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An analysis of Energy Efficient Operation of Induction Motor by Speed Control

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ABSTRACT

In this paper discuss the new approach to improve the power factor and to minimize the disturbance of harmonics generated by a variable speed drive system. Here the improved frequency performance of current ingestion method is used to increase the PF and to minimize the effect of harmonics. The inverter driving the induction motor is operated using a sinusoidal pulse width-modulation technique. The simulation model for this system is developed and the same is used for simulation analysis. The load and no load conditions with parameters are discussed.

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INTRODUCTION

Induction motors account for 76% of all electric use, and their adjustable-speed drives (ASDs) can save power consumption by around 20% to 30%. ASDs have no moving parts, which results in improved system efficiency and equipment reliability. Most of the ASDs employ rectifier–inverter arrangements. In such cases, the ac input line current waveform drawn by the rectifier contains undesirable harmonics. These harmonics are transferred to the electric network, which affects system equipment and operations. Possible problems include transformer overheating, motor failures, fuse blowing, capacitor failures, and malfunction of controls (Domijan, A. and E. Embriz-Santander, 2012).

With the increasing use of ASDs, major focus has been drawn on harmonic reduction techniques. The basic harmonic reduction techniques are as follows: 1) passive filters; 2) active filters; 3) multipulse rectifiers; and 4) harmonic current injection method. These approaches have their own advantages and disadvantages. The performance of passive filters depends on the source impedance, which is usually not accurately known. Most of the available active filters require accurate current templates, which are difficult to generate and adjust. A scheme employing two boost converters and a set of three series-connected inductance–capacitance (*LC*) branches for injecting a third-harmonic current at the ac side of the diode bridge rectifier is presented in (Mohan, N., 2003).

The drawbacks of this approach are that the current injection network draws excessive fundamental current and increases susceptibility to resonance. An optimal current programming technique proposed in (Pejovic, P. and Z. Janda, 2008) improves the performance of the scheme presented in (Mohan, N., 2003). The digital repetitive control of a three phase system for linear/nonlinear load is presented in (Pejovic, P. and Z. Janda, 2008; Kim, S. and P.N. Enjeti, 2013; Amin, A.M.A., 2007). This control technique results in a high input PF, but the control scheme is complex. In a conventional switch-mode rectifier, the inverter is controlled to obtain a nearly sinusoidal input current at a high PF. However, to control the ASD, an additional inverter is required to feed the drive. In this paper, high PF operation of a three phase rectifier for an ASD is presented (Blejis, J.A.M., 2012). A high-frequency (HF) current is injected from the output of an HF inverter into the input of a front-end rectifier. Thus, the power transistors of the active front-end rectifier are eliminated. Due to the HF current injection, the rectifier input voltage is modulated at a high frequency (Choi, S., 2013). The HF current is injected through the branch consisting of three sets of inductor L_h and capacitor C_h. Due to the HF current injection, the size of these required passive elements is reduced. It maintains a high PF under different loading conditions. The major advantage of this

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approach is that it does not require an additional active component for current injection.

II. Analysis of Proposed System:

The simplified circuit diagram of the proposed scheme are shown in Fig-1.It consists of a three-phase diode bridge rectifier a dc-link capacitance C_{rect}, and a three-phase full-bridge inverter. The HF inverter output is fed to the three-phase induction motor through small LC filters. The HF current from the inverter output is also fed back to the input of the diode bridge rectifier through an HF current injection network. The current injection network consists of three sets of inductor L_h and capacitor C_h. The inverter is operated using a sinusoidal PWM (SPWM) technique with a reference frequency of 50 Hz and a carrier frequency of 33 kHz. Thus, the HF current at 33 kHz is injected into the input of a front end rectifier from the output of an HF inverter. The SPWM technique provides a maximum duty ratio, i.e., the "on" time period of the switch is longer when compared with the "off" time period. This off time period is not sufficient for the inverter output current to reset to zero. The turn-on losses are reduced to a significant level, but they are not completely eliminated.

