Comparative analysis and experimental verification of simulation modelling approach in MATLAB-Simulink and SimInTech

E A Domakhin¹, N S Popov¹, M E Vilberger¹, V I Anibrov¹, I I Singizin¹

¹ Novosibirsk State Technical University, 20, Karla Marksaaave, Novosibirsk, 630073, Russia

E-mail: Domakhin-Evgeniy@yandex.ru

Abstract. The paper considers a simulation modelling approach validity for the control system development of real objects. Two programs for research were used then experimentally validated. The experiment showed good repeatability between software and revealed the permissible limits for a simulation modelling approach use.

1. Introduction

Modern computer technology development has led to changes in complex technical systems design approaches. Leading companies in the field of automated complexes development widely use simulation modelling. Simulations allow designing results verification, system behaviour prediction and fault risks elimination at a designing stage. Current software solutions in the field of computer applied engineering (CAE) enable engineers to repeat real physical processes accurately. The article considers a cascaded control systems approach for DC motor closed-loop speed controller development [1]. An analytical estimation, a simulation modelling and experimental verification are performed.

The goal of the article is to verify simulation model adequacy and accuracy comparing to experimental results as well as a comparative analysis of two different CAE software used.

2. Materials and methods

The reversible thyristor electric drive BTU-3601 was chosen as a study object. The speed controller is implemented by means of operational amplifier.

As CAE software for simulation MATLAB-Simulink and SimInTech have been chosen. MATLAB-Simulink has proved itself as effective software for solving wide range of technical tasks, in particular for mechatronics and electromechanical systems. MATLAB-Simulink gives engineers a variety of capabilities for control system design in range from structural modelling to real-time system simulation [2].

SimInTech is a russian analogue CAE. SimInTech is a scientific and engineering software for math models and control algorithms development, automatic PLC-code generation and etc. SimInTech provides opportunities for automatic projects documentation and mitigates the waste of time required for C-code compilation.

The authors used an analytical evaluation and simulation modelling for a speed controller design. Then experimental verification was performed for the development quality estimation.
3. Speed controller development using cascaded control system approach

The cascaded control systems approach is used for the speed controller synthesis [1,3]. Applying this strategy for a closed loop speed control of a reversible thyristor converters based DC electric drive, two cascaded control loop are to be designed. The “inner” loop is a DC motor armature current control loop (CCL). The outer is speed control loop (SCL). To simplify theoretical evaluation, the CCL development is out of the article scope, as far as the main article goal is to provide simulation approach validation and comparative analysis between two CAE software. Hence, CCL is tuned based on the modulus optimum (MO) criterion could be represented by the first-order lag block (aperiodic) as it shown in fig. 2. Control system parameters are given in table 1. The structural scheme of speed control closed loop is shown in fig. 2.

It is possible to obtain the proportional – integral controller (PI) from speed closed control loop tuning based on the symmetrical optimum (SO) criterion [3]. PI-controller transfer function is given as following:

\[ W_{pc}(p) = \frac{k_{ia} \cdot J \cdot (a_c^2 \cdot \tau_{mc} \cdot p + 1)}{a_c^3 \cdot \tau_{mc}^2 \cdot c\Phi_n^2 \cdot k_{oc} \cdot p} = \frac{k_{ia} \cdot J}{a_c^3 \cdot \tau_{mc}^2 \cdot c\Phi_n^2 \cdot k_{oc} \cdot p} + \frac{k_{ic} \cdot J}{a_c^3 \cdot \tau_{mc} \cdot c\Phi_n^2 \cdot k_{oc} \cdot p} = k_p + \frac{k_i}{p} \]

A first-order aperiodic filter [4,5] is to be installed at the speed closed loop input to improve DC – motor speed behavior:

\[ W_{\varphi}(p) = \frac{1}{4 \cdot \tau_{mc} \cdot p + 1} \]

As the result of development two simulation models have been designed in MATLAB-Simulink and SimInTech which are given in fig. 3 – fig.4.

| \( c\Phi_n, V \cdot s \) | \( J_\Sigma, kg \cdot m^2 \) | \( k_\tau, V/A \) | \( k_c, V \cdot s \) | \( \tau_{mc}, s \) |
|-----------------------------|-----------------------------|-----------------|-----------------|-----------------|
| 1.9                         | 0.096                       | 0.4             | 0.075           | 0.003           |

Figure 1. Speed control closed loop representation.

Figure 2. Simulation model structural scheme in MATLAB-Simulink.
Figure 3. Simulation model structural scheme in SimInTech.

