

Power Converters in EV & HEV

- With the focus on vehicular technology shifting towards replacing mechanical, hydraulic, or pneumatic systems with electrical systems, power electronic circuits (PECs) have gained a lot of importance in the last decade.



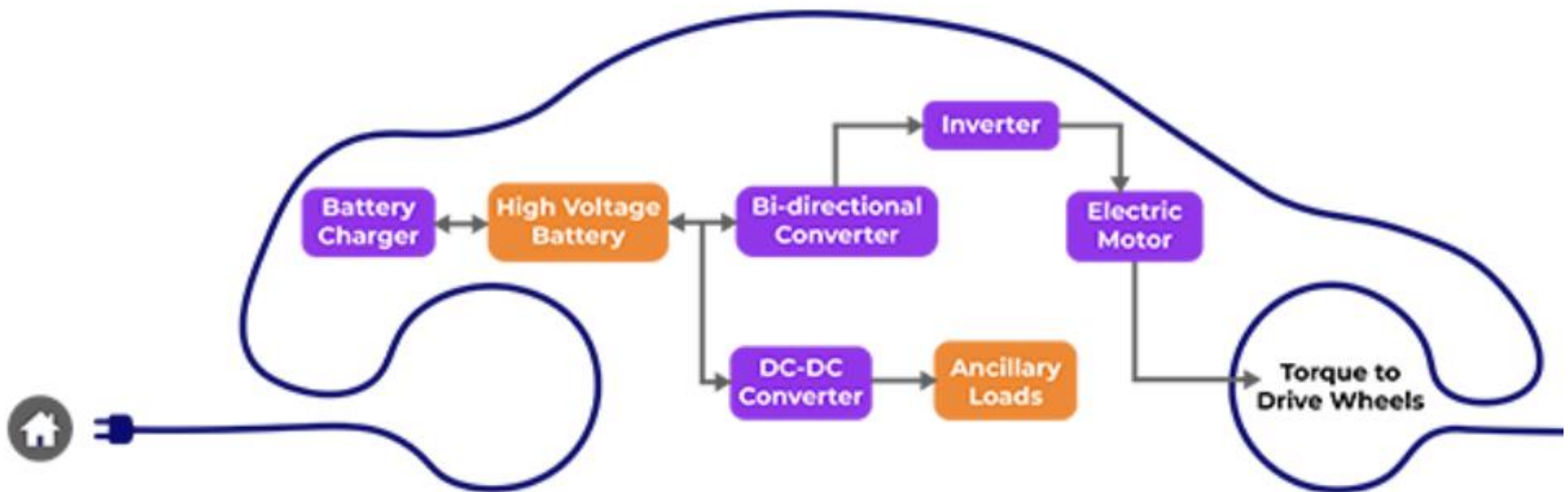
- Increasing vehicular loads such as utility, entertainment, luxury, and safety loads have increased the demand for compact and efficient PECs.
- The electric components inside the vehicle vary in their voltage requirements, with a majority of them running on lower voltages.
- This includes the radio, dashboard readouts, air conditioning, and in-built computers and displays.

Electric Vehicles classification

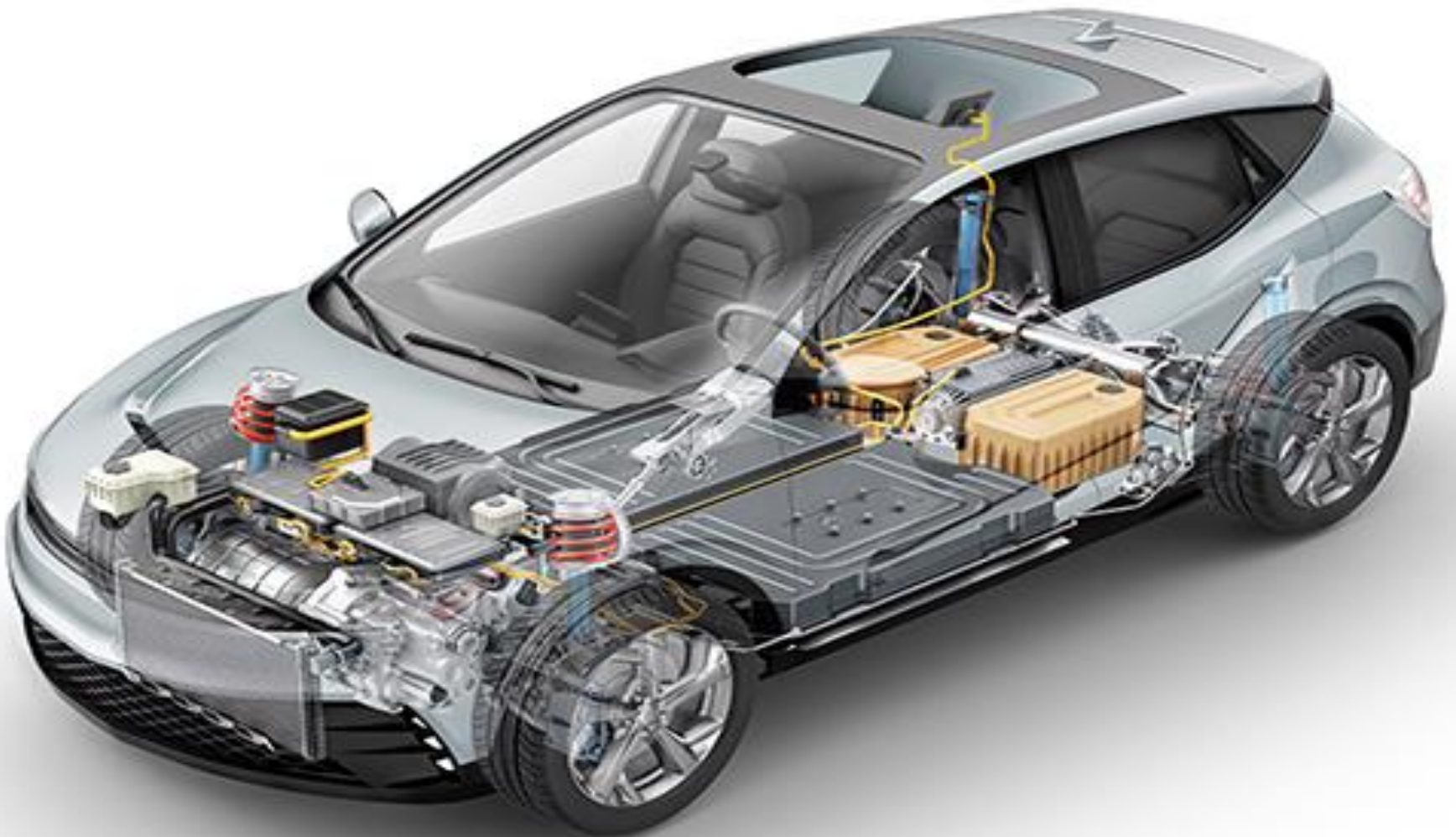
- ❑ **Commercial electric vehicles may be broadly classified as:**
 - Battery electric vehicles (BEVs),
 - Hybrid electric vehicles (HEVs) and
 - Fuel cell vehicles (FCVs).
- ❑ **BEVs are purely electric vehicles (EVs), whereas HEVs combine EVs and internal combustion engines (ICEs). FCVs use power from both the battery and fuel cell stack.**
- ❑ **The different configurations of EV power supply show that at least one DC/DC converter is necessary to interface the FC, the battery, or the supercapacitors module to the DC-link.**

Power converters : A Overview

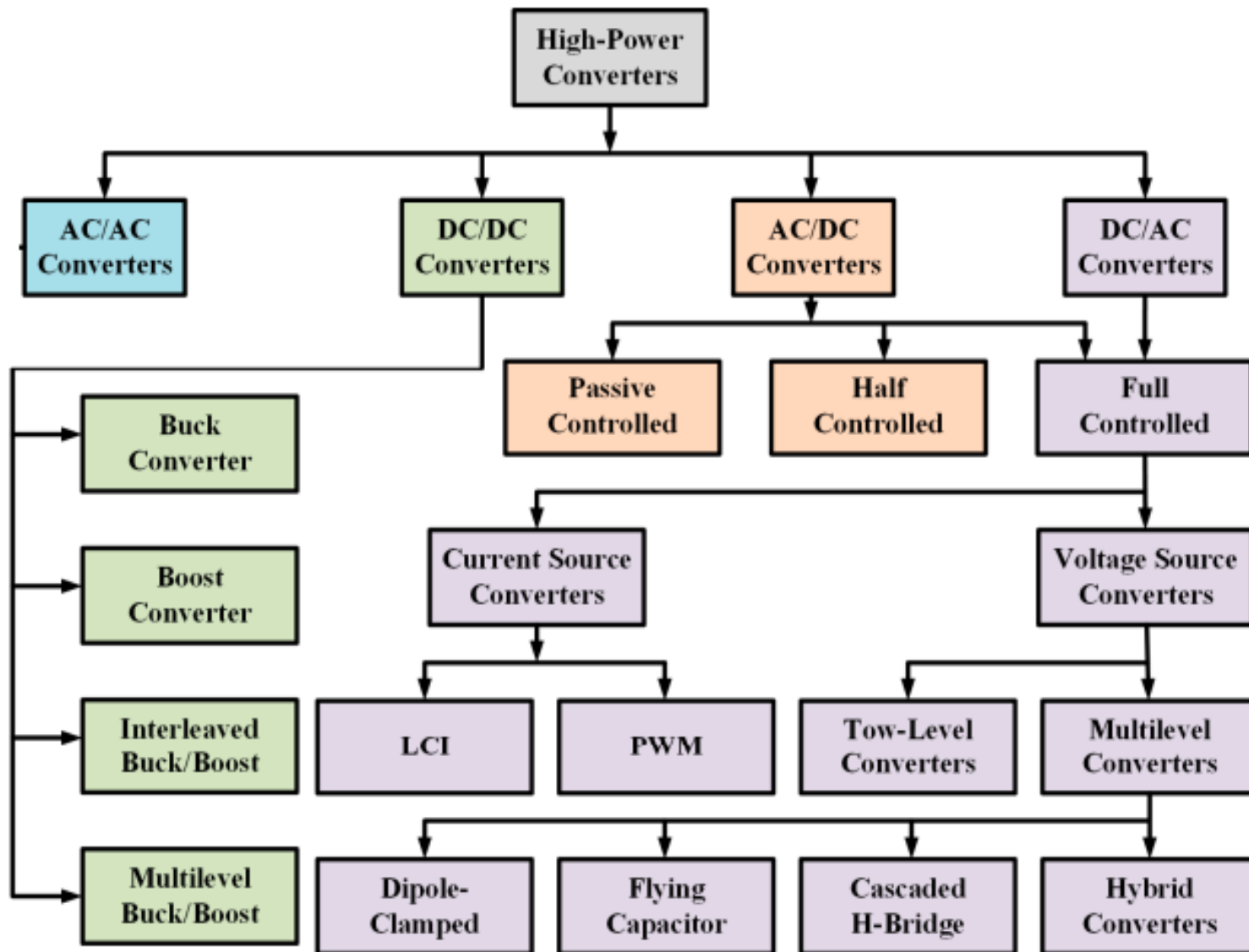
- There are two major power electronic units in the general configuration
 - DC-DC converter
 - DC-AC inverter
- Usually, AC motors are used in HEVs or EVs for traction and they are fed by an inverter and it is fed by a DC-DC converter.



