Onboard chargers for EVs using Dual Active Bridge and Totem Pole PFC

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Onboard Charging Charging System for for Electric Vehicles Vehicles

Electric Vehicles (EVs) are gaining popularity due to environmental concerns. Onboard charging systems are crucial for EV adoption and convenience. Our project focuses on developing an efficient onboard charging system.

Project Objectives

1 **To Facilitate Efficient Onboard Charging**

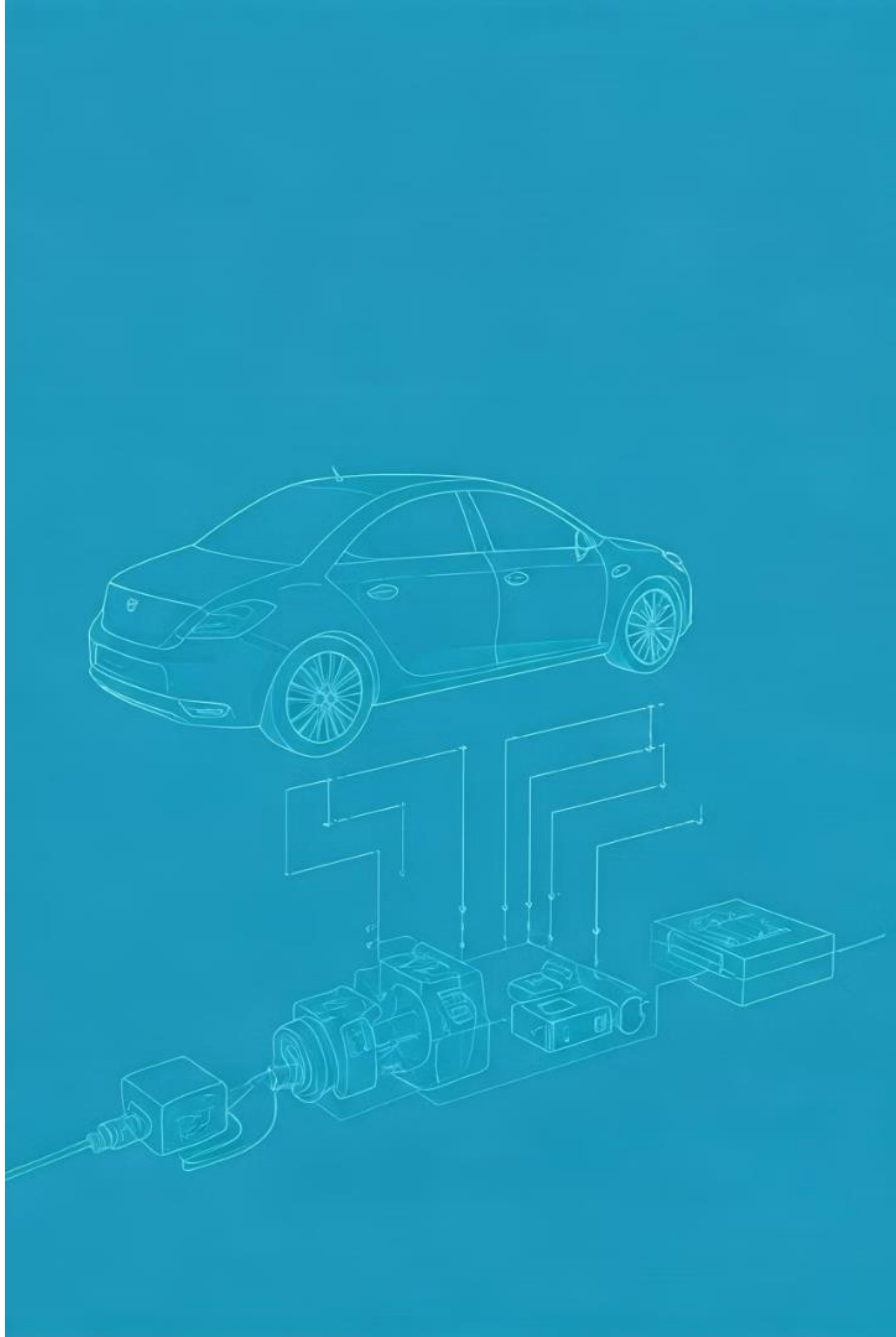
Develop an efficient onboard charging system for EVs, optimizing charging speed and and minimizing energy loss.

2 **To Implement Totem Pole PFC**

Implement and analyze Totem Pole Power Factor Correction (PFC) for AC-DC conversion, improving power efficiency and reducing harmonics.

3 **To Design Dual Active Bridge Converter**

Design a Dual Active Bridge (DAB) converter for DC-DC conversion, enabling bidirectional bidirectional power flow and supporting vehicle-to-grid applications.



System Overview

Battery Pack

Stores energy for powering the electric motor.

Electric Motor

Converts electrical energy into mechanical energy to propel the the vehicle.

Charging System

Manages the charging process, converting AC power to DC and regulating battery charging.

Thermal Management System

Regulates the temperature of the the battery pack and other components to ensure optimal performance and safety.

AC-DC Converter

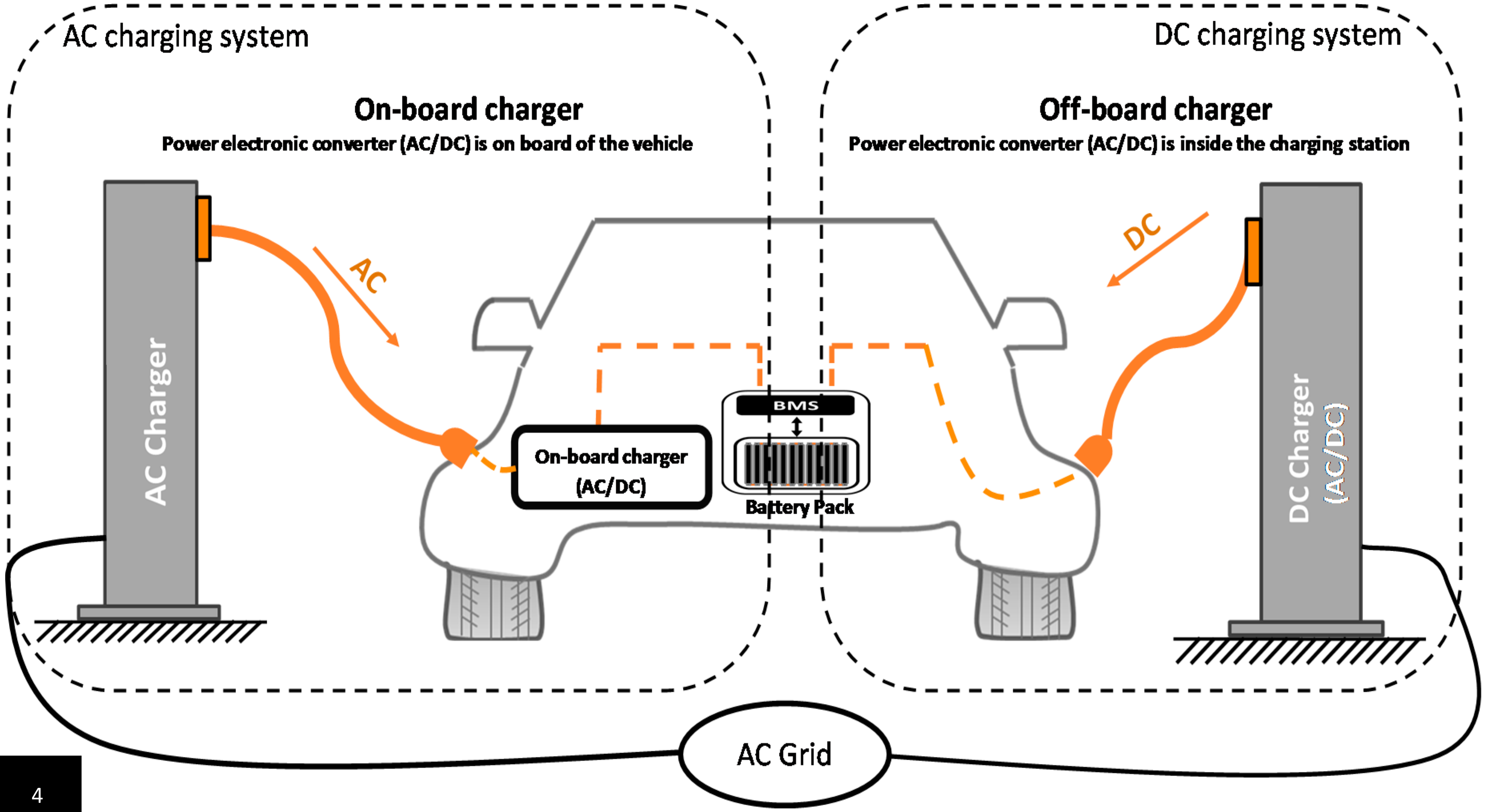
Converts grid AC power to DC power for battery charging.

Electric Vehicle Control Unit

Manages overall vehicle operation, including powertrain control, charging, and safety systems.

Filters

Reduce electromagnetic interference and noise in the system.


AC charging system
DC charging system
On-board charger
Power electronic converter (AC/DC) is on board of the vehicle
Off-board charger
Power electronic converter (AC/DC) is inside the charging station
AC Charger
AC
DC
On-board charger (AC/DC)
BMS
Battery Pack
DC Charger (AC/DC)
AC Grid

On board charging

- A bridge between Electrical Vehicle Supply Equipment(EVSE) and the battery.
- Converts alternating current available in the grid to direct current which charges the battery in the vehicle.
- Critical component in electric vehicles (EVs), enabling them to charge their batteries from standard electrical outlets or dedicated charging stations.

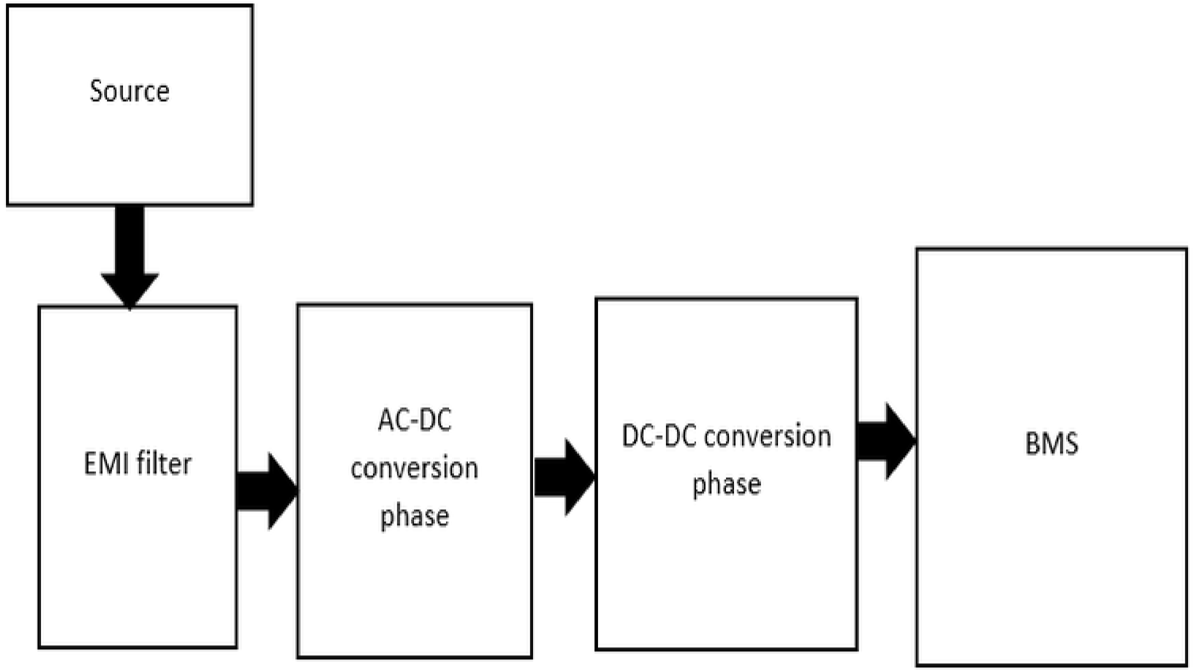


Fig: General Block Diagram of an OBC

Onboard Charging Components

EMI Filter

Reduces electromagnetic electromagnetic interference generated generated by the switching power electronics, ensuring compliance with electromagnetic compatibility standards. standards.

