Separately Excited DC Motor Parametric Control Using Electronic Workbench

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Abstract—This paper presents Electronic Workbench (EWB) model used for parametric speed control of Separately Excited DC Motor, namely armature voltage, armature resistance and field current control methods. The speed time response and the armature current time response were investigated during start up period. The speed- torque characteristics were plotted. The study is carried out using one model contacting four functional blocks. The results should be implemented in electric drive laboratory at Al-Balqa Applied University.

Keywords — DC motor, Parametric Control, EWB, Simulation, Steady State analysis.

I.   INTRODUCTION

Different software packages are used in developing dynamic models of DC motors to be implemented in designing DC drive systems, or to support and enhance machinery courses and electric drive courses. MATLAB *with its* toolboxes such as Simulink [1] and SimPower Systems [2], [3] is one of the most popular software packages used by designers and educators to study the transient and steady state characteristics of electric machines [4], [5].Dynamic simulation of DC motors is also made using other software package called LABVIEW [6]. The procedure of simulation in LABVIEW is similar to building model in MATLAB. Using previously mentioned models, the transient response of the motor is obtained directly connecting the output to an output device and running the model. For steady state analysis of DC motor the model should be run at different loads, the steady state values of speed and torque are recorded, and then the speed -torque characteristics are drawn.

In this paper Electronic Workbench (EWB) software package is used in modelling DC motor. The EWB allows user to design and analyse electronic and electric circuits with out using real components and actual instruments. EWB,s click and drug operations make editing a circuit fast and easy, the user can change parameters and circuit components on the fly. The EWB size is very small compared with MATLAB and LABVIEW and can be downloaded for free from many internet sites.

In the recent work EWB model of separately excited DC motor is developed and used to investigate the transient and steady state characteristics for different parametric speed control methods: armature voltage, armature resistance and Field current. The results of the proposed model are verified by calculations and simulation on MATLAB.

II.   MATHEMATICAL MODEL

Mathematical model of separately excited DC motor can be built using all mathematical equations describing its physical properties. These equations are [6]:

1- The armature circuit equation:

$$V_a = R_a + L_a \frac{di_a}{dt} + e_a \qquad (1)$$

Where: V_a is the armature voltage, e_a is the back EMF, i_a is the armature current, R_a and L_a are the armature resistance and armature inductance respectively.

2- The back EMF can be written as:

$$e_a = k\Phi\omega \qquad (2)$$

Where: K is a machine construction constant, Φ is the magnetic flux and ω is the motor angular speed.

3- The equation of mechanical part is:

$$T = J\frac{d\omega}{dt} + B\omega + T_L \qquad (3)$$

Where: J is the moment of inertia, B is the viscous friction coefficient and T_L is the load torque.

4- Electro magnetic motor torque is:

$$T = k\Phi i_a \qquad (4)$$

III. EWB MODEL OF DC MOTOR

The EWB model is developed for 5 hp, 240 V separately excited DC motor with parameters are given in Table 1.

Table 1: **Motor Parameters for EWB Model**

Ra	La	J	B	KΦ
0.5 Ω	0.01 H	0.05 kg.m^2	0.02	2

In this work, the DC motor will be modelled by solving differential equations and algebraic equations. For that equation (1) should be rewritten as:

$$\frac{di_a}{dt} = \frac{1}{L_a} V_a - \frac{R_a}{L_a} i_a - \frac{1}{L_a} e_a \qquad (5)$$

To open EWB click on its icon [7], initially you will see an empty circuit window and two toolbars, the circuit toolbar with the common file management, editing and graphics tools, and a Parts Bin toolbar from which you can select a wide range of circuit elements, and instruments. To build the circuit, you need a battery, a ground, and three-way voltage summer and voltage integrator.

To assemble the components for the circuit:
1. Choose File/New to open a new circuit file.
2. Click in the Parts Bin toolbar. The basic toolbar should appear.
3. Drag the necessary elements from the toolbar to the circuit window.
4. Use the voltage summer to summarise all terms in the right side oh equation (5) by double click the block and then setting the gain of input A to $1/L_a$ the gain of input B to $-1/L_a$ and the gain of input C to $-R_a/L_a$.
5. Double click the battery and set the voltage to V_a.
6. Wire the components together.

