MODELLING OF BIDIRECTIONAL DC/DC CONVERTER

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Abstract
In the current paper a model of bidirectional DC/DC converter is developed. The proposed model is composed by a separately excited DC motor, a buck-boost converter and a proportional-integral (PI) regulator. The solution is described with the aid of system of differentials equations and realized in the visual environment MATLAB/Simulink. Basically, two operation modes are studied: acceleration mode and braking (regenerative) mode. From the presented and discussed results it might be observed that the model is suitable for multiple applications such as electric vehicles and electric drives. In further researches the control of energy flows between multiple energy storage devices connected to DC bus is considered.

Keywords: bidirectional DC/DC converter, DC motor, mathematical modelling.

INTRODUCTION

Recently, the usage of a bidirectional DC/DC converter are widely distributed for multiple applications such as electric vehicles (EVs), battery charging and discharging devices and etc. The bidirectional dc-dc converters are the basic components of the systems in electric vehicles. The usage of a buck-boost dc-dc converter with DC motor are commonly used structure in electric vehicles (EVs) applications which enable control of the system in two operation modes: acceleration and regenerative braking. Nowadays, multiple bi-directional DC-DC converter topologies used a soft switching control strategy for increasing the efficiency in electric vehicles applications [1-3].

MATHEMATICAL MODELLING

A block scheme of the studied system composed of DC motor, buck-boost converter, battery and control system is presented on Fig.1.

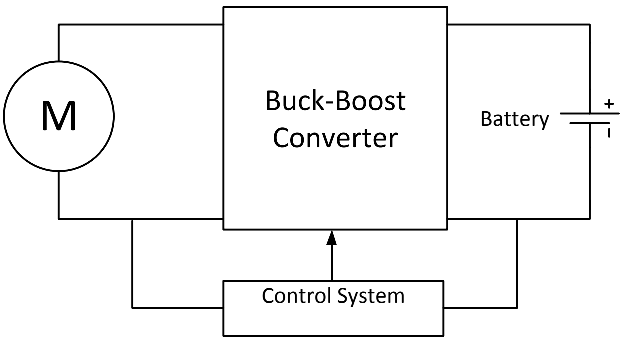

Fig. 1. *Block scheme of the studied system*

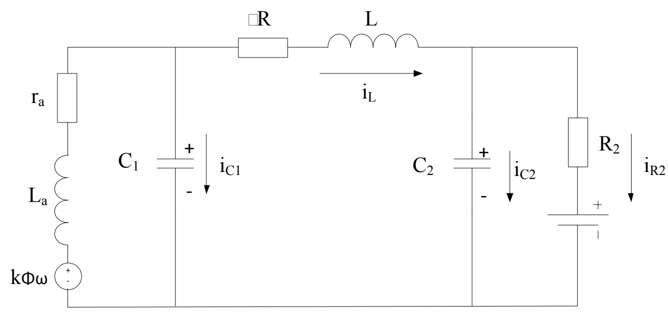

Fig. 2. *Equivalent circuit of the buck-boost converter and DC motor*

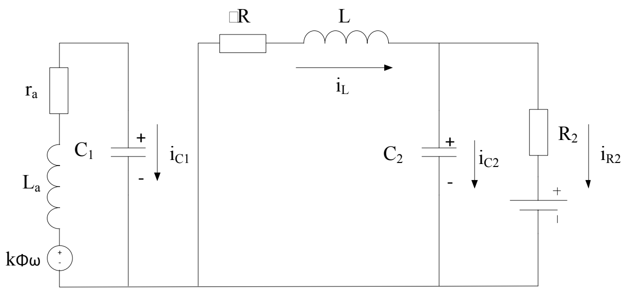

***Fig. 3.** Equivalent circuit of the buck-boost converter and DC motor*

$$
\begin{aligned}
&L\frac{di_L}{dt}=E_d\\
&C_{UC}\frac{dU_{UC}}{dt}=i_T\\
&L_T\frac{di_T}{dt}=U_{LT}=U_{UC}-R_Ti_T-Ke\omega
\end{aligned}
\qquad (1)
$$

$$
\begin{aligned}
&L\frac{di_L}{dt}+U_{UC}=0\\
&C_{UC}\frac{dU_{UC}}{dt}=i_L
\end{aligned}
\qquad (2)
$$

$$r_a i_L + L_a\frac{di_L}{dt}+k\Phi\omega=U \qquad (3)$$

$$J\frac{d\omega}{dt}=Ki_L-M_c \qquad (4)$$

Where r_a is the armature resistance of the motor, L_a is the armature inductance, $k\Phi\omega$ is the back emf of the motor, ΣR is the sum of the internal resistances of the switches and the inductance, J is the inertia, ω is the angular velocity of the motor, M_c is the resistant moment.

The mathematical model is realized in MATLAB/Simulink and presented on Fig. 4.

The control system is composed by a proportional-integral regulator and operate in two modes accelerations and regenerative braking. The reference is set to control the torque of the DC motor. If the reference is higher than the necessary rounds per minute (i.e. the error is negative) the model operate in acceleration mode. Hence, the duty cycles of the switch S_1 varying in the limits from 0 to 0,5. Otherwise, if the error is positive, than the model operates in regenerative braking and the duty cycle of switch S_2 varying in the limits of 0,5 to 1.

SIMULATION RESULTS

The simulation results are presented in the following figure 5 to 9 with duration of 100 s. It is observed the acceleration mode, establishing the definite linear velocity and regenerative braking.

