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EV MASTER CLASS CAPSTONE PROJECT

Simulation of On-Board Charger for E-Bike Application

Assumptions

The Onboard Charger was designed based on parameters specific to an Electric Bike:

- **Input Voltage (Vin): 110-240V AC**
- **Output Voltage (Vout): 48V DC**
- **Output Current (Iout): 5A**
- **Output Power: 240W**
- **Charging Efficiency >90%**
- **Power Factor >0.9**

Output Voltage with 1% ripple and Current of 1A

- Capacitor to be connected for a load (Resistive) current of 1A, ripple voltage of 1%.

$$C = I_{load}/(2 * f * dV)$$

= 1A/(2*50*230*sqrt(2)*1%

C= 3.074mF

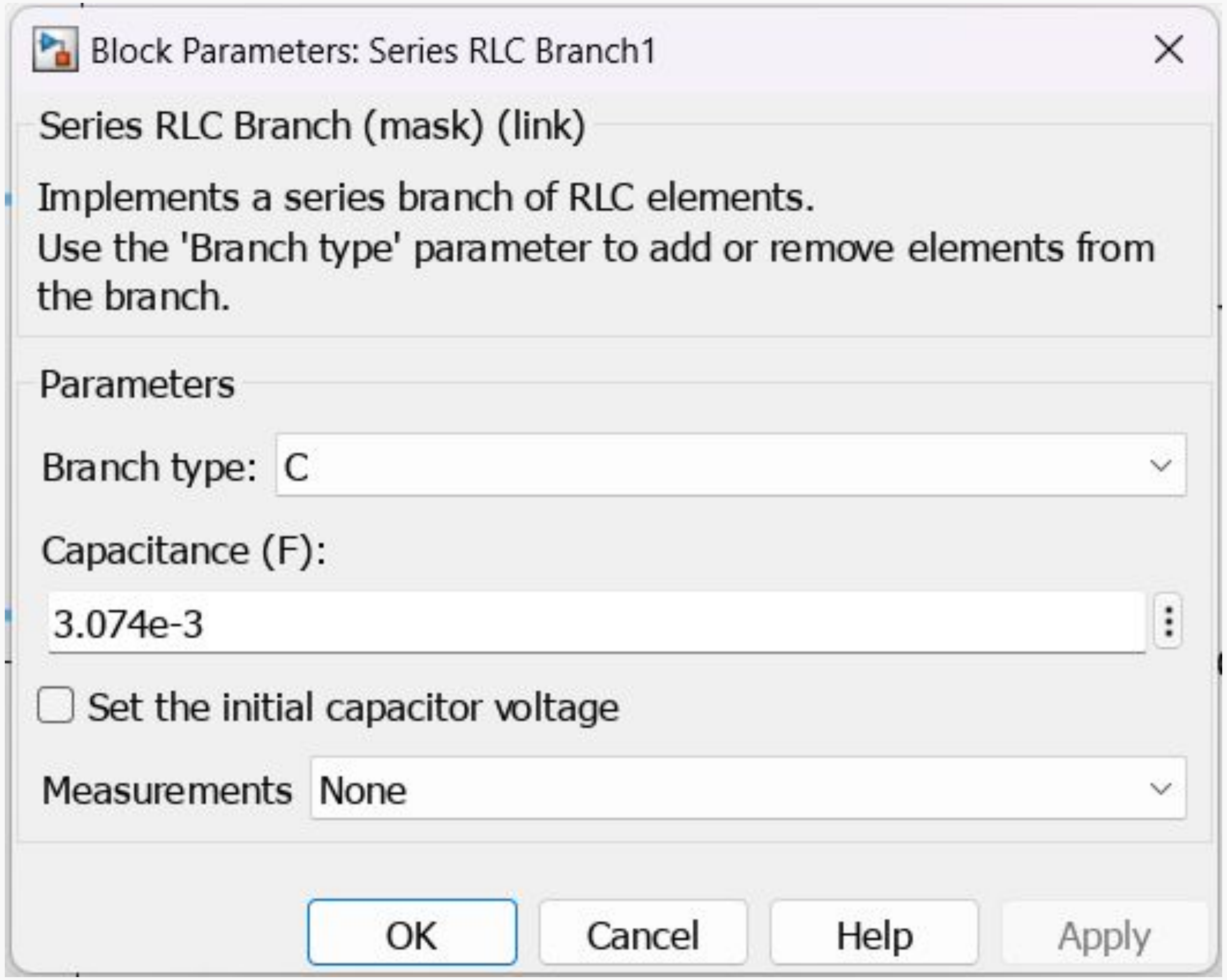
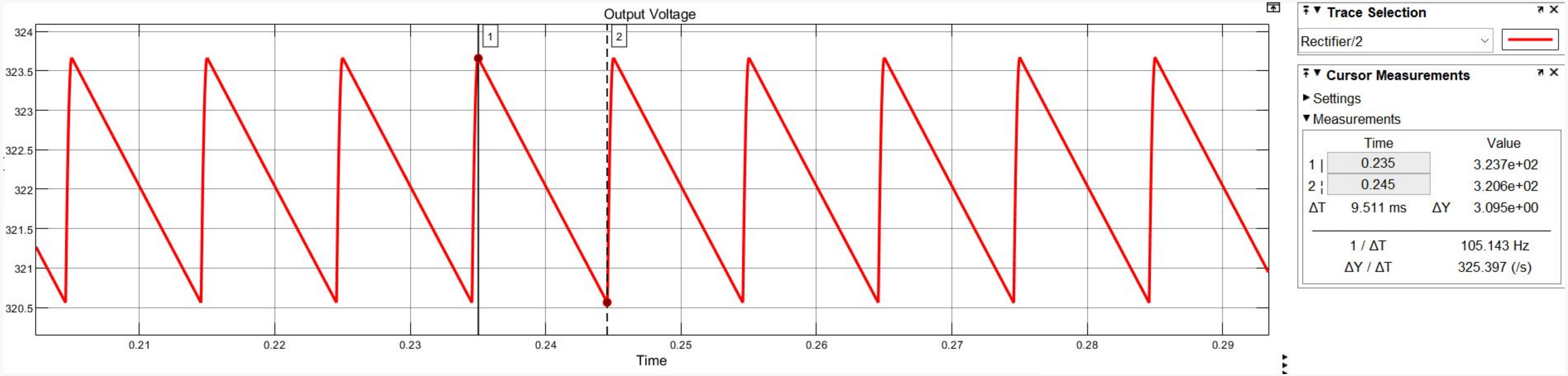
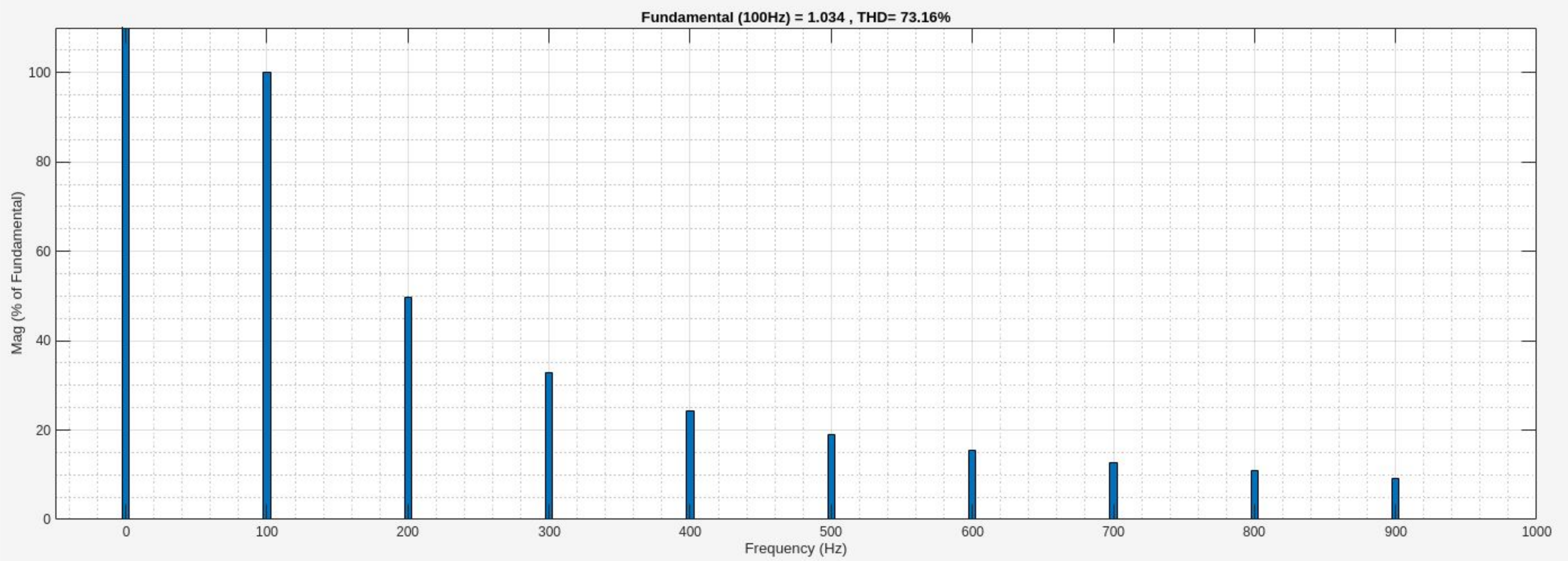


