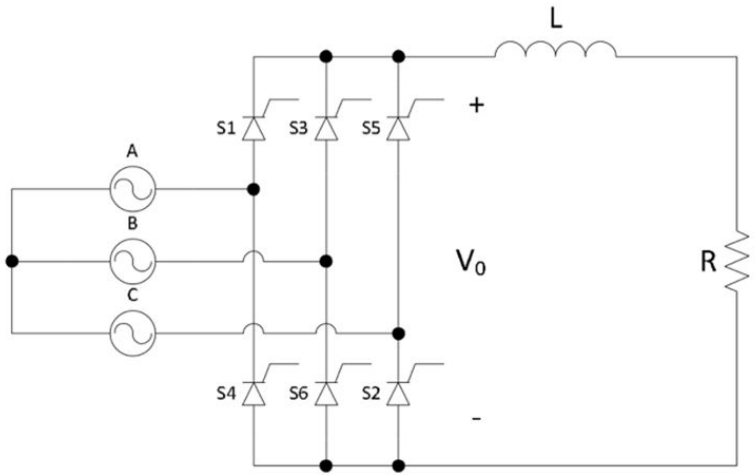
Midterm Project 1: Simulation, parameters and performance of the three-phase phase-controlled full-wave rectifier with RL load

Danissa Sandykbayeva
ROBT 307 - Power Electronics, Fall 2020

Initial requirements of the system

- V_m (phase voltage) = 300 V
- f = 60 Hz
- P_{load} = 100 kW
- Vo = 300 V
- ΔI = 2%



Calculations: Delay angle, α

$$V_o = \frac{1}{\pi/3} \int_{2\pi/3}^{\pi/3} V_{m,L-L} sin(wt) d(wt)$$

$$= \frac{3V_{m,L-L}}{\pi} cos\ \alpha$$

$$V_o = \frac{3\sqrt{3}V_m}{\pi} cos\ \alpha$$

$$V_m = \sqrt{3}V_{m,L-L}$$

$$\alpha = cos^{-1}(\frac{V_o\pi}{3\sqrt{3}V_m}) \approx 52.80°$$

Calculations: Resistance, average output current

$$P_{load} = I_o^2 R = 100\ kW$$

$$V_o = I_o R = 300\ V$$

$$\begin{cases} I_o^2 R = 10^5\ W \\ I_o R = 300\ V \end{cases}$$

$$R = 0.9\ \Omega;\ \ I_o = 333.3\ A$$

Calculations: Inductance

$$I_n = \frac{V_n}{Z_n}$$

$$Z_n = \sqrt{R^2 + (nwL)^2}$$

$$Z_6 = \frac{V_6}{I_6} = \frac{0.2563\sqrt{3}V_m}{0.01I_o}$$

$$= 39.99\ \Omega$$

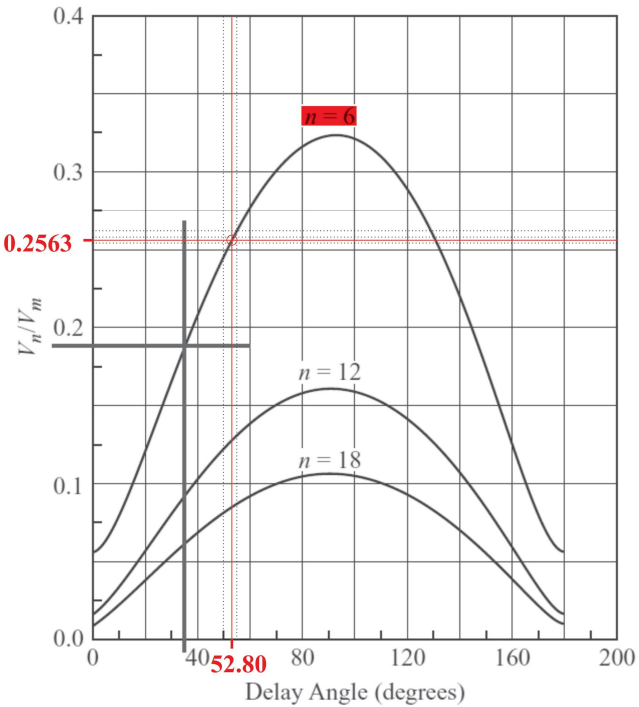
$$V_6 = 0.2563V_{m,L-L} = 0.2563\sqrt{3}V_m$$