The forgoing steps perform a EWB armature circuit shown in Fig.1.The output of the voltage summer is the derivative of the armature current and the output of the voltage integrator is the armature current.
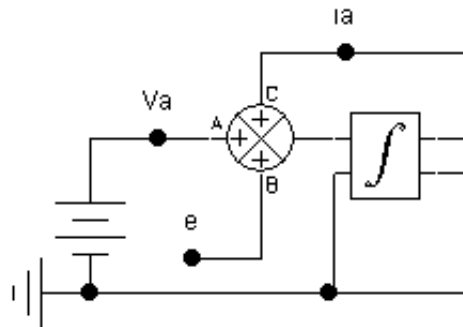

Fig.1: EWB model of armature circuit

The mechanical part of the motor is modelled using equation (3) rewritten in the following form:

$$\frac{d\omega}{dt} = \frac{1}{J} T - \frac{1}{J} T_L - \frac{B}{J} \omega \qquad (6)$$

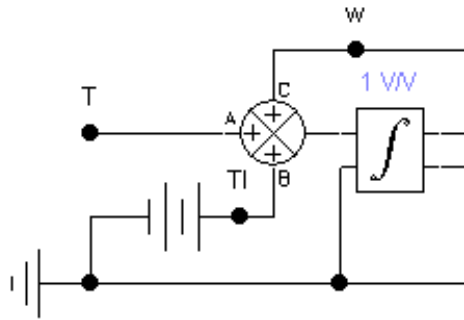Proceeding as for armature circuit, the EWB model of mechanical part will be as shown in Fig.2.

Fig.2: EWB model of mechanical part

Equation of developed torque (4) and equation of back EMF (2) are simulated as shown in Fig.3.
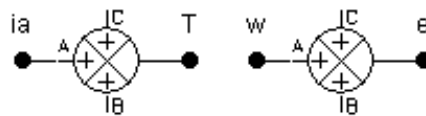

Fig.3: EWB models of developed torque and back EMF

Assembling all the created circuits together performs the final EWB model of the DC motor shown in Fig.4.
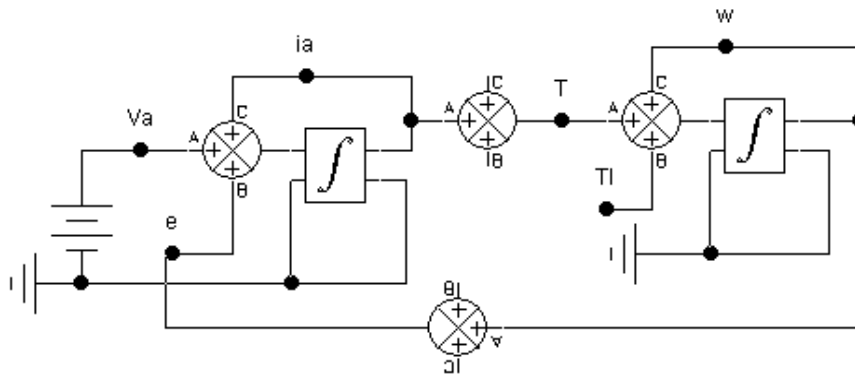