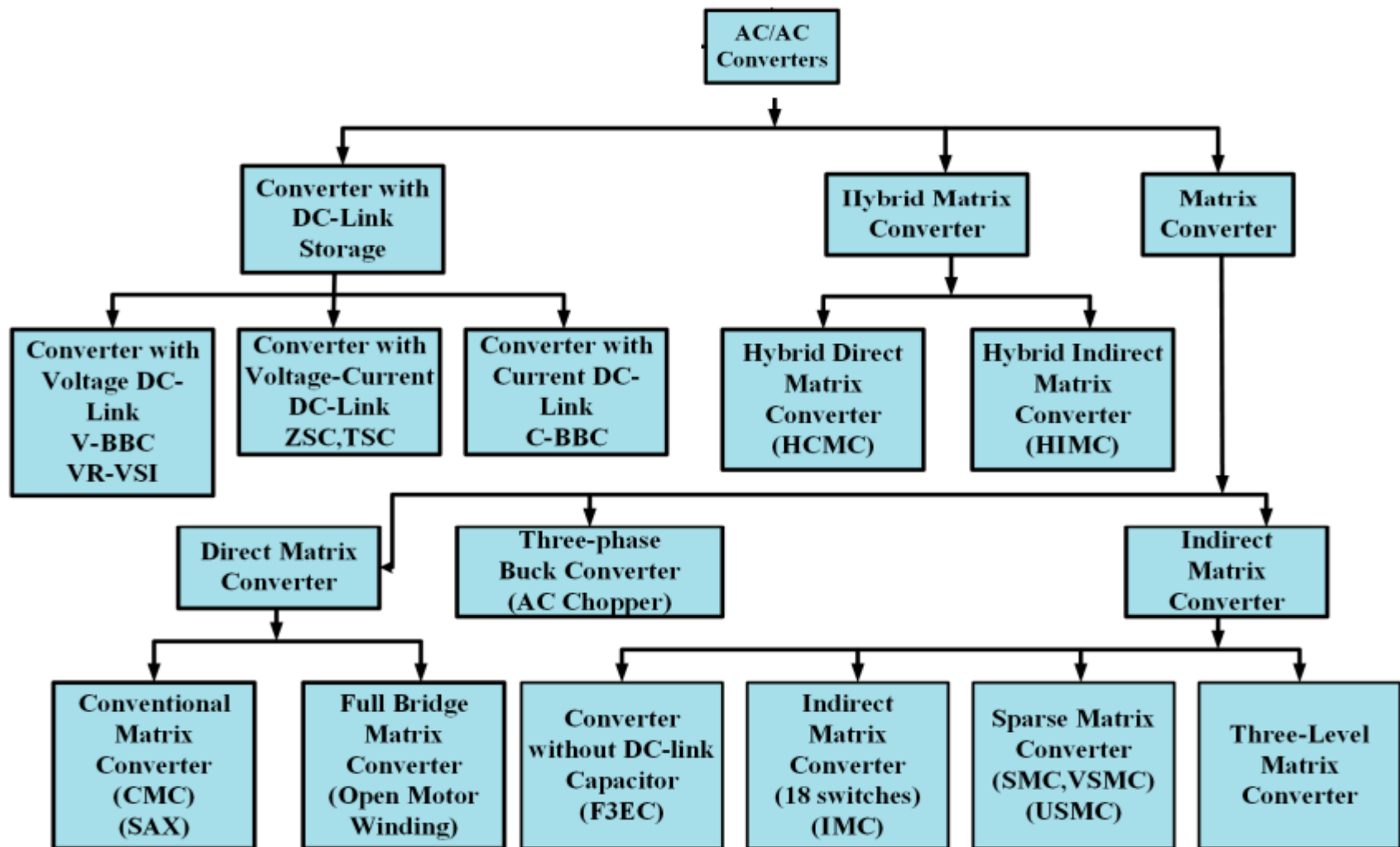
- The main components of an Electric Vehicle are a DC-AC inverter, a DC-DC converter, a battery, and an electric motor.



Detailed classification of converters



Detailed classification of converters



An Overview of DC-DC Converters

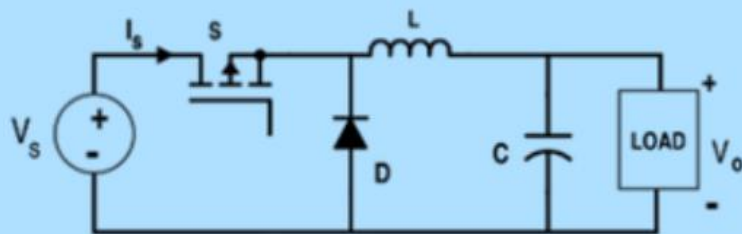
- ❑ DC-DC converters in an electric vehicle may be classified into unidirectional and bidirectional converters.
- ❑ Unidirectional DC-DC converters supply to various onboard loads such as sensors, controls, entertainment, utility, and safety equipment. They are also used in DC motor drives and electric traction.
- ❑ Bidirectional DC-DC converters find applications in places where battery charging, regenerative braking, and backup power are required.
- ❑ The power flow in a bidirectional converter is usually from a low voltage end such as a battery or a supercapacitor to a high voltage side and is referred to as boost operation.

- ❑ During regenerative braking, the power flows back to the low voltage bus to recharge the battery (buck mode).
- ❑ As a backup power system, the bidirectional DC-DC converter facilitates the safe operation of the vehicle when ICEs or electric drives fail to drive the motor.
- ❑ Due to the aforementioned reasons, high-power bidirectional DC-DC converters have gained a lot of importance in the recent past.

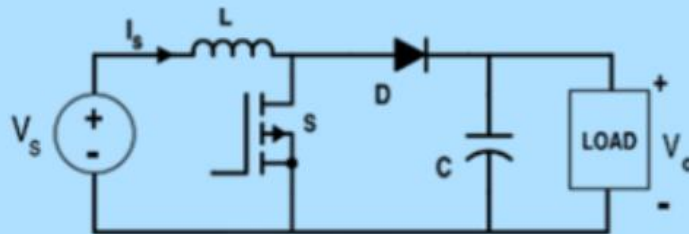
The DC-DC converter topologies are classified as

- **Buck Converter:**
 - The buck converter is a step-down converter and produces a lower average output voltage than the dc input voltage.
- **Boost converter:**
 - In the boost converter, the output voltage is always greater than the input voltage.
- **Buck-Boost converter:**
 - In a buck-boost converter, the output voltage can be either higher or lower than the input voltage.
- **Cuk converter:**
 - The output voltage can be either higher or lower than the input voltage providing some advantages over buck-boost (like a continuous current, less current ripple etc.)
- **SEPIC converter:**
 - The output voltage can be either higher or lower than the input voltage (with no polarity reversal compared to Buck-boost or Cuk converter).