$$w = 2\pi f \approx 377\ rad/s$$

$$0.9^2 + (6 \cdot 377L)^2 = 39.99^2$$

$$0.81 + 36 \cdot 377^2 L^2 = 1599.20$$

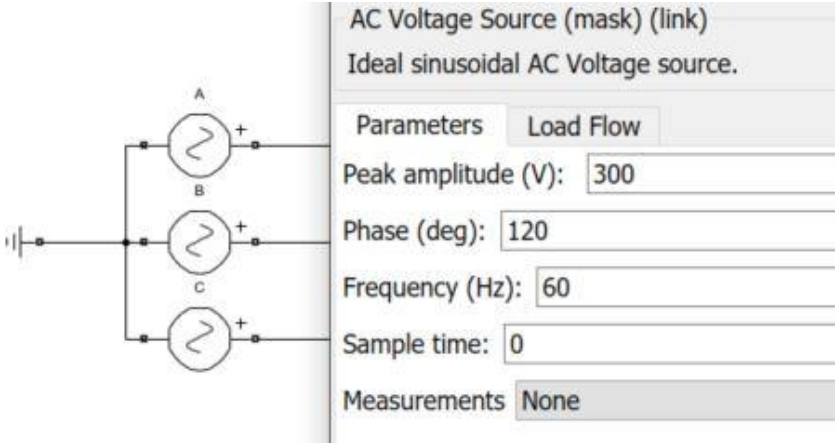
$$L = 0.0177\ H = 17.67\ mH$$



Simulink design: AC source

“AC Voltage Source” block from the Simscape Library are used with the following parameters:

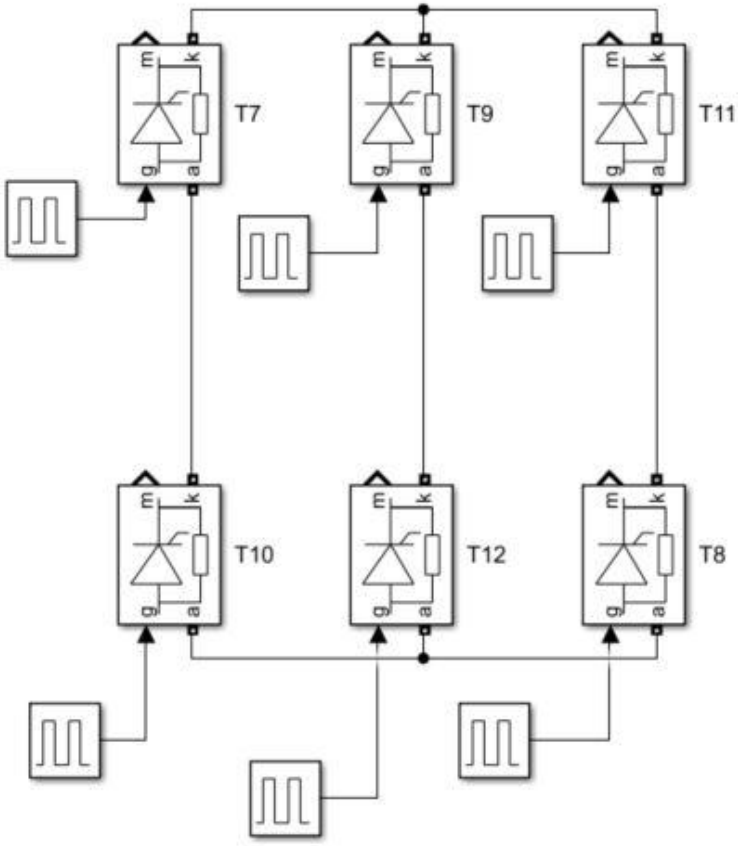
- Peak amplitude (V) = 300
- Phase (deg) = 0 (for VA),120 (for VB),240/-120 (for VC)
- Frequency (Hz) = 60

