COMPARISON OF CURRENT CONTROL METHODS ON CARRIER BASED VSI-PWM INVERTER DRIVES FROM LINE POWER QUALITY ASPECT

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Abstrak

Paper ini mengetengahkan hasil simulasi dari dua metode pengaturan arus untuk inverter jenis sumber tegangan dengan modulasi lebar pulsa (VSI-PWM) yaitu metode kendali arus hysteresis dan ramp comparison. Simulasi ini berguna dalam pemilihan metode pengaturan arus pada adjustable speed drives (ASD) dan secara umum untuk konverter daya elektrik dari sudut pandang kualitas daya. Hasil simulasi menunjukkan bahwa kedua metode control memberikan karakteristik kualitas daya yang berbeda pada tegangan maupun dan arus inputnya. Metode ramp comparison memberikan efek distorsi yang lebih rendah pada arus input dibandingkan metode hysteresis. Sebaliknya, untuk distorsi tegangan, hysteresis current control menunjukkan performa yang lebih baik..

***Kata kunci**: distorsi, kendali arus, perbandingan hysteresis dan ramp*

Abstract

This paper describes simulation result of two methods in current controlling for carrier based VSI-PWM inverter: hysteresis and ramp comparison control. The simulation useful in selection of ASDs and generally–converter, from power quality point of view. Simulation result show that both ramp comparison and hysteresis control methods gives difference characteristic on line voltage and line current. A ramp comparison method is better in form of lower effect on line current distortion compare with hysteresis control method. Meanwhile, for line voltage distortion, hysteresis control seen better.

***Keywords**: current control, distortion, hysteresis and ramp comparison*

1. INTRODUCTION

Motivated by various factor such as energy efficiency, performance and flexibility of operation ASDs shows increase trend of application in widely area. This trend is predicted to continue by supported of technology achievement especially in control and power electronics as a part of the drive system. Meanwhile, along with widely ASDs application, negative impact produced to power quality is also increase.

The current contains harmonics created by switching operation of static switch in ASDs cause voltage disturbance on point of ASDs Supply is also distorted, the higher of current harmonics the higher voltage distorted on that point. Further, this voltage harmonics spreads and influences to other part of power network and gives various negative impact to equipment that build the system [1-2].

Basically, the ASDs is aimed to regulate two main mechanical quantities as output of drive system then transmitted to load drives, i.e. angular speed and torque. Speed related to stator frequency meanwhile torque is directly related to stator current. The role of current regulator is taken by current controller which varying current quantity related to torque needed

by motor load. Controller operates to produce command for static switch by compare real current monitored and suitable current reference for certain level of load.

One among converter topologies that widely used is VSI-PWM inverter. Higher efficiency and simplicity in control system are advantages of this converter. An ASDs using voltage source inverter (VSI) with carrier based modulation PWM converter completed with current controller is showing in Fig.1. The drive system contains an uncontrolled rectifier to convert ac to DC power from network, DC link capacitor to supplying relatively constant voltage to a 3 phase bridge PWM inverter where the DC is converted back to AC power in different frequency and magnitude, and also an induction motors to convert electrical to mechanical power in form of rotating speed and torque.

There are several methods have introduced in literatures to control the current of VSI-PWM inverter [3-4]. Generally the controller use the feedback signal of torque, angular speed, calculated flux to create sinusoidal current reference for comparing with real current in current controller block. Deviation of reference and real current is limited by a mechanism such as hysteresis or ramp comparison band so that the actual current always in shape with current reference.

In operation, current controller creates harmonics distortion on its drawing current on network depend on the methods applied. This paper describes simulation to show harmonics created by different current controller operation in order to prepare certain current needed by motor for driving the load. Simulation is done on two current controllers mode; hysteresis and ramp comparison current controller. For each method, load and speed are varied and harmonics created and power factor on ac side then monitored.

The knowledge of this issue is important to give guidance for making decision in ASDs selection from the power quality (harmonics) point of view. This more important in a trend of "generation-load based system" especially in which the renewable energy is used as the energy source and employ power electronics as interface between power generation plant and network as met on application of inverter on photovoltaic and wind power plant.