Fig.4: EWB model of separately excited DC motor

IV. SIMULATION RESULTS

This section presents simulation results of the speed control of separately excited DC motor using the proposed EWM model. The no-load start up curves of angular speed and armature current are plotted. Also the speed -torque characteristics are investigated. For rated parameters of the motor listed in Tab.1, the speed time response and the armature current time response are obtained as shown in Fig.5.
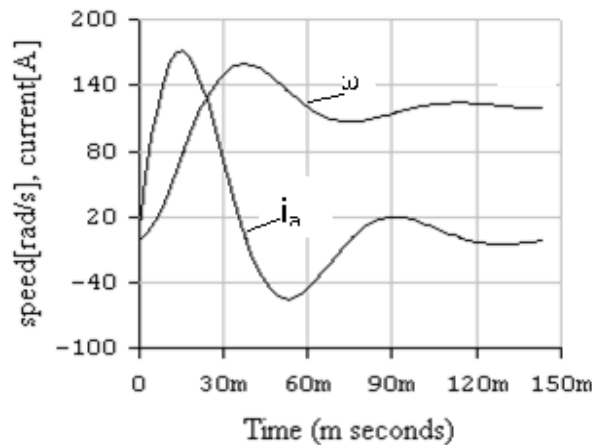

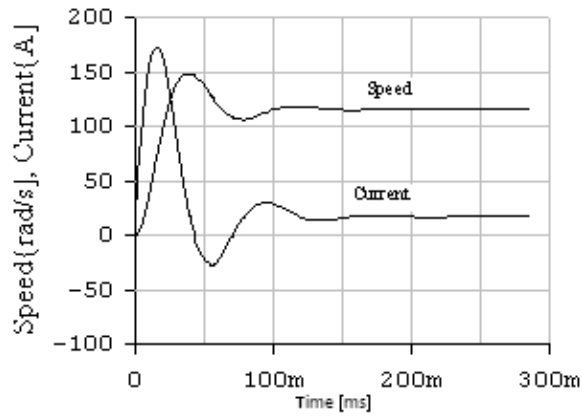***Fig.5.1:*** EWB model no-load start up time response for rated parameters

Fig.5.2: EWB model full-load start up time response for rated parameters

The same time response with no- load is obtained modelling the motor on MATLAB/SIMULINK as shown in Fig.6.
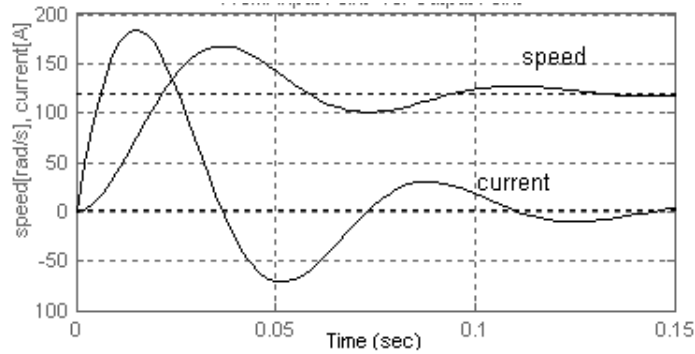

Fig.6: MATLAB/SIMULINK EWB model No-load start up time response for rated parameters.

Comparison of time response curves on Fig.5 and on Fig.6 shows a complete conformity between them, so we can conclude that the developed EWB model is accurate and will be used in speed control of DC motor.

To investigate torque speed characteristics the same EWB model is used with ramp applied torque to the shaft of the motor, and time base positioned to 1sec/div with X position to A/B. This characteristic is shown on Fig.7 and checked by calculation using the following formula:

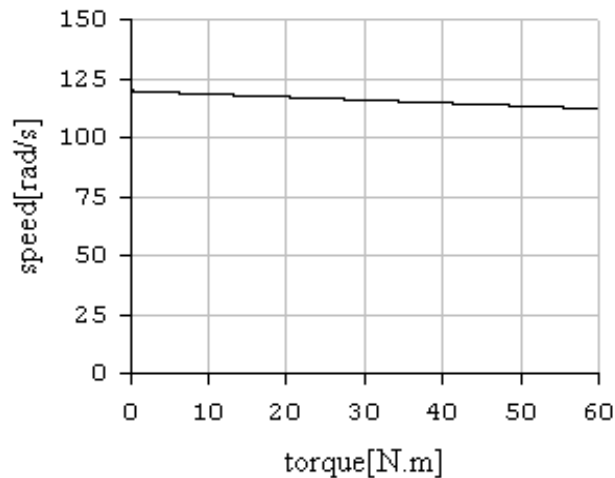$$\omega = \frac{k\Phi\,V_a - R_a T_L}{(k\Phi)^2 + R_a B}$$ (7)

