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The Research Optimal Current Control to Improve Quality of The Three - Phase Inverter System in Industrial Machine Control

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Abstract

The paper presents researches on the calculation method of designing optimal current control problem sets to improve the quality of three-phase inverter systems used in industrial machine control with loads of three-phase AC asynchronous motors. System kinetics to evaluate control methods. The main goal of adopting the optimal control method of the energy flow to the converter and the three-phase inverter is to regulate the output current. The AC side has the desired sine wave shape; the voltage across the ac phases is stable with low oscillation. When applying the proposed research method for the three-phase inverters, the simulation results were simulated on Matlab - Simulink software. And experiment with phase flow inverters has proven the converter's advantages. The proposed algorithm has improved the output voltage and current quality of three-phase inverters with the industrial load.

Keywords: *Three-phase inverters, current control, three-phase AC motor control, power electronics, inverters.*

INTRODUCTION

In recent years around the world, science and technology are making great leaps. The electric drive field has grown strongly and is present in many fields of industrial and military control. The developed capacity electronic control systems associated with electric drive systems and microprocessor techniques, programmable control techniques, technological process automation, etc., are shown in the backside [1, 2, 4, 5, 6].

Using power electronic converters with power semiconductor elements such as transistors, Bipolar junction transistors, Thyristor (Silicon Controlled Rectifier), Gate turn-off thyristor is GTO, Mosfet, JFET, IGBT, etc. is possible ability to withstand high currents and voltages. It ensures the drive system's fast action in the control measurement circuits using microchip components, microprocessors, and informatics technology to have compact structure, high technical features to maximize the electric motor's working ability to satisfy the technological requirements with high precision, wide control area.

The high - quality digital drive control systems are increasingly used. They have outstanding advantages such as easy adjustment of voltage and the frequency value of power supply to motor [2, 4], size and Compact weight, stability of characteristics, fast actuation, and easy parameter optimization thanks to microcontrollers and microprocessors. Improving the switching control algorithm of semiconductor locks is one of the urgent requirements to improve the output voltage quality and ensure safety and improve the life of semiconductor and simple equipment hardware circuitry [8, 11, 12, 15].

Some previous studies have focused only on the problem of controlling reverse system, optimally using semiconductor valves, some control methods of frequency change, modeling, and change, the opening and closing of semiconductor valves in a ballast system [7, 9]. These documents do not pay attention to the system control's quality problem and when the load is consumed.

The main research content of the paper is to study the optimal current control to improve the quality of the three-phase inverter system controlling in industrial machines: such as CNC machine tool system, robot machine system in industrial, conveyor system of mixing plants in cement factories, etc. is now very necessary.

II. THE BUILD A CONTROLLER MODEL

A. Structure diagram of the three-phase inverter bridge

The power circuit of a three-phase inverter with output LC filter considered in this paper is shown in Fig. 1. The converter and filter models are presented here, and the load is a three-phase load.

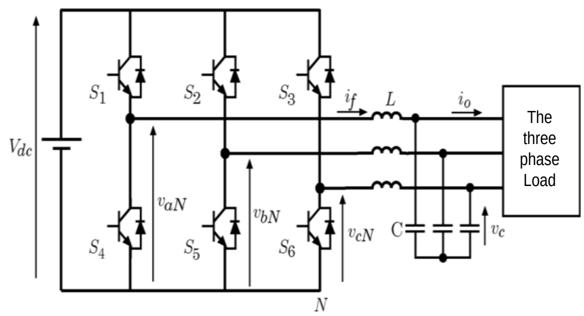

Fig 1: The three-phase inverter with output LC filter

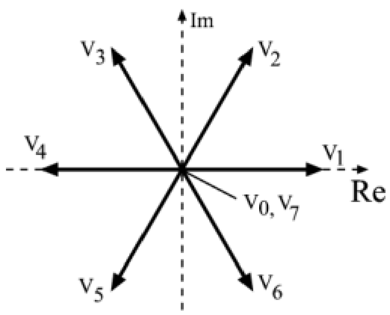

Fig 2: The voltage vectors generated by the inverter

The controller uses a system model for the three-phase inverter; on each sampling interval, the output voltage's behavior for each possible switching state. A cost function is then used as a criterion for selecting the switching state that will be applied during the next sampling interval. There is no need for internal current - control loops and no modulators; the gate - drive signals are generated directly by the control [3, 6, 8, 10].

