Igniting transistor to control three-phase alternating current motor servo

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Article Info

Article history:

Received Jun 21, 2023
Revised Jan 26, 2024
Accepted Feb 2, 2024

Keywords:

Controlled
Igniting
Position
Rate
Torque

ABSTRACT

The background of research try to use an open loop system, without feedback, by building torque in the target position. Theoretical basis manages the turning round of servo motor change direct currents to alternating currents by adjusting the rate input used. Methodology in simple terms, the flowchart of code processing from igniting transistors to managing the turning round of a three-phase alternating current (AC) servo motor. The result of the transistor ignition time with room phasor pulse width modulation (PWM) to set the ignition of a three-phase AC servo motor in the process of igniting as ordered, for manage position only igniting transistors in target position, and building torque at there. Discussion, igniting transistors to manage the turning round of servo motors, allows motion of servo motor, allows motion of servo motor to be added faster, accurately, soft, and steady. In conclusion, in this case the researcher uses it more specifically by turning on the transistor only at the target position, so that the torque generated is only at the target position, the servo motor motion from the start position immediately ends at the target position. Suggestions, this system igniting can be applied at a motion high-velocity system like a missile system controlled.

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1. INTRODUCTION

The control system for servo motors that is commonly used today to adjust positions using a closed loop system by using feedback, this system is quite time-consuming in the integration process, because it is done one by one, while here researchers try to use an open loop system, without feedback, and by building torque in the target position. Igniting the transistor driver to manage the turning round of a three-phase alternating current (AC) servo motor is needed to get a precise position when that motor is controlled, whereas a motor with a power between 0.25 to 1 kW when used to make a precise positional motion is rather difficult, because of the moment of inertia when it is commanded to stand still. The initial advance from null to nominal speed is relatively long about two seconds, as thin as when from normal rotary motion, it is ordered to stop at the null velocity the down time varies from two to three seconds. What we want is an initial period of 0.5 second for starting time and an end period of 0.75 second stops time in the controlled position as Figure 1 shows. The control system for servo motors is corrected at any time if there is a surplus or shortage of controlled position [1], [2]. This problem is very disturbing in making other control systems because if the time used is long enough in the process of starting time and stopping time, this process will repeat at any time according to the modulation of the control code received by the transistor igniting system, while the desired system operating time is only 30 seconds, such as its use on high-velocity tools above 2 much or 2×300 m/s, starting from start to stop at the end of the process, in controlling the direction of motion on high-velocity equipment to chase objects that are also high-velocity.

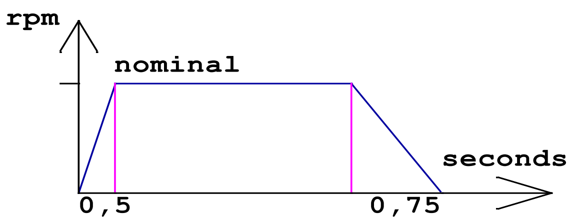

Figure 1. Round per minute (rpm) vs time servo motor requires

The processing time is only about a few minutes because the object velocity is also about 2 much or 600 m/s. When designing an igniting transistor to control a three-phase AC servo motor [3]–[5] to control the rotation of a three-phase AC servo motor. We have to learn how mechanics work and do a flow chart, physics, and mathematical descriptions. Then create a program, here the researcher does not impose research needs to prepare the entire infrastructure from the start.

Developing an igniting transistor to control a three-phase AC servo motor is an essential part of this research. The exact three-dimensional movement in the cylinder axis is the main difference in accuracy in this exploration. The theoretical basis manages the turning round of servo motor change direct current to alternating currents by adjusting the rate input used. The development of igniting transistors to control the turning round of a three-phase AC servo motor with room phasor pulse width modulation (PWM) [6]–[10].

The benefit of room phasor PWM is with the intention of it is cheaper and more realistic to apply in three-phase AC servo motors. In addition, if the room phasor PWM code creation is made computerized, a shorter running stage will be got which will decrease noise. The plan of the improvement of igniting transistors to control the turning round of a three-phase AC servo motor through room phasor PWM by means of a microcomputer equipped with some reward, explicitly simple to computerize [11]–[14], diagram and printed circuit board (PCB) wiring will be easy. To decrease or remove vibrating in the power system, some techniques have been created and used easily [15]–[18]. The room phasor PWM technique is applied to produce an active filter. The active filter make at the room phasor PWM can be planned with the microcontroller, feeding the arrangement alternating currents to compensate for an amount equal to the harmonic current created by the non-linear burden. Based on the description, the author takes the title about this research: "igniting transistor to control three-phase alternating current motor servo".

