EMSIM 1.1. – PROGRAM FOR SIMULATION OF INDUCTION MOTOR STARTING

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Abstract – *In the paper program EMSIM 1.1, developed on the Power Engineering Departement of the Faculty of Electrical Engineering in Banjaluka, is described. Program is assigned for simulation of starting process of induction motor. Program is used for teaching purposes on the Department for Power Engineering. Accuracy and ease of use are achieved by combining Matlab simulation with an graphical user interface made in Visual Basic.*

1. INTRODUCTION

There are numerous professional programs related to power engineering: programs for system planning, power flow analysis, system optimization, modeling, supervising, machine projecting etc. Beside them, there is a lot of educational programs designed for teaching and training power engineering students and professionals. The purpose of educational software is to help understanding the principles of power system operation and the basics of energy conversion, as well as to illustrate symmetric components or harmonics etc.

Students at the Faculty of Electrical Engineering in Banjaluka are trained to use programs for professional purposes, but while learning, they use educational software as help. There is a lot of illustrative software like in /2, 3, 4/ which can be easily found on internet and download as freeware or shareware software. Those programs can't always be used as granted, because usually there are no details about mathematical models on which programs are based, and usually those programs can't be modified or configured to a specific purpose.

Since 2000 Departement for Power Engineering at the Faculty of Electrical Engineering in Banjaluka started to develop a new software package for purpose of training student. This package is called *EMSIM* and its basic purpose is to illustrate the principles of electrical machines operation and output characteristics. Program package is designed as easy to use, illustrative and based on detailed machine models. At present, part of the program regarded to simulation of induction machine starting process is finished. This program is called *EMSIM 1.1.*

2. *EMSIM 1.1.* – REQUIRED CHARACTERISTICS

Required characteristics for *EMSIM 1.1* program were:

- program had to be based on detailed mathematical model of induction machine written in form of state-space model. Differential equations had to been solved by proper numerical method. Three representative kinds of motor load had to be included: as constant, lineary and parabolic function of speed;
- Program had to have *user-friendly* interface, and developed as any other *Windows* application. With this, *easy-to-use* of program by the students who had no expirience with electricall machines simulation would been achieved;
- All the results had to be represented as plots, and printing and saving of results had to be obtained.

To achieve required characteristics, program is developed in two parts. Induction motor model is made as state-space model as usually formed by the theory of electrical machine modeling. Differential equations are solved by *Matlab's Runge-Kutta* numerical method with changable simulation step. Second part of program, *Windows* application-like interface is written in *Visual Basic*-u 6.0. Connection between these to parts of program is made by using *Active X* controlls in the background /6/.

Using the program is simple and intuitive. All parameters can be inserted, changed, saved, and results can be printed as like in any other Windows program. Detailed machine model which is solved by *Matlab* routines ensures enough accuracy.

Regarded to adopted program concept, any other transient process in induction machine, or any other machine transient analysis (like synchronous or DC) routines can be added as extra modules. By this, program can be easily upgraded.

3. INDUCTION MACHINE MATHEMATICAL MODEL

Three-phase induction motor model is developed as in /7/ by usinge standard methods from electrical machines theory. Model is written in state-space form in stationary reference frame. Accuracy of this model is adequate for almost all purposes /7/.

$$\underline{u}_s = R_s \underline{i}_s + \frac{d\underline{\Psi}_s}{dt}, \tag{1}$$

$$0 = R_r \underline{i}_r + \frac{d\underline{\Psi}_r}{dt} - j\omega\underline{\Psi}_r, \tag{2}$$

$$\underline{\Psi}_s = L_s \underline{i}_s + M \underline{i}_r, \tag{3}$$

$$\underline{\Psi}_r = L_r \underline{i}_r + M \underline{i}_s, \tag{4}$$

$$m_e = \frac{3P}{2}\left(\underline{\Psi}_s \times \underline{i}_s\right), \tag{5}$$

where $\underline{u}_{s,r} = u_{\alpha,r} + ju_{\beta,r}$, $\underline{i}_{s,r} = i_{\alpha,r} + ji_{\beta,r}$, $\underline{\Psi}_{s,r} = \Psi_{\alpha,r} + j\Psi_{\beta,r}$ are voltage, current and flux vectors, ω_m is mechanical speed, $\omega = P\omega_m$ electrical speed, P, number of pole pairs, L_s, L_r i M are stator , rotor and mutual inductances, and m_e is motor torque.

