

INVESTIGATION OF VARIABLE RELUCTANCE STEPPING MOTORS DYNAMICS USING MATLAB-SIMULINK ENVIRONMENT

V. TRIFA ¹, C. MARGINEAN ², L. ZARNESCU ²

¹Technical University of Cluj-Napoca

²CCSTM Constanța

trifa@edr.utcluj.ro, marginean.calin@edr.utcluj.ro

Abstract. The paper is a theoretical approach of a common variable reluctance stepping motor (VRSM), using Matlab-Simulink environment as tool. The Simulink models include different interchangeable power supply methods, such as simple series R phase commutators, dual voltage inverters, PWM inverters. Also these models enable to study various control strategies, such as: open-loop control, closed-loop control with phase self-commutation, microstepping control

Keywords: variable reluctance stepping motor, Simulink, PWM

Introduction

The progress of incremental motion control systems, where one usually uses stepping motors, has been enforced by the multiplicity of their utilization in numerically controlled machine-tools drives, peripheral computer equipments, telecommunications through laser and satellites, nuclear techniques, industrial robots, aeronautical and military equipments etc. In this context, the VRSM promise the low-cost production and motivate the comprehensive research and design although they are not included in the classical treatment of the DC or AC electrical drives.

With the aim to provide a computer-aided investigation and to verify the performance characteristics of such a VRSM, the authors created the necessary toolboxes for VRSM through multilevel modeling procedures.

The VR stepping motor taken into consideration has the following construction features: 8 stator poles, each stator pole having 5 teeth, 50 rotor teeth, 4 phases, stepping angle $1,8^{\circ}$. For the implementation of the Simulink model, we have started from the classical voltage and torque equations:

$$Ri_k + \sum_{j=1}^{m+1} L_{jk}(\theta) \frac{di_{jk}}{dt} + \frac{d\theta}{dt} \sum_{j=1}^{m+1} i_j \frac{dL_{jk}}{d\theta} = u_k$$

$$\frac{J}{p} \frac{d^2\theta}{dt^2} + \frac{B}{p} \frac{d\theta}{dt} + M_r = \frac{p}{2} \sum_{j=1}^{m+1} \sum_{k=1}^{m+1} \frac{dL_{jk}(\theta)}{d\theta} i_j i_k \quad (1)$$

Supply methods

In order to MPP in general, and VRSM in this case responds at the higher frequencies it is necessary to settle time of current at the value of U/R_m to be lower as possible. In order to achieve high performance with VRSM, there are used the following techniques to reduce the rising time of the phase current: series-resistor drive circuit, dual voltage drive circuit and chopped or PWM drive circuit.

The series-resistor drive circuit, which is the most common and cheapest method, is based on the time constant decreases T_m through series resistance in motor phases. The time constant decreases from L_m/R_m to $L_m/(R_m+R)$, instead the supply voltage will increase from $U = R_m I$ up to the value $U = (R_m+R)I$, where I is the nominal current of phase. In this way series-resistor drive technique is framed into simple voltage source supply family.

The disadvantage of the series resistor drive circuit is the surplus of the dissipated power on the external resistance, and thus are causing the lower efficiency of the scheme. The method is suitable for low power and low cost electric drives.

A more efficient command method is to force the current by voltage. A dual voltage inverter is implemented in the proposed library. A principled scheme of the dual voltage inverter for one phase is given in fig. 1. The motor phase is supplied with the high voltage V_1 until the phase current reaches the nominal value I_N . At this time Q_1 is turned off and the motor phase is supplied with the low voltage V_2 . This low voltage maintains the current at I_N value. Usually the ratio V_1/V_2 is about 10. The scheme uses active suppression by $D_1 - D_2$ diodes.

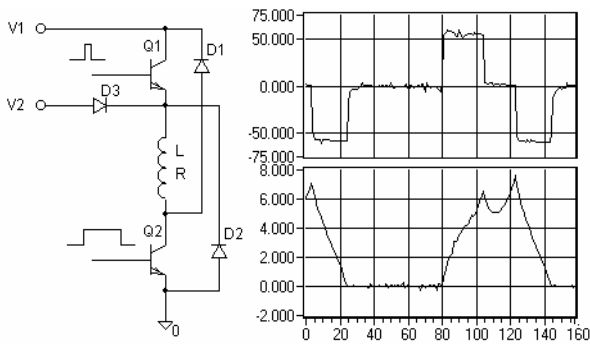


Fig. 1. Principled scheme of dual-voltage inverter

The third implemented inverter is a current source using chopped voltage. The current is maintained to the desired value with a specified hysteresis. The principled scheme and characteristic waveforms are presented in figure 2.

