Dynamic Simulation of a Load System Driven by Two Identical PMDC Motors

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Abstract – In this study, dynamic simulation of a load system driven by two identical permanent magnet direct current (PMDC) motor is performed by MATLAB / SIMULINK. In the dynamic simulation, two equivalent motors are tandem operated both at same voltage and different voltages in order to drive a mechanical load. The current of each motor, total induced torque and steady state speed of the entire drive system are obtained. It is seen that, when the motors are supplied by the same voltage they share the load equally. On the other hand, if they are operated with different voltages, the motor which is supplied with lower voltage always operates as a generator and the motor which is supplied with higher voltage is overloaded in order to supply the other one and drive the mechanical load.

Key words – pmdc motor, mathematical model, dynamic simulation, tandem operation

I. Introduction

PMDC machines have a wide range of use particularly in low-power applications because of many advantages. For instance PMDC machine's construction is simple and these machines are smaller in size. PMDC motors' excitation field is provided by permanent magnets so there is no need to additional sources and construction for excitation. PMDC motors are widely used in many driving system especially in electric vehicles [1, 2].

Dynamic simulation is one of the key steps in manufacturing a prototype machine. It exposes the probable design mistakes so that it would be possible to fix them before the production of prototype [3].

Although tandem operation of electrical machines is not a frequent application, it would be useful in electrical vehicles. In this study dynamic simulation of a load system driven by two equivalent PMDC motors is performed. This study is the first step in the investigation of load sharing in PMDC motors and it would lead to a mechanical regenerative braking application.

II. Mathematical Model of PMDC Motor

At first, the mathematical model of a single PMDC motor must be obtained, in order to double it for building a mathematical model of tandem drive system. For this purpose, the state equation given in Eq. (1) should be used. In the equation V is supply voltage, R is armature resistance, i is armature current, L is armature inductance, E is induced voltage and ΔV_b is voltage drop in brushes of the motor [1-4].

$$V = R \cdot i + L \cdot \frac{di}{dt} + E + \Delta V_b \qquad (1)$$

The induced voltage in Eq. (1) can be defined by the expression given in Eq. (2). In the equation, k_e is induced voltage constant and w is the shaft speed of the motor [1-4].

$$E = k_e \cdot w \qquad (2)$$

III. Mathematical Model of Tandem Drive System

The connection scheme of the tandem drive system is given in Fig.1. The shafts of the two motors and load come across as given in the figure.

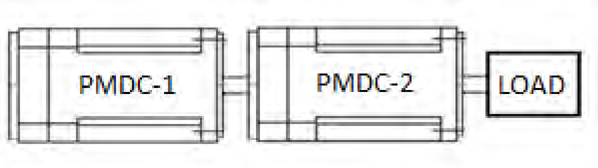

Fig. 1. Connection scheme of the tandem drive system

After preparing a trustable model of a single PMDC motor, this model is doubled and mathematical model of the tandem drive system is obtained. The mathematical model of the tandem drive system is given in Fig.2.

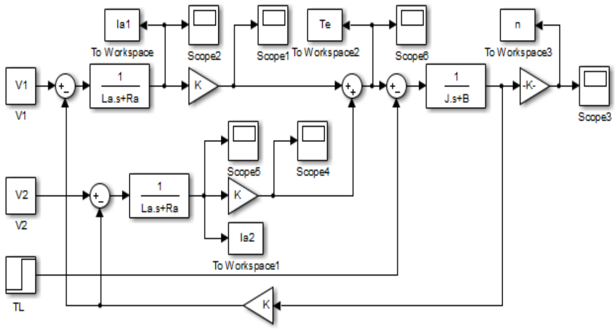

Fig. 2. Mathematical model of the tandem drive system

In the tandem drive system model, the induced torque values of each motor are summed to reach to the total induced torque. After that torque-speed equation can be written as given in Eq. (3). T_{e1} and T_{e2} are the individual induced torques of PMDC motors, T_L is the load torque, J_t is the total inertia of the load and the two motors and B_t is the total damping coefficient similarly [5-7].

$$T_{e1} + T_{e2} - T_L = J_t \cdot \frac{dw}{dt} + B \cdot w \qquad (3)$$

Total inertia of the system can be obtained by summing the inertias of two motors and load as given in Eq. (4) [5-7].

$$J_t = J_1 + J_2 + J_L \qquad (4)$$

Similarly total damping coefficient can be obtained by the summation of all damping coefficients in the system as given in Eq. (5) [5-7].

$$B_t = B_1 + B_2 + B_L \qquad (5)$$

IV. Simulations and Results

The simulations are performed in two different sections. In the first section motors are supplied by same voltage and in the second section the motors are supplied by different voltage. An existing PMDC motor's parameters are used in the simulation. Some parameters of the motor was not given in datasheet, such as voltage drop in brushes, damping coefficient and induced voltage constant. These values are calculated over other given parameters. In addition to that some assumptions are made in the model. The magnetic circuit is assumed to be linear. Air gap between armature and excitation is assumed to be uniform. Finally the eddy currents and the iron losses are neglected. After completing simulations, operational characteristics of the scenarios are given with graphs.

