3 Phase Ac Servomotor Switching System

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Abstract. The background of the research is the need for switching ac 3 phase servomotor systems for precise position control purposes, in a fairly short displacement step with ac motor actuators. For this purpose, researchers controlled the direction of torque rotation of the servomotor magnetic field by controlling the switching system of the ac 3 phase bridges. The resultant torque of the resulting stator magnetic field represents the desired motor shaft position. For switching systems, we use space vector pulse wide modulation, with the consideration that the switching step is only 8 steps, where 2 steps are the high voltage short circuit arm step and the low voltage short circuit arm. Because the response of the motion is fast enough, the actuator used must be a winding rotor or permanent magnet rotor, better known as servomotor, for the cage rotor ac motor there are obstacles, where the motor loses torque, due to insufficient magnetic field generated by the rotor to move the rotor shaft in time quite short.

1. INTRODUCTION

1.1 Background

The need for switching the ac 3 phase servomotor system for precise position control needs, in a fairly short displacement step with an ac motor actuator. In designing switching servomotor ac 3 phase systems, of course, we learn the needs of their needs, how does the mechanical work of the sketch in the form of flowcharts, determine physical equations, mathematical equations, then for the program and the control circuit[1]. The development of ac 3 phase servomotor switching systems for precise position control needs, in a fairly short displacement step with an ac motor actuator is an important part, because the exact position value, in a fairly short displacement step, is very much determined by the precision of the servomotor control system.

1.2 Formulations

Development of switching ac 3 phase servomotor systems for the purposes of precise position control, in a fairly short displacement step with ac motor actuators ie changing the dc to ac voltage by regulating the voltage and frequency output, used to control 3 phase ac servomotor. There are several types of development of switching ac 3 phase servomotor systems for the purpose of precise position control, in a fairly short step transfer with ac motor actuators including development of switching ac 3 phase servomotor systems for precise position control purposes, in a fairly short displacement step with ac motor actuators with SVPWM (Space Vector Pulse Width modulation) [2],[5]. The advantage of SVPWM is that it is very economical and practical to use on 3 phase ac servomotor. Besides, if the SVPWM signal generation is done digitally, it will get shorter working system steps which will reduce noise. The design of the development of an ac 3 phase servomotor switching system for precise position control needs, in a fairly short displacement step with an ac motor actuator by means of
SVPWM using a microcontroller, provides several advantages, namely easy to deprogram [6], [7] and schematic and PCB circuits will be simpler. To reduce or eliminate harmonics in power systems, several methods have been developed by people and use them more practically. The SVPWM method is used to generate active power filters. Active power filters built from SVPWM can be programmed with a microcontroller, supplying the network with ac current as compensation in the same amount as the harmonic current produced by non-linear loads. The principle in the PWM Vector Space theorem (SVPWM) is based on the fact that there are only 8 steps of a switching combination to drive an electronic power 3 phase ac bridge, the basic switching system of the ac 3 phase servomotor system for precise position control purposes, in that the displacement step is quite short with the motor actuator ac as shown in Figure 1. Two steps V0 and V7 relate to short circuit, while the other six steps are considered vectors in the hexagon plane. The maximum voltage phase value of each of the 6 vectors is as:

\[
V_{\text{phase max}} = 2/3V_{dc}
\]

\[
V_{\text{phase-phase max}} = \sqrt{3} V_{\text{phase max}}
\]

\[
V_{\text{phase-phase max}} = 2/\sqrt{3} V_{dc}
\]

The modulation index or amplitude ratio is defined as:

\[
m = \frac{V_{dc} \cos 30^\circ}{V_{dc}}
\]

\[
m = \frac{V_{dc} \sqrt{3}}{2}
\]

