

MIDDLE EAST TECHNICAL UNIVERSITY

Electrical & Electronics Engineering

Simulation Project

EE 462 – Utilization of Electric Energy

EE-464 – Static Power Conversion II

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**INTRODUCTION**

We need to make a simulation project for EE462 and EE464 courses. The aim of this project is designing a motor drive by using sinusoidal PWM for surface mount permanent magnet synchronous machine. For controlling motor, we implemented a current and speed controller by using id-iq parameters. We cannot use Simulink blocks. Therefore, we need to create our own blocks. For part B, we should use sinusoidal PWM technique. Also, in part D, we select the ideal component for project.

**PART A: PRE-DESIGN STAGE**

1-) We know a relation between torque and power. By using that equation, we can find the rated speed.

wmech = 266.67 rad/sec

Trated=300 N.m

The rated torque is given the specification.

2-) Maximum speed is given the specification. By using that, we can find maximum applied frequency.

fmaximum is 467 Hz. For switching frequency, we should take it at least 21 times of fmaximum. We can choose the switching frequency as 10 kHz.

3-) The ripple value of input voltage is not specified but we want almost DC voltage and we can choose the ripple value as %2. We can use below equation

Where I=250A (maximum motor current), f=300 Hz (since three phase rectifier output)

When we calculate by using that equation, we find DC link capacitor value as 83 mF.

In order to test DC capacitor, we need to calculate resistance value. We know voltage value (565 V) and rated current (120A). Then, we calculate resistance as 2.16 ohm.

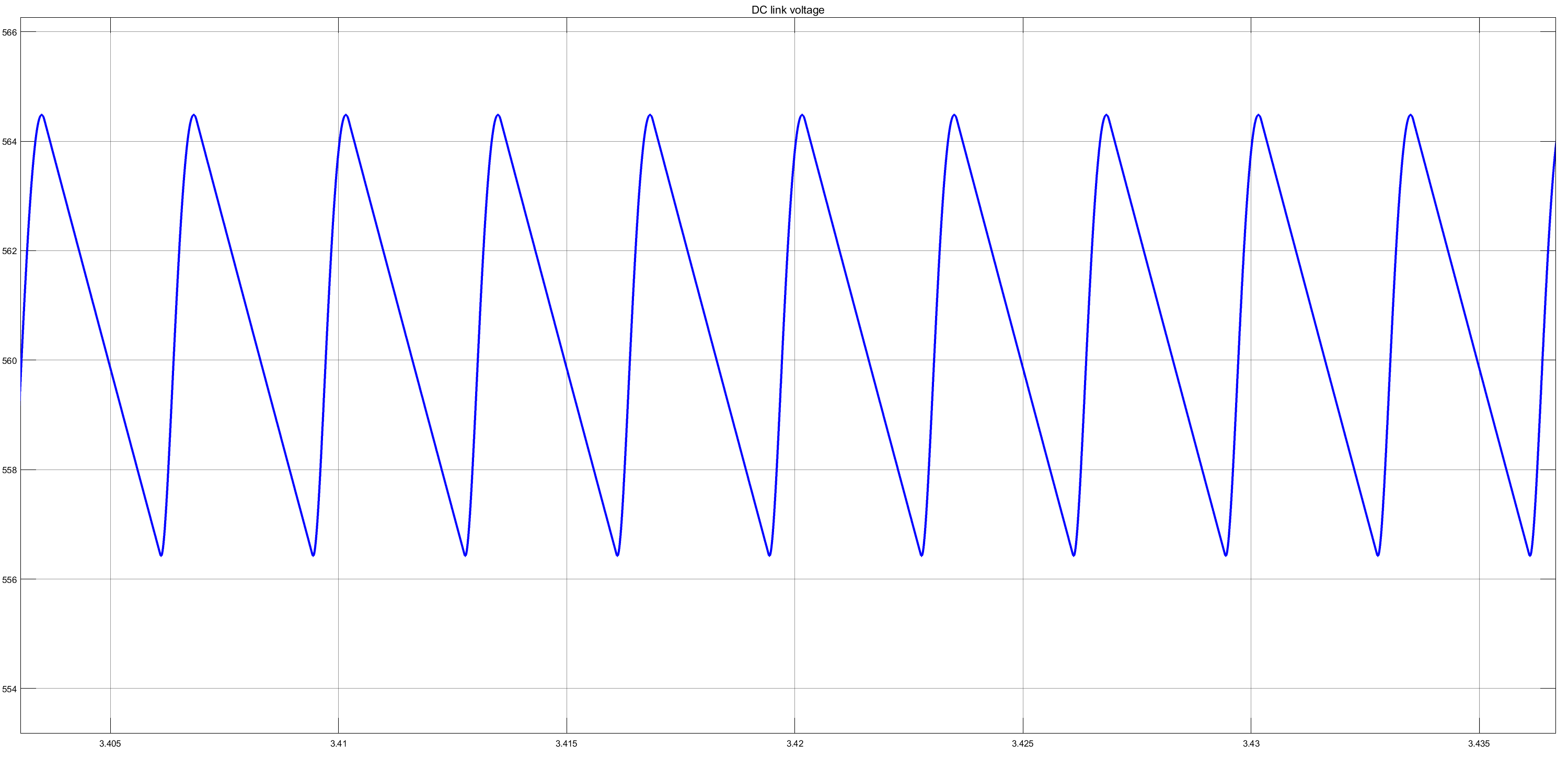


Figure 1: Output waveform of DC link voltage

Therefore, we established the circuit and tested it. We can see the voltage waveform in the figure XXX. And, ripple value is %1.5.

**PART B: SINUSOIDAL PWM**

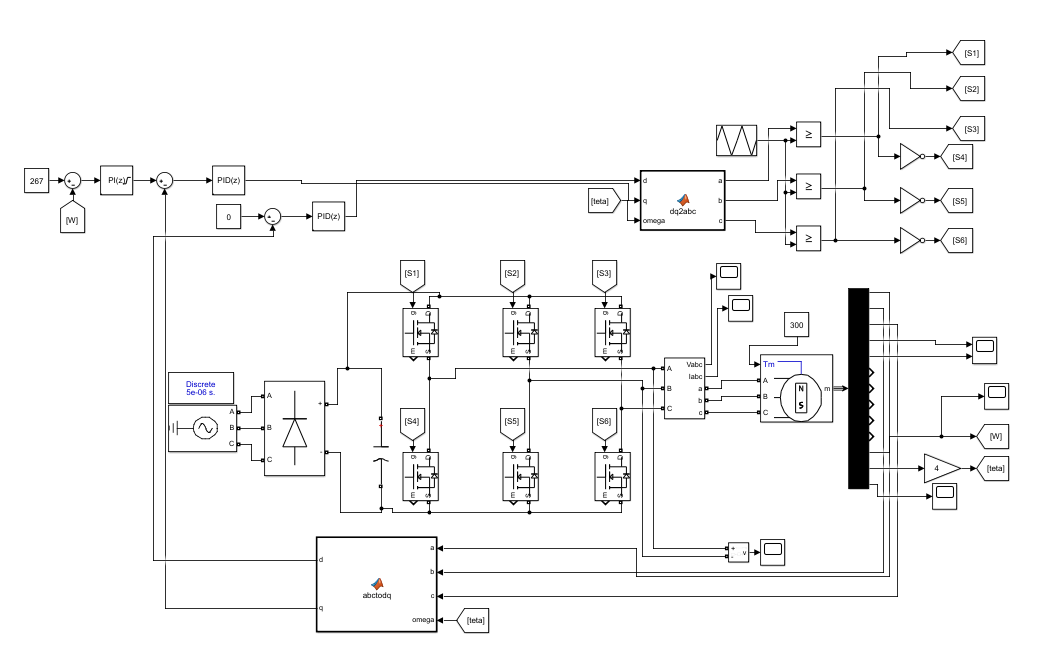


Figure 2: Whole block diagram of motor drive

1. In this part, we should 60 Nm constant torque load to motor input torque parameter. However, firstly, we need to give %90 of rated speed. Then, after reaching steady state, we need to give rated speed as speed reference.