B. The Optimized quality improvement for a three-phase reverse flow system

With the current pulse-width modulated inverters' switching rules, the same current is often present in the inverters' column. To eliminate it normally in the microcontroller must integrate a firing tool. Deat time complicates the programming algorithm, so eliminating duplicate current only by improving the switching law contributes to simplifying the microcontroller structure and easily set up control. Each state of the inverse bridge. The gating determines the switching states of the converter signals S_a, S_b, and S_c as follows [2, 4, 5, 11]:

$$S_a = \begin{cases} 1, \text{ if } S_1 \text{ on and } S_4 \text{ off} \\ 0, \text{ if } S_1 \text{ off and } S_4 \text{ on} \end{cases} \quad (1)$$

$$S_a = \begin{cases} 1, \text{ if } S_2 \text{ on and } S_5 \text{ off} \\ 0, \text{ if } S_2 \text{ off and } S_5 \text{ on} \end{cases} \quad (2)$$

$$S_a = \begin{cases} 1, \text{ if } S_3 \text{ on and } S_6 \text{ off} \\ 0, \text{ if } S_3 \text{ off and } S_6 \text{ on} \end{cases} \quad (3)$$

and can be expressed in vectorial form by:

$$S = \frac{2}{3}(S_a + aS_b + a^2 S_c) \quad (4)$$

Where, $a = e^{j2\pi/3}$. The output voltage space vectors generated by the inverter are defined by:

$$v = \frac{2}{3}(\upsilon_{aN} + a\upsilon_{bN} + a^2\upsilon_{cN}) \quad (5)$$

Where, υ_{aN} , $a\upsilon_{bN}$, υ_{cN} are the phase to neutral (N) voltages of the inverter (Fig. 1). Then, the load voltage vector v can be related to the switching state vector by:

$$v = V_{dc}.S \quad (6)$$

Where V_{dc} is the DC link voltage.

Considering all the possible combinations of the gating signals S_a, S_b, and S_c, eight switching states, and consequently, eight voltage vectors are obtained. Note that $v_0 = v_7$ resulting in only seven different voltage vectors, as shown in Figure 2. Here, using modulation techniques like PWM, the inverter can be modeled as a linear system.

A more accurate model of the converter model could be used for higher switching frequencies. It may include deadtime, insulated gate bipolar transistor (IGBT) saturation voltage, and diode forward voltage drop. In this work, the emphasis has been put on simplicity so that a simple inverter model will be used for the control system.

In a balanced three-phase load, the current can be defined as a space vector.

$$i = \frac{2}{3}(i_a + ai_b + a^2 i_c) \quad (7)$$

and the load EMF as

$$e = \frac{2}{3}(e_a + ae_b + a^2 e_c) \quad (8)$$

In this way, the load current dynamics can be described by the vector equation

$$v = Ri + L\frac{di}{dt} + e \quad (9)$$

R is the load resistance, L the load inductance, v the voltage generated by the inverter, and e the load back - EMF. For simulation and experimental results, the load back - EMF is assumed to be sinusoidal with constant amplitude and constant frequency. Then authors building a discrete-time form of the load current (9) for a sampling time T_s can predict the future value of load current with the voltage and measured current at the k_{th} sampling instant. Approximating the derivative di/dt by:

$$\frac{di}{dt} \approx \frac{i(k) - i(k-1)}{T_S} \quad (10)$$

And then replacing it in (9), the following expression is obtained for the future load current:

$$i(k) = \frac{1}{RT_S + L}[Li(k-1) + T_S v(k) - T_S(k)] \quad (11)$$

The term RTs could be neglected if the sampling period is small enough, and the load is mainly inductive. Shifting the discrete-time one step forward in (11), the future load current can be determined by:

$$i(k+1) = \frac{1}{RT_S + L}[Li(k) + T_S v(k+1) - T_S e(k+1)] \quad (12)$$

The load back - EMF can be estimated using (11) and measurements of the load voltage and current, resulting in the following expression:

$$\hat{e}(k) = v(k) + \frac{L}{T_S} i(k-1) - \frac{RT_S + L}{T_S} i(k) \quad (13)$$

where, $\hat{e}(k)$ is the estimated value of $e(k)$.

Then during the time the semiconductor valves are in service, the EMF component value can be calculated using the extrapolation of the estimated current and past values of the set setback - EMF, or the state that the following - EMF did not change significantly over a sampling period and in that case, assume $e(k+1) = \hat{e}(k)$.

