The Occurrence of Faults in Permanent Magnet Synchronous Motor Drives and its Effects on the Power Supply Quality

J. O. Estima A. J. Marques Cardoso

University of Coimbra, FCTUC/IT
Department of Electrical and Computer Engineering
Pólo II – Pinhal de Marrocos, P – 3030-290, Coimbra, Portugal
Phone/Fax number: +351 239 796 232/247, e-mail: **jestima@co.it.pt**, **ajmcardoso@ieee.org**

1. Introduction

The last few decades saw a definite change in the dynamics of consumer loads. The loading pattern has moved from simple linear loads to non-linear solid-state converters such as the devices used in variable speed/frequency drives. These became very popular in the last decades and are, nowadays, widely used in industry. An issue, however, that is giving increasing cause for concern is the harmonic distortion of voltage supplies caused by the non-sinusoidal currents drawn during the power conversion process inside drive converters. In general, the source of these current harmonics is the front-end 6-pulse uncontrolled rectifier using either a full-wave diode or an SCR bridge followed by a large electrolytic capacitor [1].

High levels of harmonic content can lead to overheating and destruction of power factor correction capacitors, overheating of cables, additional risk of failure due to resonance, overheating of transformers and fixed-speed electric motors, spurious tripping of electrical circuit breakers and interference with electrical, electronic and control system equipment [2]-[3]. Due to these negative consequences, building design and equipment specifications often require compliance with some standards which provide guidelines and acceptable limits of harmonic current and voltage distortion allowed back into the public power system [4].

Another parameter that is related to the supply network quality is the power factor. The typical 6-pulse front-end converter used in the majority of variable speed drives has an inductive power factor. As a result, the current tends to be higher than the current actually needed, and an excessive load current represents a loss for the consumer, who not only pays for the over-dimensioning of the cable, but also for the excess power loss in the cables [5].

The most common variable speed drives are based in induction motors. However, permanent magnet synchronous motors (PMSM) have been recently considered as an attractive alternative to the use of induction motors. Due to the replacement of the electromagnetic excitation with permanent magnets, this kind of motors has higher efficiency, electromagnetic torque and power density [6]-[7].

This paper presents a study on the occurrence of open-circuit faults in the inverter power switches of a 6-pulse static power converter, which feeds a PMSM, and its effects on the power supply quality. Mains supply currents harmonic distortion and power factor results will be presented. Only single fault occurrences are considered.

Key words

Power quality, harmonics, total harmonic distortion, power factor, permanent magnet synchronous motor drives.

2. Modelling and Simulation

The modelling and simulation of the PMSM drive system was developed in the Matlab/Simulink environment, in association with the Power System Blockset.

The PMSM drive control system is basically comprised by an outer speed loop and an inner current loop (Fig. 3). Good dynamic performance is achieved controlling the PMSM like a separately excited DC motor by the implementation of vector control. Hysteresis current controllers generate the six pulse signals to command the inverter power switches, maintaining the three currents within a hysteresis band.

Results concerning time-domain mains supply current waveform and its respective spectrum, were obtained by simulation of a 2.2 kW, 4-pole PMSM at 600 rpm and at half nominal load torque, for both normal and faulty operating conditions.

In order to analyse the impact of harmonic content in the quality of the current, Total Harmonic Distortion (THD)

values for both operating conditions are presented and compared.

They are also presented and analysed results related to the time-domain evolution of the power factor on the mains supply side for the two situations.

3. Experimental Results

A laboratory prototype for the aforementioned permanent magnet synchronous motor drive was implemented. A machine with 2.53 kW, 200 V, 50 Hz and with four poles was used.

This prototype was prepared for a digital control based on a personal computer, equipped with a National Instruments PCI 6071E board and a standard parallel port. The main control program was developed with Matlab, namely trough the Simulink, Real-Time Workshop, and xPC Target toolboxes. All necessary signals for the control strategy implementation were acquired by both voltage and current probe sensors through the PCI 6071E board. The command signals of the controlled power switches were sent by the PC using the standard parallel port. Under both normal and faulty operating conditions, the PMSM reference speed was configured to 600 rpm.

Experimental results related to the time-domain mains supply current waveform and its corresponding spectrum are presented. THD values were also calculated for normal operating conditions and with an open-circuit fault in the inverter power switch.

At last, results concerning the time-domain evolution of the power factor on the mains supply side are discussed. Both THD and power factor values are analysed and compared with simulation results.

4. Conclusions

The results obtained and presented in this work show that the occurrence of an open-circuit fault in a transistor of the power converter of a PMSM drive will have a negative impact on the power supply quality. Under these operating conditions, interharmonics will be injected into the supply network which may lead to the need of installing power filters in order to reduce or eliminate them. The harmonic content injected into the supply system depends on the drive design, its connection with the distribution system impedance and its load operating conditions.

Operation under these fault conditions will also affect the power factor on the mains supply side, reducing its mean value and bringing more disadvantages, especially in facilities with no power factor correction equipment. Besides this fact, the resulting oscillation in the power factor may also have adverse effects on the supply system.

Acknowledgment

The authors would like to express their acknowledgment to Dr. A. M. S. Mendes for his wise advices given during the development of this work.

References

[1] Mihalache, L., "A high performance DSP controller for three-phase PWM rectifiers with ultra low input current THD under unbalanced and distorted input voltage," *Conference Record of the 2005 IEEE Industry Applications Society Annual Meeting*, vol.1, pp. 138-144, October 2-6, 2005.

[2] "Power System Harmonics: Causes and Effects of Variable Frequency Drives Relative to the IEEE 519-1992 Standard", *Square D Product Data Bulletin No. 8803PD9402*, August 1994.

[3] Evans I., "Harmonic mitigation for AC variable frequency pump drives", *World Pumps*, Elsevier Science Ltd, December 2002.

[4] "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems", *IEEE Standard 519*, 1992.

[5] Luo, F. L., "Single-stage power factor correction AC/DC converter," *The 7th International Power Engineering Conference*, vol. 2, pp. 974-979, November 29-December 2, 2005.

[6] Estima, J. O.; Cardoso, A. J. M.; Mendes, A. M. S., "Simulation of a Permanent Magnet Synchronous Motor Drive With Voltage Source Inverter Fault Diagnosis", *Proceedings of the 20th International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management*, Faro, Portugal, pp. 587-595, June 13-15, 2007.

[7] Estima, J. O.; Cardoso, A. J. M.; Mendes, A. M. S., "Simulação de um Accionamento Baseado num Motor Síncrono de Ímanes Permanentes", *10th Portuguese-Spanish Conference in Electrical Engineering*, Madeira (Funchal), Portugal, CD-ROM, 6 pp., July 5-7, 2007.