For the induction motor drive, the three phase voltage references are given in a balanced set as

$$Va = Vm\sin\omega t,$$
$$Vb = Vm\sin\left(\omega t - \frac{2\pi}{3}\right),$$
$$Vc = Vm\sin\left(\omega t + \frac{2\pi}{3}\right) \quad (1)$$

In the absence of a neutral connection to the bridge rectifier, the sum of ac currents must be equal to zero at all times, i.e.

$$i_A + i_B + i_C = 0. \quad (2)$$

At any instant, the sum of derivatives of the input currents is also zero. The input supply currents are given as

$$i_A = iL_{fA} + i_{\text{rectA}},$$
$$i_B = iL_{fB} + i_{\text{rectB}},$$
$$i_C = iL_{fC} + i_{\text{rectC}} \quad (3)$$

Where iL_{fA}, iL_{fB}, and iL_{fC} are the HF injected currents, and i_{rectA}, i_{rectB}, and i_{rectC} are the input currents of the three phase diode bridge rectifier.

The supply voltages described in equation (1) contain only the fundamental component. Hence, for the harmonic content of the supply current to exist. The harmonic current components are then solely determined by the harmonic voltages of the input voltage to the diode bridge rectifier. The HF injected current produces HF modulation of the input voltage to the diode bridge rectifier. The HF modulated voltage V_A has an HF sinusoidal PWM pattern, which is analogous to the unipolar voltage switching scheme. This scheme has the advantage of "effectively" doubling the switching frequency the harmonic analysis of V_A shows that it has a fundamental component of 50 Hz and that the sets of the switching frequency sideband clustered around twice the integer multiples of the switching frequency, i.e. $2mf \pm 1$, $4mf \pm 1$, . . ., where mf is the frequency modulation index.. The HF modulated voltage *Va* depends on the switching frequency *fs*, the switched inductor current *iLh*, and the input voltage *Va*. The magnitude of the current i_{Lf} increases with the decrease in *Lh* ,which forces *Va* to increase. Thus, the output dc voltage of the input diode bridge rectifier *V*rect increases with the increase in the injecting current *iLh*. Hence, the value of *Lh* is selected such that the minimum dc voltage V_{rect} is twice of *Vm*. *Ls* must be small to achieve a high PF.

III. Simulation Results:

This section presents design example and simulation results for the proposed scheme for a high-power factor operation induction motor. The proposed scheme is studied by simulating the circuit. The three-phase induction motor that was used and the converter specifications are given as follows:

• input three-phase supply voltage = 400 V (rms), 50 Hz;

• three-phase induction motor: 3 hp 400 V, 50 Hz, 1500 rpm.

For this drive the full-load inverter switching frequency *fs* = 33 kHz is selected.

The value of the inductor used in the current injection network isLh= 1mh and the capacitor is used *Ch* =100 μF and C_{rect} = 5000 μF is chosen. The simulation is carried out using MATLAB. The complete drive system is shown in Fig-1. The Fig-2 and Fig-3 shows the SPWM pulses to Mosfets. The 3-phase currents are shown in fig-4. The speed of Induction motor the torque and stator current of phase-A is shown in Fig-5 without load.

Speed increases linearly and reaches at rated speed (1500 rpm) in steady state at .8 sec. At starting the torque increases and reduces at minimum value when the speed reaches at rated value. In Fig-6 the same torque, speed and stator current of phase as shown with full load at 14 N-m. The comparison is made on the basis of Total Harmonic Distortion (THD).It is found that THD with and without load is 2.28% in HF injection drive system in Fig-7 and Fig-8. The THD of drive system without HF injection is 6.33 as shown in fig-9. It is observed that due to high frequency current injection circuit, the high PF is maintained under different loading conditions.

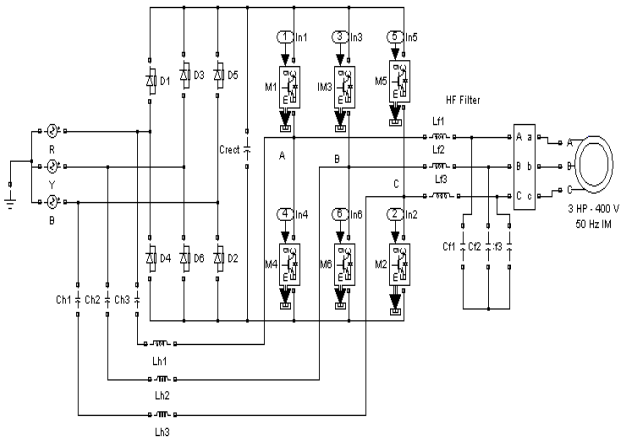

Fig. 1: The Detail diagram of HF Drive system.