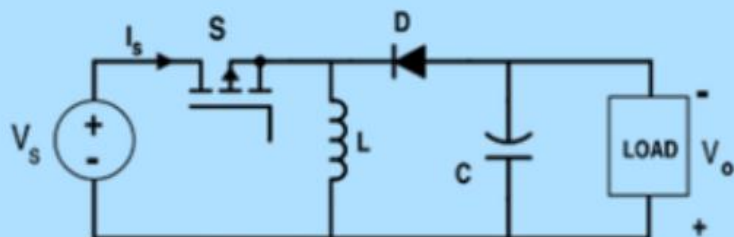
Circuit diagram of DC-DC converters



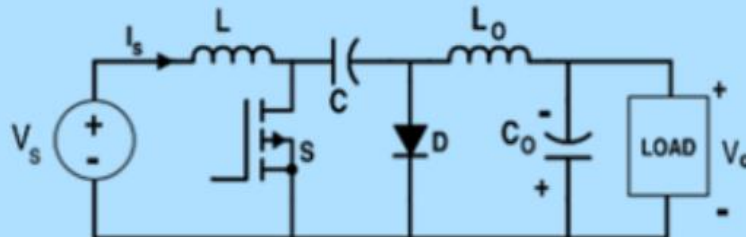
Buck Converter



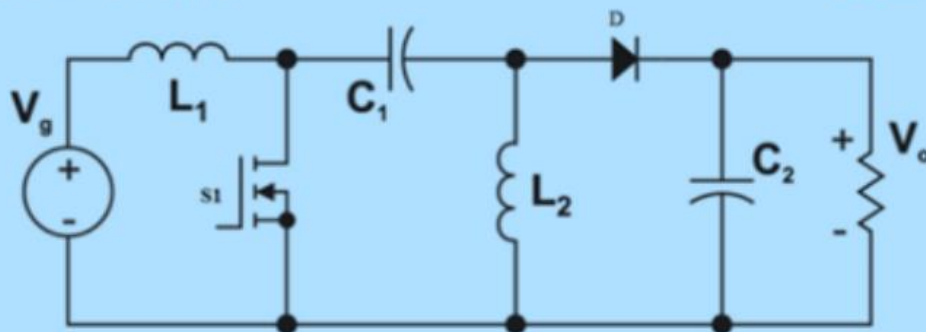
Boost Converter



Buck-Boost Converter

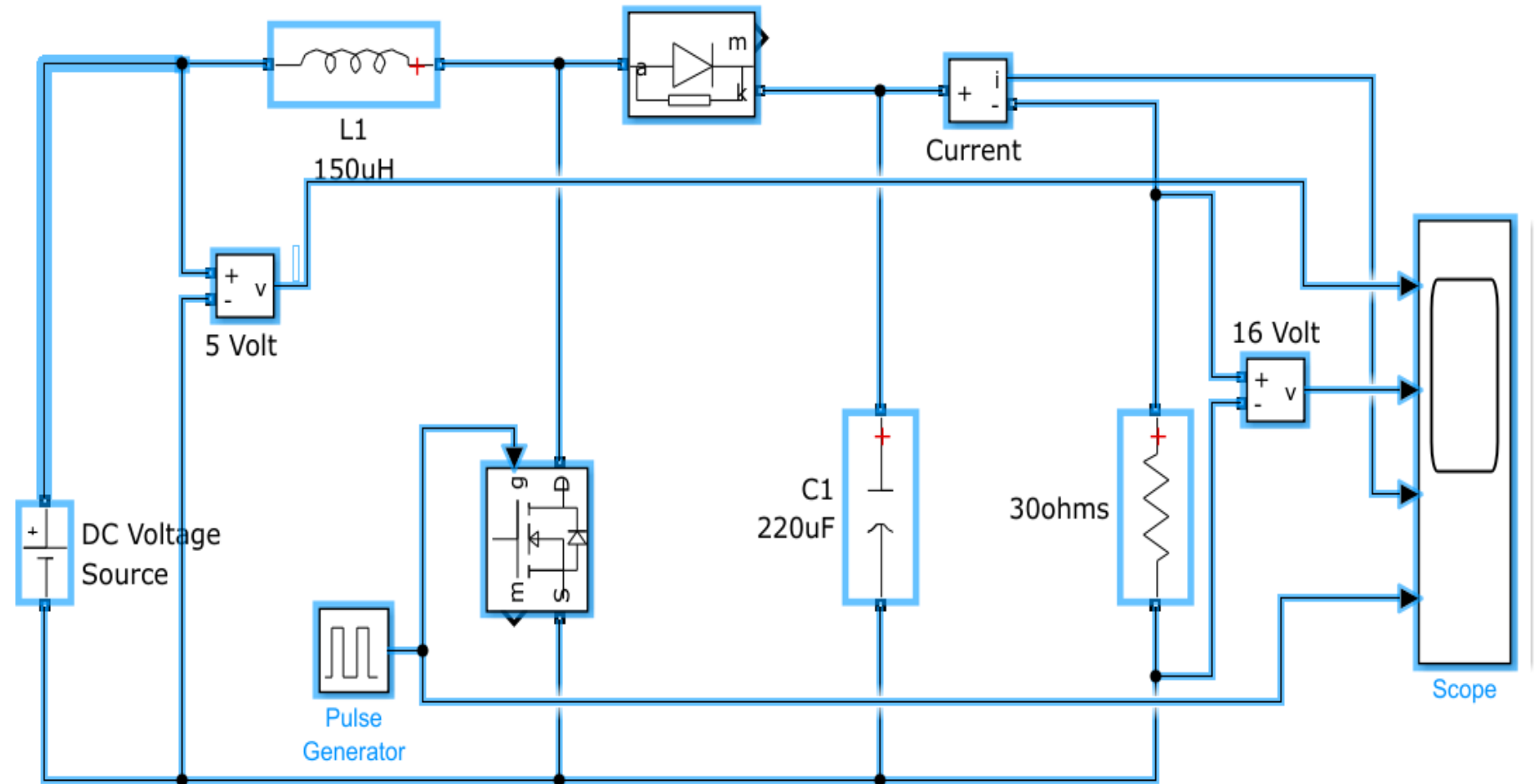


Cuk Converter

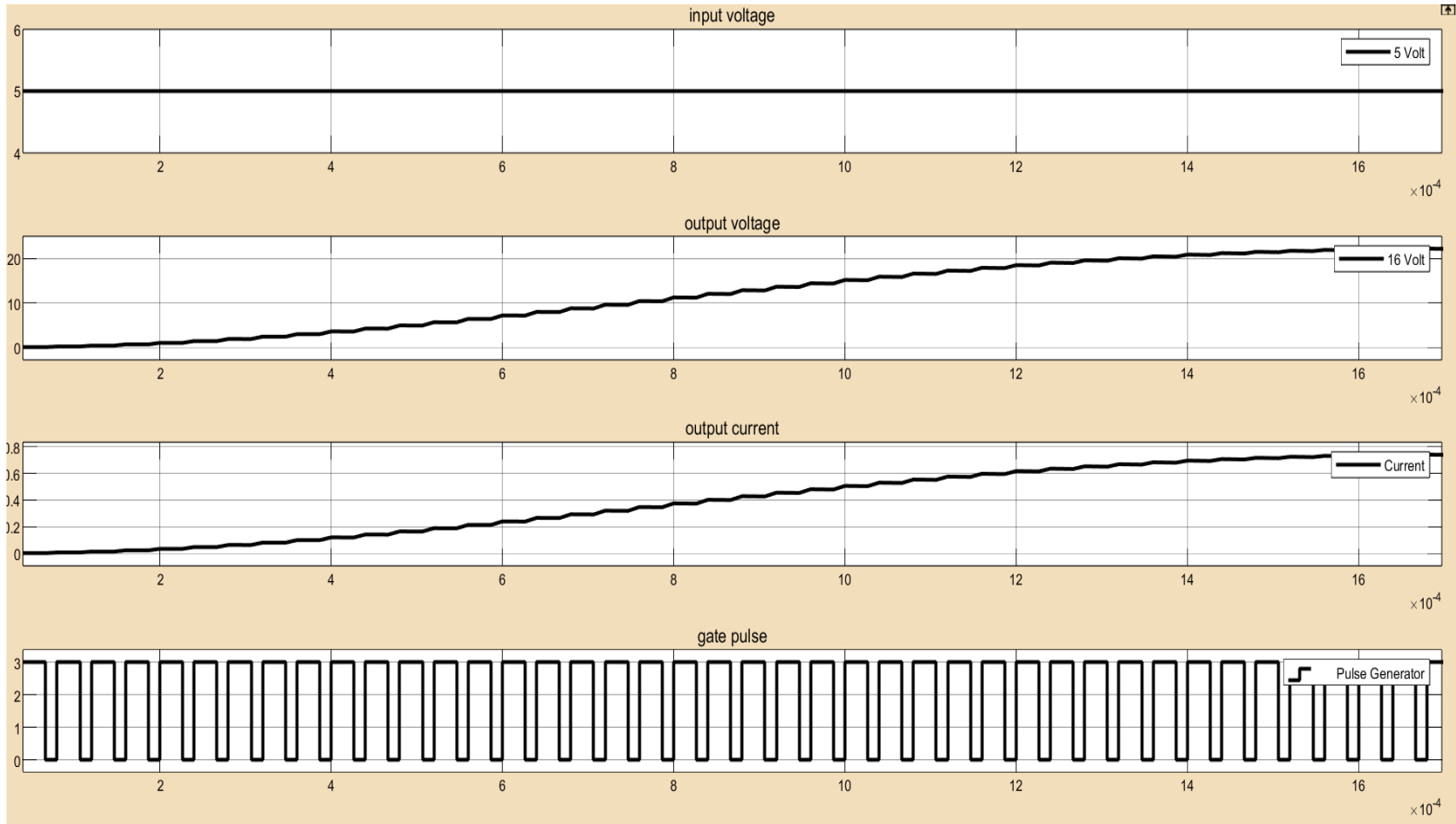


SEPIC Converter

BOOST CONVERTER

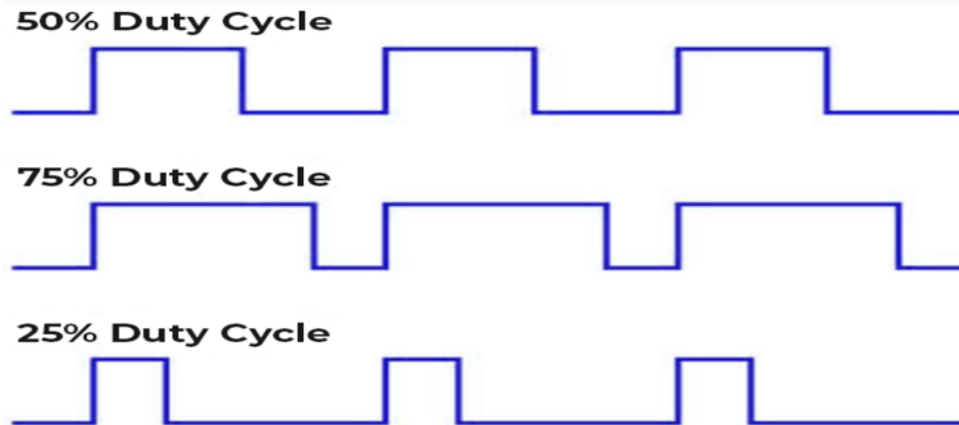


Boost converter output



Isolated DC-DC converter

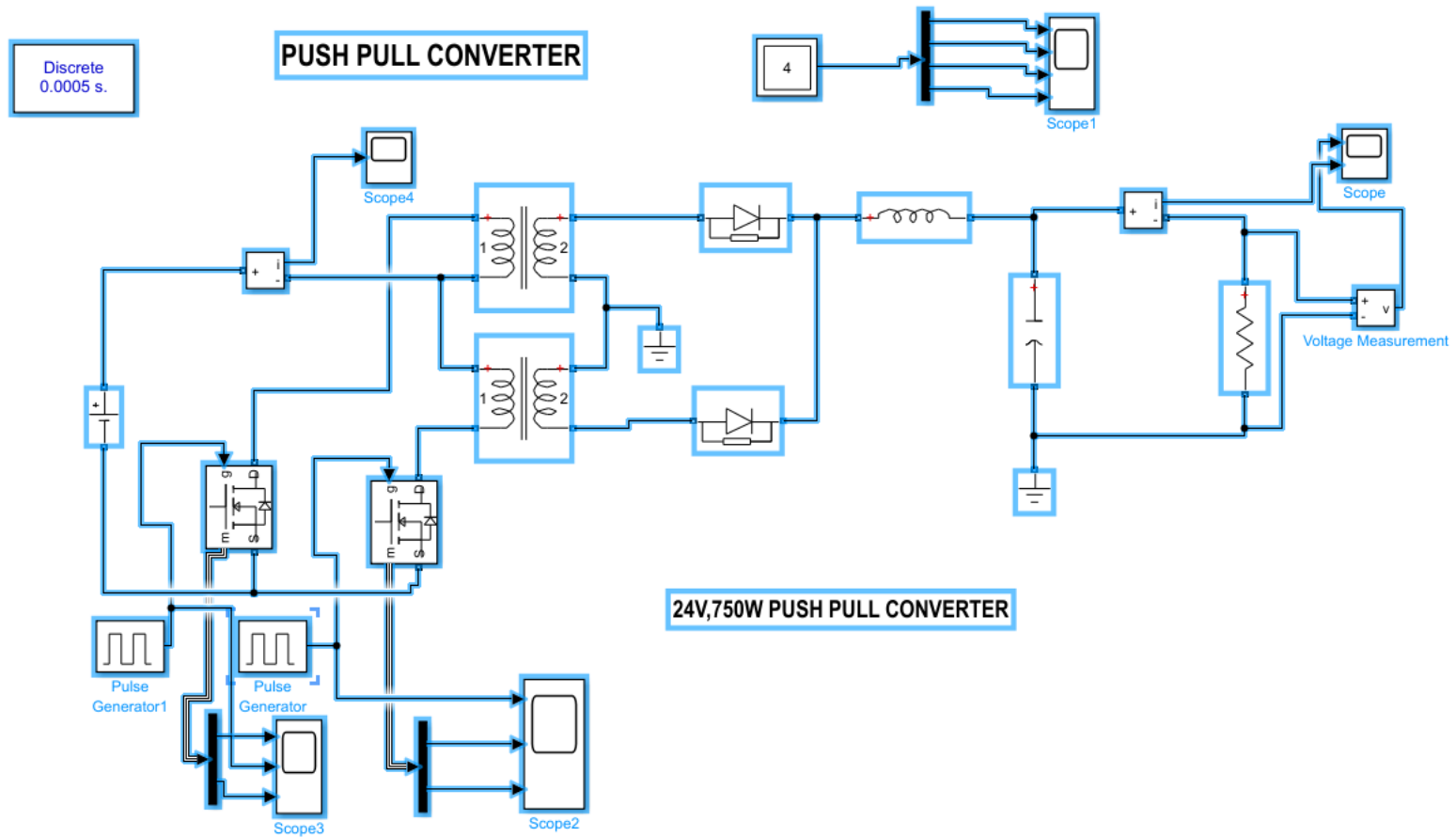
- ❖ In this type, the input and output stages are separated and there is a presence of a transformer which can further reduce (or increase) the output voltage apart from being done by the duty cycle.
- ❖ Forward, Flyback, Half bridge, Full bridge, and Push-pull converters fall under this category.
- ❖ The amount of power flow between the input and the output can be controlled by adjusting the duty cycle (ratio of on/off time of the switch).

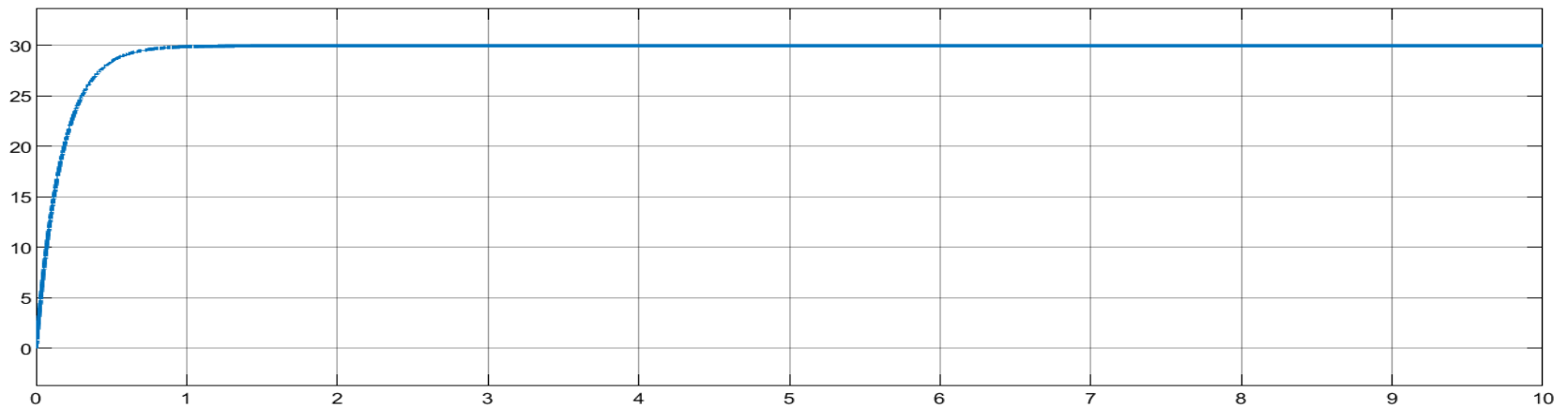
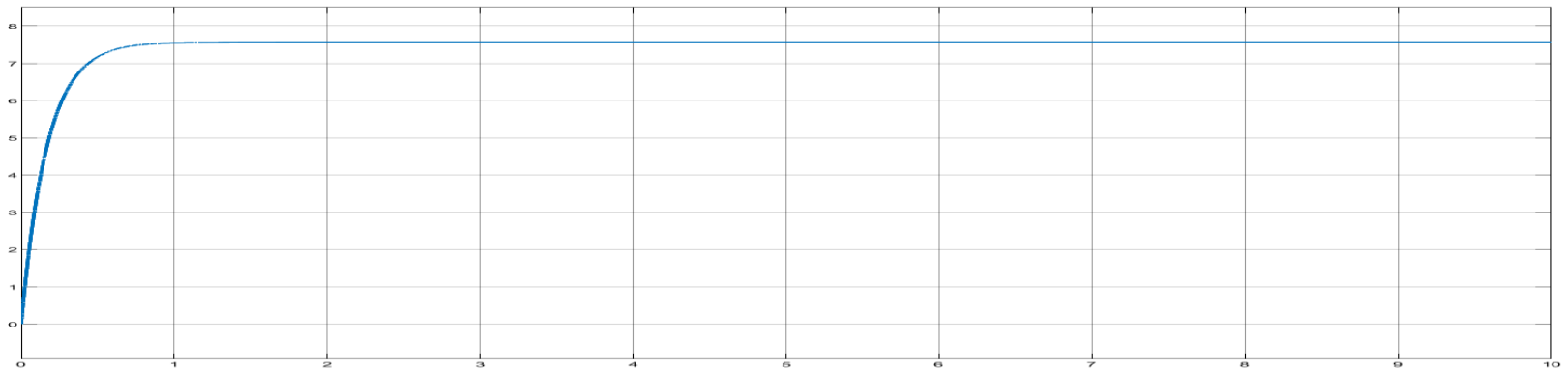


- ❖ Usually, this is done to control the output voltage, the input current, and the output current or to maintain constant power.

The Importance of DC/DC Converters

- While DC/DC converters can be based on several different designs, the underlying function remains the same.
- A step-up converter, which turns a low-voltage input into a high-voltage output, or a step-down converter, which does the exact opposite.
