JTE HCMUTE
ISSN: 2615-9740

JOURNAL OF TECHNICAL EDUCATION SCIENCE
Ho Chi Minh City University of Technology and Education
Website: https://jte.edu.vn
Email: jte@hcmute.edu.vn

The Application of BMS in Electrical Energy Management and Carbon Emission Reduction

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ARTICLE INFO

Received:	05/07/2024
Revised:	19/08/2024
Accepted:	04/09/2024
Published:	28/12/2024

KEYWORDS

Building Management System;
Energy management;
Carbon Emission Reduction;
CO_2 emissions;
Optimizing energy usage.

ABSTRACT

This article presents the application of Building Management System (BMS) in electrical load management. The BMS system in this article structure includes DDC, IOT 2050 Siemens, sensors, inverters and loads. Implementing this system in buildings saves energy, reduces operating costs and reduces CO2 emissions. A comparative analysis was conducted between projects with and without BMS implementation. The investment in the BMS incurs an additional capital expenditure, with a payback period of 7.3 years and a system lifespan of 20 years, providing a return of more than 13% on the investment. The results show significant energy savings with total consumption reduced by 13%. These findings highlight the effectiveness of BMS in optimizing energy use across different areas of a building, providing significant financial and environmental benefits. This research contributes to understanding the economic and environmental implications of integrating BMS into infrastructure development, creating favorable conditions for stakeholders in the construction and energy sectors.

Doi: https://doi.org/10.54644/jte.2024.1617

1. Introduction

Previously, when there was no building management system (BMS), buildings due to undeveloped technology, so the scale was not large, often managed by many simple automation systems. By the end of the 19th century a strong turning point in the electronics industry, computers drove the formation of BMS. Honeywell, an American building automation solutions company [1] unveiled the Energy system as one of the first BMS systems in the 1960s, followed by a new era in building management, from simple BMS automation systems to flourishing and demonstrating strengths when combining Many functions in a single system, optimizing efficiency, as well as operating costs for the building, reduce the load of a large amount of electricity consumption that electricity for the building accounts for up to 40% of global energy use [2], [3], [4].

With the development of science and technology, BMS is increasingly researched, applied, and improved, not only stopping at management but also going further with the application of the Internet of Things (IoT) [5], [6], [7], integrating the internet to synchronize data processing in the cloud. More recently, with the development of AI, the Common Energy project [8] uses AI to perform monitoring and solve system problems. In addition, Roja Eini [9] integrates control models based on environmental parameters, control, and learning to give reasonable control commands when necessary—in [10] offering a dual-application control model of temperature humidity, and CO_2 concentration data, increasing the accuracy of control. However, the initial investment cost for optimal BMS is quite large, which raises questions about whether BMS applications are profitable because investors need profits. In general, in buildings, especially large or very large buildings, the amount of energy consumed mainly comes from air conditioning and cooling (HVAC) systems, before this situation, in the study [11], [12] they used a predictive control algorithm based on a simple synthetic mathematical model describing the construction of thermal dynamics and being mined Generated using real-world heat and electricity data, This method offers significant benefits at peak-hour demands. Several studies [13] use ESS energy storage systems for efficient energy management. Reduce the energy consumption of the HVAC system by reducing uptime by changing the indoor temperature limit at the expected peak time, simulated using an algorithm using MatLab [14]. Building Information Modeling is also applied in BMS system construction to provide a more visual view of the BMS system, studies of [15], [16], [17] have built the system based on the preliminary Design of Building Information Modeling (BIM), which facilitates the future design and construction as well as reasonable investment costs and system scale helps to minimize errors and save significant time.

Most studies delve into system optimization and control without specifically analyzing the advantages of building BMS deployment or not. Thereby, this study clarifies the issues of fuel consumption, and comparative analysis between projects with and without BMS implementation. Another contribution of the research paper is on the environmental aspect when operating optimally, reducing emissions, and saving energy.

2. Methodology

2.1. Introduction to the configuration of the Building Management System

Figure 1 shows a building management system (BMS) consisting of components of Management Level management levels, including the IOT 2050 suite connected to a PC and Router responsible for storing data for the system from sensor feedback data to control data released and executed in the system from Direct Digital Control (DDC) at the Automation Level and send data to the Cloud, Field level including MFM meter, CO_2 sensor, Contactor, IG5A Inverter and fan system. This design was designed to clarify the difference between the two fan systems, a conventional fan system controlled by contactors when receiving signals from DDC and a somewhat more complex controlled fan system when the speed is controlled by VSD-IG5A strata converters that receive signals from DDC but take into account CO_2 content. In the system conventional fans most of the time the fan will operate at maximum power. However, in fan systems with VSD and CO_2 sensors due to consideration of CO_2 content, the fan power will be changed to suit the return value from the sensor according to the se equation mentioned at the back. This method allows the fan to operate more economically as the power will be continuously regulated through the controller.

