3 Phase Inverter Switching Algorithm for Industrial Needs

R Syafruddin1*, D Nataliana2, R Hidayat1, Anung1, A G Mahardika1 and G D Ramady1

1Sekolah Tinggi Teknologi Mandala, Bandung, Indonesia
2Institute Teknologi Nasional, Bandung, Indonesia

*syafruddinr@yahoo.com

Abstract. 3 phase inverter is needed, besides to change the dc to ac voltage as needed, in the industry every CNC or NC machine needs an inverter to regulate the rotation speed of the motor, constant motor rotation requires for cutting in certain a variety of speeds feeding processes, wherein conventional machines gear is used to change the rotation speed of the motor, here the AC voltage is changed to DC and returned to AC according to the required frequency. For this reason, the researchers tried to research switching the 3 phase inverter algorithm with the principle of space vector pulse wide modulation. Here the switching theory follows the SVPWM switching rule, where the resultant vector is the result of each sector of each phase. The microcontroller accepts the input data, that will be used to generate frequency, the required PWM calculation, the sector, estimates the switching process per sector, the switching sector according to the algorithm results rule. These results will generate inter-phase voltage greater than conventional switching methods, reducing noise, switching steps shorter only 6 steps, improve the power factor. The switching algorithm is ready to be used to make 3 phase inverters.

1. Introduction
The background of research that is 3 phase inverter is needed, besides to change the dc to ac voltage as needed, in the industry every CNC or NC machine needs an inverter to regulate the rotation speed of the motor, constant motor rotation requires for cutting in certain variety of speeds feeding processes, wherein conventional machines gears are used, here the ac voltage is changed to dc and returned to ac according to the frequency needed. For this reason, the researchers tried to research switching the 3 phase inverter algorithm with the principle of space vector pulse wide modulation. The SVPWM principle enables switching processes that are shorter steps than conventional switching, less noise is generated, allows generating capacitive reactive power to compensate for the inductive reactive power of the network, so that it can improve the power factor[1].

In designing switching 3 phase inverter algorithms for industrial needs, of course, we learn examples that exist how do they work mechanically and translate in flowcharts, physical, mathematical, then create programs according to preferred language, do not force any research to prepare from the beginning of all its infrastructure, quite adapted with the infrastructure that we have, make modifications as needed, because the current software and hardware can be made interfaces, so that what is standard in the global world can be called through the interface, including the mechanics can also be made interfaces that are better known as jointing systems. The development of 3 phase switching algorithm for industrial needs is an important part of the inverter.
Formulation in this research is the case of special objectives, researchers limit themselves only to the 3 Phase Inverter Switching Algorithm For Industrial Needs relating to information technology, electronics.

Identification of the object the 3 phase inverter switching algorithm for industrial needs consists of:
- Switching algorithm for inverter,
- Rule of space vector pulse wide modulation,
- Illustration inverter bridge in space.

Research purposes and objectives are the findings targeted in this research that are switching algorithm for an inverter.

Where is use of research are to development of switching inverter algorithm 3 for industrial needs, namely changing the dc to ac voltage by regulating the voltage and frequency output used to control the 3 phase ac induction motor[2][3]. There are several types of development of 3 phase switching algorithm for industrial needs including the development of 3 phase switching algorithm for industrial needs with svpwm (vector space pulse width modulation) [4], [5]. The advantage of 3 phase inverter is that it is very economical and practical for use on 3 phase ac induction motors. Besides, if the SVPWM signal generation is done digitally, we will get a shorter working system step which will reduce noise. The design of the development of a 3 phase inverter switching algorithm for industrial needs by the method of SVPWM using a microcontroller provides several advantages, namely easy to program [6], [7] and schematic and PCB circuits will be simpler. To reduce or eliminate harmonics in the power system, several methods have been developed by the researcher to generate capacitive reactive power to eliminate the inductive reactive power generated by the network so that it can improve the network power factor and use it more practically. The SVPWM method is used to generate reactive power filters. Reactive power filters built from SVPWM can be programmed with a microcontroller, supplying the network with AC as compensation in the same amount as the harmonic current produced by non-linear loads.