Mechanical subsystem is modeled by Newton equation:

$$J\frac{d\omega}{dt} = m_e - m_{opt}, \tag{6}$$

where J is inertia, and load torque m_{opt} can be given as function with constant, linear and parabolic part:

$$m_{opt} = m_{const} + k_1\omega_m + k_2\omega_m^2. \tag{7}$$

Transformation of terminal quantities from original (phase) domain to transformed domaien is obtained by Clark's transformation matrix /7/.

3. PROGRAM STRUCTURE

Program structure is shown on Fig. 1. Main program module is written in *Visual Basic*, and subprogram for numerical solving of mathematical model (1-7), called asinh1.m, is written in *Matlab*. Motor and load parameters, as well as simulation step size, can be typed directly, or loaded from file in the main module. When the simulation is started, parameters are saved in par.m file, and than *Matlab* is started via *Active X* controls. *Matlab* than loads the parameters, starts the file asinh1.m. After the simulation is over, the results are saved in file simout.dat. All these processes are run in the background. The results can be shown as plots, using *Matlab's* drawing engine, also controlled by the *Active X* controls. All data transfer, error controll and communication between main module and *Matlab* are done by *Active X* controls. *Active X* controlls are written in *C++* language.

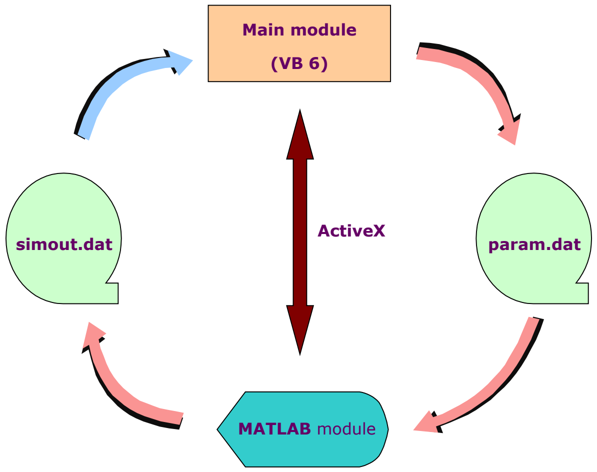

Fig1*: Program Structure*

4. PROGRAM INSTALLATION

Program is delivered on two floppy disks and is installed like standard *Windows* application. Software requirements are *Windows 9x* or *Windows XP* and installed *Matlab 5.2* or newer verison. There are two versions of *EMSIM 1.1* due to different *Active X* controls for *Windows 9x* and *Windows NT* (this information must be submitted before purchasing). Hardware requirements are *Pentium II* on 300 MHz, with 64 MB RAM and 4 MB free on hard disk.

After the installation, *EMSIM* icon will appear on *Desktop* as in the *Start Meny*. Installation process takes usually few minutes.

5. USING THE PROGRAM

EMSIM 1.1. can be started via *Start Meny*, or by double click on the icon on *Desktop*. Main screen is shown on Fig. 2.

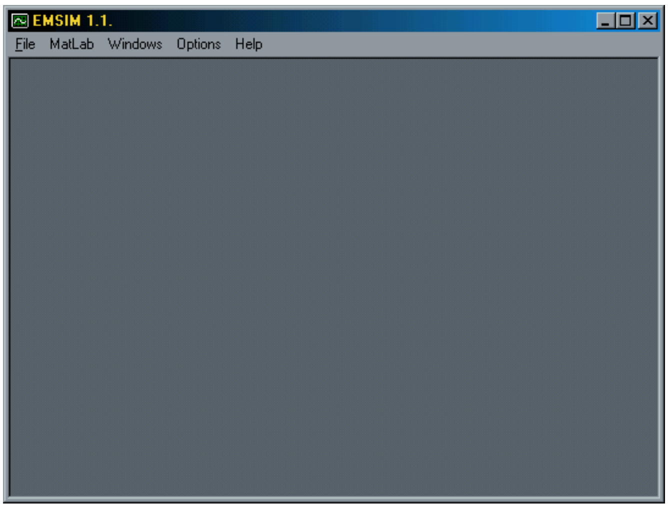

Fig. 2: *EMSIM 1.1. Main Screen*

Description of commands:

FILE – has options: creating a new simulation file (NEW), opening the existing simulation file (OPEN), saving (SAVE), printing the parameters (PRINT) and exit (EXIT);

MATLAB – with options for starting the simulation (START) and drawing the results (GRAPH);

WINDOW – choosing the active window;

OPTIONS – available only on versions for *Windows 9x* and *Matlab 5.1.* Before the first run, it is necessary to define the path to *MATLAB BIN* directory where simout.dat and param.dat files are to be placed.;

HELP – help, written in *Help Scribble*.