Fig. 8: FBR filter Capacitance Value

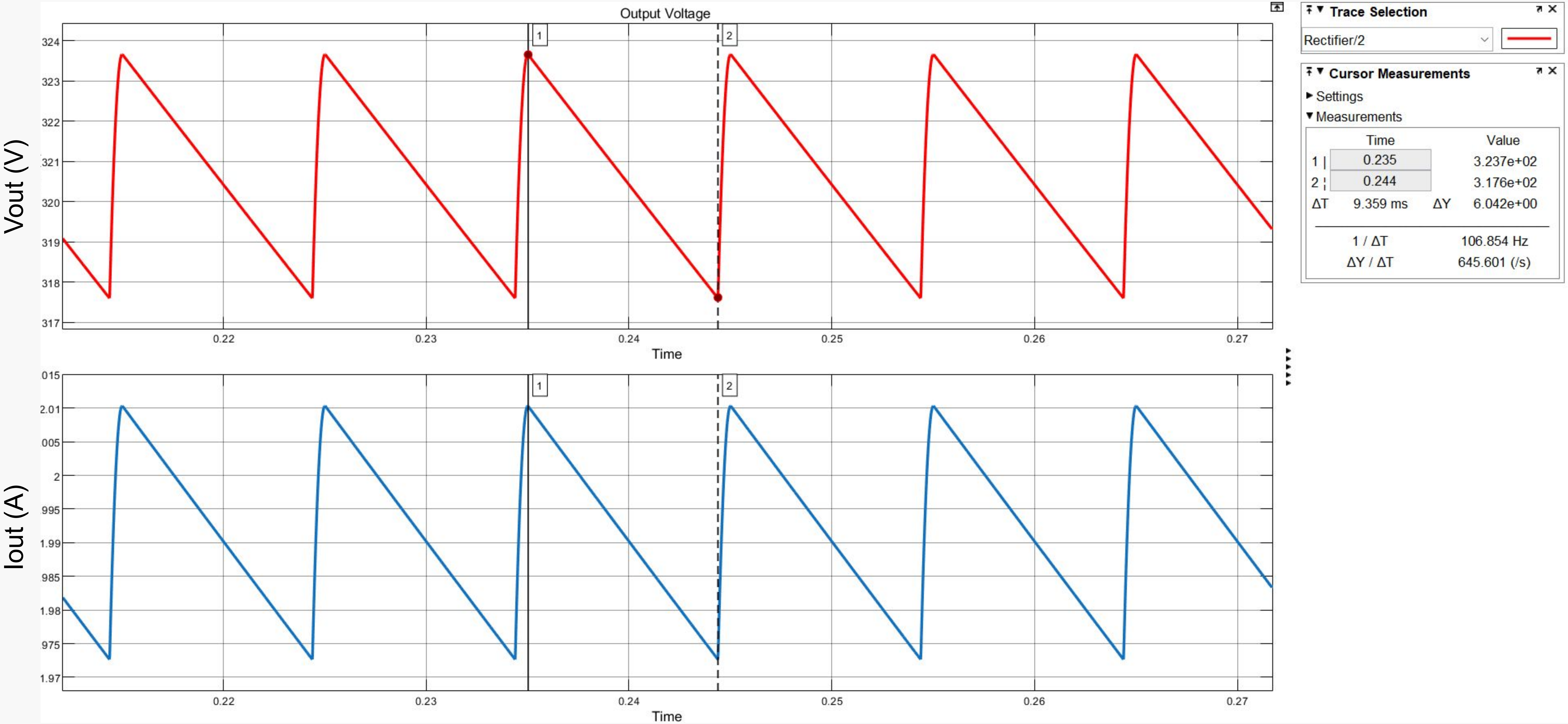
Output Voltage with 1% ripple and Current of 1A