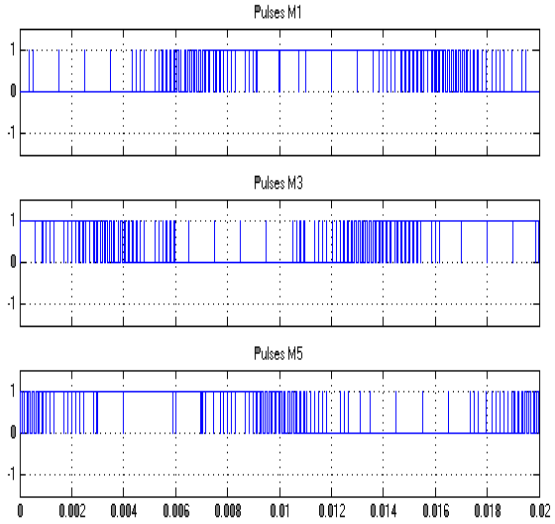

Fig. 2: SPWM Pulses of M1, M3 and M5.

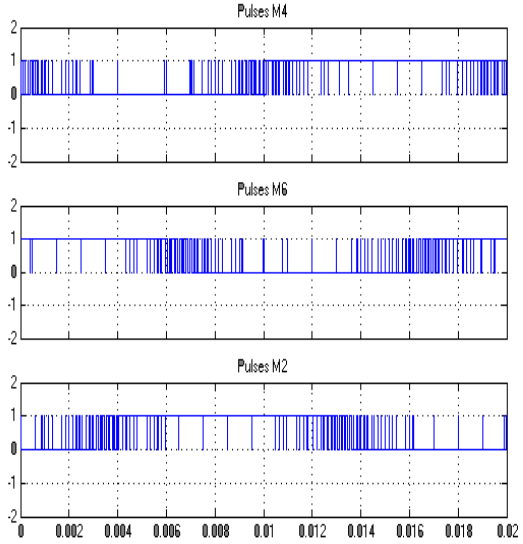

Fig. 3: SPWM Pulses of M4, M6 and M2.

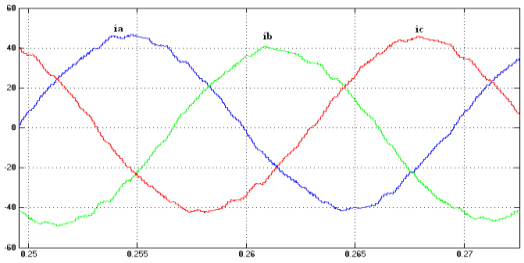

Fig. 4: Three phase stator currents ia, ib and ic.

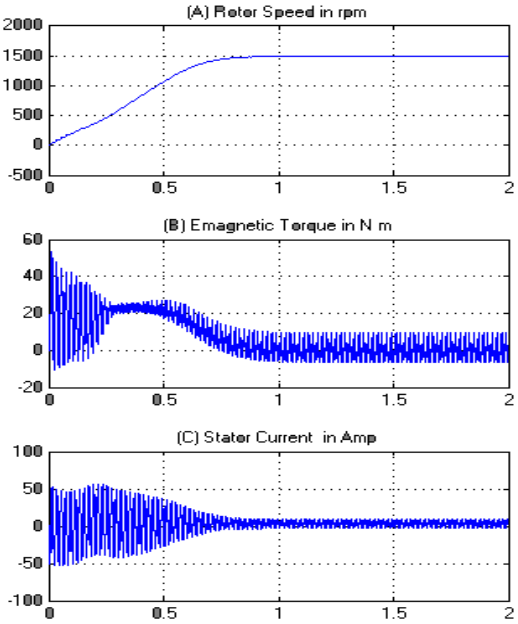

Fig. 5: (A) Rotor speed in rpm vs time in sec (B)Electromagnetic torque vs time in sec,(c)Stator current in amp vs time in sec , without load.

