Development of Energy-Analysis Platform for Carbon Neutrality

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Abstract

To achieve carbon neutrality in the entire value chain by 2050, JATCO is promoting energy conservation through the advancement of DX production and innovation in production technologies. Whereas the visualization of power consumption has been established in each factory area, JATCO has restructured its system to promote power conservation at the operational level in each workplace through a more comprehensive power management.

This paper reports the development of an in-house system that can acquire electricity and air-consumption data in real time for each facility as an energy-analysis platform for achieving carbon neutrality by the production division.

1. JATCO's efforts to reduce greenhouse gas emissions

1.1 Targets in Japan

In April 2021, the Japanese government announced the goal of achieving carbon neutrality by 2050 and a 46% reduction in greenhouse gas emissions by 2030 (compared with FY2013 levels).

1.2 JATCO's goal setting

JATCO aims to achieve carbon neutrality throughout its value chain by 2050 and reduce CO_2 emissions by 46% by 2030 (Fig. 1).

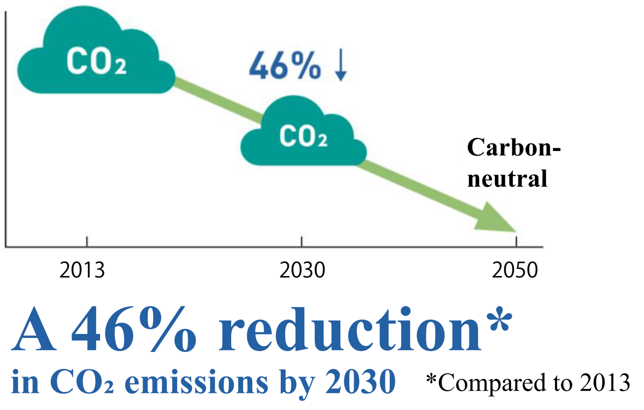

Fig. 1 JATCO's Greenhouse Gas Reduction Targets

1.3 Ratio of CO_2 emission in JATCO's production activities

In FY2023, 80% of JATCO's CO_2 emissions from its production activities were from electricity consumption, whereas 20% were from fuel consumption. Therefore, the use of electricity, which emits a significant amount of CO_2, must be reduced (Fig. 2).

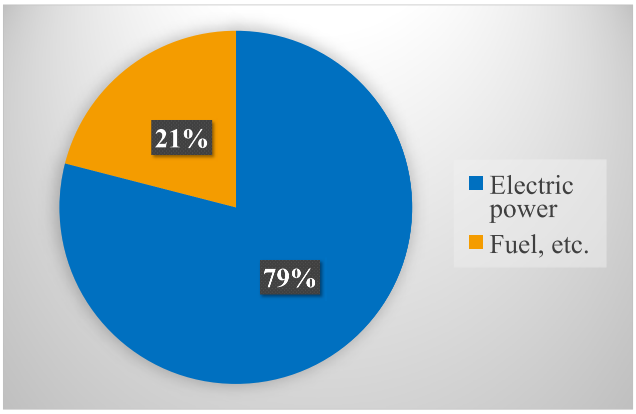

Fig. 2 Percentage of CO_2 emissions from production

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1.4 Activities to reduce electricity consumption

The current power-visualization activities are discussed below. Fig. 3 shows a factory floor plan in which power visualization is performed block by block using different colors.

Fig. 3 Schematic diagram of the entire factory

For example, by clicking on the green block [A] in Fig. 3, a graph is displayed, as shown in Fig. 4, which depicts the transition of power consumption in the area within one month. The vertical axis represents the electric energy used (kWh) and the horizontal axis represents the time (h), which can be set arbitrarily.

1.5 Current issues and next steps for power visualization

Power-consumption visualization by factory blocks was performed as described previously. However, a manufacturing site highlighted that power saving did not improve as the electric energy by the equipment in that site was unknown.