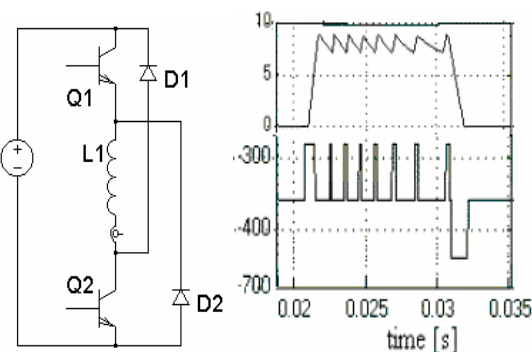


Fig. 2. Principled scheme of chopper inverter

Simulated results

All the implemented models have an user-friendly interface that allows introducing different values for the motor and inverter parameters. Different command strategies are also implemented, open-loop and minor-loop. In such a manner one can easily analyse a large palette of drive system configurations and supplementary the influence of different parameters to the system behaviour. The figure 2 exemplifies one possible configuration: the VRSM supplied from a dual voltage inverter.

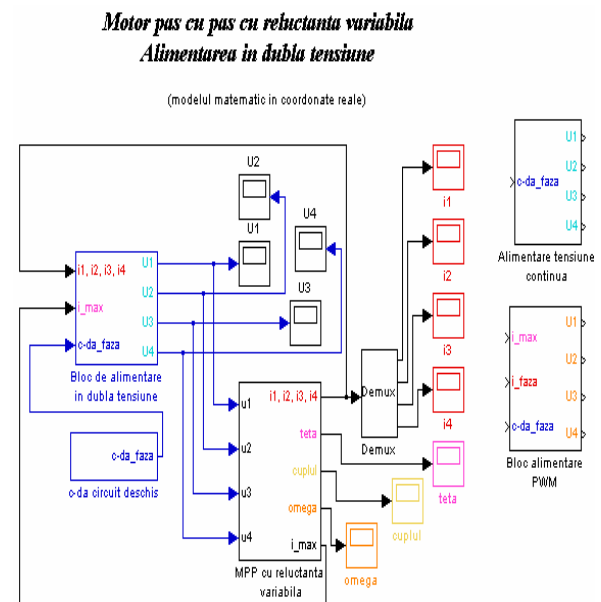


Fig. 3 The drive system block diagram.

In the following section there are presented and compared different drive system configurations: open loop series resistance circuit, dual voltage inverter and chopper (PWM) inverter. The figures present the phase current and voltage and the variation of position and torque with the time.

As shown, rapid step response occurs when modern supply techniques are involved, such as dual voltage or PWM.