The proposed predictive algorithm (12) is then evaluated for each of the possible seven voltage vectors, giving seven different current predictions. The voltage vector, whose current prediction is closest to the expected current reference, is applied to the load at the next sampling instant.

C. The linear Current Control With PWM

In this control strategy, shown in Figure 3, measured load currents are compared with the references using hysteresis comparators. Each comparator determines the switching state of the corresponding inverter leg (S_a, S_b, and S_c) such that the load currents are forced to remain within the hysteresis band.

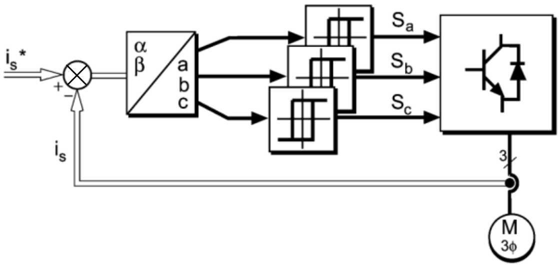

Fig 3: The current model control with three-phase load

The PWM current control scheme is shown in Fig. 4. Here, the error between the reference and the measured load current is processed by a proportional-integral controller to generate the reference load voltages. A modulator is needed to generate the drive signals for the inverter switches. The reference load voltages are compared with a triangular carrier signal, and the output of each comparator is used to drive an inverter leg.

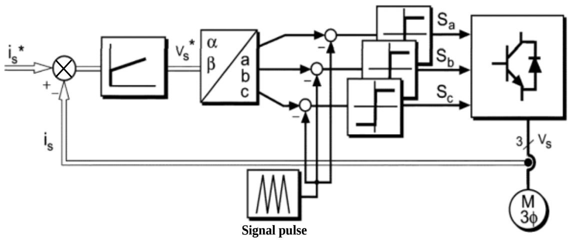

Fig 4: The pulse width modulation current control

Pulse width modulation (PWM), or pulse-duration modulation, reduces the average power delivered by an electrical signal by effectively chopping it into discrete parts. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off quickly. The longer the switch is on than the off periods, the higher the total power supplied to the load. Along with maximum power point tracking, it is one of the primary methods of reducing solar panels' output to that which can be utilized by a battery. The PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching because their inertia causes them to react slowly [2, 5]. The PWM switching frequency has to be high enough not to affect the load, which means that the resultant waveform perceived by the load must be as smooth as possible. With this method, constant switching frequency, fixed by the carrier, is obtained. This control scheme's performance depends on the controller parameters' design and the frequency of the reference current. Although the PI controller assures zero steady-state error for continuous reference, it can present such an error for sinusoidal references. This error creases with the reference current's frequency and may become unacceptable for certain applications [1, 2].

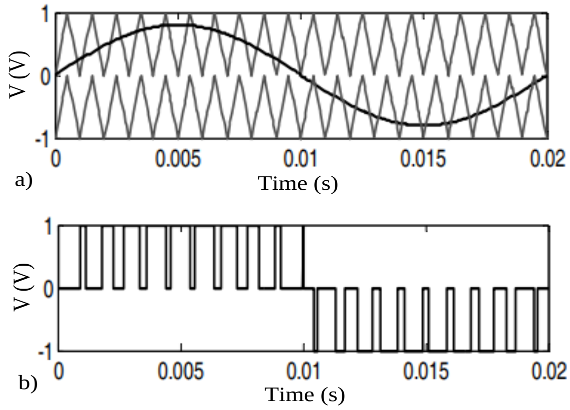

Fig 5: a) Carrier waveform and modulation; b) the output voltage waveform

With the three-phase inverters' design and control structure, we have the waveform of the PWM -modulated reverse voltage source converter with the three-phase inverters structure diagram using the valve. IGBT has the waveform simulated, as shown in Figure 5, as [2, 4].

III. THE SIMULATION AND EXPERIMENTATION

A. The Simulation

After studying the calculation, algorithm and modeling, and control of the three-phase inverted system, the control system structure was proposed in Part II. To illustrate the operation of the control system with three-phase asynchronous motor alternating loads, we conduct simulation and evaluation results to verify the correctness of the system is research problems in the environment Matlab - Simulink, [13, 14, 16] with the following parameters: Three-phase AC motor, P = 2,2kW, U = 380V, I = 8,6A, speed 1500 rpm, p = 2, frequency 50Hz.