2. Research Methods
The principle in the space vector PWM (SVPWM) theorem is based on the fact that there are only 8 combination steps of switching to drive the 3 phase ac bridge electronic power, the basic 3 phase inverter switching system for industrial needs as shown in figure 1. The two steps V0 and V7 are related to the short circuit, while the other six steps are considered vectors in the hexagon plane. The maximum phase value of each of the 6 vectors is:

\[ V_{\text{phase maximum}} = \frac{2}{3} \cdot V_{dc} \] (1)
\[ V_{\text{phase maximum}} = \sqrt{3} \cdot V_{\text{phase maximum}} \]
\[ V_{\text{phase maximum}} = \sqrt{3} \left( \frac{2}{3} \cdot V_{dc} \right) \]
\[ V_{\text{phase maximum}} = \left( \frac{2}{\sqrt{3}} \right) \cdot V_{dc} \] (2)

The modulation index or amplitude ratio is defined as:

\[ m = V_{dc} \cdot \cos 30^\circ /V_{dc} \]
\[ m = V_{dc} \cdot \left( \frac{\sqrt{3}}{2} \right)/V_{dc} \]
\[ m = \sqrt{3}/2 \] (3)

This vector is a function of time[8], the average voltage can be calculated by adding the vectors in one switching period. The other 5 vectors are calculated in the same way. The geometric addition is
shown in figure 1, for each switching period, is \( \Delta T \). Vector \( V_s \) has real and imaginary values related to \( F = 20 \text{ kHz} \),

\[
TS = \frac{1}{F}
\]

(4)
as shown in figure 2. Indoor vectors are divided into 6 sectors each sector 60°. each sector is built by two vectors. Vectors \( V_0 \) and \( V_7 \) are vectors with zero amplitude in the hexagonal original point. The simultaneous \( V_s \) output is a result of switching SVPWM. For the digital implementation of SVPWM. Here switching at high frequency (\( F_{\text{pwm}} \)), this frequency is quite high (> 20 kHz) already outside the audio noise due to switching. Taking \( F_{\text{pwm}} \) as TS time sampling for \( V_s \), where

\[
TS = \frac{1}{F_{\text{pwm}}}
\]

(5)
There are several switching variation techniques to generate \( V_s \) from \( V_0, V_1, V_2, V_3, V_4, V_5, V_6, V_7 \). Mathematically can be shown by the equation

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

(6)
\[
TS = T_0 + T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7
\]

(7)
Variables \( T_0, T_1, \ldots, T_7 \) are the turnaround time 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 line-to-phase 3 phase voltage greater than the VDC itself.

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 transition state,
- 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).

![Figure 1. Hexagon space vector](image1)

![Figure 2. Vector Vs in sector 1 in the field x-y](image2)
Where is \( V_0 = V(Q_0, Q_2, Q_4), V_7 = V(Q_1, Q_3, Q_5), V_1 = V(Q_1, Q_2, Q_4), V_2 = V(Q_1, Q_3, Q_4), V_3 = V(Q_0, Q_3, Q_4), V_4 = V(Q_0, Q_3, Q_5), V_5 = V(Q_0, Q_2, Q_5), V_6 = V(Q_1, Q_2, Q_5) \).

Concerning figure 1 we get:

\[
V_S = \left[ \frac{TA}{TS} \ast V_1 \right] + \left[ \frac{TB}{TS} \ast V_2 \right] + \left[ \frac{T0}{7} \right] / TS \ast V0 / 7
\]  

(8)

\[TS = TA + TB + T0/7\]  

(9)

Switching 3 phase inverter algorithm for industrial needs [8]. Development of 3 phase inverter switching algorithm for industrial needs itself is a 3 phase ac motor mounted control [9], [10] to control the rotation by the wishes of the control maker, here the author wants the 3 phase inverter to be controlled by inputting the command signal from outside [11], the 3 phase inverter will stop according to the command signal [12].

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**Table 1a.** Space vector pulse wide modulation (svpwm)

|       | 001 | 011 | 010 | 110 | 100 | 101 |
|-------|-----|-----|-----|-----|-----|-----|
| **ON**| S1  | S2  | S3  |     |     |     |
| **OFF**| Q0  | Q1  | Q2  | Q3  | Q4  | Q5  |
| **R**  | 0   | 0   | 0   | E   | E   | E   |
| **S**  | 0   | E   | E   | 0   | 0   | 0   |
| **T**  | E   | E   | 0   | 0   | 0   | E   |

**Table 1b.** Space vector pulse wide modulation (svpwm)

|       | 001 | 011 | 010 | 110 | 100 | 101 |
|-------|-----|-----|-----|-----|-----|-----|
| **ON**| S1  | S2  | S3  |     |     |     |
| **OFF**| Q0  | Q1  | Q2  | Q3  | Q4  | Q5  |
| **R**  | 0   | 0   | 0   | E   | E   | E   |
| **S**  | 0   | E   | E   | 0   | 0   | 0   |
| **T**  | E   | E   | 0   | 0   | 0   | E   |
It can be seen simply the signal processing flowchart from the 3 phase inverter switching algorithm for industrial needs as follows:

The results are said to be successful if 3 phase inverter switching algorithm for industrial needs running according to frequency as Command be ordered [13], [14].