- In electric vehicles that use a DC motor, the running motor can use up to three times the voltage provided by the battery.
- With the help of the right converter, we can bridge this gap without having to use a larger, heavier battery.



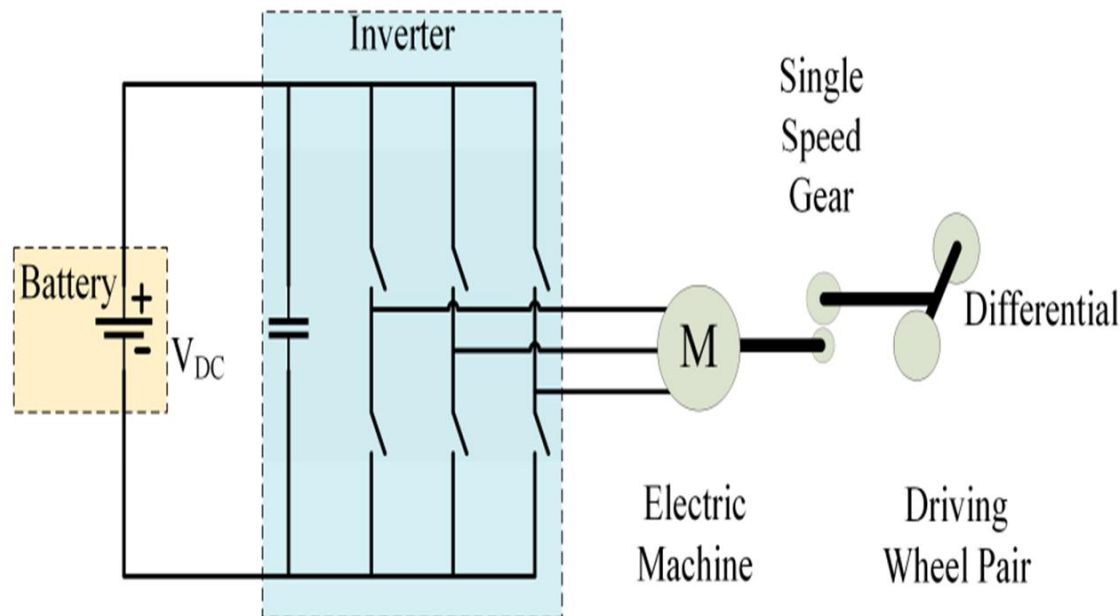


Converters with EV application displaying their key features and uses in EVs

Configuration	Reference	Operation	Key Features	Application in EV
Buck converter	Bose [92]	Step down	Can operate in continuous or discontinuous mode	Sending power to the battery
Buck-Boost converter	Bose [92]	Step up and step down	Two quadrant operation of chopper	Regenerative action
Interleaved Boost PFC converter	Williamson et al. [46]	Step up with power factor correction	Relatively small input EMI filter	Charging
Bridgeless/Dual Boost PFC Converter	Williamson et al. [46]	Step up with power factor correction	Does not require rectifier input bridge	Charging
ZVS FB Converter with Capacitive Output Filter	Williamson et al. [46]	AC-DC conversion	Zero voltage switching	Charging

DC-AC converters (Inverters)

- An inverter is a device that converts DC power from the battery to AC power in an electric vehicle motor.
- The inverter can change the speed at which the motor rotates by adjusting the frequency of the alternating current.