By choosing the option FILE/OPEN an existing parameter file can be opened (in *EMSIM* format *.pib), and the parameters can be changed. This window is shown on Fig. 3.

Terminal voltages are inserted as effective voltages per phase, and all the motor parameters are the parameters from equivalent circuit. Load torque (7) can have all three parts, or just one or two of them.

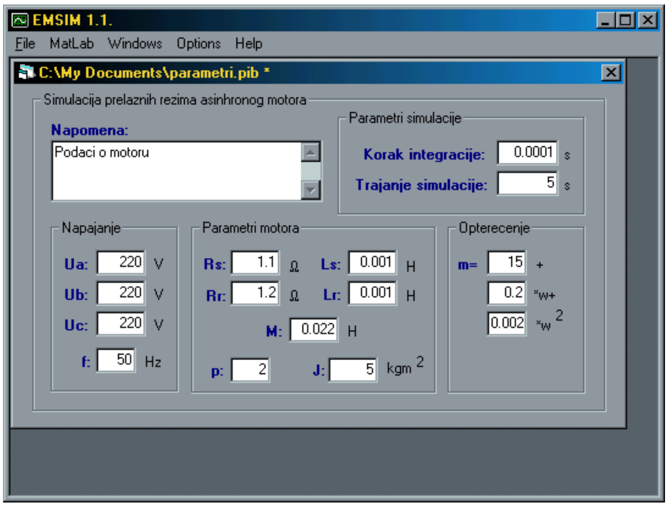

Fig. 3*: Parametar Entry Window*

After the simulation parameters are set, simulation can be started by option MATLAB/START. Simulation time depends of version of *Matlab*, step size and computer processor power. Program starts *Matlab* in the background (what can be seen on *System Tray*), but the user can not interrupt the simulation.

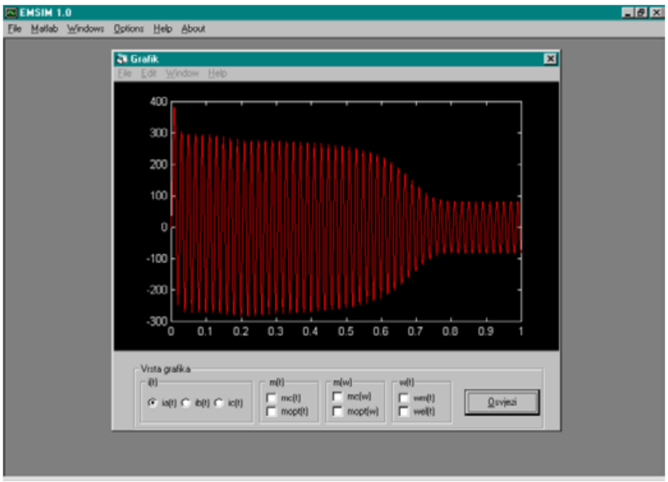

Fig. 4.: *Simulation Results (Phase Current)*

It can be noticed that simulation is finished faster than if the model is started directly in *Matlab*. After the simulation is over, program sends message “Simulation is done”, and graphs can be plotted.

By choosing the option MATLAB/GRAFIK graph window will open. If the simulation parameters are changed in the meanwhile, then the program displays the message that the simulation must be restarted before the graphs are shown. On Fig. 4. plot window is shown. It has options for saving and printing the results. *EMSIM 1.1* can show phase currents/time, motor torque/time or torque/speed, and mechanical and electrical speed/time.

After choosing the value (current, torque or speed), button “Refresh” must be pressed. In newer version of software this will be obtained automatically. On Fig. 5. torque/time plot is shown (parameters are changed from Fig. 2). Torque/speed and speed/time plots are shown on Fig 6/7.