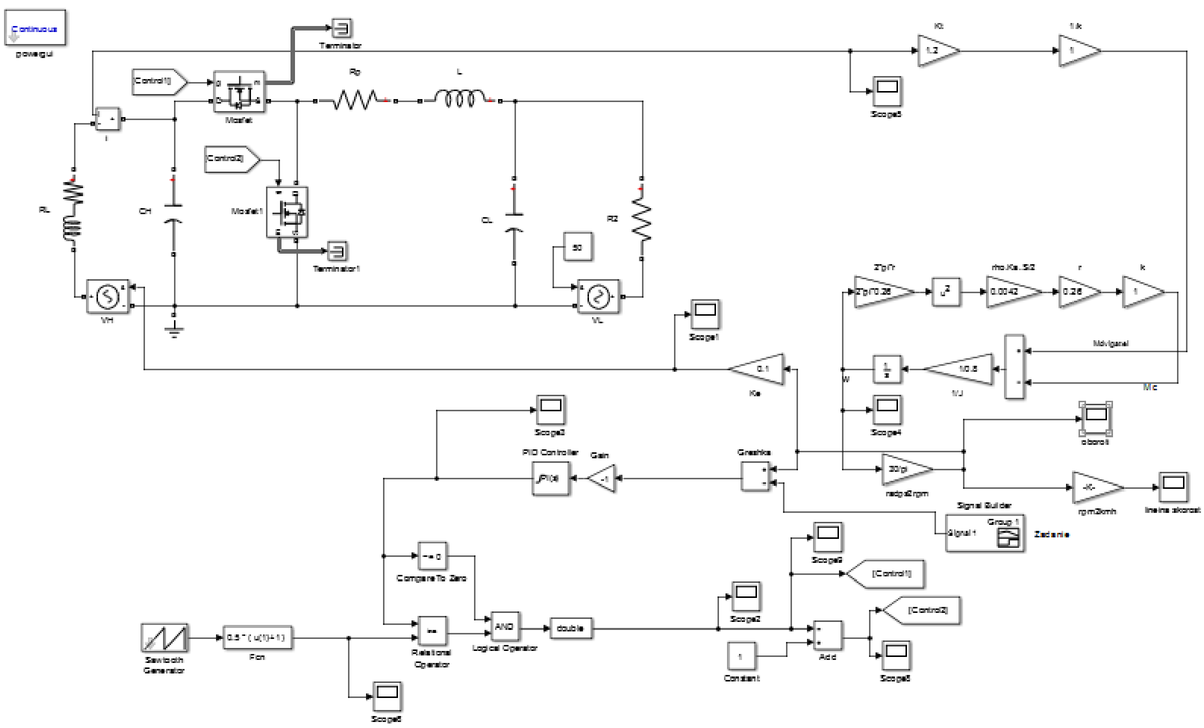

***Fig. 4.** Scheme of the simulation in MATLAB/Simulink*

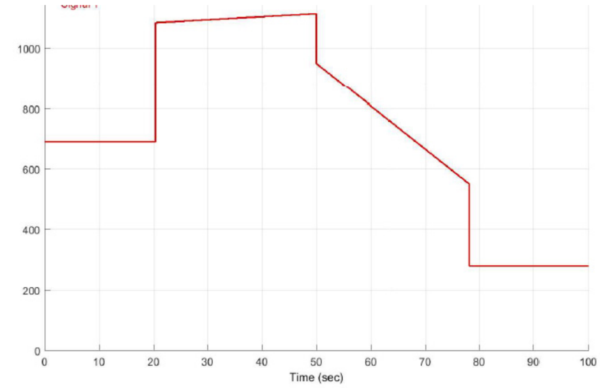

Fig. 5. *Reference of torque in rounds per minute*

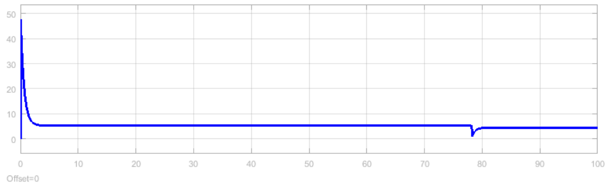

Fig. 6. *Current of the DC motor*

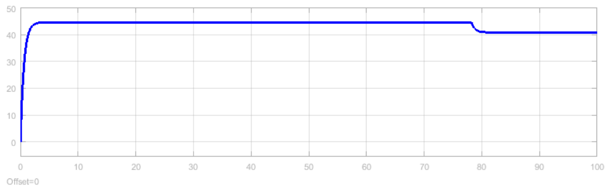

Fig. 7. *Voltage of the DC motor*

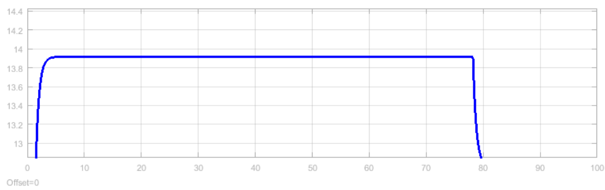

Fig. 8. *Velocity of the electric vehicle*

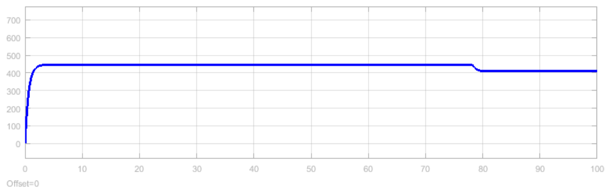

Fig. 9. *Rounds per minute of the of DC motor*

CONCLUSION

A mathematical model of bidirectional DC/DC converter for applications in electric vehicles is presented.

The solution is described with the aid of system of differentials equations and realized in the visual environment MATLAB/Simulink. Basically, two operation modes are studied: acceleration mode and braking (regenerative) mode.

In further researches the control of energy flows between multiple energy storage devices connected to DC bus is considered.

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