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Electric Motor PSPICE Simulation

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Abstract:
DC motors are still the commonly used machines as variable speed drives. The methods used for modeling DC machines are far simpler and more straightforward than those used for modeling AC machines. Especially, since developments in the design of controlled rectifiers and DC–DC converters, the control of DC motors is realized more quickly. The motor contains mechanical variables and components in armature circuit and the output circuit. Besides, The electrical equivalent circuit has the same equation structure with the mechanical system. By using the correlation of equations, all of mechanical variables and components are indicated regarding electrical circuit elements and electrical variables. Even though the DC motor system contains mechanical components and variables, all variables and components in the model are electrical. The desired variable voltage is achieved by a controlled rectifier or DC–DC converter. In these motors, The armature current, field current, torque, and flux are controlled separately from each other. It lets motors get high performance. Therefore, in the control of the motor, the field current is used as a constant value. Besides, the motor drive system is controlled by only one variable, armature current. The main objective of this experiment was to develop a control system to create the speed profile given with the motor given. A load and motor were to be simulated by using PSPICE with a given speed profile. The control system was to be designed with an inner current loop and an outer speed loop. The system included the load, DC motor, and DC-DC converter.

1. Introduction

The system was mainly composed by the load, the motor, the gain representing the PWM converter, the current controller, and the speed controller. The system adopts the closed loop (P) regulator to implement control. The system was simulated to move a load through a desired speed profile. Moreover, the system was composed of an electrical system and a mechanical system as shown in Figure 1. In the electrical system, a DC motor was fed from a switch mode dc-dc converter controlled by the current and speed loop controller. The armature voltage was modeled by a V_{PWL}. The motor armature winding was modeled using a voltage controlled source block, a resistor, and an inductor. The mechanical system was modeled using a current controlled source block. The inertia load was modeled by a capacitor, and the damping coefficient was modeled by a resistor. A software usable in electrical engineering must be able to simulate mechanical system. This does not necessarily constitute an initial feature. We did however accomplish this by using a classical analogy between mechanical and electric system.

Mechanical System	**Electrical System**
Speed	Voltage
Torque	Current
Rotational inertia	Capacitance of a capacitor
Viscous friction	Reciprocal of a resistor
Elastic connection	Reciprocal of an inductance

Table 1: Variables of mechanical and electrical system

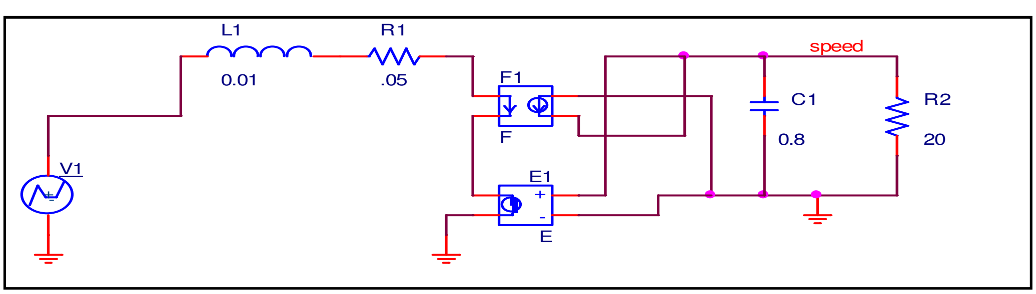

Figure 1: PSPICE model of electrical and mechanical system

2. Procedure

In this experiment, a motor was controlled by simulating the control system driven by a DC-DC converter for a given speed profile as shown in Figure 2. The V_{PWL} was set up with armature voltage and the time. Then, linked the V_{PWL} with the armature inductance and armature resistance in series. Next, the capacitor in the load was used instead of load inertia (j_L), and the resistor was used instead of damping coefficient. As seen in Figure 3, the inner current control loop was designed using a proportional controller. The current output profile was simulated by PSPICE illustrated in Figure 4. After that, the outer speed loop controller was designed with a proportional controller. The control system used to combine an inner current control loop and outer speed control loop in one circuit as shown in Figure 5. Finally, the current and speed obtained are shown in Figure 6 and Figure 7 respectively.

4. Results and Discussion

The current loop was able to output the desired current as the load was moved along the speed profile as shown in Figure 4. The calculated for k_p was 2.49. Given the motor and load characteristics, the theoretical calculation of the torque for the system was 52.5 Nm during acceleration and -52.5 Nm during deceleration. In the PSPICE, the simulated torque during acceleration and deceleration was consistent with the theoretical calculation of torque as shown in Figure 7. The simulated speed output was depicted in Figure 6**.** The current loop was not able to output the speed profile as shown in Figure 3. However, the speed loop controller was able to output the desired speed as the load was moved along the speed profile as shown in Figure 5. The speed loop controller calculated k_p was 2.49. The combined speed and current loops were able to output the desired speed and torque.

