HIGH FREQUENCY ELECTROMAGNETIC PROCESSES IN INDUCTION MOTORS SUPPLIED FROM PWM INVERTERS

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Abstract*:* *The paper presents the electromagnetic interference between induction motors and inverters when at high frequency electromagnetic process appears in induction motors having a parallel resonant effect because of parasitic capacitive coupling between windings and ground, using a numerical model in simulink and a high frequency induction motor equivalent circuit model this effect is shown.*

1. INTRODUCTION

In modern PWM variable frequency AC motor drive the switching frequency is very high, up to 200 kHz. The high frequency components of the inverter output voltage involves electromagnetic interference problems, such as resonant parallel effect, due to the stray capacitance between windings and ground. The output voltage of the inverter is generated as a pulse string; the resultant current is modified substantially by the motor inductance and consists basically of a sine wave at the fundamental frequency [1].

When supplying AC motors with high switching frequency because of the resonant effect the motor inductance is modify and the current no longer consists of a sin wave but becomes more like the inverter output voltage thus the *di/dt* greatly increases.

In order to predict the conducted electromagnetic interference, high frequency induction motor equivalent circuit will be used.

2. THE BASIC MODELS

The simulink model of the investigated system in shown in fig.1, it composes of a 400 V IGBT inverter supplying a 7.5 kW induction motor.

The induction motor high frequency equivalent model have been proposed and deeply analyzed in [2], and the proposed equivalent three phase circuit is shown in fig.2. In [2] it has been verified that the stator winding phase resistance and the turn-to-turn distributed capacitive coupling can be neglected in the high frequency motor model.

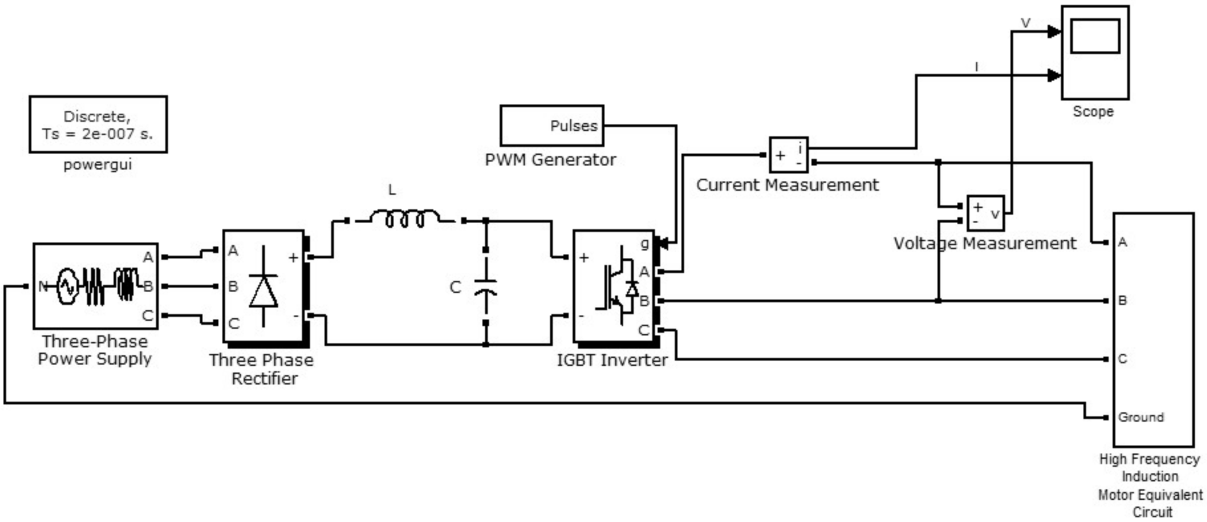

Fig. 1 – The investigated drive system

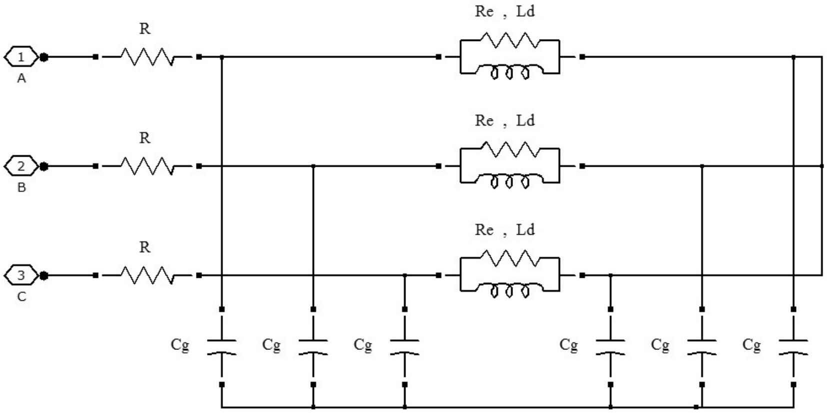

Fig. 2 – The selected equivalent circuit of the induction motor

The parameters considered in fig. 2 are:

R - winding resistance;
Ld- phase leakage inductance;
Re- resistance representing eddy currents inside the magnetic core and the frame;
Cg- capacitance representing the winding to ground distributed capacitance;

3. SIMULATION RESULTS

The simulations were made in simulink using the models in fig.1 and fig. 2; the fundamental frequency of the inverter has been keep at a constant 50 Hz only the switching frequency is modify.

The values for the parameters considered in fig. 2 were obtained from [2], for a 7.5 kW induction motor:

Cg= 0.953[nF];
Ld= 12.5[mH];
Re= 7.54[kΩ];

The first simulation was carried out at a 2.5 kHz switching frequency, representing a low switching frequency thyristor inverter; the results are shown in fig. 3.

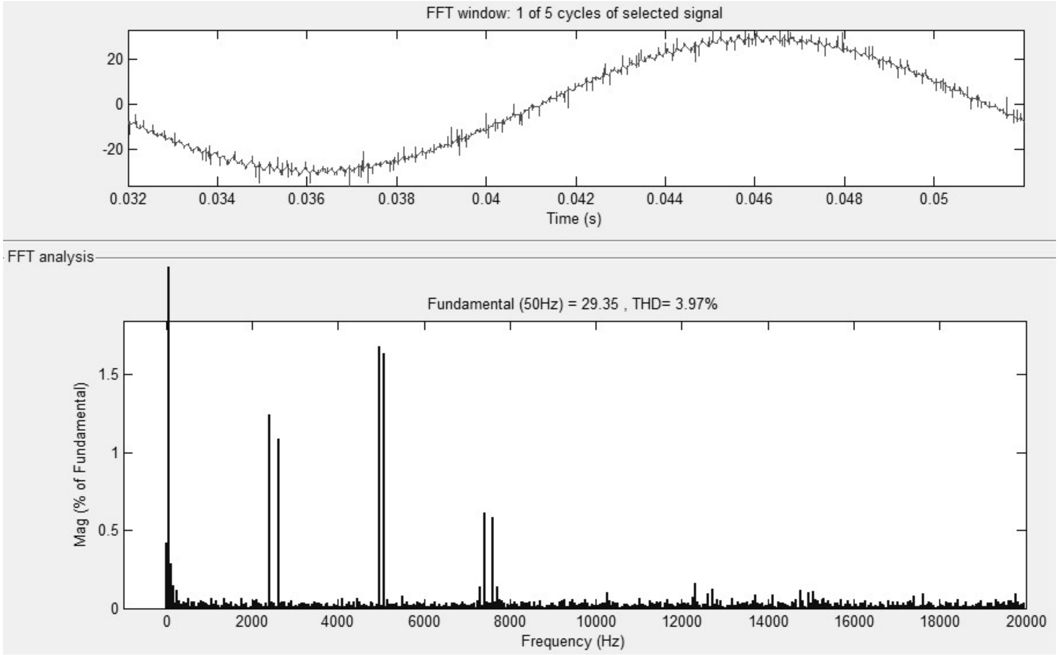

Fig. 3 – FFT result at 2.5 kHz switching frequency

Using the FFT (Fast Fourier Transform) Analysis Tool from simulink software, the waveform and harmonic content of the inverter output current is presented in fig. 3.

The output current waveform of the inverter is modified substantially by the motor inductance consisting of a sine wave at the fundamental frequency; because of the motor inductance the harmonic content of the output current is very low.

In fig. 4 the switching frequency is increased to 25 kHz, representing most transistor inverters switching frequency.

It can be seen that the motor inductance did not substantially modified the output current waveform of the inverter, meaning that the motor inductance has decreased; because the winding inductance and the winding to ground parasitic capacitive the motor becoming a parallel LC circuit.

In fig. 5 the switching frequency is increased to 200 kHz, representing a modern IGBT inverter [3]. The motor inductance has decreased even more because of the parallel resonant effect that cancels the motor inductance accentuated by the high switching frequency.

The harmonic content of the inverter output current is very high especially in high frequency harmonics with a THD (Total Harmonic Distortion) of 27%.

In all of the tree simulation results, represented in fig.3, fig.4, fig.5; only the switching frequency was modify (2.5 kHz, 25 kHz and 200 kHz), the fundamental frequency was constant at 50 Hz.

