

# Speed Control Strategy for Three Phase Induction Machine Fed Inverter Base on Carrier Base Pulse Width Modulation (CBPWM)

I Ketut Wiryajati<sup>1\*</sup>, I A.D Giriantari<sup>2</sup>, I N. S. Kumara<sup>3</sup>, Lie Jasa<sup>4</sup>

<sup>1</sup>Department of Electrical Engineering, Faculty of Engineering Mataram University, NTB, Indonesia

<sup>2,3,4</sup>Departement of Electrical Engineering, Faculty of Engineering, Udayana University, Bali, Indonesia

\*email : [kjatiwirya@unram.ac.id](mailto:kjatiwirya@unram.ac.id)

**Abstract**— An induction motors (IM) in many industries is used because it has several advantages, such as a very simple and strong construction, the price is relatively cheap, has good efficiency, power factor is quite good, and maintenance is easier. Besides the advantages of induction motors also have disadvantages, one disadvantage of induction motors is not being able to maintain a constant speed when there is a change in load. If the load changes, the speed of the induction motor will decrease. One method of regulating the speed of an induction motor presented in this study is the regulation of an induction motor using a carrier based PWM (CBPWM) inverter with the field oriented control (FOC) technique. The estimation of rotor rotation, torque and flux is done by carrier- based PWM technique which is given input voltage and stator current. To achieve the desired flux and torque, estimation is used as feedback in the control system. In this study, it will be simulated the induction motor speed regulation with a carrier base-based inverter using Matlab. The results obtained through simulation show the length of time to reach the reference speed for speeds of 1500 rpm and 1450 rpm is around 0.45 seconds. And THD average 2,675%.

**Keywords:** *Induction Motor, Carrier base PWM*

## I. INTRODUCTION

The field oriented control technique on an induction motor is a separation between field and torque technique that was first published in 1971 by F. Blaschke. The basic concept of this separation is to use a vector control model so that it can also be called a vector control. Since this invention the speed control strategy of the induction motor is very good, so too the development of the performance and reliability of the induction motor is getting better.

In recent industrial development, induction motor is broadly used for variable speed control system, which needs a precise and quick torque response [1]. An enhancement of the drive performance can be obtained using a field oriented control algorithm based on the application of the carrier base PWM modulation. The performance of the output voltage of inverter that fed induction motor system is mostly determined by pulse width modulation (PWM) strategy. The plain implementation is use current control based on hysteresis current controller.[3] With this method,

fast response current loop will be attained and information of load parameter is not required. However, this method can cause variable switching frequency of inverter and produce undesirable harmonic generation. Another method of PWM that have become popular and obtained big interest by researcher is carrier base pulse width modulation (CBPWM). This technique have better DC bus exploitation and easy for digital implementation [2].

## II. LITERATURE STUDY

The field orientated control (FOC) consists of controlling the stator currents represented by a vector. This control is based on protrusions which transform a three phase time and speed dependent system into a two coordinate (d and q co-ordinates) time invariant system. These protrusions lead to a structure similar to that of a DC machine control. Field oriented controlled machines require two constants as input references: the torque component

(aligned with the q co-ordinate) and the flux component (aligned with d co-ordinate). As field orientated control is merely based on projections the control structure holds instantaneous electrical quantities. This makes the control accurate in every working operation (steady state and transient) and independent of the limited bandwidth mathematical model. In order to estimate the rotor flux vector is possible to utilize FOC[3-5]

Mathematical modeling is required for simulation and analysis of drive system. IM equations are presented in d-q reference frame.

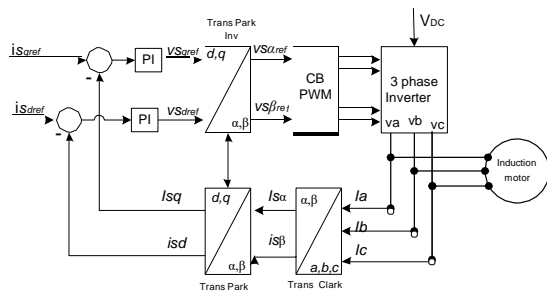


Figure 1. Basic concept of field oriented control

In Figure 1 explains the concept of an induction motor model by starting with the transformation process from *abc* to *dq* with park transform, then the results of the transformation are entered as a reference signal on the inverter, in this case using the CBPWM concept, the output current signal from the inverter is processed again with the back transformation. Transformation of park is *dq* to *abc* then made feedback with the addition of a PI controller (proportional integrator) even using fuzzy logic control to get better output [6, 7]. The basic idea adopted from [7].