Power Factor Correction

Improves power efficiency by correcting correcting the power factor of the AC input, reducing energy loss and and improving grid compatibility.

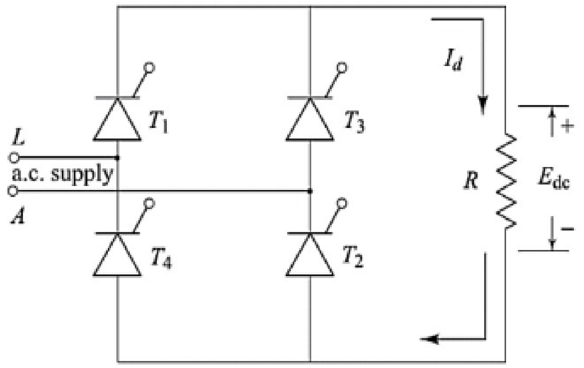
AC-DC Converter

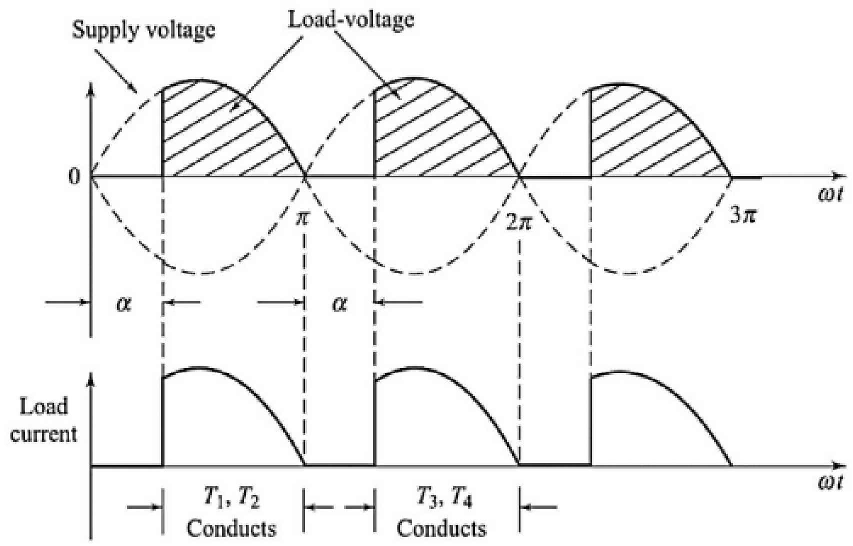
Converts the grid's AC power to DC power, suitable for charging the the battery pack.

DC-DC Converter

Adjusts the voltage levels levels of the DC power to to match the battery's requirements, ensuring ensuring efficient and safe charging.

AC-DC Conversion

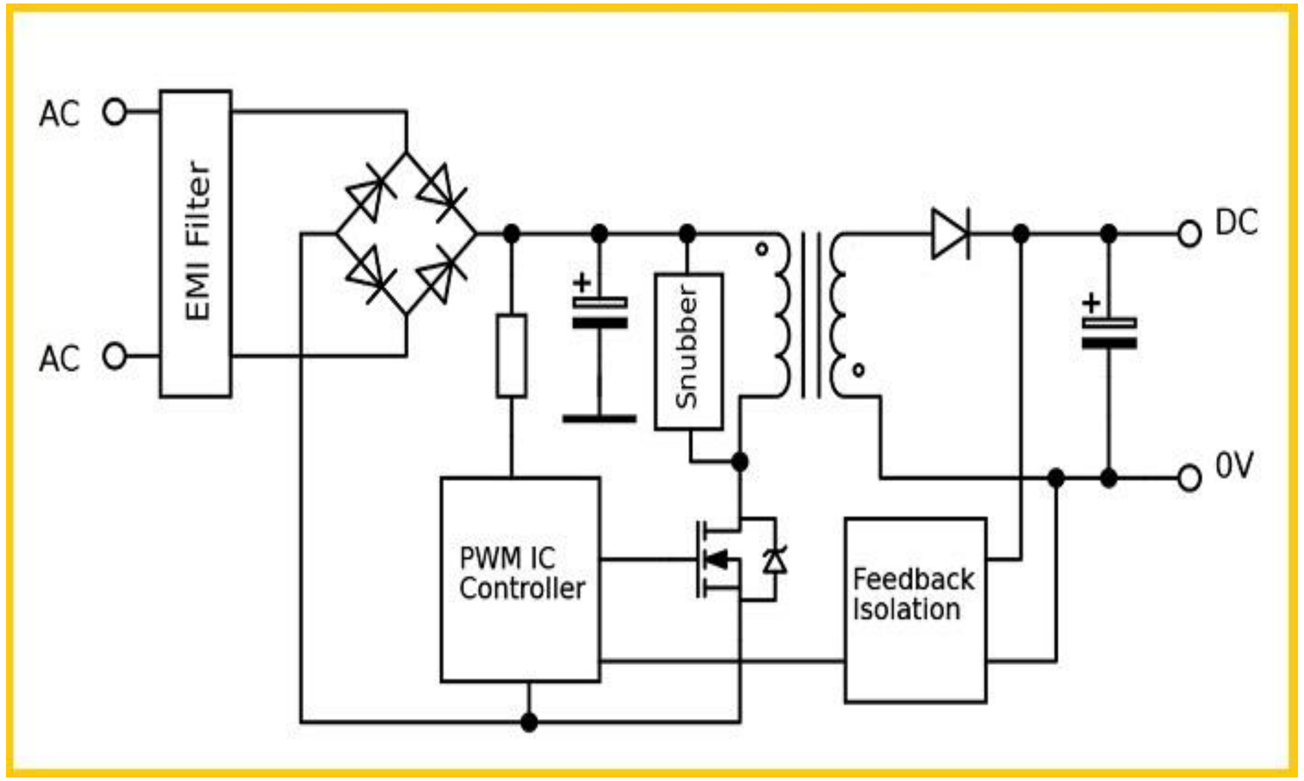




For onboard charging various types of circuitry have been used, to begin with, we might look at the full-wave controlled rectifier circuit for AC/DC conversion

Major Problem: Pulsating Voltage and Current

AC-DC Conversion



1

Grid AC to DC Conversion

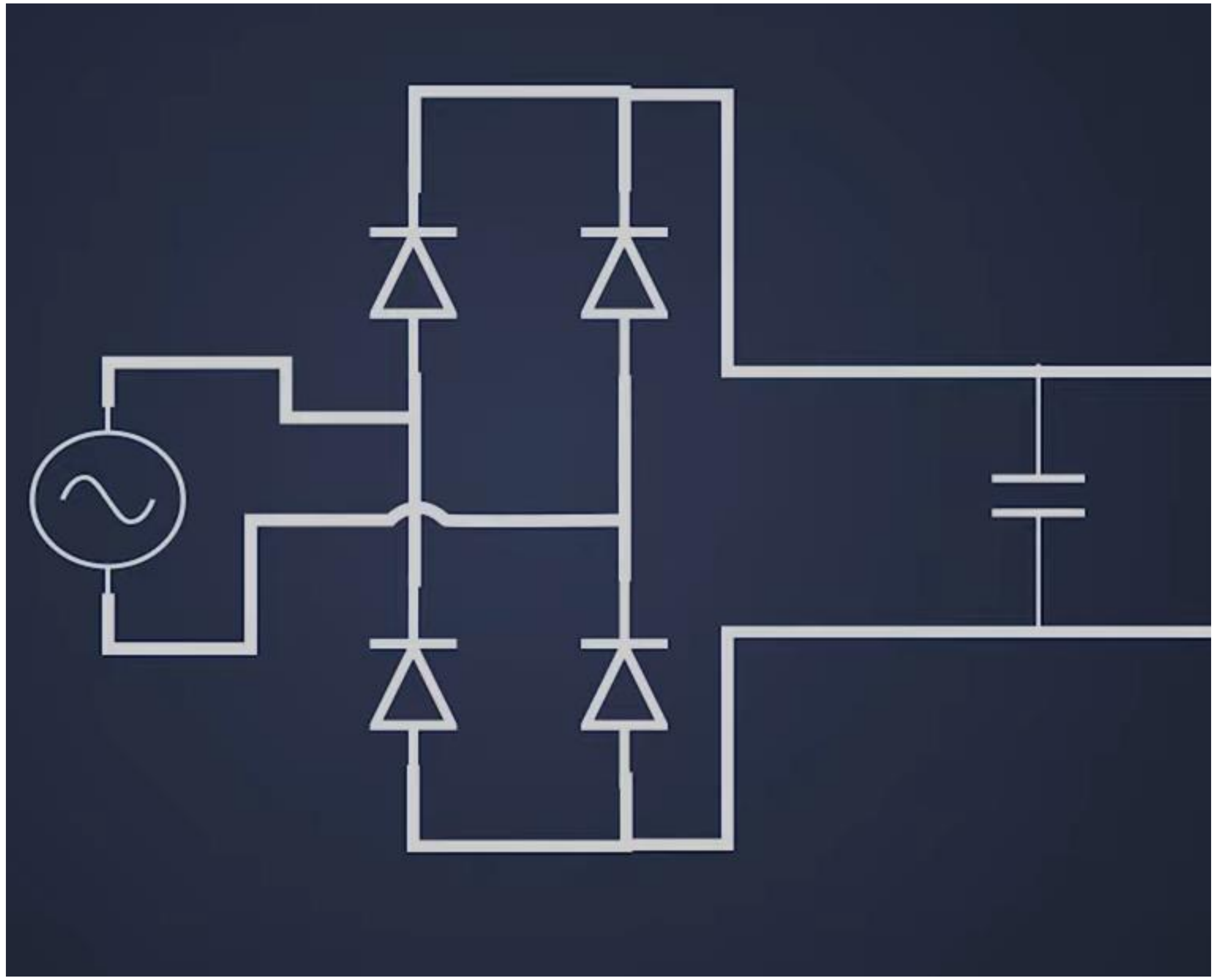
Critical for converting the grid's AC power to DC power for for battery charging.

2

Various circuit topologies can be used

Various circuit topologies including Interleaved Boost PFC,Totem Pole PFC and Interleaved Totem Pole PFC.

AC-DC Conversion



The ripple/pulse in output voltage can be reduced through a capacitor filter.

