Pspice Simulation of Power Electronics and Induction Motor Drives

Bojan Banković, Nebojša Mitrović, Vojkan Kostić, Milutin Petronijević

Abstract- Possibility of the PSPICE software package application on simulation of complex electromechanical systems is presented in this paper. The system considered is composed of two various subsystems, static semiconductor frequency converter - inverter and electrical motor. Validity of the proposed computer simulation concept is confirmed on the model of induction motor open loop variable speed drive supplied by square wave and PWM voltage inverter.

Keywords - variable frequency drive, PWM inverter

I. INTRODUCTION

In computer simulation of complex electromechanical system as variable speed drives with static power converter, in dependence of the goal and assignment the various methods exist, leading to the usage of different program packages. When the purpose of the analysis is concetrated on the power converter, CAD (Computer Aided Design) program packages for electrical circuit simulation like SPICE, ECAP etc. are used [1, 2]. The main characteristic of such models is that motor model is highly simplified and represented as RL circuit with electromotive force. If attention is directed toward electric machine program package based on the computer representation of the electric drive mathematical model, like SIMULINK, VISSIM etc. are used [3, 4]. This method is based on the idealization of the power source.

In this paper the system which consist of the induction motor - square wave (SQ) inverter and induction motor - pulse width modulation (PWM) inverter are simulated using PSPICE. The advantage of PSPICE application is the simple way of modelling the inverter, its switching, control and snubber circuits.

II. SYSTEM MODEL

The system considered is composed of two subsystems, static semiconductor frequency converter - inverter and induction motor.

The behaviour of the induction motor is analyzed on the basis of dynamical model. The classical rotating field theory with well-known *qd0* transformation is used [5].

The mathematical model in stationary reference frame is presented by Eqs. (1)-(3).

$$\begin{bmatrix} v_{qs} \\ v_{ds} \\ v_{qr} \\ v_{dr} \end{bmatrix} = \begin{bmatrix} R_s + sL_s & 0 & sL_m & 0 \\ 0 & R_s + sL_s & 0 & sL_s \\ sL_m & -\omega_r L_m & R_r + sL_r & -\omega_r L_r \\ \omega_r L_m & sL_m & \omega_r L_r & R_r + sL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \quad (1)$$

$$T_e - T_m = J \frac{d\omega_r}{dt} \quad (2)$$

$$T_e = \frac{3}{2}\left(\frac{p}{2}\right) L_m \left(i_{qs} i_{dr} - i_{ds} i_{qr} \right) \quad (3)$$

The inverter is modelled on the basis of scheme in Fig. 1. The switching components are modelled as ideal voltage switches with RC snubber circuit. The fundamental frequency harmonic of the inverter output voltage is controled by means of appropriate control logic. A dc circuit is presented by three phase diode rectifier and appropriate LC filter. The control logic enables continual rise of the voltage along the defined *V/f* characteristic limiting in that way starting current.

The characteristic of the SQ inverter is that every half bridge unit alternates between ON and OFF state, Fig.3.

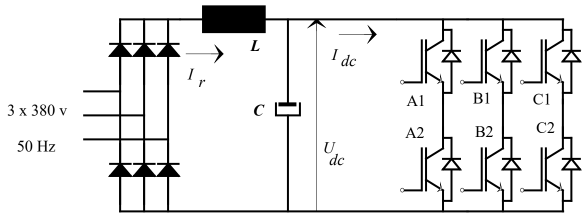


Fig 1. Three phase voltage source inverter

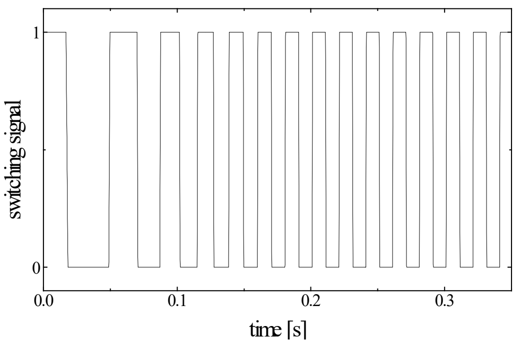


Fig. 3. Control impulses for switche A1

Bojan Banković, Nebojša Mitrović, Vojkan Kostić, and Milutin Petronijević are with the Dep. of Power Engineering, Faculty of Electronic Engineering, University of Niš, Serbia, E-mail: nebojsa.mitrovic@elfak.ni.ac.rs.