This vector is a function of time, the average voltage can be calculated by adding up the vectors in one switching period. The other 5 vectors are calculated in the same way. The geometric addition shown in Figure 1, for each switching period is \( \Delta T \). Vector Vs has real and imaginary values related to \( F = 20 \) kHz,

\[
T_S = 1/F
\]

as shown in figure 2. Space vectors are divided into 6 sectors each sector 60\(^\circ\). each sector is built by two vectors. Vectors V0 and V7 are vectors with zero amplitude in the hexagonal original point. VS output is a result of sum V1 and V2 when the simultaneous switching SVPWM on sector 1. For the digital implementation of SVPWM, here switching at high frequency (F pwm), this frequency is quite high (> 20 kHz) already outside the audio noise due to switching. Taking F pwm as TS time sampling for Vs, where

\[
T_S = 1/F_{\text{pwm}}
\]

there are several switching variation techniques to generate VS from VO, V1, V2, V3, V4, V5, V6, V7. Mathematically can be shown by the equation :

\[
V_S = \left[ \frac{T_0}{T_S} \ast V_0 \right] + \left[ \frac{T_1}{T_S} \ast V_1 \right] + \left[ \frac{T_2}{T_S} \ast V_2 \right] + \left[ \frac{T_3}{T_S} \ast V_3 \right] + \left[ \frac{T_4}{T_S} \ast V_4 \right] + \left[ \frac{T_5}{T_S} \ast V_5 \right] + \left[ \frac{T_6}{T_S} \ast V_6 \right] + \left[ \frac{T_7}{T_S} \ast V_7 \right]
\]

\[
T_S = T_0 + T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7
\]
Variables $T_0$, $T_1$, ..., $T_7$ are the ignition times associated with the SVPWM statement and the TS sampling time. When SVPWM follows the switching pattern: 1-2-3-4-5-6-1-2 ...., this is known as the 6 step PWM control algorithm. This 6 step PWM algorithm is easier to implement compared to other control algorithms. The 6 step PWM control algorithm can generate a line to line 3 phase voltage greater than its own VDC. Looking at Figure 1 you get:

$$VS = \left[ TA \times \frac{T_0}{T_S} \times V_1 \right] + \left[ TB \times \frac{T_0}{T_S} \times V_2 \right] + \left[ T_0/7 \times \frac{T_0}{T_S} \times V_0/7 \right]$$ (8)

$$TS = TA + TB + T_0/7$$ (9)

SVM (Space Vector Modulation) switching rule: To implement the SVM algorithm, the following rule switching is implemented: • The trajectory of SVM must be a circle, • Only one switching per state transition, • Should not be more than 3 switchings in one TS, • The final state of one sampling must be the initial state for the next sampling. This rule helps in limiting the switching process, and from that, it will reduce switching losses. Also, it will maintain symmetry in the form of switching waves at the SVPWM output to suppress smaller Total Harmonic Distortion (THD).

Table 1. Value of the duty cycle of 3 phase ac servo position based on the location of the voltage Vs

| Sector No. | Phase R Duty Cycle | Phase Y Duty Cycle | Phase B Duty Cycle |
|------------|--------------------|--------------------|--------------------|
| 1          | $T_0/2$            | $T_0/2 + TA$       | $TS - T_0/2$       |
| 2          | $T_0/2 + TB$       | $T_0/2$            | $TS - T_0/2$       |
| 3          | $TS - T_0/2$       | $T_0/2$            | $T_0/2 + TA$       |
| 4          | $TS - T_0/2$       | $T_0/2 + TB$       | $T_0/2$            |
| 5          | $T_0/2 + TA$       | $TS - T_0/2$       | $T_0/2$            |
| 6          | $T_0/2$            | $TS - T_0/2$       | $T_0/2 + TB$       |