Significance of DC-AC converters

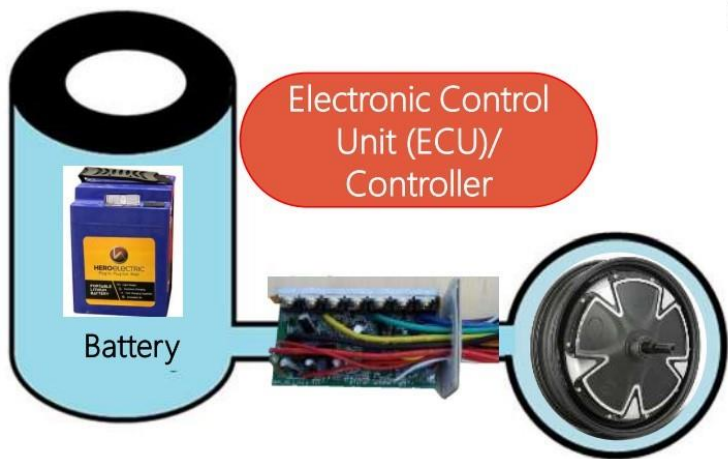
The Significance of DC/AC Converters

The use of inverters can increase or decrease the power or torque of the motor by adjusting the amplitude of the signal.

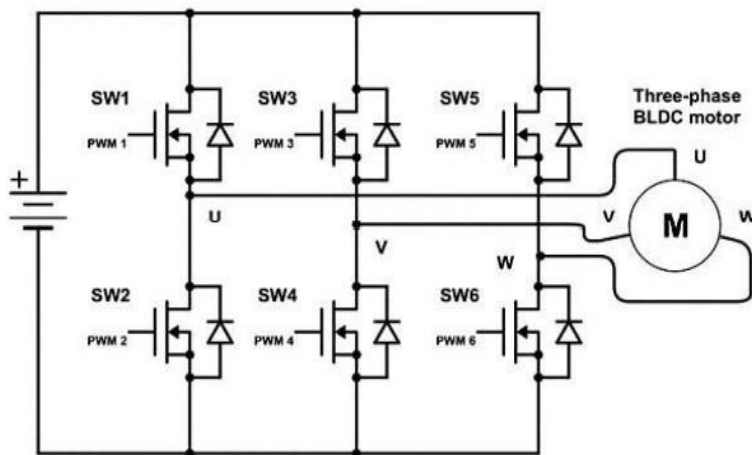
It plays a significant role in capturing energy from regenerative braking and feeding it back to the battery. The key component is that it has a direct impact on on-road performance, driving range, and reliability of the vehicle also as a consequence of their weight and size.

CONTROLLER

Controller (Electric Control unit)

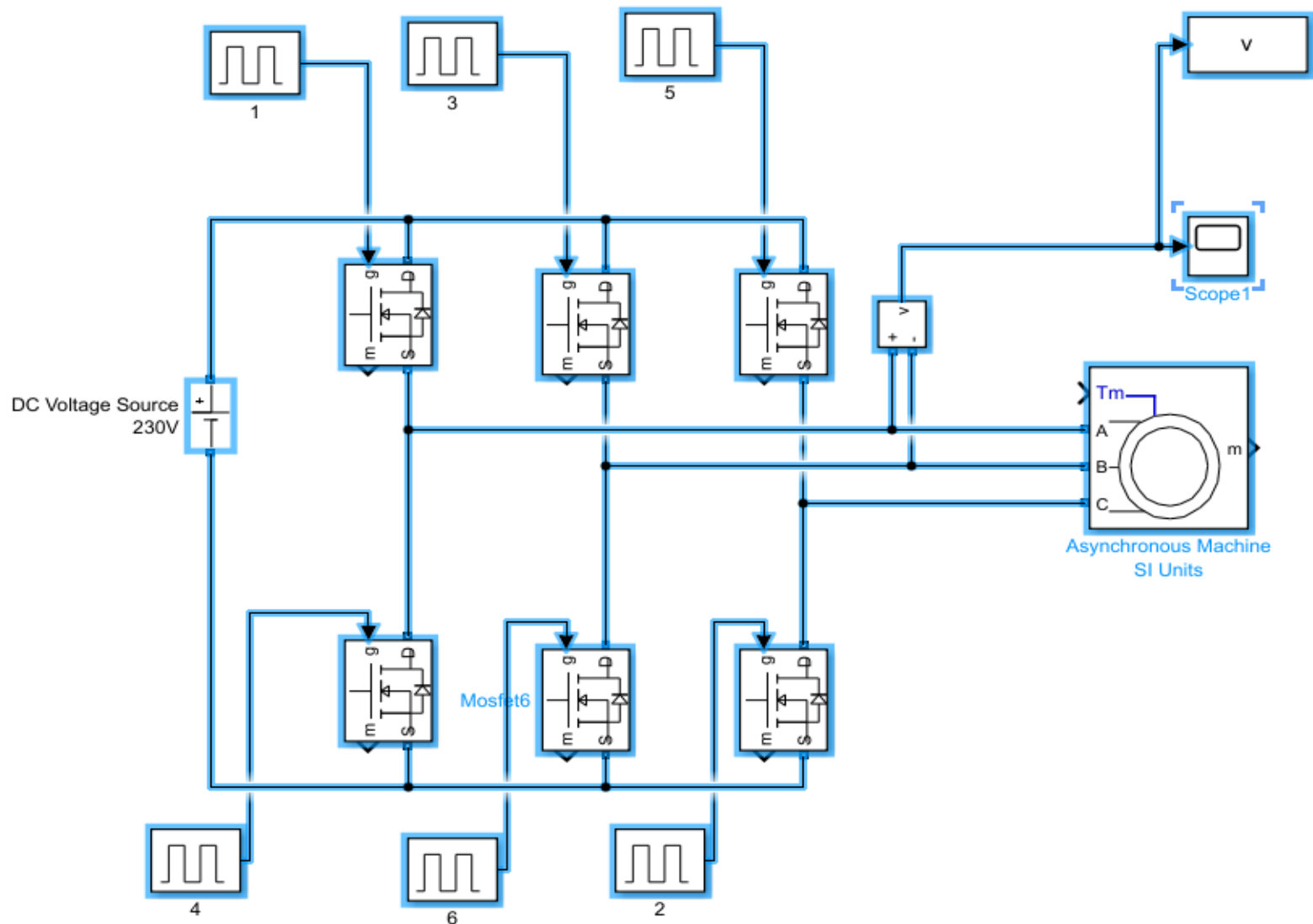


Electric Power controlled by Electronic Control unit (ECU) /Controller

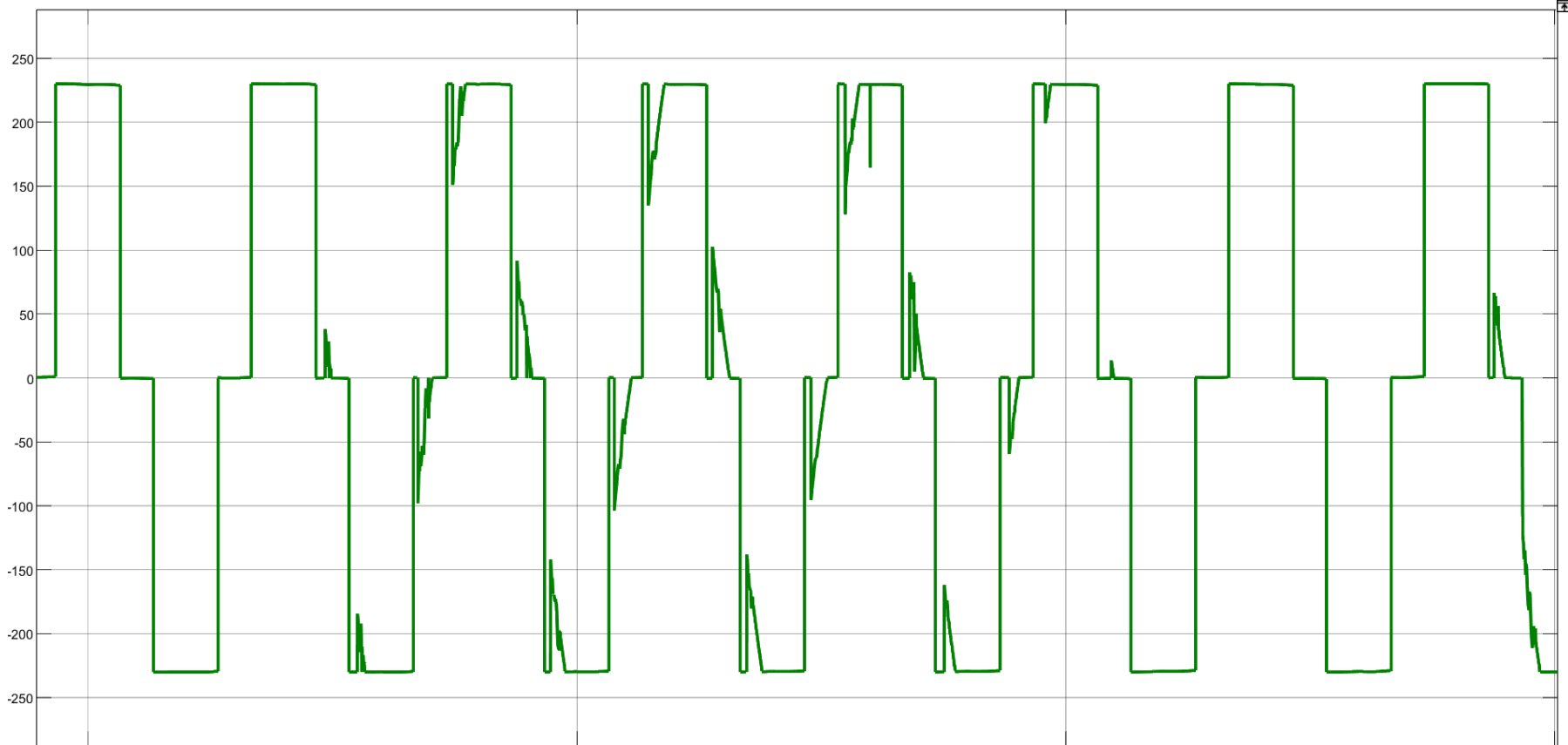


A typical 3 phase bi-directional MOSFET switch setup for a 3 phase load or in this case a BLDC motor. This configuration is often called a 3 phase H-Bridge.

