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A Design and Construction of Speed Controlled Inverter for 1 Phase Induction Motor

Paiboon Taninsurat[1] Luck Kitjarak[2] Tienchai Nogkrut[2] and Polphadung Phadungkul[1]
[1]Department of Electronic, Faculty of Engineering,
King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand
[2]Department of Electronic, Faculty of Engineering,
Mahanakorn University of Technology, Bangkok 10530, Thailand

Abstract

This paper presents the designing of an inverter for controlling a single-phase induction-motor. The approach of the development exploits the concept that the change of switching frequency to dropped voltage across motor can be used to control the flow rate of fluid. As the state variables of controller such as quantities of cooling-liquid and its temperature are low sensitive to the rate of controlling, therefore, the use of micro-controller is adequate to handle the controlling. The test results show that the developed inverter has high performance at low switching-frequency which is applicable to improve efficiency of air-conditioner unit or pump motor.

Keyword: Inverter for 1 phase, Induction motor

Introduction

In this paper, the speed-controlled inverter is developed to control the rate flow of fluid in the air-conditioner unit. The conceptual design of inverter is based upon the simple structure[Timothy L. Skvarenina, 2001] and cost effective. As the state variables of controller such as quantities of cooling-liquid and its temperature are low sensitive to the rate of controlling, therefore, the use of micro-controller is adequate to handle the changing. One obstructive problem in implementing the system is the limited memory size for contenting the controlled-code as formed in looking-up table format. To expense the spectrum band of controlling, the new technique in reducing the controlled-code is exploited. This results in improving the capability of fine controlling of the rate flow.

Relevant Background and System Implementation

Inverter for Driving Induction Motor

In general, the inverter has a major role to converse the DC (direct current) power to be an AC (alternative current) power to the induction motor. By the role, the variable frequency has to be proportional to the desire speed. Another meaning is to maintain the constant ratio of phase voltage and controlled frequency throughout the constant commanded-torque. This results in full driving over the controlled-frequency band. The structure of inverter is shown in Figure 1.

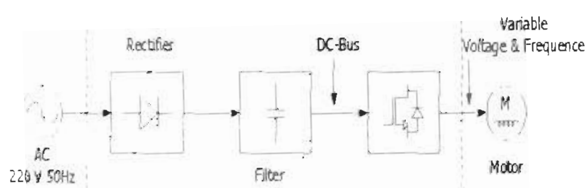

Figure 1: Simple structure of inverter

As shown in Figure 1, the rectifier and filter circuits are formed the DC bus 600V. The DC supply will be conversed to AC supply by the switching circuit. An amplitude and frequency can be varied following the controlled-code commanded by the processing unit. The controlled-signal from the processing unit can be generated in such a form, for instance a 2 kHz PWM (pulse width modulation) which requires a small filter circuit.

Controlling Format and Switching Structure

The capacitor motor consists of main coil and auxiliary coil as shown in Figure 2. The capacitor is connected in series to both coils. This causes an angle in between two sinusoid signals as shown in phasor diagram of Figure 2. The misalignment results in generating torque to drive the motor.

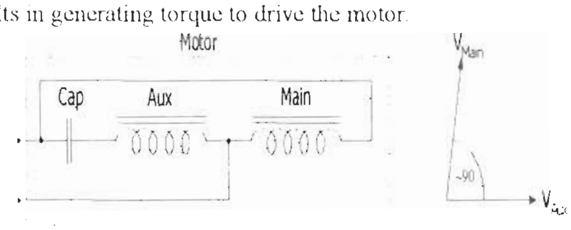

Figure 2: Equivalent Circuit of Motor and Phasor Diagram of Vmain and Vaux

Nevertheless, in controlling point of view, the maximum torque will be occurred when that angle is 90 degrees. In order to avoid any modifications on the motor structure, the structure of 3-phases switch is exploited to generate two sinusoid signals in 90 degrees phase difference.