A. Same Supply Voltage

In this section two motors are supplied with same voltage. As two motors are identical it expected that two motors must share the load equally.

This section has two subsections. First the entire system is loaded with the rated torque of a single motor which is equal to 20N.m. In Fig.3, Fig.4 and Fig.5, variation of current of each motor, total induced torque and shaft speed of the system with respect to time are given respectively.

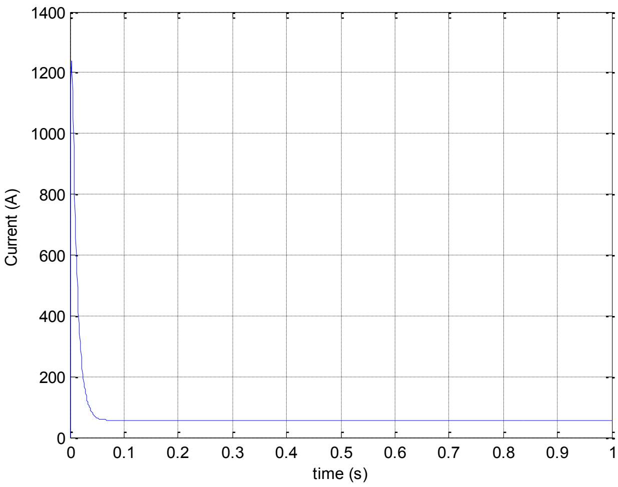

Fig. 3. Variation of current of each motor (20 N.m.)

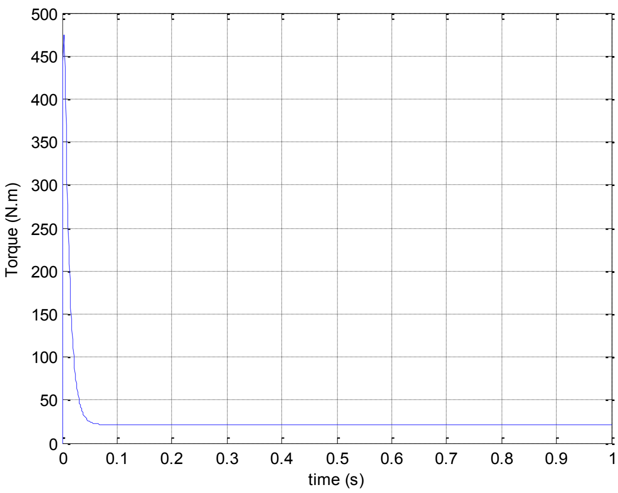

Fig. 4. Variation of total induced torque (20 N.m.)

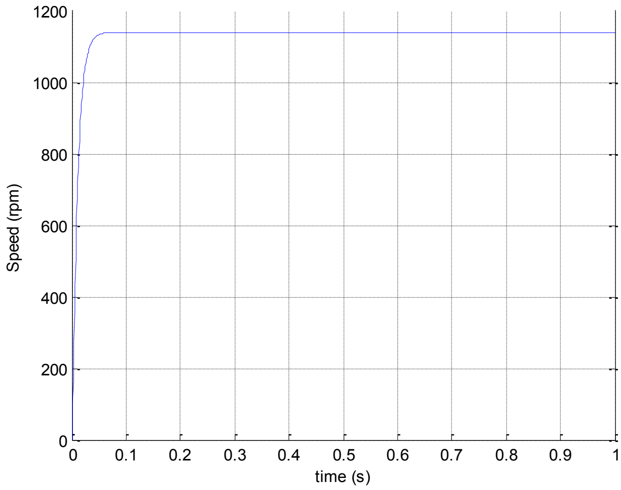

Fig. 5. Variation of shaft speed (20 N.m.)

In the second subsection, the entire system is loaded with the sum of rated torque values of two motors that is equal to 40N.m. In Fig.6, Fig.7 and Fig.8, variation of current of each motor, total induced torque and shaft speed of the system with respect to time are given respectively.