Fig.7: Speed -torque characteristic for rated parameters

The speed of the motor can be controlled varying the armature voltage, setting this voltage to half its rated value (120 V); the time response is obtained as shown in Fig.8, and the steady state response in Fig.9.
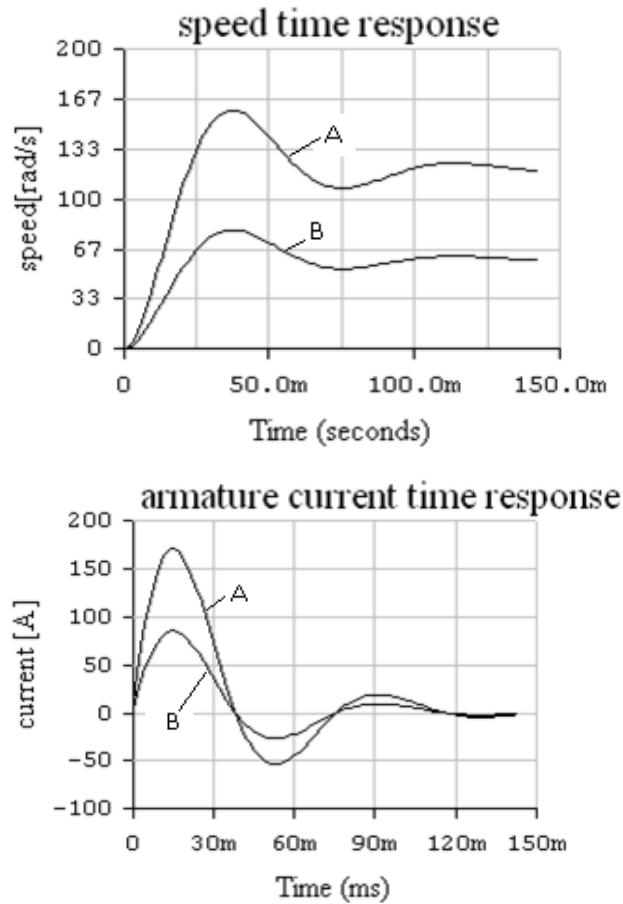

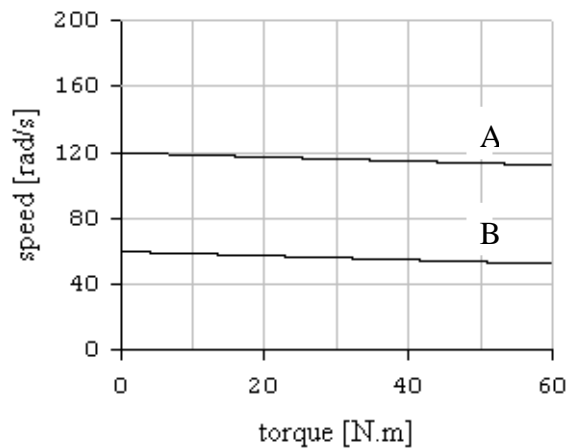**Fig.8:** EWB model n start up time response for: (A) V_a = 240 V, (B) V_a = 120 V

Fig.9: EBW model speed- torque characteristic for: V_a = 240 V, (B) V_a = 120 V

During transient period, the speed of the motor and the armature current are reduced proportional to reduction of applied voltage. This is true, because the model is linear and developed using linear equations. The no-load speed of the motor on the speed -torque characteristic is half its value at rated voltage, and the slope of the speed load curve remains constant.