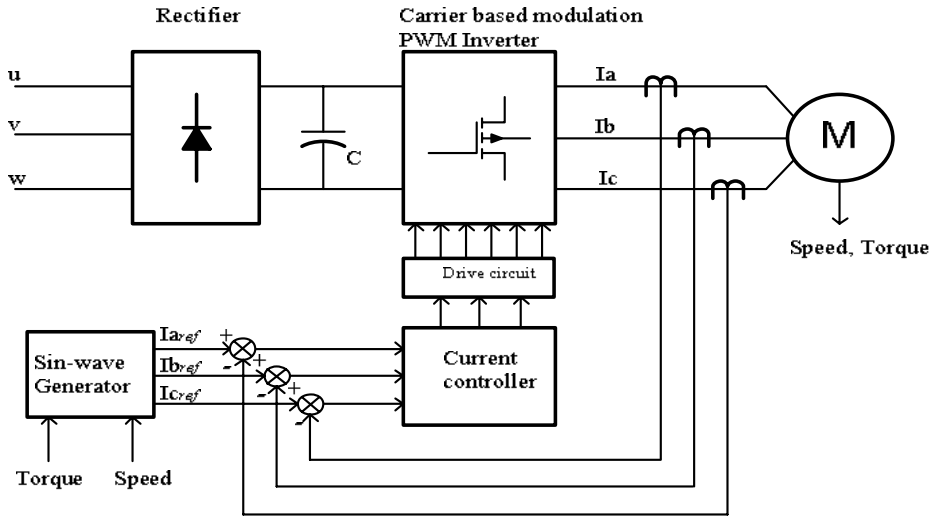


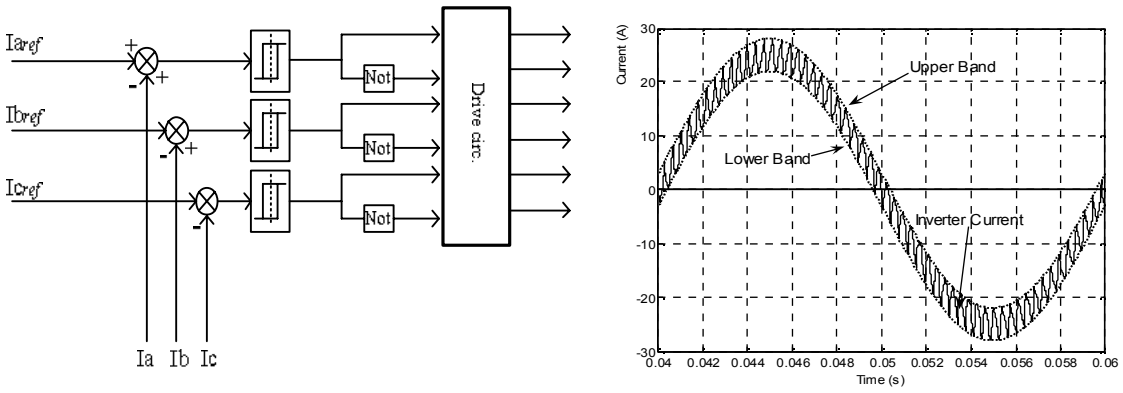
Fig.1 current controller basic diagram

2. CURRENT CONTROL OF CARRIER BASED VSI-PWM INDUCTION MOTOR DRIVES

The current controller as shown on Fig.1, use the error signal between a reference and the actual current, reference signals are generated three sinusoidal waves which magnitude and frequency proportional to speed and torque needed (i_{aref}, i_{bref}, i_{cref}). According to how the error signal is used as modulator for switching point the power inverter device, the method such as hysteresis and ramp comparison beside other methods is used. Here the two methods describe as follow [5]:

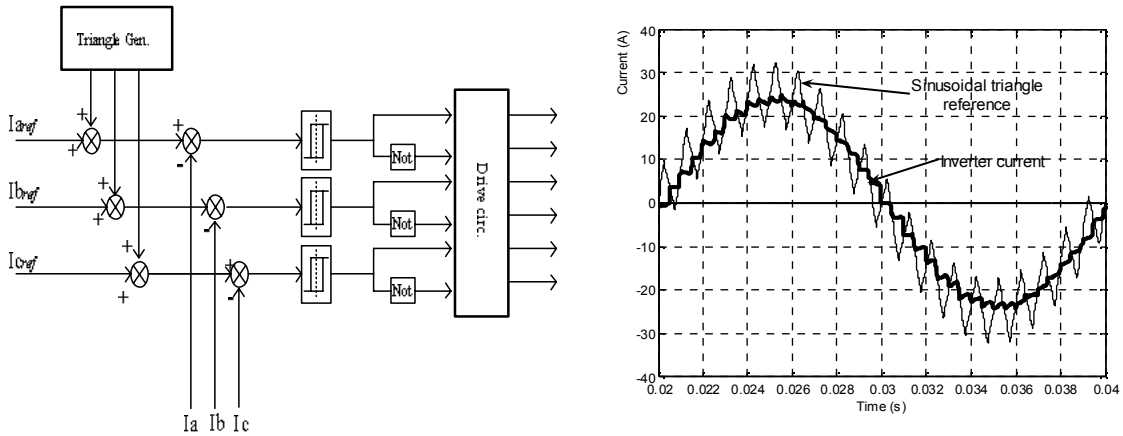
2. 1. Hysteresis current control

In this method, inverter output current is forced to follow the current reference in each phase. Deviation between these two quantities is limited by upper and lower band in a hysteresis loop. If actual current reach upper limit of hysteresis band, the inverter leg is switched off so that the current decrease till reach lower band of hysteresis loop where the inverter leg is switch on again and actual current increase to upper band. The sin-wave shape of reference signal causes inverter switching frequency vary and gives different current ripple in one fundamental inverter period. Gap wide between upper and lower band of hysteresis loop determine the magnitude of current ripple. The hysteresis control method and inverter current shape is shown in Fig.2.



a. Model b. Current shape

Fig.2. Hysteresis controller



a. Model b. Current shape

Fig.3. Ramp comparison controller

2. 2. Ramp comparison current control

In this mode of controller, sin-wave reference signal produced previously is added with triangle signal to create other sinusoidal-triangle reference, one for each phase. This reference then compare with actual current. The point where sinusoidal-triangle wave and actual current cross become time when the inverter leg is switched. If the current error greater than sinusoidal-

triangle then the inverter leg is switch off and if the current error less than sinusoidal-triangle then the inverter leg is switch on or vice versa. As the hysteresis methods, this methods also cause the inverter switching frequency and PWM pulse wide vary and give different current ripple in one fundamental inverter period. The Ramp comparison current control method and inverter current shape is shown in Fig.3.

3. HARMONICS DRAWN BY ASDs

Power quality, especially harmonics study created by ASDs has reported by many researchers. Generally the aim of study is to identify and to make effort for reducing quantity and impact of harmonics. Harmonics can identify by its order, magnitude and harmonics order phase shift. Harmonics is quantify by THD (total harmonics distortion) defined as:

$$THD_M = \frac{\sqrt{\sum_{h=2}^{\infty} M^2{}_{hrms}}}{M_{1rms}} x100\% \quad (1)$$

where M is effective value of power quantity (voltage or current) for h order. Other quantity to describe harmonics is TDD (total demand distortion), written as;

$$TDD_I = \frac{I_{hrms}}{|I|} x100\% \quad (2)$$

TDD may better represent degradation of power quality (by harmonics) because TDD compares harmonics content to current or load where its exist.

A network with excess harmonics content may cause poor power factor. The relation between harmonics content to power factor expressed in following relation:

$$pf = \frac{P_{avg}}{V_{1rms} I_{1rms}} \frac{1}{\sqrt{1+(THD_V)^2}\sqrt{1+(THD_I)^2}} \quad (3)$$

where factor $\frac{P_{avg}}{V_{1rms} I_{1rms}}$ is displacement power factor or Cos θ, express the cosines of displacement angle between voltage and current, K_d.

The factor $\frac{1}{\sqrt{1+(THD_V)^2}\sqrt{1+(THD_I)^2}}$ express the effect of wave form distortion caused by harmonics content.