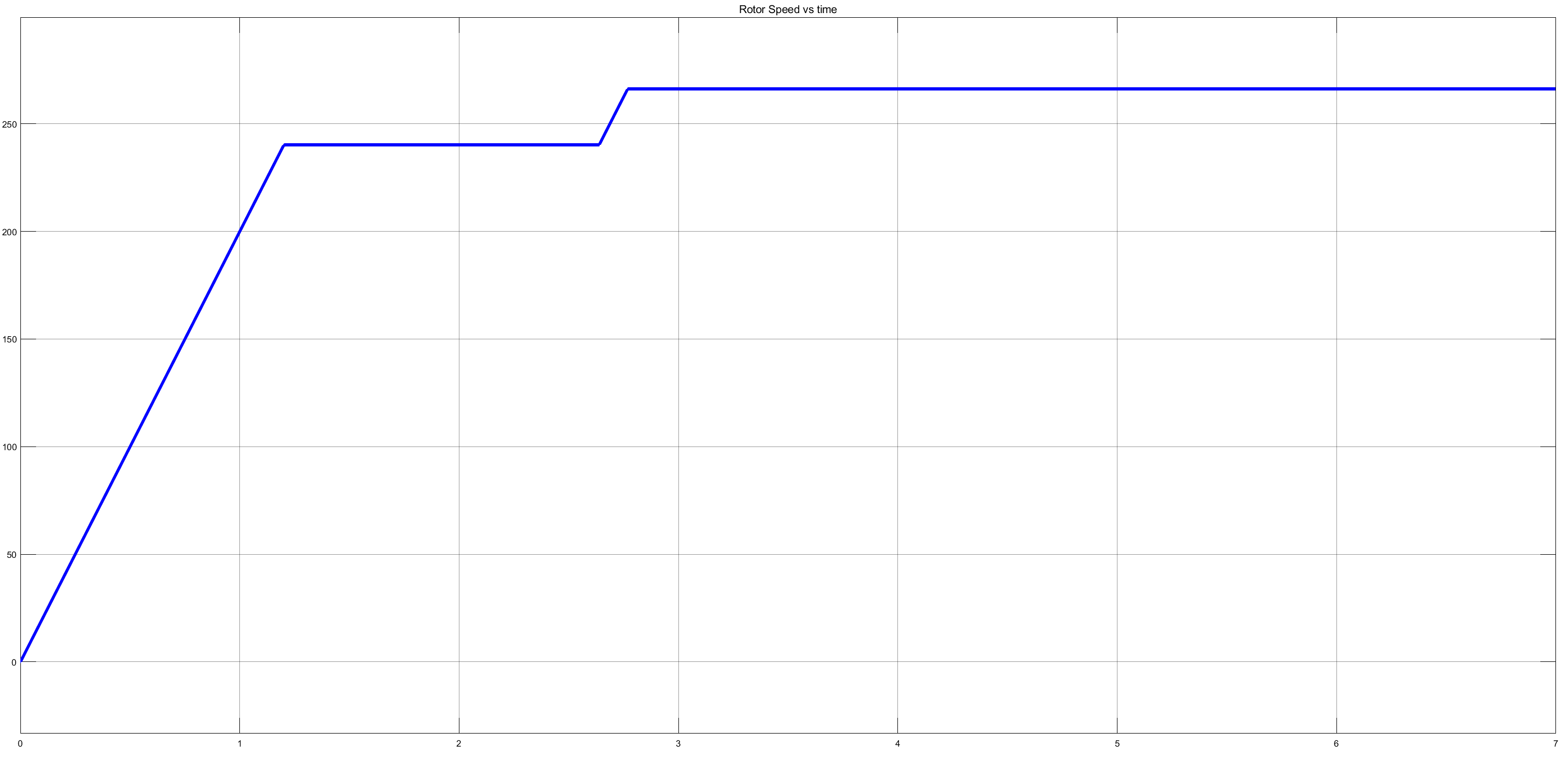


Figure : Rotor Speed(rad/sec) vs time(sec) characteristic

When we change the speed reference, as seen in the figure XXX, motor reaches the steady state in short amount of time.

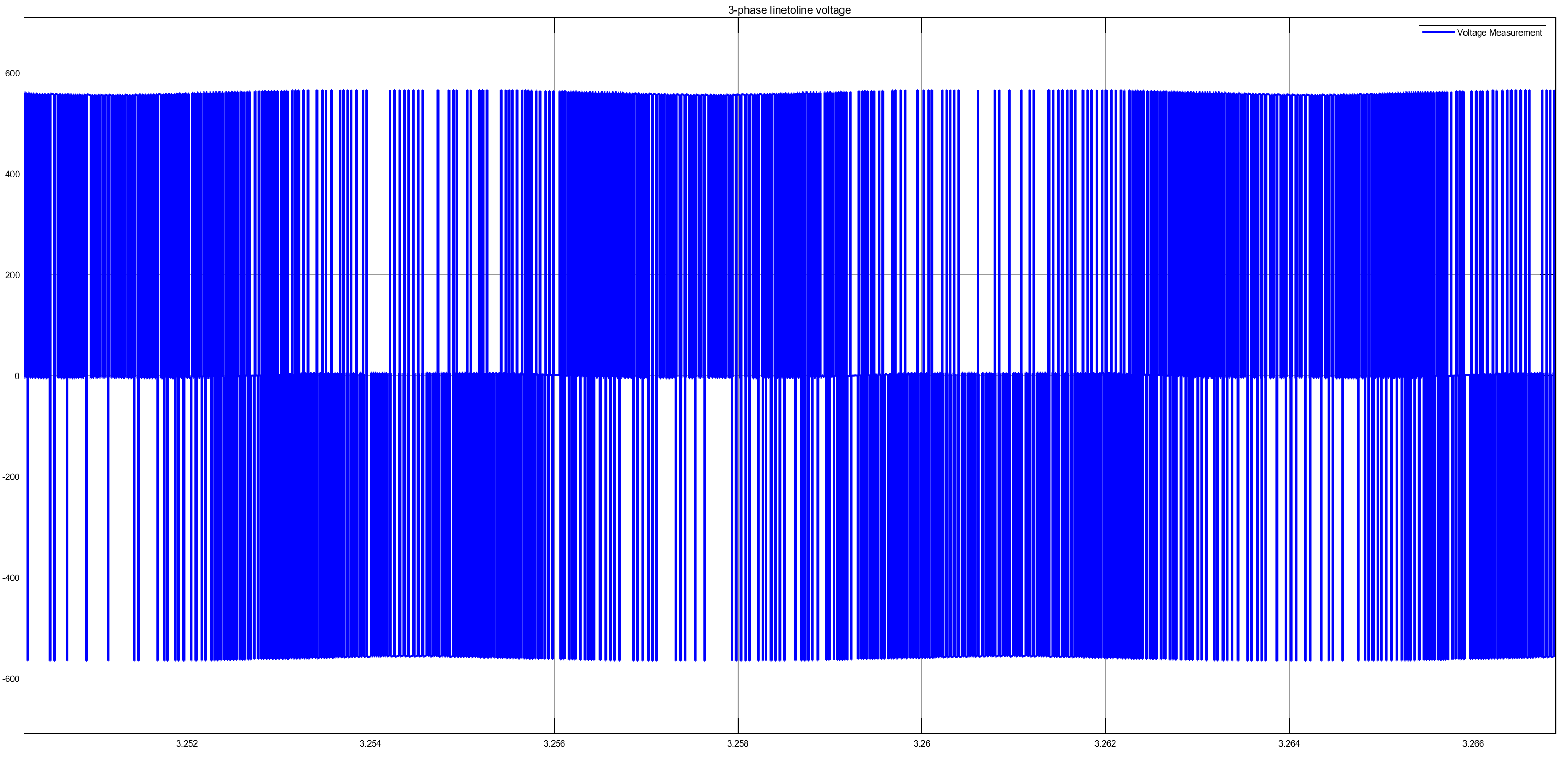


Figure : VAB linetoline voltage from a distance

In the figure XX, we see the VAB line-to-line voltage. However, in the real sinusoidal pwm technique, we should not see like this waveform. We should see like in the figure XX. The reason is that frequency and magnitude of references are changing continuously. Due to that, we do not see proper waveforms.