2. METHOD

Igniting transistor to control three-phase alternating current servo motor, where the ignition command is received via radio receiver, Accordance with the command received, this command is in exadecimal code form, which is the input program igniting transistor to control three-phase alternating current servo motor, with igniting on the transistor according to the command, then by igniting the transistor to carry out the command, where the servo motor starts to move and stops at the intended place, without integrating one by one with the feedback, but directly generating the intended torque by igniting the transistor at its angular coordinates, because the command received is the target position, while the duration of turning on the transistor has been programmed on the room phasor PWM technique. Use in special conditions, such as shaft movement in a narrow range, for example fin rocket movement is only -5º to +5º. Here, when the power supply is on or reset, the resultant torque goes directly to the target position according to the switching code given in the range above. Methodology in simple terms, the flowchart of code processing from igniting transistors to managing the turning round of a three-phase AC servo motor can be seen in Figure 2 signal flow diagram.

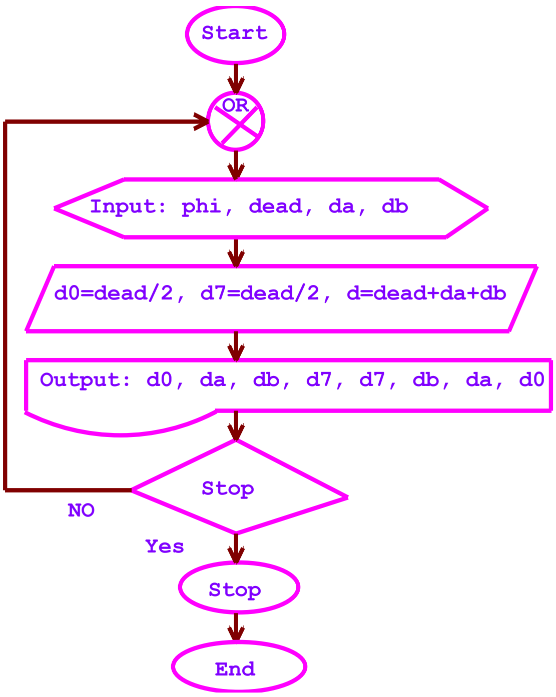

Figure 2. Signal flow diagram

3. RESULTS AND DISCUSSION

This part, it describes stage by stage of exploration, then the outcome of exploration, and at a similar period is prearranged a complete dialogue. To show the ignition process transistor at AC servo motors in industry, in these conditions whole of transistor T0, T1, T3, T4, and T5 are assumsed on conduct, let's look at Figure 3, by imagining knob K1, K2, and K3 from the load side in the form of AC servo motors. Knob K we draw on the Cartesian in the form of a cube. Next, we look at in line with the point coordinates (1, 1, 1) to the point (0, 0, 0). We get a view of the hexagonal plane.

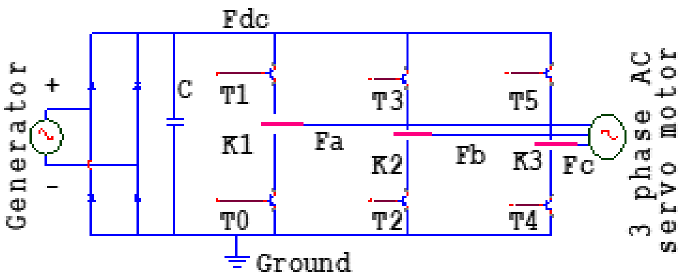

Figure 3. Knob K looks from the load side

The rule in the room phasor PWM rule [19], [20] is founded on the reality with the intention of there has 8 stages of combination ignition to handle the power electronics of a three-phase AC bridge, the basis of a transistor igniting system to control the turning round of a three-phase AC servo motor. Two steps, the first F_0 corresponds to the short circuit to the low voltage side, and the second F_7 short circuits the high voltage side, and the six stages are looking phasor in the hexagon axis. The magnitude of the peak value of every one of the 6 phasors is:

$$F_{phasa\ max} = \frac{2}{3} F_{dc} \tag{1}$$

$$F_{phasa\ phase\ max} = \sqrt{3} \times F_{phasa\ max} \tag{2}$$

$$F_{phasa\ phase\ max} = \sqrt{3(\tfrac{2}{3} \times\ F_{dc})} \quad (3)$$

$$F_{phasa\ phase\ max} = \tfrac{2}{\sqrt{3}}\ F_{dc} \quad (4)$$

The inflection indicator or amplitude percentage is clearly defined as (5)-(7):

$$F_{phasa\ max} = \frac{(F_{dc}\cos 30)}{F_{dc}} \quad (5)$$

$$F_{phasa\ max} = \frac{(F_{dc}\sqrt{\frac{3}{2}})}{F_{dc}} \quad (6)$$

$$F_{phasa\ max} = \sqrt{\frac{3}{2}} \quad (7)$$

If we want to turn on part 4 with the center at (1, 1, 1) as shown in Figure 4. In the same way, turn on part 5 with a flashlight at (0, 0, 0). And in the same way it is done according to counter clock wise, namely part 6 center at (1, 1, 1), part 1 center at (0, 0, 0), part 2 center (1, 1, 1), and part 3 center at (0, 0, 0) completed 1 ignition cycle as shown in Figure 5. We can imagine if the point (0, 0, 0) is adjacent to the point (1, 1, 1) in projecting it, then we can describe the ignition process in the form of a hexagonal in the room as shown in Figure 6. Next, we give the projection of the ignition in the room of in the Cartesian coordinates x, y, z as shown in Figure 7 and to make it easier to analyze Figure 7 which is still in phasor in the Cartesian plane or the room, the image can be viewed as a projection on a flat plane like Figure 8, that is simple drawing in Cartesian coordinates. This phasor is a variation of period, the average phasor can be computed by summing the phasor within an ignition range. The else five phasors are taken into consideration in the identical technique. The phasor of the sum exposed for every ignition range is d. The F_S phasor separates actual and unreal values concerning F_{OSC}=40 kHz.

$$d_{ocs} = \frac{1}{F_{os}} \quad (8)$$

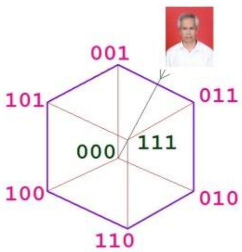

Figure 4. Ignition room phasor

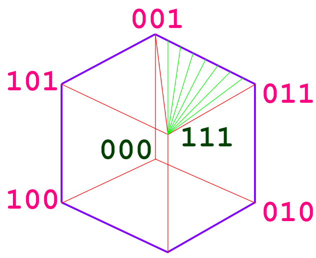

Figure 5. Ignition room phasor in part 4

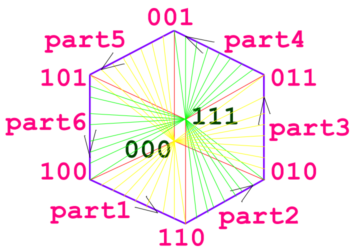

Figure 6. Ignition rules

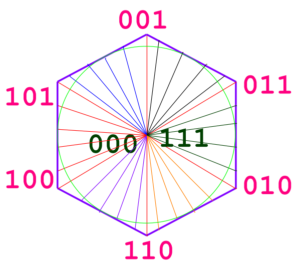

Figure 7. Ignition is in hexagon

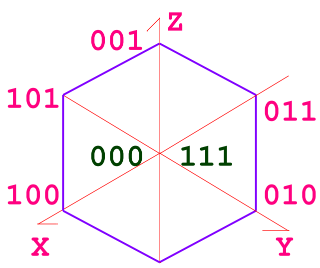

Figure 8. Ignition is in hexagon simple

As shown in Figure 9 ignition hexagons in room, the phasor in the room is separated 60º each part into 6 parts. Phasors F_0 and F_7 are phasors with null values at the original hexagon points. The resultant output phasor is F_S in support of the digital working of SVPWM. At this, point the igniting is at a high rate (F_{OSC}), this rate is rather high (> 40 kHz) which is beyond the audio noise causation igniting. Pleasing Fpwm as sampling period d, to make a symmetric PWM arrangement at the center and total harmonic distortion (THD) will be smaller, d is taken as (9) [21], [22].

