Laboratory "**Modeling and Simulation of Dynamic Systems**"
Institute of the Theory of Electrical Engineering, Measurement and Information Systems, WUT

Exercise No 3B
Series DC motor
Author: S. Osowski

1. The aim of experiments

Modeling of the transient phenomena in series connected DC machine using the program of SIMULINK.

2. Dynamic model of series DC machine

We assume that the series motor is supplied from the DC voltage source through the additional series resistance R_d and additional series inductance L_d (to limit the current in the dynamic state). The general equations describing the motor are then in the form

$$u = \frac{d\psi(i)}{dt} + L_d \frac{di}{dt} + i(R_d + R_s) + e + \Delta u$$
$$J\frac{d\omega}{dt} = M_e - M_m \qquad (1)$$

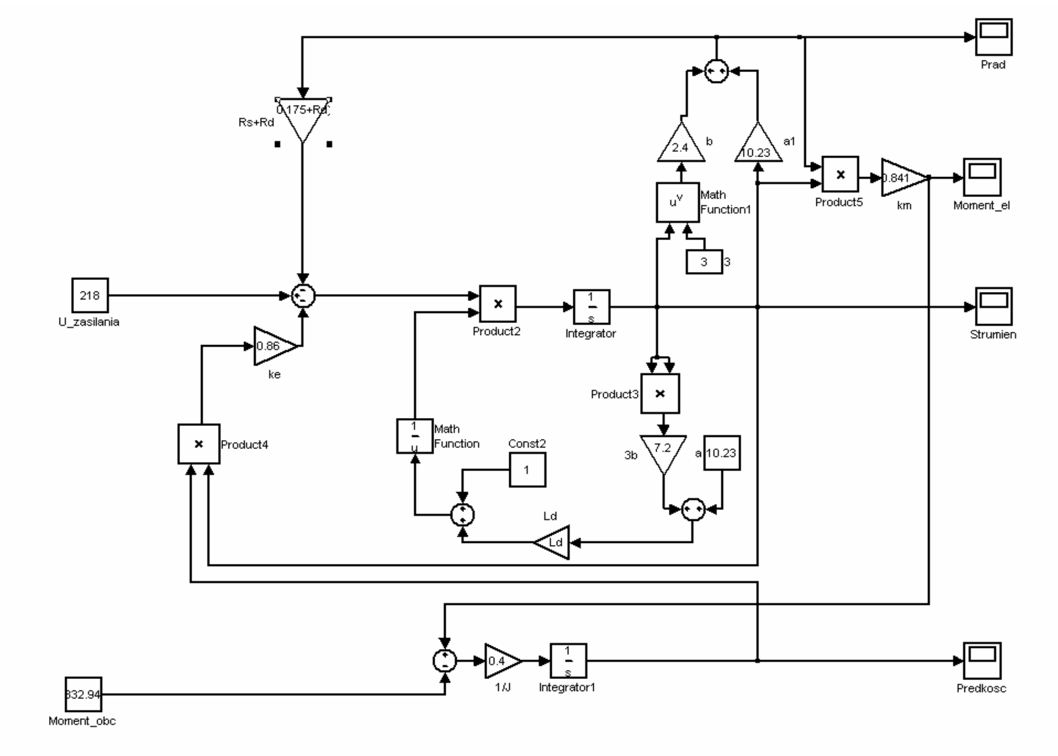
at $e = k_e \omega \psi(i)$, $M_e = k_m i \psi(i)$, $\omega = \frac{2\pi n}{60}$ (n – revolutions per minute). The typical values of the motor used in experiments are as follows (R_d and L_d are set up by the student):

- P_n=23000W
- U_n=220V
- I_n=120A
- n_n=660 rev/min
- η=87% (efficiency)
- ψ_n=3.3Wb
- Δu=2V
- R_s=0.175Ω
- J=2.5kgm^2
- $\omega_n=2\pi n_n/60=69.08$
- $k_e = \frac{u - \Delta u - I_n R_s}{\omega_n \psi_n} = 0.864$
- $M_n = \frac{P_n}{\omega_n} = 332.94 Nm$
- $k_m = \frac{M_n}{I_n \psi_n} = 0.841$

In series excited DC motor the excitation flux is largely dependent on the current. Let us assume this dependence in the form $i=a\psi+b\psi^3$ (typical values for this DC motor are: a=10.23, b=2.4). At such assumption we get the state space description of the motor in the normal form as follows.

$$\frac{d\psi}{dt} = \frac{1}{1 + L_d(a + 3b\psi^2)}\left[(u - \Delta u) - k_e\omega\psi - (R_s + R_d)(a\psi + b\psi^3)\right]$$
$$\frac{d\omega}{dt} = \frac{1}{J}\left[k_m\psi(a\psi + b\psi^3) - M_m\right] \qquad (3)$$
$$i = a\psi + b\psi^3$$
$$M_e = k_m\psi(a\psi + b\psi^3)$$

Fig. 1 presents the Simulink model of these equations (file **sil_szer2.mdl**).



Rys. 1 The Simulink model of the series DC motor

3. Program of numerical experiments

In simulation of the dynamic state of the series DC motor we should first determine the values of the additional resistance R_d and additional inductance L_d (write the proper values in the workspace of Matlab). Start from zero values and then apply the values of R_d and $Z_L=j\omega L_d$ in such a way, that the maximum current does not exceed the nominal current value of the machine by 2.

In the experiments simulate the following modes of operation:

- start of the motor at $M_z = 0$ and at different values of M_z (for example M_n, $2M_n$, $5M_n$)
- change of the load torque M_z for the running motor at constant supply voltage (for example M_z equal $0.5M_n$, $1.5M_n$, $5M_n$
- change of the supply voltage at $M_z = 0$ and M_z different from zero
- change the supply voltage to zero (electromagnetic breaking) at $M_z = 0$ and M_z = different from zero (at active load)