Major Problem: Poor Power Factor

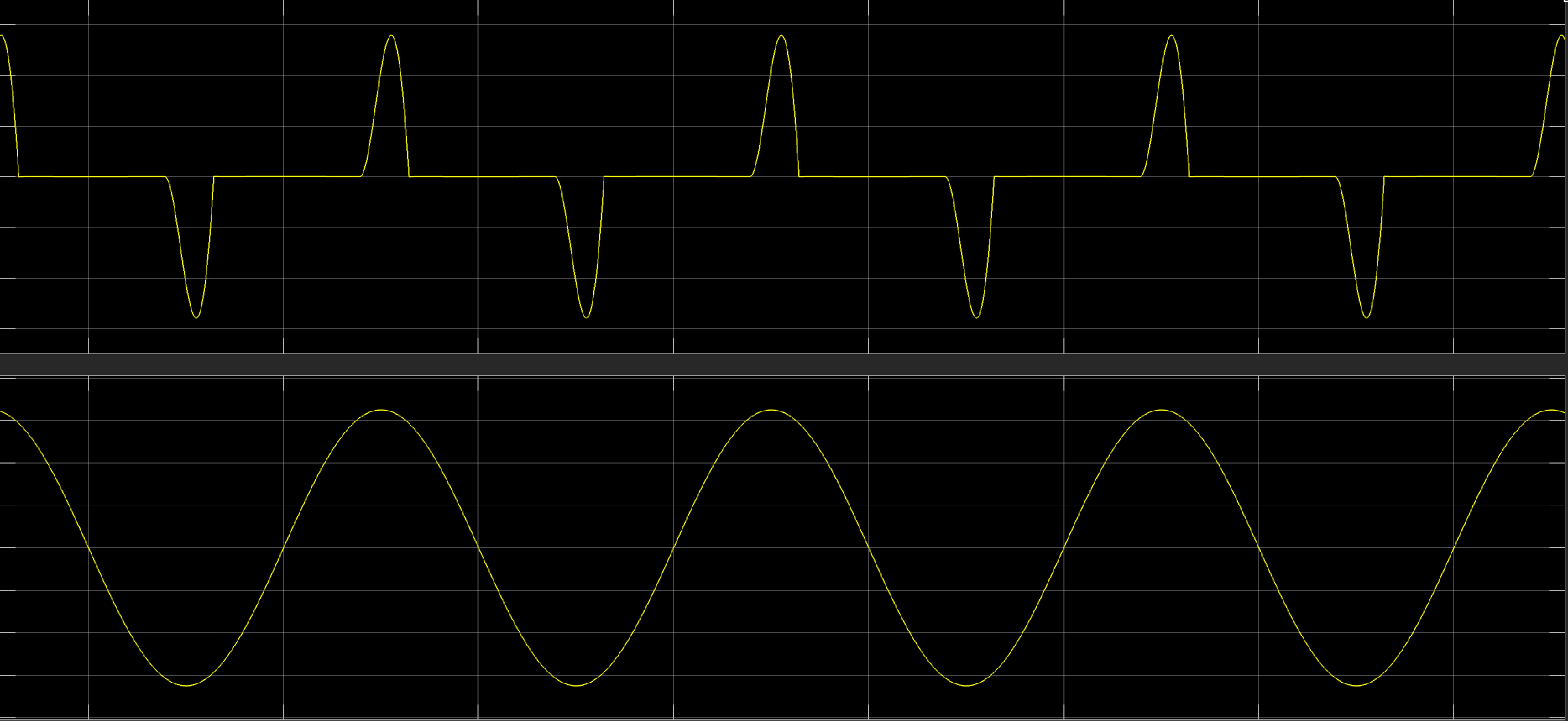


Fig: The waveform of source current (top) and Source Voltage (bottom) of a normal diode converter with capacitor filter

TOTEM POLE PFC

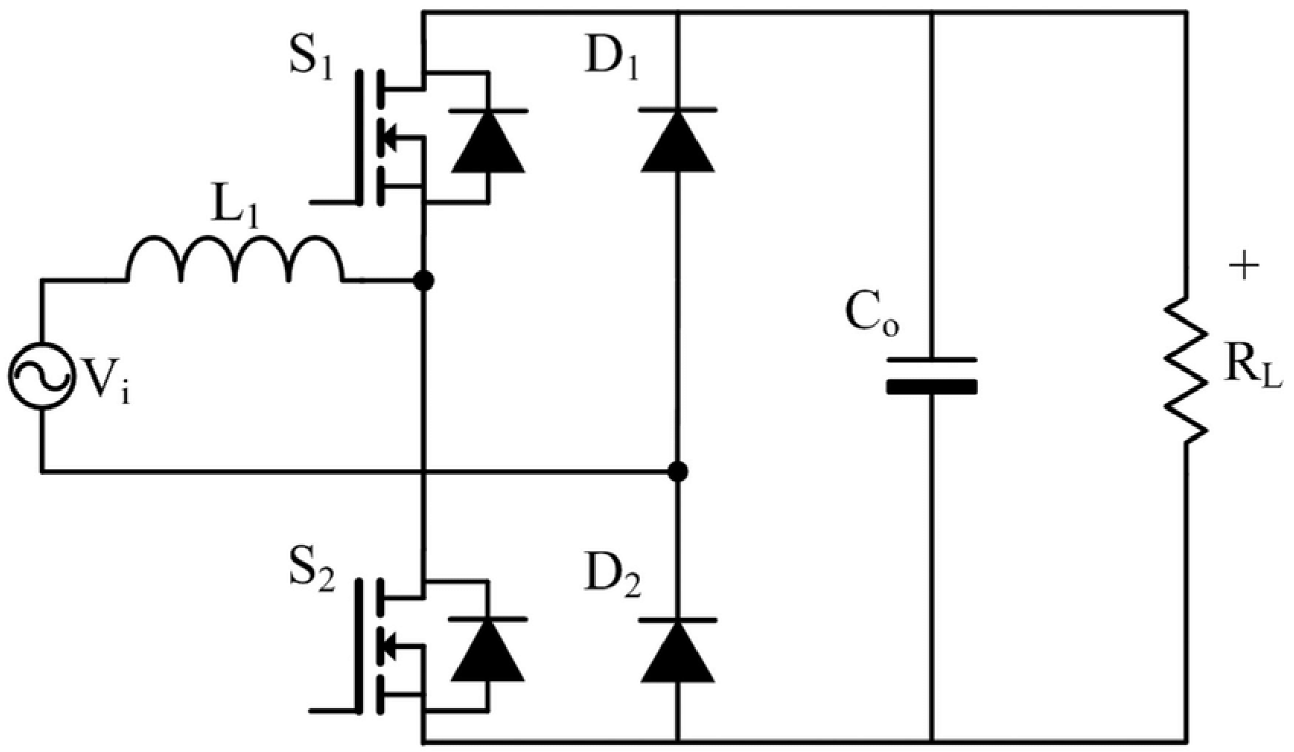
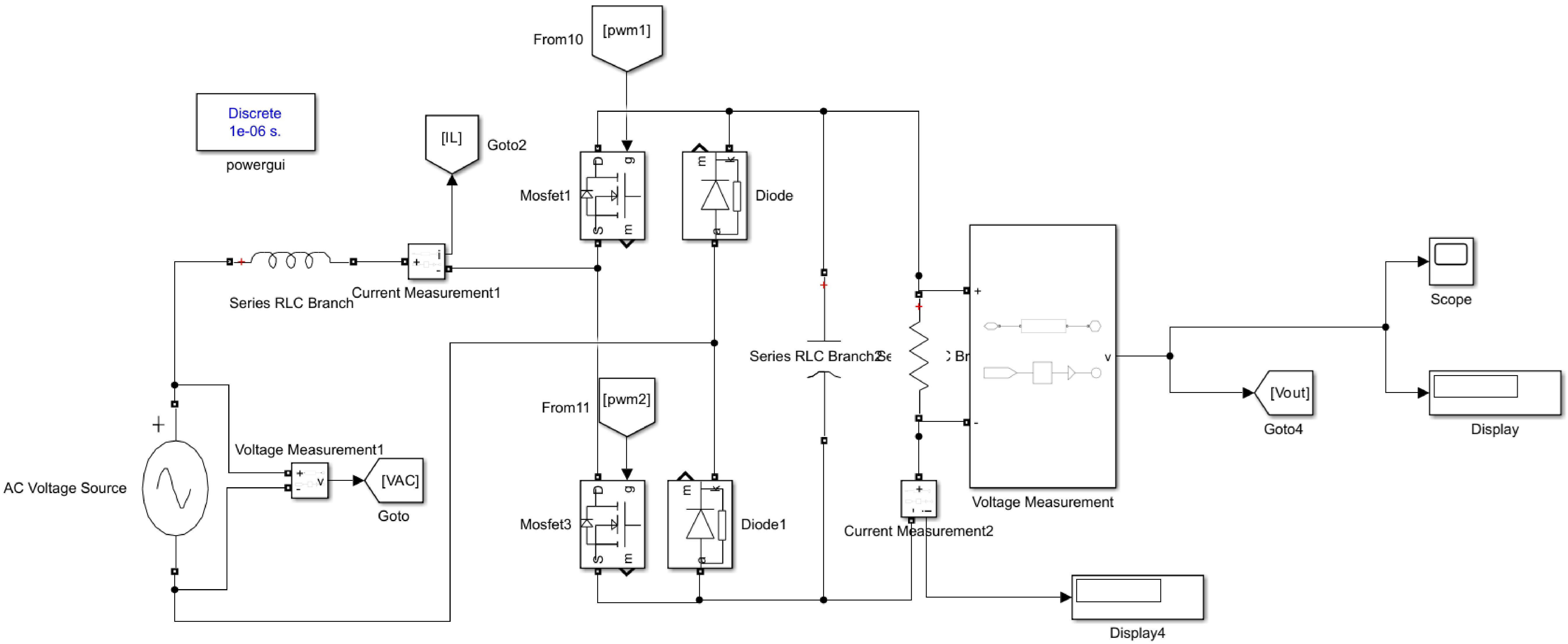


Fig: A Basic Totem Pole PFC Circuit

Here, rather than the usual four diodes as a bridge, two active switches are in one leg with the diodes on the other.

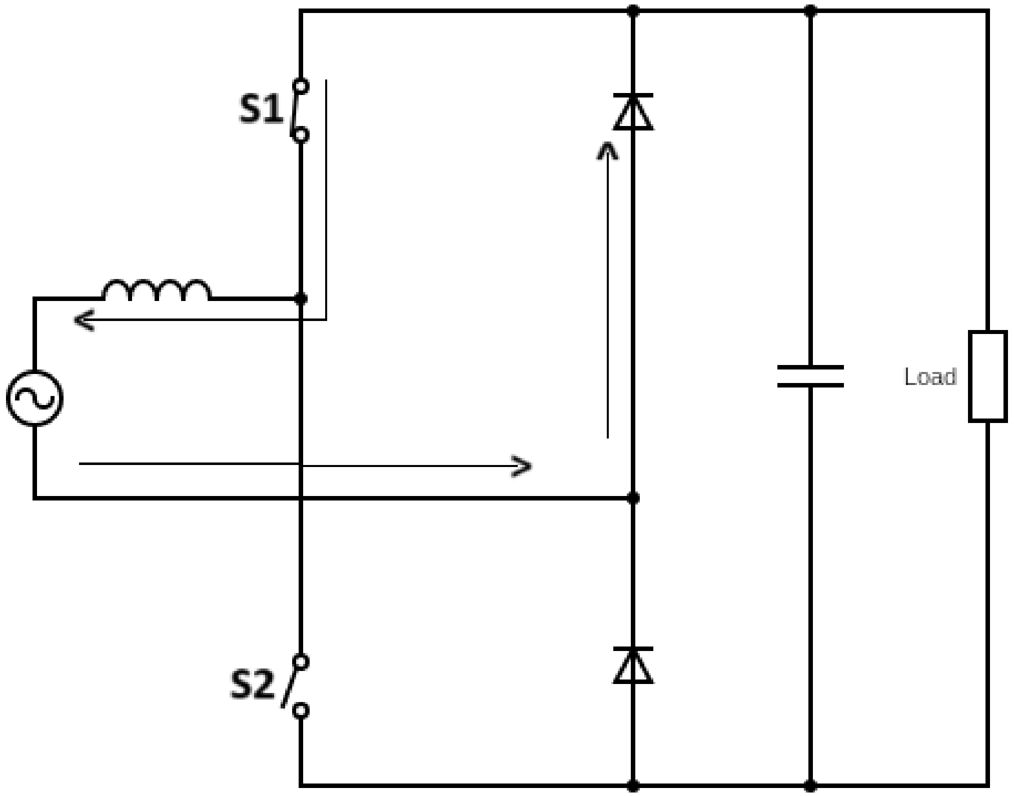
It operates in two states:

1. Zero State
2. Active State

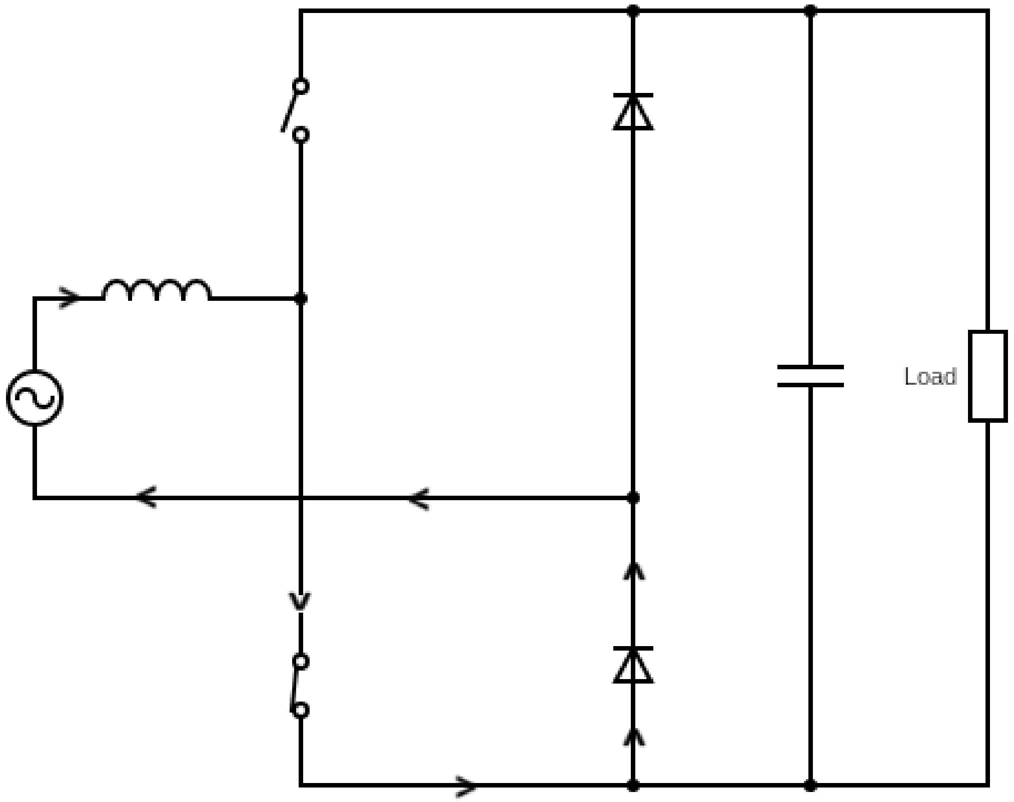


Discrete
1e-06 s.
powergui
[pwm1]
From10
[IL]
Goto2
Mosfet1
Diode
Series RLC Branch
Current Measurement1
Series RLC Branch2
Voltage Measurement
Scope
[Vout]
Goto4
Display
[pwm2]
From11
Voltage Measurement1
[VAC]
Goto
AC Voltage Source
Mosfet3
Diode1
Current Measurement2
Display4

