EE6303: ELECTRIC MACHINES II

LABORATORY 03

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SEMESTER: 06

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Table 1 : Summative laboratory form

Semester	06
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Module Name	Electric Machines II
Lab Number	03
Lab Name	Simulation of Brushless DC Motor
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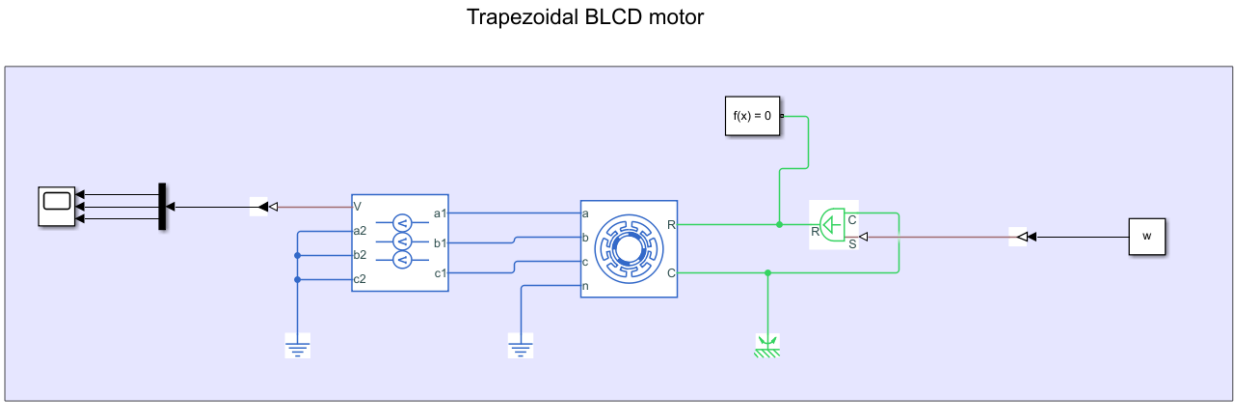
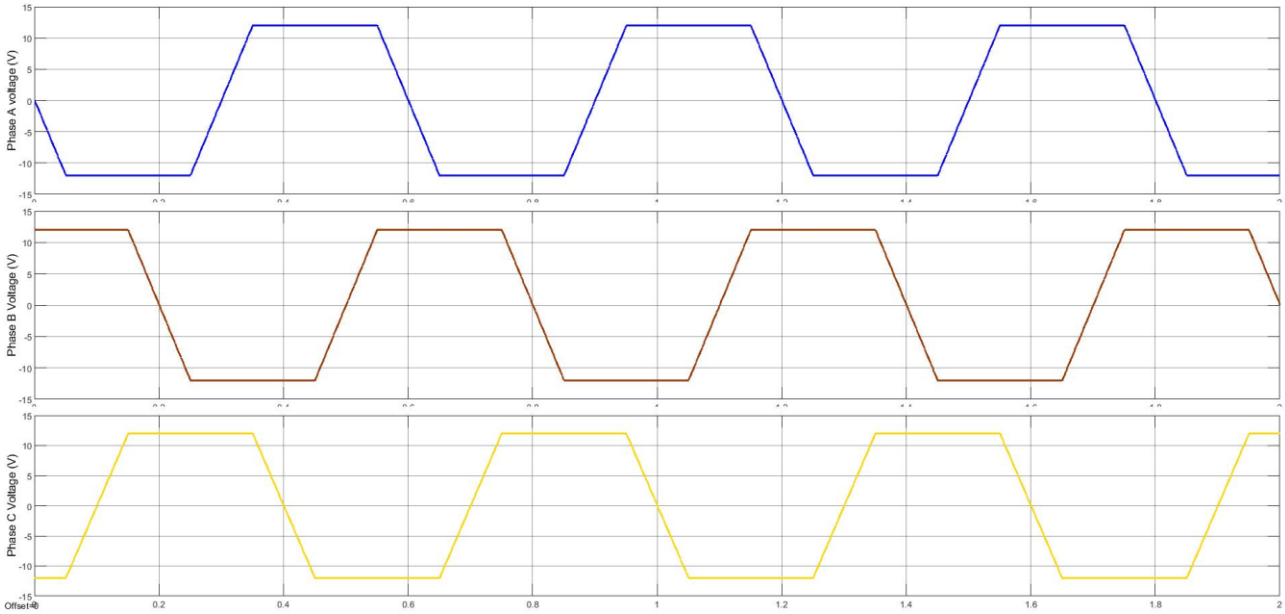


Figure 1 : SIMULINK model for back EMF profile of trapezoidal BLDC motors



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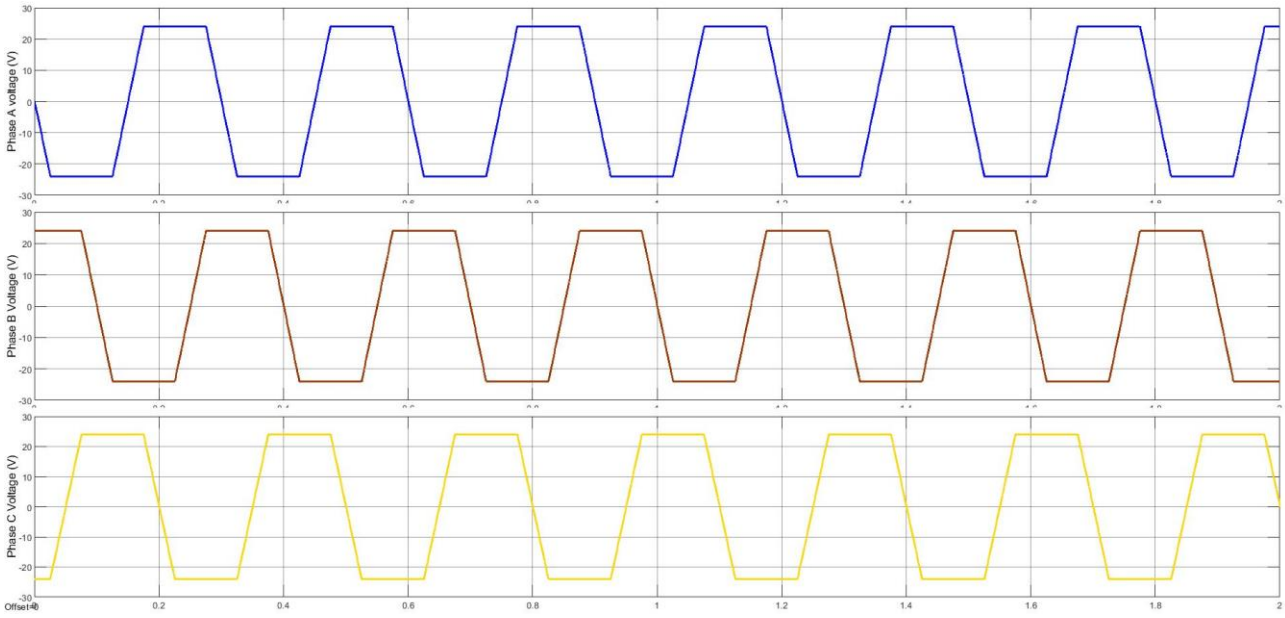

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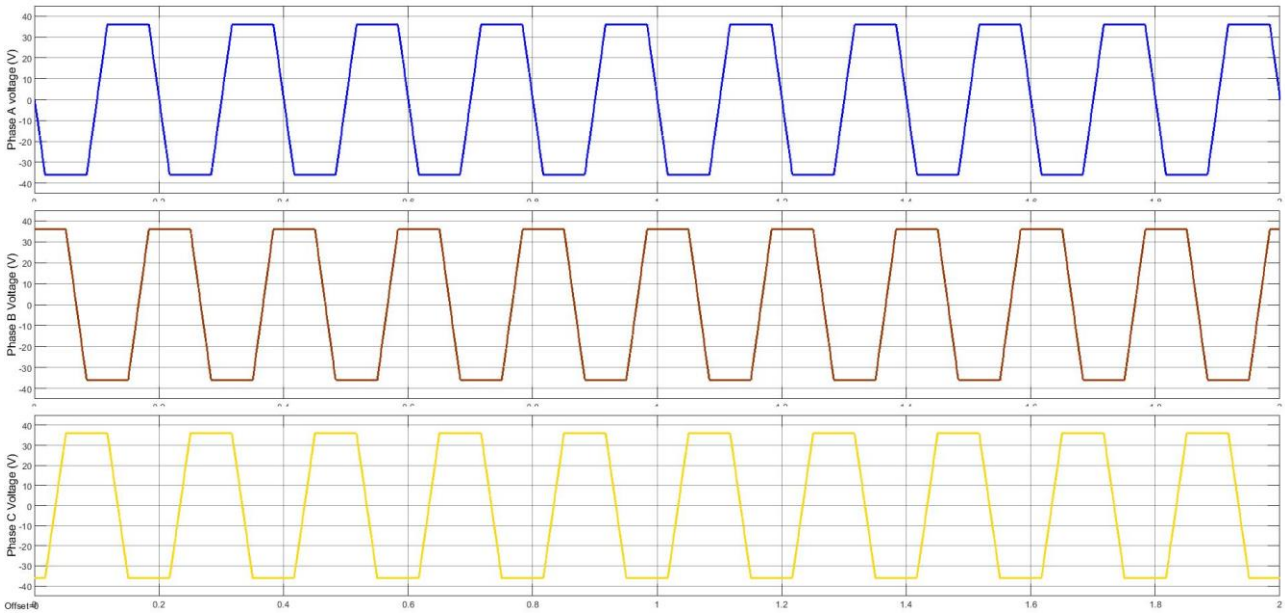