To promote energy conservation in factories, one must understand the amount of energy consumed by each piece of equipment as well as identify any waste. Currently, each workplace houses approximately 30 pieces of equipment, although not all are installed with watt-hour meters. The installation of watt-hour meters at each facility requires a significant amount of time and money; thus, it is rarely considered.

Additionally, most equipment in plants use compressed air, and a significant electric power is required to generate compressed air.

Therefore, an in-house system was developed to acquire and understand the power and air-consumption data at each facility.

2. Development Concept

As mentioned above, our company aims to visualize the power consumption at each facility to achieve carbon neutrality.

JATCO's facilities use electricity and air as power sources and employ equipment from various manufacturers. Many commercial products are sold in packages that are inflexible, expensive, and incompatible with other manufacturers' equipment. Therefore, our company has developed an in-house power-visualization and -measurement unit that can be installed universally.

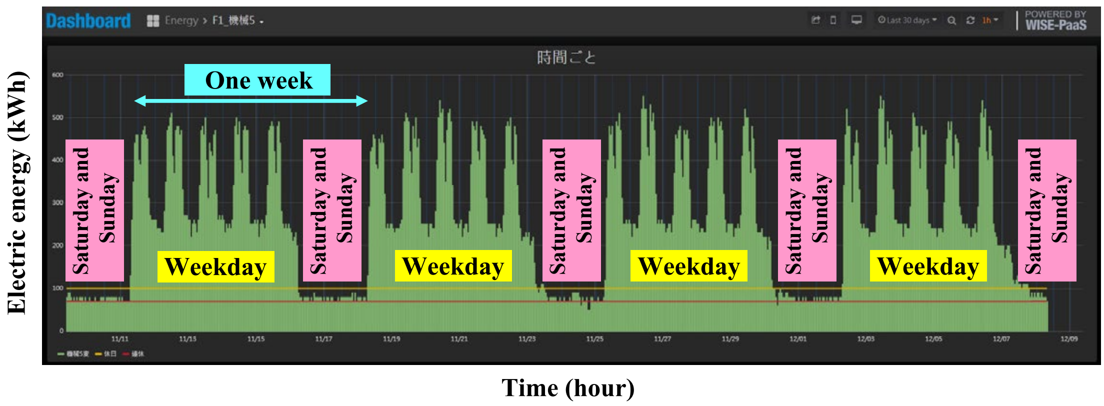

Fig. 4 The power transition of the block

3. Design of power-visualization and -measurement unit

3.1 Configuration overview

The power-visualization and -measurement unit was designed with three components: a Raspberry Pi[1], a power-measurement board, and an uninterruptible power supply (UPS) board.

A diagram of the system configuration, including the power-visualization and -measurement unit, is shown in Fig. 5.

3.2 Selection of Raspberry Pi

JATCO typically uses Raspberry Pi for in-house IoT development. This is because Raspberry Pi is inexpensive, compact, and suitable for driving motors and visualizing equipment status, in addition to being compatible with Python.

3.3 Design of power-measurement infrastructure

Continuous quantitative detection is required to measure the airflow and current consumed by the equipment, and the sensor output is an analog signal. However, because the Raspberry Pi does not have an analog I/F, one must convert its analog signals to digital signals using an analog-to-digital converter (ADC). A power-measurement board was fabricated for this purpose.

3.4 Design of UPS infrastructure

In our assembly facilities, power is turned off during safety inspections of equipment and in emergency situations. Interruption of the power supply may cause equipment failure and data corruption. To address errors that may occur during forced power cutoff, a UPS for Raspberry Pi was created.

3.5 Data flow

The airflow rate was acquired using a flow sensor, and the current consumed by the equipment was obtained using a clamp sensor. The analog current was converted to voltage using a shunt resistor, which was used to detect the current in the circuit. The voltage was converted to a digital signal, whereas the air and electricity consumptions were calculated and sent to the PLC. Data acquisition by the PLC enables connection with the higher system, whereby power visualization becomes possible for each equipment, line, and factory (Fig. 6).

