EFFECT OF A DIRECT CURRENT ADJUSTABLE SPEED DRIVE ON THE VOLTAGE INPUT OF A THREE-PHASE INDUCTION MOTOR

Bruno Osorno
California State University Northridge
18111 Nordhoff St
Northridge CA 91330-8346
Ph: 818-677-3956
Email: Bruno@ecs.csun.edu

INTRODUCTION

Because of the proliferation of Adjustable Speed Drives (ASD) systems, certain side effects occur. The effect we will study in this paper is that of reduction of voltage levels to other loads. More specifically, when an ASD is on, the voltage sinusoidal wave at the bus becomes distorted, i.e. harmonics are introduced to the system. This effect produces a less efficient operation of our induction motor, and could affect sensors and other equipment connected to the same bus. This paper attempts to prove such effect using "Harmflow" [1].

ANALYSIS

A one-line diagram is shown in figure 1 indicating the system under study.

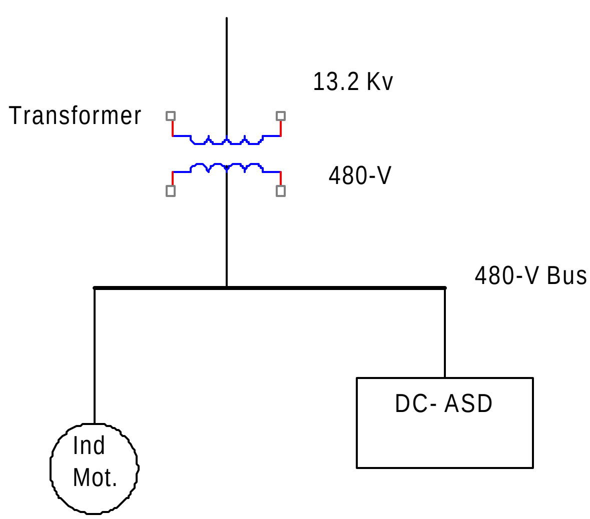

Figure 1. One-line diagram for the system under study.

According to Jain [3] and Osorno [4], each harmonic present in our voltage signal can be treated independently with its respective model. See figure 2. If the voltage input to our induction motor is reduced other parameters in our machine will be affected.
The slip can be obtained using the following equation:

$$s_h = \frac{hN_s \pm N}{hN_s} \tag{1}$$

Where: h=harmonic
N_s=Synchronous speed
N=Rotor speed
S=Slip

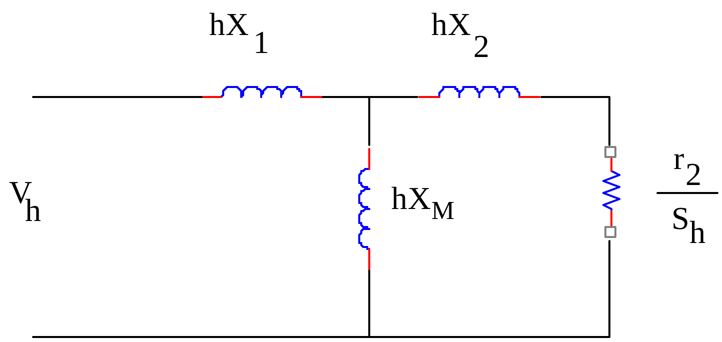

Figure 2. Induction Machine Model for Harmonic Analysis

And the rotor copper losses are:

$$P_{cus_h} = (V_h \frac{X_M}{X_O})^2 \frac{S_h}{r_2} \frac{1}{1+h^2 S_h^2 T_d^2} \tag{2}$$

And the torque developed becomes:

$$T = \frac{P_{msh}}{N} = \frac{P_{msh}}{\pm hN_s(1-S_h)} = (V_h \frac{X_M}{X_O})^2 \frac{S_h}{r_2} \frac{1}{hN_s} \frac{1}{1+h^2 S_h^2 T_d^2} \tag{3}$$

As it can be seen the copper losses increase due to harmonics present in our voltage waveform and consequently the torque developed is reduced. The harmonic voltage reduction, also, causes a larger stator current and therefore larger stator copper losses.

SIMULATION

Using Harmflow we simulated the circuit shown in figure 1. The voltage input to the induction motor at the bus with no harmonic distortion is 277-V, ($\frac{480}{\sqrt{3}}$)

Figure 4 shows the voltage input to the induction motor with harmonics caused by the ASD connected to the 480-V bus. Figure 5 shows the voltage waveforms with distortion. Notice that the RMS voltage is 261 V. The voltage change is 5.8 %. The scope of this paper is just the voltage change, but also we can observe the Total Harmonic Distortion and Telephone Interference in our simulation.