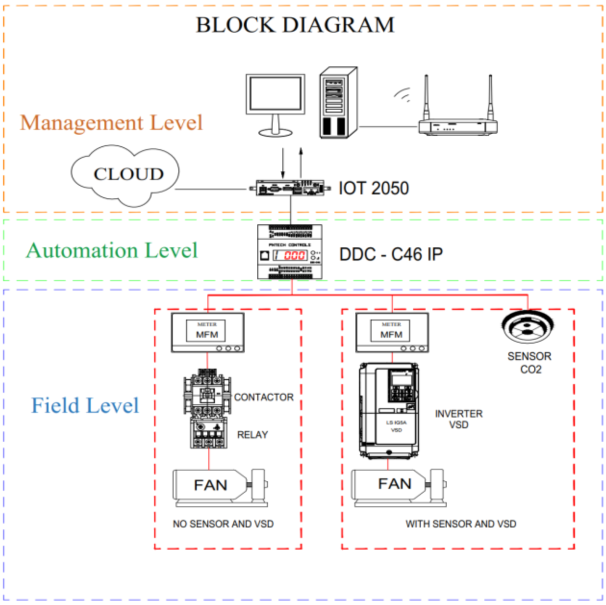

Figure 1. *Configuration of the BMS system in monitoring and controlling motor speed according to CO_2 concentration*

2.2. Diagram of the principle of system connection

In more detail about this model, Figure 2 shows the diagrams of principles and connections specific to each device: SIMATIC IoT2050 is an industrial communication gateway (Industrial Gateway) used to connect OT (Operational Technology) and IT (Information Technology) automation systems as well as cloud computing services (Cloud) for Digital transformation of production. ECO-C46 Direct Digital Control Modbus RTU 485 | BACnet MSTP, supports BACnet MSTP communication interface, Modbus RTU 485 from BMS system, easy to install, highly aesthetic, 7-segment LED screen displays intuitive parameters, controlled by 2 buttons, Integrated real-time clock (RTC) allows configuring control to run or stop the system according to a preset schedule. QTG-054P 1.5hp ventilation exhaust fan with 7000m3 airflow. The Modbus RS485 communication standard is integrated in the MFM 383 multifunction meter and IG5A Inverter. After that, MFM 383 and IG5A Inverter are controlled by ECO-C46 via RS485 communication standard. The ECO-C46 is connected via IoT 2050 via the Modbus RS 485 standard. From IoT 2050 linked to Personal computers and routers through TCP / IP communication standards.