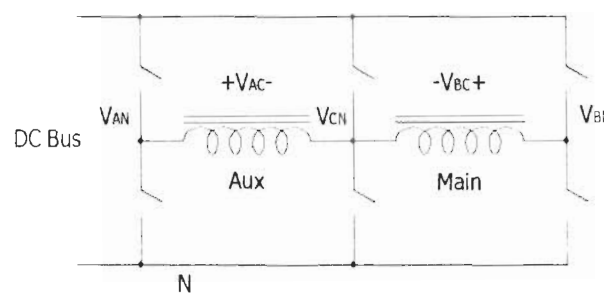

Figure 3: Circuit of 3-Phases Switch

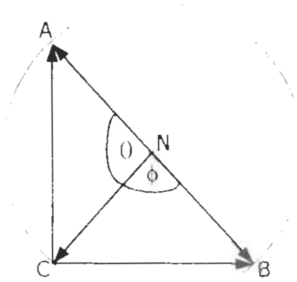

Figure 4: Phasor Diagram of 3-Phases Switch

As shown in Figure 4, we assume that magnitude of voltages V_{AN}, V_{BN} and V_{CN} are balanced and phase difference between V_{AN} and V_{BN} is 180 degrees constantly. The reason is to reduce the data-base of modulation scheme. In following, the angle θ is then adjusted to give the 90 degrees phase difference between V_{AC} and V_{BC}. By doing this, one-set of controlled-code needed to be generated for each adjustment of frequency. To aim for fine adjustment, the thousand set of controlled-code have to be generated. This may results in facing difficulty of system implementation due to the limitation of memory size.

Pulse Width Calculations and Data Compression

As mention previously, the fine adjustment requires a thousand set of controlled-code. Therefore, the scheme of pulse width calculation and data compression required to duce the set of controlled-code. The intersected duration between sinusoid and triangular signals is defined as the width of controlled signal. The computation is performed by algorithm which is implemented on Visual Basic. In each single time frame, at least 3 intersected signals are generated. The multiple sets of repeated data of these signals over multiple time frames are reduced to be a set of controlled-code associated with number of time frames. For the un-repeated data in consecutive time frames, they are defined an un-correlated sets of controlled-code associated with single time frame. This scheme can reduce the number of controlled-code significantly.

The procedures of pulse width calculation are described in step 1, 2 and 3 of flowchart as shown in Figure 5. In addition, the procedures of data compression are described in step 4 and 5 of the same flowchart as shown in Figure 5.

Implementation of PWM Inverter

The structure of PWM inverter consists of converter circuit as shown in Figure 7. In general, the diode-rectifier circuit is used to convert AC voltage to DC voltage. The convert DC voltage is fed to the PWM inverter for driving a single-phase motor. The use of DC supply 600V will provide a 220V for the run coil (V_{BC}), whereas the voltage of start coil (V_{AC}) depends upon the type of motor. However, from the test result which uses of a single –phase induction motor, the V_{AC} was 290 V.

