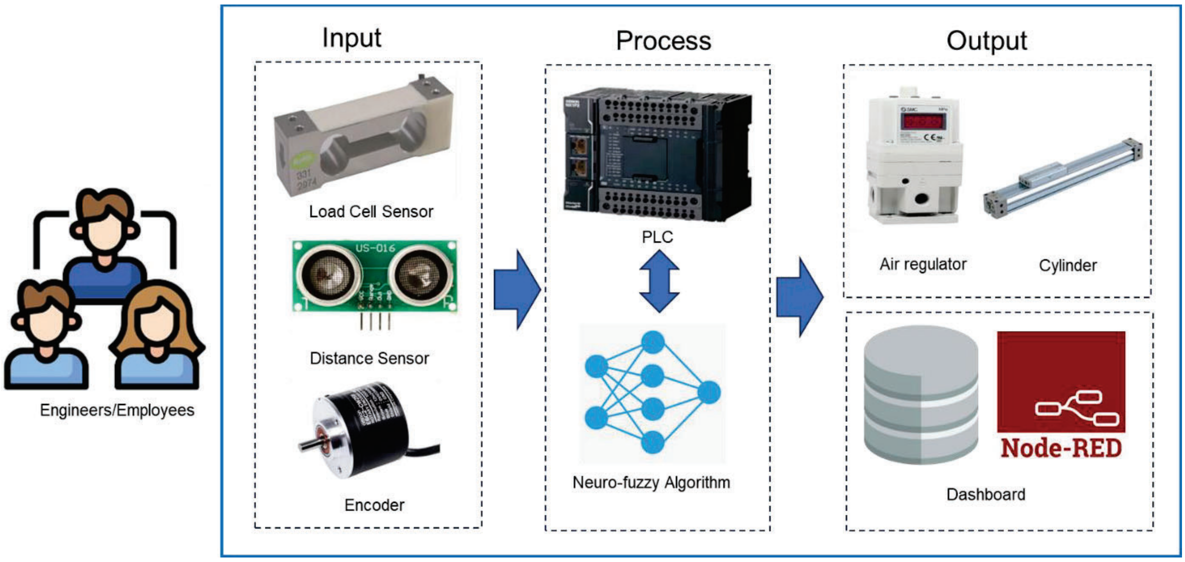

Figure 1. Training model framework

In addition, we design energy savings scenarios to consist of 1) controlling the compressed air pressure fed to the air cylinder while being subjected to loads of different sizes. 2) controlling the compressed air pressure supplied to the air cylinder while operating the air cylinder without load. 3) controlling the compressed air supplied to the machine while it is stopped, as shown in Figure 2.

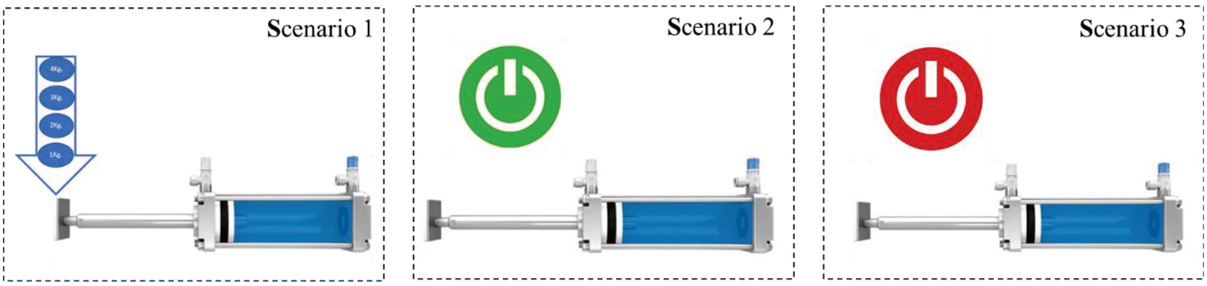

Figure 2. Energy savings scenarios

3.2 A compressed air systems training kit

To design the structure of the training kit, we identify the performance of training materials able to compare the scenarios in case of saving energy. Figure 3. shows a compressed air systems training kit consisting of a Programmable Logic Controller or PLC (Omron NX1P2 V1.50), a device that automatically controls a machine. A load cell sensor is an electro-mechanical sensor that measures force or weight. A distance sensor is a sensor that measures the distance by emitting a signal and measuring how long it takes to return to the transducer. An air regulator is a pneumatic device that receives air at any pressure within its tolerance and then dispenses air at a pressure no more significant than its intended output. A DC-to-DC converter temporarily stores electrical energy to convert the direct current (DC) from one voltage level to another. A camera is an optical instrument that captures images. A cylinder is A device that converts energy from wind pressure into mechanical energy.