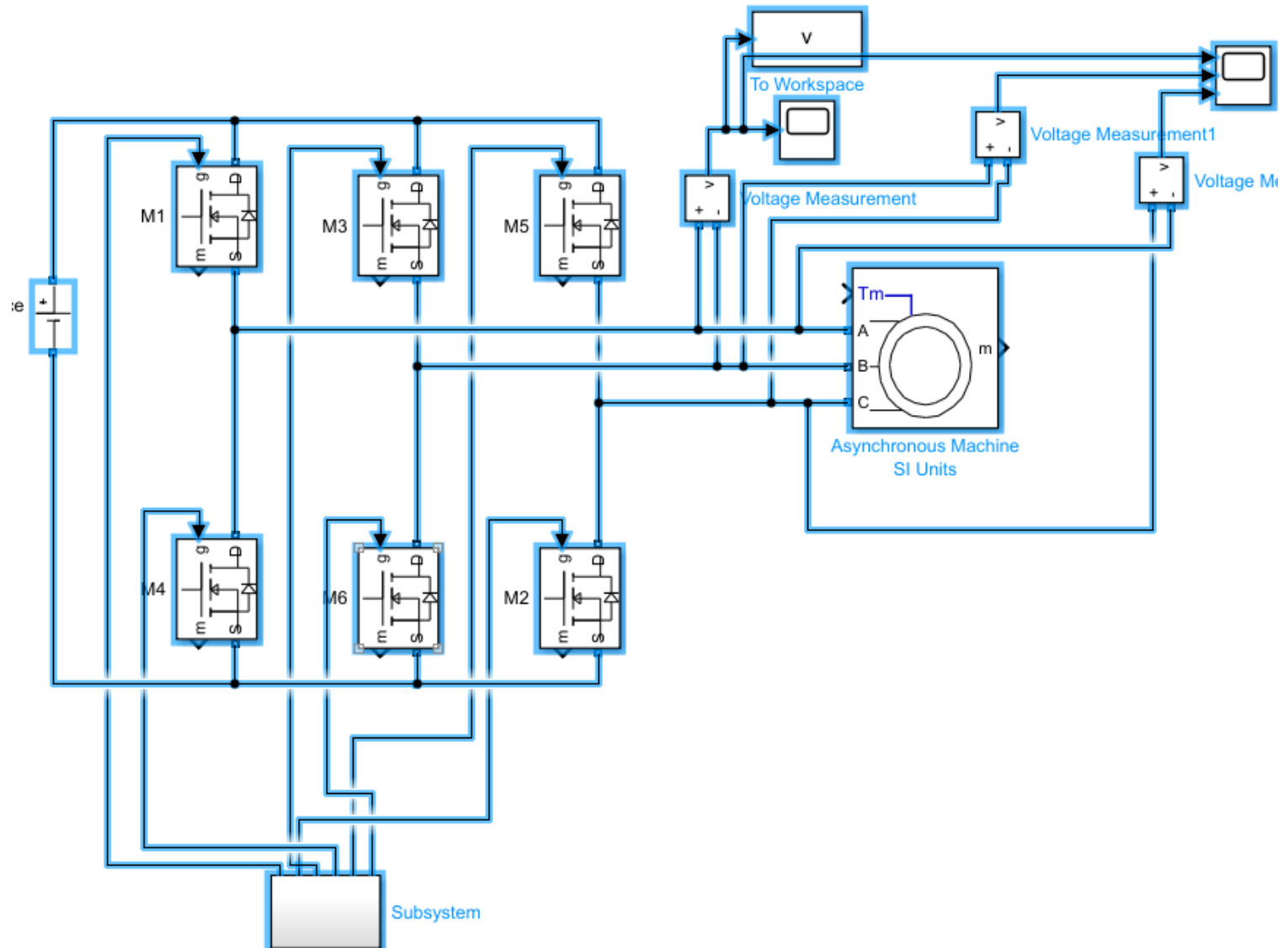
Simulation and Design of Power Converters for EV using MATLAB and

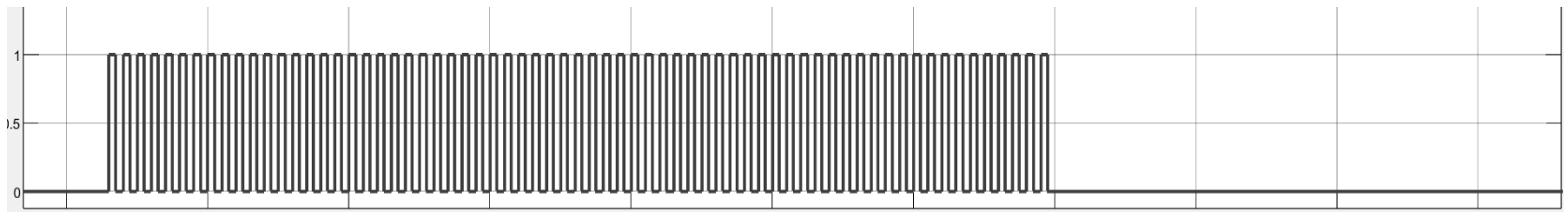
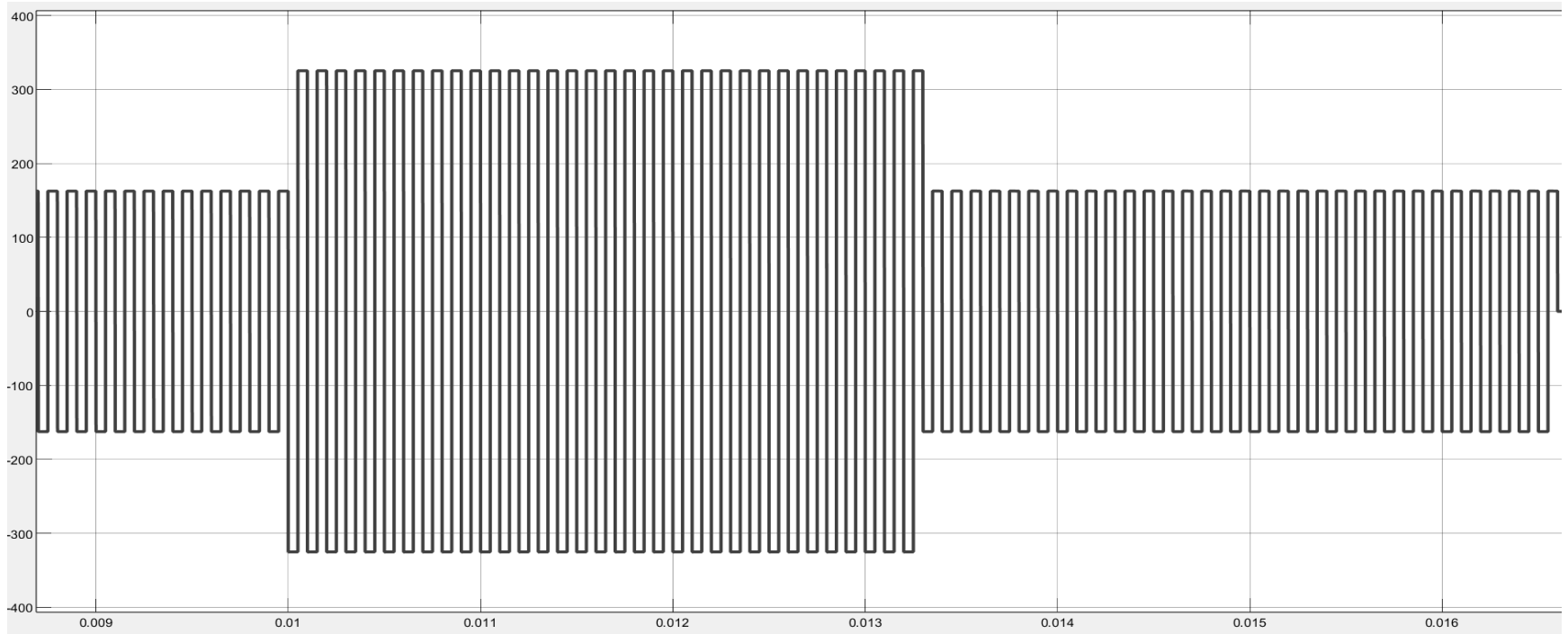