4. SIMULATION

Simulation is done on a model of induction motor Fed from an PWM inverter in Matlab/Simulink. Current control circuit and inverter driver as shown in Fig. 2 and 3 is built in a block simulation completed with a generator block adjustable frequency and magnitude of sinusoidal wave reference. In a level of current drawn by motor for current control scheme, the harmonics of voltage and input current on utility point is measured. Harmonics content is presented with its THD and harmonics spectrum extracted from FFT analysis. Fig 4 show circuit simulation is done in this research.

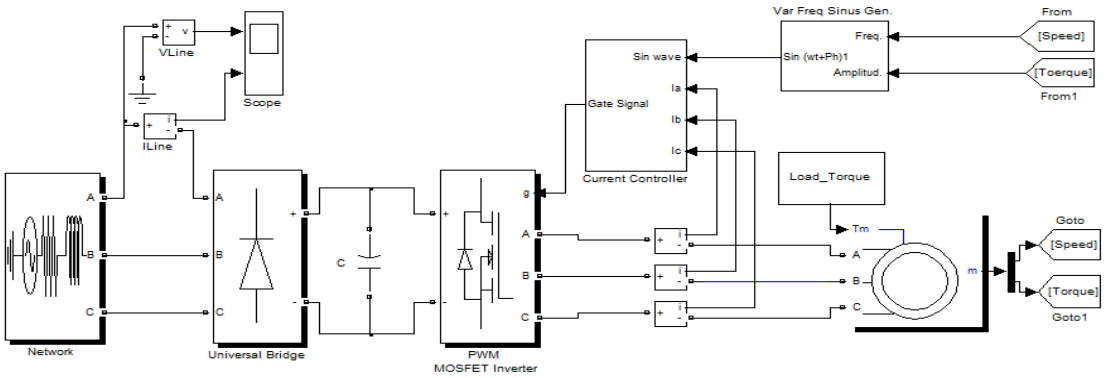


Fig. 4. Circuit Simulation

5. RESULTS AND DISCUSSIONS

Fig. 5, 6, 7 and 8 describe simulation result of ASDs system. Its shown the voltage and current wave-shape on network when VSI-PWM inverter operates for drawing current of 3.53 A for both current control methods on a 10 HP 460, 50 Hz induction motor.

Hysteresis control data is taken for a bandwidth of ± 1 Ampere while the frequency of triangular wave on ramp comparison control is 1000 Hz. The line voltage and current ripple on peak area every half fundament inverter frequency for both methods shows higher value than other one, it's because in this area inverter device operates in higher switching frequency as can understood by consult Fig. 2b and 3b. Voltage and current distortion for both current control methods dominated by harmonics order of 5, 7, 11, 13 … (6p± 1). Higher distortion performed by ramp comparison control and according to equation (3), lower power factor will occurred on network.