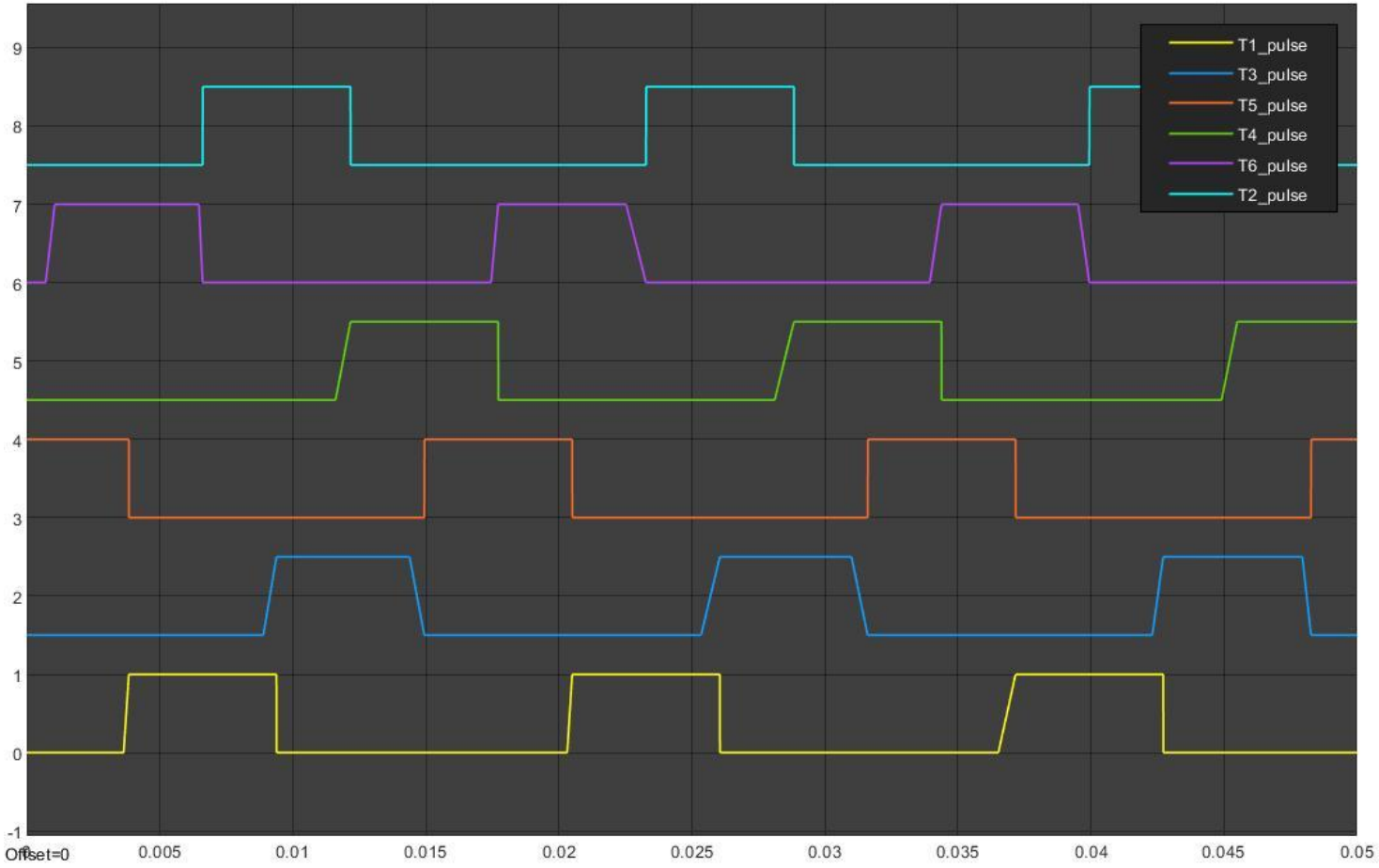


Simulink design: Thyristors and pulse generators

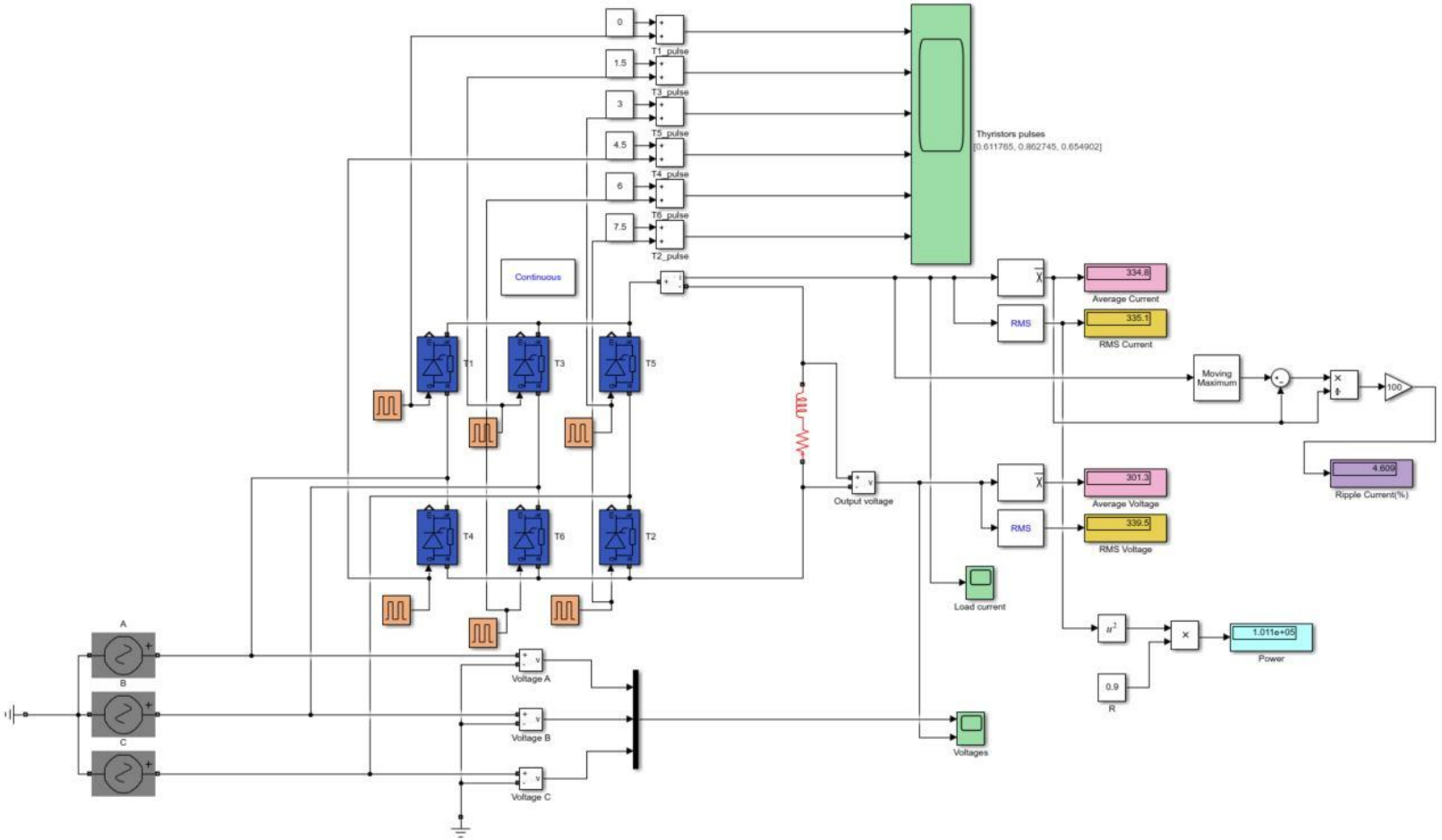
Parameters for pulse generators:

- Period (secs): 1/60
- Pulse width (% of period): 100/3
- Phase delay (secs): $\alpha+n\cdot30^\circ$ $360^\circ*60$, where n depends on the thyristor