Table 2. Conventional modulation

|     | Q1 | Q0 |
|-----|----|----|
| $Q_1$ | 1  | 0  |
| $Q_0$ | 0  | 1  |
Table 3. Space Vector Pulse Wide Modulation (SVPWM)

|   | 001 | 011 | 010 | 110 | 100 | 101 | 001 | 011 | 010 | 110 | 100 | 101 |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| **upward** |     |     |     |     |     |     |     |     |     |     |     |     |
| S1 |     |     |     |     |     |     |     |     |     |     |     |     |
| S2 |     |     |     |     |     |     |     |     |     |     |     |     |
| S3 |     |     |     |     |     |     |     |     |     |     |     |     |
| **down** |     |     |     |     |     |     |     |     |     |     |     |     |
| Q1 | ON  | OFF | OFF | ON  | ON  | ON  | OFF | OFF | ON  | ON  | ON  | ON  |
| Q2 | OFF | ON  | ON  | OFF | OFF | OFF | ON  | ON  | OFF | OFF | OFF | OFF |
| Q3 | OFF | OFF | OFF | ON  | ON  | ON  | OFF | OFF | OFF | ON  | ON  | ON  |
| Q4 | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| R  | 0   | 0   | 0   | E   | E   | E   | 0   | 0   | 0   | E   | E   | E   |
| S  | 0   | E   | E   | E   | 0   | 0   | E   | E   | 0   | E   | E   | 0   |
| T  | E   | E   | 0   | 0   | E   | E   | E   | 0   | 0   | E   | E   | 0   |

1.3 Identification
Identification of problems in switching 3-phase ac servomotor systems include:
1. Switching algorithm for servomotor,
2. Rule of space vector pulse wide modulation,
3. Illustration servomotor bridge in space.

1.4 Research Objectives and Authenticity
The target of this reset is in the form of a 3 phase ac servomotor switching system for precise position control purposes, in that the transfer step is quite short with ac servomotor actuators to be precise.

1.5 Research Uses
Development of a 3 phase ac servomotor switching system for precise position control needs, in a fairly short displacement step with an ac servomotor as ac actuator which is a 3 phase ac motor mounted control to control its motion according to the wishes of the control maker, here the author wants the 3 phase ac servomotor to be controlled by inputting the command signal from outside [8]–[10], the 3 phase ac servomotor will stop position according to the command signal given[11].

2. RESEARCH METHOD
It can be seen simply the signal processing flowchart from switching ac 3 phase servomotor system [12] for precise position control requirements, in a fairly short displacement step with ac motor actuator as follows:
The test results are said to be successful if the signal received, will command a switching 3 phase ac servomotor system in a fairly short displacement step, to stop at the exact ordered position, smooth and stable, where the Tx command signal is obtained from the input of the program received through the communication protocol RS232C [13].

3. RESULTS AND DISCUSSION

3.1 Results

The results obtained are in the form of switching voltage data as in table 4. below:

| Sector 1 | 100 | 110 | Sector 2 | 110 | 010 | Sector 3 | 010 | 011 | Sector 4 | 011 | 001 | Sector 5 | 001 | 101 | Sector 6 | 101 | 100 |
|----------|-----|-----|----------|-----|-----|----------|-----|-----|----------|-----|-----|----------|-----|-----|----------|-----|-----|
| Vc       |     |     | Vb       |     |     | Va       |     |     | Vc       |     |     | Vb       |     |     | Va       |     |     |
| td td    | td td | td td | td td    | td td | td td | td td    | td td | td td | td td    | td td | td td | td td    | td td | td td | td td    | td td | td td |

3.2 Discussion

Ac 3 phase servomotor switching system for the purposes of precise position control, in a fairly short displacement step with an ac motor actuator, allowing precise position control, in a fairly short displacement step [14] with an ac motor actuator more precise, smooth and stable.

4. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusions
The results of switching ac 3 phase servomotor systems for precise position control purposes, in a fairly short displacement step with ac motor actuators ready to be applied in making prototypes in the field.

4.2 Suggestions
To make ac 3 phase Servomotor Switching System it is recommended to use svpwm rules and switching table 4. to get precision and short times, in addition to other advantages such as low noise, only 6 steps, simple in the dead time process i.e. with the short circuit of the upper arm or the lower arm of the 3 phase ac bridge

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