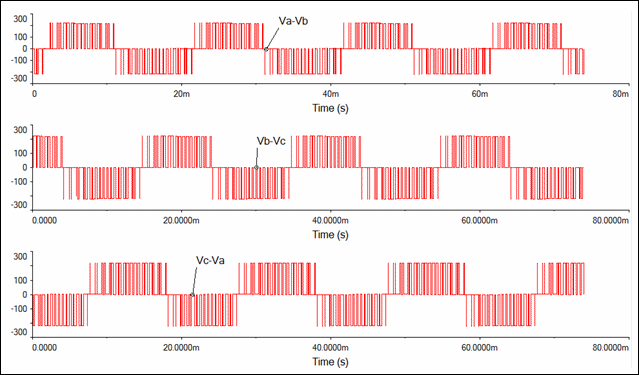


Figure 5: Sinusoidal pwm output waveforms

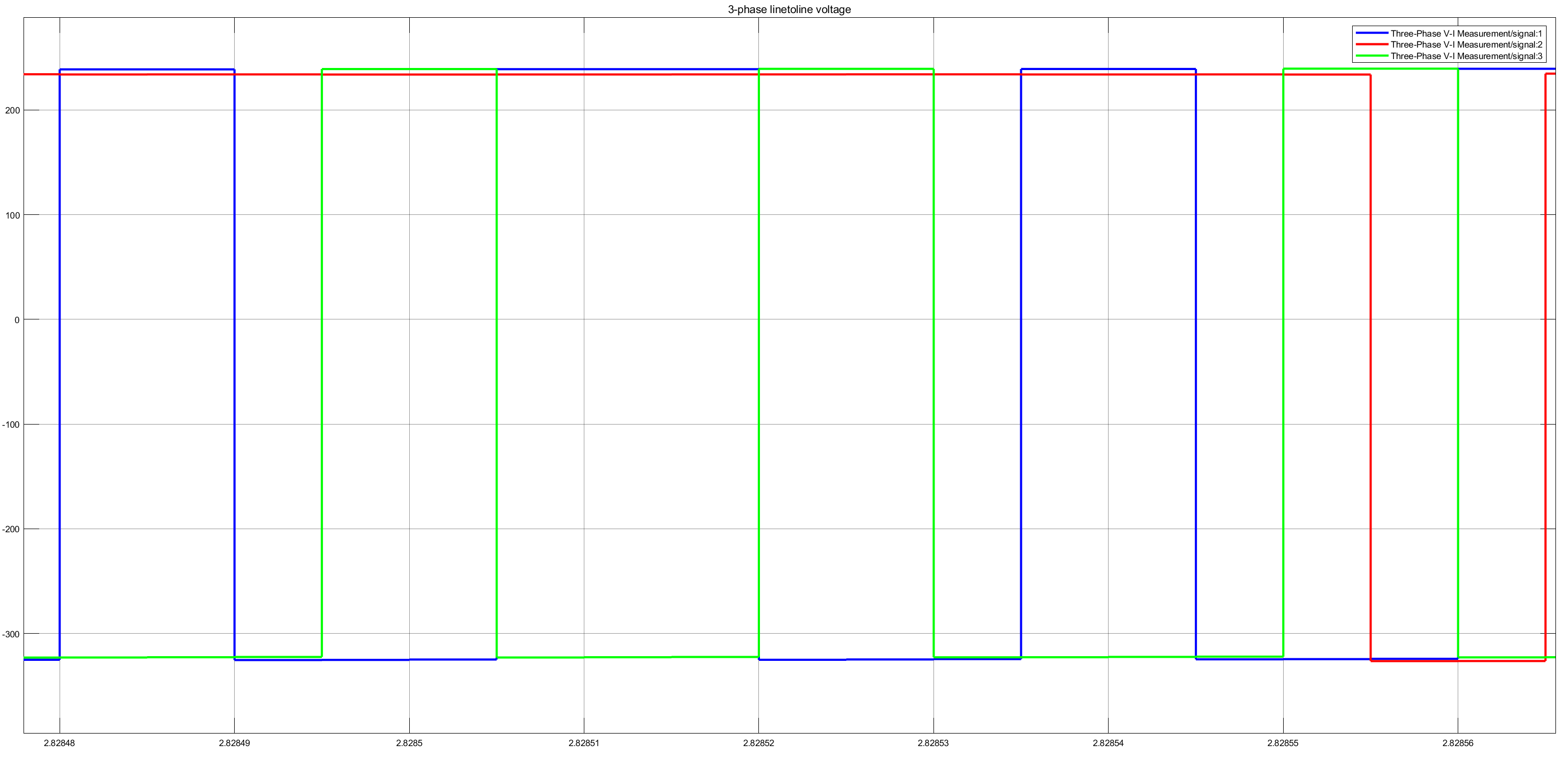


Figure : Three phase line voltages upon close look

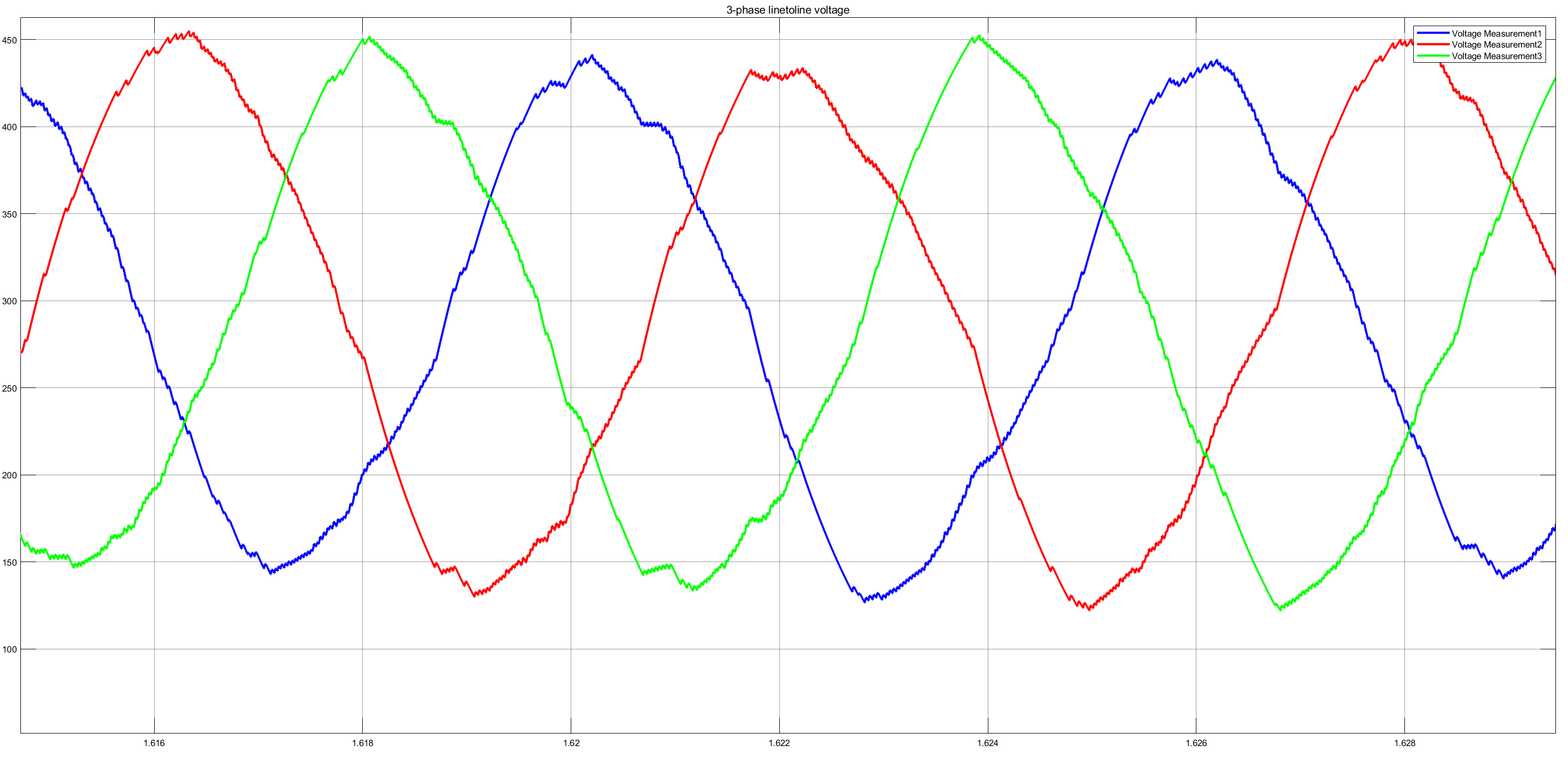


Figure : Three phase line voltages upon close look with low pass filter

The motor 3 phase voltages is not obvious since they occurs from square wave like in the figure XXX. However, when we added low pass filter to output of inverter voltage, we can see clearly the sinusoidal waveforms in the figure XXX.