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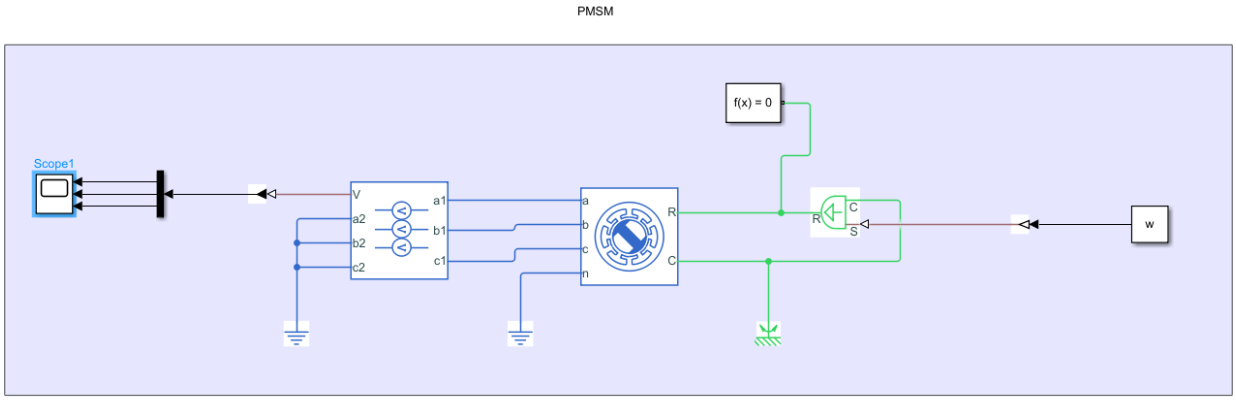

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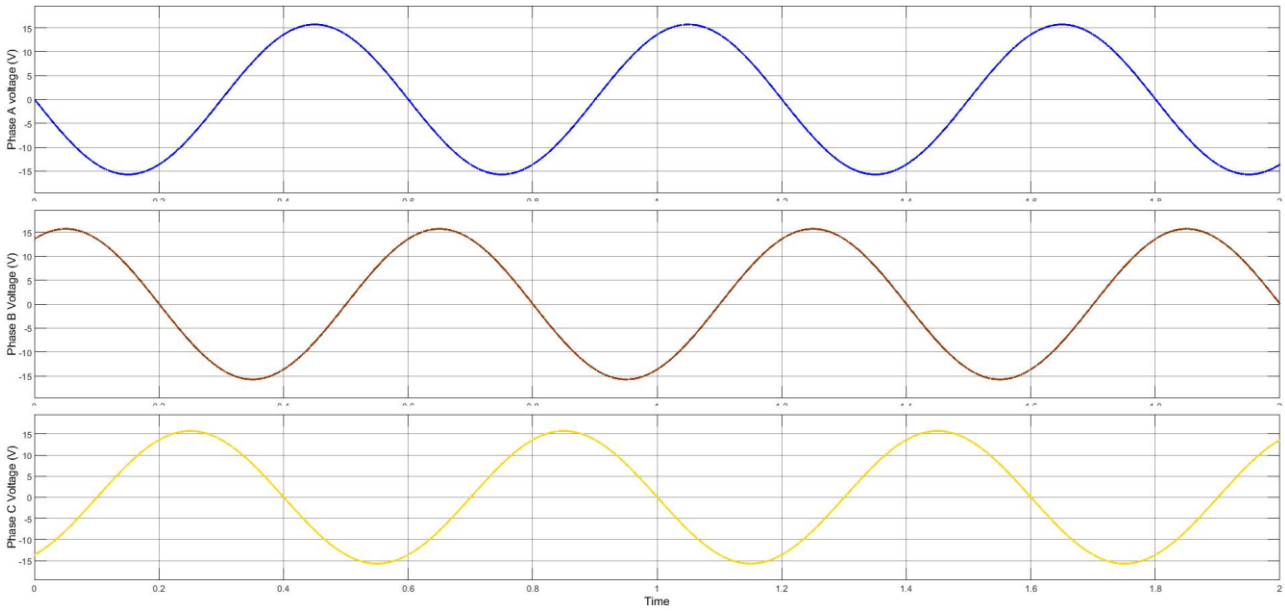

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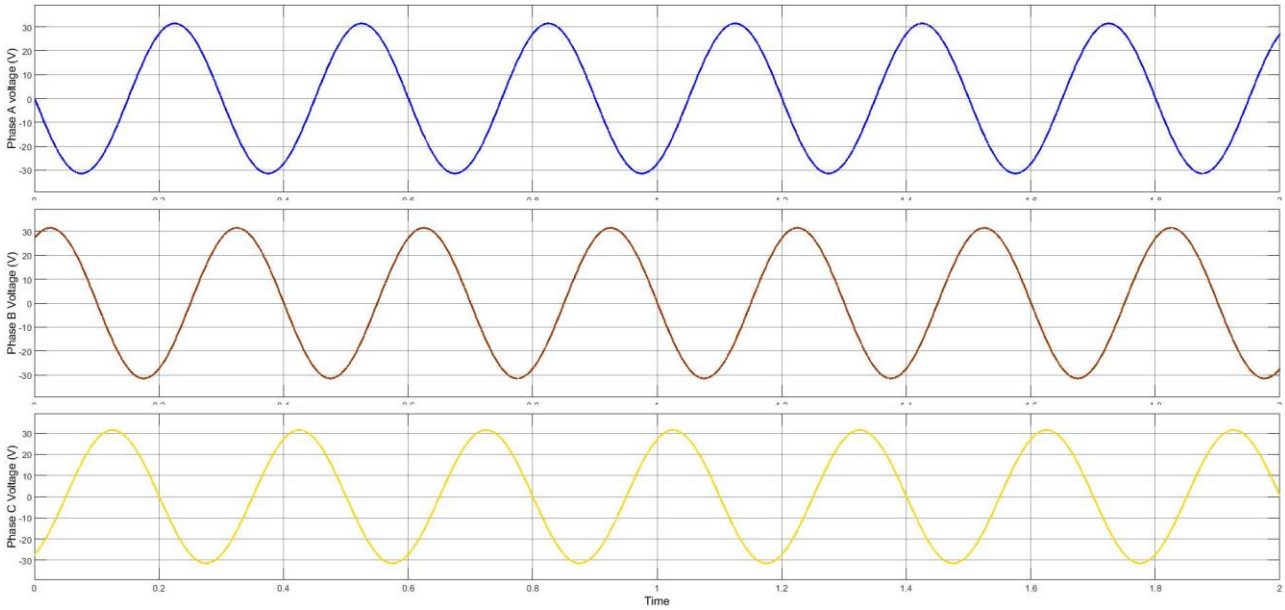