Zero State Operation



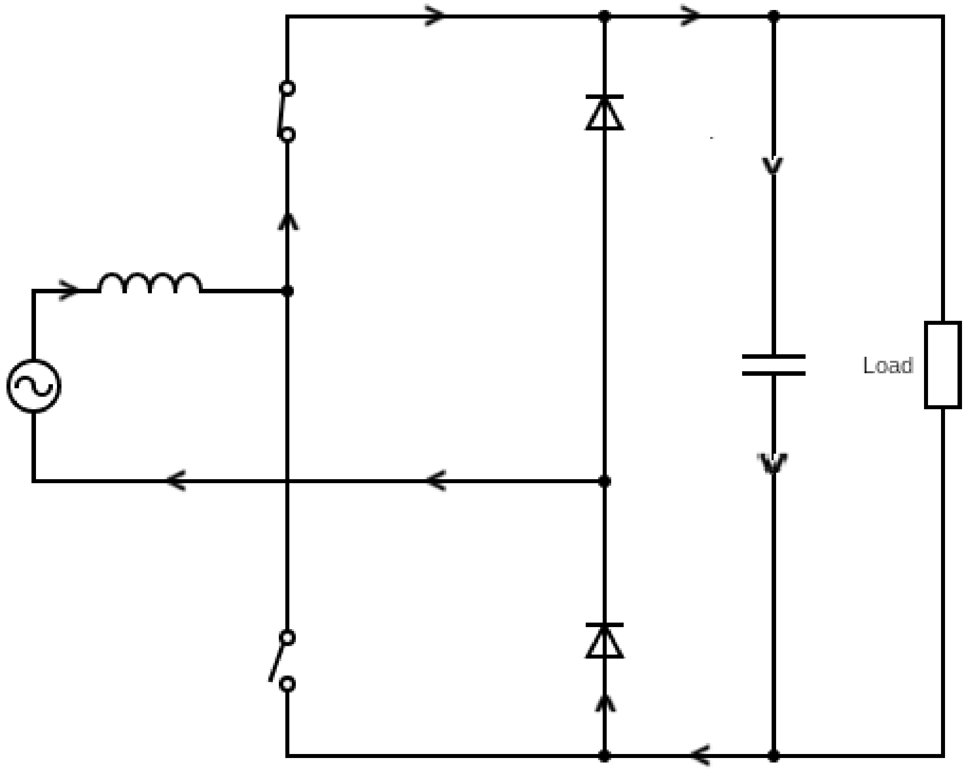
During the –ve half cycle



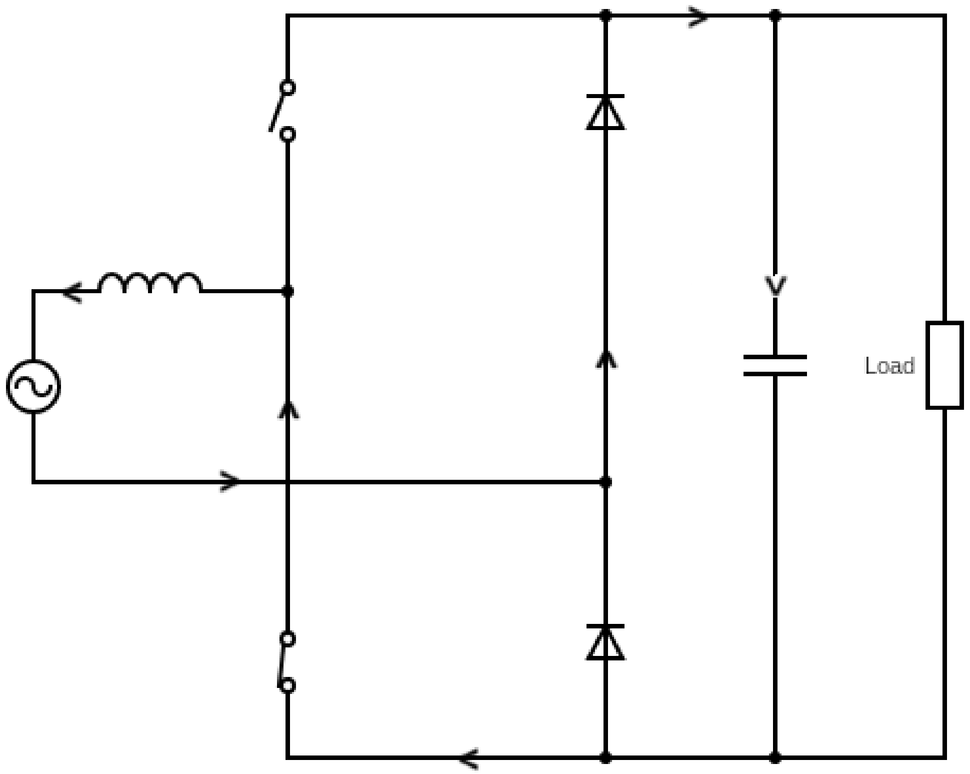
During the +ve half cycle

In this state, the inductor is charged and the capacitor powers the load

Active State Operation

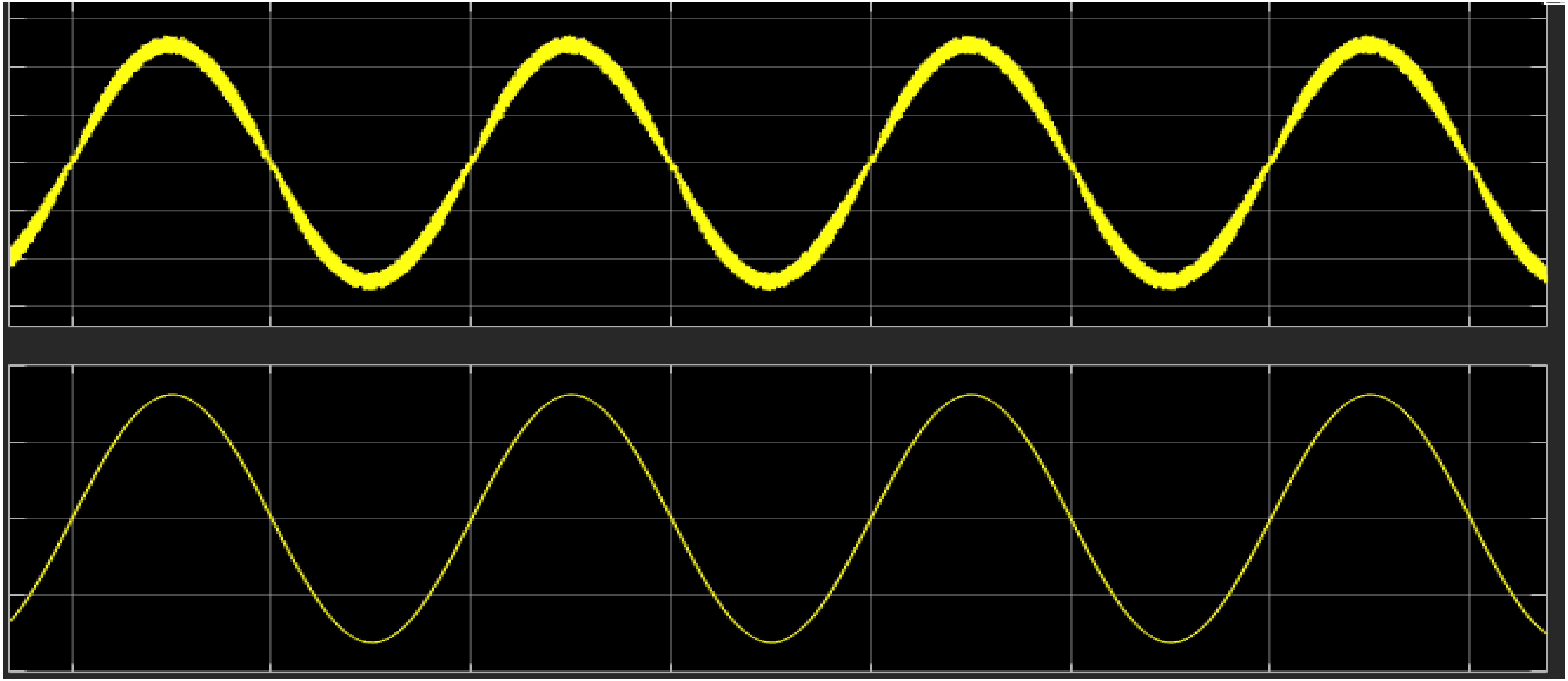


During the +ve half cycle

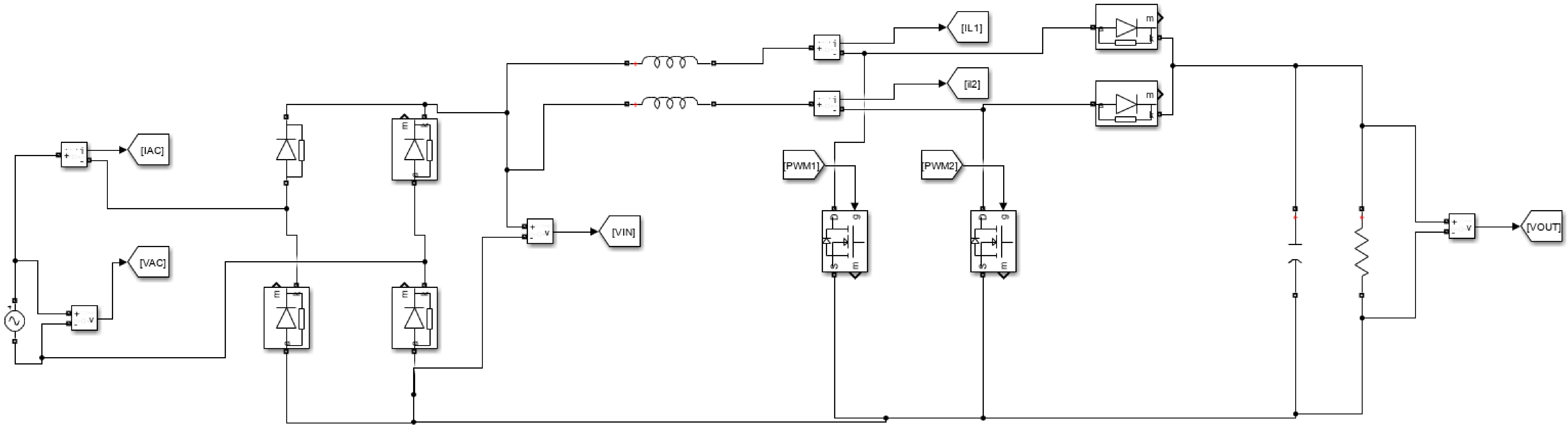


During the –ve half cycle

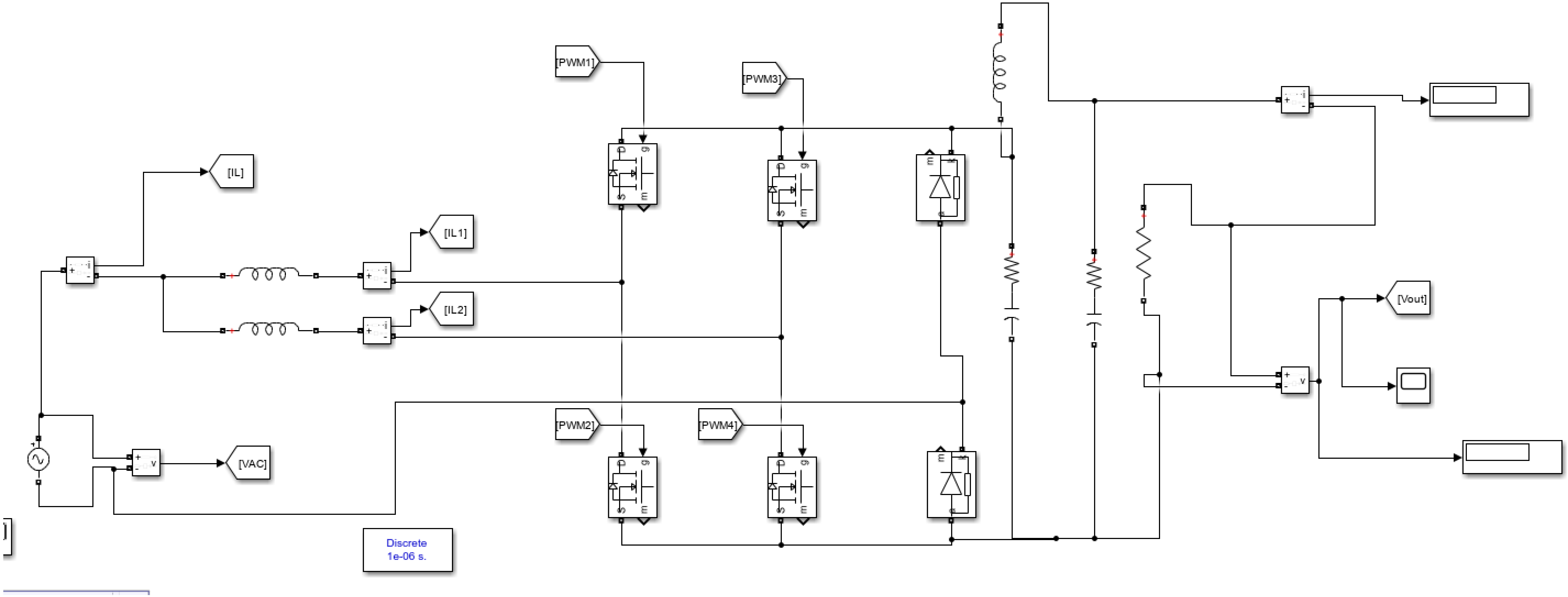
In this state, the inductor is discharged and the capacitor is charged.

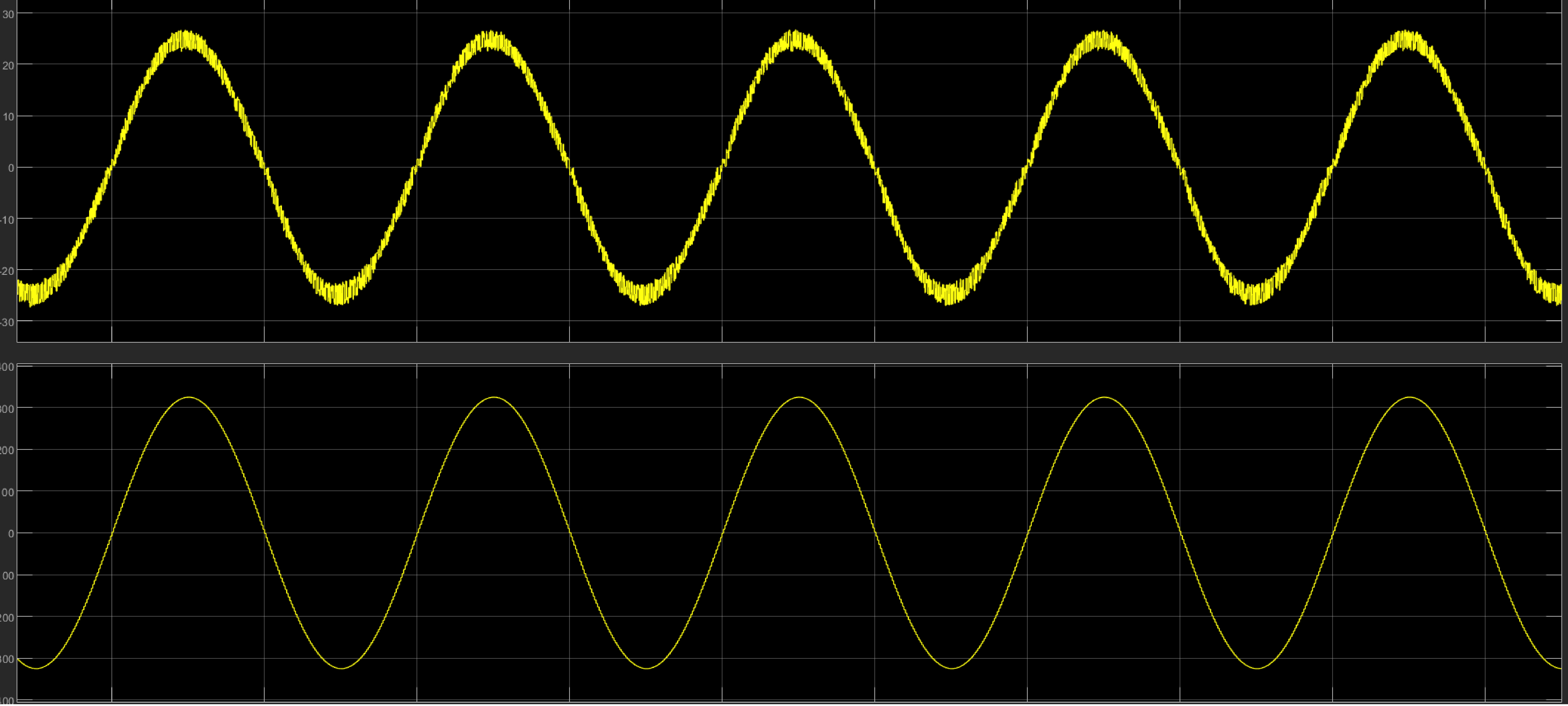


Interleaved Boost PFC converter



Interleaved TOTEM POLE PFC




30
20
10
0
-10
-20
-30
0

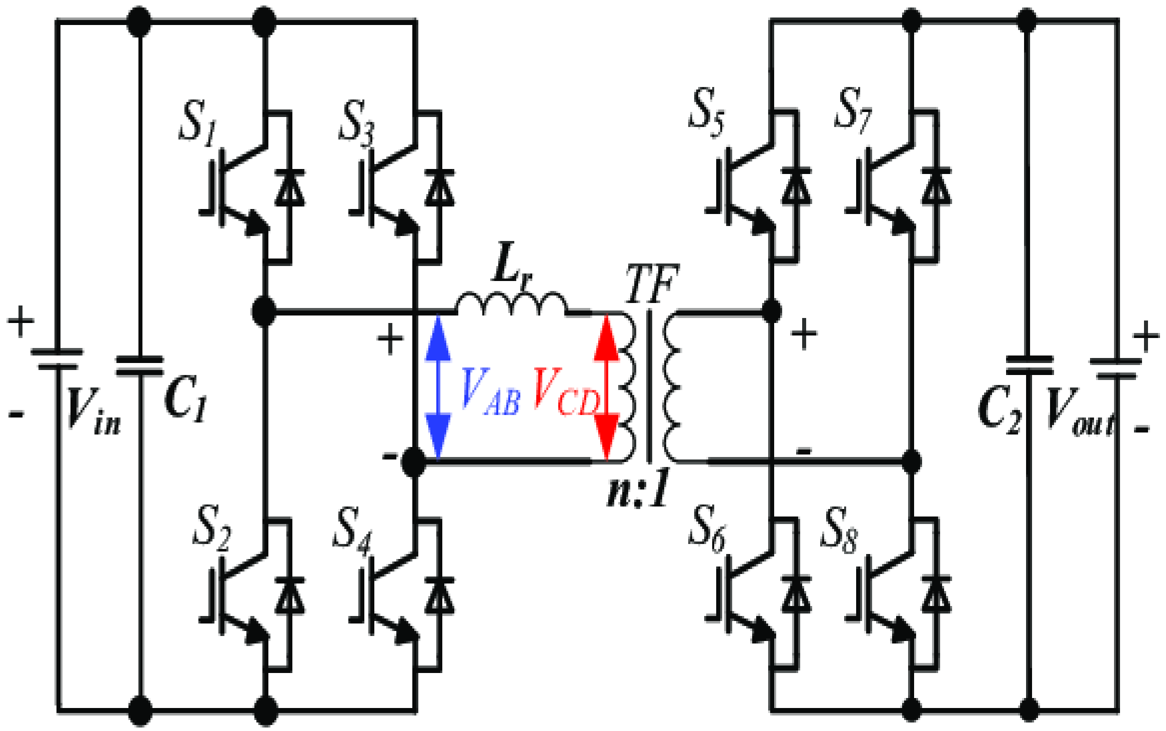


Fig: DAB Converter Topology

DC-DC Conversion: Introduction Introduction

1

Dual Active Bridge (DAB) Converter

Chosen for the DC-DC stage due to its advantages in bidirectional power flow, high efficiency, and compact design.

