Energy Saving Air Conditioner Compressor Control by Speed Controller

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***Abstract*— Regarding rapidly economic growth of Thailand, the country needs more energy, especially in the industrial sector needs a keen awareness to speed up energy saving. The various energy conservation projects have been implemented for efficiency and performance improvement, including the value of an investment. This paper presents a principle of operation and behavior of the 36,000 BTU/hrs. Air conditioner compressors modified using the Variable Speed Drive (VSD) to control the speed of the compressor, the experimental results compared between before and after the installation of VSD, the obtained results lead to the energy-saving analysis to evaluate the break-even point, the proposed energy-saving plan is reliable and can be used in the long term.**

Keywords—energy saving, speed control, air conditioner.

I. INTRODUCTION

Since Thailand located in a tropical clim ate which has a high temperature in almost the season, the use of "air conditioning" to achieve the living comfort of residents is prevalent. However, air conditioning is High-power electrical machinery, and consumers must be awa re of the higher electricity bills. Therefore, to preserve the electrical energy of the air conditioning system without harming the user's comfort and saving the cost, the technology can be used to improve the efficiency of theoperation and reduce the energy cost. The use of Variable Speed Drive (VSD) is the solution in the technological era.

Air conditioning is a process of tem perature control, humidity, cold distribution. In large buildings such as office buildings, the energy used in air cond itioning systems is about 60 percent of t he total energy used. Therefore, it is essential to study and understand the cooling system and air conditioning system. If it can save energy in the cooling system and air cond itioning, it can sav e the ov erall energy consumption. The heating, ventilation, and air conditioning (HVAC) is an exciting and well-researched resource for developing power management systems and control systems widely available today.

Advanced HVAC systems can reduce consumption in unoccupied zones of a building and made the total energy consumption of the system significantly reduced. In [1], Tzu M. W. proposed experimental, which measure through each sensor in the surrounding circumstances, in the database using multi-point sensing network and fuzzy theory to control air conditioning system effectively achieve a m ore comfortable environment and m inimize the energy consumption when using. In [2], Wang R. C. and Lui G. use fussy-PID to compare the difference of temperature between the output water and input water in central air-conditioning. It can control the rotational speed of an electrical machine, and the controller is faster, more stability, and less error. In [3] Ashoka M. and Shilpi B. present sensing operation that can transfer information to th e system controller a bout the densely populated area i s relatively unoccupied, and the ambient conditioning will be done area wise or zone wise according to that sensed signal. The proposed system is also proper for any smart residential. In [4], Nam K. H. et al., assembled and explained the Simulink model for a predictive control strategy for the control of temperature, humidity, and C02 level to implement the optimization of energy recovery ventilation (ERV) control integrated into the whole HVAC, ERV has excellent potential for significantly saving total energy consumption. In [5], Young K. K. and Hasim A. made the evaluating dynamic simulation model and get energy reduction achievement by HVAC c ommissioning, the case study building's energy-saving was achieved by 5.3% by implementing variable speed drive (VSD) control. In [6], Youde H. and Fadhil A. M. ap ply the Constant Air Volume (CAV) and Variable Air Volume (VAV) strategies to analyze the energy consumption, the two-stage cooling system contributes to redu cing the required energy consumption dramatically as much as 40%.

II. EXPERIMENTAL DESIGN

The reduction of energy consumption of compressors, air conditioners with speed control is proposed. The experiments were carried out using 36,000 BTU/hr. Air conditioner compressors, which use i n the m ain electrical distribution room. While the room is not air-conditioned, the temperature in the room can be as hi gh as 40 de grees Celsius; the air conditioning information described in Table 1.

TABLE I. AIR CONDITIONING SPECIFICATION

Description	Air Conditioning Components	
	Conditioner	***Compressor***
Brand	Uni Air	Copeland
Cooling capacity	36,000 BTU/hrs.	
Operating voltage		3 Phase 380 – 420 V.
Frequency		50 Hz.
Locked rotor current		41 – 46 A.
Running Current	6.	9 A.
Compressor speed		2,900 RPM

A. *Variable Speed Drive (VSD) Selection*

From the accessible inform ation, it is not possi ble to determine the VSD d esignation to use for controlling the compressor, since it only knows the maximum current about 6.9 A. Th e Analysis Power Meter is tak en into account to analyze the energy information. The connection is the same as the three -phase meter cooperative with current transformers (C.T.) After connecting to the air c ompressor, the energy values provided in Table 2.

TABLE II. ENERGY INFORMATION

Description	Analytical Value
Running current	5.93 A. (Measured) / 6.9 A. (Nameplate)
Available voltage range	3 Phase 380 – 420 V.
Operating power	3.12 kW.
Power factor	0.8

From the measurement values, it can specify the VSD that suitable for this compressor.

- VSD is 3 PH type that qualified t o receives current more than 5.9 - 6.9 A.
- VSD must support the load more than 3.12 kW.

B. *Experimental Circuit Design*

For three-phase compressor connection, it is similar to the three-phase motor cable connection, but for the closed-loop compressor, the internal connector is fixed as Star connection. As show n in Fi g. 1, th e left shows a regular compressor connection with th e magnetic contactor and overload to control the operation, and the compressor connected to VSD adjusting its motor speed to the air demand displays on the right.