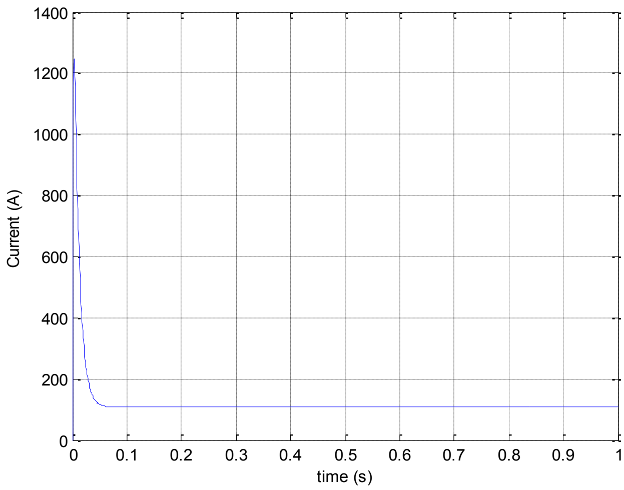

Fig. 6. Variation of current of each motor (40 N.m.)

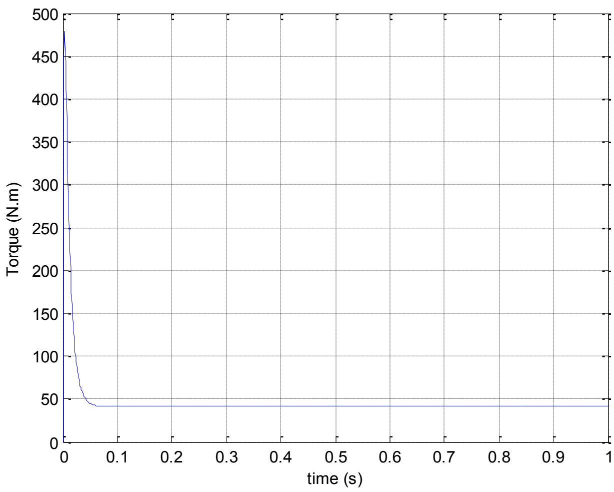

Fig. 7. Variation of total induced torque (40 N.m.)

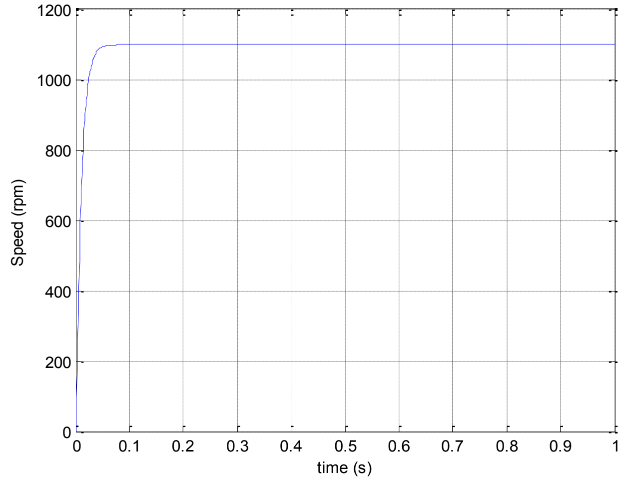

Fig. 8. Variation of shaft speed (40 N.m.)

In each case it is traced that the motors were able to drive the load and shared the load equally.

B. Different Supply Voltage

In this section, the first motor is supplied with 36V and second motor is supplied with 24V. Similar with previous section, the entire system is loaded first with 20N.m.

In the first stage the entire system is loaded with 20N.m. In Fig.9 current of the each motor with respect to time is given.

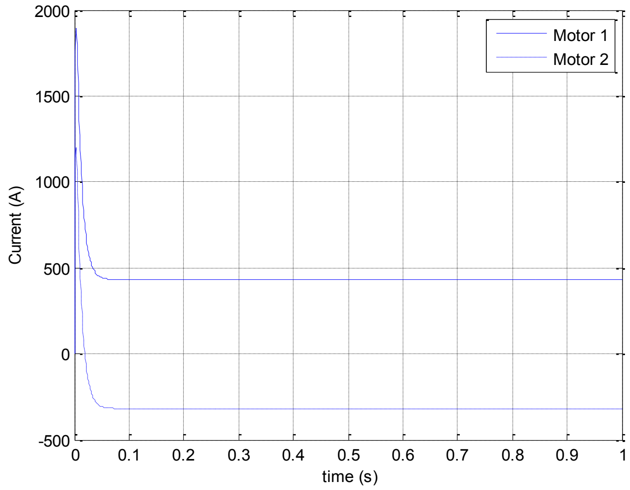

Fig. 9. Variation of current of each motor (20 N.m.)