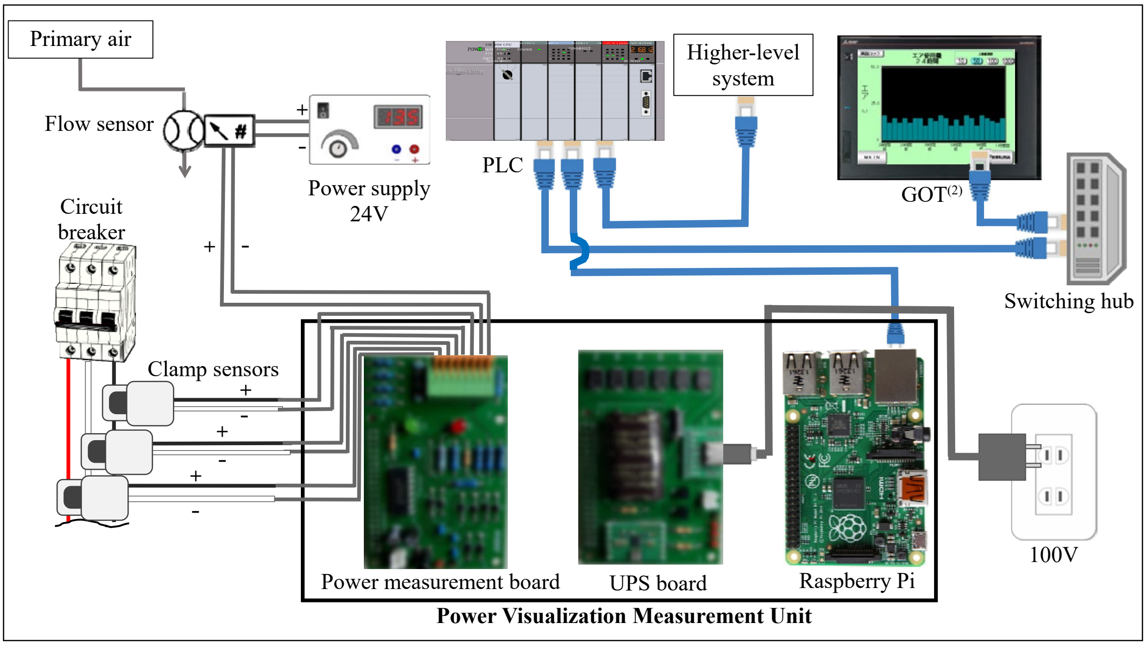

Fig. 5 System configuration

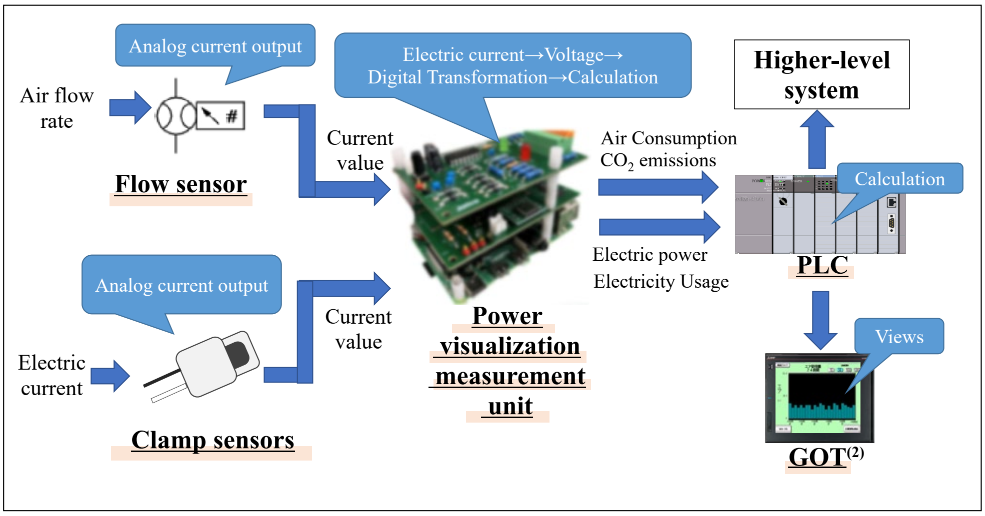

Fig. 6 Data processing flow

4. Development topics

A detailed list of topics that emerged during the development process is provided below.

