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Design and Implementing of a Buck Dc-To-Dc Converter into the DC Motor's Speed Controller in Matlab/Simulink

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ABSTRACT

This paper presents a method for controlling the speed of a DC motor that is energized individually by utilizing a DC-DC Buck converter that is fed from a DC source. It can be easily controlled with the help of different types of DC-DC converters. This project was introduced a study and analyses of the buck DC to DC converter with PID controller cascaded with DC motors which is simulated in MATLAB. The required speed of the DC motor can then be obtained by giving a variable regulated voltage to the armature of the DC motor. A controller of the proportional-integral type is utilized so that the user can adjust both the amount of current flowing through the DC motor as well as the rate at which it rotates. These controllers allow for a quick control response. In addition to that, this paper presents a Simulink model for a DC motor that was created with Matlab Simulink. The purpose behind the development of the current and speed controller was to achieve stable and high-speed control of the DC motor. The final step is the display of the simulation results for the proposed system, which show that they are consistent with the expected results. This paper shown the DC motors was able to reach the necessary speed within a few attempts; however, as the load rose, the settling time increased as well.

1. Introduction

DC motors have been used in industry as variable speed drives, and they give high starting and torque, both of which are required in certain applications such as rolling mills and traction drives. In addition, DC motors have been used in industry as variable speed drives. Controlling DC motors over a broad speed range is easier and less expensive than controlling AC motors of the same range. There are a variety of approaches to managing the speed of a DC motor; however, the armature voltage control and the field control are the approaches that are utilized the most frequently.

A typical controller is utilized in a number of today's driving systems. This controller performs well, but only under a particular set of load conditions and system characteristics that are already well known to it. However, if the system parameters or load circumstances deviate from their known values in any way, the performance of the closed loop system will suffer. This will result in higher overshoots and undershoots, longer rise and settling periods, and maybe even an unstable system. It is important to keep in mind that the other parameters, such as the system inertia and damping ratio, are subject to wide ranges of variation as a direct result of changes in the load conditions. DC motors are ubiquitous electromechanical energy converters. Printers and rolling mills use it. Despite their potential use in real-time software development, technologies for building and analyzing control systems are generally concealed from public access. Some problems can be fixed with hardware, while others

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require advanced software. Control systems can be easily and thoroughly analyzed. DC motors come in several sizes and speeds, making them versatile. If a DC motor's armature circuit is linked directly to a DC power source, startup armature current will be high. This high cost is due to the motor's lack of regenerative braking (EMF). Back electromotive force increases with motor speed. High armature current harms DC motors in several ways (shortened lifespan, erroneous activation of motor protection systems, etc.). Bridge rectifiers and massive filter capacitors convert ac to dc. Harmonic currents and invariable dc voltages are drawbacks. For dc motor drives, controlled bridge rectifiers need several switching circuits. PWM-based switching devices fix this. Single-switch buck-boost converters create variable voltage. The converter circuit is simplified. Duty cycle ratio can be used to pulse a switching device based on the reference output voltage. DC motors have high initial armature current. Because no back emf. Speed impacts back emf. High armature current can damage and decrease motor life. Traditional treatments involve limiting the current with a resistance and removing it after it stabilizes. Startup wastes energy, but armature current may be regulated. Source voltage and circuit resistance limit armature current. Power electronics circuits can help. Chopper circuit hysteresis. Hysteresis control maintains two thresholds.