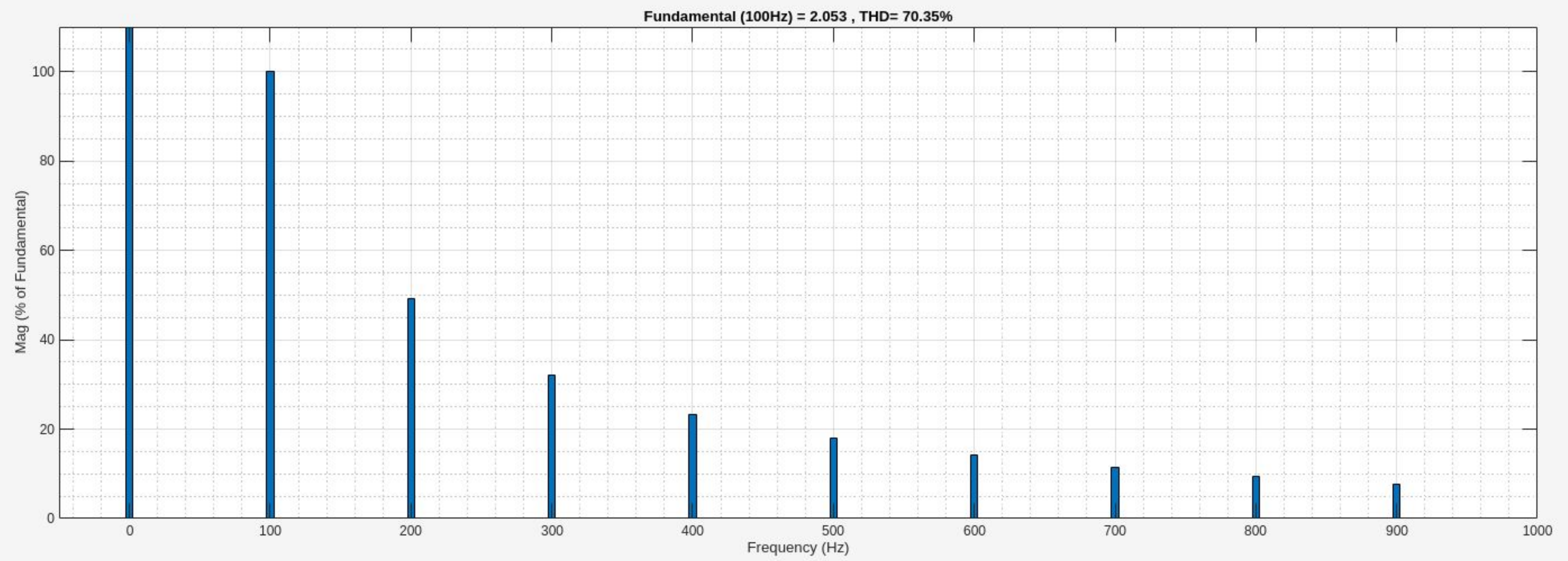


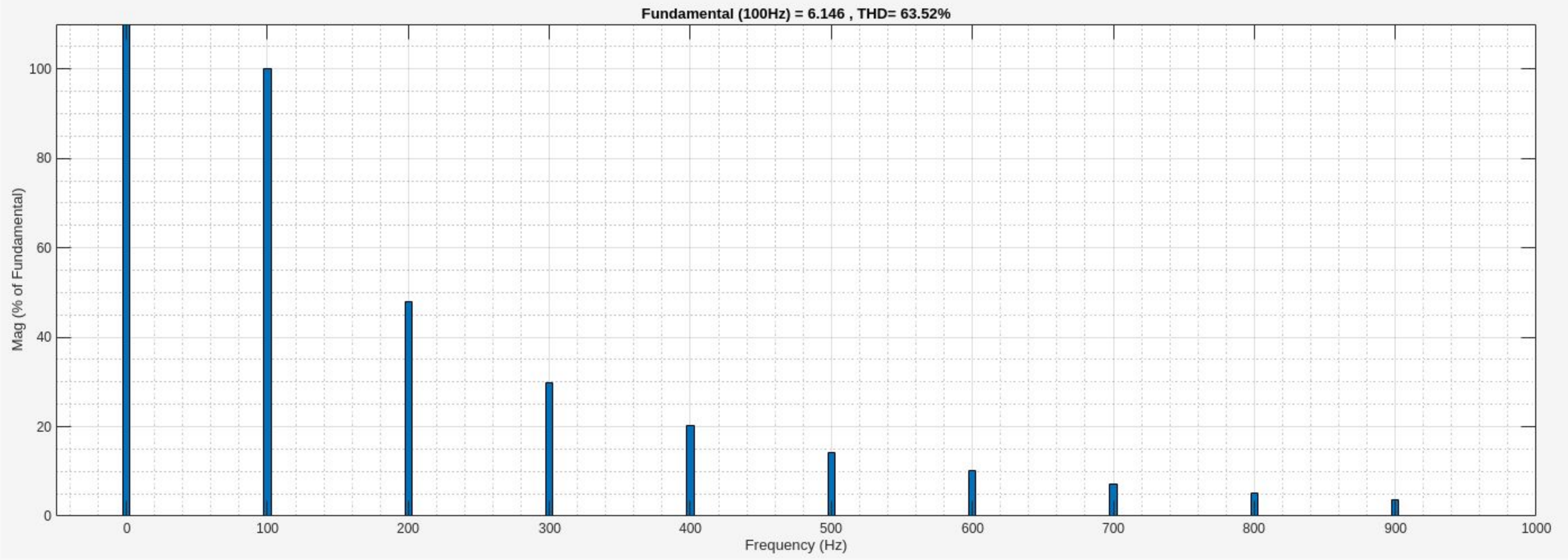
With the calculated value of capacitance, the TDH was observed to be 73.18%, and the voltage ripple was around 3.01V which is <1%

Output Voltage and Current of 2A by varying load



THD: Output Voltage with 1% ripple and Current of 2A

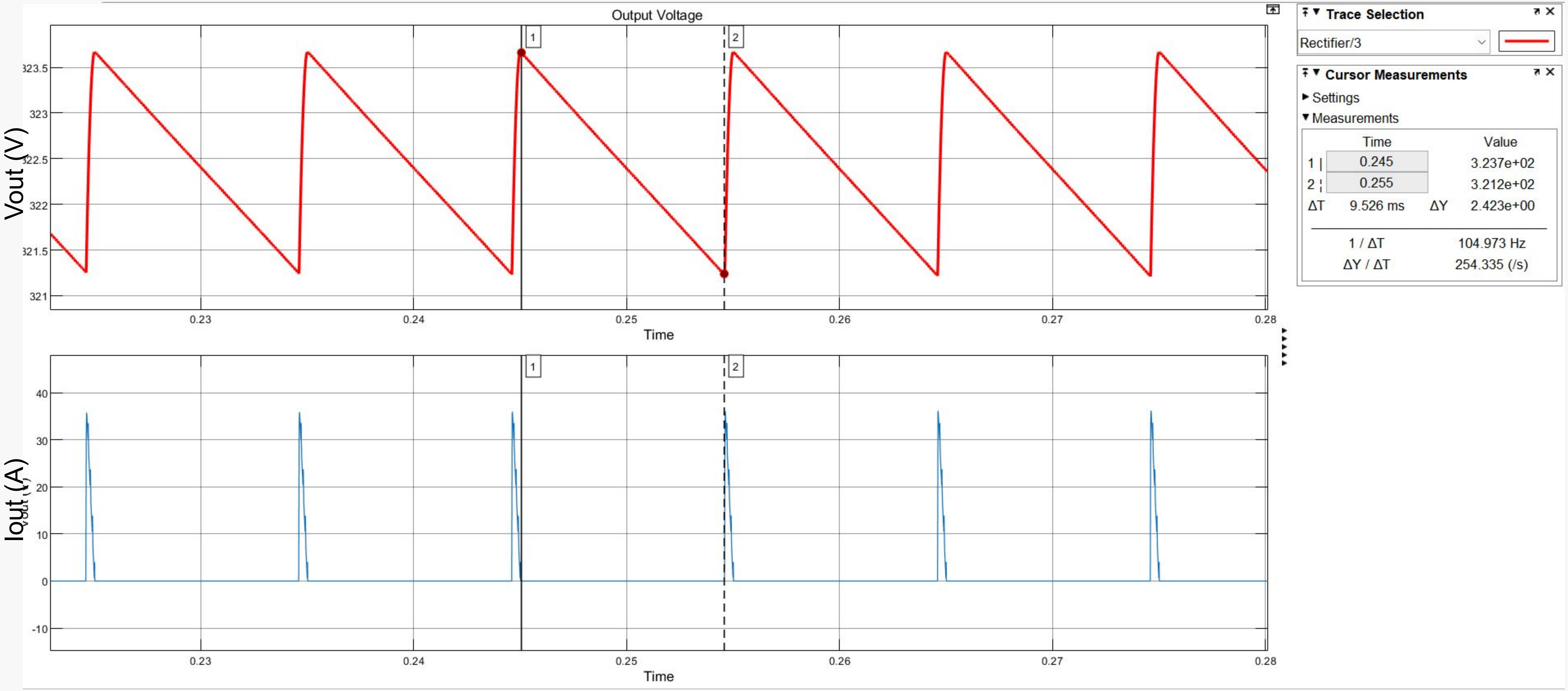




With the calculated value of capacitance, the TDH was observed to be 70.35%, and the voltage ripple was around 6.02V which is >1%.

To get the output voltage ripple <1%, the filter capacitor was change to 5mF and then simulated, which yielded 3.036V which <1% voltage ripple with TDH = 63.52.

SCOPE: Output Voltage and Current of rectifier after connecting buck converter as load