### III. RESEARCH METHOD

In this study the FOC method is used by using a inverter to induction motor, to control many method used for it [8-10]. An inverter with a carrier base based CBPWM modulation scheme is using Matlab and Simulink introduce in this research. The principle of the CBPWM method is the generation of pulses obtained by comparing reference sinusoidal waves (*Vref*) with triangular waves or high frequency saw tooth waves [9]. A triangle wave or a saw tooth is also called a carrier wave (*Vc*). The pulse generation from the CBPWM method is similar to the sinus PWM or SPWM by using very simple logic as governed by equation (3-1). Equation (3-1) means that if the reference sine wave (*Vref*) is greater than the carrier wave (*Vc*) then the pulse is one (high) and vice versa if the sine wave (*Vref*) is smaller than the carrier wave (*Vc*) then the pulse is zero (low). It is called CBPWM because the dominant carrier wave becomes a modulation wave because the fundamental wave is summed with all

the harmonic waves produced. Carrier waves usually have a frequency of at least 20 times faster than sine wave frequencies so that they can shift the harmonics low enough far from the fundamental components of the inverter output voltage. This is needed to improve the control quality of the three-phase[11, 12]. Schematic diagram of inverter adopt from [13].

$$\begin{aligned} V_{ref} > V_c & \quad M_x = 1(\text{high}) \\ V_{ref} < V_c & \quad M_x = 0(\text{low}) \end{aligned} \quad \dots\dots\dots(3.1)$$

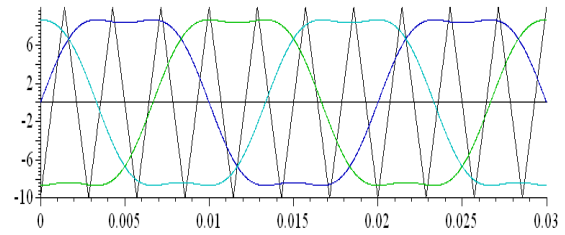


Figure 2 (a) Three phase CBPWM signal

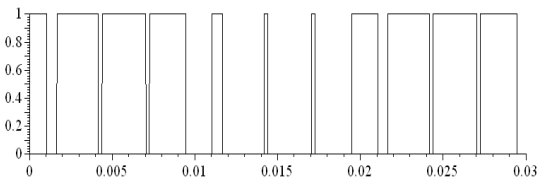


Figure 2. (b). Pulse based on CBPWM technique

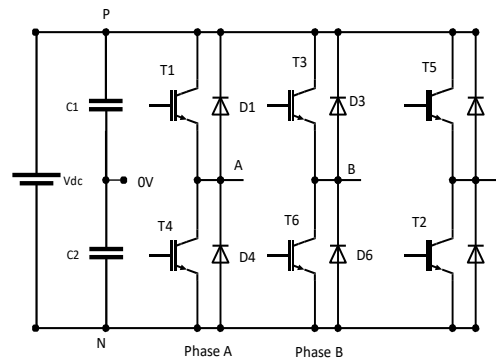


Figure 3 Inverter topologi with CBPWM

### IV. SIMULATION RESULT AND DISCUSSION

This section describes the experimental results with the method of Carrier base Pulse width modulation method and Field oriented control method.

Figure 4 illustrates the scheme consisting of three main schemes, namely the engineering module with CBPWM as the modulation signal, the inverter module with six switches /power electronic as a three-phase inverter, and the induction motor module that has been modeled with the FOC technique

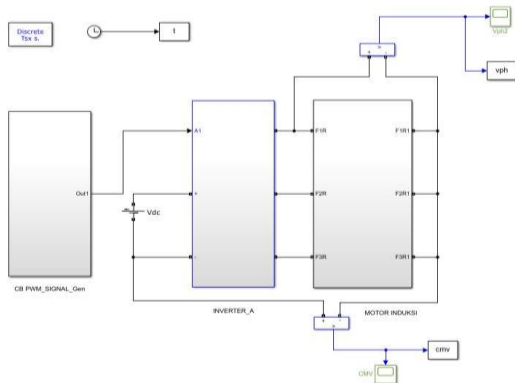


Figure 4 Model control strategy for induction Motor with CB PWM

This scheme becomes one unit to carry out control techniques on induction motors with a rating like in table 1 and table 2 to show parameter of switch power electronic.