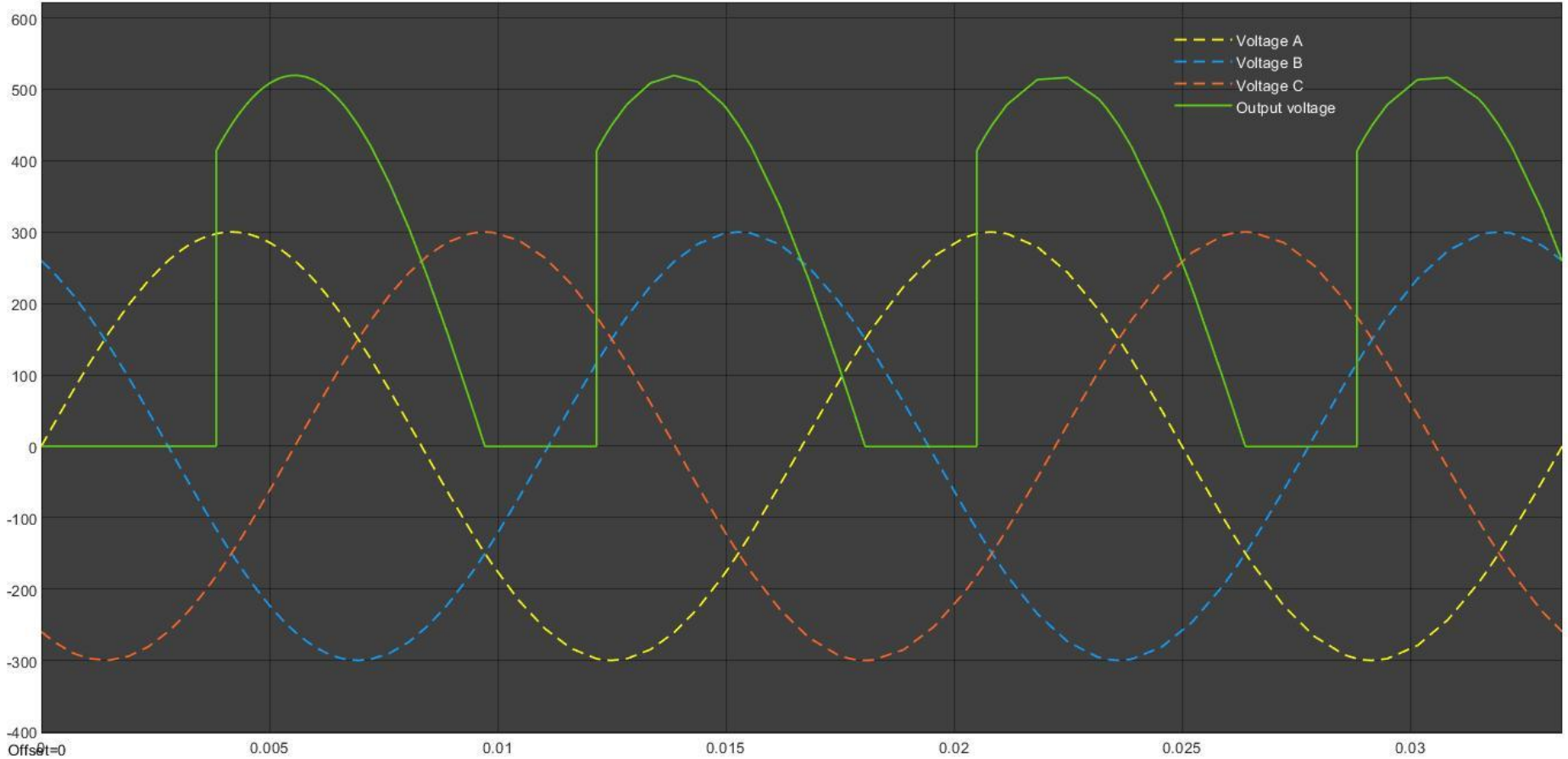




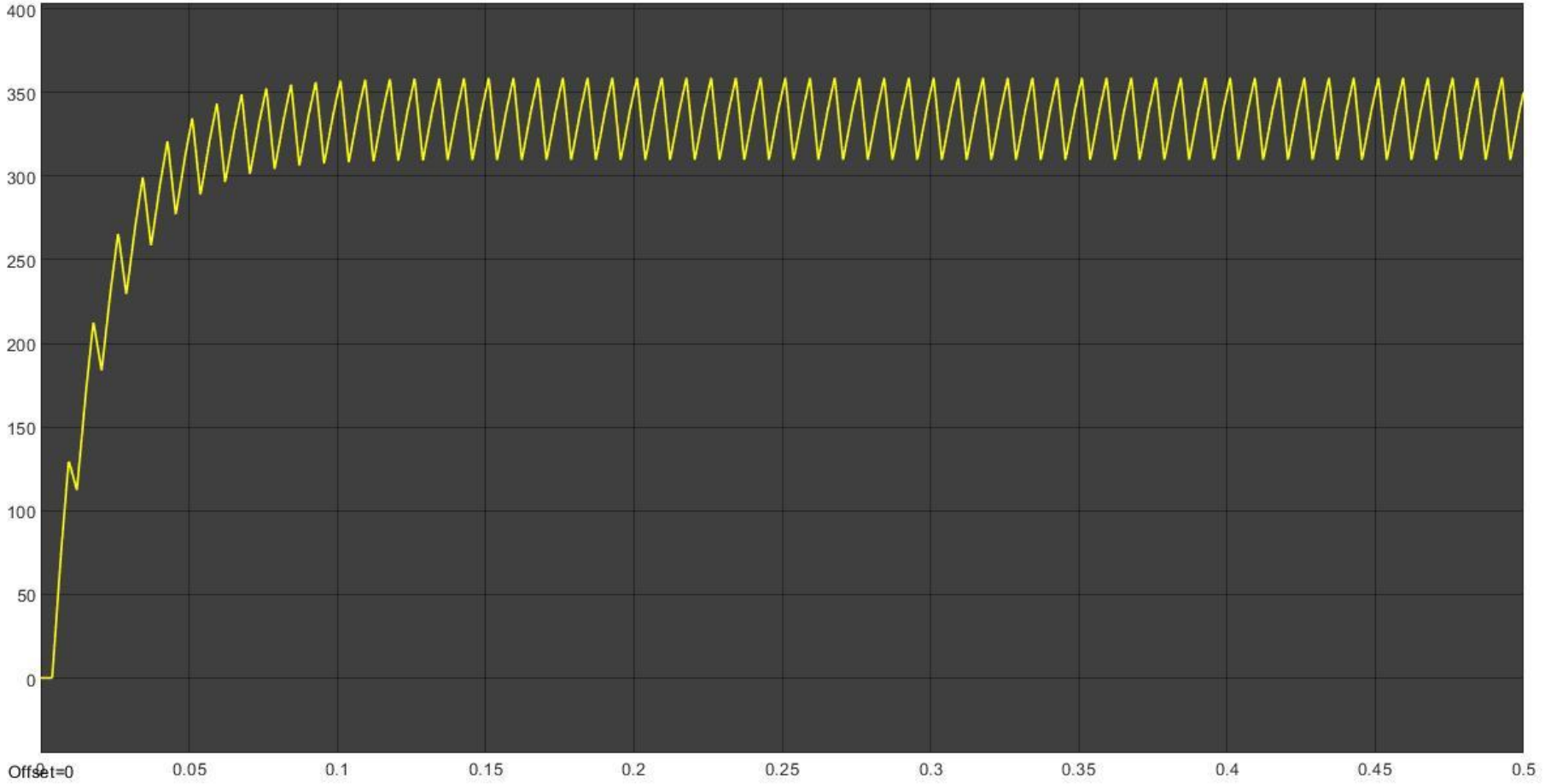
Thyristors firing pulses



Final SIMULINK model

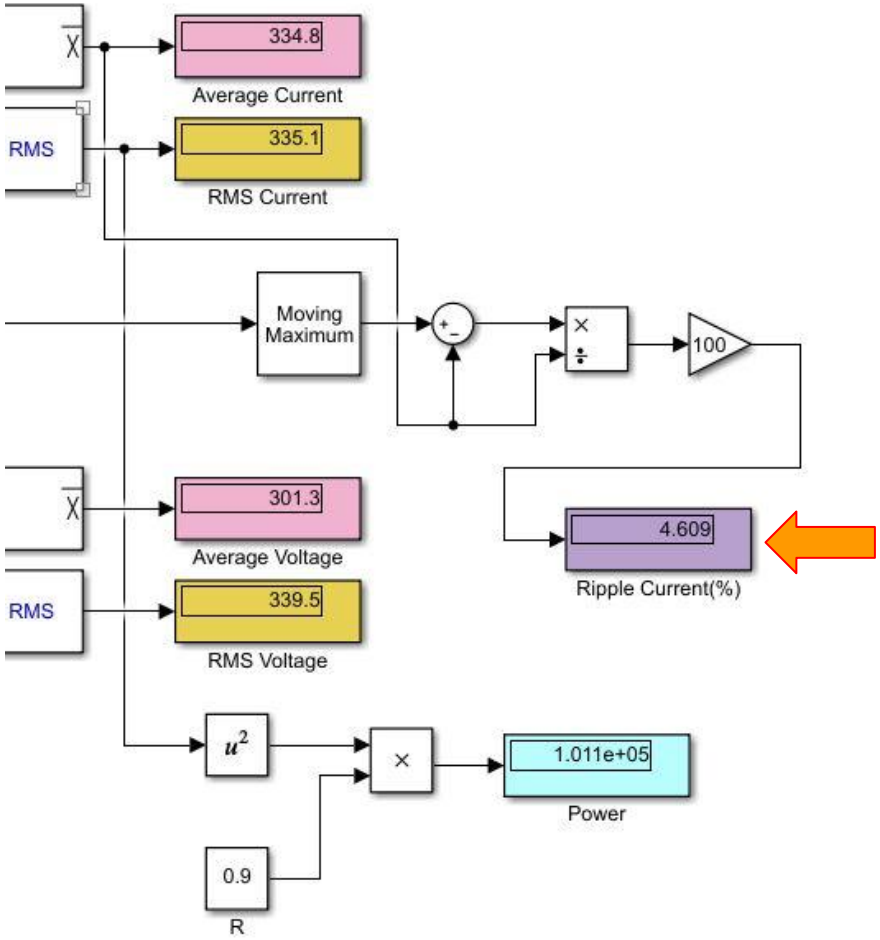


Voltage results of the simulation

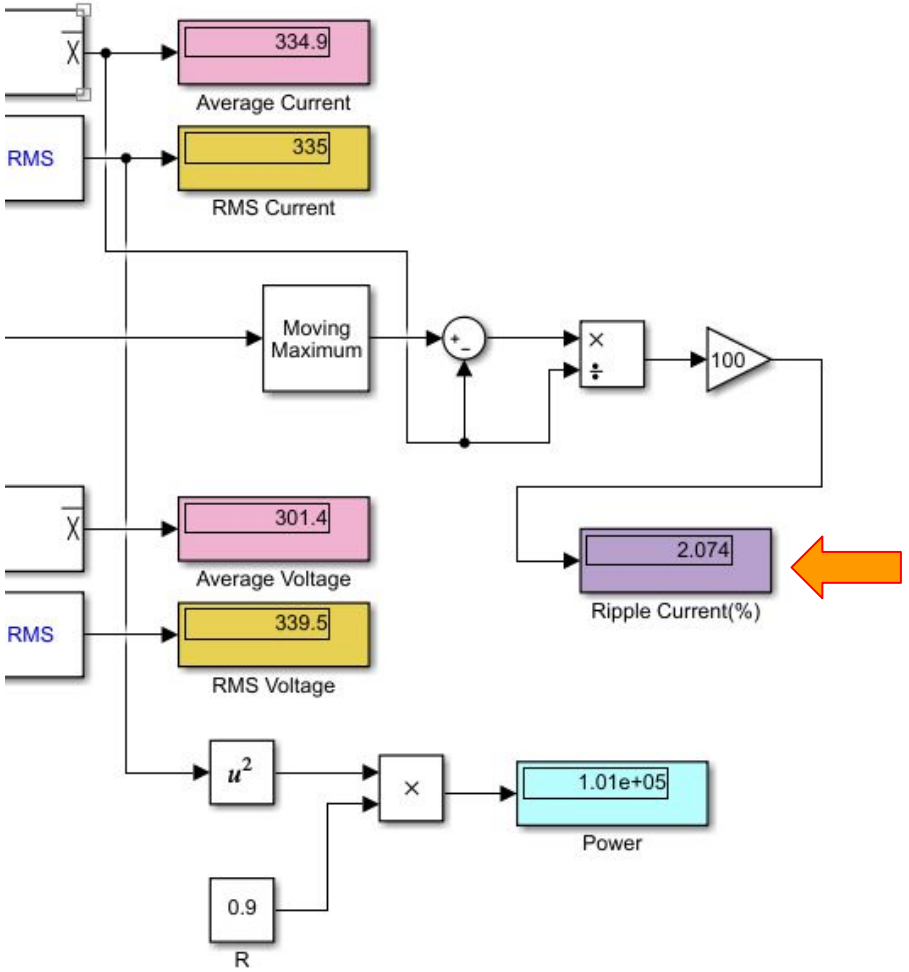


Current results of the simulation

Simulation results



Simulation results, with Inductance manual tuning (L=0.038H)



Conclusion

All of the initial requirements have been met, even though obtaining proper current variance required some additional tuning the to the values that differ from our calculated ones. On the other hand the remaining requirements of load power, average output voltage followed the behaviour predicted in the calculations. Final parameters are:

- R = 0.9 Ω
- L = 0.038 H
- α = 52.8 ◦