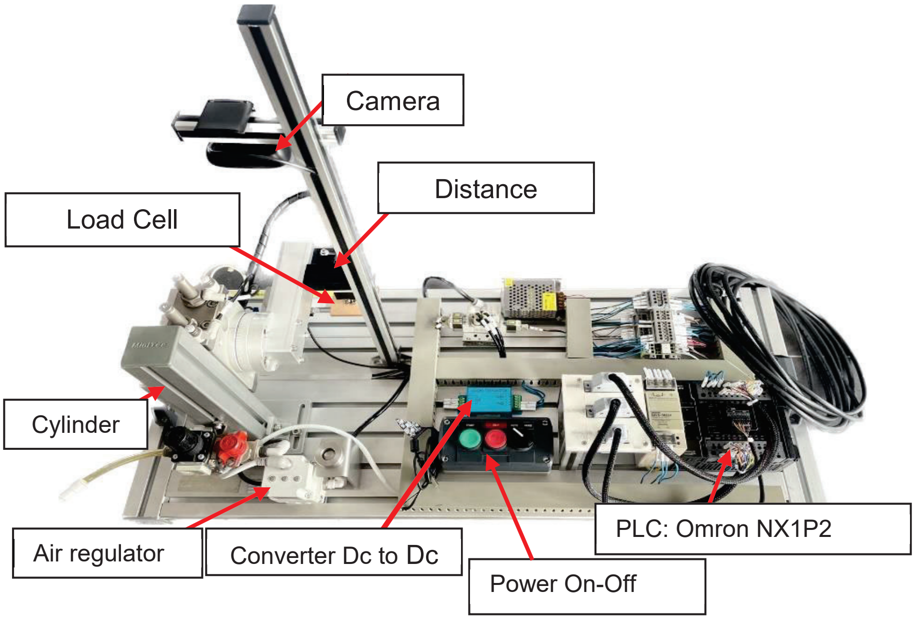

Figure 3. The component of a compressed air systems training kit

3.3 Neuro-fuzzy algorithm

Neuro-fuzzy is an artificial intelligence method effectively utilized in control engineering to demonstrate neuro-fuzzy usage in training for managing the energy of compressed air systems. Neuro-fuzzy algorithms, also known as fuzzy neural networks or adaptive neuro-fuzzy inference systems (ANFIS), combine elements of fuzzy logic and neural networks to create hybrid models that can handle complex and uncertain data. These algorithms aim to leverage the strengths of both fuzzy logic and neural networks to improve the accuracy and interpretability of the models (Tiruneh et al.,2020; De et al., 2020). In this study, PLC is necessary for building its control programs and is appropriately tied with AIoT. In addition, the MATLAB program can run a Neuro-fuzzy algorithm, as shown in Figure 4.