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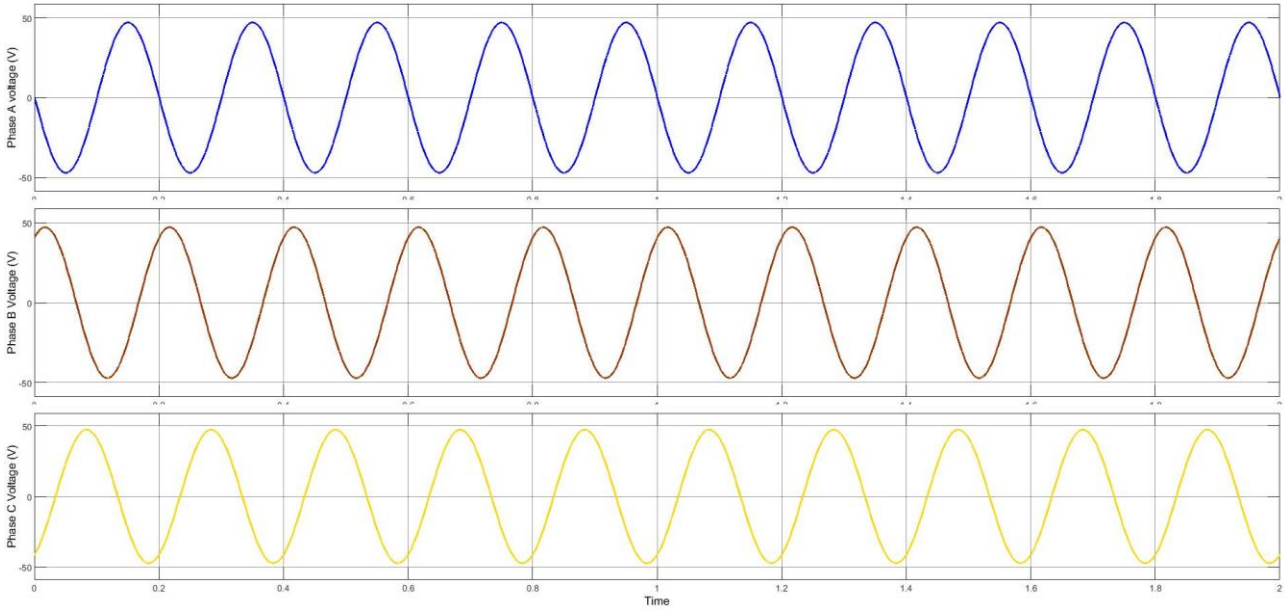

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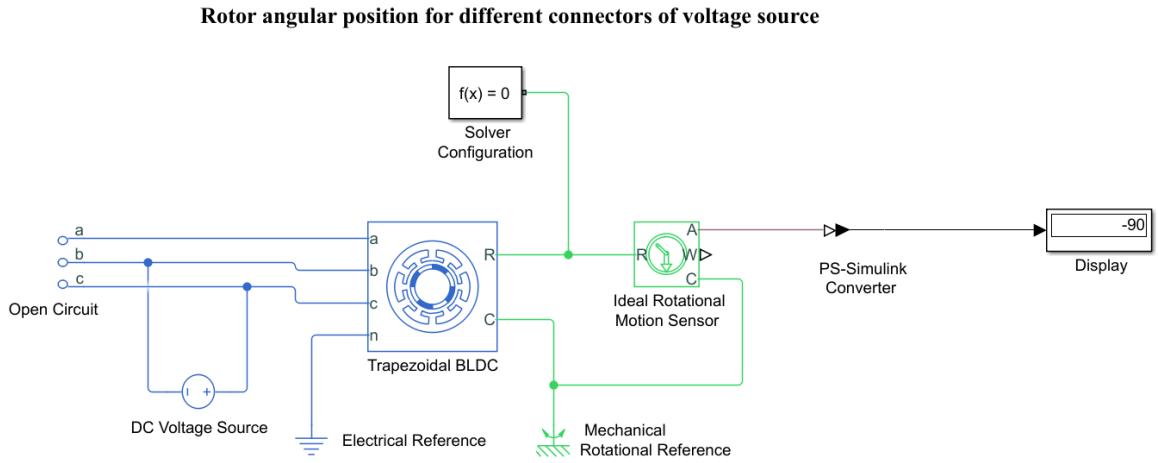

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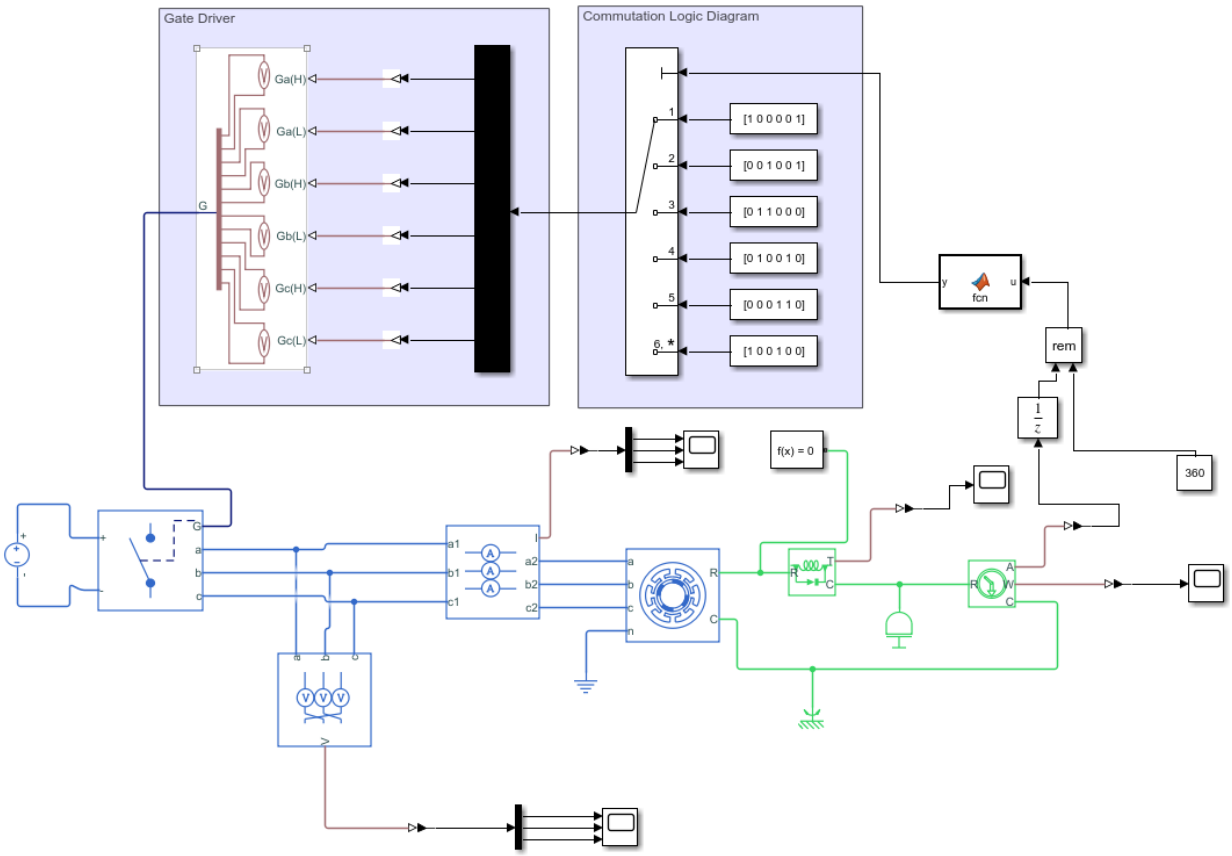

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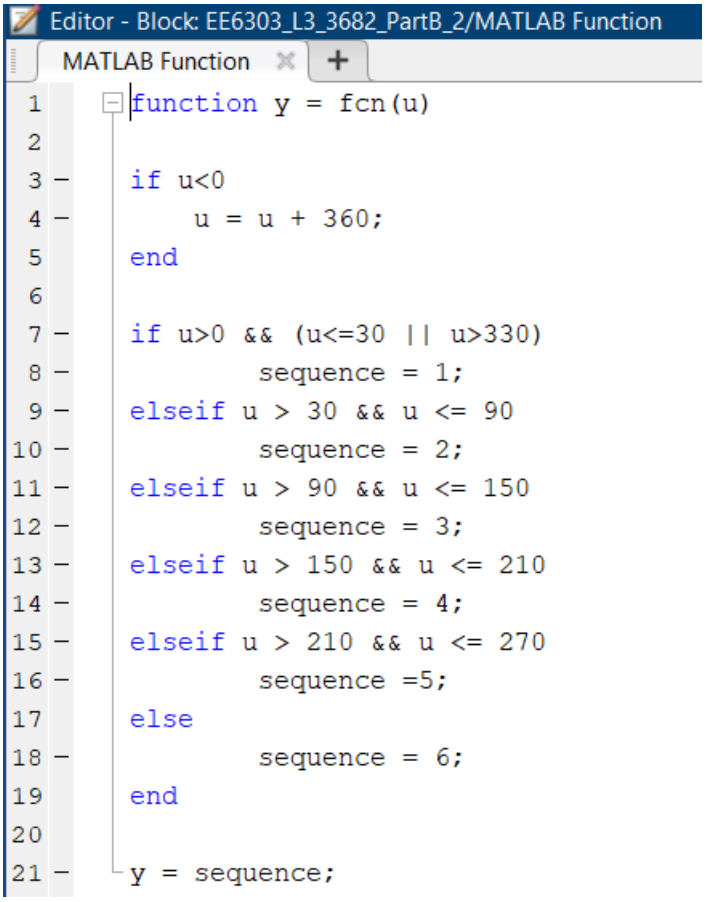