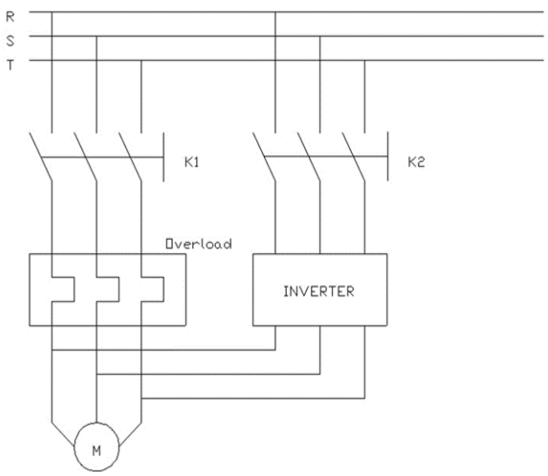

Fig. 1. Compressor connection before and after installation VSD.

Fig. 2. Toshiba VSD VF-S15.

After calculating the capacity of the VSD to be used with the compressor, Toshiba VSD VF-S15 has been selected. Because it is suitable for regular operation and covers when the compressor operates in t he maximum current situation, the VF-S15 are depicted in Fig. 2.

III. EXPERIMENTAL RESULT

In this section, the information on the pressure values of the reagents, speed percentage and frequency of the VSD, the phases current and power consumption per hour which is the result of both the pre-installation and post-installation and the energy-saving data. The data collected and displayed in the form of a record of both pre-VSD and VSD data in a couple of week period; seven days before the VSD installation and connecting VSD for another seven days, the before and after VSD installation information are shown in Table 3 and Table 4 respectively. Then take the results to calculate the energy savings and find out the break-even point of the experiment.

Electricity tariffs in Thailand base on the use of electricity at the tim e of use rate (TOU) . The on-peak period is fr om Monday to Frid ay from 09.00 to 22.00, and the off-peak period is from Monday to Friday from 22:00 to 09:00 and Saturday and Sunday throughout the day. The charge of electricity in the on-peak period is 0.11 USD and 0.08 USD for off-peak. The summarize of the daily electricity costs of experiments displays in Table 5.

TABLE III. DAILY ENERGY MEASUREMENT DATA (PRE-VSD INSTALLATION)

Day	Reagents Pressure (Psi)	Speed (%) / Frequency (Hz)	Average Current (A)			Average Power (kW)
			R	*S*	*T*	
1	55	100/50	5.91	5.24	5.12	3.13
2	55	100/50	5.90	5.24	5.12	3.13
3	55	100/50	5.91	5.24	5.12	3.14
4	55	100/50	5.92	5.24	5.12	3.13
5	55	100/50	5.91	5.24	5.12	3.13
6	55	100/50	5.91	5.24	5.12	3.13
7	55	100/50	5.91	5.24	5.12	3.13

TABLE IV. DAILY ENERGY MEASUREMENT DATA (POST -VSD INSTALLATION)

Day	Reagents Pressure (Psi)	Speed (%) / Frequency (Hz)	Average Current (A)			Average Power (kW)
			R	*S*	*T*	
1	55	80/40	4.81	4.18	4.07	2.51
2	55	80/40	4.81	4.18	4.07	2.51
3	55	80/40	4.81	4.19	4.07	2.51
4	55	80/40	4.81	4.18	4.07	2.51
5	55	80/40	4.81	4.18	4.07	2.51
6	55	80/40	4.81	4.18	4.07	2.51
7	55	80/40	4.81	4.18	4.07	2.50

TABLE V. TOTAL ELECTRICITY CHARGE

Day	Before Install VSD			After Install VSD		
	On-peak costs (USD)	*Off-peak costs (USD)*	*Total electricity charge (USD)*	*On-peak costs (USD)*	*Off-peak costs (USD)*	*Total electricity charge (USD)*
1	4.67	2.38	7.05	3.74	1.90	5.64
2	4.67	2.38	7.05	3.75	1.91	5.66
3	4.69	2.39	7.08	3.75	1.91	5.66
4	4.67	2.38	7.05	3.75	1.90	5.65
5	4.67	2.38	7.05	3.75	1.91	5.66
6	-	5.19	5.19	-	4.17	4.17
7	-	5.18	5.18	-	4.15	4.15

The results show the difference between the energy usage before and after the VSD installation to controlling the speed of the compressor. From the table, the power consumption decreases by approximately 1 kw after the VSD installation. It also reveals the benefit in term of energy cost, especially when the time of usage (TOU) by reduce both on and off peak.

The results of the VSD i nstallation are s ummarized as follows.

- Energy saving: 5,447.82 kW/year
- Cost saving; Difference between VSD installatio n case and non-VSD case

= 2365.85 USD / year - 1902.36 USD / year

= 1463.49 USD/year (about 20%)

- Payback period = Investment ÷ Cost savings after installation VSD

= 426.53 USD ÷ 463.49 baht = 0.92 years

IV. CONCLUSION

The conclusion from an energy point of view. Based on the results of the pre-installation of the VSD, the total annual electricity consumption was 27,104.9 kW / year, which is quite high. However, when we installed the speed control (VSD) and then collected the power consumption. The annual electricity consumption is 21,657.08 kW / year, which results in a reduction in electricity consumption of 5,447.82 kW / year (20%). Recognizing that the speed control device (VSD) can significantly reduce the power lost by the utility.

The conclusion from an economy point of view based on the analysis of power, tariffs concludes that the annual power consumption before the installation of the VSD was 2,365.85 USD a year. When the Speed control (VSD) subjected to the system, the cost of electricity is 1,902.36 USD/year, which is considerably reduced by 463.49 USD/year (19.6%), that is considerably rate of cost savings. Moreover, the break-even point of installing a speed control device (VSD) is around 11 months. The result of the trial is that the breakeven point is fast and worth the investment.

The results of the study should propagate to the operators in various industries, office buildings, which require large amounts of air conditioning, to understand the factors that affect the use of electricity. The air condition improvement using VSD is a great way to save money yearly.

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