PWM inverter switches are controled by modulation signal shown in Fig. 2a. The modulation signal is generated with the purpose of the motor soft-start realization. The way in which the control impulses are generated for one PWM inverter switch is shown in Fig. 2b [1].

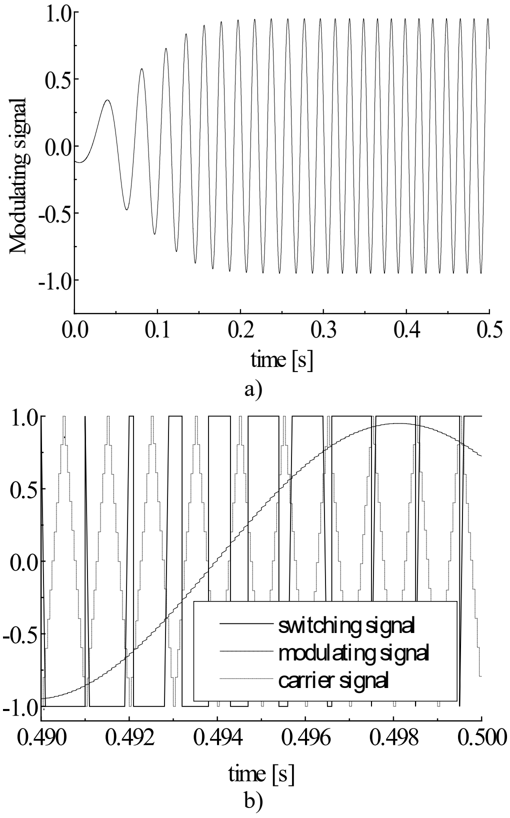


Fig.2a) Soft start modulation signal b) Generation of PWM signal

III. INVERTER-MOTOR COUPLING

Equivalent scheme of the system is chosen in order to enable simple connection of the motor and inverter. The ac power supply is modelled with three ideal voltage sources and the inverter load with three current sources with the currents equal to the phase motor currents. In that manner the influence of the induction motor on the inverter together with the load influence on the inverter dc link current are taken into account.

The complete equivalent scheme of the whole system is shown in Fig.4.

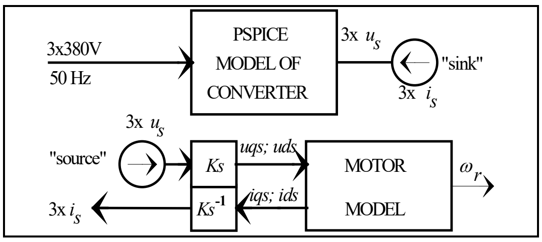


Fig. 4: Principle block diagram of system model

IV. COMPUTER SIMULATION RESULT

Application of the described models in the PSPICE simulation package under different working conditions of the system induction motor-inverter have been simulated. The control logic have been designed in order to enable the well-known *V/f* regulation characteristic [5]. The behaviour of the system at the start of the induction motor with limited starting current have been simulated. The computer simulation results for PWM induction motor drive are shown in Fig. 5., and for SQ induction motor drive in Fig. 6.