On-Board Charger Circuit

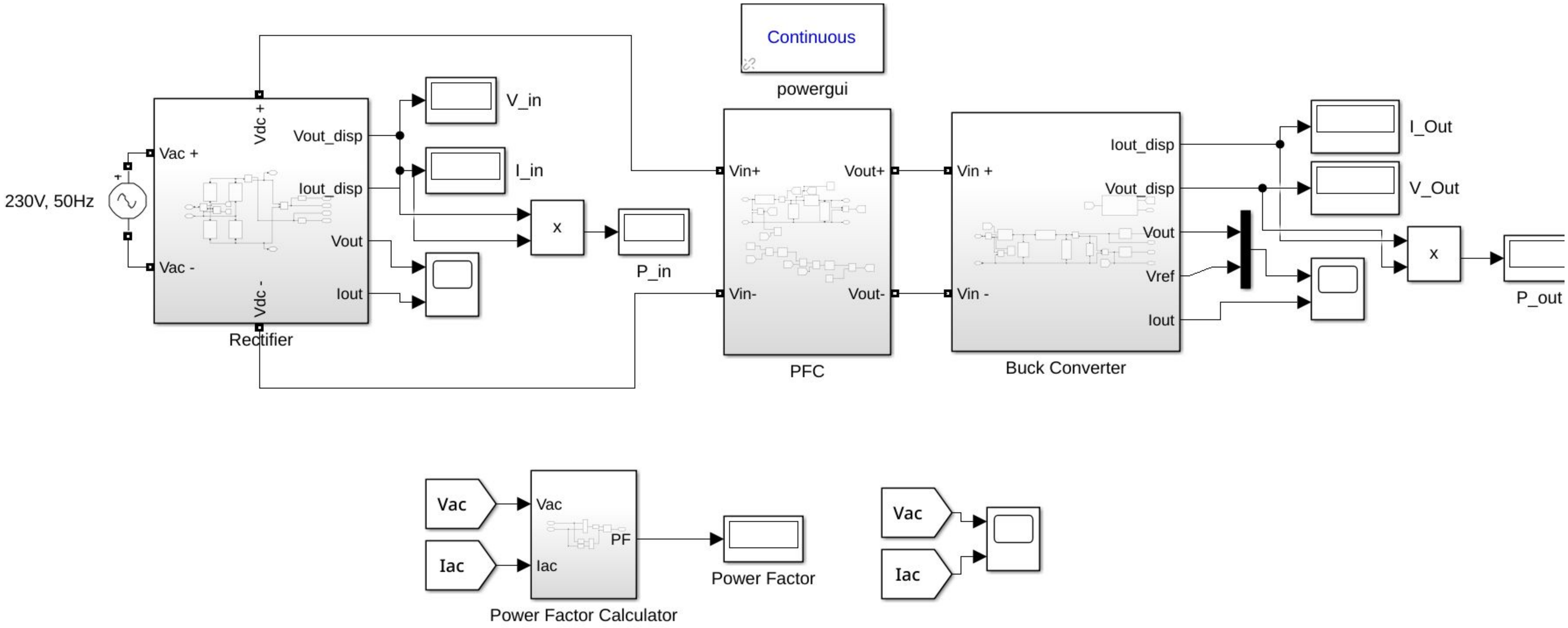


Fig: Full Circuit of the On Board Charger

Single-Phase Full Bridge Diode Rectifier

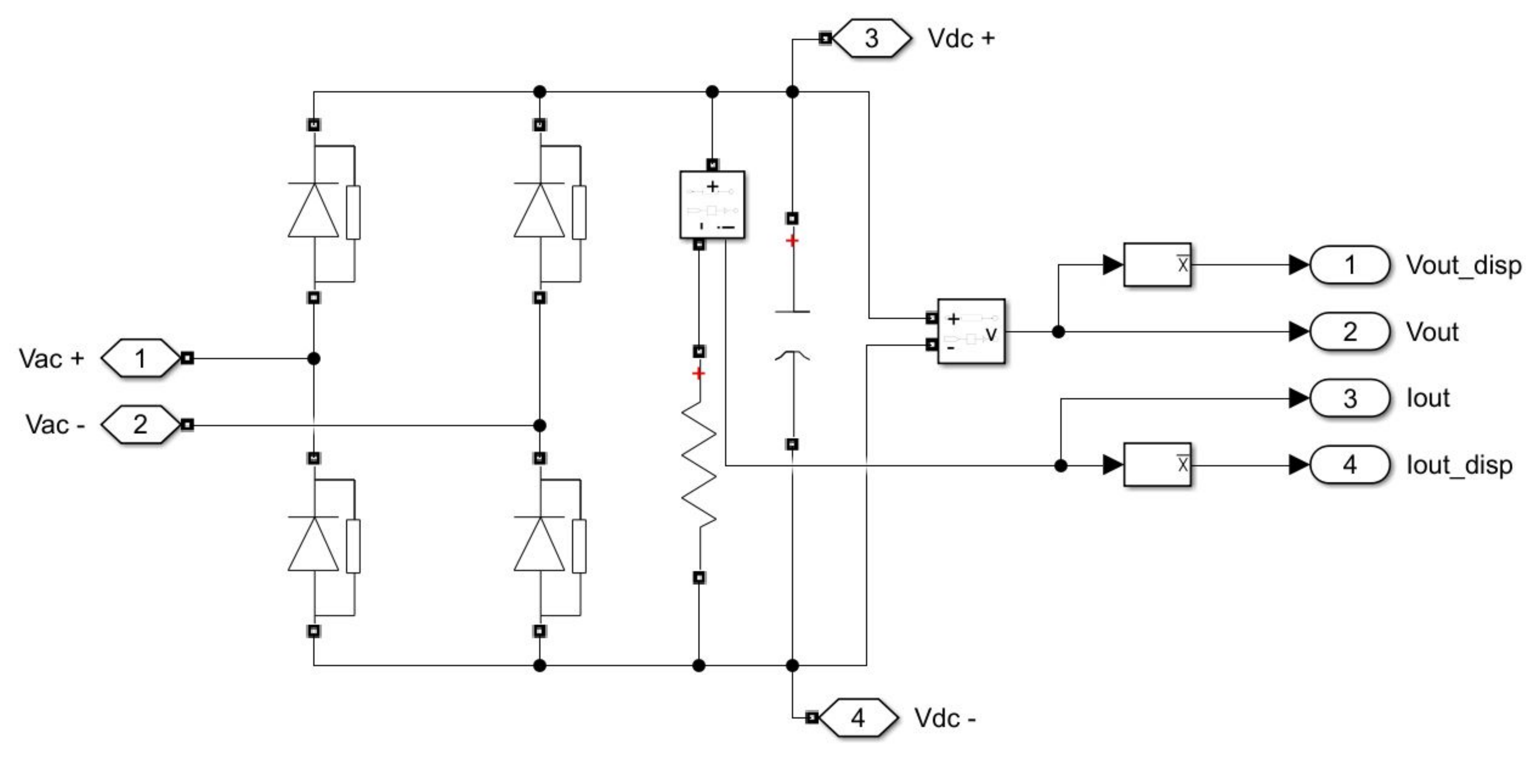