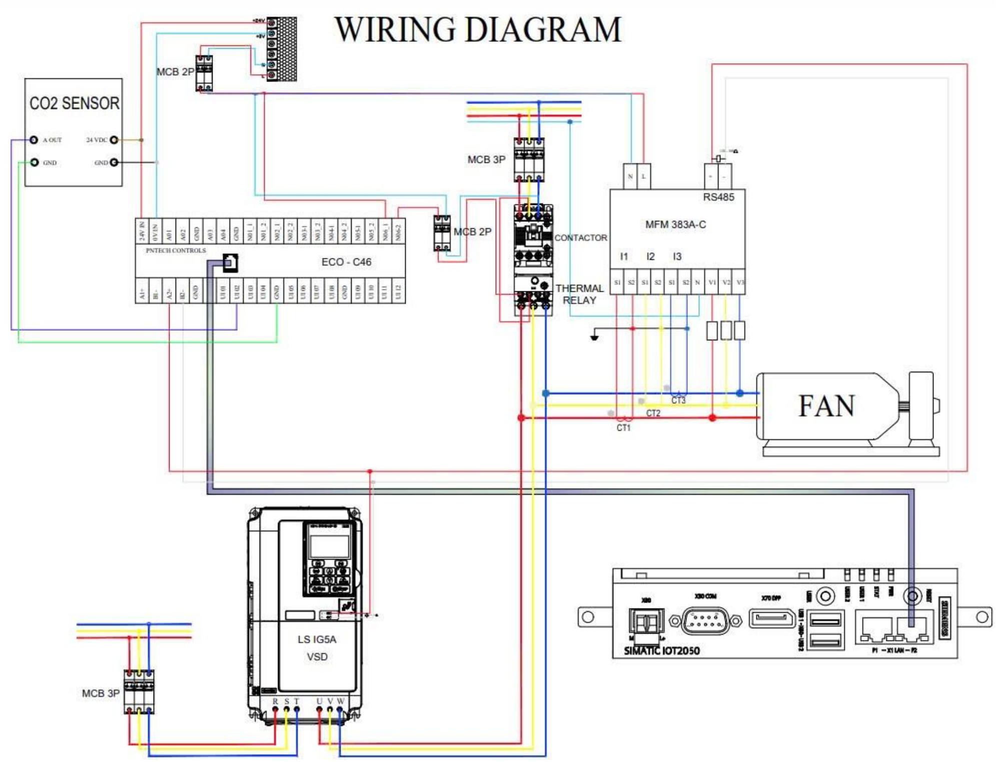

Figure 2. *BMS system wiring diagram in monitoring and controlling engine speed according to CO concentration*

2.3. The principle of controlling the ventilation fan according to CO_2 concentration

CO_2 concentration is measured in parts per million (ppm). Concentrations of 250-350 ppm are often found outdoors. CO_2 concentrations in the range of 350-1,000 ppm are considered typical in occupied spaces with decent ventilation. When CO_2 levels are more than 1,000 ppm, this can lead to feelings of drowsiness, stuffiness, and mild confusion. At concentrations between 2,000 and 5,000 ppm, there may be an increase in symptoms associated with increased CO_2 exposure, including.

- Decreased concentration
- Increased heart rate
- Mild nausea

CO_2 concentrations above 5,000 ppm are dangerous and can lead to toxicity and hypoxia.

Providing an alert at 1,100 ppm is important but may not prevent CO_2 from rising beyond that. Because indoor CO_2 levels can be harmful to human health, it's important to set an alert threshold below this level — which can be 900 or 1,000 ppm.

To be able to know the current CO_2 concentration in an area, the CO_2 level management system collects all the data from the CO_2 sensor. Sensors located in the same zone will be analyzed. Based on the choice of control type, the system will take the minimum/maximum value or average value from the sensors.

After obtaining the CO_2 concentration value from that area, the controller compares it with the preset values of the system to issue commands to control the rotating fans through the inverter.

Therefore, when the CO_2 concentration is above 900 ppm, the system will start the fan to start running at a low speed. When the CO_2 concentration is above 2000 ppm, the system will control the fan to run at maximum speed.

The following equation will be used to control fan speed according to CO_2 concentration:

$$y = 0.7x \quad (1)$$

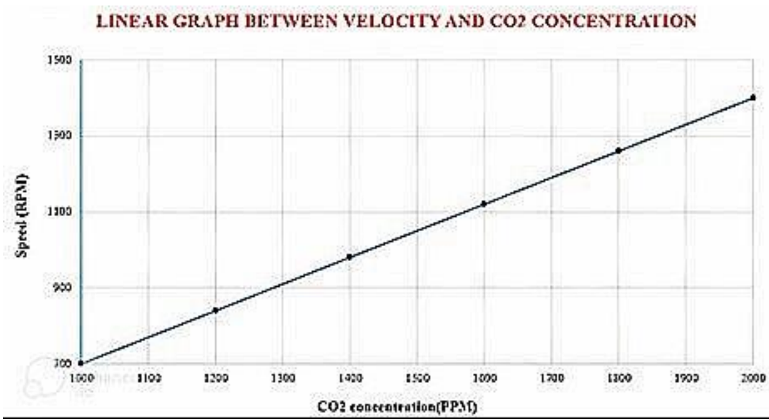

Figure 3. *Linear diagram between velocity and CO_2 concentration*

In this paper, PNTech's IG5A inverter, 1.5kW motor, and DDC will be used to control and monitor CO_2 speed and concentration. First, the inverter will be configured hardware as follows:

- Drv (Drive Mode): 3 – Modbus RS485 communication
- Frq (Frequency Mode): 7 – Modbus RS485 communication protocol
- LED display: I59 – 0: Install Modbus RS485 protocol
- LED display: I60 – 3: Inverter address setting
- LED display: I61 – 3: Set the Baud speed of the inverter
- LED display: I62 – 0: Continuous operation mode when the transmission signal is lost
- LED display: H30: Power of motor (1.5kW)
- LED display: H31: Install number of poles (4)
- LED display: H32: Slip factor setting
- LED display: H33: Setting the rated current of the motor
- LED display: H34: No-load current setting (50% of rated current)
- LED display: H36: Efficiency of motor
- LED display: H39: Carrier frequency setting

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- LED display: F22: Maximum frequency of the inverter

Next, configure the software as follows:

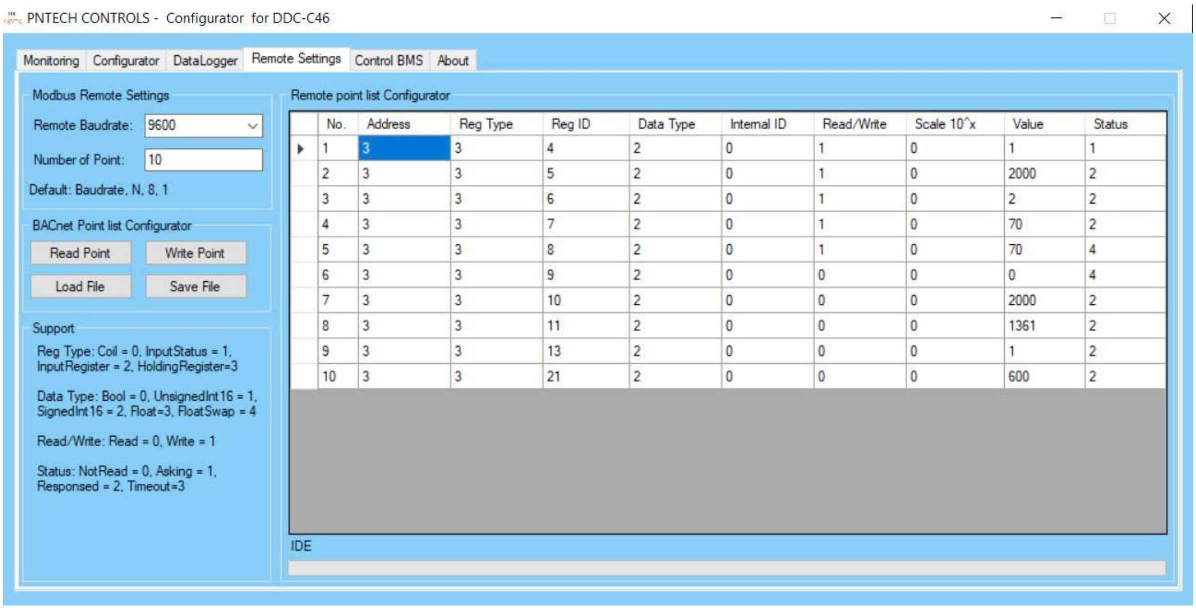

Figure 4. *Setting parameters for the inverter*

3. Test and results

The case study described in this paper is Design of a ventilation system for a university laboratory with dimensions of Length 9m, Width 5m and Height 3.5m. This laboratory operates 24/24 and has a variable number of students entering and exiting during the day. The design requirement is to maintain the CO2 concentration below 900ppm according to the standard. The volume of the laboratory is calculated according to the equation below:

V= Length x Width x Height = 9x5x3.5=157.5m^3

According to TCVN 5687:2010, this laboratory requires a multiple of 10-12 air exchanges. In this study, the average value of 11 times is chosen. The total air flow required to be supplied in 1 hour to maintain the CO_2 concentration according to the standard is:

Q=V.n = 157.5x11=1732.5 m^3/h

Based on this calculation result, the centrifugal fan is selected with the parameters as in Table 1.

Table 1. *Parameters of ventilation fans for laboratories*

Name	Parameter
Power	1.1kw
Pressure	870-515Pa
Flow	1000-2000m^3/h
Speed	2800 rpm
Blower size	D224x196mm
Suction size	D224 mm

3.1. Surveying motors running on CO_2 sensors

This experiment monitors the energy consumption of the motor (1.1kw) when there is a change of the CO_2 sensor (24-hour uninterrupted data acquisition time).

In the period from 0h to 24h, the amount of CO_2 has different changes at different times, so the engine speed changes.