Table 1 Parameter of induction machine

No	Parameter	Value
1	Rs (Stator resistor)	10 Ohm
2	Rr (Rotor resistor)	6.3 Ohm
3	Lls ( Stator inductance )	0.004 Ohm
4	Llr ( Rotor inductance )	0.004 Ohm
5	Lm ( Stator reactance )	0.42 Ohm
6	J ( Moment inertia )	0.01 N-m
7	P ( number of pole in pair )	2 pair
7	V ( voltage rate )	380 volt
8	f ( frequency )	50 hz
9	Rpm	1500 rpm

Table 2 Parameter of power electronic switch

No	Parameter	Value
1	IgbtRon	0.001
2	IgbtInductance	0
3	IgbtVf	1.2
4	IgbtTf	1e-6
5	IgbtTt	2e-6
6	IgbtRs	inf
7	DiodeRon	0.01
7	DiodeLon	0
8	DiodeVf	1.2V
9	DiodeRs	500e6
10	DiodeCs	250e-9

The basic concept of CBPWM modulation is as illustrated in Figure 5. The reference signal which is adjusted to the gain compared to the carrier signal which is 20 times the reference signal will be made for three switches and the three switches below are the complement. This signal will be used to refrigerate the switch so that the inverter can work to flow current to the load

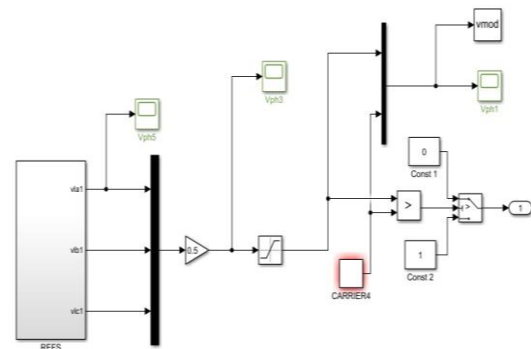


Figure 5 CB PWM

Carrier base can be created by adding a zero sequence calculator in schema CBPWM which has the function of adding third harmonics and components with fundamental signals [14]. So we get the modulation signal as shown in figure 6. Figure 7 illustrate how to get signal reference with three phase voltage sources[15].

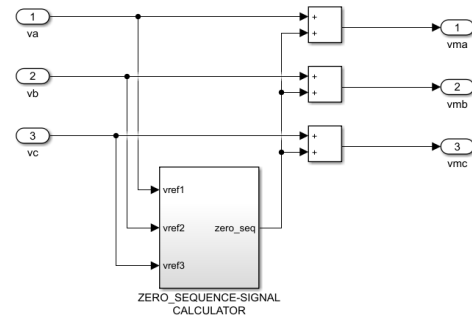


Figure 6 Carrier Base model

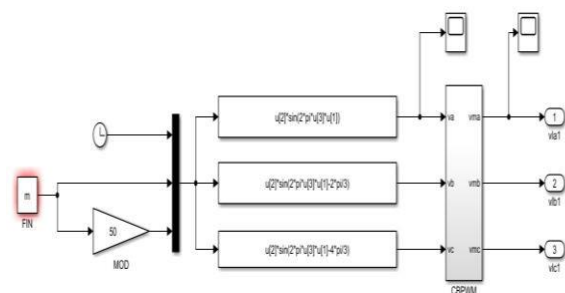


Figure 7 Reference signals

The simulation results, in figure 8, show that the current, voltage with simetrical componen with TDH as below.

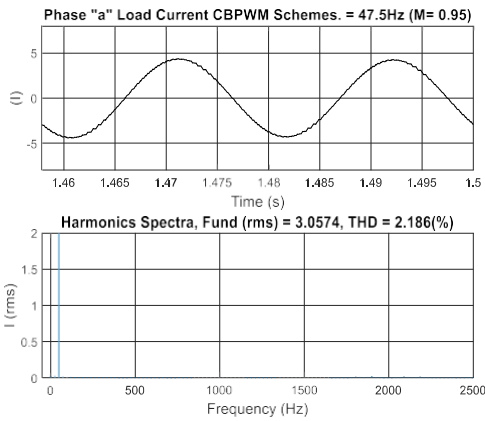


Figure 8 Load current CBPWM

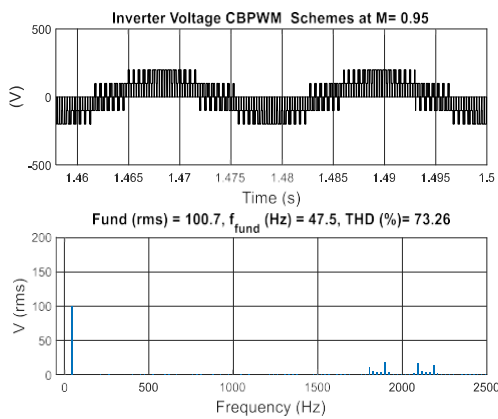


Figure 9 Voltage inverter CBPWM

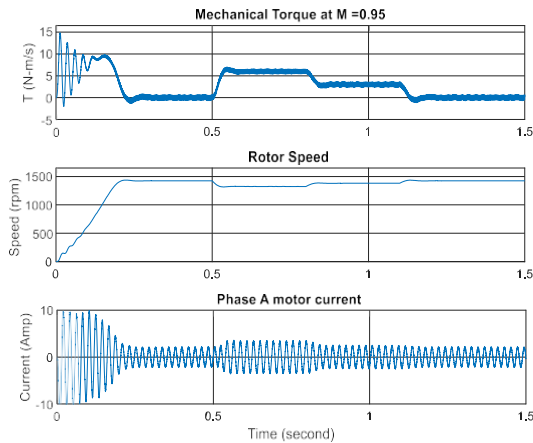


Figure 10 Torque and Speed induction Motor with CBPWM

The results of this technique can be seen in Figure 8 showing the symmetry waveforms in phase a phase current on the induction motor and THD of 2.86% at the modulation index of 0.95, while the resulting voltage form is symmetry like in figure 9.