120 DEGREE MODE INVERTER

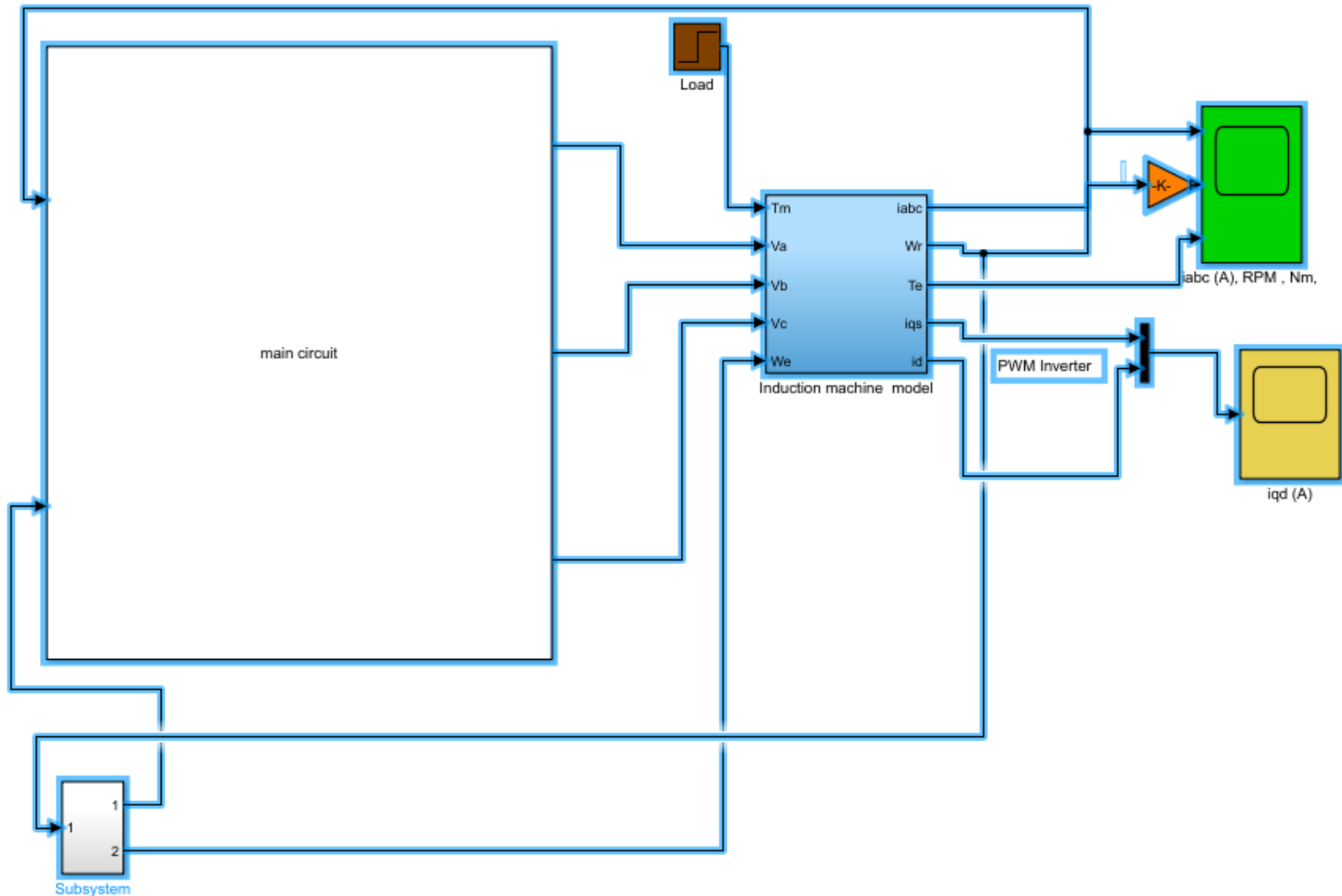


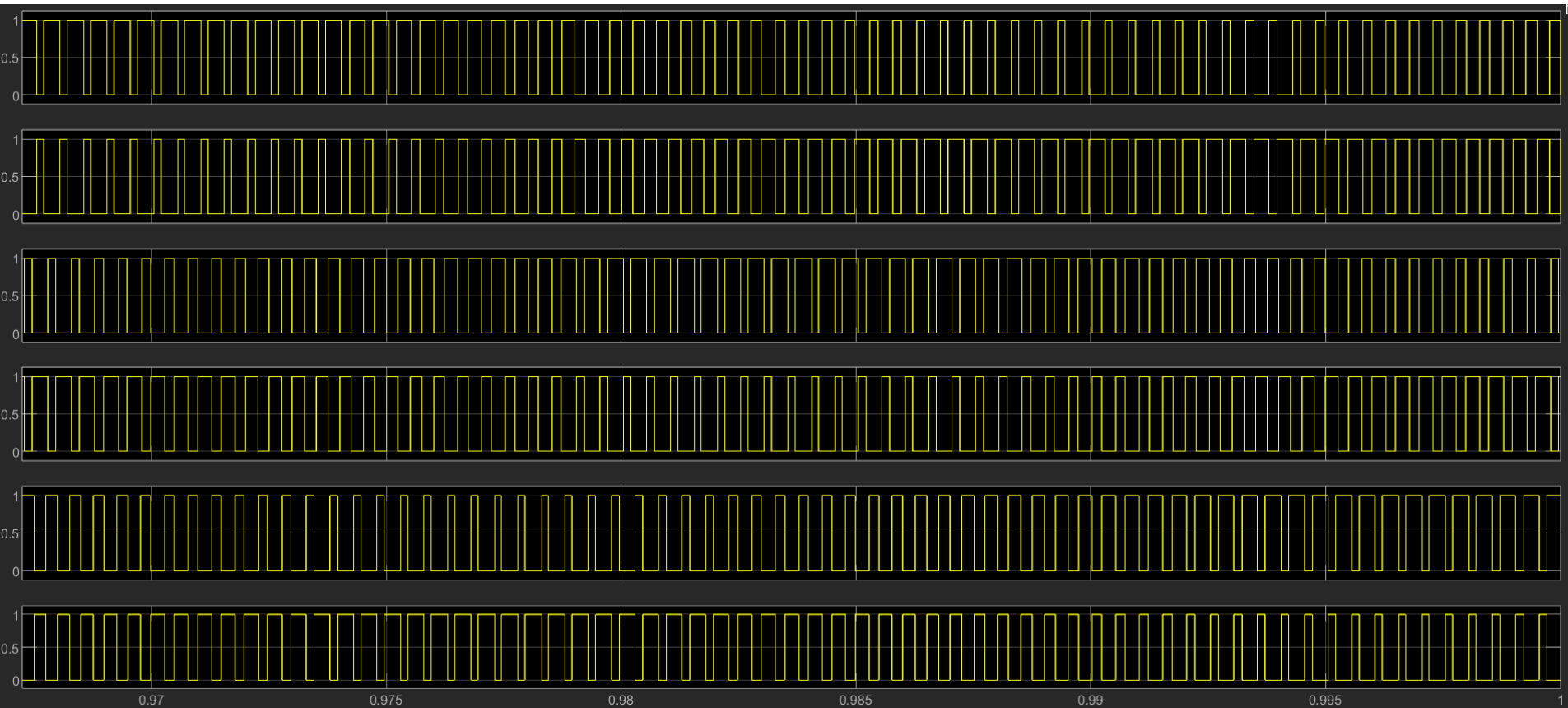
PWM Inverter

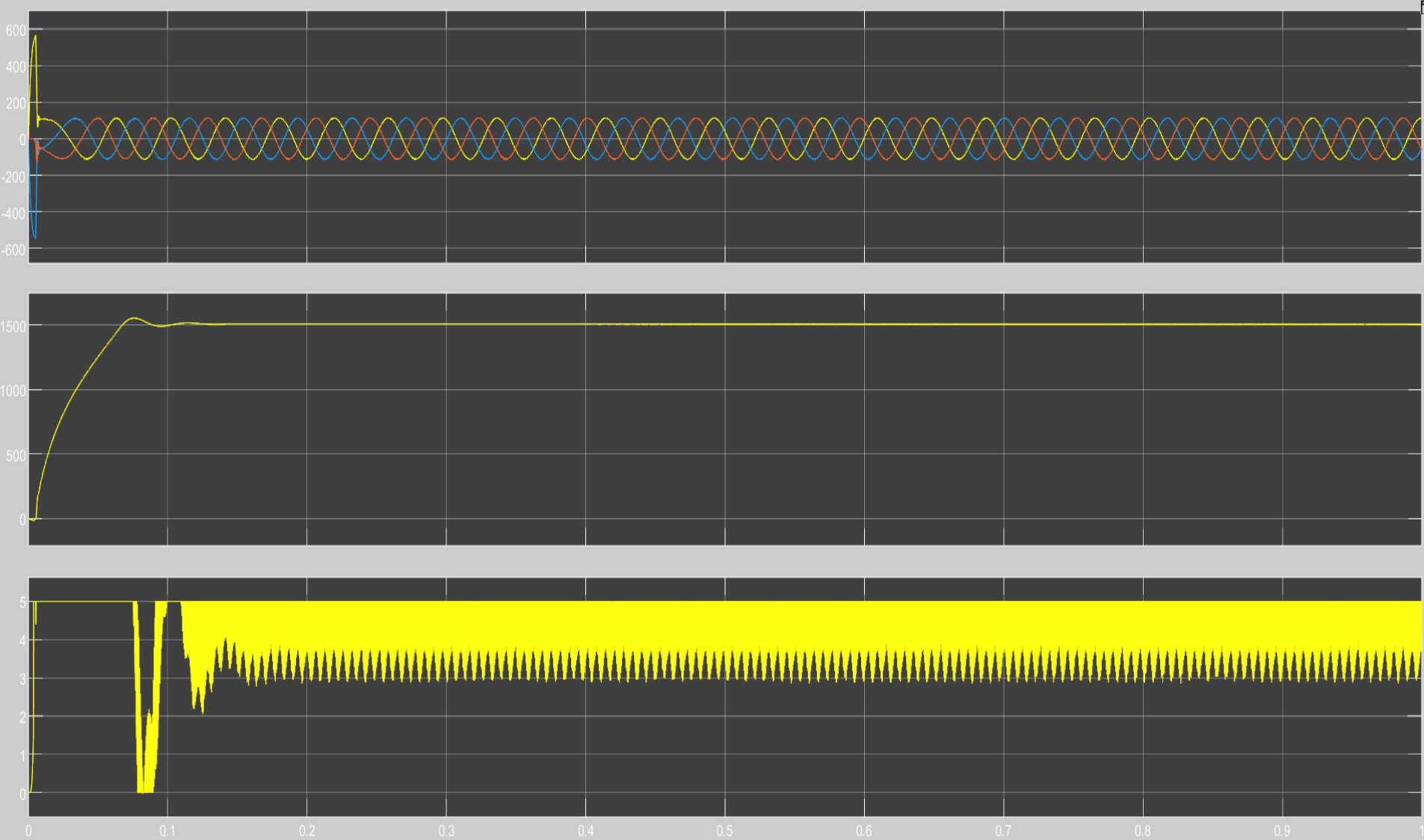