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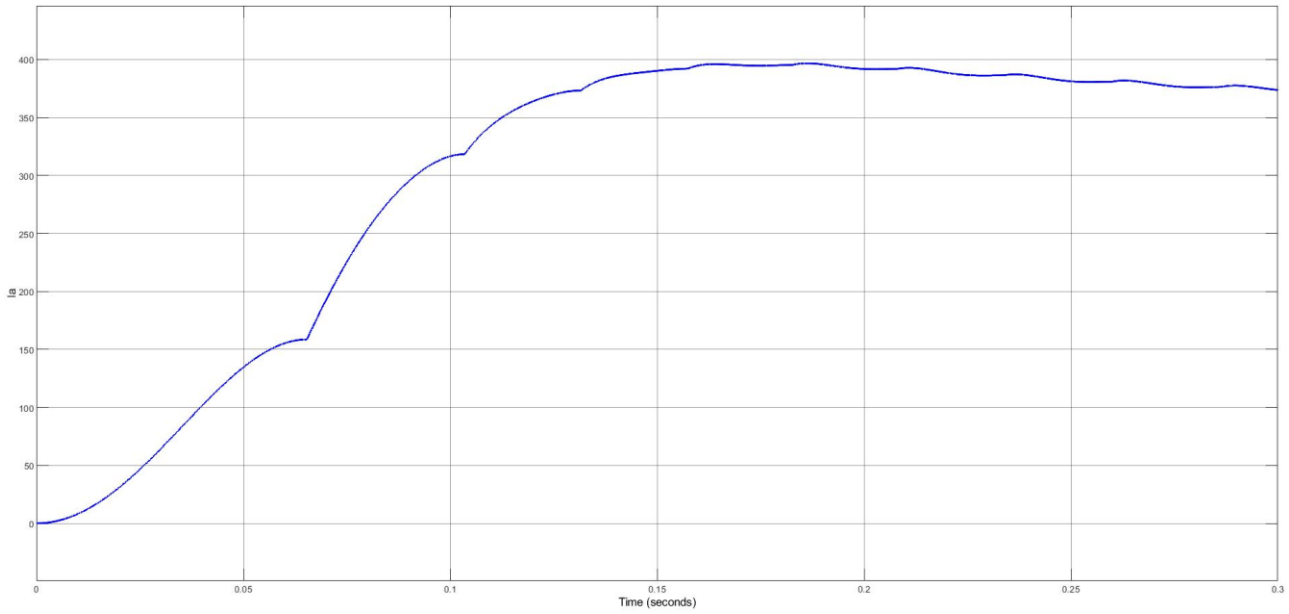

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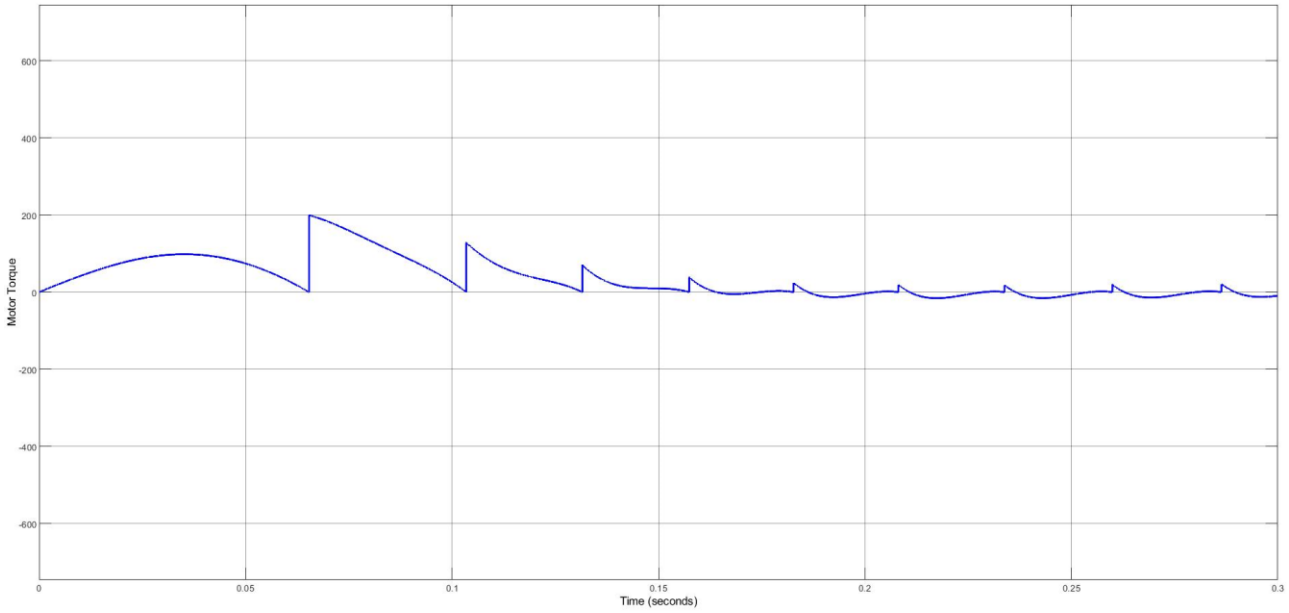

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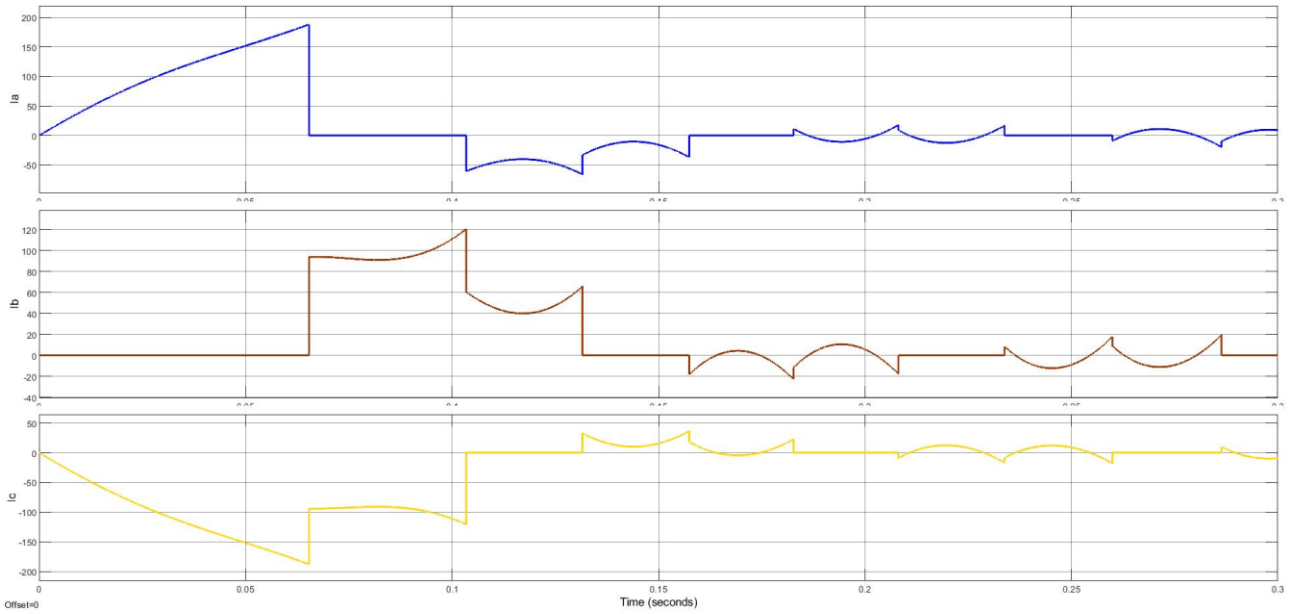