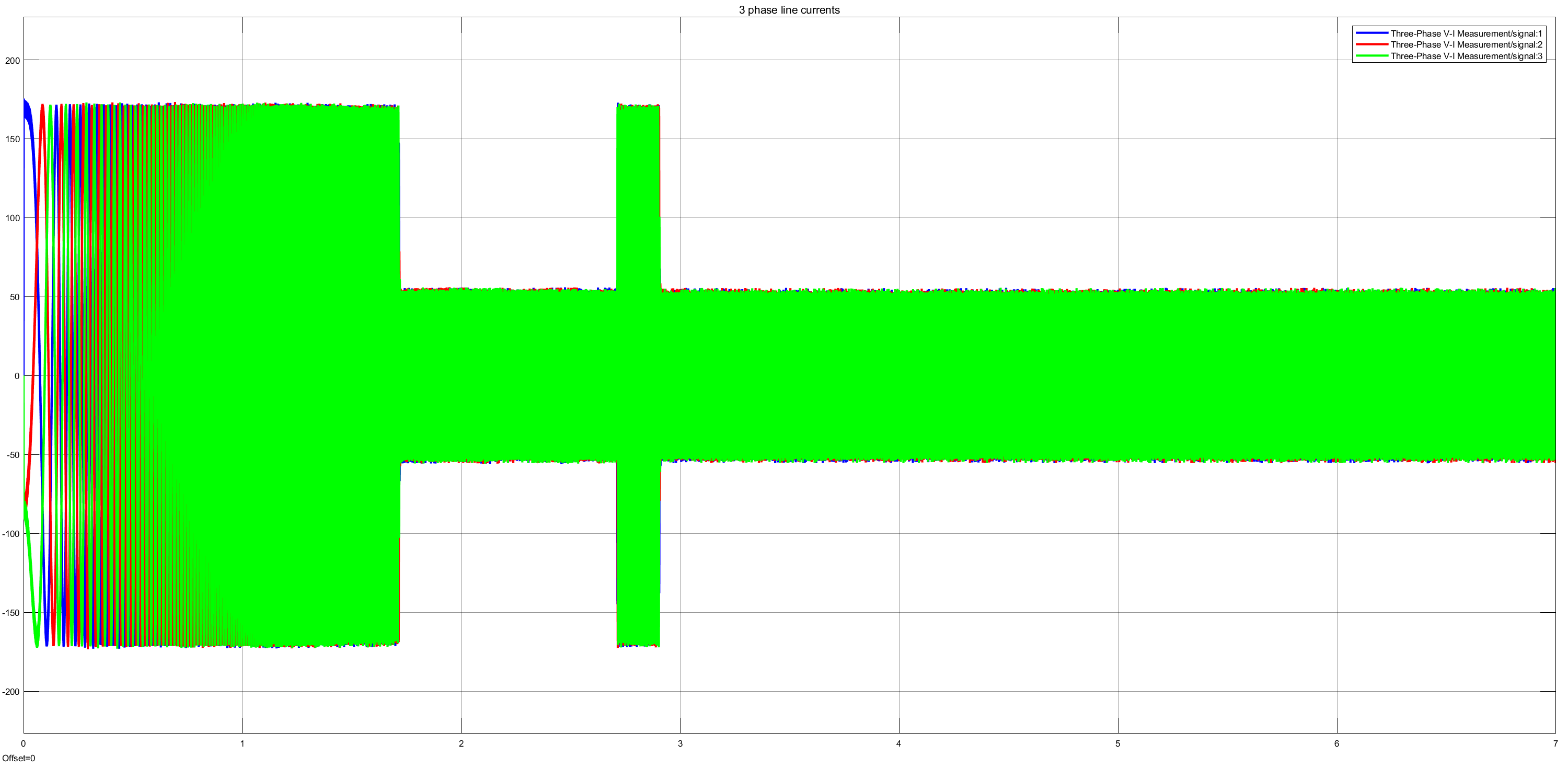


Figure : VABCline currents from a distance

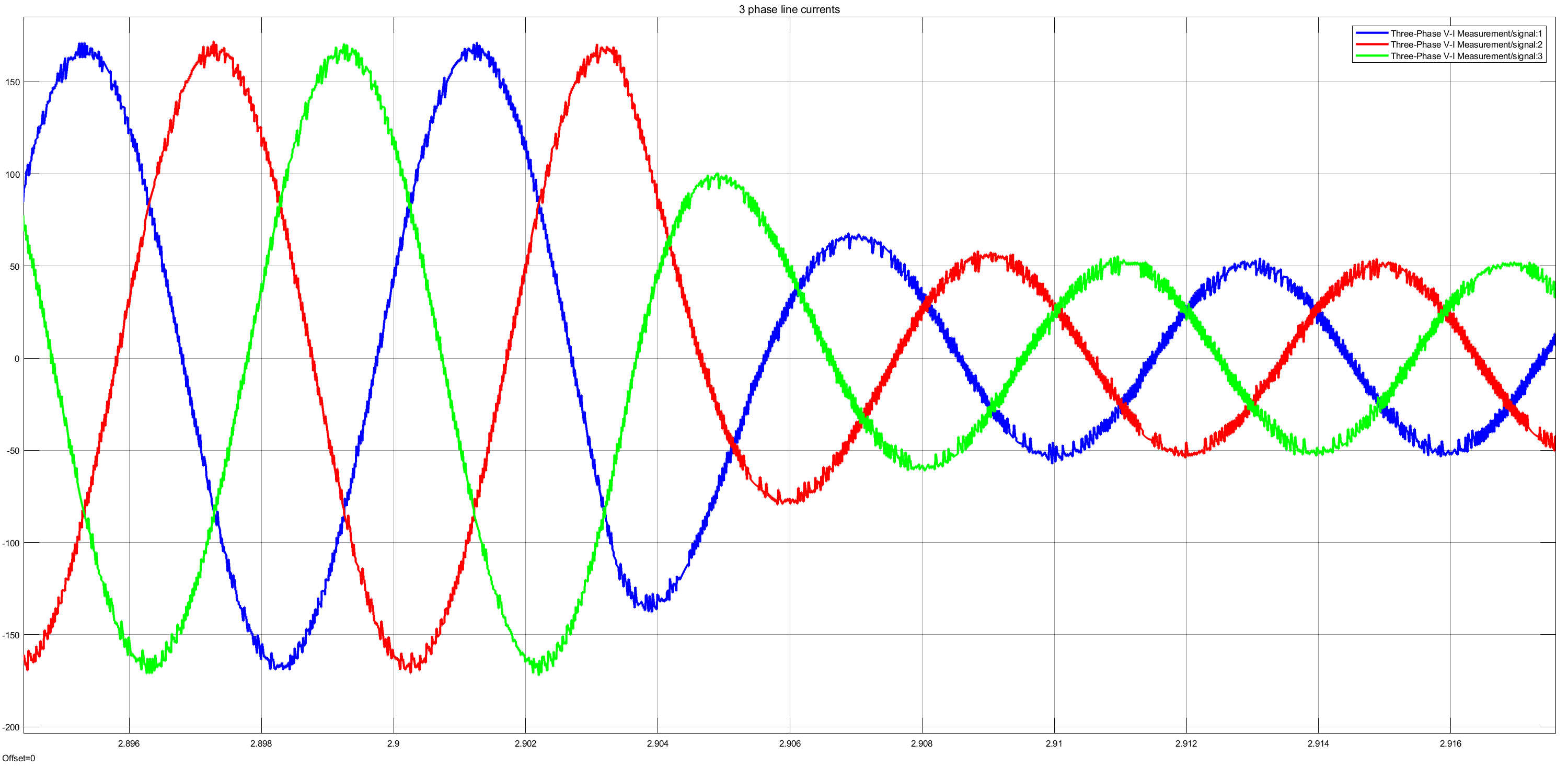


Figure : Three phase line currents upon close look

In the figure XXX, we see the waveform of line currents from a distance. In the beginning of the simulation, motor draws huge current that is starting current. Then, when it reaches to steady state, current value decreases. In a moment, we change the speed reference, motor draws huge current to speed up. After reaching to the steady state, current decreases. We see this relation in the figures XX and XX. One of them means torque and the other means d-q currents. We see that q current is responsible from torque since when torque increases, q current increases and vice versa. Moreover, current waveforms are sinusoidal and we expect this results.

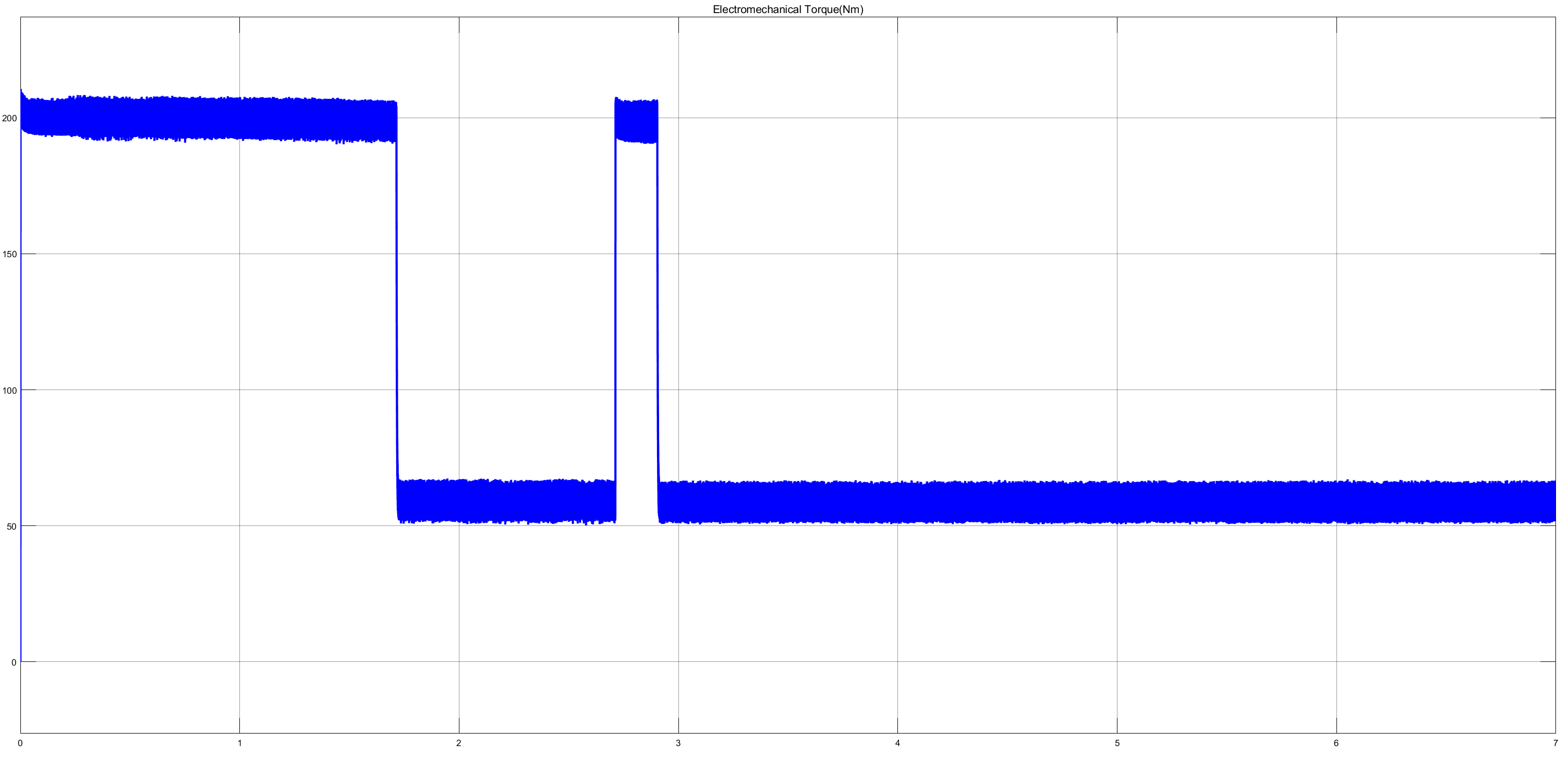


Figure : Electromechanical Torque (Nm) vs time characteristic

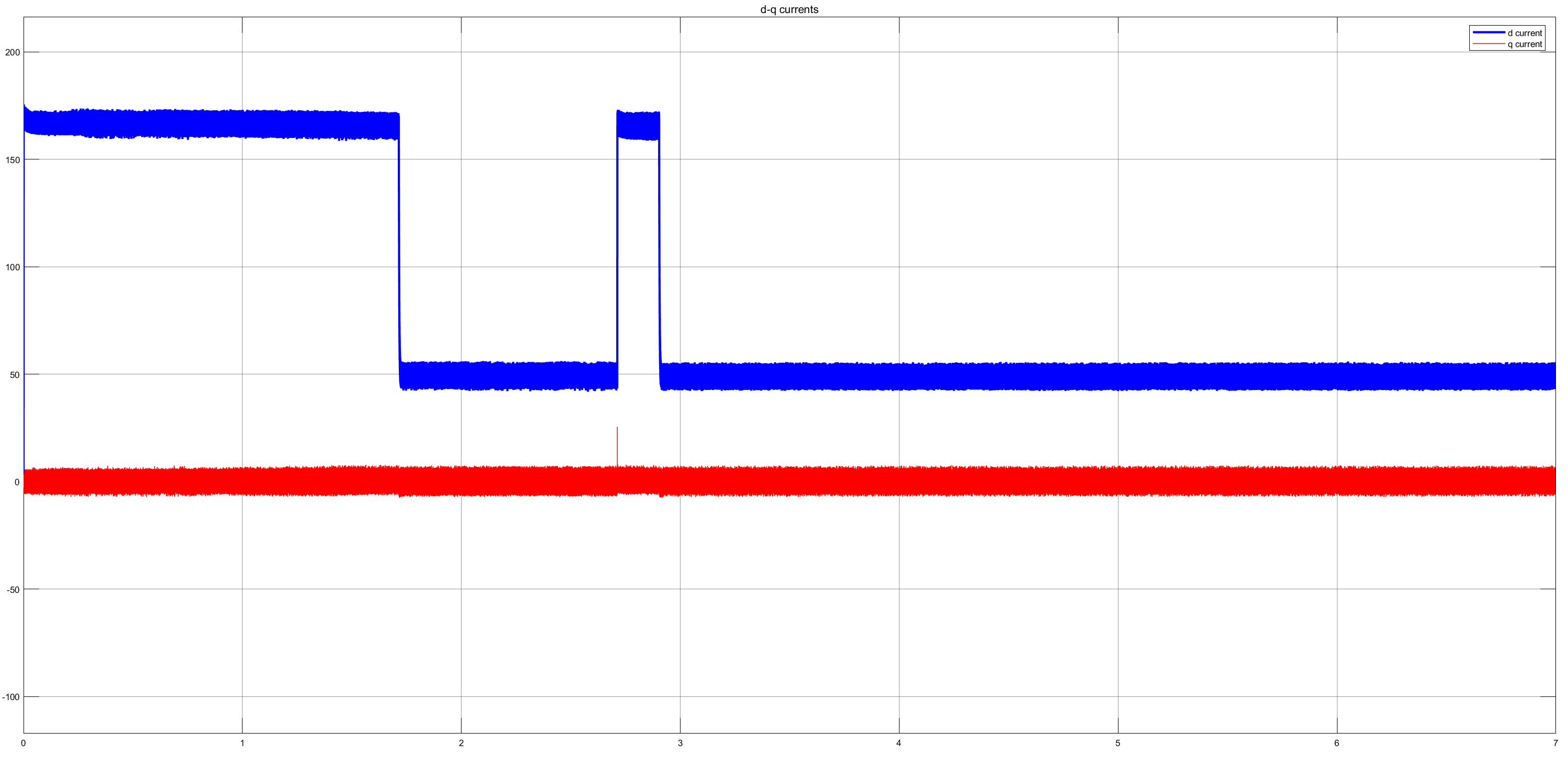


Figure : d (blue) and q(red) currents vs time characteristics

2-) In this part, when motor reaches to the steady state, we need to remove load. Then, as seen in the figure XX, rotor speed is changing a little bit, but, after a while, speed becomes reference speed.