Back emf and armature current affect motor speed. Armature current governs dc motor speed. To limit armature current, a PI controller converts reference voltage into reference current. This work creates a simulink model. First, the ac-dc buck-boost converter is tested. PWM and voltage control followed. This paper explains input and output. Research shows that a dc motor's soft starter manages startup inrush current. MOSFET-based dc motor drive with hysteresis current regulation is the soft starter. Speed controllers are created based on soft starter performance. The system's two switches reduce installation costs and energy loss. Adding a starting resistor [1] to the motor armature circuit fixes this. When the motor accelerates, remove the starting resistor. Each start-up wastes energy, even if the armature current can be adjusted. DC-DC converters lower or boost the DC input level on uncontrolled power supplies. Step response, impulse response, and the Bode plot represent DC motors in MATLAB/Simulink [2, 3]. Simple. DC motor features are evaluated using MATLAB and design calculations. You can choose any DC motor based on MATLAB modeling. Control and motor technology cause time difficulties. MATLAB's Modeling and Simulink can be utilized for high-tech control analyses. Fewer maths. Dc-Dc converters power electric cars, trolleys, ship hoists, and forklifts. Easy, quick, and enjoyable. DC-to-DC converters dc-dc converters convert fixed- to variable-voltage dc. The dcdc converter's output voltage can be increased for regenerative braking of dc motors. This feature saves energy in idling vehicles. buck, boost, and buck-boost are DC-DC converter types (step up-step down). Convertor fuzzy logic. Simple linguistic rules can be used to contribute expert knowledge to the fuzzy controller without having the converter's mathematical models. Voltage error, voltage error change, and duty cycle are inputs. dc-dc Buck and Book converters power and control BLDC motor speed (300 rpm). This model uses dSPACE and Simulink. The DC motor is operated by passing the MATLAB signal to the gate of the transistor in the converter. Buck and Boost converters use GaN and SiC transistors to control BLDC motor speed. First, we'll discuss how to regulate a DC motor's speed with MATLAB Simulink and dSPACE. [8] State space models include inputs, outputs, and variables. DC motors with several inputs and outputs are straightforward to examine. Simulink and MATLAB steady-state equations showed DC motors and DC-DC converters in this project. Combining building-block models and simulations.

2. Buck converter

The speed of an independently stimulated DC motor has been controlled through the use of Simulink by carefully researching and designing three fundamental types of converters. The following are the types of converters available: buck converters, boost converters, and buck boost converters. We are going to refer to "Converter Transfer Functions. In: Fundamentals of Power Electronics" by Erickson RW and Maksimovi D. in order to derive the transfer function so that we can simulate the transfer function of the buck-boost converter. This will allow us to simulate the transfer function of the buck-boost converter. The buck-boost converter's two transfer functions, on which our attention will be focused, are as indicated below:

$$\boldsymbol{G_{vd}(s)} = \frac{\boldsymbol{V_g}(\boldsymbol{s}\frac{\boldsymbol{DL}}{\boldsymbol{R}} - \boldsymbol{D^*})}{\boldsymbol{D^{*2}}(\boldsymbol{s^2LC} + \boldsymbol{s}\frac{\boldsymbol{L}}{\boldsymbol{R}} + \boldsymbol{D^{*2}})} \quad (1)$$

$$G_{vg}(s) = -\frac{D}{D^*}\frac{1}{(s^2\frac{LC}{D^{*2}}+s\frac{L}{D^{*2}R}+1)} \quad (2)$$

For a DC motor, a buck converter and their equivalent circuit are depicted in Fig. 1. Here, we have a binary representation of all system parameters: the input voltage E, the value stored in the inductor L, the capacity of the capacitor C, the forward voltage of the diode D, and the switching action of the inductor L. The armature windings of a DC motor have both inductance Lm and resistance Rm. The electromotive force (E) and torque (tk) constants of a DC motor are also important quantities. Other DC motor parameters include the angular velocity (), load torque (TL), moment of inertia of the DC motor (J), and coefficient of viscous friction (f).These converters, which are illustrated in Figure 1, reduce the level of DC voltage and find widespread application in the regulation of DC motor speed as well as the provision of regulated DC power.

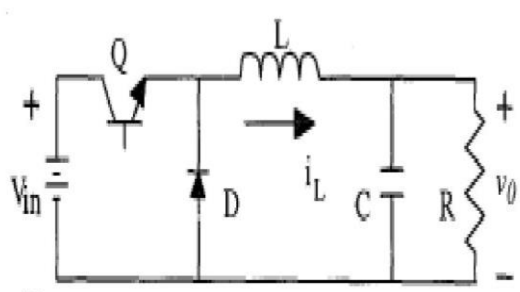

Figure 1. Buck converter

The outcomes of utilizing KVL and KCL are as follows:

$$\begin{cases}\frac{diL}{dt} = \frac{1}{L}(Vin - Vo) \\ \frac{dvo}{dt} = \frac{1}{C}\left(iL - \frac{Vo}{R}\right)\end{cases}, 0< t < dT, Q: ON \quad (3)$$

When the Switch is off:

$$\begin{cases}\frac{diL}{dt} = \frac{1}{L}(-Vo) \\ \frac{dvo}{dt} = \frac{1}{C}\left(iL - \frac{Vo}{R}\right)\end{cases}, dT < t < T, \ Q : OFF \quad (4)$$