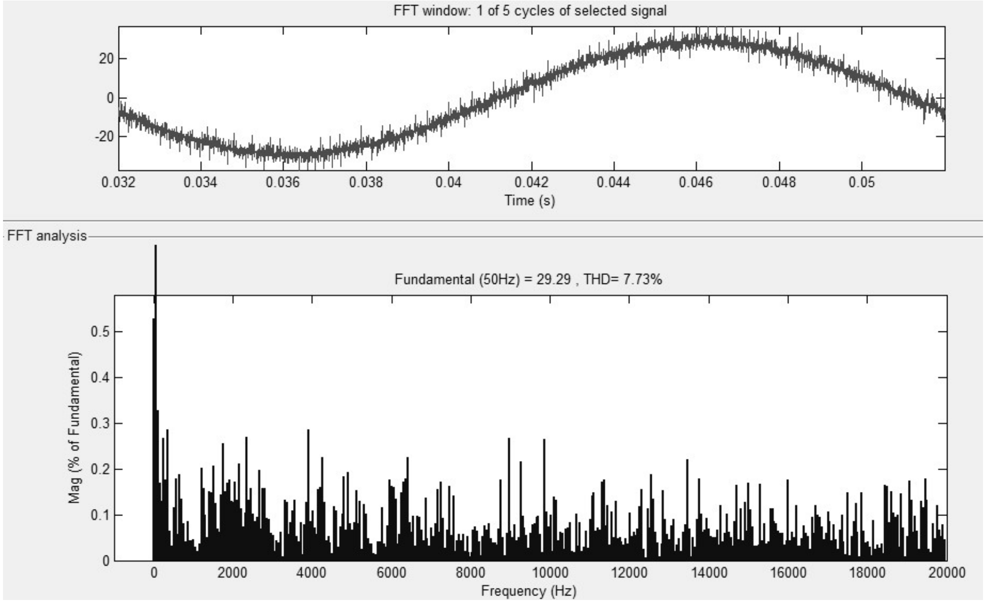

Fig. 4 – FFT result at 25 kHz switching frequency

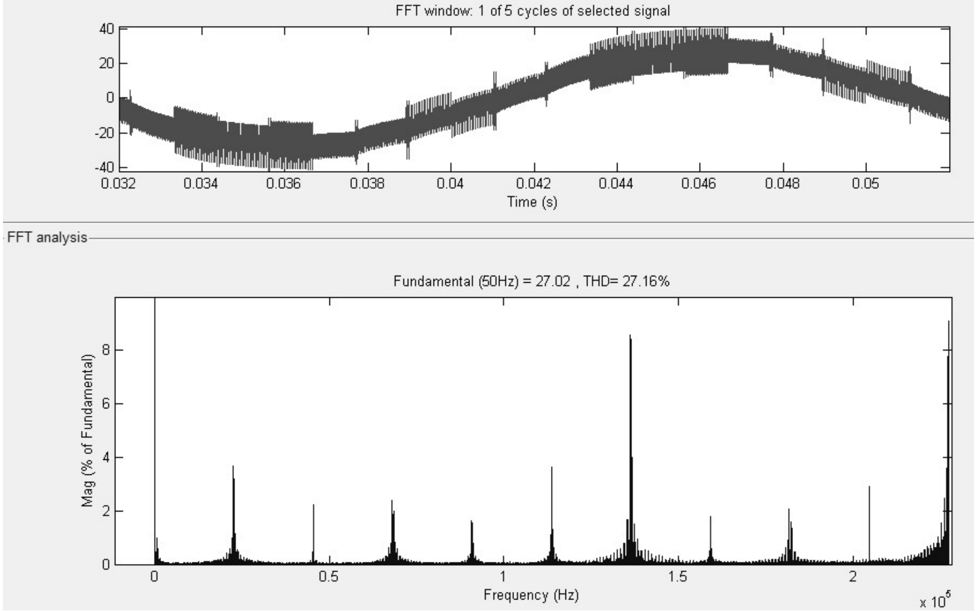

Fig. 5 – FFT result at 200 kHz switching frequency

4. CONCLUSION

At high switching frequencies the inverter power losses dramatically decreases so there is an interest in making inverters that can work at high switching frequencies. Using a power filter will minimize the effect of the high switching frequency but some application such as vector control used in variable speed drives cannot work using output power filters.

High switching frequencies create electromagnetic interference problems between inverter and motor in the form of resonant effects that cancels out the motor inductance, increasing the *di/dt* output current of the inverter producing even more electromagnetic interference along inverter-motor cable path.

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