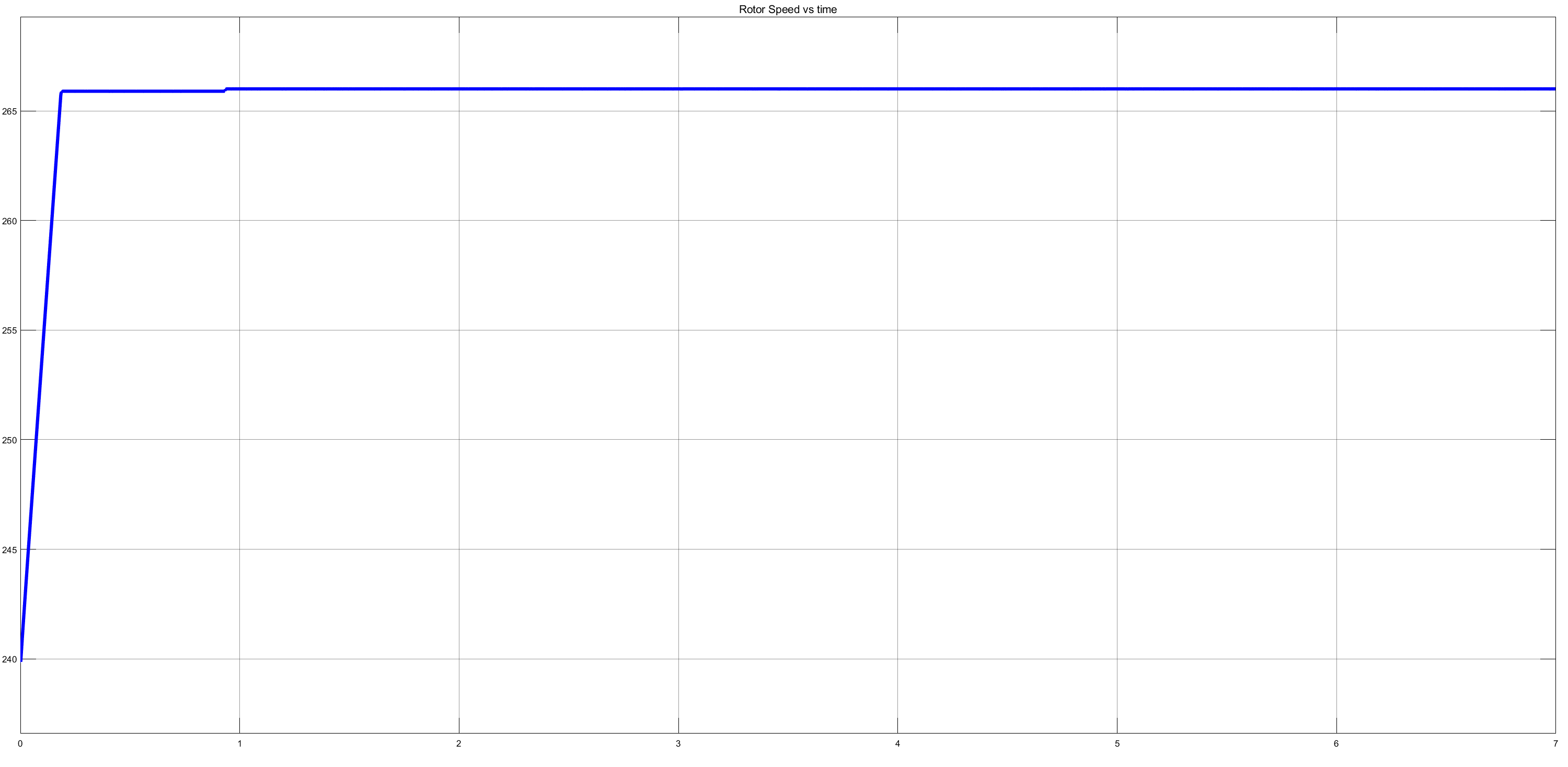


Figure : Rotor Speed(rad/sec) vs time(sec) characteristic

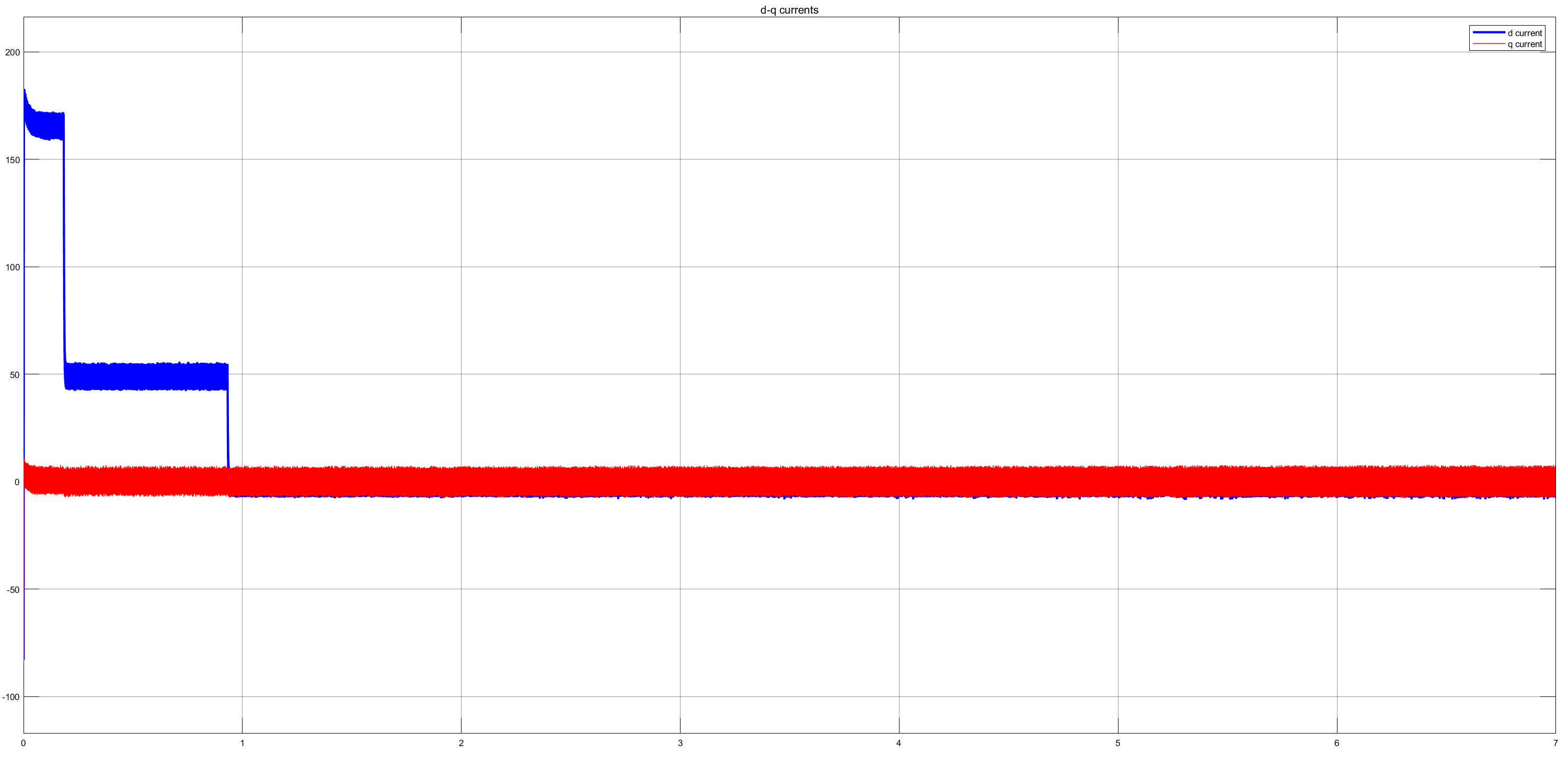


Figure : d (blue) and q(red) currents vs time characteristics