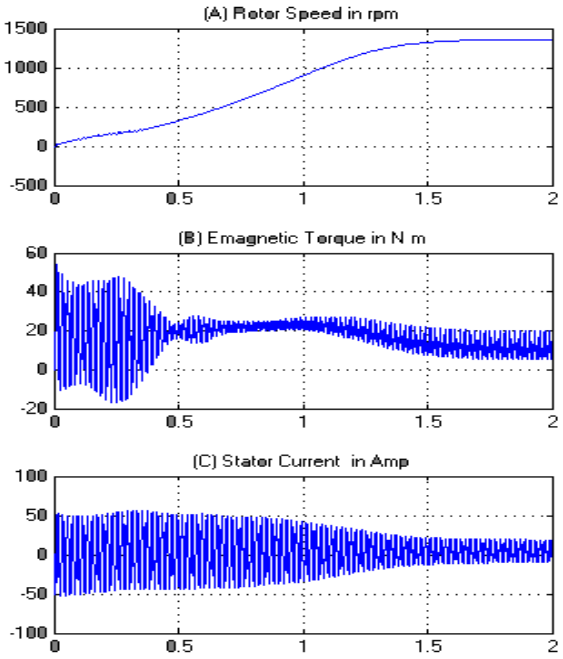

Fig. 6: (A) Rotor speed in rpm vs time in sec (B)Electromagnetic torque vs time in sec,(c)Stator current in amp vs time in sec , with full load(14 N-m).

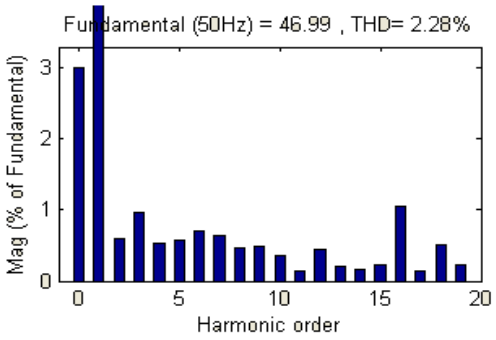

Fig. 7: THD of HF injection circuit without load.

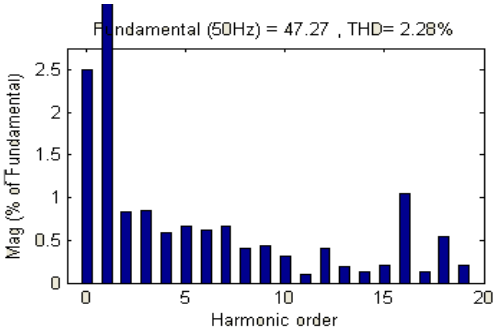

Fig. 8: THD of HF injection circuit with full Load.

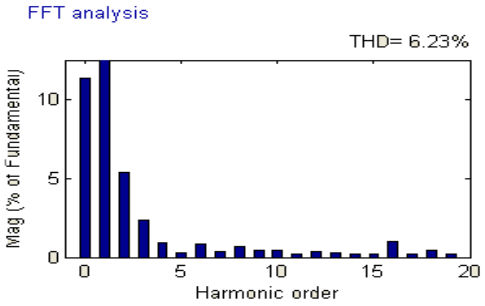

Fig. 9: THD without HF injection circuit without load.

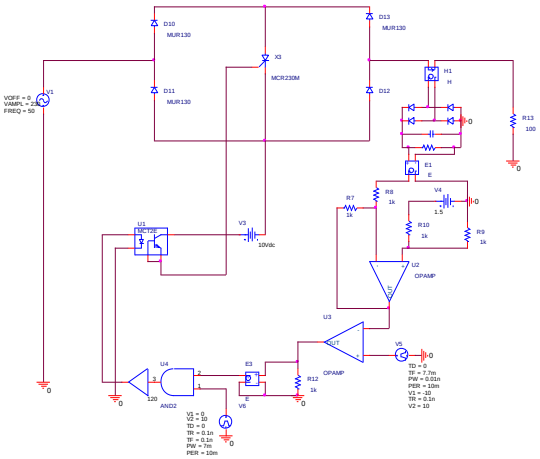

Fig. 9: Closed loop control of IM.