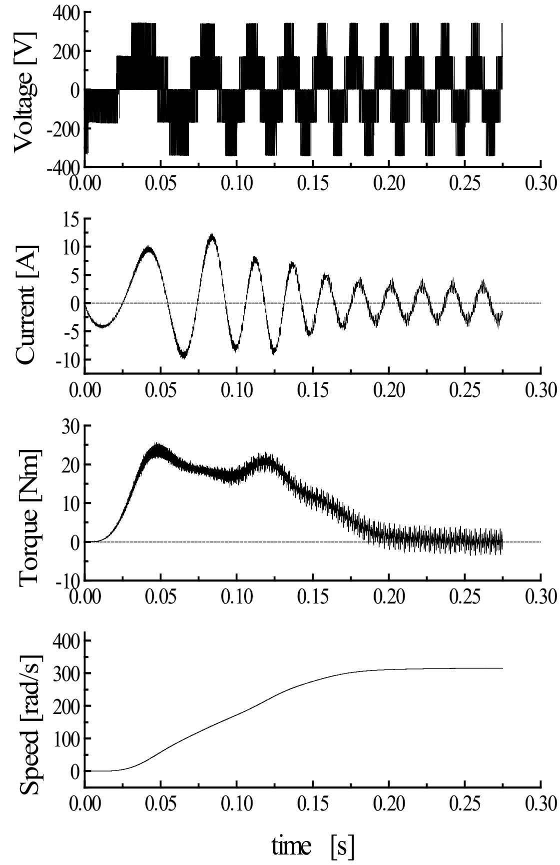


Fig. 5. Machine variable during free acceleration of PWM inverter induction motor drive

V. EXPERIMENTAL MODEL VERIFICATION

In order to verify the validity of the proposed concept experiment have been carried on the real PWM inverter fed drive in the Electric Drives Laboratory at the Faculty of Electronic Engineering in Nis.

Phase motor current, voltage and dc link current of the inverter for the frequency of the inverter carrier signal equal to 3.9 kHz are shown on Fig. 9-11.

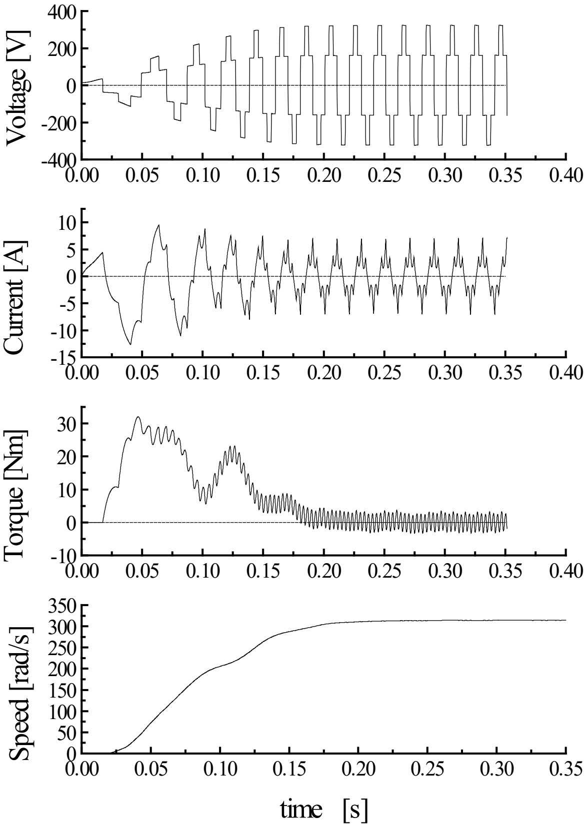


Fig. 6 Machine variable during free acceleration of SQ inverter induction motor drive