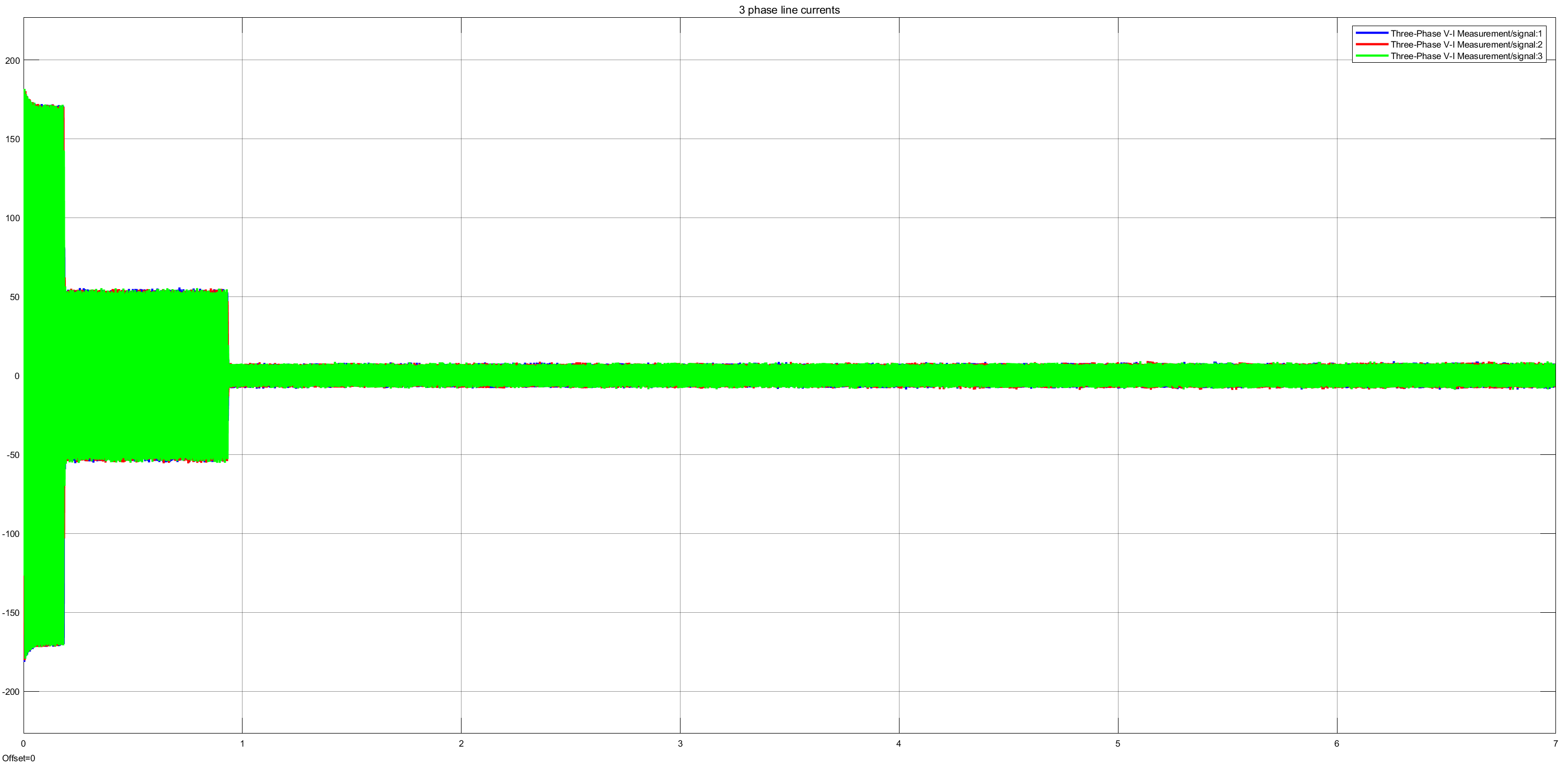


Figure : VABC line currents from a distance

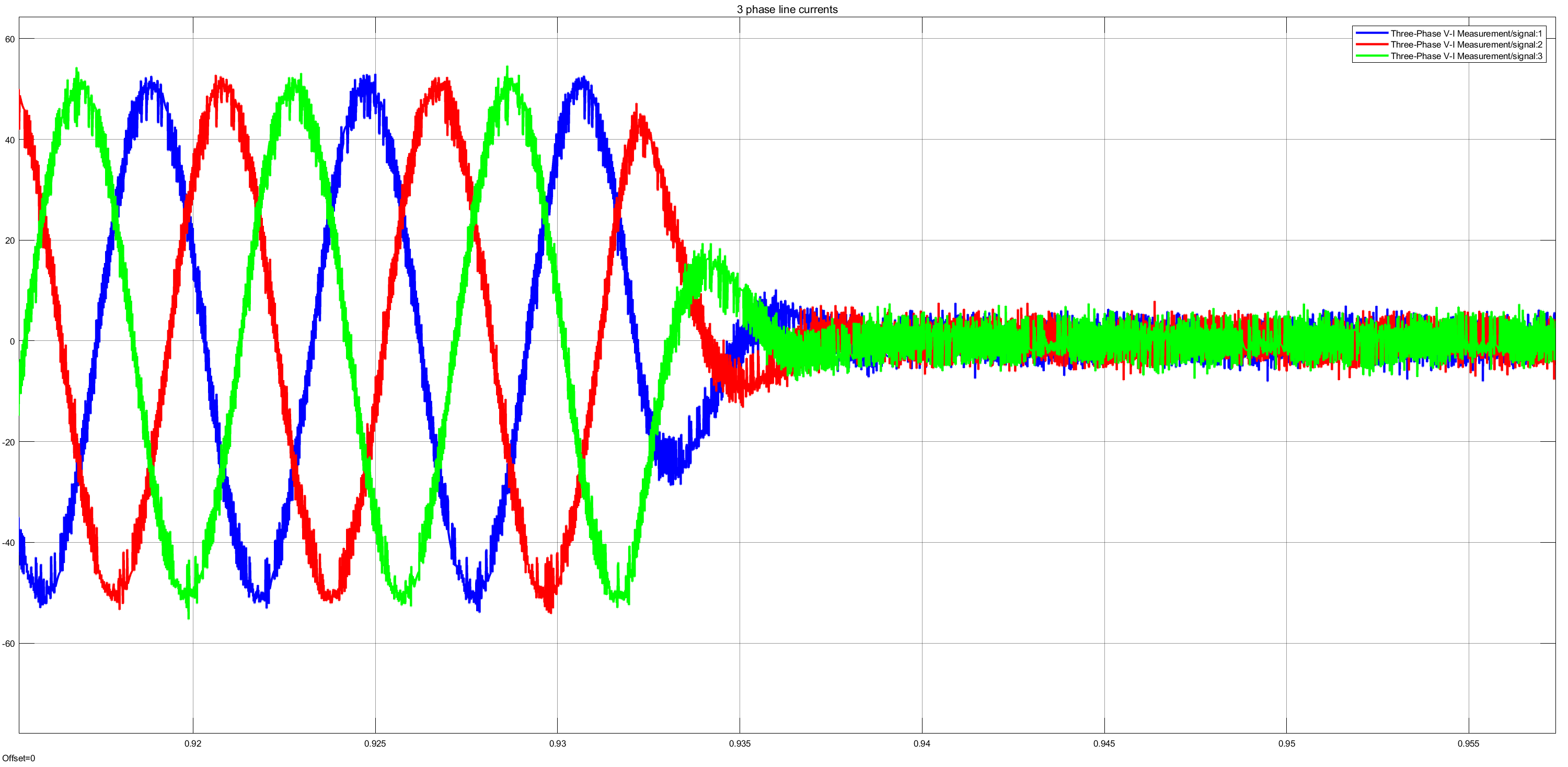
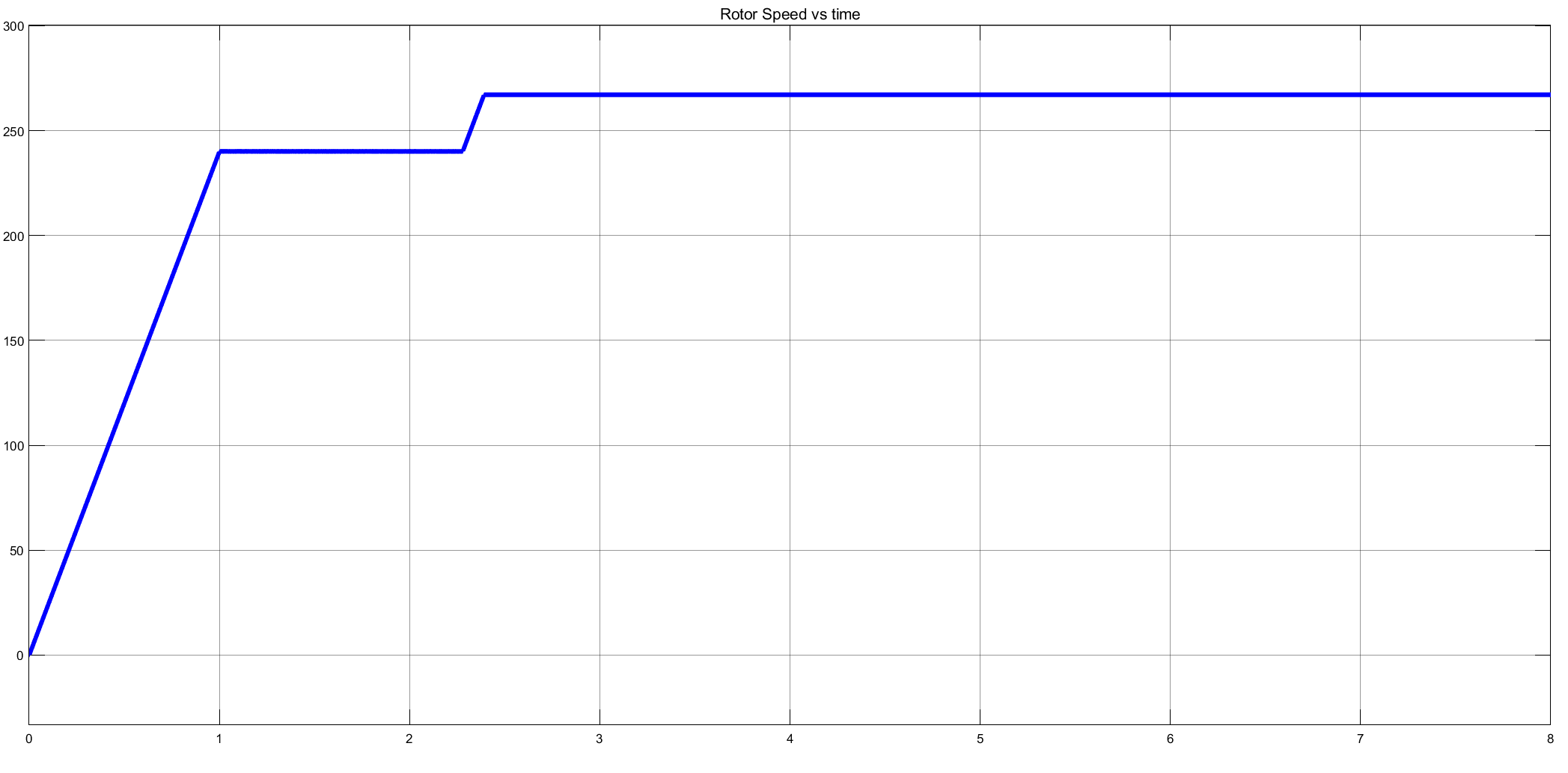
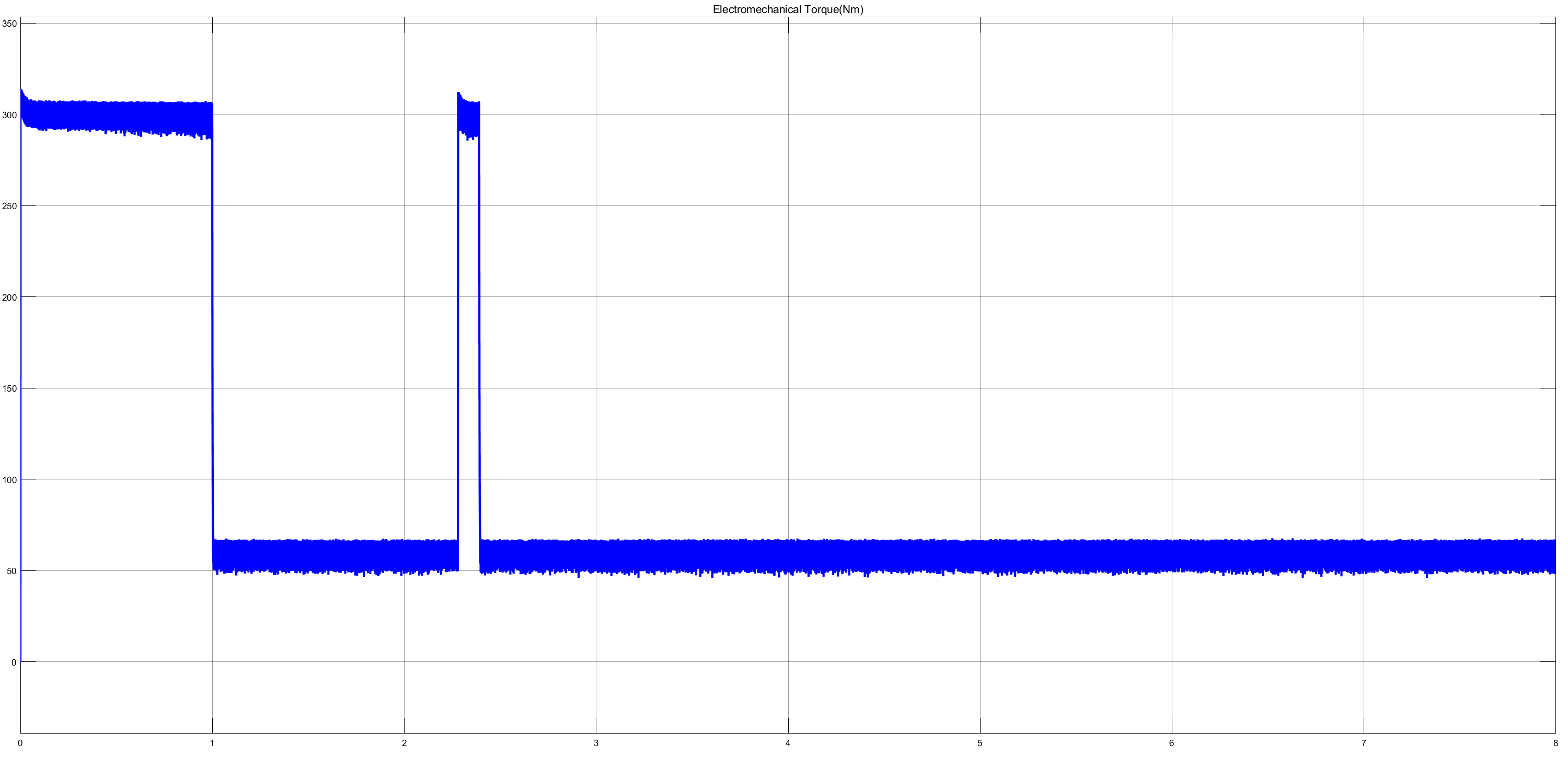