$$d = \frac{2}{F_{osc}} \tag{9}$$

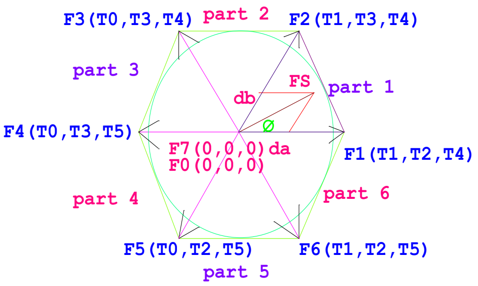

Figure 9. Ignition is hexagon coordinate

Any are some variations of ignition ways to create F_S from F_O, F_1, F_2, F_3, F_4, F_5, F_6, and F_7. Mathematically, it can be exposed by:

$$F_s = \left[\frac{d_0}{d} \times F_0\right] + \left[\frac{d_1}{d} \times F_1\right] + \left[\frac{d_2}{d} \times F_2\right] + \left[\frac{d_3}{d} \times F_3\right] + \left[\frac{d_4}{d} \times F_4\right] + \left[\frac{d_5}{d} \times F_5\right] + \left[\frac{d_6}{d} \times F_6\right] + \left[\frac{d_7}{d} \times F_7\right] \tag{10}$$

$$d = d_0 + d_1 + d_2 + d_3 + d_4 + d_5 + d_6 + d_7 \tag{11}$$

variables d_0, $d_{1,}$ ....., and d_7 are the ignition times linked with the room phasor PWM declaration and the d cycle period. Room phasor PWM follows an ignition arrangement: 1-2-3-4-5-6-1-2, this is recognized as a 6-stage PWM management rule. This 6-stage PWM rule is simple to realize and appealed to else manage rules. The 6-step PWM manage rule can create a three-phase line-to-line phasor bigger than its own Fac. Room phasor modulation ignition regulation. To apply the room phasor modulation rules, the next ignition rules are applied:

– The route of room phasor modulation has to be circular as shown in Figure 9 are given their coordinate values. Figure 10 is a zoom part 1, here we can turn on the phasor 1 and 2 with values da and db. In Figure 11, 2 examples of clock generator ignitions are given for 2-phase pair ignition, in this research the example used in Figure 11 is in the hope that it will be easier to get the ignition sampling balance. To balance the ignition process of phasor 1 and phasor 2, we take the same sampling for phasor 1 as shown in Figure 12, where 1 cycle is 2 sampling clock generators.

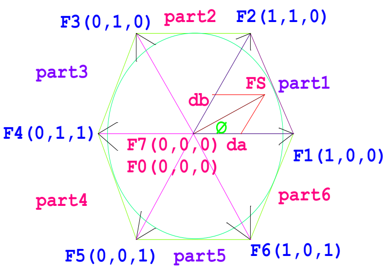

Figure 10. Ignition hexagon in room

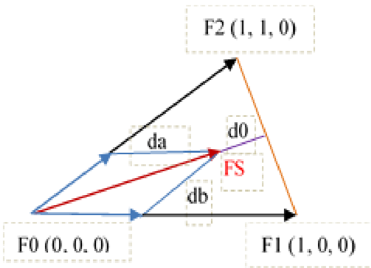

Figure 11. Voltage F_S is in part 1

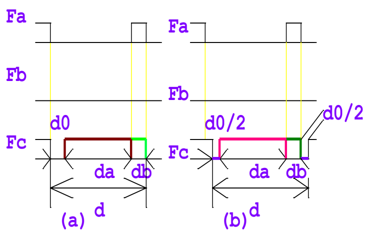

Figure 12. Timepiece vs period

– Less than four igniting in one cycle as shown in Figure 12
– Only one ignition per condition change as shown in Figure 13
– The ending condition of one cycle has to be the early condition for the then cycle