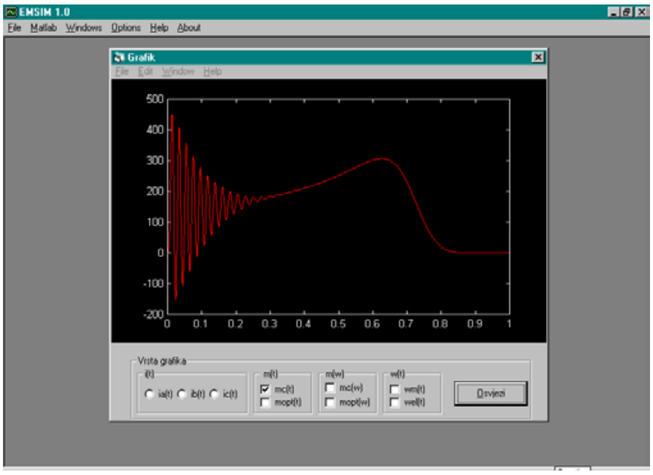

Fig. 5. Torque/time plot

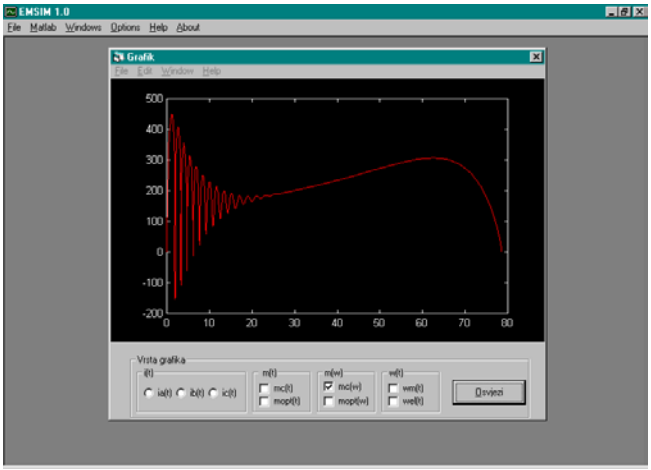

Fig 6. *Torque/speed plot*

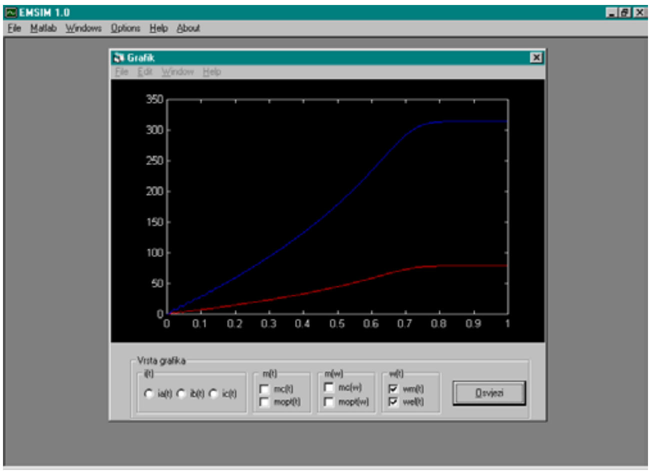

Fig 7. *Mechanical speed/time and electrical speed/time plots*

On Fig 8 motor and load torque characteristics are plot together. Operating point (torque/speed) can be found on intersection these two characteristics.

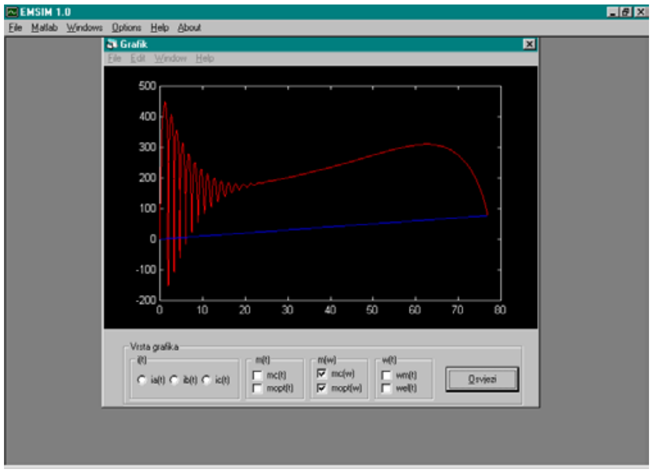

Fig 8: *Motor and Load Torque*

Help window is shown on Fig. 9.

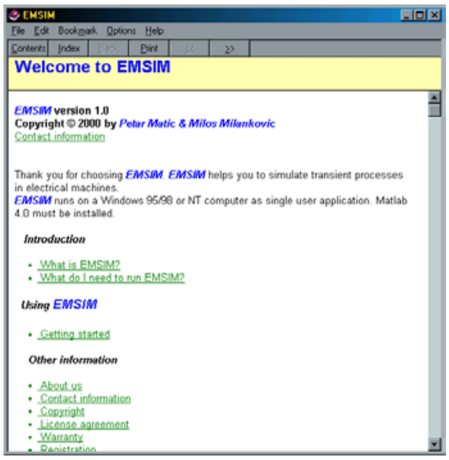

Fig. 9. *HELP Window*

6. CONCLUSION

In this paper development and use of a simple educational program is presented. This program has good accuracy, user friendly interface, and scalability for analysis of different electrical machine types and operating regimes / transient processes.

7. LITERATURE

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