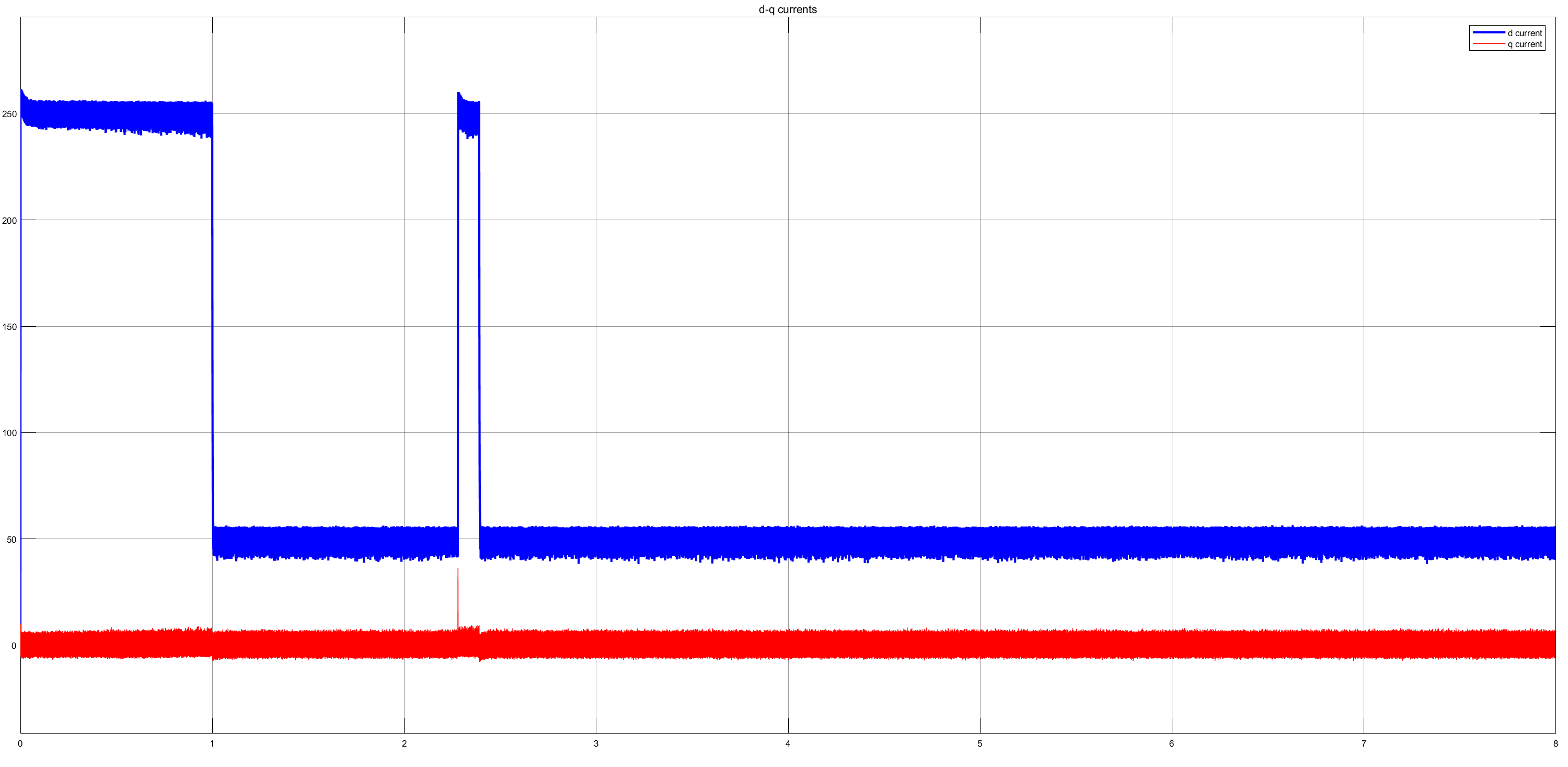
Figure : Three phase line currents upon close look

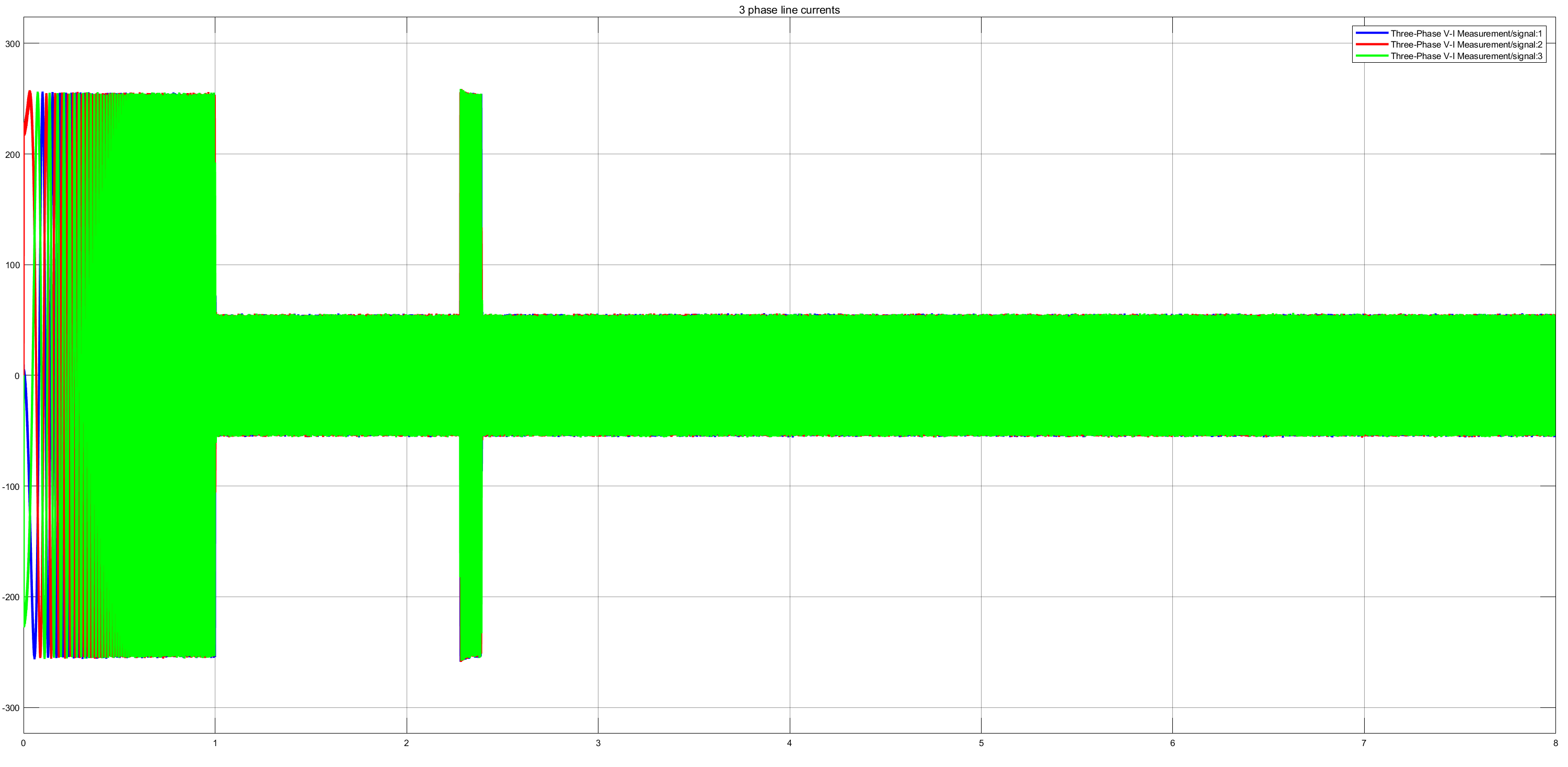
After removing the load, as seen in the figures XX,XX and XX, all of them decreases. We can mention their relation in the part 1. Again, we that relation.