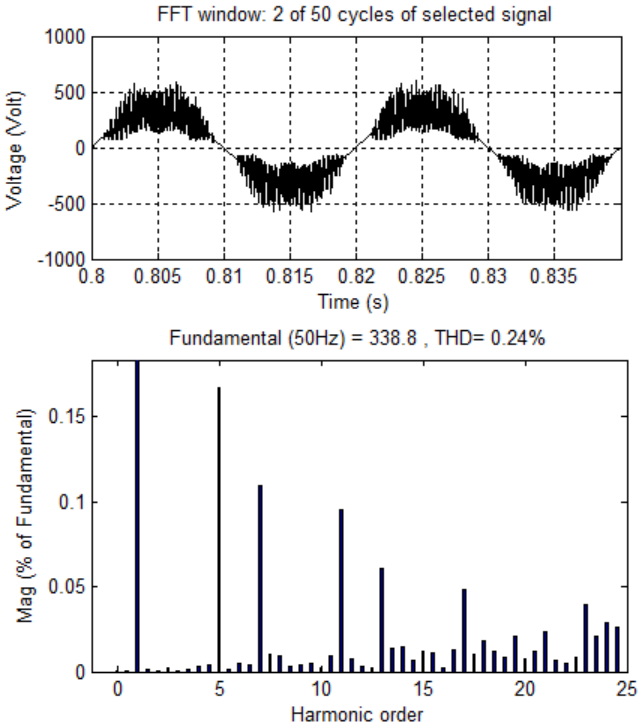


Fig.5.Line voltage spectrum of hysteresis controller

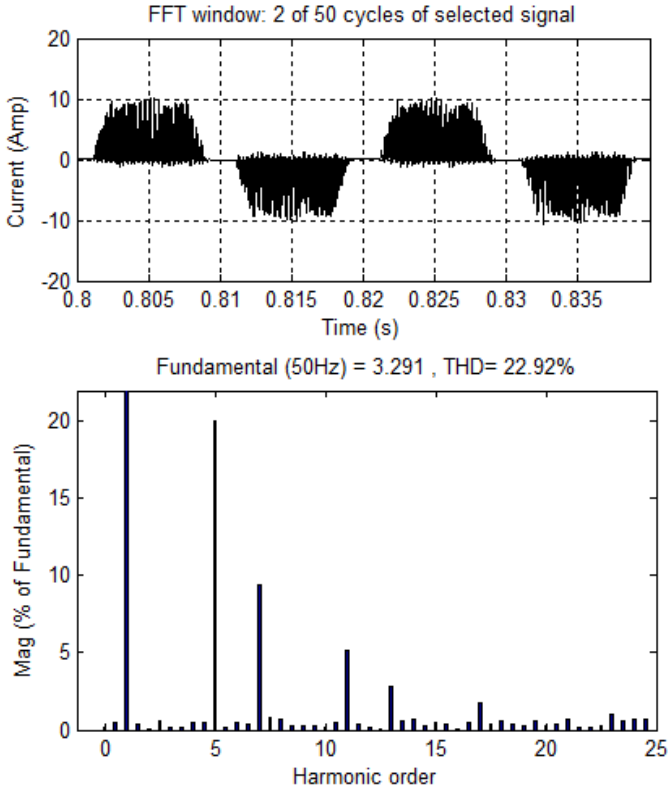


Fig.6. Current spectrum of hysteresis controller

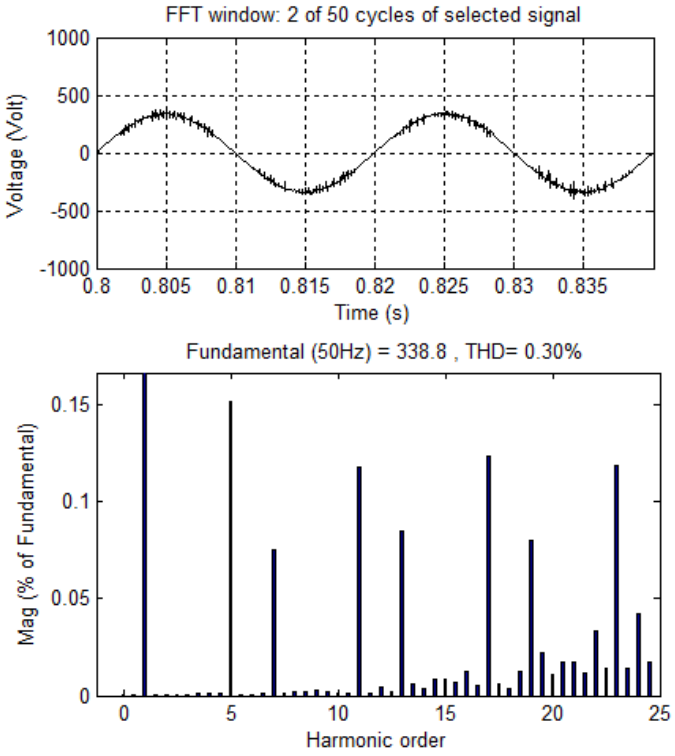


Fig.7.Line voltage spectrum of Ramp comparison controller

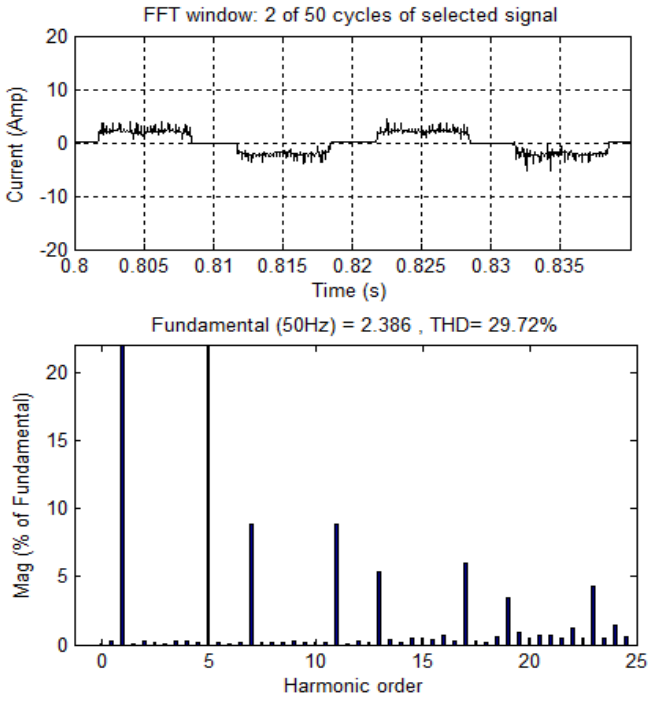


Fig.8. Current spectrum of ramp comparison controller

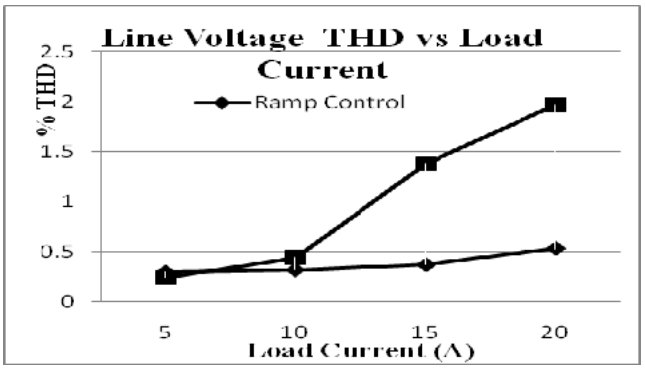


Fig.9.Line voltage distortion caused by two methods in increasing load current.

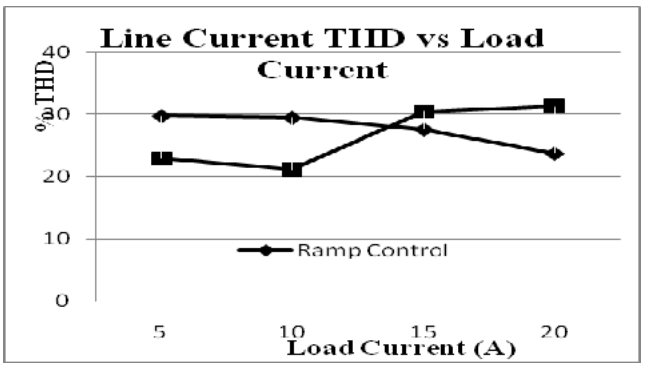


Fig.10. Line current distortion caused by two methods in increasing load current.

Simulation also shows that both methods give more distortion to line voltage by increasing load current. Hysteresis control show larger rate of change than ramp control as shown on Fig.9. In other hand, both methods give different effect to current line distortion, ramp comparison method tend to give lower distortion due to increasing of load current, whereas hysteresis control give inverse tend, Fig.10.

6. CONCLUSION

In this paper, characteristic based on simulation of two methods of current control in carrier base VSI-PWM inverter has been presented. Simulation is aimed can be used as guide to make decision in selection of current control methods of many ASDs drives in market for use in real application.

Simulation result, show that both ramp comparison control and hysteresis control methods gives difference characteristic on line voltage and line current. A ramp comparison method is better in form of lower effect on line current distortion compare with hysteresis control method. Meanwhile, for line voltage distortion, hysteresis control seen better.

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