Fig: Single Phase Uncontrolled Full Bridge Rectifier

Buck Converter

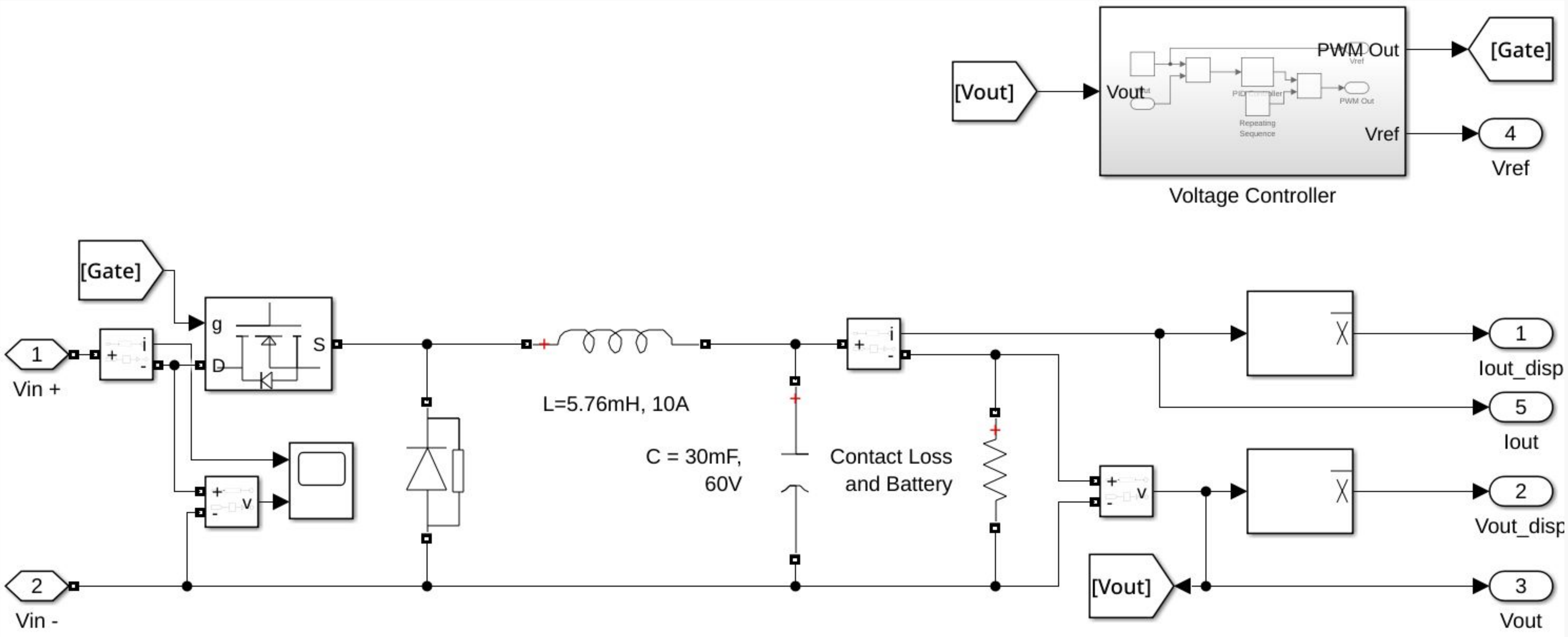
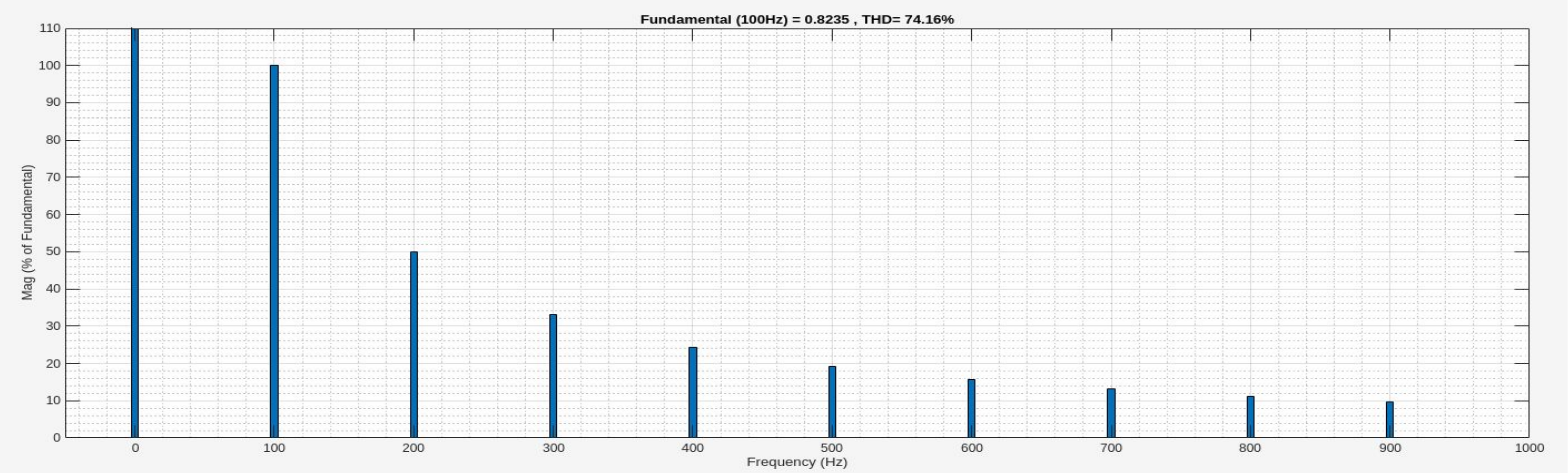
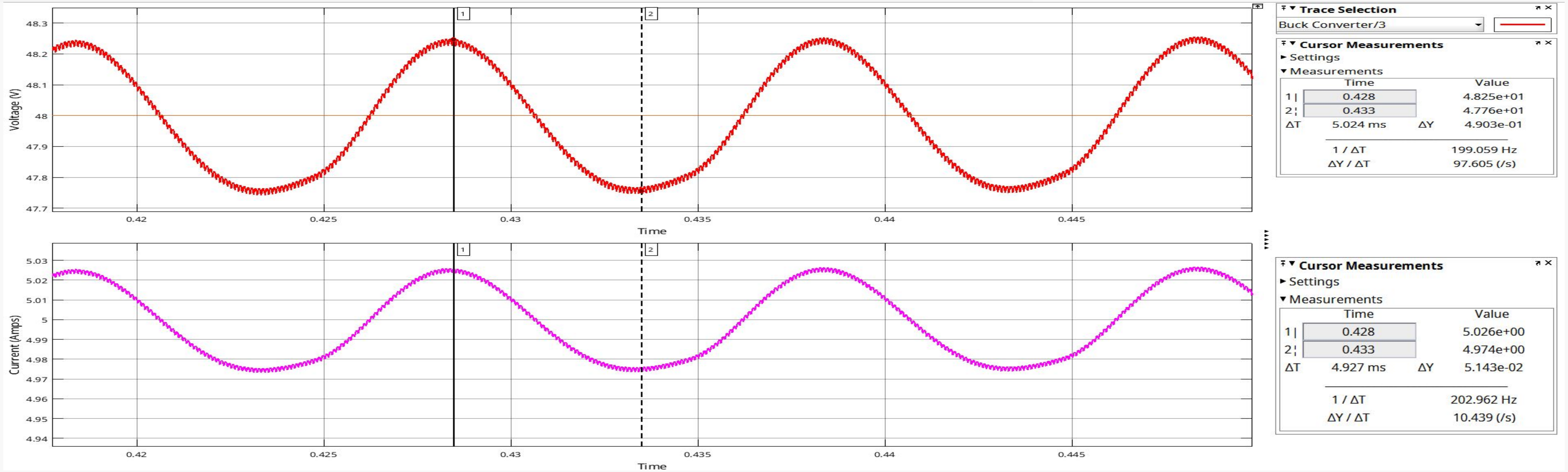