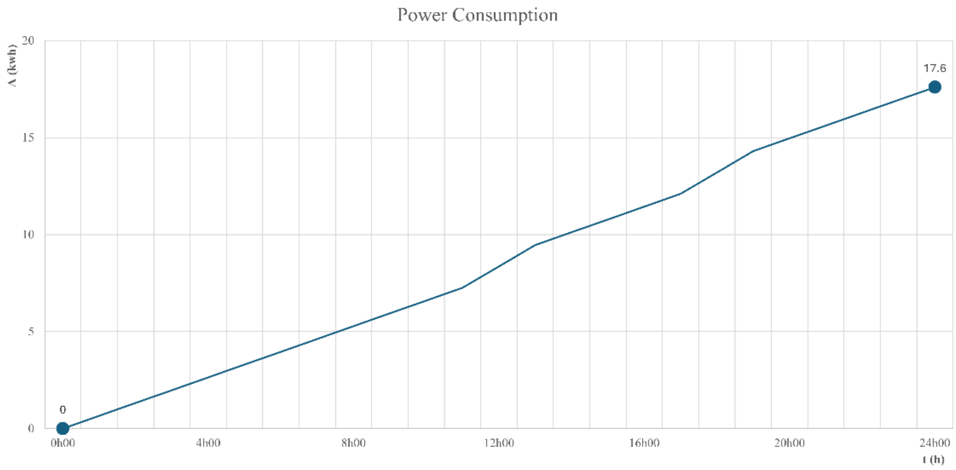

Figure 5. *Total power consumption per day of the motor*

Figure 5 shows the total daily power consumption of the motor when applying the BMS system combined with the CO_2 sensor to monitor and control the motor speed. Observation of Figure 5 shows that the motor power changes at the time periods of 10:30-14:00 and from 16:30-20:30. This leads to the power consumption also changing during the above time periods. The reason for this change in power is that the CO_2 concentration changes a lot during this period.

When the CO_2 concentration exceeds Setpoint 1500 (PPM), the motor will run at an increasing frequency from 30 Hz to 50 Hz. Other while, below the Setpoint, the motor will run at the lowest frequency of 30 Hz.

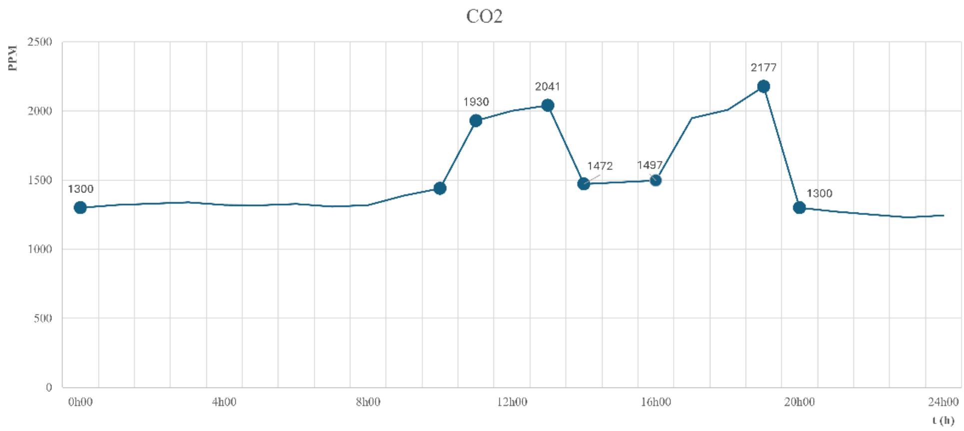

Figure 6. *CO_2 concentration over time*

Figure 6 shows that the CO_2 concentration changes according to the actual time intervals of the day in the laboratory. This value changes according to the number of students in the laboratory. At the time intervals of 10:30-14:00 and from 16:30-20:30, the CO_2 concentration fluctuates a lot. Therefore, the motor speed controlled by the inverter will change linearly according to the change in this concentration. In this case study, because the laboratory has students continuously, the CO_2 concentration is always high and maintained above 1300ppm-1500ppm. Therefore, this is the basis for the Setpoint of the engine speed threshold to change linearly when the CO_2 concentration value is above 1500ppm. If this concentration is below 1500 ppm, the Setpoint of the engine speed remains constant at 30Hz.

Figure 7 shows the change in engine power over time. In this figure, the effective power of the engine fluctuates a lot during the periods of 10:30-14:00 and 16:30-20:30, reaching a maximum value of 0.825 kW. The reason for this change is that the CO_2 concentration changes a lot during this period, so the motor power also changes accordingly to save energy. During the remaining periods, because the CO_2 concentration is lower than the Setpoint value, the engine power changes little and runs at a frequency of 30Hz.