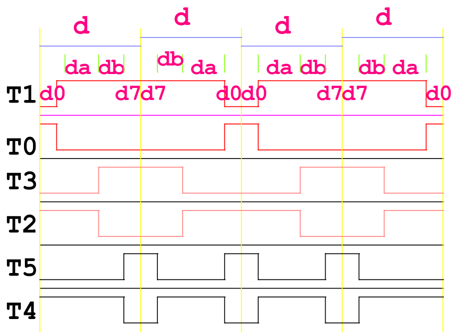

Figure 13. Period diagram ignition is in part 1

This regulation makes it easy in restraining the igniting progression, and hence, reduces igniting losses as shown in Figures 14 and 15. Too, it will uphold balance in the ignition waveform at the room phasor PWM crop to repress THD [23], [24]. By paying attention to Figure 7, we get:

$$F_s = \left[\frac{d_a}{d} \times F_1\right] + \left[\frac{d_b}{d} \times F_2\right] + \left[\frac{d_{\frac{0}{7}}}{d} \times F_{\frac{0}{7}}\right] \tag{12}$$

$$d = d_a + d_b + d_{\frac{0}{7}} \tag{13}$$

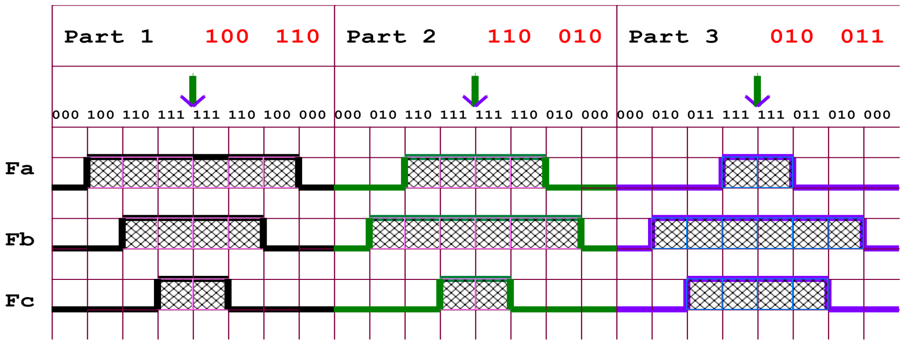

Figure 14. Period chart is ignitions at room phasor part 1, 2, and 3

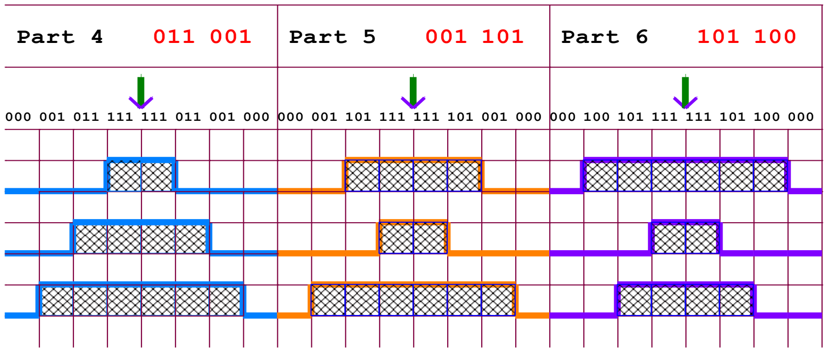

Figure 15. Period chart is ignitions at room phasor part 4, 5, and 6

Igniting the transistor to control the turning round of the three-phase AC motor is expected to be precise because the target is moving at high velocity [25]. Choice of an AC servo motor to avoid motor loss torque, when using a caged rotor AC motor, the motor loses torque when controlled, because the magnetic ground generated in the rotor is not fast enough to reach maximum when generated by the induction principle when high-velocity igniting is performed (>40 kHz). Instead of that, the improvement of ignition transistors to manage the velocity in circles of a three-phase AC servo motor itself is a three-phase AC motor with a winding rotor or a permanent magnet rotor (AC servo motor) or a brushless direct current motor, permanent magnet rotor (BLDC) servo motor, which is next wiring systems to manage its movement appropriately from the desires of the regulator. Here the author wants the three-phase AC servo motor to be controlled by inputting a command code from the outside through radio, the three-phase AC servo motors will stop according to the command code given. For 3-phase ignition loading, we can see in Table 1. Next pulse width modulation in principle as shown in Table 2 and for pulse width modulation phasor in room principle as shown in Table 3.