Fig: Buck Converter with Voltage Feedback

THD for FBR with Buck Converter



- The TDH of FBR with Buck Converter load was observed to be 74.16%.
- The Buck converter's output ripple was 0.51mA and voltage ripple was 0.49V, which were below the 1% limit.



Varying Duty Cycle Ratio of PWM to gate of MOSFET

- Output voltage is controllable by varying the duty ratio using PID control by providing reference voltage needed as per application (48V) and output voltage as feedback.

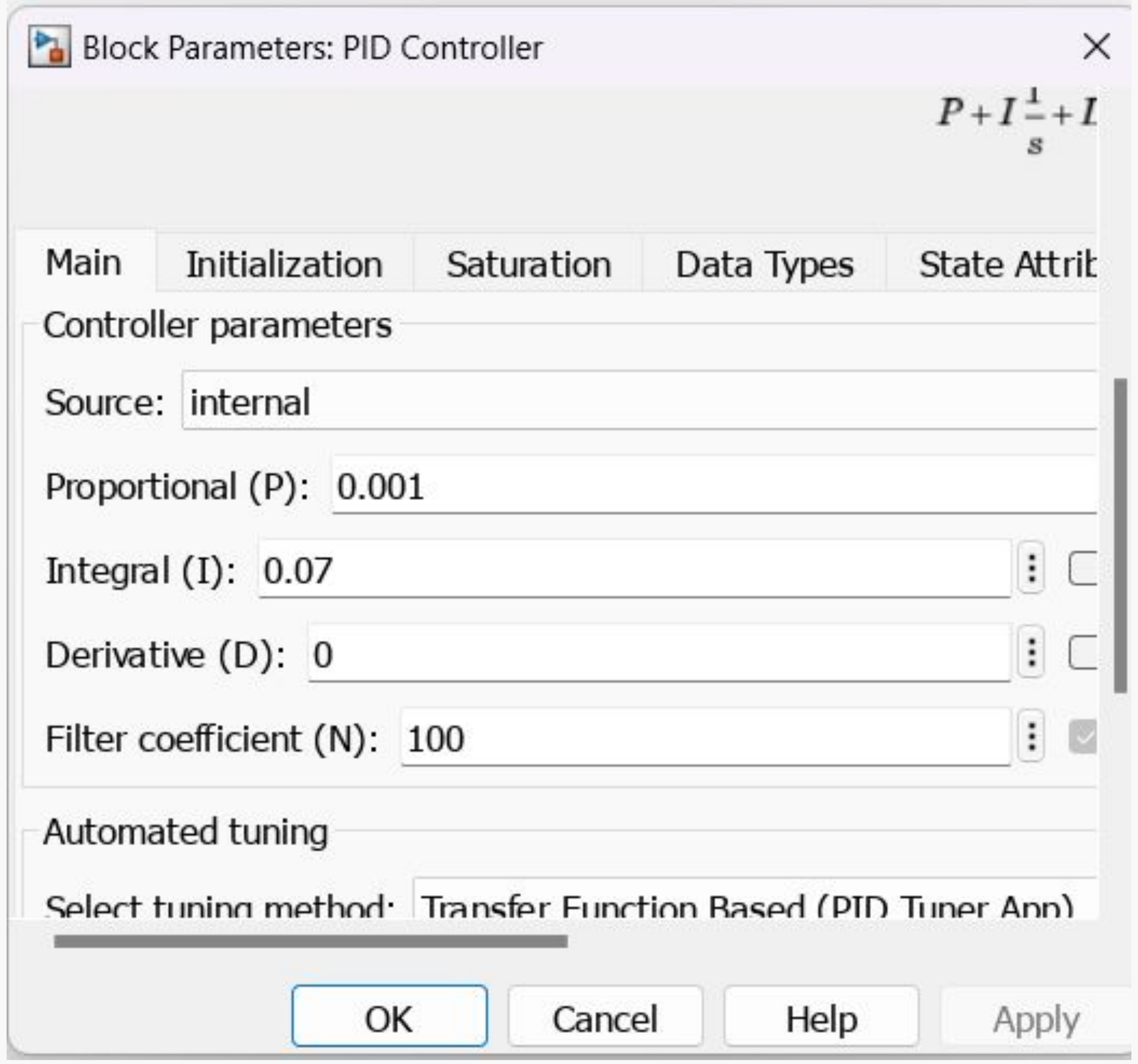


Fig: PI Controller values

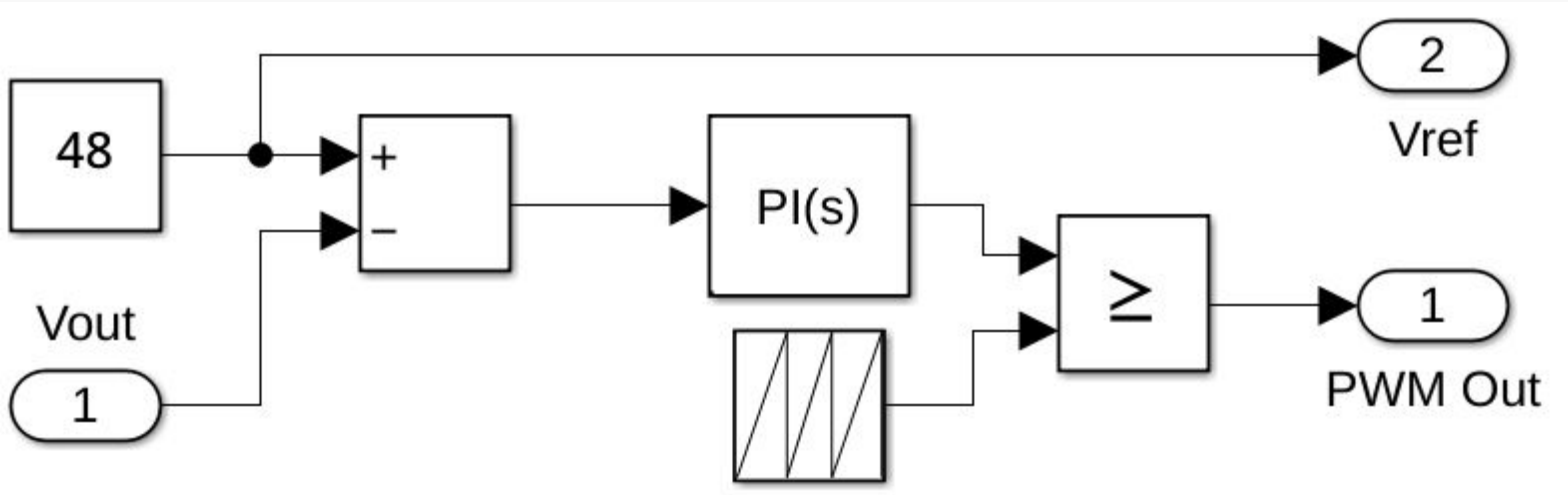


Fig. 4: PI Controller for setting the Duty Cycle

- In this Buck Converter a PI controller is used, and its PI values are carefully tuned to have the acceptable voltage and current ripple and transients.
- The P value was found out to be 0.001, and I was found out to be 0.07.

Boost Converter-Based Power Factor Correction (PFC)

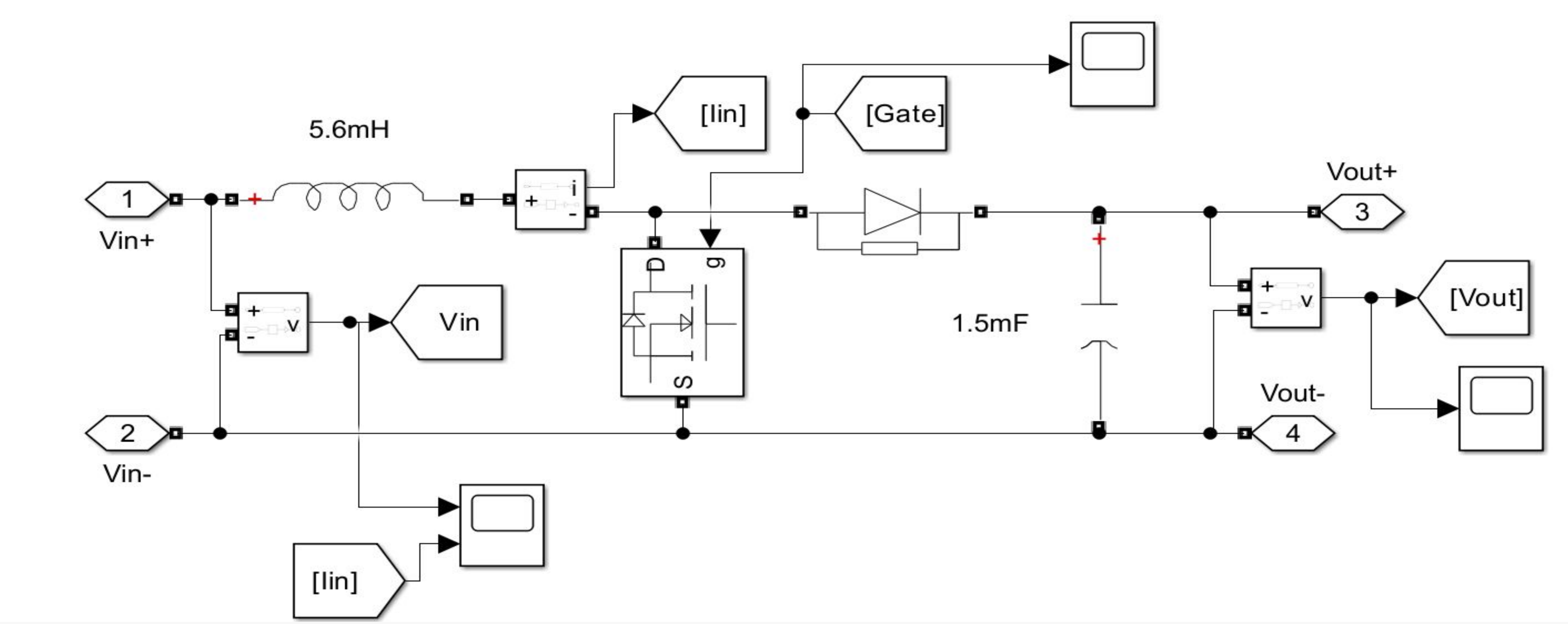


Fig: Boost Converter Based Power Factor Correction Circuit

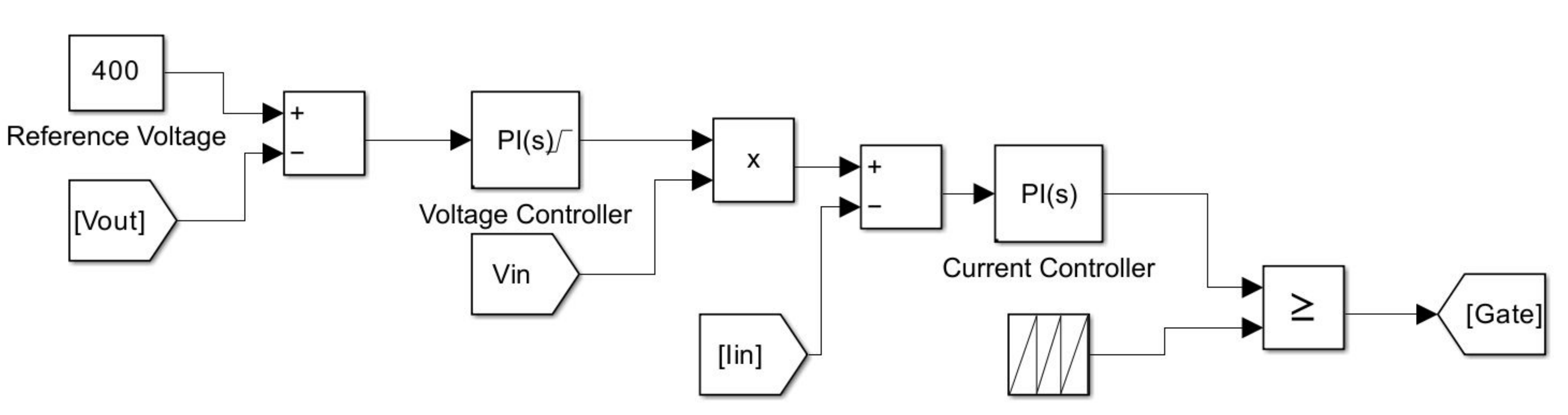


Fig: PFC Boost converter gate controller

230V AC Input Scope

The circuit makes the input current from the grid sinusoidal by using two PI controllers that adjust the duty cycle of the boost converter. The **outer PI controller** regulates the boost converter's output voltage by adjusting the reference current, while the **inner PI controller** controls the duty cycle to ensure the input current follows the sinusoidal reference waveform, keeping it in phase with the grid voltage. This synchronization of current and voltage results in a sinusoidal current draw.