In armature resistance speed control an external resistance (R $_{ex}$) is inserted in series with the armature circuit. In EWB model this can be done by varying input C gain of the three –way voltage summer in armature circuit. For R $_{ex\,=}$ R $_{a,}$ the time response and the speed torque characteristics are drawn in Fig.10 and in Fig.11 respectively. The speed time response and the armature current time response are slower than that for rated armature resistance, because the external

resistance decreasing the electromagnetic time constant and decreasing the damping ratio of the system. An increase of armature resistance results a significant increase in the slope of speed torque characteristic, while the no-load speed remains constant.
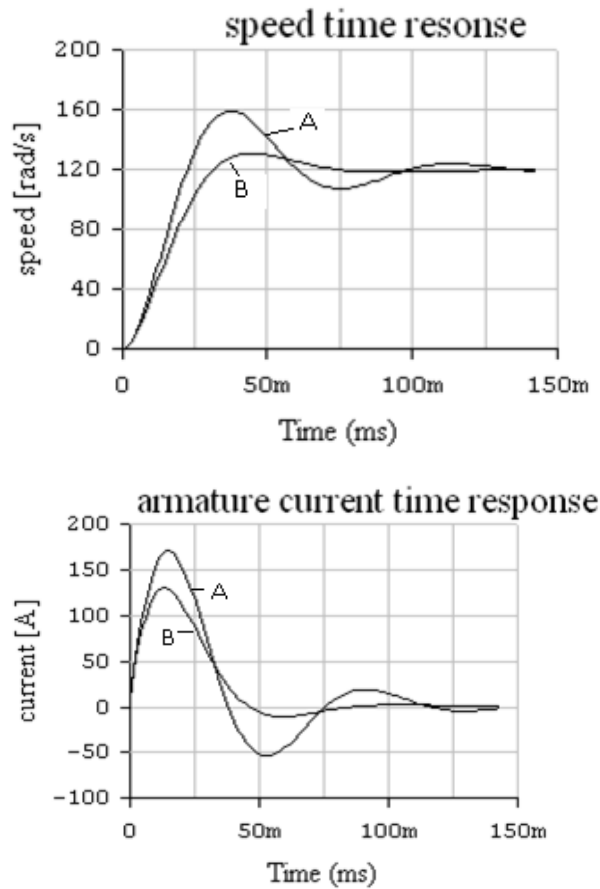

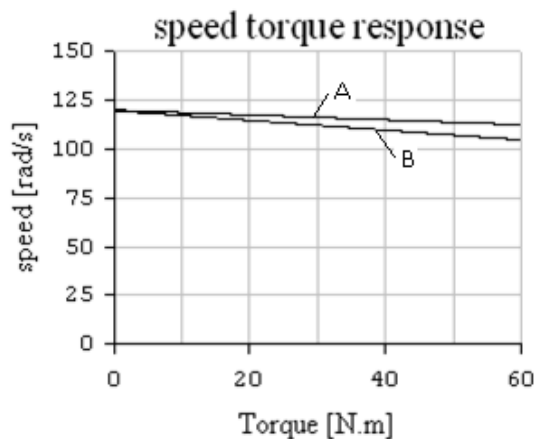**Fig.10:** EWB model no-load start up time response for: (A) $R_{ex}=0$, (B) Rex=R_a