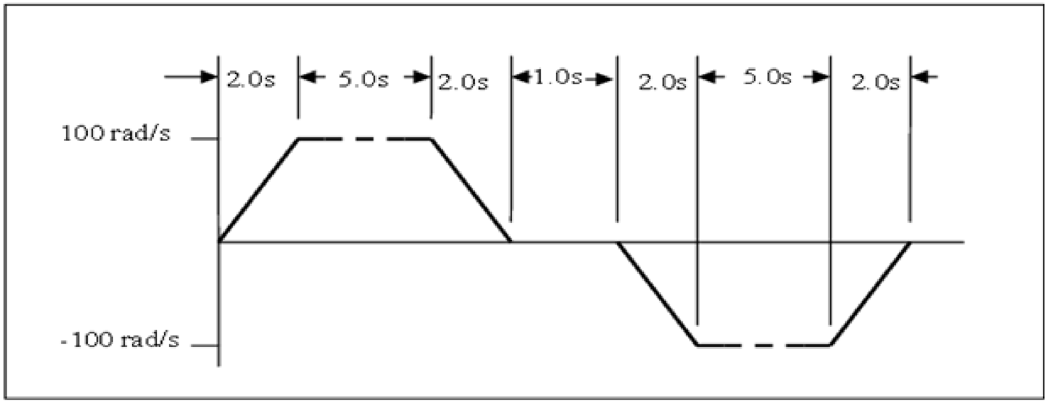

Figure 2: Desired speed profile

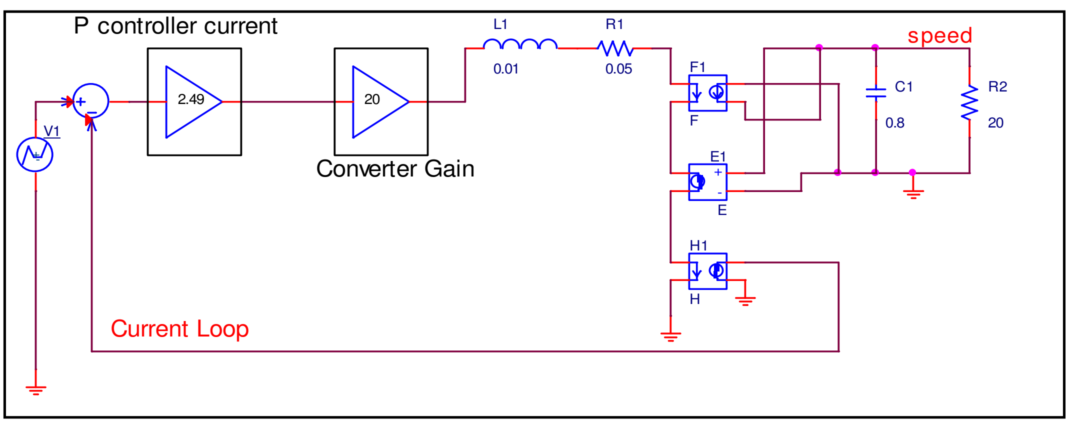

Figure 3: PSPICE model of the current loop

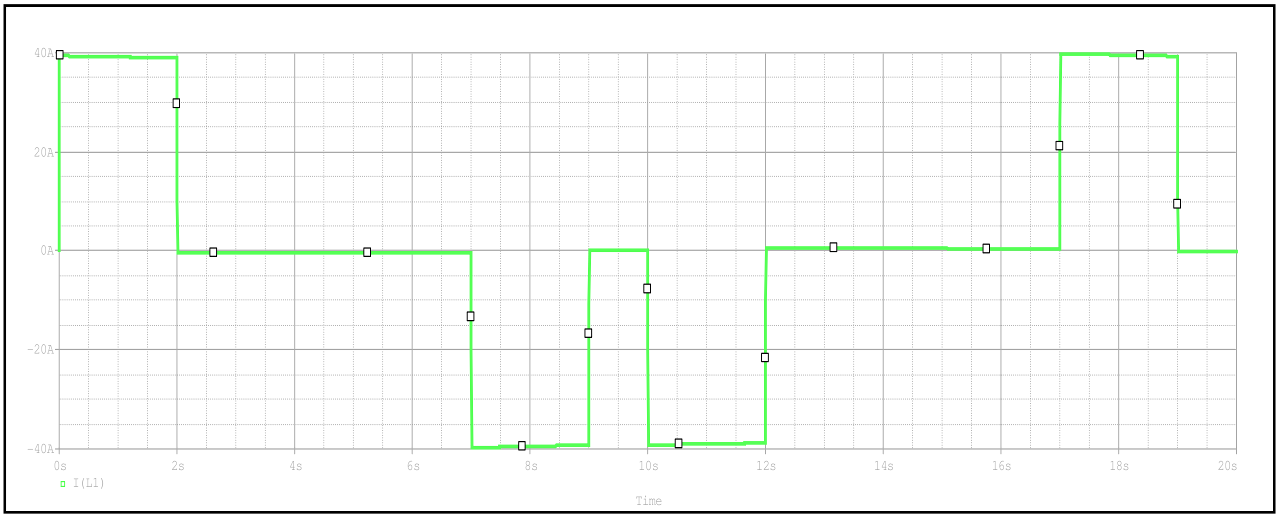

Figure 4: The output current of current control system

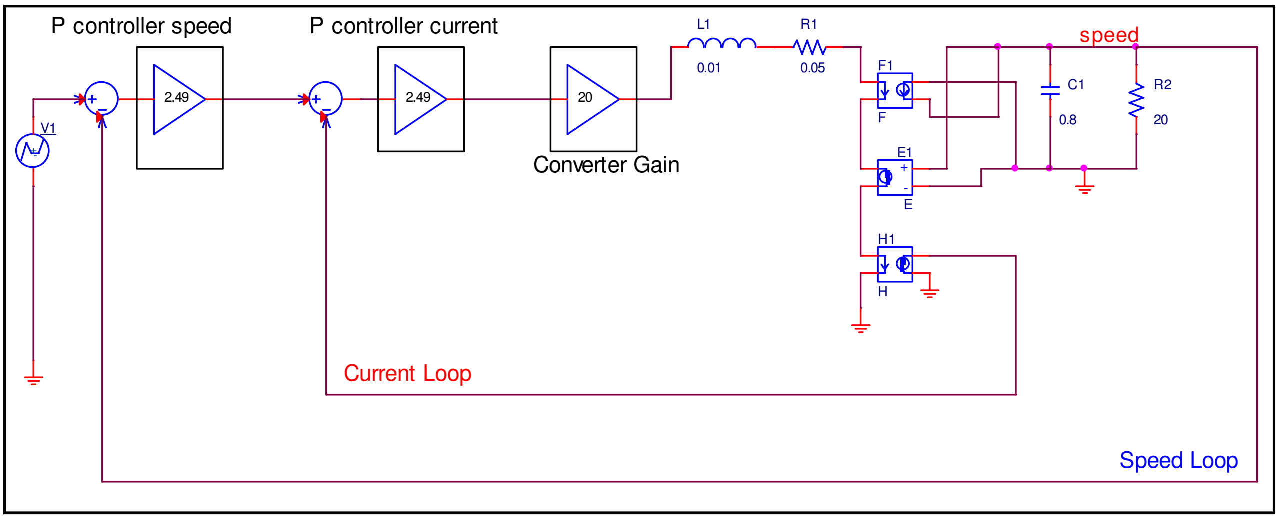

Figure 5: SPICE graph of speed current control system

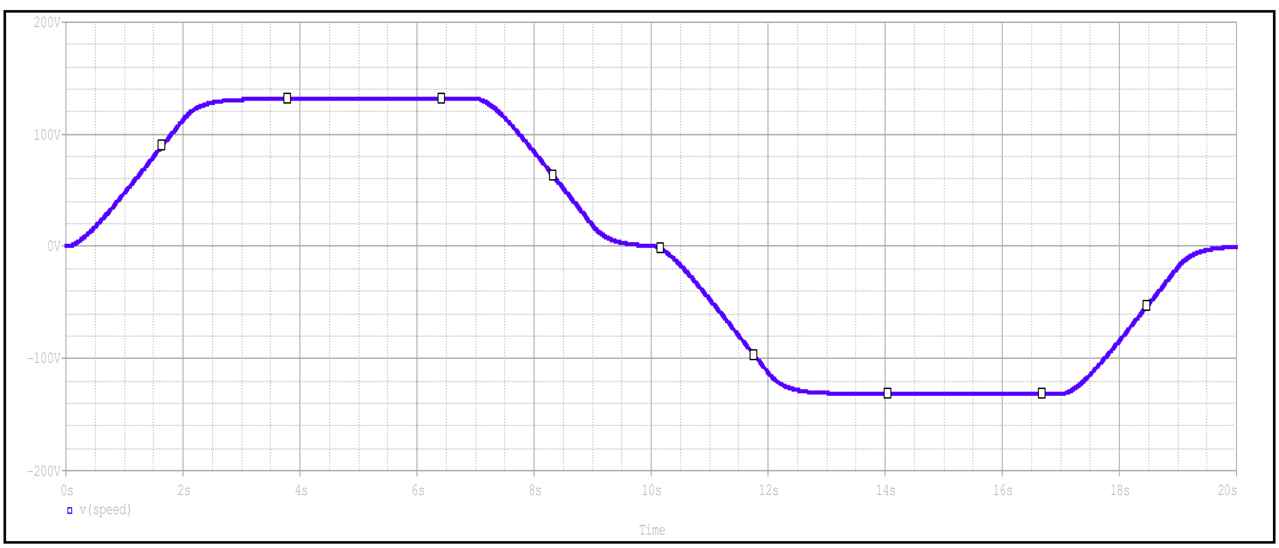

Figure 6: Speed output graph of speed current control system

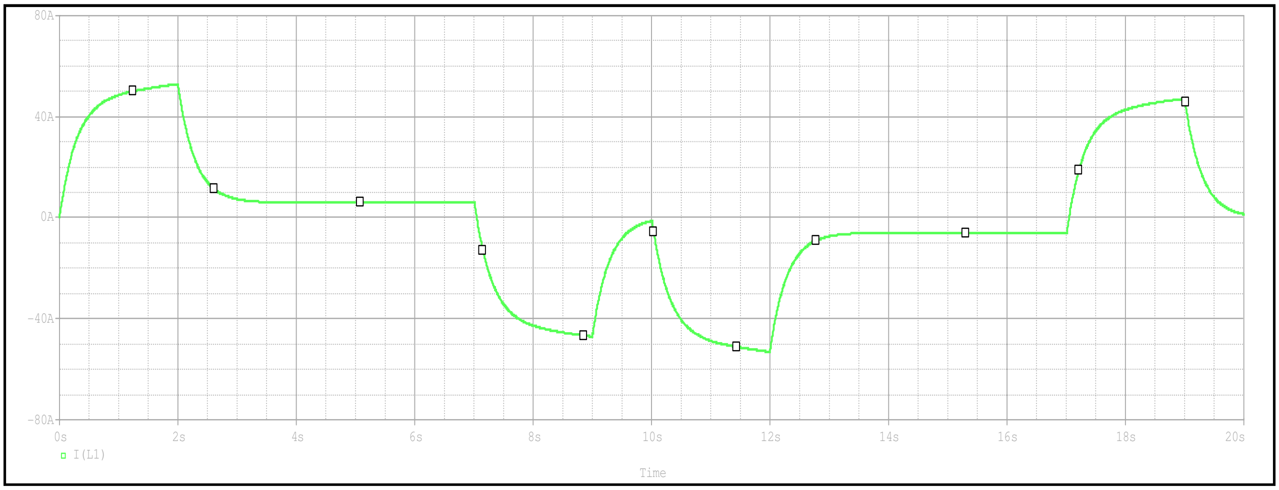

Figure 7: Current output graph of speed current control system