Choice of DC motor in the fact that the field and armature characteristics can be changed independently is one of the most important advantages of employing a separately excited DC motor like the one shown in Figure.2. The steady state equations for the individually stimulated DC motor utilizing KVL and Newton's 2nd Law of Motion are provided below [14] with the assumption that there are no frictional losses or any losses related to copper or the core in the DC motor:

$$i_a(s) = \frac{1}{L_a s+R_a}\left[-L_{af} i_f(s)\omega_r(s) + V_a(s)\right] \quad (5)$$

$$i_f(s) = \frac{1}{L_f s+R_f}\left[V_f(s)\right] \quad (6)$$

$$\omega_r(s) = \frac{1}{Js}\left[L_{af} i_f(s) i_a(s) - TL\right] \quad (7)$$

As shown in Figure 2, these equations have now been made operational in Simulink with the assistance of a variety of library blocks.

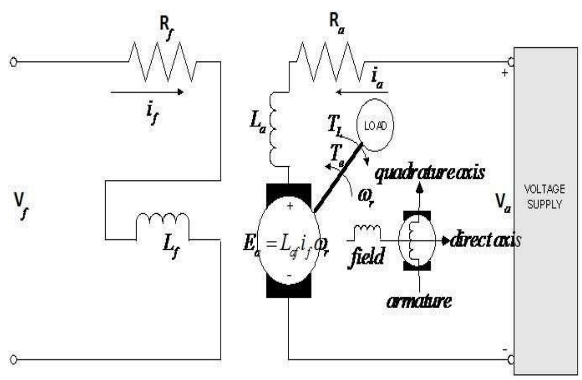

Figure 2. Direct current motor that is excited separately.

3. Matlab Simulink Modeling

In this paper a MATLAB Simulink was used to regulate the Buck converter's output frequency. The BLDC motor's analog impulses needed to be converted to digital form before they could be processed by Simulink, and this was only possible with the help of the dSPACE system. dSPACE was built with the DS1104 R&D Controller Board, CP1104 Connector Panel, and ControlDesk. Typical Velocity Used as a Benchmark The primary goal of the Simulink model's development was to programmatically cycle through multiple motor-speed configurations over certain time intervals. It was thought to use a pulse generator block or a stepped system, however neither of these options met the criteria. The motor is programmed to speed up by 10 percent every ten seconds, with a 0.1 second pause in between increases. The timeout gives the motor enough time to ramp up to the next preset speed. As can be seen in Figure1., the interval starts at 0 rpm and increases by 100 rpm, then 200 rpm, then 300 rpm before resetting to 0 rpm and starting the cycle over again. The advantage that the repeating sequence was able to provide, which was the purpose of this paper, was to make the control of the reference input very simple and straightforward.

4. DC motor with buck converter and PID

The overall speed control system for a DC motor was simulated, and it was shown in Figure 3 below utilizing a buck converter and a few helper blocks, including a current controller and a speed controller including a mean block.

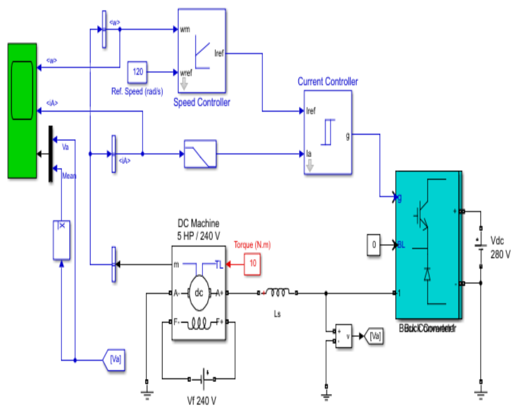

Figure 3. Simulation of overall speed control of DC motor

5. Results and discussion

Three different applied torque values (5 Nm, 10 Nm, and 20 Nm) were utilized to run simulations and compare the outcomes. When the load is 5, 10, or 20 N.m, as shown in Figure 4, the speed reaches the target value of 20 Rad/sec, but it does so in a different time-stable area.Stability was achieved in 0.2 seconds when the load was 5 N.m, 0.24 seconds

