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Author(s):

SPOLJARIC, Z[eljko]; MIKLOSEVIC, K[resimir] & VALTER, Z[dravko]*

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ANALYSIS OF SYNCHRONOUS MOTOR DRIVE USING SIMPOWERSYSTEMS

SPOLJARIC, Z[eljko]; MIKLOSEVIC, K[resimir] & VALTER, Z[dravko]*

Abstract: *Practical usage of existing model for analysis and testing of large synchronous motor drive made in Matlab SimPowerSystems is presented. Basic principle and application field of synchronous motors is given. Problems that occur in motor during load change are explained. Model made in SimPowerSystems is explained. Essential parameters used for simulation starting are given. Usage of m-files for different motor types is shown. Results of simulation during load change of motor are shown. Usage of model for different testing and analysis is purposed.*
Key words: *model, analysis, motor, simulation, SimPowerSystems*

1. INTRODUCTION

The paper main topic is usage of SimPowerSystems in analysis of large synchronous motors (SM). SimPowerSystems is part of Matlab Simulink and it operates in Simulink environment. It consists of electrical power circuits and electromechanical devices such as motors and generators. By knowing all essential motor parameters it can provide complete analysis of dynamic behaviour of SM (Fig.1.). In this paper the behaviour of motor during load change will be shown. Similar simulation is done with asynchronous motor by (Miklosevic at al., 2008). In that paper the building of asynchronous motor model in Simulink is shown. Complete DC (direct current) motor drive analysis is also made by (Miklosevic at al., 2009). DC motor dynamics were tested during motor load change. Model building of DC motor in Simulink and comparison with SimPowerSystems model is given. SimPowerSystems provides application for modeling and simulation of electric motor drives in three levels: modeling of simple drives by using classical electrical devices, modeling more complex drives by using semi-conductor elements and circuits, and modeling of complex drives by using subsystems for control and regulation of electric machines. This application of mentioned program in modeling and simulation of electrical machines and drives is done by (Valter, 2009). The speed of a SM with DC excitation in the rotor is determined by the stator frequency and the number of poles (Leonhard, 2001). Speed control of large SM is similar to control of small motors with permanent magnets which is based on variable power frequency. Control and supervision of small synchronous motor in LabView program is done by (Spoljaric at al., 2007; Ertugrul, 2002).

2. BASIC PRINCIPLE, PROBLEM DEFINITION AND APPLICATION FIELD OF SM

A synchronous machine, as the name indicates, must rotate at synchronous speed which is uniquely related to the supply frequency (Bose, 2002). The stator winding is three-phased but rotor winding carries direct current. The equivalent circuit per phase of SM (Fig. 2.) links the stator and moving rotor windings. Main elements of equivalent circuit are stator and rotor resistance (R_s, R_f), stator and rotor leakage inductance (L_{ls}, L_{lf}), supply (stator) voltage (V_s), excitation or speed emf (V_f), stator and field (rotor) current (I_s, I_f), magnetizing current (I_m), core-losses resistance (R_m) and magnetizing inductance (L_m).

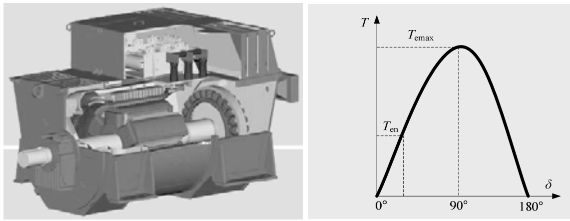

Fig. 1. Over section and load diagram of synchronous motor

Mentioned equivalent circuit is starting phase for building dynamic synchronously rotating d-q frame model developed by Park. The SimPowerSistems model of SM is based on electrical equations of sixth-order nonlinear system as given in equation (1) and mechanical equation of second order (2) (Bose, 2002):

$$\begin{bmatrix} v_{qs} \\ v_{ds} \\ 0 \\ 0 \\ v_{fr} \end{bmatrix} = \begin{bmatrix} R_s + sL_{qs} & \omega_e L_{ds} & sL_{qm} & \omega_e L_{dm} & \omega_e L_{dm} \\ -\omega_e L_{qs} & R_s + sL_{ds} & -\omega_e L_{qm} & sL_{dm} & sL_{dm} \\ sL_{qm} & 0 & R_{qr} + sL_{qr} & 0 & 0 \\ 0 & sL_{dm} & 0 & R_{dr} + sL_{dr} & sL_{dm} \\ 0 & sL_{dm} & 0 & sL_{dm} & R_{fr} + s(L_{lfr} + L_{dm}) \end{bmatrix} \cdot \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \\ I_{fr} \end{bmatrix} \quad (1)$$

$$T_e = 3\left(\frac{P}{2}\right)\frac{V_s}{\omega_e}\frac{V_f}{X_s} sin\delta \quad (2)$$

From the equations it is visible that SM model is based on complex mathematical system which is also given in (Jadric & Francic, 1995). The analysis and design of a control system for a synchronous machine electric drive calls for a complex dynamic model. Problems with large SM operating on a constant frequency supply may be caused by their inherent oscillatory response since the torque (2) depends on the load angle δ. Angle δ between voltages V_s and V_f is known as the power or torque angle (Fig. 1.) and its maximal value can be 90° but recommended value is between 20 to 25°. This problem is presented in the simulation. Speed of synchronous motor does not change with load of motor so all values of motor torque are at the constant synchronous speed. This characteristic of SM determines their field of application in areas where constant speed is required and it does not depend of motor load. Such drives are low speed reversing drives, such as needed for gear-less rolling mills with stringent requirements for high dynamics performance (Leonhard, 2001). The other application is in large, high speed compressor drives up to 100 MW for pipe-lines or wind-tunnels. Large synchronous motors with permanent magnets are used for propulsion of military ships because of improved efficiency.