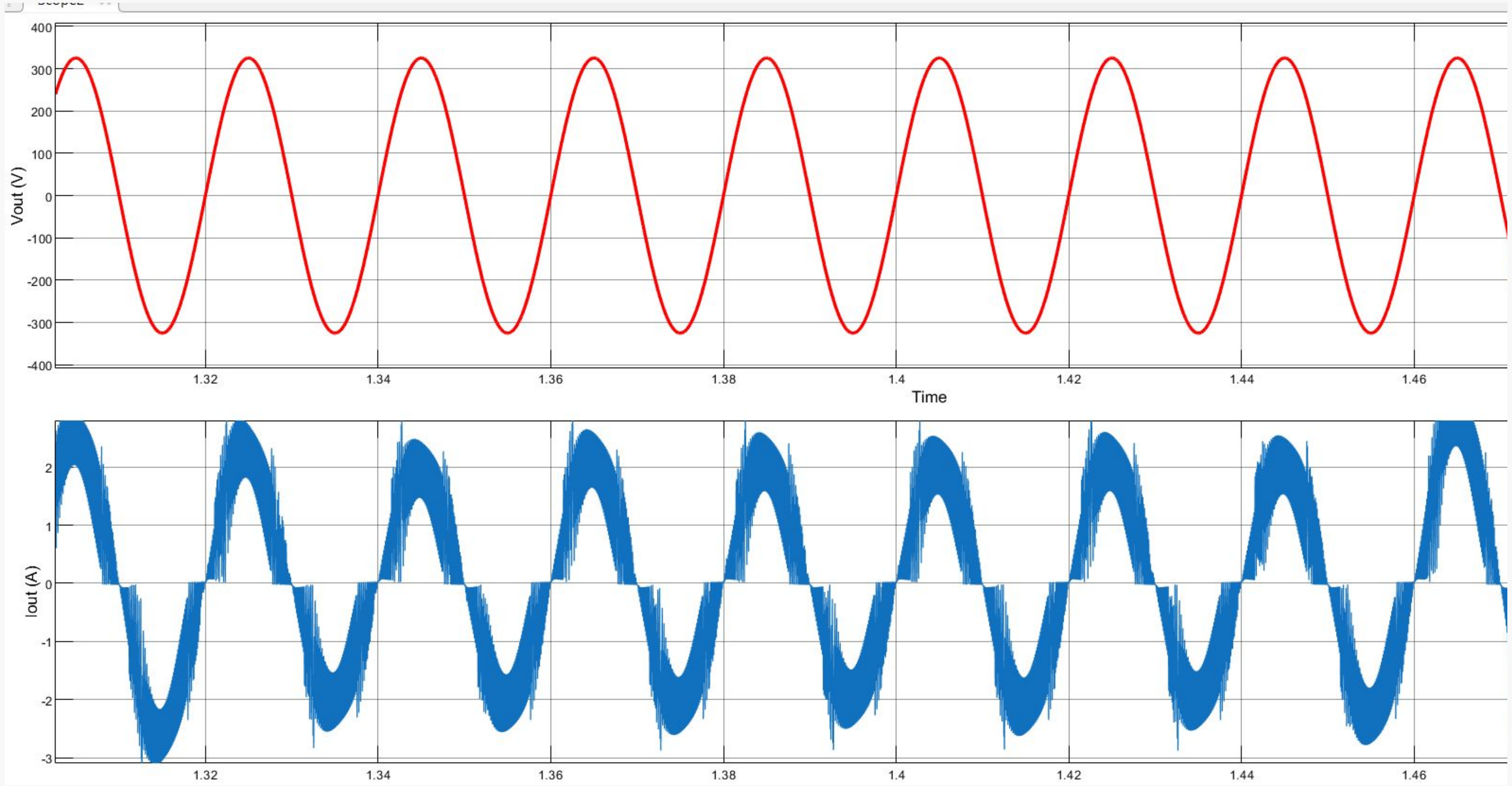
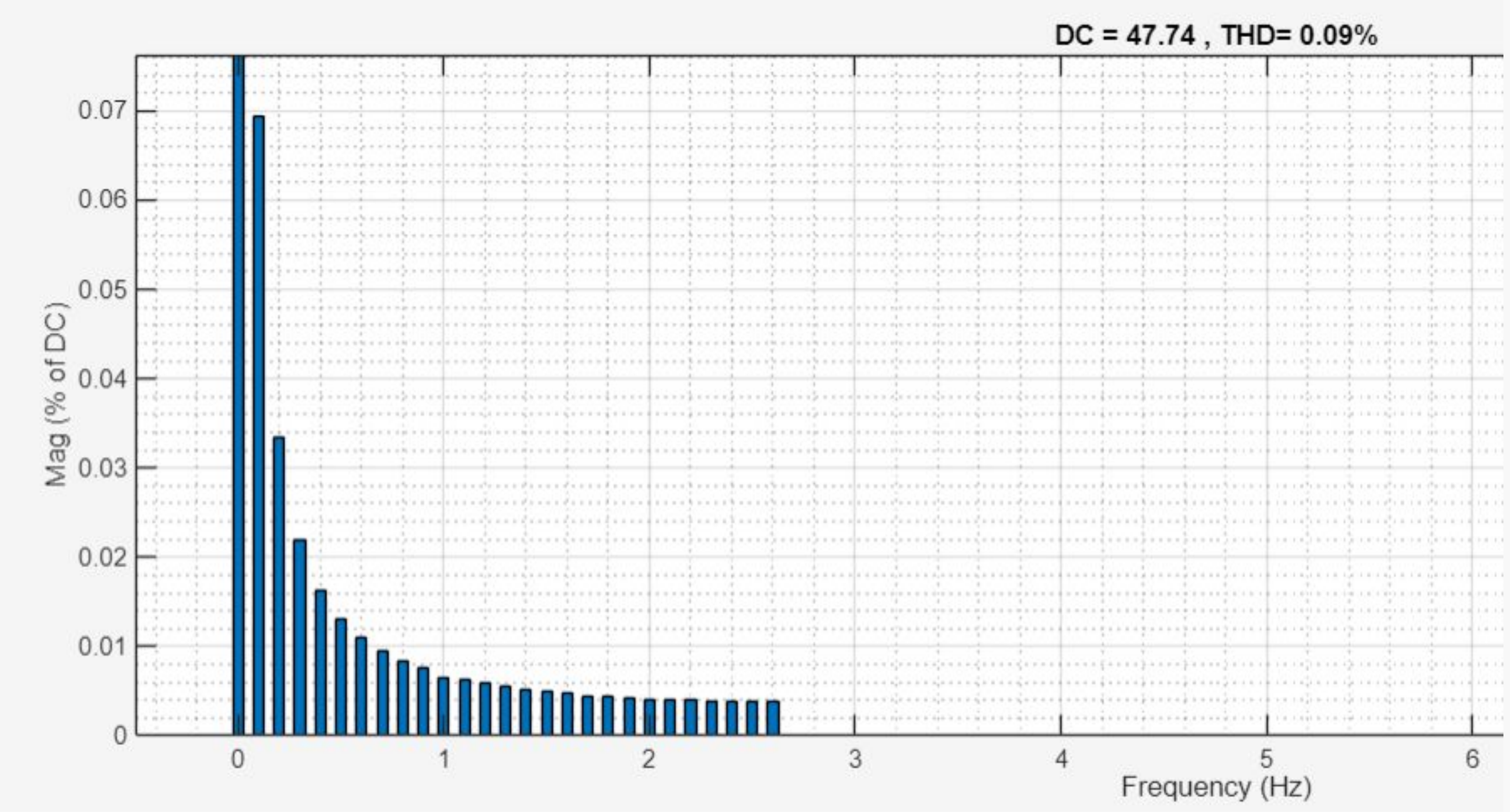
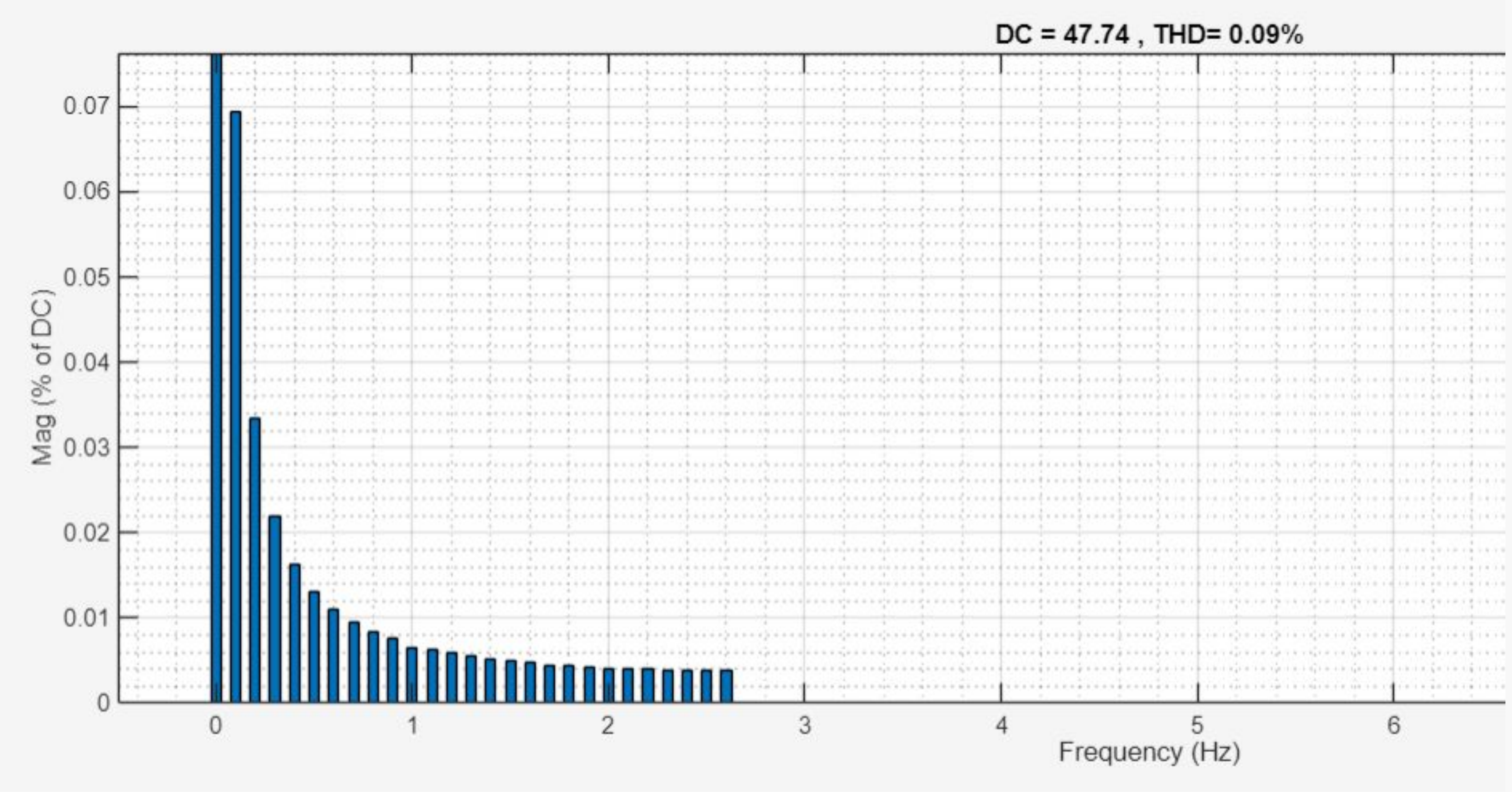