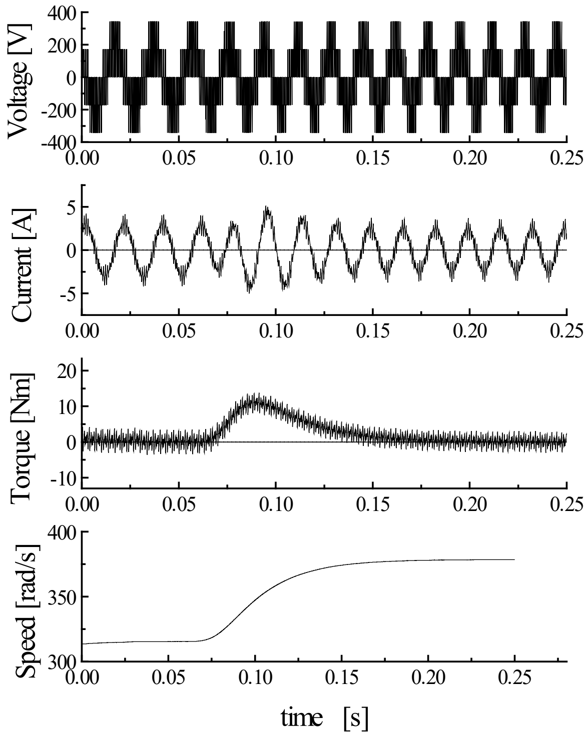


Fig. 7. Performance of a PWM inverter induction motor drive for a step change in inverter frequency

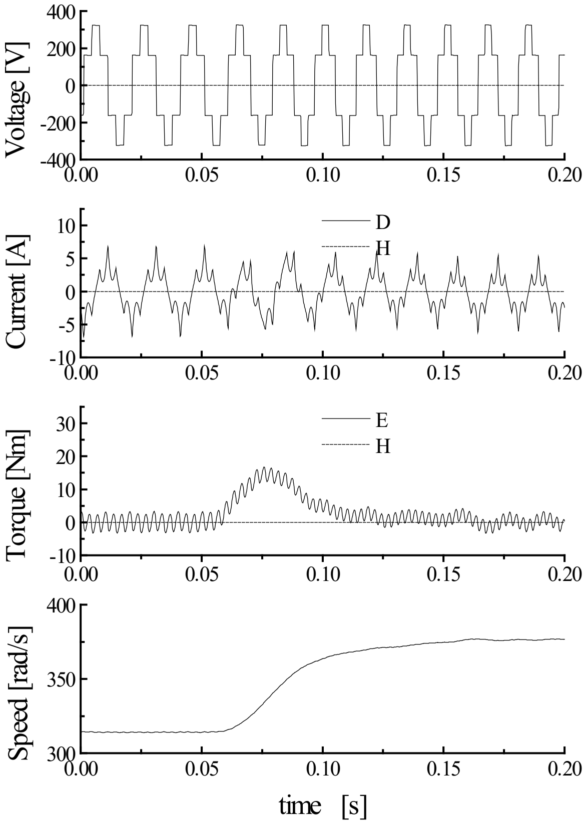


Fig. 8. Performance of a SQ inverter induction motor drive for a step change in inverter frequency

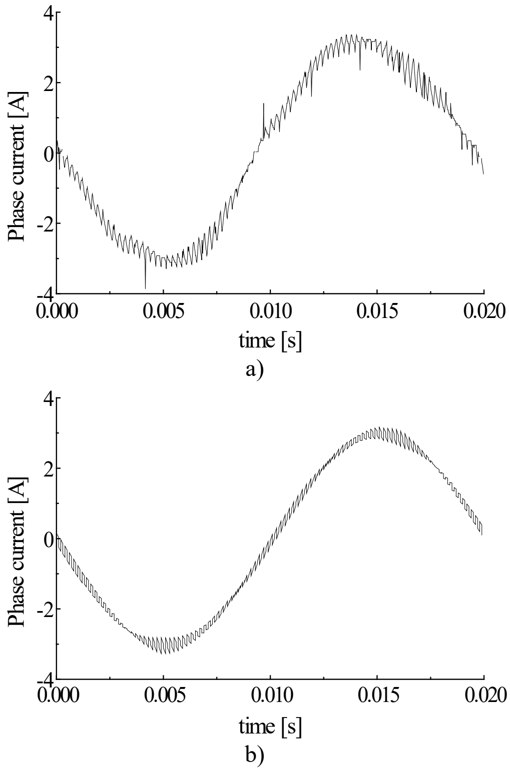
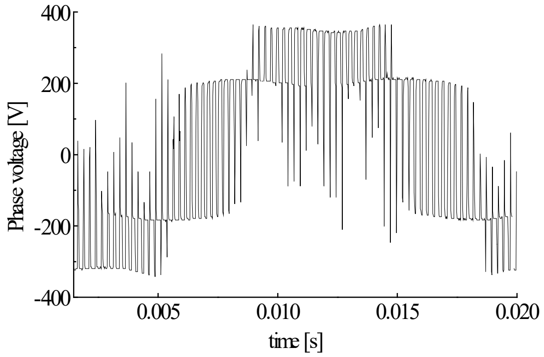
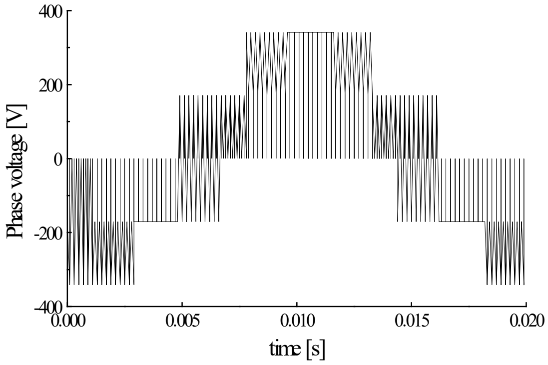