The simulation model of a three-phase reverse flow system is built on Matlab Simulink with a three-phase AC machine load, as shown in Figure 6.

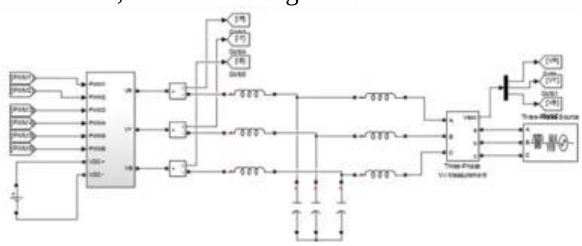

Fig 6: Schematic simulation system built on Matlab Simulink

The simulate a three-phase reverse flow system with voltage values of phases A, B, C, and current values corresponding to phases A, B, C, as shown in figure 7, results of a separate price simulation. The value of phase A voltage and current of phase A are shown in figure 8.

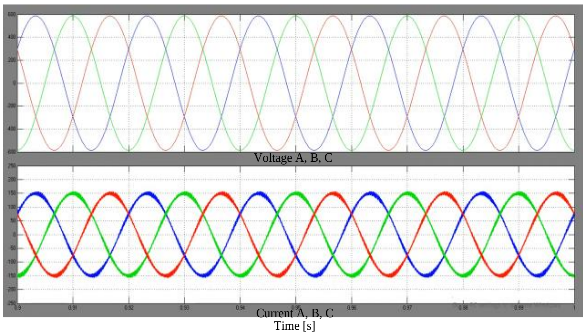

Fig 7: The voltage and current values of phase A, B, C of three-phase inverters simulated on Matlab Simulink

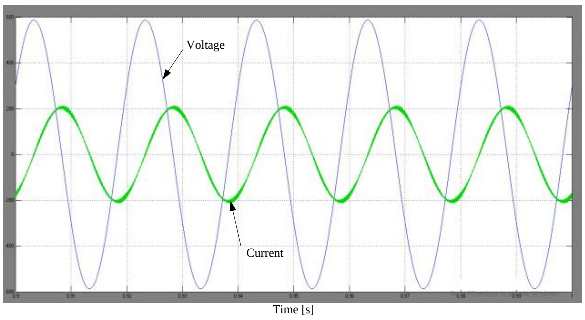

Fig 8: Voltage and current in one phase

Comment: Observing the simulation results above, we see that the response time from 0 to 1 second, the system response to the voltage and current values of the inverter shows the correct control structure. Correct with the selected parameters of the rectifier. We see that the output response is always asymptotic to the initial set value from the curvature characteristics of the speed, current, and flux. Even when the speed of a three-phase motor is changed, the system always works well. This is a new scientific issue, completely applicable to the practical industrial and civil production.

B. The experiment

An experimental study with three-phase reverse flow system as shown in figure 9 and figure 10, including Parameters of AC asynchronous motor three-phase are the same as those in simulation, the motor is hard coupled to the load: DC motor: P = 4kW, U = 220V, I = 8,6A, speed 1750 rpm, frequency 50Hz. Devices located on inverted table: current transformer 50A / 5A, power module IGBT 25A / 1200V, digital control module dsPIC30F4011, display module LCD - ICEA, oscilloscope, power source transformer, etc. The test system with inverters parameter table is as follows:

TABLE 1: Parameters to select devices for inverters

Description	Value
Voltage DC input for inverter	60-200VDC
Voltage DC - link	750 V
Pulse frequency	10kHz
Filter cutoff frequency fc	25Hz
Capacitor C of the filter	4800 µF
Filter reactor L	2,5mH

The detailed layout of the three-phase inverted test table's control equipment is shown in Figure 9. Figure 10 is an actual experimental table connected to a three-phase motor load and a DC motor load (to generate load).