4.1 Significance of noise suppression

Noise-suppression measures for factory equipment are essential for the safety control, quality control, and stable operation of machines. These measures are important because equipment malfunctions can result in the shutdown of equipment operations, thereby affecting production and safety.

Our factory is located near the Shinkansen bullet train (Fig. 7), where many 200–400 VAC facilities operate in a noisy environment. Hence, robust noise-suppression measures are necessary.

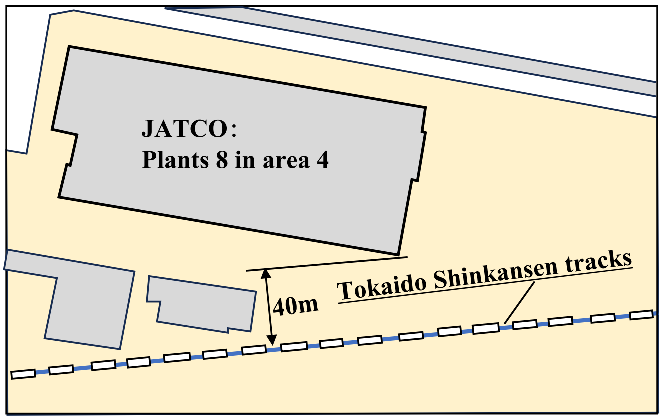

Fig. 7 Distance between Shinkansen and JATCO

4.2 Examples of noise suppression

Based on knowledge regarding noise-suppression measures for CVT ATCU,

JATCO selected the following six measures to enhance the system reliability.

Measure 1) Detailed implementation of single-point grounding

The circuit and board design ensured single-point grounding.

Measure 2) Optimization of placement of analog and digital signals

To prevent chattering noise in the analog and digital signals on the board, the ADC was placed near the GPIO pin, i.e., the input/output pin of the Raspberry Pi, which is close to the board output. Additionally, the layout was designed to maintain a certain distance between the signals.

Measure 3) Signal-noise reduction

The analog currents were converted to voltage using shunt resistors on the board to improve the noise resistance.

Measure 4) Preventative measures for IC malfunction

The IC-free pins were fixed to the GND level via a resistor, and a bypass capacitor was used between the IC power supply and GND to stabilize the power supply.

Measure 5) Measures for signal-input terminals

A low-pass filter was implemented in the input-signal section of the board to eliminate high-frequency noise components. A diode-clamp circuit was constructed to protect the CPU by preventing overvoltage at the input terminal.

Measure 6) Protection using metal casing

The board case was made of a metal with high noise-shielding properties, which protects it from external noise and prevents internal-clock noise generated by the Raspberry Pi from leaking.

4.3 Durability

The durability of the Raspberry Pi used in this study was an issue. Based on previous failures, the following measures were adopted to achieve stable operation over a long duration: A cooling fan was installed to prevent overheating the CPU, a highly reliable power supply unit with a PSE mark[3] was selected, and a highly durable and reliable industrial microSD card was used.

5. Verification results

The verification results for the development of the power-visualization and -measurement unit are provided below.

5.1 Verification of noise suppression

As mentioned above, the implementation of noise-suppression measures prevented malfunctions and improved reliability.

5.2 Verification of UPS board

The verification results for the UPS board are shown in (Fig. 8). The horizontal and vertical axes represent time and voltage, respectively. The blue and yellow lines represent the output-signal and UPS power-supply waveforms, respectively. The power supply time of the UPS was 15 s, which was higher than the 10 s required to shut down the Raspberry Pi after the power was cut off, thus verifying that power was maintained.