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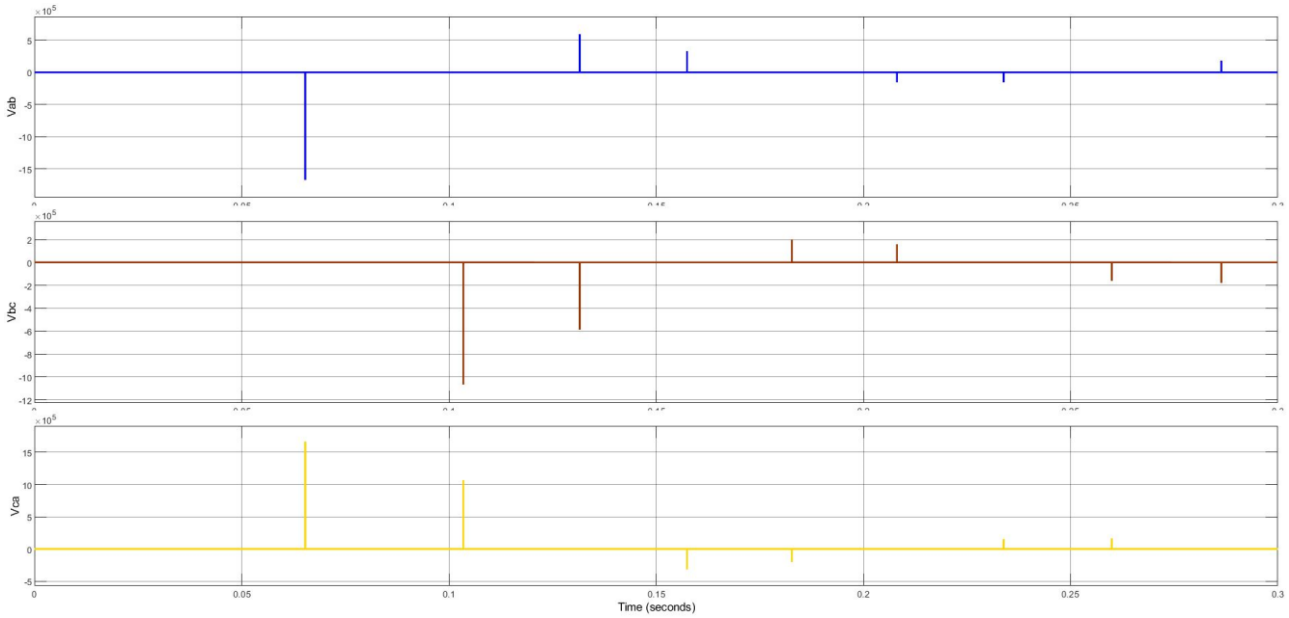

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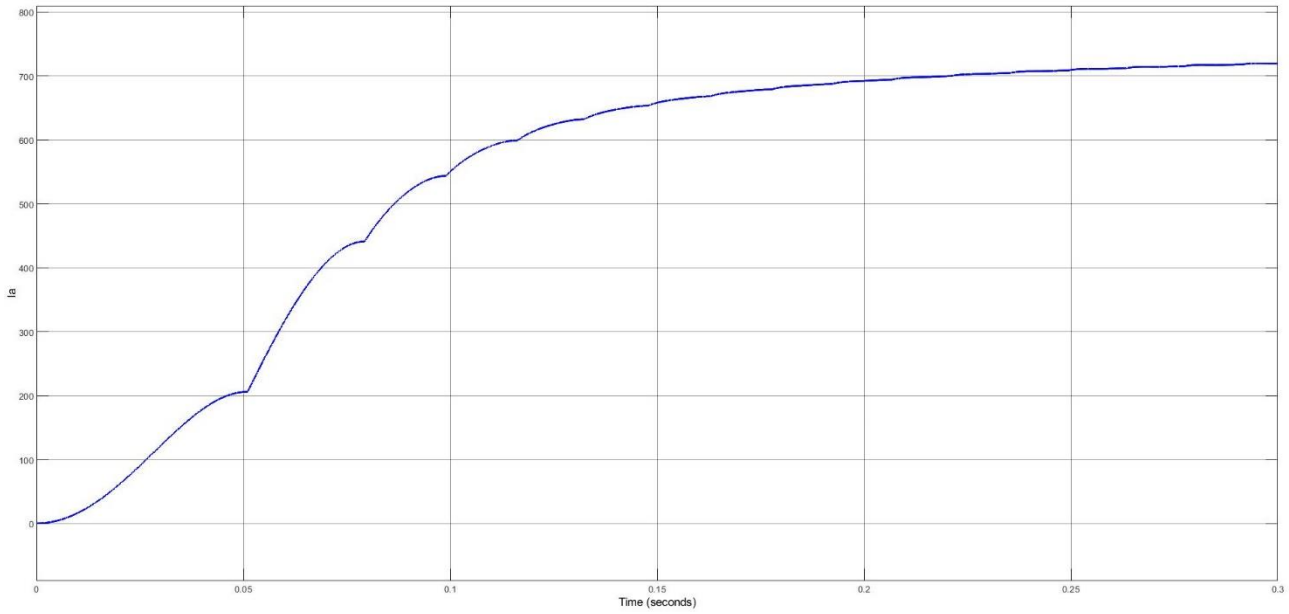

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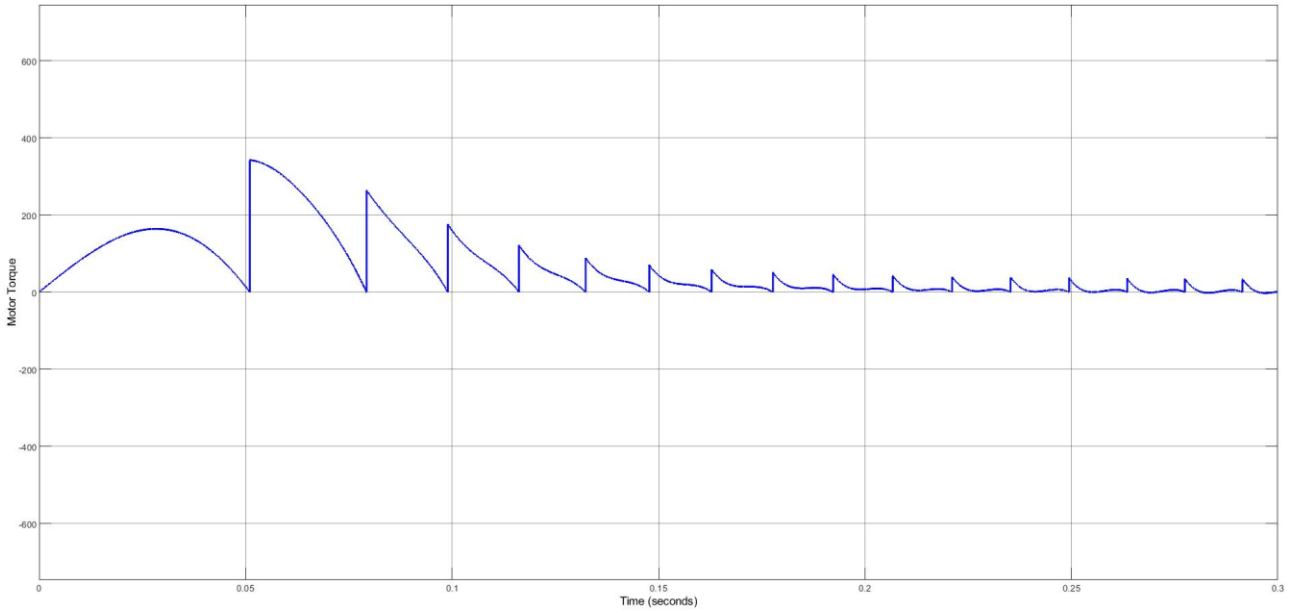