2

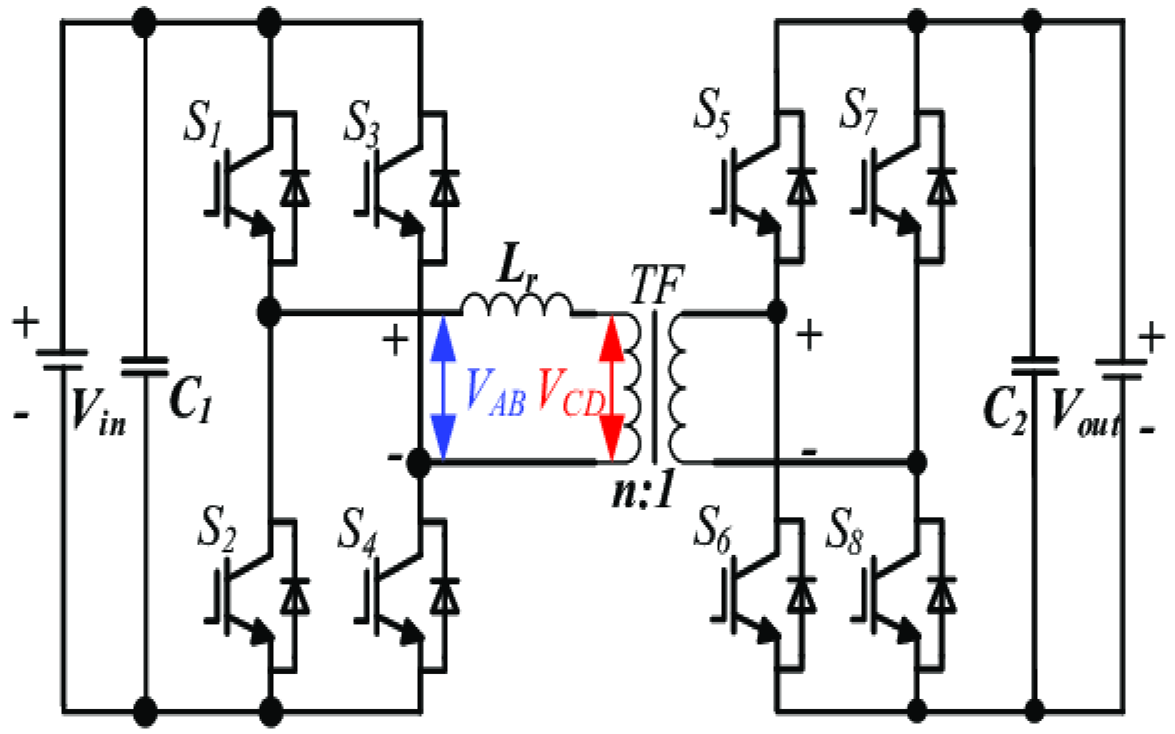
Advantages of DAB Converter

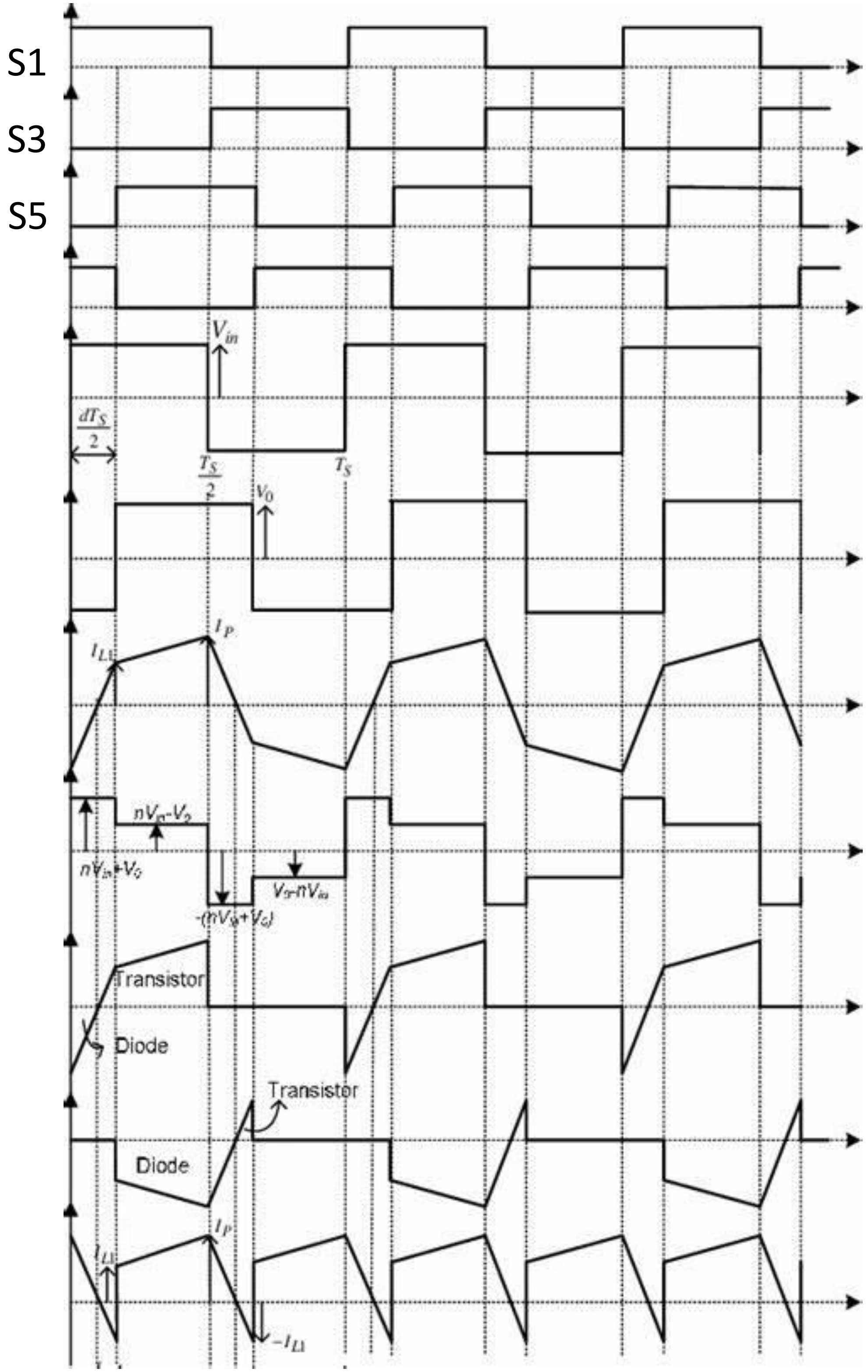
Bidirectional power flow, enabling vehicle-to-grid applications, high efficiency, efficiency, and compact design.

3

Vehicle-to-Grid Applications

Supports potential vehicle-to-grid applications, where the EV can act as a act as a distributed energy storage system, providing power back to the grid. the grid.





S1,S4 are triggered at first, then at some angle phi S5 is triggered. This is the single phase shift control strategy.

METHODOLOGY:

- ***For totem pole pfc:***
- Vin = 85–265 V
- Vout = 400 V
- Pout = 2–5 kW
- Fline = 50 Hz
- Fsw = 40 kHz
- Iripple = 0.3
- Vripple = 0.01
- IL = 2500 0.95×85 = 30.98
- Ipeak = IL × 1.30 = 30.98 × 1.3 = 40.27 A
- L = Vout/ 4×fsw×Iripple = 400 /4×40×10^3×0.3×43.78 = 1.903 × 10^-4 = 190.3 µH
- Cout = Pout / Vout 4Π × Fline × Vripple = 2500 / 400 4Π × 400 × 0.01 × 50 = 2486.71 µF

METHODOLOGY:

- ***For totem pole pfc:***

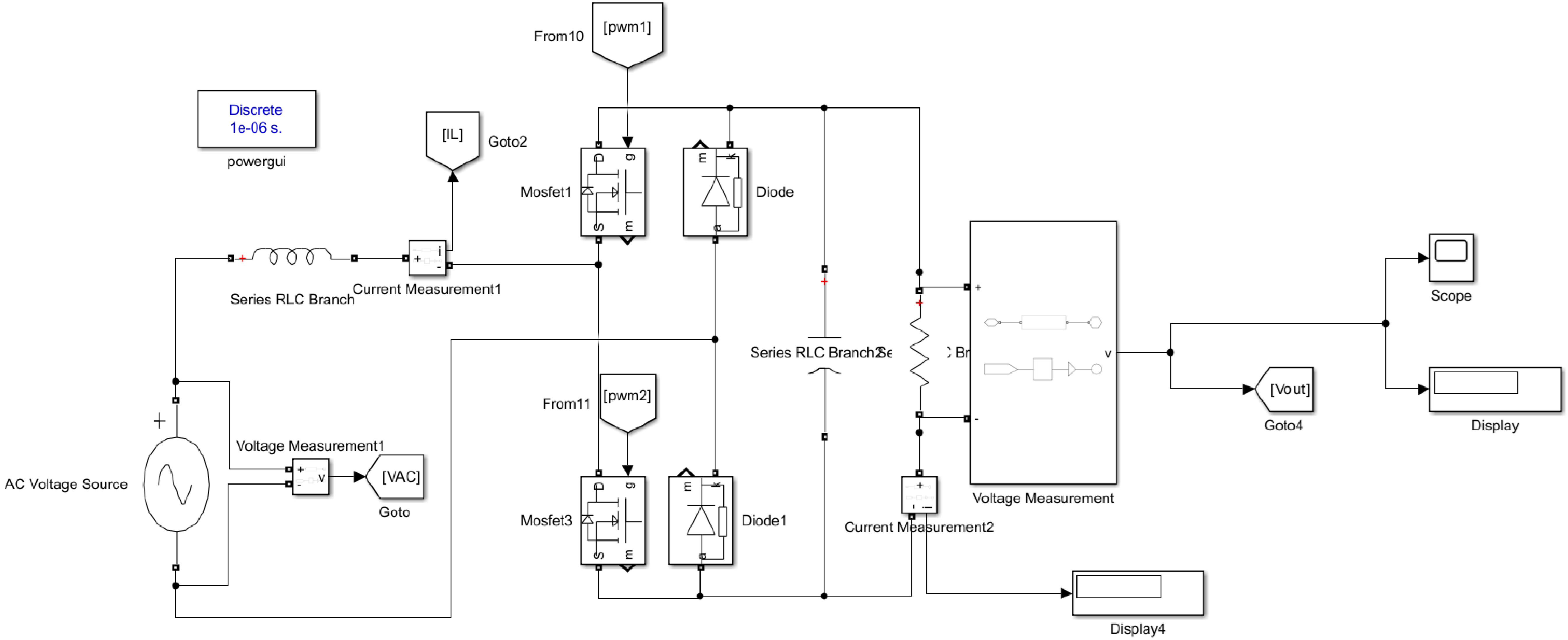


Fig: SIMULINK Model for Totem Pole PFC Circuit

METHODOLOGY:

- ***For totem pole pfc:***

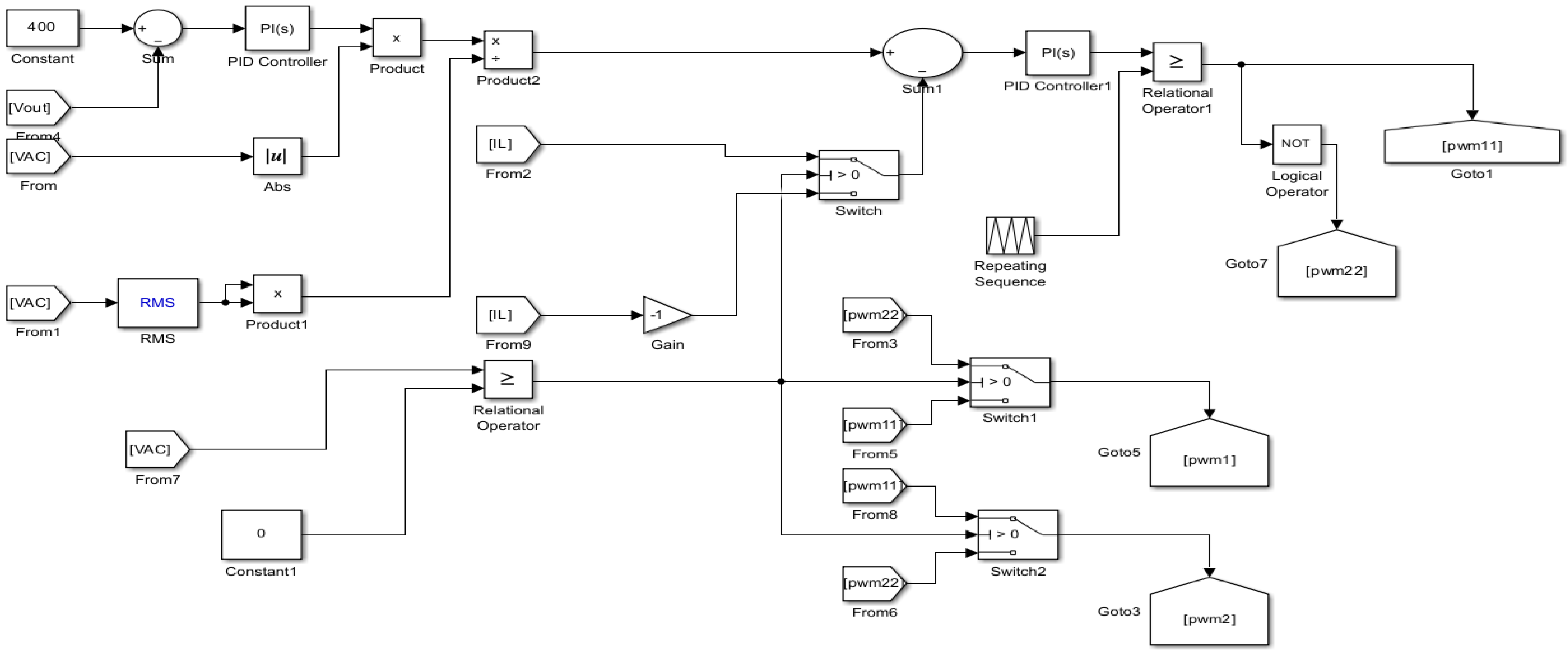


Fig: SIMULINK Model for Closed Loop Control of Totem Pole PFC Circuit

METHODOLOGY:

- ***For DAB Converter:***

We know,

$Po = Vi^2 \cdot d\Phi / Xl(1 - \Phi / \Pi)$

$Po = 2500$

$Vi = 400$

Put $L = 0.3 \times 10^{-6}$ H

$d = Vo / nVi$

$n = ½$

For $Vo = 200$ V

$Vi = 400$ V

$d = 2 \times 200 / 400$

$d = 1$

$2500 = 400^2 / 2\Pi \times f \times 0.3 \times 10^{-6} \cdot \Phi(1 - \Phi / \Pi)$

Also, $f = 500$ kHz $= 500 \times 10^3$

$2500 = 169765.2726\, \Phi(1 - \Phi / \Pi)$

$0.0463 = \Pi\Phi - \Phi^2$

$\Phi^2 - \Pi\Phi + 0.0463 = 0$

$\Phi = 3.13, 0.0148$(in radian)

$\Phi = 179.33, 0.85$(in degree)

Since, $-90<phi<90$

So,

$\Phi=0.85$

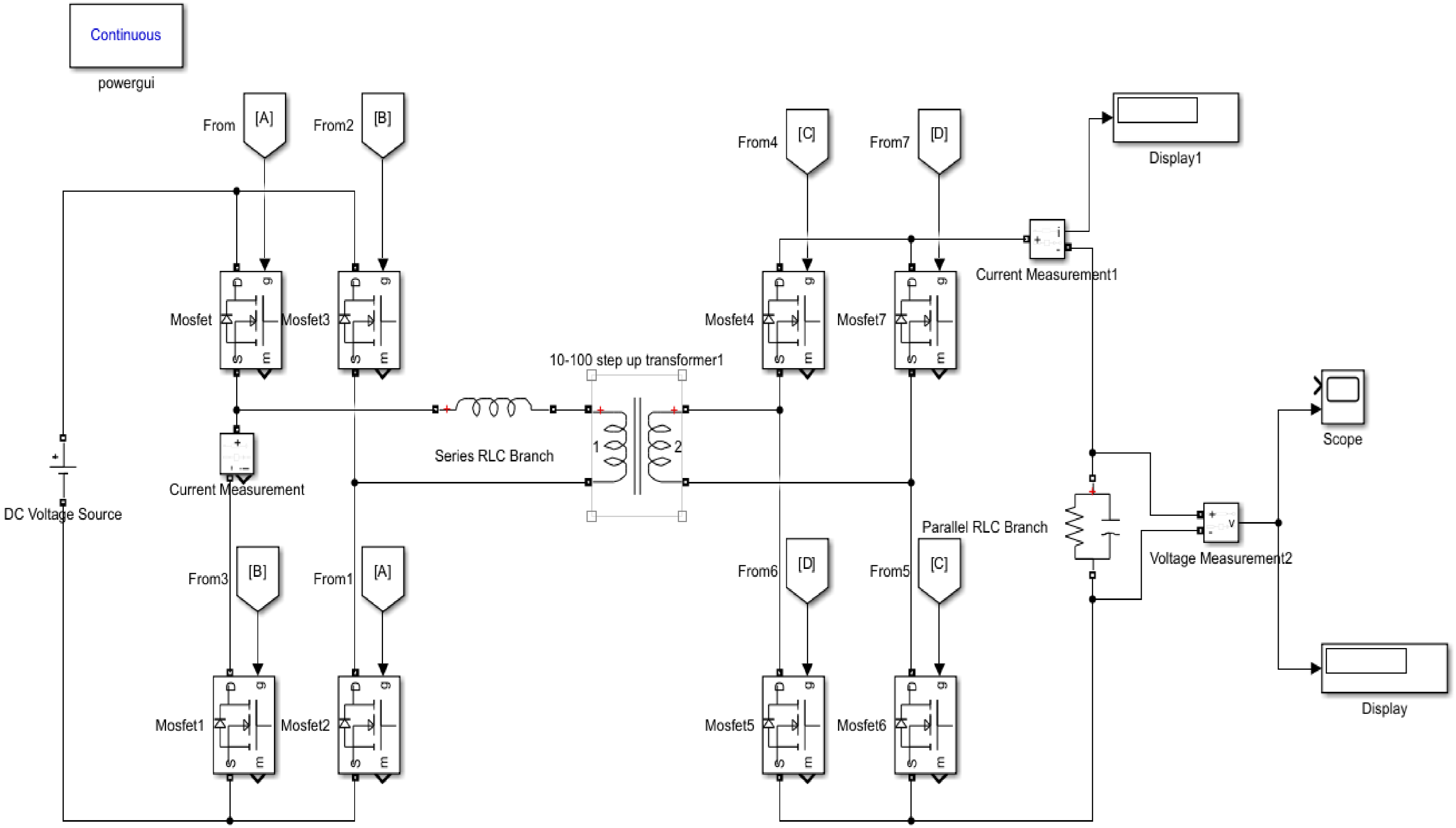


Fig: SIMULINK Model for Dual Active Bridge (DAB) Converter

Integration of AC/DC and DC/DC phase

Fs(swtiching frequency)					
DAB	20KHz	30KHz	40KHz	80KHz	100KHz
Totem Pole	40KHz	40KHz	40KHz	40KHz	40KHz
Remarks	Good voltage level	Irregular output	Output not as good as 20kHz	Output not as good as 20kHz	Decreased Voltage Level

Design of Filter and system parameters

- We tried various values of L and C values to smooth out the circuit and finally settled for the following system parameter:
- Input Voltage=230V rms (AC)
- Output Voltage=200V DC

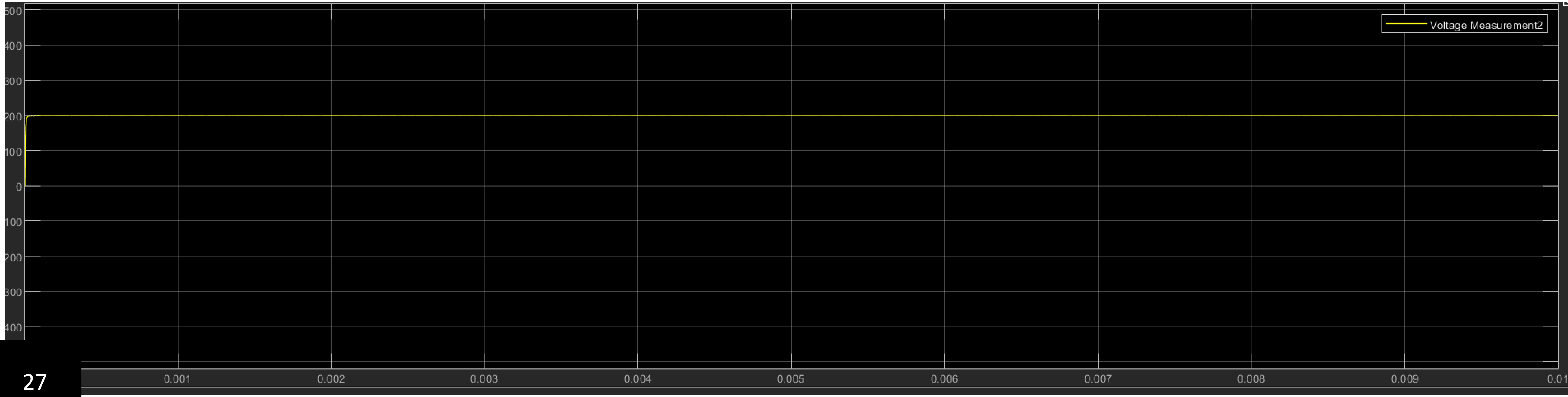
	AC/AC phase
fs	40kHz
L	500mH
C	5mf
	Filter
L	Data
C	5mf
	Link Capacitor
C	50mf
	DAB
fs	20KHz
L	0.03 e-6h