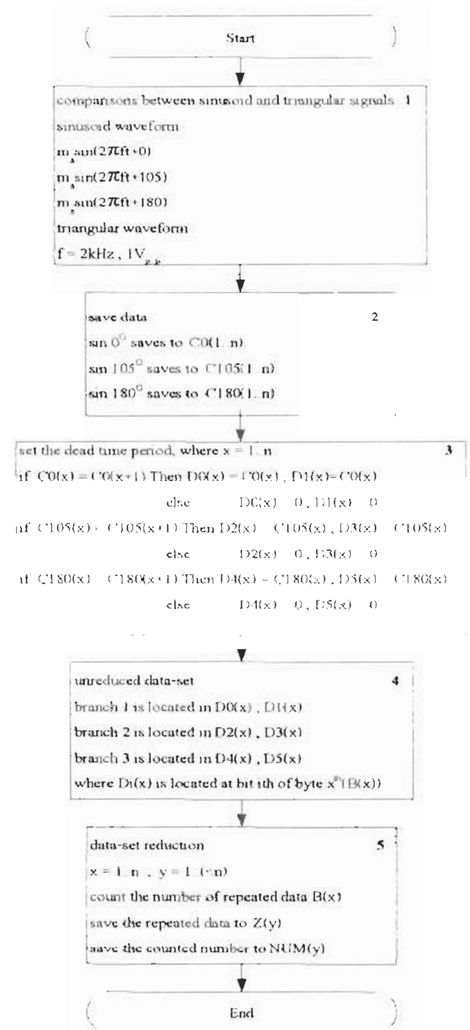

Figure 5: Procedures of Pulse Width Calculations and Data Compression

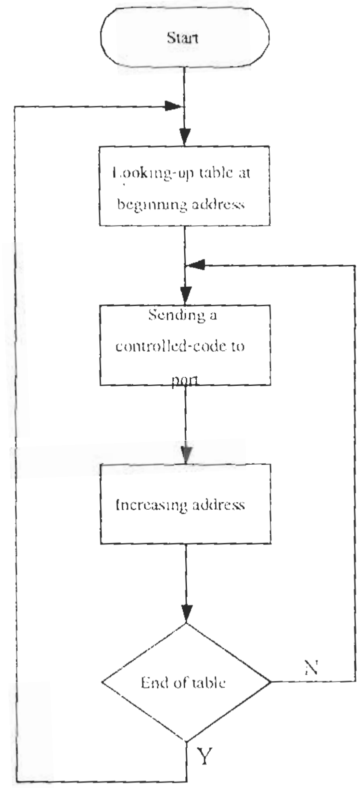

Figure 6: Procedures of controlling algorithm

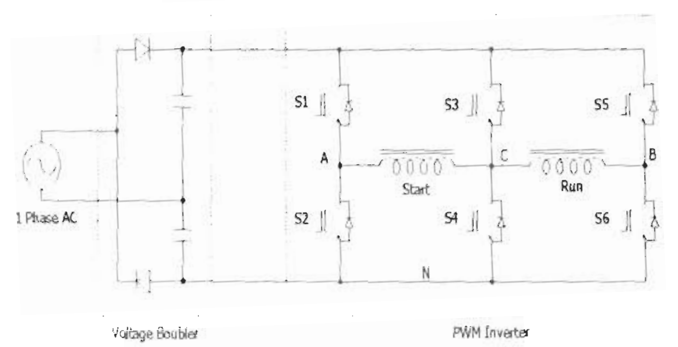

Figure 7: Structure of PWM Inverter

At the state of modulation $m_a \leq 1.0$, the fundamental frequency of output voltage is linearity to modulation ratio. As shown in figure 8, the maximum figure of fundamental frequency of individual branches is given by

$$V_{AN} = 0.5V_S + m_a \frac{V_S}{2}\sin(\omega_a t) \tag{1}$$

$$V_{BN} = 0.5V_S + m_a \frac{V_S}{2}\sin(\omega_a t + 180) \tag{2}$$

$$V_{CN} = 0.5V_S + m_a \frac{V_S}{2}\sin(\omega_a t + \theta) \tag{3}$$

Therefore, the voltage at Run coil can be computed from

$$V_{AC} = V_{AN} - V_{CN} \tag{4}$$

$$V_{AC} = 0.5V_S + m_a \frac{V_S}{2}\sin(\omega_a t) - 0.5V_S - m_a \frac{V_S}{2}\sin(\omega_a t + \theta) \tag{5}$$

$$V_{AC} = m_a \frac{V_S}{2}\sqrt{2 - 2\cos(-\theta)}\sin\left(\omega_a t + \left(\frac{\theta}{2}\right) - 90\right) \tag{6}$$

Consequently, the line voltage V_{BC} can be computed from

$$V_{BC} = V_{BN} - V_{CN} \tag{7}$$

$$V_{BC} = m_a \frac{V_S}{2}\sqrt{2 - 2\cos(\theta - 180)}\sin\left[\omega_a t + \left(\frac{\theta + 180}{2}\right) - 90\right] \tag{8}$$

Test Circuit

The variable-frequency PWM waveform is generated by using the P89C51RD2 and AT89C2051 micro-controllers as shown in Figure 9. The AT89C2051 has a role to control the frequency of PWM, whereas the P89C51RD2 has a role to generate the PWM waveform. The generated PWM is fed into thyristor device, IGBT. To isolate the driven circuit and load, the opto-isolator is used to this purpose. The frequency of generated PWM can be adjusted to 10 Hz, 20Hz, 30Hz, 40Hz, 50Hz. As the dead time of generated PWM is close to one machine cycle of micro-controller, therefore, the use of single micro-controller to handle the whole activities of the system may face the condition of short circuit of thyristor devices. To avoid this severe circumstance, the 2nd micro-controller (P89C51RD2) plays a major role to generate PWM only.