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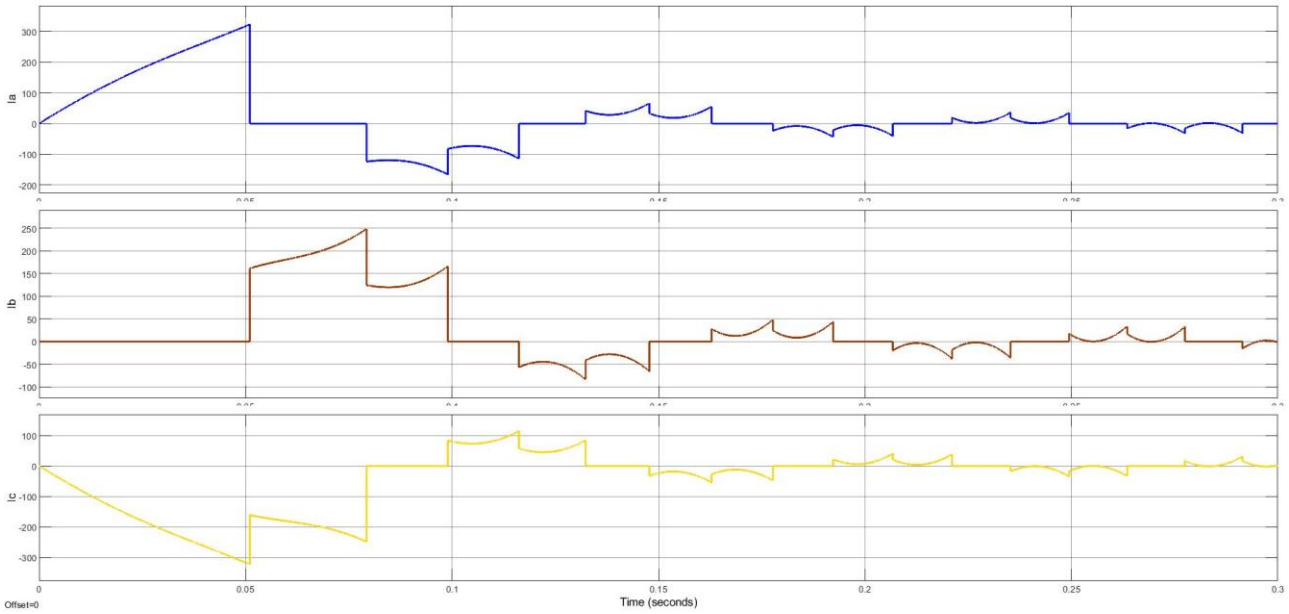

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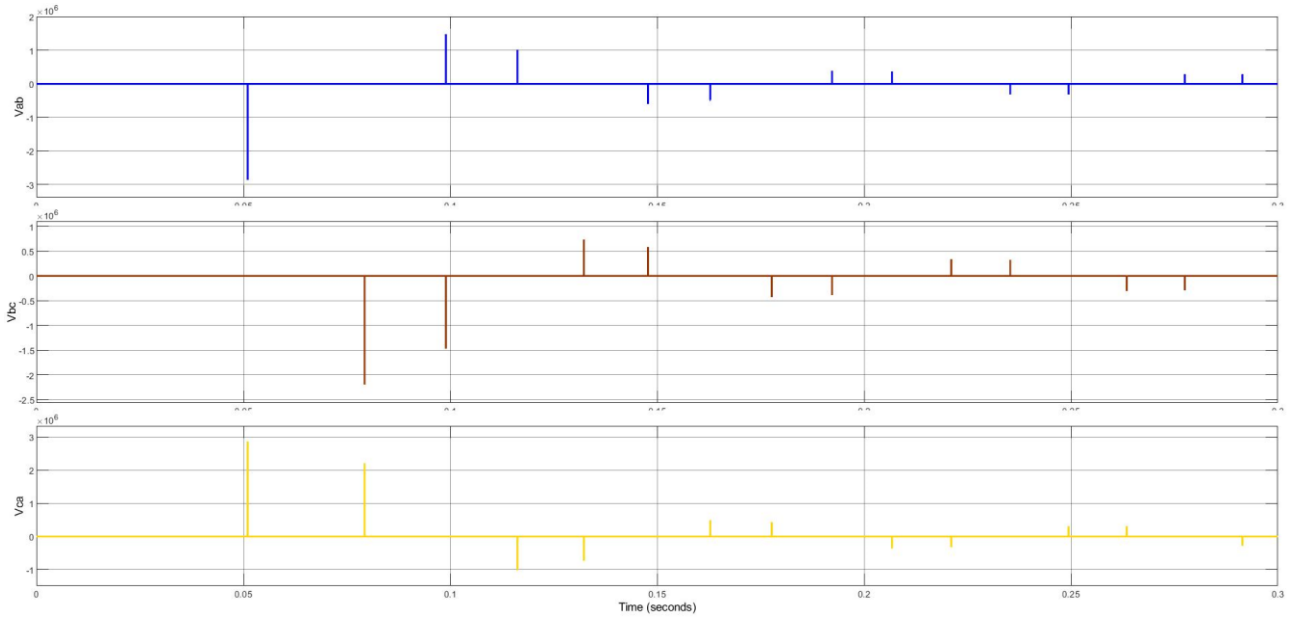

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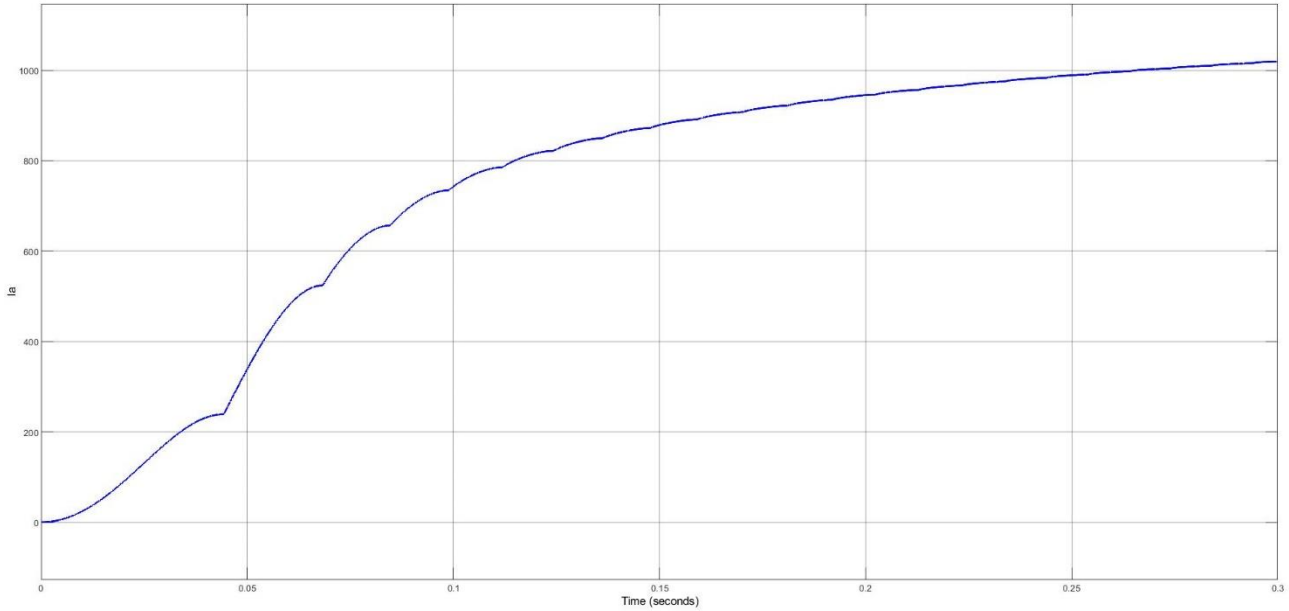

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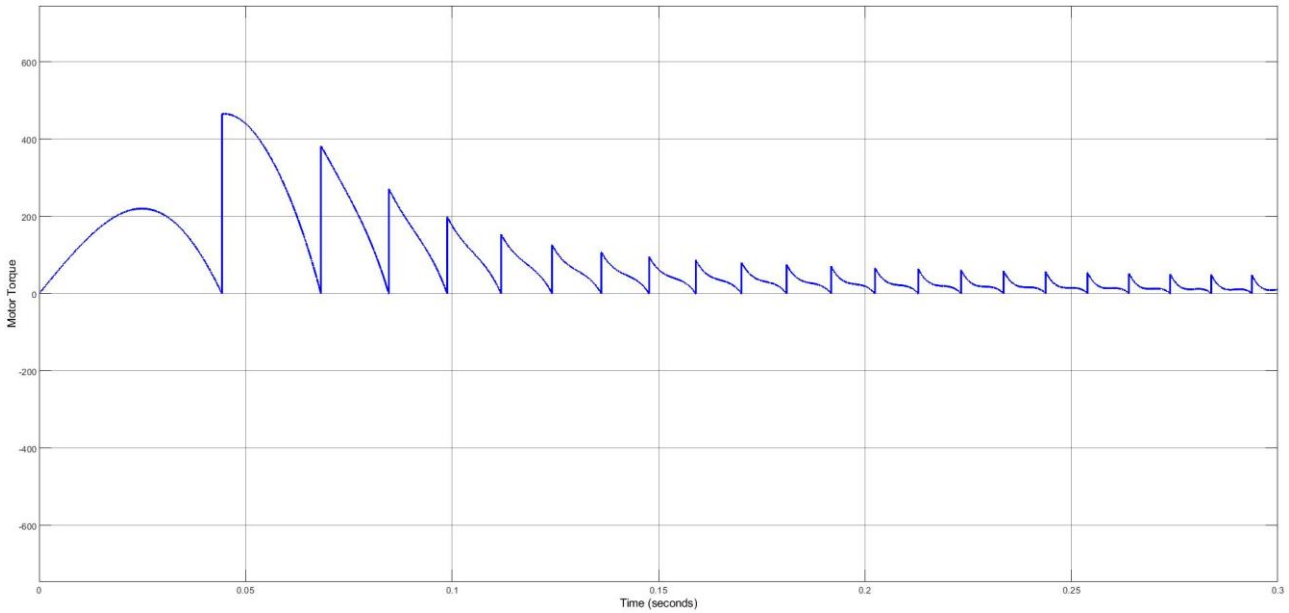