Fig. 7: 230V AC Input (PFC)

Buck Converter Output Characteristics



The TDH of the output current of the Buck Converter was 0.09%



The TDH of the output voltage of the Buck Converter was observed to be 0.09%

Buck Converter Output Characteristics

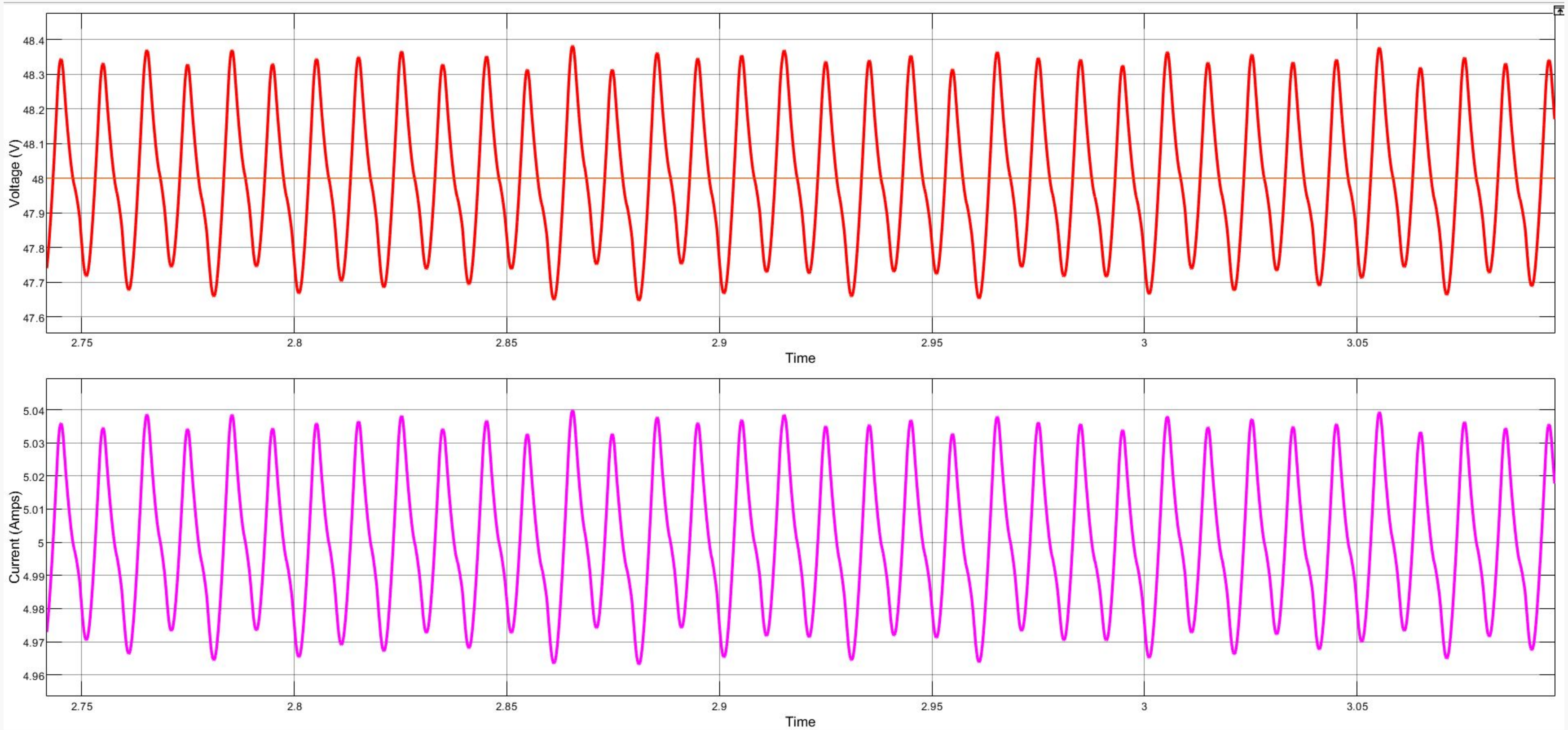


Fig: Buck Converter output voltage and current with <1% ripple

Conclusion

- In this project, we successfully integrated a full-wave rectifier (FWR) with a buck converter to create a reliable and efficient 48V, 5A e-bike charger. By using a PID-controlled buck converter, the system achieves a stable output suitable for e-bike battery charging, while minimizing ripple at the rectifier's output.

- The efficiency of the converter was found out to be around 95%.

- The power factor was observed to be around 0.4, and was improved to 0.95 with PFC.

- When the PFC circuit was added, the buck converter's output voltage TDH dropped from 74% to 0.09%, which showed how important PFC is in a charger circuit.

References

[1] Erickson, R. W., & Maksimovic, D. (2007). Fundamentals of Power Electronics (2nd ed.). Springer.
[2] Texas Instruments. (n.d.). Battery Charger IC Data Sheets. Texas Instruments website.
[3] Mohan, N., Undeland, T. M., & Robbins, W. P. (2002). Power Electronics: Converters, Applications, and Design (3rd ed.). John Wiley & Sons.
[4] D. W. Hart, “Power Electronics,” McGraw-Hill Companies Inc., New York, 2010
[5] https://in.mathworks.com/discovery/power-factor-correction.html

Future Scope of this Project

- Test other types of PFC methods (using SEPIC PFC etc.)
- Make the PI values adaptable to the load change.
- Use of MOSFET for Full Bridge Rectification.
- Use of other efficient techniques to bring down DC voltage.

Acknowledgement

We sincerely thank IEEE Kerala and BGSW for their invaluable guidance, support, and expertise. This project would not have been possible without their contributions and the resources provided.

Thank you