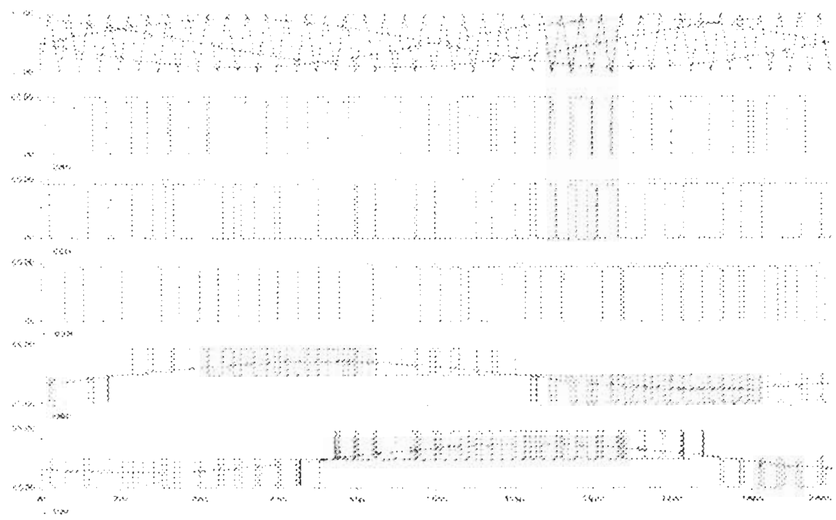

Figure 8: PWM Waveform

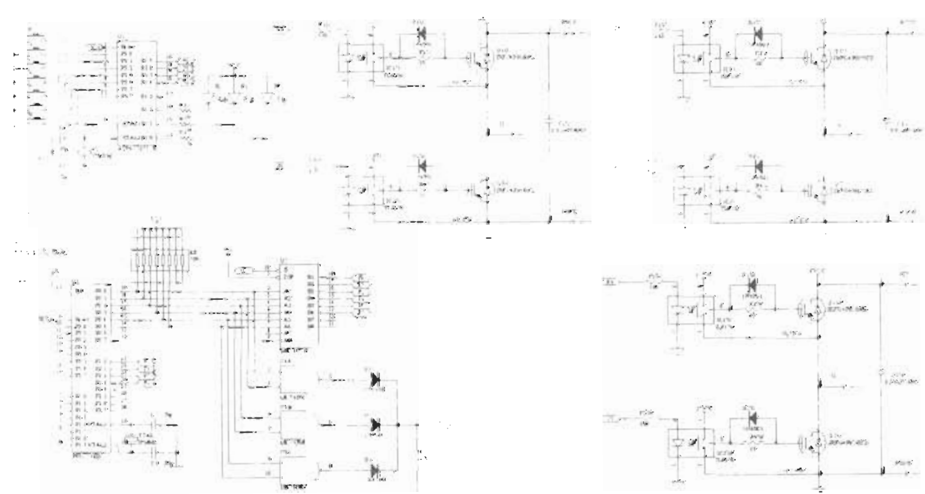

Figure 9: Test Circuit

Test Results and Analysis

The property of water pump motor can be measured from the rate flow of fluid at different frequencies. This information can be used to analyse the performance of tested motor. In this paper, we test the motor at 5 different frequency rates.

Speed/Frequency Test

Figure 10 shows the test result of speed motor while varying frequency. As can be seen, the change in speed of motor is proportional to frequency

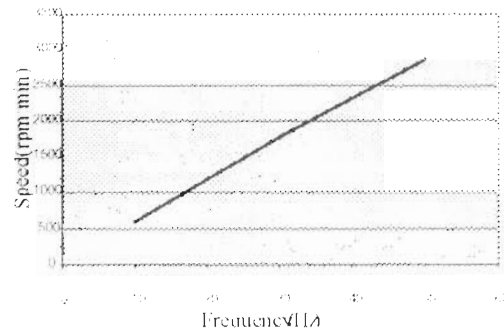

Figure 10: Test Result of Speed Versus Frequency

Flow Rate/Frequency Test

Figure 11 shows the flow rate of fluid at different controlled-frequency (10Hz, 20Hz, 30Hz, 40Hz, 50Hz). It can be seen that the change in flow rate is proportional to frequency.