The details of the graph in Fig. 8 are as follows:

Point A: Start automatic shutdown of Raspberry Pi

Point B: Complete the shutdown of Raspberry Pi

Point C: Turn off UPS power supply

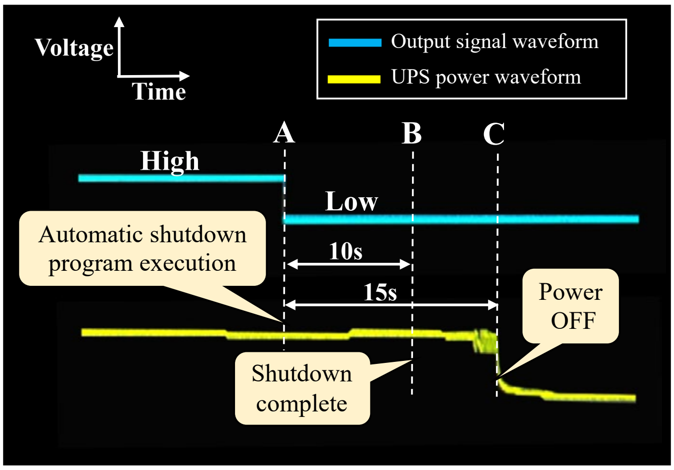

Fig. 8 Verification of the operation of the backup power supply when the power is turned off

5.3 Verification of power-measurement board

As described in the concept-development section, a universal measurement unit was developed. The unit can communicate universally with any commercially available PLC with an Ethernet communication port.

Correlation analysis was performed to verify the accuracy of the measurement unit. For each current value, a comparison was performed between the current measured by the clamp meter (vertical axis) and the current obtained by the clamp sensor attached to the measurement unit (horizontal axis). A strong correlation was observed (Fig. 9). The power value P is expressed as P = VI. Because the voltage V is a fixed value, the power value can be determined when the current value is known.

Furthermore, a comparison was performed at each airflow rate between the digital-display value of the flow sensor (vertical axis) and the value calculated using Python from the analog current output measured by the flow sensor (horizontal axis), which showed a strong correlation (Fig. 10). The conversion from airflow rate to power was performed using the conversion coefficient for compressed air at each factory[4].

The results confirmed that the measurement unit operated accurately.

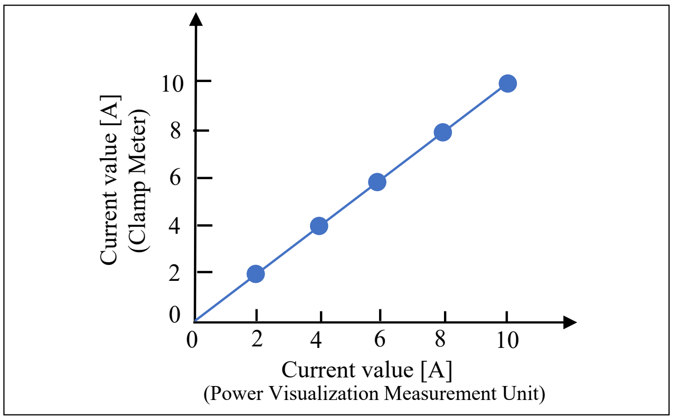

Fig. 9 Relationship between the actual current measured by the clamp meter and the measured current by the measurement unit