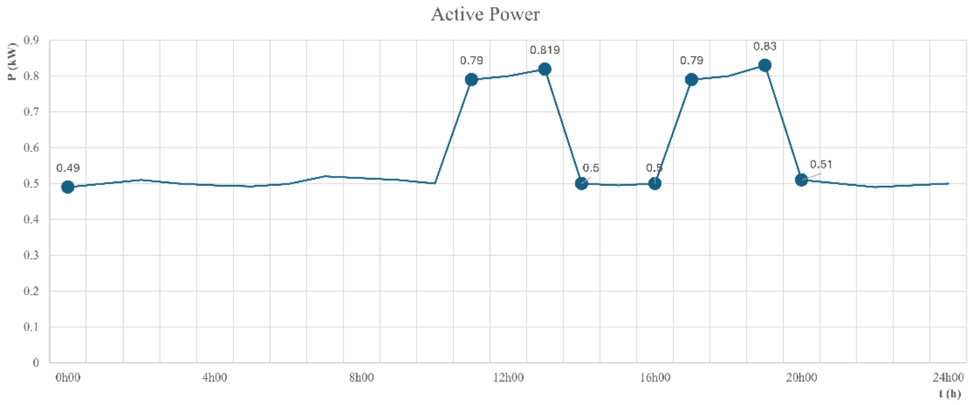

Figure 7. *Active power over time control by BMS*

3.2. Survey of power consumption when the engine is idling continuously for 24 hours

The average power of motor when running at a frequency of 50Hz for 1h is 0.825kW, from which we can calculate 24 hours when running the motor continuously, the Power Consumption per day is 19.8kWh.

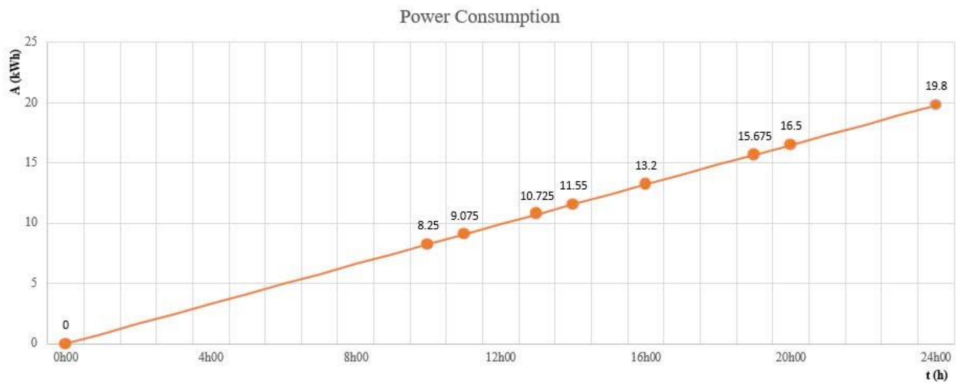

Figure 8. *Total power consumption of the motor without using BMS system and CO_2 sensor.*

Figure 8 shows the total daily power consumption of the motor without applying the BMS system combined with the CO_2 sensor to control the motor speed. With this method, the motor runs at a speed and power that is almost unchanged. Therefore, observing Figure 8 shows that the motor's power consumption is little changed over time and the straight line depicting the total power consumption over time is almost linear.