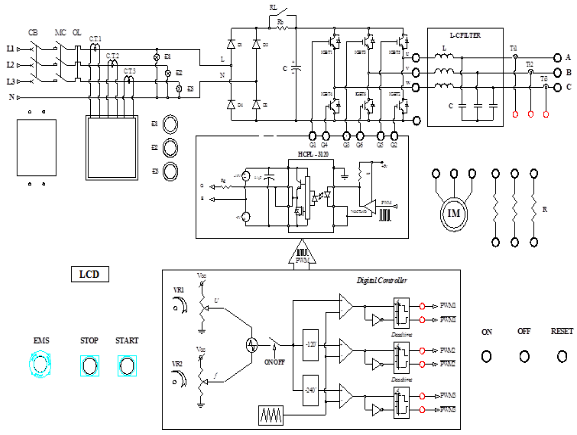

Fig 9: The structure diagram of the reverse flow table with three-phase storage AC, motor control with load

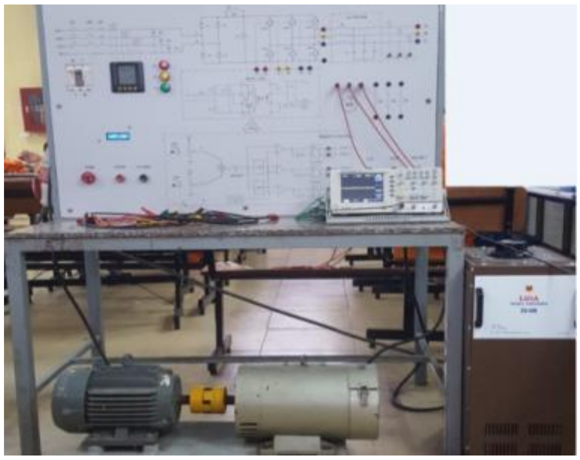

Fig 10: Image of experimental structure of three-phase inverter flow in the laboratory

The experimental process's objective is to evaluate the quality, demonstrate the performance of a three-phase inverter using the filter to improve the inverter's output voltage, to feed the rotating machine dimension with the load as calculated and proposed above. From there, checking, surveying, and evaluating the quality and comparing with the system's simulation results proves that the system works well on the Matlab Simulink simulation and works well in the system real-time system.

The measured response is the voltage and current value at the back of the three-phase inverter when the filter is passed. When the system is operating when the load changes from no load to the load, the load change time is 25ms out of the total system response time of 50ms.

The measured response is the voltage and current value at the back of the three-phase inverter when passed through the filter, as shown in figure 11, at the time of system operation when the load changes from no load to load. , the load change time is 25ms; in the total system response time is 50ms.

Through the research results, we can see that the system has been calculated and built to contribute to improving the quality of electric energy sources of three-phase inverter systems in industrial machine control; The system meets the standards of power quality; this is a new scientific issue, completely applicable to the practical production of industrial machines, in civil, defense and security.

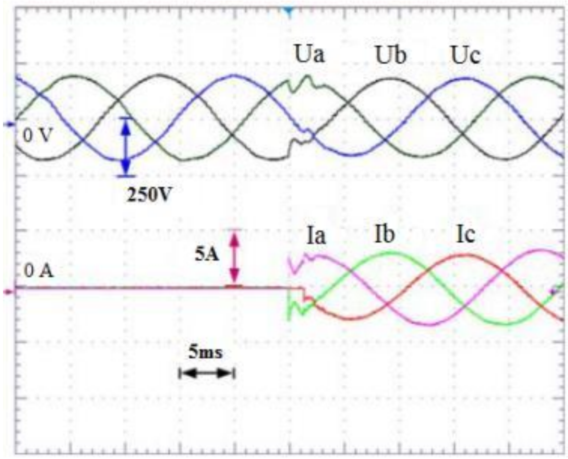

Fig 11: Voltage and current values of the system with variable load: from no load to have a load

Comparing the results with studies in [7], and in previous studies [9], the results achieved by the paper are better than the simulation with time to reach a small equilibrium value both value of current, voltage, capacity and experimentation with an optimal current control system to improve the quality of three-phase inverter systems in control in industrial machines, with process control Load controls work well in real-time.

IV. CONCLUSIONS

The improving quality of electrical Energy from other energy sources such as (solar Energy, wind energy, generator energy, etc.) that is DC power produced, want to bring In industrial use, it is necessary to pass an optimized three-phase inverter to control current to improve the quality of three-phase inverter systems in industrial machine control that the authors have studied. The simulation results have shown the correctness and feasibility of the proposed solution. The system can be used for industrial and civil production and balance energy supply and demand in renewable energy systems that work either independently or with a microgrid. Optimal current-controlled inverters for improved quality of three-phase inverter systems in industrial machine control have been developed and verified with experimental results on in-room three-phase inverters Experiments in figure 11, the results given in this paper are consistent with the IEEE 519 power quality standard that countries are using.

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