The solver configuration parameters in both programs were set identical to enable comparative study of simulation results. The type of solver, a step size, a relative and absolute tolerance and etc. were chosen to ensure accurate modelling. The solver configuration parameters are given in Table 2.

| Software     | Solver            | Min step size | Max step size |
|--------------|-------------------|---------------|---------------|
| Matlab - Simulink (ode5,Dormand-Prince) | RK45            | 1E-5          | 1E-4          |
| SimInTech    | RK45              | 1E-5          | 1E-4          |

It should be noted that simulation analysis was performed using PC with following parameters: Intel Core i7 (4 cores) 2.6GHz; 8Gb RAM.

The simulation analysis goal is to evaluate transient performance indexes of control object. Simulation analysis allows preliminary estimation of the developed system parameters to apply it for real system [6,7]. The research provides comparative study for MATLAB-Simulink and SimInTech. Obtained results then experimentally validated on the reversible thyristor electric drive BTU-3601. The PI-controller design analytically evaluated was implemented in simulation models as well as in real electric drive.

Two scenarios for speed control loop simulation were chosen:
1. DC motor no-load starting up to rated rotational speed value \( \omega_{idle} = 133 \text{ rad/s} \);
2. Step load surge with load torque \( M = 19 \text{ N·m} \) for DC motor operating at idle mode \( \omega_{idle} = 133 \text{ rad/s} \).

DC motor rotational speed transients for above mentioned modes 1 and 2 are given in fig. 5 – fig.6 correspondingly. For ease of comparing simulation results with experimental data fig.5 and fig.6 were equipped with oscilloscope snapshots from the experimental setup.
Figure 4. Rotational speed transients during no-load starting.
Transient performance indexes are given in table 3 and table 4.

**Figure 5.** Rotational speed transients during step load surge

Experimental results.

**Table 3.** Transient performance indexes for no-load starting

| Software            | Steady state value, rad/s | Settling time, ms | Overshoot, % | Computation time, s |
|---------------------|---------------------------|-------------------|--------------|---------------------|
| Matlab - Simulink   | 133                       | 262               | 2.48         | 2.25                |
| SimInTech           | 133                       | 262               | 2.48         | 1.05                |
| Experimental Setup  | 133                       | 320               | 9.2          | -                   |
Table 4. Transient performance indexes for step load surge

| Software          | Steady state value, rad/s | Dynamic speed decrease, % | Computation time, s |
|-------------------|---------------------------|---------------------------|---------------------|
| Matlab - Simulink | 133                       | 0.98                      | 1.15                |
| SimInTech         | 133                       | 0.96                      | 0.65                |
| Experimental Setup| 133                       | 4.76                      | -                   |

4. Conclusion

Results obtained during the research showed good repeatability between two CAE software and revealed a difference with experimental data. The difference could be observed in such parameters as overshoot and settling time. By authors opinion this was caused by several issues:

1. CCL performance was approximated for the research needs;
2. Reversible thyristors electric drive operation features were not been taken into account;
3. Authors neglected additional inertia masses installed to DC motor shaft (speed gages, connection sleeves).

The executed research proved the opportunity of CAE software for control system development of real objects. Results obtained in the simulation could be used as “approximation” for implementation in real system. For more precise simulation results agreement with experimental data a more complex simulation model representation is required.

A computational time required for simulation in MATLAB-Simulink and SimInTech is different. Results showed that the MATLAB-Simulink computational time approximately 2 times greater than the computational time in SimInTech. It should be noticed that the simulation mode in MATLAB-Simulink was switched to Normal, also, the computational time does not includes the time required for software starting and initialization, which is also greater for MATLAB-Simulink.

References

[1] Dyakonov V P 2012 *MATLAB is a complete tutorial* (Moscow: DMK press)
[2] Pankratov V V 2013 *Automatic control of electric drives* (Novosibirsk: NSTU) p 200
[3] Kartashov B A, Shabaev E A, Kozlov O S, Shchekaturov M A 2017 *The environment of dynamic modelling of technical systems SimInTech: Workshop on modelling automatic control systems* (Moscow: DMK press)
[4] Schreiner R T 1997 *Systems of subordinate regulation of electric drives* (Yekaterinburg: USPPU)
[5] Terekhov V M, Osipov O I 2006 *Drive control systems* (Moscow: Academy)
[6] Moskalenko V V 2004 *Automated control systems for electric drives* (Moscow: Infa-M)
[7] Egorov V N, Shestakov V M 1983 *The dynamics of electric drive systems* (Moscow: Energoatomizdat)