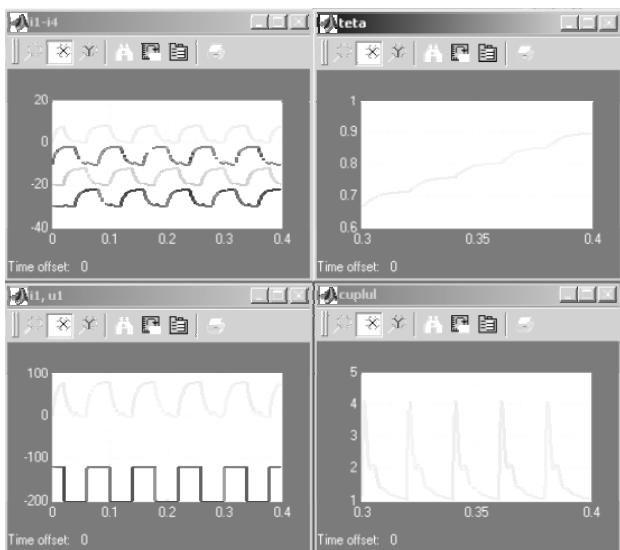


Fig. 4. Simulation results for series resistance circuit

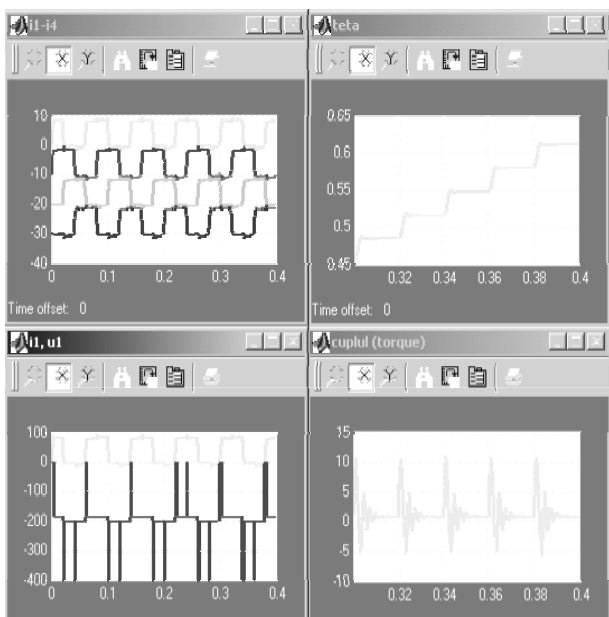


Fig. 5. Simulation results for dual voltage circuit

Conclusions

An adequate library for analysed VRSM drive system is implemented. The library contains models for the VRSM and interchangeable inverters. All the models feature a user-friendly interface that allows setting different parameters for all of the drive-system components.

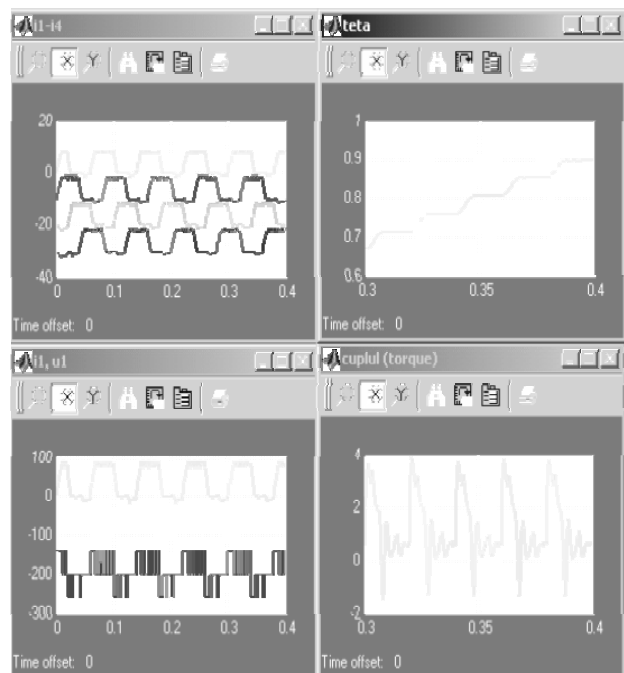


Fig. 6. Simulation results for chopper circuit

Due to its modular configuration, the developed library is a useful instrument that allows the study of many aspects regarding the VRSM drive system: dynamics, the stability, the influence of parameters to the system etc. Three possible system configurations are studied and analysed comparatively.

References

- [1] B.C. KUO (USA), A. KELEMEN, M. CRIVIL, V. TRIFA (1981) - *Sisteme de comandă și reglare incrementală a poziției*. Editura Tehnică, București
- [2] L. ZĂRNESCU, (2000) *Modelarea și simularea pe calculator a sistemelor de poziționare cu motoare pas cu pas*. Referat de doctorat. Universitatea Tehnică din Cluj Napoca
- [3] V. TRIFA, O. RĂBULEA, L. ZĂRNESCU - *New Control Strategies of Variable Reluctance Stepping Motors Using LabVIEW Environment*. Proceedings of 6th International Conference EMES'01, 24-26 May 2001, Oradea, 448-451.
- [4] DOUGLAS W. JONES, *Control of Stepping Motors*, <http://www.uiowa.edu/~jones/step/>