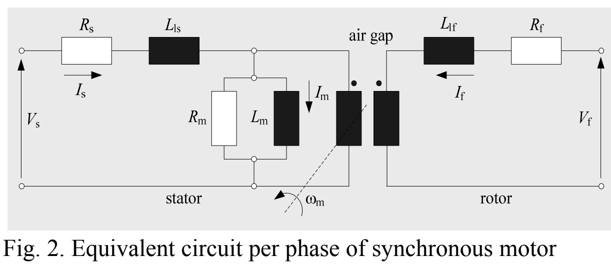

Fig. 2. Equivalent circuit per phase of synchronous motor

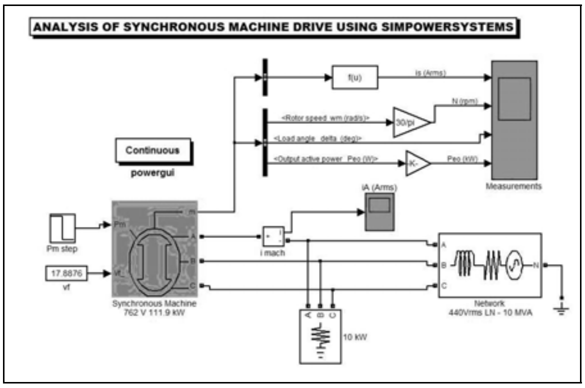

Fig. 3. Simulation model of SM in SimPowerSystems

3. SM MODEL IN SIMPOWERSYSTEMS

As mentioned, SimPowerSystems is part of Matlab Simulink and contains a library (*powerlib*) with synchronous, asynchronous and DC machines. Powerlib contains 6 different models of three phase synchronous machines with parameters in SI units or in pu. Model for testing SM for load change or load impact is presented in Fig. 3. Simulated model consists of industrial grade SM (111,9 kW) connected to a power source presented with 10 MVA/440 V generator. All essential parameters of SM are presented in Fig. 4. (left) in SI units. All motor parameters are entered by using *m-file* editor (Fig. 4., right) where the values of variables (parameters) were defined. Start of simulation is initiated in block *powergui* by application of Load Flow and Machine Initialization option. The machine is set to output mechanical power of - 48,9 kW (negative value for motor mode). The P_m Step Block is programmed to apply a sudden increase of mechanical power from -48,9 kW to -60 kW at time t = 0,1 s. Connection "*m*" on SM model contains 22 measurement signals which can be presented with block Scope.

4. RESULTS

Results of simulation are given in Fig. 5. There are four measured signals: stator current (i_s), rotor speed (N), load angle (δ) and electric power (P_{eo}). After simulation start oscillation of all four values can be noticed. There are speed oscillations from nominal value (1500 rpm) after load increase in duration of 1.4 s. Load angle increases from -21° to -53°. Electric power that motor uses also increases after oscillations to 75 kW. It is important that duration of these oscillations is not to long. It is visible that oscillation time is 2.5 s.

5. CONCLUSION

In this paper possibility of usage SimPowerSystems, as part of Matlab program family, in synchronous motor analysis is purposed. The given simulation explains the problems which occur during motor load change, especially the problem with

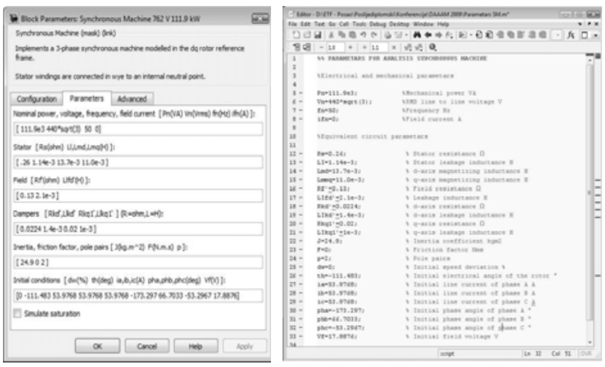

Fig. 4. Motor parameters (left) and m-files (right)

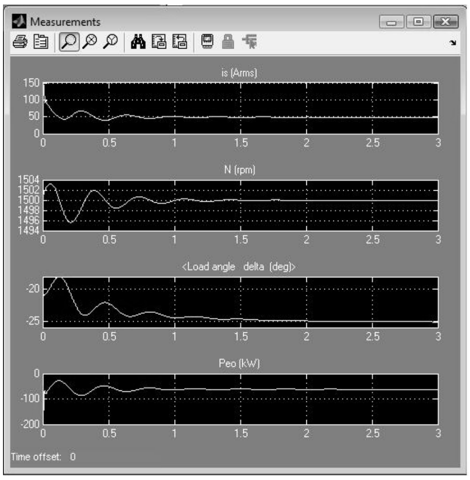

Fig. 5. Results of simulation during load change of SM

load angle which gives limit to maximal load of motor. SimPowerSystems provides possibility for complete dynamic analysis of large synchronous motors and other electrical machines. Further it can be used for dynamic analysis during short circuit or load limits analysis of motor and generator. In this way many kinds of drives in which motor could be implemented can be tested before real application in industrial enviroment. There is also possibility for testing motor prototypes in easy way of changing motor parameters by using *m-files*. In further reaserch load angle estimation of SM will be analized. This is important because of better motor stabilization and protection durring the load change. It is important to mention that for good model and reaserch all parameters have to be reliable. Durring further reserach testing of SimPowerSystems on real laboratory SM will be done.

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