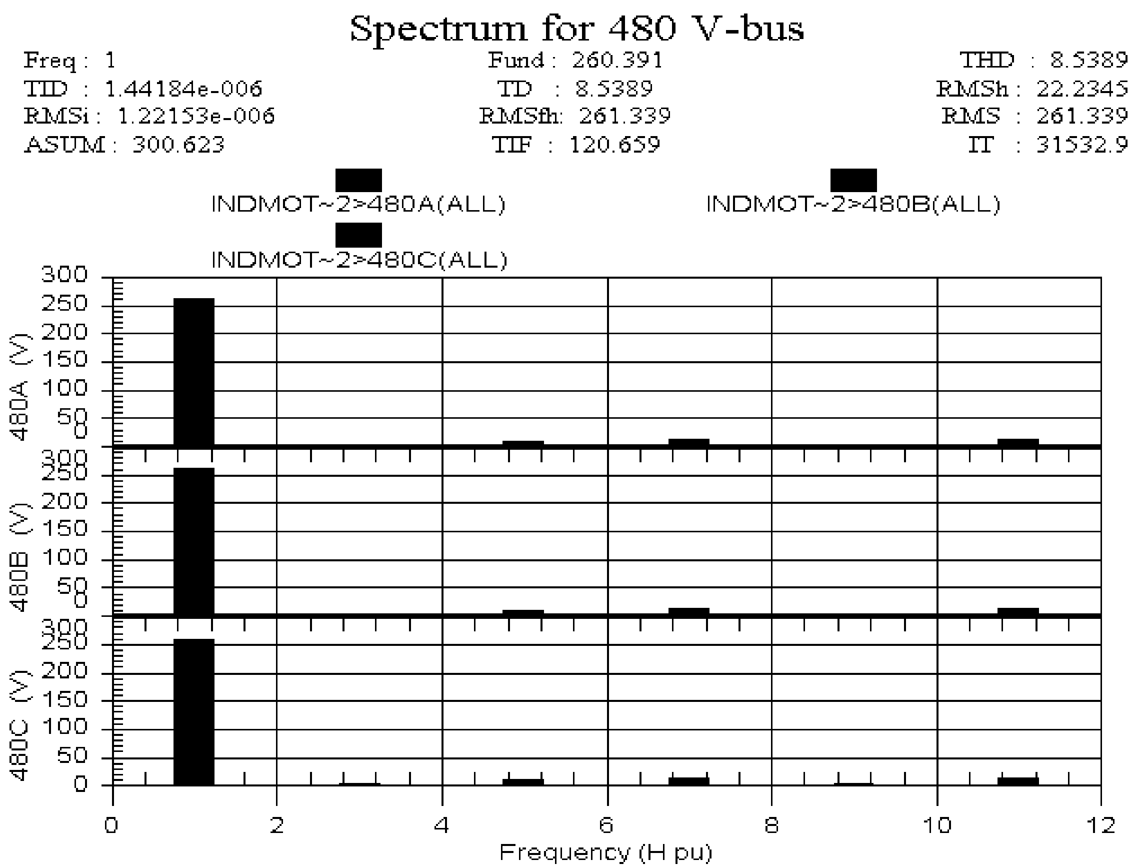

Figure 4. Spectrum of Voltage Input to Induction Machine

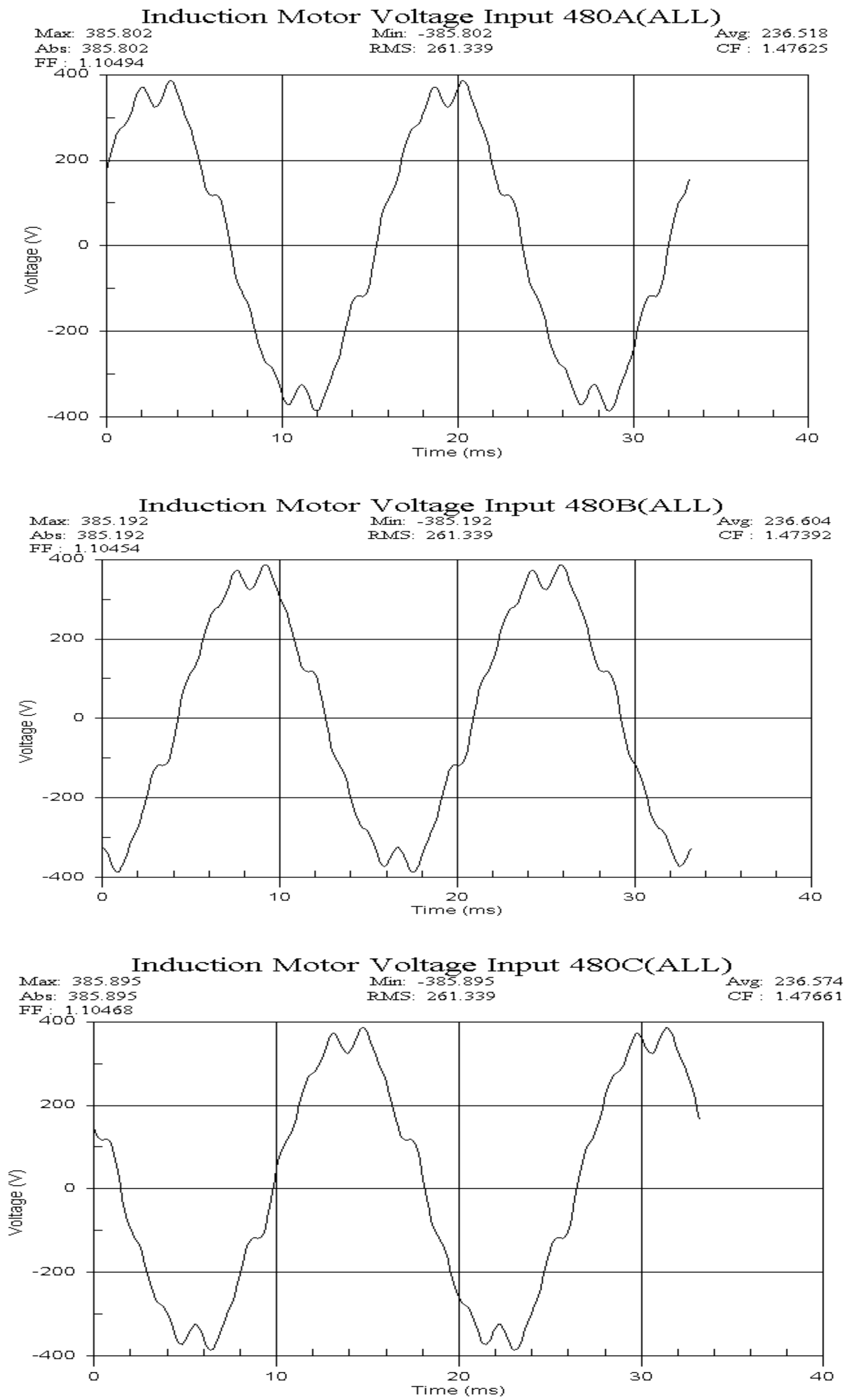

Figure 5. Voltage Waveforms of Voltage Input to the Induction Machine.

CONCLUSIONS

Loads that generate harmonic distortion in the voltage signal definitely have an effect on other loads connected to the same bus. In our paper there was a 5.8% voltage reduction that increased copper losses and reduced the torque developed. It could very easily be proved that stator currents increase with the effect of an increment in stator losses. Finally the efficiency of our machines decreases. A solution to this problem is the filtering of such harmonics at the DC-ASD load or at the utility level. Standards such as IEEE-519 and reference [5] address the issue of how much harmonic level is allowed to avoid malfunctioning of the loads and electromagnetic interference.

BIBLIOGRAPHY

1. Electrotek, “SuperHarm User’s Guide,” Electrotek Concepts, Knoxville, Tennessee, 1999.
2. Bhag S. Guru, Huseyin R. Hiziroglu, “Electric Machinery and Transformers,” Oxford Publishing, Third Edition, 2000.
3. G.C. Jain, “The effect of Voltage Waveshape on the Performance of a 3-Phase Induction Motor,” Proceedings IEEE Rotating Machinery, November 27, 1963.
4. Bruno Osorno, “Effect of Inductance on Motor Side Harmonics,” Electrotek Case Studies, January 2000.
5. Roger C. Dugan, et al, “Electrical Power Systems Quality,” MacGraw-Hill Publishing, 1996.
6. Derek A. Paice, “Power Electronic Converter Harmonics,” IEEE Press, 1996.
7. Navid R. Zargari, et al, “Near Unity Displacement Power Factor For Current Source PWM Drives,” IEEE Industry Applications Magazine, Vol. 5, No 4 July/August 1999.