3. Calculation

$j_L = 0.8kgm^2$ $j_m = 0.25kgm^2$ $K_E = K_T = 1.33V_s$ $L_A = 10mH$

$R_A = 0.05\Omega$ $B = 0.05NMs$

To find the torque:

$$T = j_{eq}\frac{\Delta w}{\Delta t}$$
$$= 1.05\frac{100}{2}$$
$$= 52.5\ N.m$$

To find the voltage armature:

$$V_a = I_A R_A + K_E w$$

$$I_A = \frac{T}{K_T} = 39.47A \Rightarrow V_a = 134.97v$$

To find the K_p value:

$$\frac{I_s}{I_S^X} = 0.999$$

$The\ steady\ state\ close\ loop\ gain\ is:$

$$G_{ss} = \frac{I_s}{I_S^X} = 0.999$$

$solving\ for\ K_p$:

$$K_p = \frac{G_{ss} \times R_a}{K_{pwm}(1 - G_{ss})} = 2.49$$

5. Conclusion

This paper shows how power electronics circuits, electric motors and drives, can be simulated with PSpice TM software. The motor had the ability to move the desired load through the speed profile. The desired torque was achieved when using only a current loop. However, the motor was not able to observe the speed profile over the desired time. The desired speed and torque profiles were achieved with the speed and current control system.

6. References

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