The circuit diagram for closed loop speed control of Induction Motor using variable frequency drive is shown in Fig. 9. In this closed loop control method, the motor running speed and the reference speed are compared and it is given to a controller circuit. So that the motor can always run at the

reference speed. Here the reference speed given is 1430 rpm and the waveform shows that the Output current and triggering pulses. The output current and triggering pulse is as shown in the Fig.10.

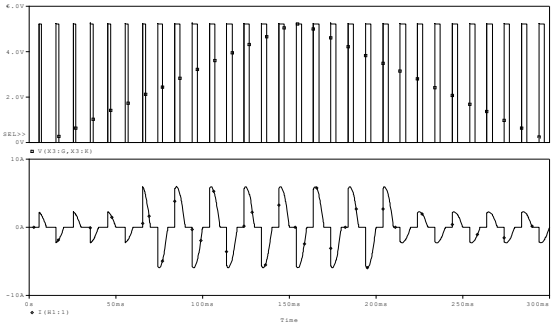

Fig. 10: Output current and triggering pulses.

In this controller, it has to be able to adapt to other load conditions as shown in the Fig. 11 it is the speed control performance of the rated motor parameters (Jrated and Brated) and at No load condition, deteriorated at FL condition. Here this mean that one has to train the data that is generated from all the possible operating conditions of the motor. This system can be trained with data that has been generated at a few prime situations that may be able to help it generalize for other untrained situations. In this analysis of training, it was hoped that the machine would not only be able to adapt to the motor's NL and FL condition.

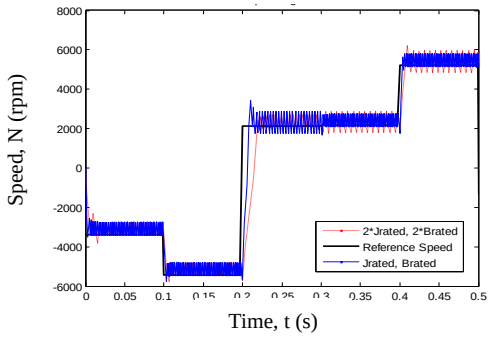

Fig. 11: Comparison of the speed control performance motor parameters.

IV. Conclusion:

In this drive system the high input PF and improved harmonic performance has been proposed. The PF of the three-phase ac simulation waveform of the inverter in terms of THD and operating triggering pulses are represented. The main advantage of this approach is that it does not require any additional active component for HF current injection. Due to the current injection at a high frequency, inductors and capacitors have small values. The inverter switches maintain ZVS for most of the period of the output phase voltage, except at the peak of the output voltage. It is observed that the high PF is maintained under different loading conditions.

REFERENCES

Amin, A.M.A., 2007. "Line current harmonic reduction in adjustable speed induction motor drives by harmonic current injection," in Proc. IEEE ISIE, Jul. 7–11, 2: 312-317.

Blejis, J.A.M., 2012. "Continuous conduction mode operation of threephase diode bridge rectifier with constant load voltage," Proc. Inst. Electr. Eng.—Electric Power Appl., 152(2): 359-368.

Choi, S., C.Y. Won and G.S. Kim, 2013. "A new three-phase harmonic-free rectification scheme based on zero-sequence current injection," IEEE Trans. Ind. Appl., 41(2): 627-633.

Domijan, A. and E. Embriz-Santander, 2012. "A summary and evaluation of recent developments on harmonic mitigation techniques useful to adjustable speed drives," IEEE Trans. Energy Convers., 7(1): 64-71.

Kim, S. and P.N. Enjeti, 2013. "A new approach to improve power factor and reduce harmonics in a three-phase diode rectifier type utility interface," IEEE Trans. Ind. Appl., 30(6): 1557-1563.

Mohan, N., M. Rastogi and R. Naik, 2003. "Analysis of a new power electronics interface with approximately sinusoidal 3-phase utility currents and a regulated DC output," IEEE Trans. Power Del., 8(2): 540-546.

Pejovic, P. and Z. Janda, 2008. "Optimal current programming in threephase high-power-factor rectifier based on two boost converters," IEEE Trans. Power Electron., 13(6): 1152-1162.