Fig.9. Motor phase current a) experiment b) model

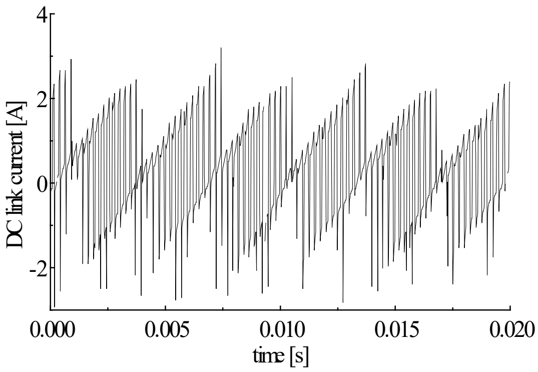


a)

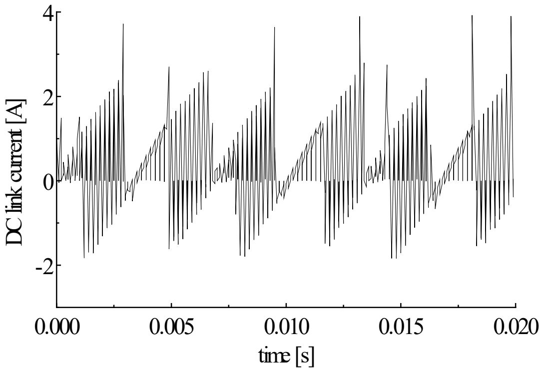


b)

Fig.10. Motor phase voltage a) experiment b) model



a)



b)

Fig.11. Inverter DC link current a) experiment b) model

VI. CONCLUSION

The application of CAD package like PSPICE admits efficient analysis of the behaviour of the different components of the modern variable speed drive. Described models and simulation results point out the important advantages of this concept in the modelling and analysis of the complex systems. This advantages are mainly based on adequate modelling of the interaction between electric machine and power converter. The proposed circuit topology is very closed to practical realization enabling in that way easy practical design and analysis of the complete system electrical machine-power converter.

Experimental verification of the proposed model confirmed our expected advantages of the proposed concept.

We would like to point out the possibility of analysing higher harmonic influence on the motor torque and influence of the inverter dead time.

New method for modelling of interaction between power electronic circuit and electric machine enables high flexibility in analysis and design. The main disadvantage of the proposed concept is the long simulation time conditioned by the extremely high ratio of the dominant time constants of the dynamical processes involved.

List of simbols:

v - instataneous voltage	i - instataneous current
T_e - electrical torque	ω_r - rotor speed
T_m - load torque	R_r - rotor resistance
L_m - magnetizing inductance	R_s - stator resistance
L_r - rotor inductance	J - inertia
L_s - stator inductance	s - diff. operator d/dt

- subscript:
a,b,c - phase quantities,
s- stator; r - rotor
d, q - direct and quadrature axis

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