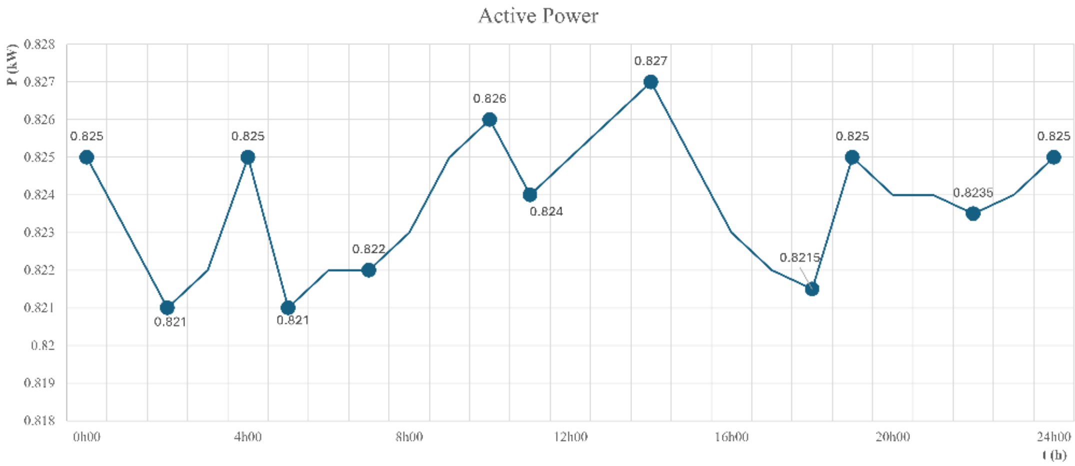

Figure 9. *Active power over time without BMS*

Figure 9 shows the motor power over time without using the BMS system. Therefore, the motor power fluctuates less and the value is in the range of 0.821kW-0.825kW. This shows that not using the BMS system and CO_2 sensor to control and monitor the motor speed will not save energy.

4. Discussion

Table 2. *System Configuration*

NO	Name of Devices	Amount	Prices (VND)	Prices ($)
1	IOT Gateway Simatic 2050	1	6,300,000	250.056
2	ECO – C46 - IP	1	5,400,000	214.3337
3	Inverter LSLV0015G100-4EONN	1	3,700,000	146.8583
4	Sensor CO_2 (detection area: 100m^2)	1	1,000,000	39.6914
Total			**16,400,000**	**650.9395**

Table 3. *System Configuration*

Description	Power consumption per day (kWh)	Power consumption per year (kWh)	Prices (VND)	Price Per Year (VND)	Price Per Year ($)
No Sensor CO_2	19.8	7,227	2,500	18,067,500	717.125
With Sensor CO_2	17.24	6,292	2,500	15,731,500	624.4058

Through the survey, we found that when the fan is controlled by the BMS through DDC combined with IoT and CO_2 sensor, the energy consumption will be less when the fan is not running through the BMS. The results are presented in Table 3.

For the study case of a fan operating without a BMS, the motor runs 50Hz in Fig. 9. Power consumption per day is 19.8kWh and Power consumption per year is 7,227kWh. Power consumption total cost is 18,067,500 VND (717.125$).

Also operating the fan via BMS in Fig. 7 with an initial investment of 16,400,000 VND (650.9395$) in Table 2. Power consumption per day is 17.24kWh and electricity consumption per year is 6,292.6kWh. Power consumption total cost is 15,731,500 VND (624.4058$).

Through the above 2 cases, the study has shown one year of savings: 18,067,500 – 15,731,500 = 2,336,000 VND (92.7192$) equivalent to 934.4 kWh.

According to [18], the result of calculating Vietnam's grid emission coefficient in 2022 is 0.6766 t CO_2/MWh. Based on calculations, in one year, the user will save 0.630488 t CO_2, with 1.0 t CO_2 for 5$. Thereby, one year can save 78,500 VND (3.1158$).

From the above results, the study proceeds to the calculation of the payback time according to the following formula:

$$[(6,292.6).(2,500)].x + (78,500).x + 16,400,000 = [(7,227).(2,500)].x$$

$$\Rightarrow x = 7.26(years)$$

The amount of electricity saved in a year is 78,500 VND (3.1158$), it takes a period of 7.3 years to pay back.

The article presents the application of BMS system including: BMS devices (DDC, computer, IoT 2050, meter,...), inverter and CO_2 sensor in monitoring and controlling motor speed to save energy. The research results can be applied to energy-consuming systems such as ventilation systems, air conditioning systems, etc... in buildings and industrial works. The article has not much scientific contribution but has a lot of meaning in practical application to save energy and reduce greenhouse gas emissions.

5. Conclusions

The BMS system operating in sensor mode will bring more economical efficiency than the no sensor mode, helping to save about 13% of power consumption in a year and the ability to pay back in 7.3 years. In addition, the use of sensors for the BMS system will help save power consumption as well as increase the life of the fan and reduce CO_2 emissions. However, investing in a BMS system with sensors initially requires more challenges in terms of capital investment and payback of the BMS system. Therefore, in subsequent studies, the BMS system will be optimized to reduce the estimated payback period by 4 to 5 years.

Acknowledgments

This work was supported by Thu Duc College Of Economics And Technology and HCMC University of Technology and Education.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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