Table 4.1: Final system parameter

Results and analysis:

For output=200V and Power,P=2.5kW
For dc/dc conversion circuit:
Iout=12.31A
Vout=199.2V
Pout=Iout*Vout
=12.31*199.2
=2452W
Efficiency_1=(2452)/2500
=98.08%

Graph for Vout:



For rectification circuit:

For output=400V and Power,P=2.5kW

Iout=6.249A

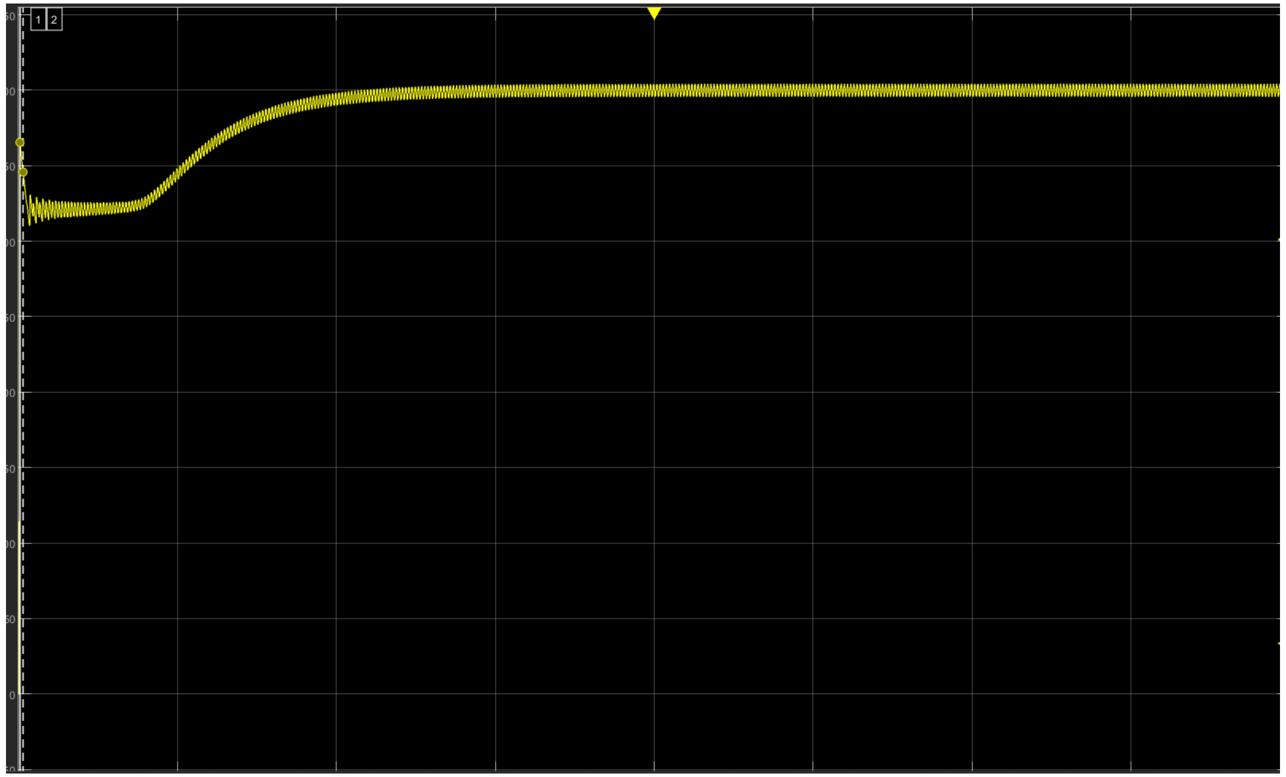
Vout=399.9V

Pout=Iout*Vout

=2499

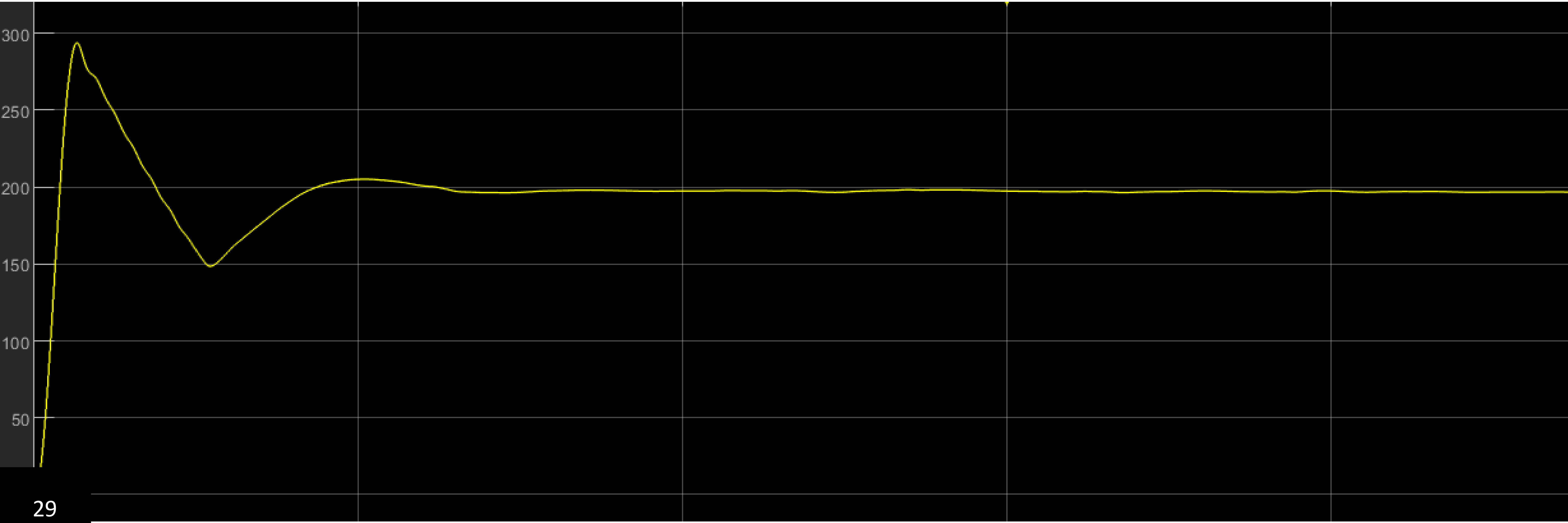
Efficiency_2=(2499)/2500

=99.96%



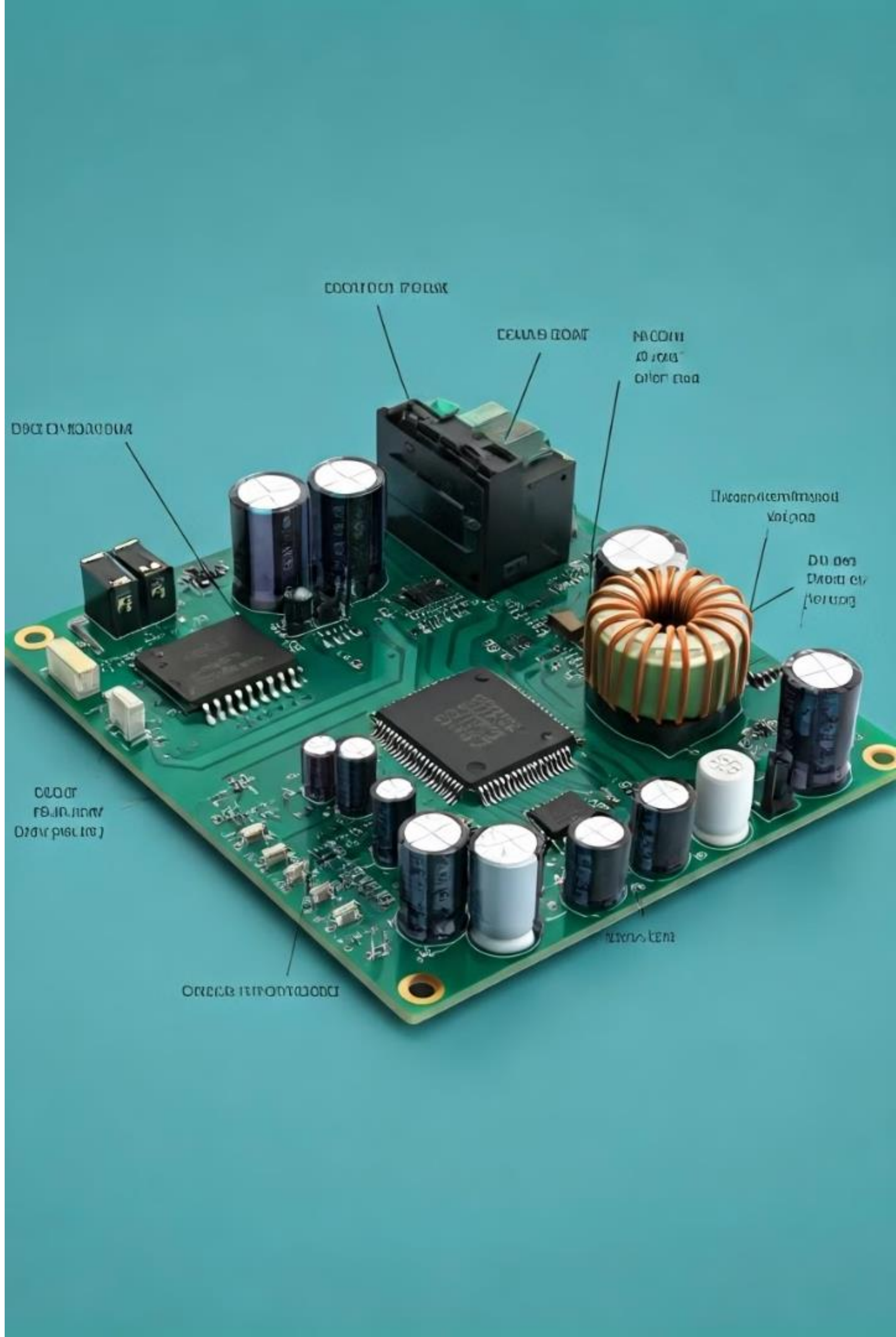
Limitation: Although both stages of the onboard charging circuit have high efficiency when isolated, the overall efficiency of the system is likely to decrease when both circuits are connected.

- This the output out of dual active bridge converter circuit for simulation time of T=30s
- There is an stagnation of output voltage at around 197V with the efficiency of 97%



Future Implementation Plans

1. Fine tune current circuit parameters
2. Improve the voltage regulation.



Project Timeline

1

Completed

Literature review, system design, Totem Pole PFC and DAB implementation

2

In Progress

PFC and DAB optimization, Micro controller hardware selection

3

Next

Microcontroller implementation, system integration

4

Future

Comprehensive testing, performance analysis, and potential enhancements

Challenges and Learning Outcomes

Challenges

- Dealing with high-frequency switching noise
- Balancing efficiency and output quality in both Totem Totem Pole PFC and DAB Converter
- Ensuring robust operation under various conditions. conditions.

Learning Outcomes

- Deeper understanding of power electronics in EV applications
- Practical experience with PFC and DAB circuit design and design and implementation
- and improved problem-solving skills in real-world engineering scenarios.

Conclusion

Successfully implemented Totem Pole PFC with 400V output

Achieved implementation of DAB converter with the output voltage 200V

Integrated different phases of dual active bridge converter

The project aims to contribute to more efficient EV charging systems

Potential impact: Faster charging times, improved grid integration for EVs

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Any Questions?

Thank you for your attention. We welcome any questions or feedback on our progress so far.