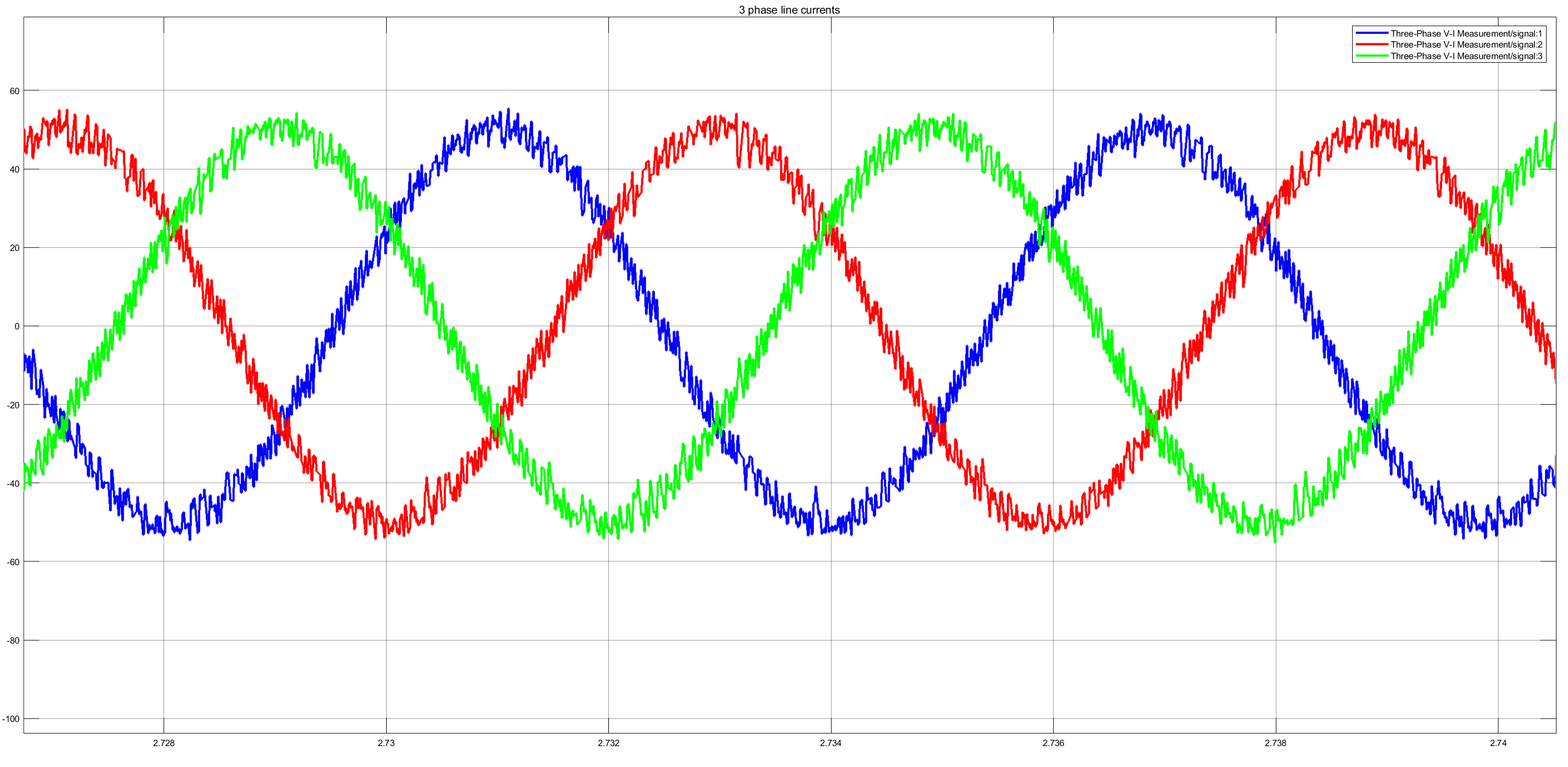
**PART C: SPACE VECTOR PWM (SVPWM)**

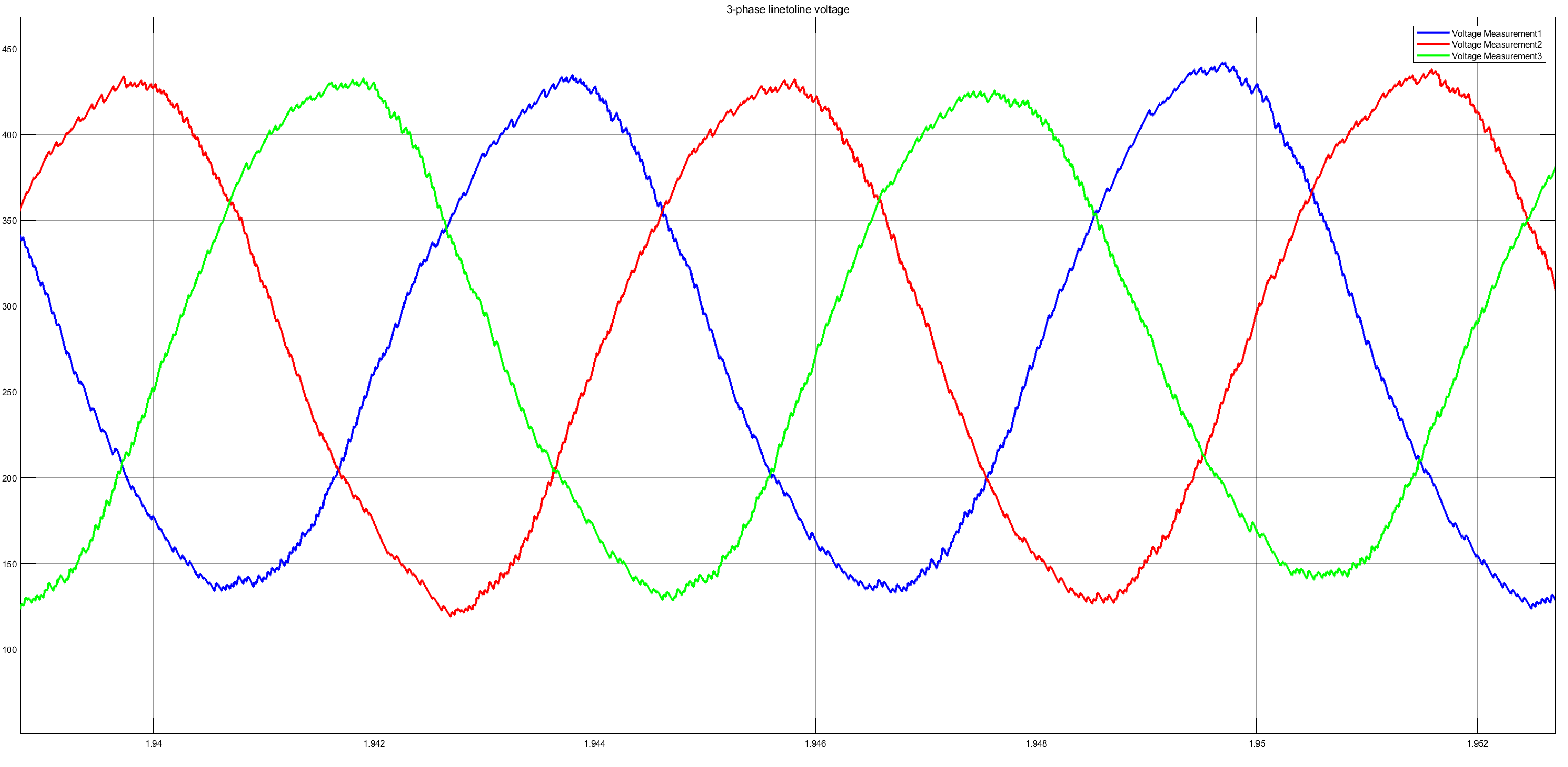












2-) The SVPWM technique gives higher level of fundamental voltage as compared to SPWM. The comparison of these two modulations gives the results that SVPWM is the best and most reliable modulation because it enables efficient use of DC voltages and smartly works with vector control thus, gives less Total Harmonic Distortion (THD), better PF, and less switching losses at high frequencies.

**PART D: COMPONENT SELECTION AND VERIFICATION**