According to the standards of IEEE No. 519 of 2014, that the provisions for the allowable current THD are smaller or equal to 5%, in this simulation,

the THD limits obtained is already below the required.

In Figure 10 shows the performance of an induction motor with a speed of 1450 rpm with the highest torque at 15 and the load given to the motor is worth 5 N-m at 0.45 seconds.

## V. CONCLUSION

Performance of Inverter Three phase using CBPWM with induction motor in this study obtain an average Total harmonic distortion (THD) and indeks modulation (M) from 0.1 to 1.15 and the average value of THD is 2.67%. the method of carrier base pulse width modulation with induction motor can be used to improve THD and performance of induction motor.

## REFERENCES

- [1] A. Z. Latt and N. N. Win, "Variable Speed Drive of Single Phase Induction Motor Using Frequency Control Method," in *2009 International Conference on Education Technology and Computer*, 2009, pp. 30-34.
- [2] R. Wang, Z. Zhong, J. Zhang, and W. Wang, "Carrier-based PWM control strategy for three-level indirect matrix converter," *IET Power Electronics*, vol. 12, no. 8, pp. 1964-1972, 2019.
- [3] T. Rai and P. Debre, "Generalized modeling model of three phase induction motor," in *2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS)*, 2016, pp. 927-931.
- [4] P. Brandstetter and M. Kuchar, "Rotor flux estimation using voltage model of induction motor," in *2015 16th International Scientific Conference on Electric Power Engineering (EPE)*, 2015, pp. 246-250.
- [5] S. H. Asgari, M. Jannati, and N. R. N. Idris, "Modeling of three-phase induction motor with two stator phases open-circuit," in *2014 IEEE Conference on Energy Conversion (CENCON)*, 2014, pp. 231-236.
- [6] B. Kimiaghalam, M. Rahmani, and H. Halleh, "Speed & torque vector control of induction motors with Fuzzy Logic Controller," in *2008 International Conference on Control, Automation and Systems*, 2008, pp. 360-365.
- [7] I. K. Wiryajati, I. A. D. Giriantari, I. N. S. Kumara, and L. Jasa, "Simple carrier based Space Vector PWM schemes of dual-inverter fed three-phase open-end winding

- motor drives with equal DC-link voltage," in *2018 International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS)*, 2018, pp. 65-70.
- [8] S. S. Tomar, N. Agrawal, and P. Bansal, "Various modulation techniques in symmetrical multilevel inverters," in *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*, 2017, pp. 1322-1327.
- [9] L. Wei, J. McGuire, and J. Hu, "Study of PWM frequency and its impact to adjustable speed drive reliability," in *2017 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2017, pp. 3844-3850.
- [10] K. Niraimathy and S. Krithiga, "A new adjustable-speed drives (ASD) system based on high-performance Z-source inverter," in *2011 1st International Conference on Electrical Energy Systems*, 2011, pp. 62-66.
- [11] H. B. Ertan and Y. Şener, "Sinus output 3-phase inverter topology for improved drive efficiency," in *2014 16th International Power Electronics and Motion Control Conference and Exposition*, 2014, pp. 1350-1357.
- [12] D. Stanciu and C. N. Popescu, "PWM Three-Level Inverter Control," in *2006 IEEE International Conference on Automation, Quality and Testing, Robotics*, 2006, vol. 1, pp. 243-247.
- [13] I. N. W. Satiawan, I. B. F. Citarsa, and I. K. Wiryajati, "A simple PWM scheme for a four-level dual-inverter fed open-end winding five-phase motor drive," in *4th IET Clean Energy and Technology Conference (CEAT 2016)*, 2016, pp. 1-7.
- [14] P. S. Prof.R. Kamaweswara Rao, M.V. Sresh Kumar, "Design and Analisis of Various Inverters Using Different PWM Techniques," *The International Journal Of Engineering And Science (IJES)*, p. 11, 2014.
- [15] I. K. Wiryajati, I. A. D. Giriantari, I. N. S. Kumara, and L. Jasa, "The performance analysis of dual-inverter three phase fed induction motor with open-end winding using various PWM schemes," *Wireless Networks*, 2019/11/16 2019.