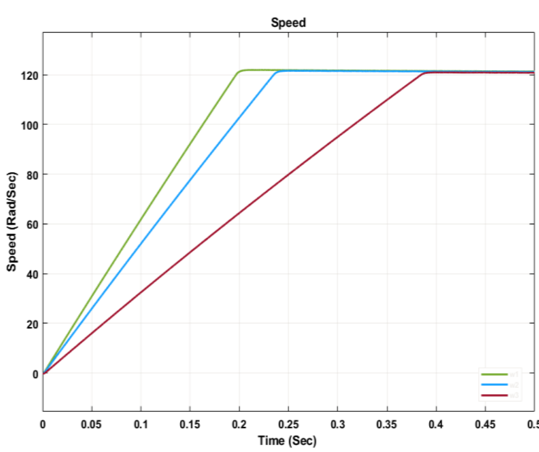

Figure 4. Speed response with time

when the load was 10 N.m, and 0.016 seconds when the load was 20 N.m (0.375 Sec). DC motor speed response at 5, 10, and 20 Nm of load, shown in Figure4 . it shows the armature current response when the load is varied (5,10,20 N.m). The armature current is proportional to average torque [6, 10, 17] A.

Figure 5 illustrates the average voltage that was applied to the DC motor as the load grew from five to ten to twenty Newton-meters. When the load was increased by 152, 155, or 158 V, we can observe that the mean voltage increased only a very modest amount. This occurred during the same period of stable time that was described earlier.

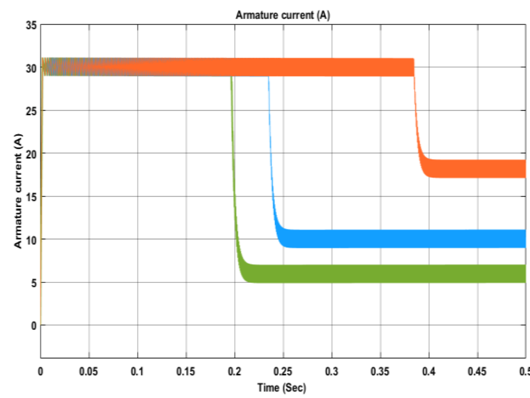

Figure 5. Armature current response for DC motor with 5,10,20Nm loads.

The average voltage that was applied to the DC motor is shown in Figure 6 and it changed as the

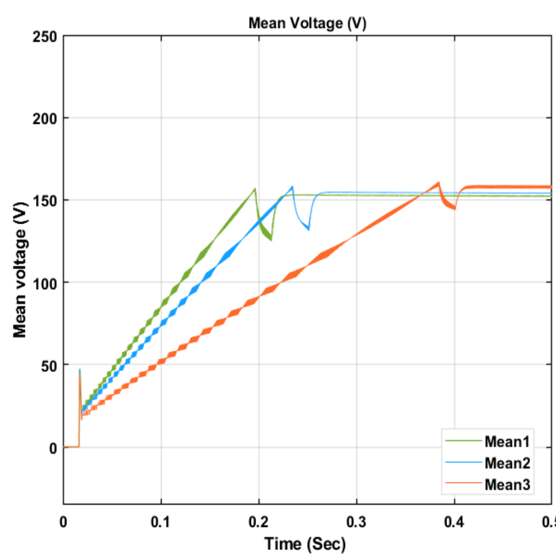

Figure 6. mean voltage response for DC motor with 5,10,20Nm loads.

load amount. This occurred during the same period of stable time that was described earlier grew from 5 to 10 to 20 Nm. When the load was increased by 152, 155, or 158 V, we can observe that the mean voltage increased only a very modest.

Figure 6 depicts the mean voltage that was applied to the DC motor when it was under loads of 5, 10, and 20 Nm.

6. CONCOLSION

In this study, an attempt was made to examine this particular converter by utilizing MATLAB Simulink in conjunction with a DC motor. The buck converter is one type of the many DC to DC converters. The PI controller is used to govern the actual speed relative to the reference speed, and it is also responsible for obtaining the reference armature current, which is then compared with the actual reference current in the current controller block. The output was put to use as a switching mechanism in order to design the functioning point of the transistors that are utilized in the buck converter. According to the findings of the simulation, when we applied a load of 5 Newton-meters, the DC motor was able to reach the necessary speed within a few attempts; however, as the load rose, the settling time increased as well. Additionally, the armature current was raised when the load was increased, which added to the already higher voltage that was being applied to the DC motor by the buck converter.

Nomenclature

Vin	Input voltage
Vo	Output voltage
i	current
L	inductance
c	capacitance
R	resistance

Acknowledgements

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