Fig.11: EWB model speed torque characteristic for: (A) $R_{ex}=0$, (B) Rex=R_a

In the field speed control method a series resistance is connected in the field circuit of the motor. This additional resistance reduced the magnetic field by controlling the field current. Assume that the additional resistance is selected to reduce the magnetic flux to half its rated value ,i.e. KΦ =1.In EWB model this can be implemented varying the gain of equations (2) and (4).For this assumption the time response curves and the speed- torque characteristics are depicted on Fig.12 and Fig.13
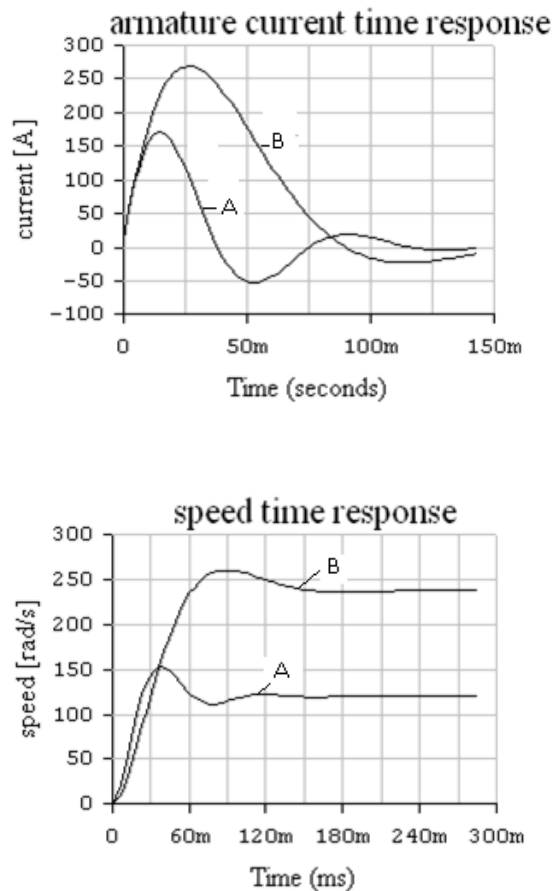
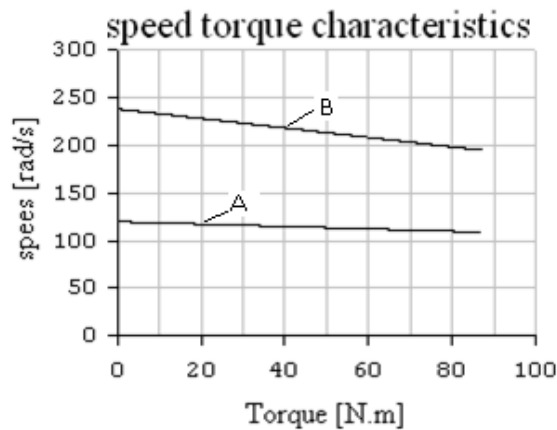***Fig.12:*** EWB model no-load start up time response for: (A) KΦ =2, (B) KΦ =1

Fig.13: EWB model speed torque characteristic for: (A) KΦ =2, (B) KΦ =1

Increasing the field resistance reduces the magnetic flux that results in less developed torque and slow time response, on speed -torque characteristic the no load speed is doubled and the slope is larger.

V.   CONCLUSIONS

Simulation model of a separately excited DC motor has been developed using EWB software .It has been shown that the proposed model correctly predicts dynamic and static characteristics of the motor. The same model could be used to study different speed control method during transient response and steady state response. This model has been successively integrated into an electric drive laboratory in Faculty of Engineering Technology. Future work will involve further development of simulation models for other type of motors.

REFERENCES

[1]. Saffet Ayasun, Gültekin Karbeyaz, "DC motor speed control methods using MATLAB/Simulink and their integration into undergraduate electric machinery courses," *Computer Applications in Engineering Education*, vol.15, Issue: 4, pp. 347-354, 2007.

[2]. Atul Kumar Dewangan, Sashai Shukla,and Vinod Yadu3, "Speed Control of a Separately Excited DC Motor Using Fuzzy Logic Control Based on Matlab Simulation Program," *International Journal of Scientific & Technology Research* ,vol.1, Issue 2, March, 2012.

[3]. Ioon Boldea, and S.A.Nasar, *Electric Drives*, 2nd ed., Taylor and Francis Group, 2006.

[4]. Hoang Le-Huy, "Modeling and simulation of electrical drives using MATLAB/Simulink and Power System Blockset," *IEEE Industrial Electronics Society,* vol.3 , pp.1603 – 1611, 2001.

[5]. Sarat Kumar Sahoo, Ashwin Kumar Sahoo, and Razia Sultana, "LabVIEW Based Speed Control of DC Motor using Modulus Hugging Approach," *European Journal of Scientific Research*, vol.68, No.3, pp. 367-376,2012.

[6]. S.B. Dewan, G.R. Slemon , and A. Straughen, *Power Semiconductor Drives*, John Willey, 2011.

[7]. Electronic Work Bench tutorial, Avaiable:http://www.physics.udel.edu/~nowak/phys645/EWB_tutorial.pdf/