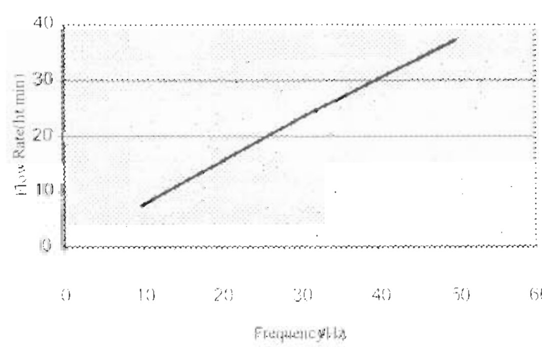

Figure 11: Test Result of Flow Rate Versus Frequency

Power/Frequency Test

The load of test circuit is a water pump, LuckyPro model MCP130, 220V~240V, 50Hz, 0.37kW, 0.5HP. The capacitor which accommodated with the motor has to be removed. The test circuit is shown in Figure 7. The consumed power by inverter is measured by FLUKE 41B Power Harmonic Analyser. As the results shown in Figure 12, the characteristic of consumed power by inverter is non-linear to the frequency band

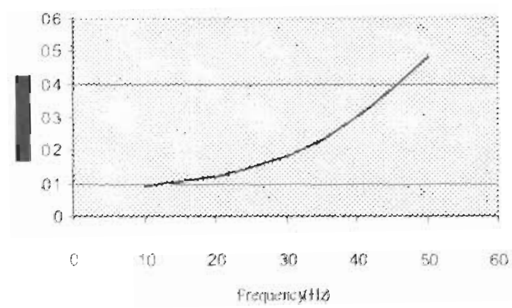

Figure 12: Test Result of Power Versus Frequency

The characteristics shown in Figure 11 and Figure 12 can be combined to give the new curve which represents the flow rate at different consumed-power.

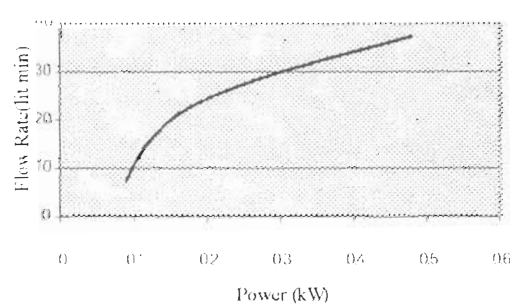

Figure 13: Test Result of Power Versus Flow Rate

Test Results of Start and Run Coils

The voltage at the start and run coils are shown in Figure 14 and Figure 15

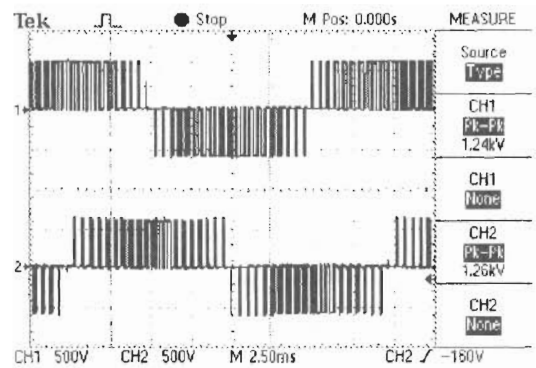

Figure 14: Ch1 Shows the Voltage of Start Coil, Ch2 Shows the Voltage of Run Coil

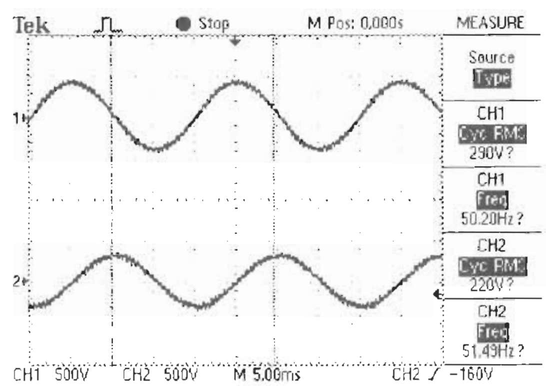

Figure 15: Ch1 Shows the Voltage of Start Coil at Fundamental Frequency, Ch2 Shows the Voltage of Run Coil at Fundamental Frequency

Conclusion

This paper presented the designing PWM inverter for single phase induction motor. As shown in the test result section, the flow rate of fluid can be controlled by varying the frequency of PWM signal. Furthermore, once the frequency was tuned down, the power was reduced significantly. This may conclude that the operation at low frequency provide more performance. Finally, the tested result showed that the phase difference in voltage signals between start coil and run coil was 90 degrees. This showed that the developed inverter provided a maximum torque

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