As seen in the figure the current of the second motor is negative which indicates that it is operating as a generator. For this reason first motor must supply both the load and the second motor which is operating as a generator. This condition causes overloading in first motor. The system has a theorical and mathematically calculable operating point which has a definite total induced torque and shaft speed value. On the other hand individual currents of the motors indicates that it is not possible to operate the system in this condition as the currents of the motors are too high than rated values. Total induced torque and shaft speed of the system are given in Fig.10 and Fig.11 respectively.

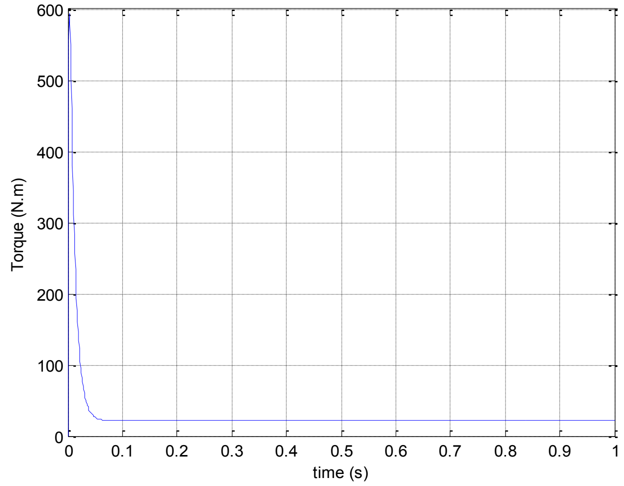

Fig. 10. Variation of total induced torque (20 N.m.)

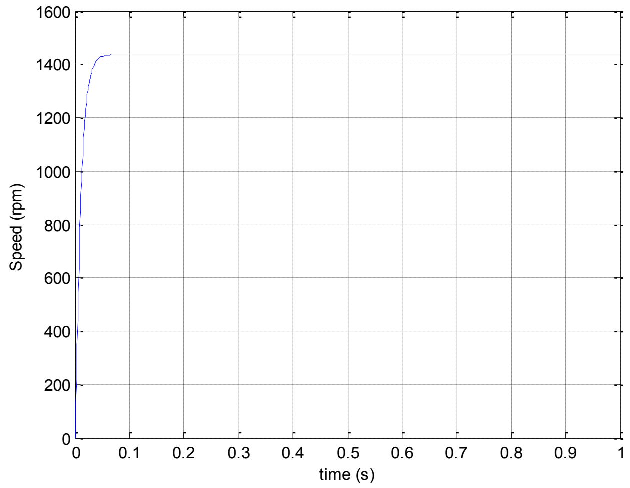

Fig. 11. Variation of shaft speed (20 N.m.)

In the second stage the system is loaded with 40N.m, but the results are similar with the previous stage. For this reason the results of the second stage are not given graphically.

Conclusion

In this study, dynamic simulation of a load system driven by two identical PMDC motors is performed. At first mathematical model of a single PMDC motor is obtained then this model is doubled in order to realize the mathematical model of the tandem drive system. An existing PMDC motor parameters are used for simulation with some assumptions such as, neglecting iron losses, assuming magnetic circuit as linear and air gap is uniform. After the realization of the mathematical model, various simulations are performed. Simulations are classified in two main groups.

In the first stage, same supply voltage is applied to each motor. The system is loaded with 20N.m. and 40N.m. individually. It is traced the tandem drive system was able to drive the load successfully and share the load equally in each case.

In the second stage the motors are supplied with different voltages. The system is loaded with 20N.m. and

40 N.m. respectively. It is traced the system is operating with a speed which is between the rated shaft speed values that corresponds to each voltage level. As far as the motors are identical, the induced voltage is same in each motor. On the other hand this induced voltage value is higher than the supply voltage of the motor which is supplied with lower voltage. For this reason in such case the motor which is supplied with lower voltage will operate as a generator. In addition to that it will become a load for the other motor so the other motor will have to drive both the load and the motor which operates as generator in that condition. This situation will result with overloading of the other motor.

As a conclusion, in such cases which identical motors are driving same load their supply voltages must be equal, otherwise some of them would operate as generator which leads others to overload. When they are supplied with same voltage they can easily drive the load with equally load sharing.

The obtained model can be successfully used for the simulation of tandem system build of PMDC motors which are not identical. The future of the study will be directed on this issue.

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