3. Results and Discussion
Results
Following the results of the Timing chart switching Space vector PWM for switching 3 phase inverter algorithms for industrial needs such as figure 5 and figure 6

![Figure 5. Timing chart switching vector space PWM 1 cycle](image1)

![Figure 6. Timing chart switching vector space PWM 1 cycle](image2)

Discussion
Switching 3 phase inverter algorithm on the guided missile launcher, allows the motion of the guided-missile launcher to be more precise, smooth and stable. Meanwhile, to keep the component voltage stable and at the same time, a filter is installed in parallel electrolyte capacitors with the component voltage source for each PCB.

4. Conclusions and Suggestions
Conclusions
The results of the Switching 3 phase inverter algorithm for the industry are ready to be applied in the field. Timing chart switching Space vector PWM figure 6 makes it easy to switch the 3 phase inverter algorithm, the output voltage of the 3 phase wire is greater than the dc input voltage. The advantage of SVPWM is that it is very economical and practical to use on 3 phase AC motor servo. Besides, if the SVPWM signal generation is done digitally, we will get a shorter working system step which will reduce noise.

Suggestions
The results 3 phase inverter switching algorithm for industrial needs can be continued to apply at the next step that is inverter manufacture.

References
[1] R. Antoine, “A flexible real-time simulation platform dedicated to embedded rocket engine control systems development and testing,” in 7th European Conference for Aeronautics and Space Sciences (EUCASS), 2017.
[2] R. Syafrudin and A. H. A. Rachman, “Analisis Total Harmonik Distorsi Pada Panel Acpdb Akibat Beban Non Linear,” J. Online Sekol. Tinggi Teknol. Mandala, vol. 13, no. 2, pp. 33–44, 2018.
[3] S. SYAFRUDIN and A. PRATAMA, “Analisa Kandungan Harmonis Pada Motor Ac 3 Phasa 0, 12 Kw Terkendali Inverter 3 Phasa,” J. Online Sekol. Tinggi Teknol. Mandala, vol. 13, no. 1, pp. 31–37, 2018.
[4] R. Parekh, “VF control of 3-phase induction motor using space vector modulation,” Microchip
[5] R. Sufyani, R. Syafruddin, G. D. Ramady, A. G. Mahardika, and D. Nataliana, “Kontrol Motor AC 3 Fasa Pada Peluncur Peluru Kendali,” in Prosiding Seminar Nasional Teknoka, 2019, vol. 4, pp. 1126–1132.

[6] R. Hidayat, S. Syafruddin, S. Santoso, G. K. Sukandi, and H. S. Winahyu, “Smart key implementation for BTS gate door based on the internet of things,” in The 1st International Conference on Computer Science and Engineering Technology (Muria Kudus University), 2018.

[7] R. Hidayat, H. S. Winangun, N. S. Lestari, and G. D. Ramady, “Development of BTS Site Smart Key Based on Internet of Things,” in 2019 International Seminar on Application for Technology of Information and Communication (iSemantic), 2019, pp. 507–512.

[8] G. D. Ramady and R. G. Wowiling, “Analisa Prediksi Laju Kendaraan Menggunakan Metode Linear Regresion Sebagai Indikator Tingkat Kemacetan,” J. Online Sekol. Tinggi Teknol. Mandala, vol. 12, no. 2, pp. 22–28, 2017.

[9] K. J. Aström, T. Hägglund, and K. J. Astrom, Advanced PID control, vol. 461. ISA-The Instrumentation, Systems, and Automation Society Research Triangle …, 2006.

[10] R. Bindu and M. K. Namboothiripad, “Tuning of PID controller for DC servo motor using genetic algorithm,” Int. J. Emerg. Technol. Adv. Eng., vol. 2, no. 3, pp. 310–314, 2012.

[11] R. Syafruddin, H. Fadriani, and D. Nataliana, “Pengembangan Prototipe Sistem Kontrol Pada Transmitter Peluru Kendali,” J. Online Sekol. Tinggi Teknol. Mandala, vol. 14, no. 1, 2019.

[12] G. K. Sukandi, R. Syafruddin, and D. Nataliana, “Pengembangan Prototipe Sistem Kontrol Pada Reseiper Peluru Kendali,” J. Online Sekol. Tinggi Teknol. Mandala, vol. 14, no. 1, pp. 63–71, 2019.

[13] D. Nataliana, R. Syafruddin, G. D. Ramady, Y. Likli kwatil, and A. G. Mahardika, “Servo Control for Missile System,” in Journal of Physics: Conference Series, 2019, vol. 1424, no. 1, p. 12040.

[14] R. Syafruddin, G. D. Ramady, R. Hidayat, H. Fadriani, and D. Nataliana, “Locking Target on Missile System,” in Journal of Physics: Conference Series, 2019, vol. 1424, no. 1, p. 12039.