Figure 21 : Torque of the BLDC motor for 150V supply voltage

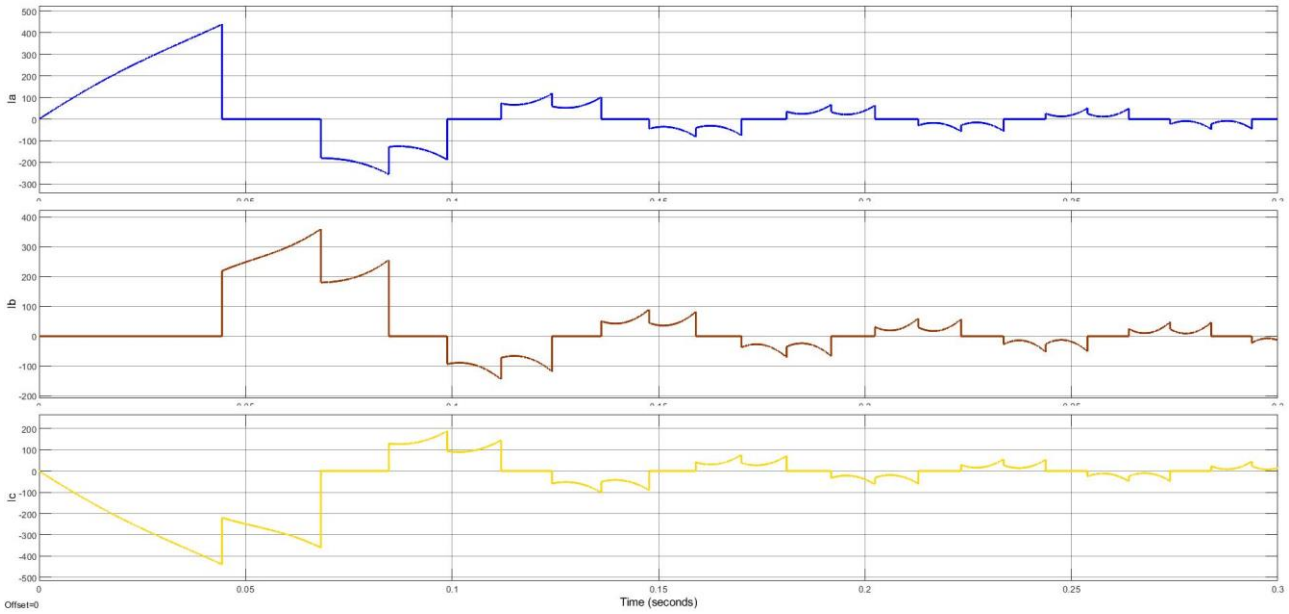

Figure 22 : Motor input line currents of the BLDC motor for 150V supply voltage

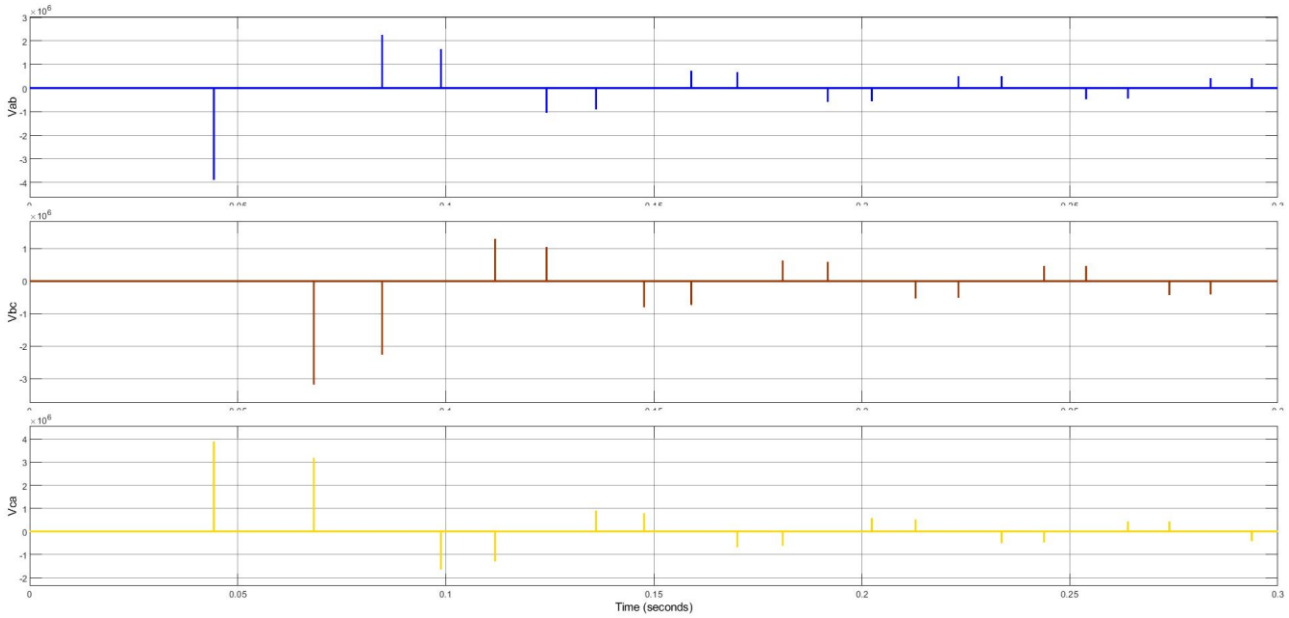

Figure 23 : Motor input line to line voltages of the BLDC motor for 150V supply voltage

2 TABULATION

PART B : SIX-STEP COMMUTATION OF A TRAPEZOIDAL BLDC MOTOR

Table 2 : Rotor angular position for different connections of DC voltage source

Positive Connection	Negative Connection	Rotor Angle (deg)
Phase a	Phase b	-30
Phase a	Phase c	30
Phase b	Phase c	90
Phase b	Phase a	150
Phase c	Phase a	-150
Phase c	Phase b	-90

Table 3 : Commutation logic to drive the BLDC motor in positive direction

AH	AL	BH	BL	CH	CL	Positive Connection	Negative Connection	Rotor Angle (deg)
1	0	0	0	0	1	Phase a	Phase c	30
0	0	1	0	0	1	Phase b	Phase c	90
0	1	1	0	0	0	Phase b	Phase a	150
0	1	0	0	1	0	Phase c	Phase a	-150
0	0	0	1	1	0	Phase c	Phase b	-90
1	0	0	1	0	0	Phase a	Phase b	-30

Table 4 : Commutation logic to drive the BLDC motor in negative direction

AH	AL	BH	BL	CH	CL	Positive Connection	Negative Connection	Rotor Angle (deg)
1	0	0	1	0	0	Phase a	Phase b	-30
0	0	0	1	1	0	Phase c	Phase b	-90
0	1	0	0	1	0	Phase c	Phase a	-150
0	1	1	0	0	0	Phase b	Phase a	150
0	0	1	0	0	1	Phase b	Phase c	90
1	0	0	0	0	1	Phase a	Phase c	30

3 DISCUSSION

1)

PART A : BACK EMF PROFILES OF TRAPEZOIDAL AND SINUSOIDAL BLDC MOTORS

The block diagram and waveforms of a trapezoidal BLDC motor at three different angular speeds are shown in Figures 1 through 4. Similarly, Figures 5 through 8 show these elements for a sinusoidal BLDC motor. With an increase in rotational speed, the magnitude and frequency of the induced back EMF also increase, following the synchronous speed equation:

$$n_s = \frac{120f}{p}$$

At an synchronous speed of 100 rpm, the frequency is 1.667 Hz and the period 0.6 sec. Whereas at 200 rpm. the frequency is 3.333 Hz and the period 0.3 seconds, at 300 rpm. the frequency rises to 5.000 Hz and the period to 0.2 seconds. Thus PMSM and BLDC motors are classified as synchronous motors, since both of them follow the synchronous speed relation characteristic of synchronous machines.