Table 1. Duty sequence Ignition is in hexagon

Part no.	Phase A duty sequence	Phase B duty sequence	Phase C duty sequence
1	$d_0/2$	$d_0/2+d_a$	$d-d_0/2$
2	$d_0/2+d_b$	$d_0/2$	$d-d_0/2$
3	$d-d_0/2$	$d_0/2$	$d_0/2+d_a$
4	$d-d_0/2$	$d_0/2+d_b$	$d_0/2$
5	$d_0/2+d_a$	$d-d_0/2$	$d_0/2$
6	$d_0/2$	$d-d_0/2$	$d_0/2+d_b$

Table 2. Pulse width modulation in principle

T1	1	1	1	0	0	0	1	1	1	0	0	0
T0	0	0	0	1	1	1	0	0	0	1	1	1
T3	0	0	1	1	1	1	0	0	0	1	1	1
T2	1	1	0	0	0	0	1	1	1	0	0	0
T5	0	0	0	0	1	1	1	0	0	0	1	1
T4	1	1	1	1	0	0	0	1	1	1	0	0
Ty	0	0	0	0	0	0	0	0	0	0	0	0
Tx	0	0	0	0	0	0	0	0	0	0	0	0
bits	1001 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100	0110 0100

Table 3. Pulse wide modulation phasor in room

Label	Part 1	Part 6	Part 5	Part 4	Part 3	Part 2	Part 1	Part 6	Part 5	Part 4	Part 3	Part 2
Bits	001	011	010	110	100	101	001	011	010	110	100	101
PWM ↑ up ↓ down	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓
Bits	000	111	000	111	000	111	000	111	000	111	000	111
K1	↓	↓	↓	↑	↑	↑	↓	↓	↓	↑	↑	↑
K2	↓	↑	↑	↑	↓	↓	↓	↑	↑	↑	↓	↓
K3	↑	↑	↓	↓	↓	↑	↑	↑	↓	↓	↓	↑
ON T1	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON
OFF T0	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
ON T3	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
OFF T2	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON
ON T5	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON
OFF T4	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
Bits: T1T0T3T2 T5T4TyTx	0101 1000	0110 1000	0110 0100	1010 0100	1001 0100	1001 1000	0101 1000	0110 1000	0110 0100	1010 0100	1001 0100	1001 1000
Fa	0	0	0	Fdc	Fdc	Fdc	0	0	0	Fdc	Fdc	Fdc
Fb	0	Fdc	Fdc	Fdc	0	0	0	Fdc	Fdc	Fdc	0	0
Fc	Fdc	Fdc	0	0	0	Fdc	Fdc	Fdc	0	0	0	Fdc

3.1. Result

The following is the result of the transistor ignition time with room phasor PWM to set the ignition of a three-phase AC servo motor in the process of igniting as ordered. According to specific needs, for example if you want to adjust the fin position in part 2, with a switching range of -5^o to + 5^o. For manage position only igniting transistors in target position, and building torque at there as shown in Figures 14 and 15.

3.2. Discussion
Igniting transistor to manage the turning round of servo motors, allows the motion of servo motor to be added faster, accurately, soft, and steady. The examination outcome is believed to be doing well if the received code will order the three-phase alternating current servo motor to move, and stop at the ordered position, where command transmission X (TX) is obtained from input. According to specific needs, for example if we want to adjust the fin position in part 2, with a switching range of -5º to + 5º. For manage position only igniting transistors in target position, and building torque at there. This idea is very practical for motion control needs in limited space, requiring speed and precision, where the control is simple open loop.

4. CONCLUSION
The results of igniting transistors to control the turning round of a three-phase AC servo motor are complete to apply on the ground. Especially to control the position of the servo motor for specific requirements at high speeds that require fast execution time, using transistor ignition with conventional PWM to get constraints in terms of time, researchers tried room phasor PWM methods which provide faster times, shorter steps, and flat AC voltage output higher average. In this case the researcher uses it more specifically by turning on the transistor only at the target position, so that the torque generated is only at the target position, the servo motor motion from the start position immediately ends at the target position. This system igniting can be applied at a motion high-velocity system like a missile system controlled or guided that missile to target in either where technique moving at high velocity and also target moving at high velocity.