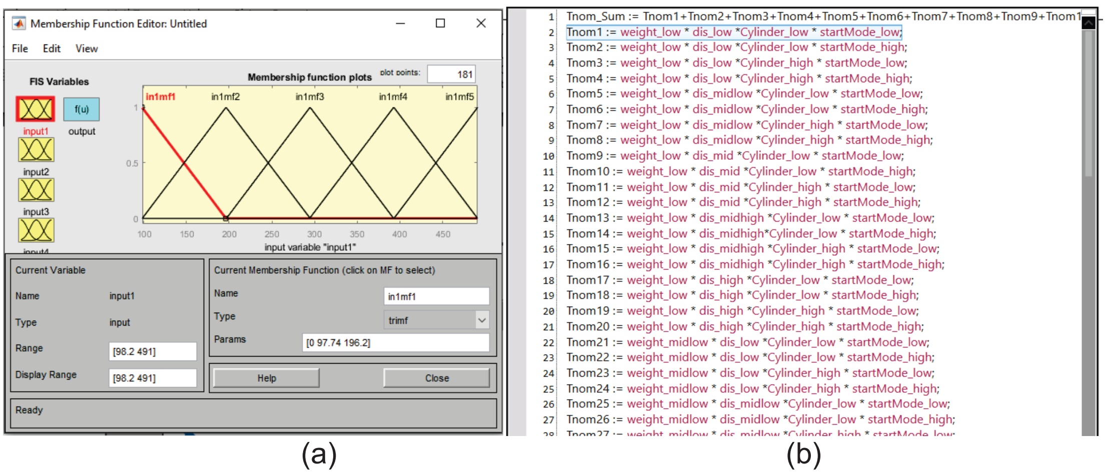

Figure 4. (a) Example of Membership Functions in MATLAB (b) Example of PLC program

3.4 Dashboard

A dashboard is a visual representation of essential information, data, metrics, and performance indicators displayed in a consolidated and easily understandable format. It provides a snapshot or summary of data to help users monitor, analyze, and make informed decisions based on the information presented. Node-RED is a development tool for connecting hardware devices, application programming interfaces, and online services (as shown in Figure 5). It has a browser-based editor to enable wiring together flows using the wide range of nodes in the palette. The industrial flows automation created in the Node-RED tool and a programmable logic controller (PLC) can be stored, imported, and exported for information-sharing as a dashboard in the gateway connected with the open platform communications unified architecture (Chookaew & Howimanporn, 2022).

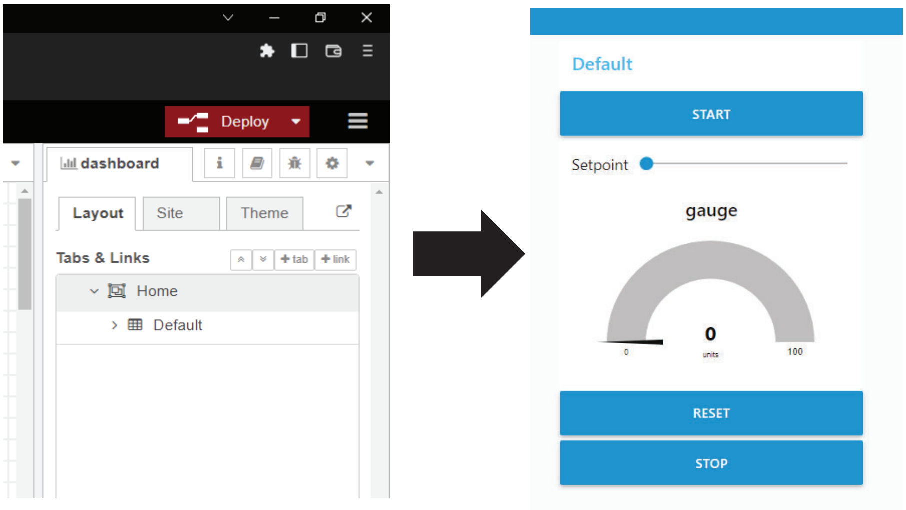

Figure 5. The screen snapshot of Node-RED dashboard

4. Conclusion and Future work

In this study, we proposed a training model consisting of a compressed air systems training kit based on the Artificial Intelligence of Things (AIoT), and the energy-saving scenarios consist of 1) controlling the compressed air pressure fed to the air cylinder while being subjected to loads of different sizes. 2) controlling the compressed air pressure supplied to the air cylinder while operating the air cylinder without load. 3) controlling the compressed air supplied to the machine while it is stopped. In addition, we use an outcome-based approach to drive training activities. The results show that the training model can simulate the process of energy management systems of compressed air systems and show it on the dashboard. It can be implemented in employee or engineer practical training. We plan to investigate the effectiveness of the proposed models by comparing pre- and post-test performance and evaluating attitudes toward training as part of future work.

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