PART B : SIX-STEP COMMUTATION OF A TRAPEZOIDAL BLDC MOTOR

Figures 12, 16 and 20 represent the rotational speed of the BLDC at supply voltages equal to 50V, 100V and 150V, respectively. Due to the six-step commutation of the controller, small ripples show up when the speed ramps up from zero. The motor finally reaches a constant steady-state speed, proportional to the supply voltage.

Figures 13, 17 and 21 show the torque of the BLDC motor for these input voltages. The torque shows significant ripple and is not constant, again due to the six-step commutation. When the motor starts, it gives peak torque which reduces with an increase in speed of the motor and then settles. This happens because the load starts moving which reduces the requirement of torque on the motor as time advances.

The line current drawn by the BLDC motor with inputs of 50V, 100V and 150V are shown in Figures 14, 18 and 22 respectively. This is because controller-driven commutation produces step-like changes in the input current. During this time, as the load starts to rotate, its amplitude decreases because the effective torque applied to the motor decreases. Another point to be noticed is that the time period of these fluctuations also decreases as the motor reaches its steady state speed.

The line-to-line input voltages at the motor for the respective supply voltages can be seen in Figures 15, 19 and 23. It is remarkable that large voltage spikes arise due to back EMF generated from commutation. In the absence of protection diodes for back EMF a real controller may be damaged

by these spikes. These spikes shorten for longer time as the motor reaches a steady speed, hence there are less commutation intervals as the motor stabilizes.

2) There is, however, a relation between the motor's speed and the supply voltage: when the supply voltage increases, the speed of the motor rises accordingly. That can be seen from Figures 12, 16, and 20. Here, in this simulation, motor speed will be kept constant by manipulating the supply voltage. Using a controlled voltage source and a PID controller with negative feedback can stabilize the motor to any constant value. The configuration of modified controller is shown in Figure 24, and its characteristics of speed control are shown in Figure 25. In the real application, this method is impracticable because an additional voltage controller that must be capable of handling high current to supply the voltage is required. Actually, in BLDC motor drives, PWM for motor-speed regulation is used. In PWM, during each commutation cycle, the power supply is intermittent, not continuous, and is proportional to the required output speed of the motor.

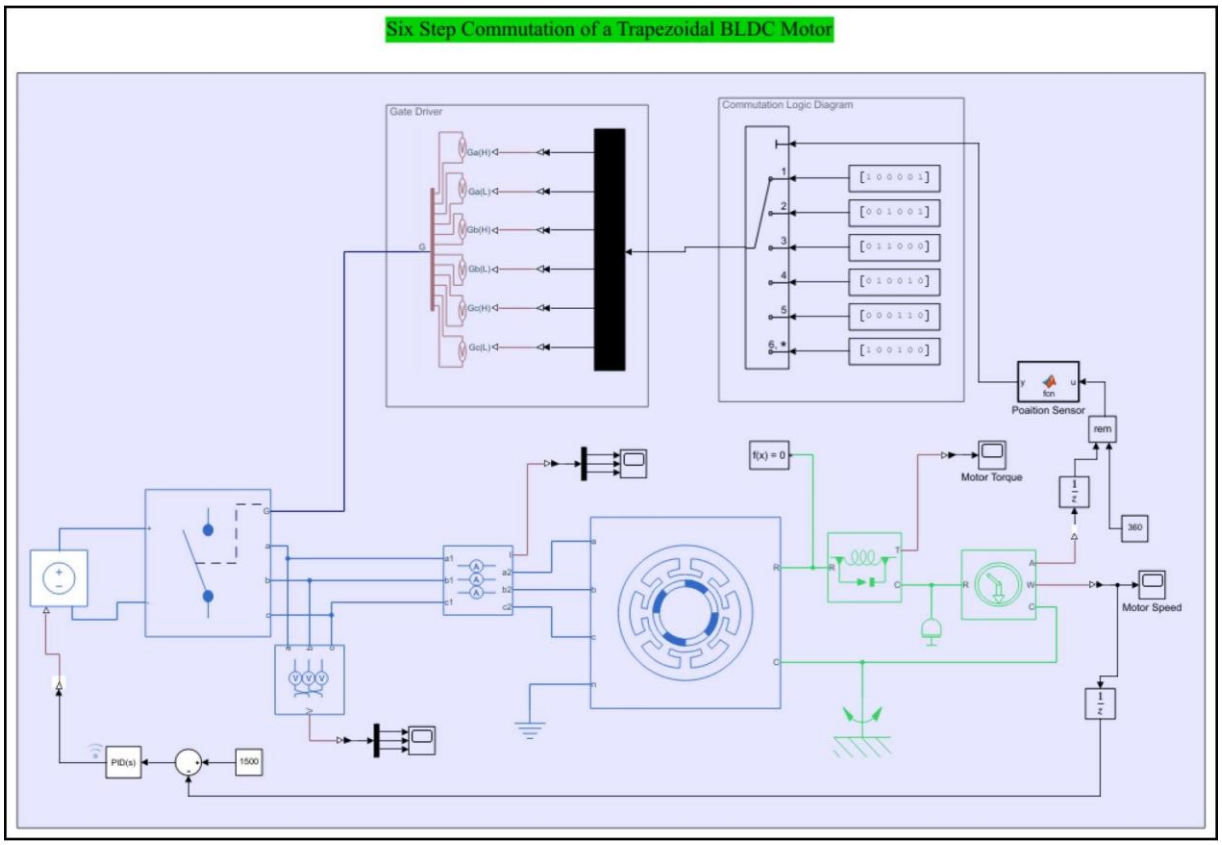

Figure 24:BLDC controller model with PID based speed control

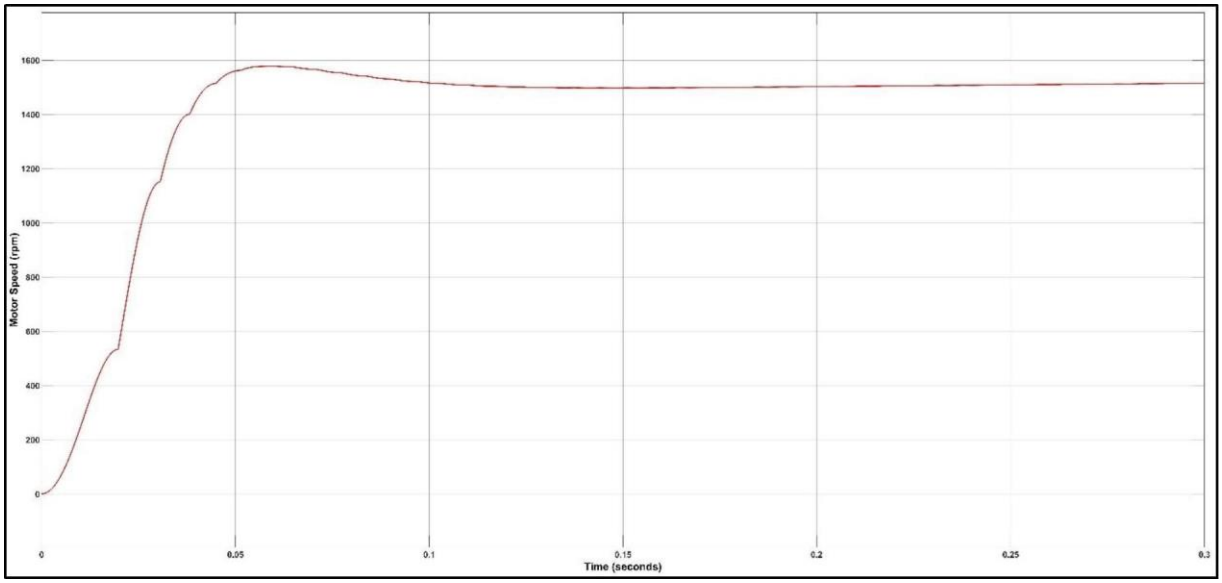

Figure 25:Reponse of the BLDC motor controller with PID speed controller