ACKNOWLEDGMENTS
We are grateful to Sekolah Tinggi Teknologi Mandala of the Head of Research and community service of the for supporting this project.

REFERENCES
[1] Y. Mikhaylov, G. Buticchi, and M. Galea, “A gate driver for parallel connected MOSFETs with crosstalk suppression,” *iEnergy*, vol. 2, no. 3, pp. 240–250, Sep. 2023, doi: 10.23919/ien.2023.0024.
[2] Q. Xu, X. Cheng, H. Yang, Y. Wei, and H. Xue, “Servo control system of permanent magnet synchronous motor based on feedforward control,” in *2020 IEEE 9th Joint International Information Technology and Artificial Intelligence Conference*, IEEE, Dec. 2020, pp. 1799–1804. doi: 10.1109/ITAIC49862.2020.9339046.
[3] Y. Xia, H. Zhao, S. Wang, X. Huo, and Y. Yao, “Software and Hardware Development of a Universal AC/DC Motor Drive Control System,” in *Proceedings of 2019 IEEE 3rd Advanced Information Management, Communicates, Electronic and Automation Control Conference, IMCEC 2019*, IEEE, Oct. 2019, pp. 170–174. doi: 10.1109/IMCEC46724.2019.8983906.
[4] S. Farajdadian, A. Hajizadeh, and M. Soltani, “Recent developments of multiport DC/DC converter topologies, control strategies, and applications: A comparative review and analysis,” *Energy Reports*, vol. 11, pp. 1019–1052, Jun. 2024, doi: 10.1016/j.egyr.2023.12.054.
[5] D. Nataliana, R. Syafruddin, G. D. Ramady, Y. Liklikwatil, and A. G. Mahardika, “Servo Control for Missile System,” *Journal of Physics: Conference Series*, vol. 1424, no. 1, p. 12040, 2019, doi: 10.1088/1742-6596/1424/1/012040.
[6] G. Buticchi, P. Wheeler, and D. Boroyevich, “The More-Electric Aircraft and beyond,” *Proceedings of the IEEE*, vol. 111, no. 4, pp. 356–370, Apr. 2023, doi: 10.1109/JPROC.2022.3152995.
[7] K. S. Gaeid, T. Al Smadi, and U. Abubakar, “Double control strategy of PMSM rotor speed-based traction drive using resolver,” *Results in Control and Optimization*, vol. 13, p. 100301, Dec. 2023, doi: 10.1016/j.rico.2023.100301.
[8] T. F. Etanya, M. L. Katche, and P. Tsafack, “Low threshold DC–AC power converter with optimized standby power consumption,” *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 6, p. 100369, Dec. 2023, doi: 10.1016/j.prime.2023.100369.
[9] M. B. Essa, L. A. Alnabi, and A. K. Dhaher, “Distribution power loss minimization via optimal sizing and placement of shunt capacitor and distributed generator with network reconfiguration,” *Telecommunication Computing Electronics and Control*, vol. 19, no. 3, pp. 1039–1049, Jun. 2021, doi: 10.12928/TELKOMNIKA.v19i3.15223.
[10] G. Kamalapur and M. S. Aspalli, “Direct torque control and dynamic performance of induction motor using fractional order fuzzy logic controller,” *International Journal of Electrical and Computer Engineering*, vol. 13, no. 4, pp. 3805–3816, Aug. 2023, doi: 10.11591/ijece.v13i4.pp3805-3816.
[11] R. Palanisamy, C. S. Boopathi, K. Selvakumar, and K. Vijayakumar, “Switching pulse generation for DC-DC boost converter using Xilinx-ISE with FPGA processor,” *International Journal of Electrical and Computer Engineering*, vol. 10, no. 2, pp. 1722–1727, Apr. 2020, doi: 10.11591/ijece.v10i2.pp1722-1727.
[12] C. Park, “Electrets: A Remedy for Partial Discharge Caused by Power Electronics Switching,” *IEEE Transactions on Industrial Electronics*, vol. 68, no. 12, pp. 12947–12952, Dec. 2021, doi: 10.1109/TIE.2020.3045707.
[13] M. A. N. Kasiran, A. Ponniran, N. N. M. Siam, M. H. Yatim, N. A. C. Ibrahim, and A. Md Yunos, “DC-DC converter with 50 kHz-500 kHz range of switching frequency for passive component volume reduction,” *International Journal of Electrical and Computer Engineering*, vol. 11, no. 2, pp. 1114–1122, Apr. 2021, doi: 10.11591/ijece.v11i2.pp1114-1122.
[14] Y. Wang, Y. Liu, J. Ding, and D. Wang, “Adaptive type-2 fuzzy output feedback control using nonlinear observers for permanent magnet synchronous motor servo systems,” *Engineering Applications of Artificial Intelligence*, vol. 131, p. 107833, May 2024, doi: 10.1016/j.engappai.2023.107833.
[15] R. Syafruddin *et al.*, “Conventional Switching to Drive A Brush DC Geared Servomotor,” *Journal of Physics: Conference Series*, vol. 1933, no. 1, p. 012086, Jun. 2021, doi: 10.1088/1742-6596/1933/1/012086.