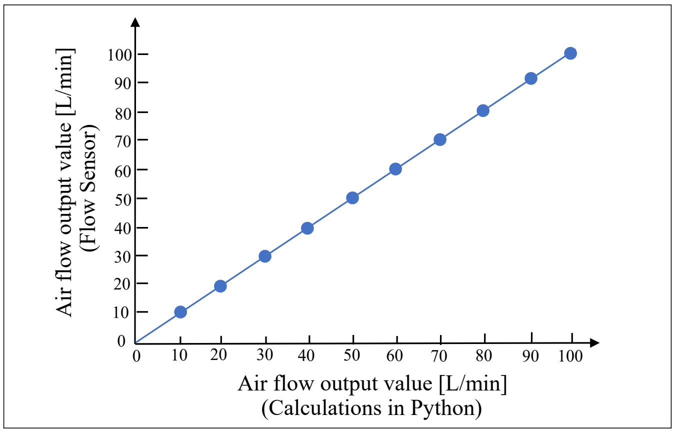

Fig. 10 Relationship between the actual current measured by the air flow sensor and the measured current by the measurement unit

6. Conclusion

An energy-analysis platform was developed to measure the airflow and current consumed by each facility and to visualize the power consumption. This platform was developed to satisfy the requirements of detailed power management and power saving at manufacturing sites. The platform determines the electric energy consumed by each factory facility, thus enabling effective energy conservation activities. The cost of the system was reduced by half, compared with the standard price of commercially available products.

7. Future outlook

Fig. 11 shows a graph that visualizes the total electric-power consumption. The graph was created by installing power-visualization and -measurement units for each piece of equipment. The horizontal axis indicates time, the vertical axis (axis 1) indicates the electric energy, and the vertical axis (axis 2) indicates the number of units produced. The analysis of the measured power consumption revealed that a significant electric power was consumed even during nonproduction hours (standby power) compared with the electric power consumed during production, thus providing ideas for concrete measures to reduce power consumption (CO_2 emission reduction).

The use of a PLC enables various analyses and the utilization of data concomitantly with equipment operation. In the future, extensive test monitoring will be conducted to investigate various reduction measures for achieving carbon neutrality, thus contributing to the goal of reducing greenhouse gas emissions by 46% in FY2028 (compared with FY2013 levels).

(1) The Raspberry Pi is a trademark registered with the Raspberry Pi Foundation. The photograph of the circuit board cited in this article was obtained from Wikimedia Commons (©2016 Herbfargus CC-BY-SA-4.0).

(2) GOT is a trademark or registered trademark of Mitsubishi Electric Corporation in Japan and other countries.

(3) The PSE mark certifies that the electrical appliance satisfies the standards of the Electrical Appliance and Material Safety Law.

(4) Because compressed air is generated on a plant-by-plant basis using large air compressors, the conversion factor was determined based on the electricity consumption of the compressors.

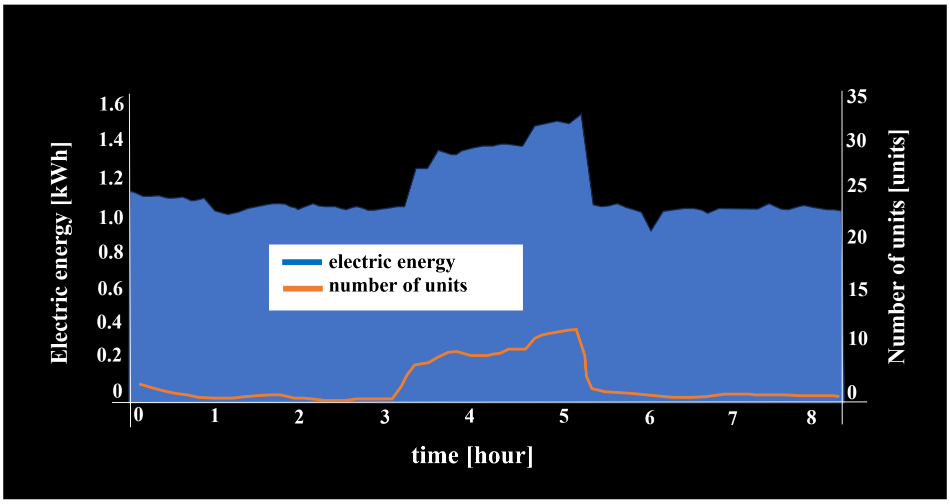

Fig. 11 Total electric energy and number of units produced by the hour

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