[16] D. Divan, R. P. Kandula, and M. J. Mauger, "The Case for Soft Switching in Four-Quadrant Power Converters," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 9, no. 6, pp. 6545–6560, Dec. 2021, doi: 10.1109/JESTPE.2021.3112658.
[17] T. J. P. Liang, F. Blaabjerg, D. Tan, and O. Ojo, "Editorial Special Issue on Future of Power Electronics: Components, Circuits, and Systems," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 11, no. 3, p. 2399, Jun. 2023, doi: 10.1109/JESTPE.2023.3275688.
[18] M. Pahlevani and P. K. Jain, "Soft-Switching Power Electronics Technology for Electric Vehicles: A Technology Review," *IEEE Journal of Emerging and Selected Topics in Industrial Electronics*, vol. 1, no. 1, pp. 80–90, Jul. 2020, doi: 10.1109/jestie.2020.2999590.
[19] A. Valade, P. Acco, P. Grabolosa, and J. Y. Fourniols, "A study about kalman filters applied to embedded sensors," *Sensors (Switzerland)*, vol. 17, no. 12, p. 2810, Dec. 2017, doi: 10.3390/s17122810.
[20] S. Nadweh, O. Khaddam, G. Hayek, B. Atieh, and H. H. Alhelou, "Time response enhancement for variable speed drive systems by using five-level cascade four quadrant chopper in dc-link," *Heliyon*, vol. 6, no. 8, p. e04739, Aug. 2020, doi: 10.1016/j.heliyon.2020.e04739.
[21] S. Y. Chang and H. C. Wu, "Tensor Kalman Filter and Its Applications," *IEEE Transactions on Knowledge and Data Engineering*, vol. 35, no. 6, pp. 6435–6448, 2023, doi: 10.1109/TKDE.2022.3169129.
[22] P. Karamanakos, E. Liegmann, T. Geyer, and R. Kennel, "Model Predictive Control of Power Electronic Systems: Methods, Results, and Challenges," *IEEE Open Journal of Industry Applications*, vol. 1, pp. 95–114, 2020, doi: 10.1109/OJIA.2020.3020184.
[23] H. Han, C. Liu, Z. Chen, C. Li, H. Teng, and W. Wang, "Electromagnetic noise analysis of servomotor used in secondary water supply equipment," *Energy Reports*, vol. 9, pp. 5694–5703, Dec. 2023, doi: 10.1016/j.egyr.2023.05.009.
[24] A. A. Kadum, "PWM control techniques for three phase three level inverter drives," *Telecommunication Computing Electronics and Control*, vol. 18, no. 1, pp. 519–529, Feb. 2020, doi: 10.12928/TELKOMNIKA.V18I1.12440.
[25] S. Devadoss, P. Ramasamy, Amit, A. Agarwal, and S. Gupta, "Design of 15 level reduced switches inverter topology using multicarrier sinusoidal pulse width modulation," *Telecommunication Computing Electronics and Control*, vol. 21, no. 1, pp. 214–222, Feb. 2023, doi: 10.12928/TELKOMNIKA.v21i1.24263.

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