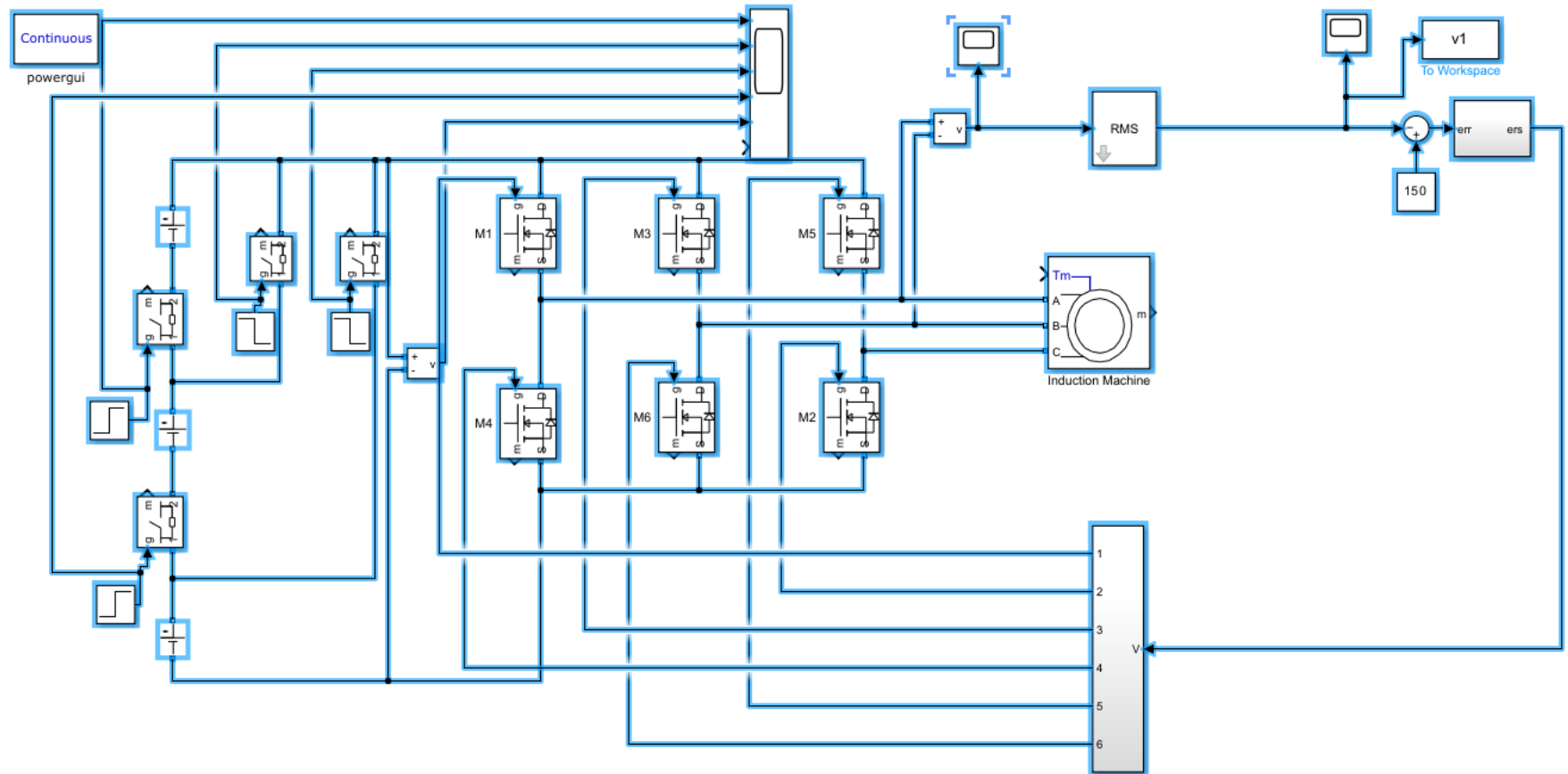
INDUCTION MOTOR DRIVE

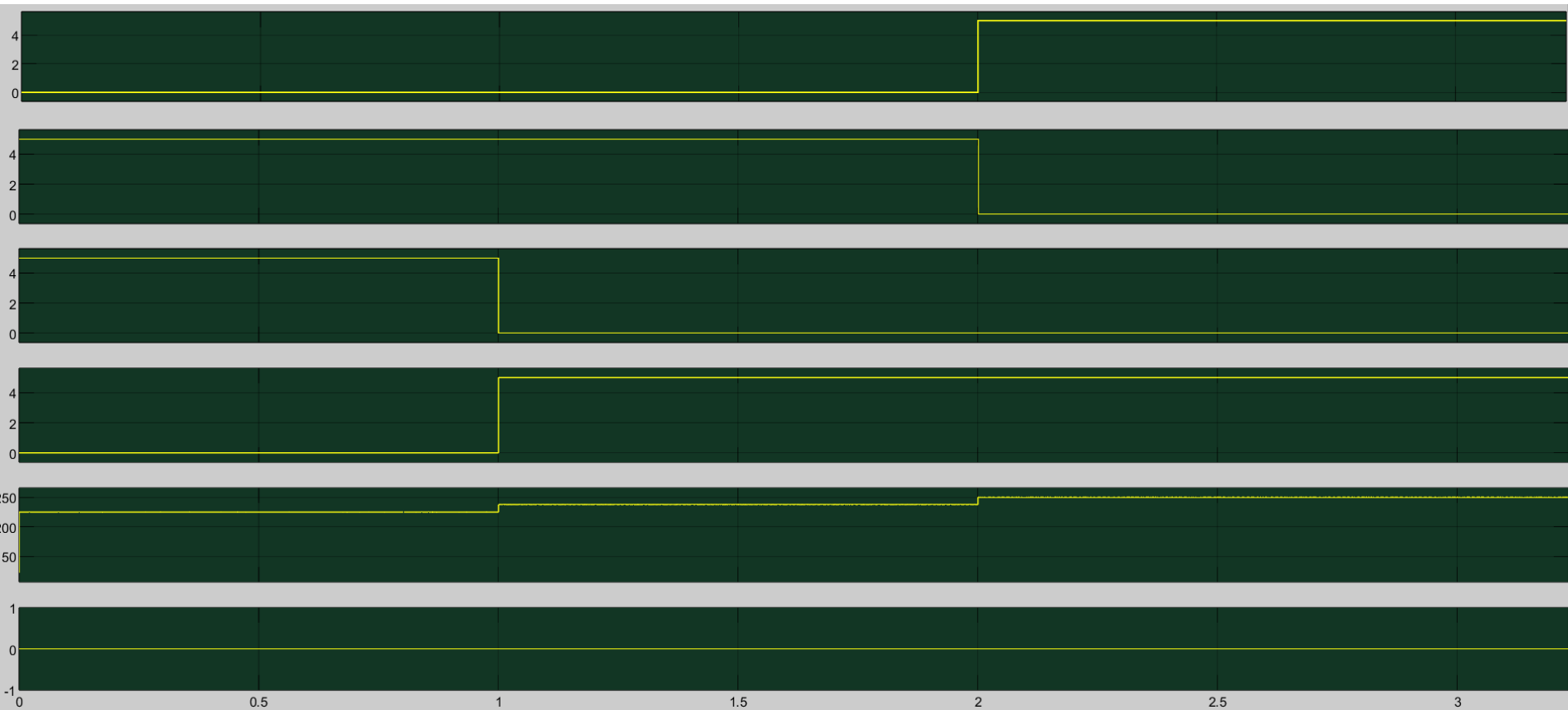


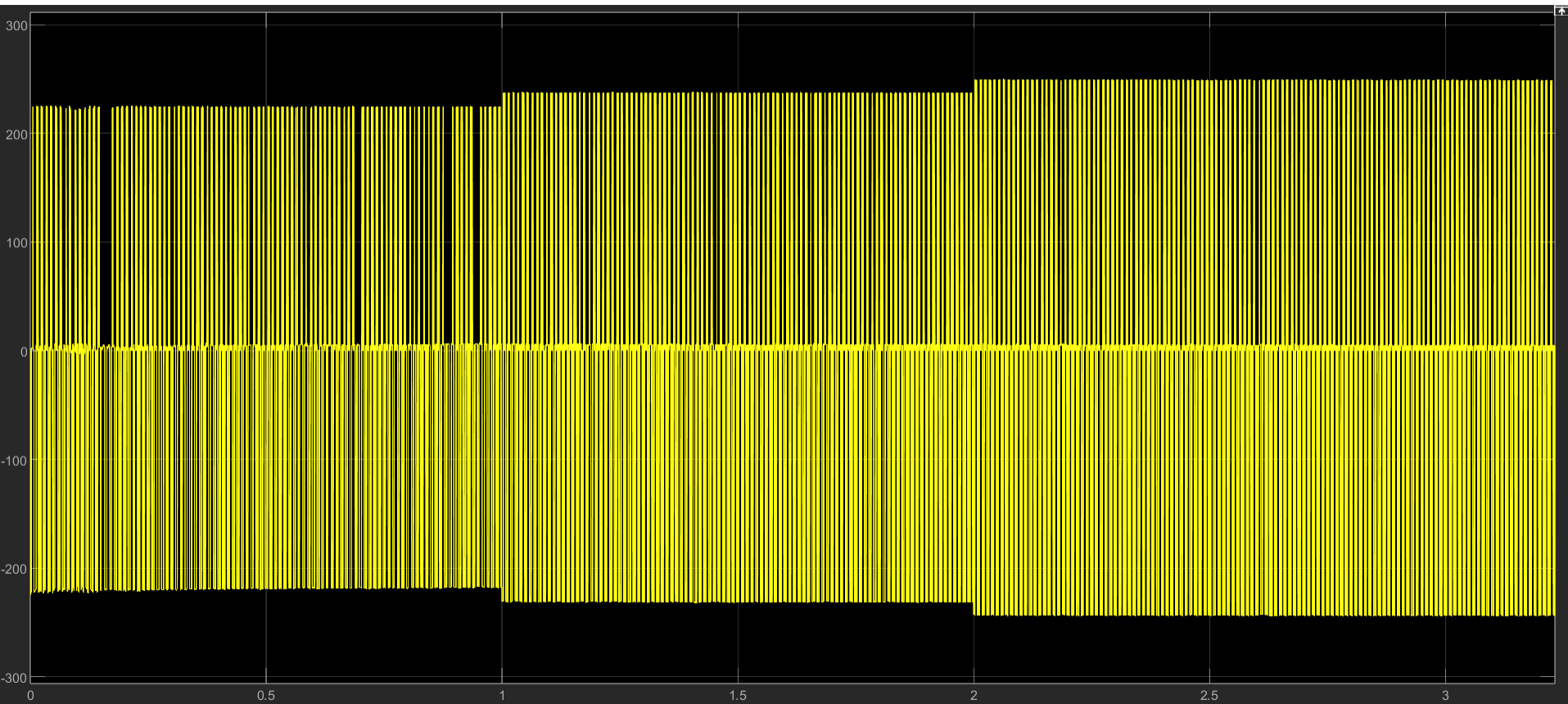


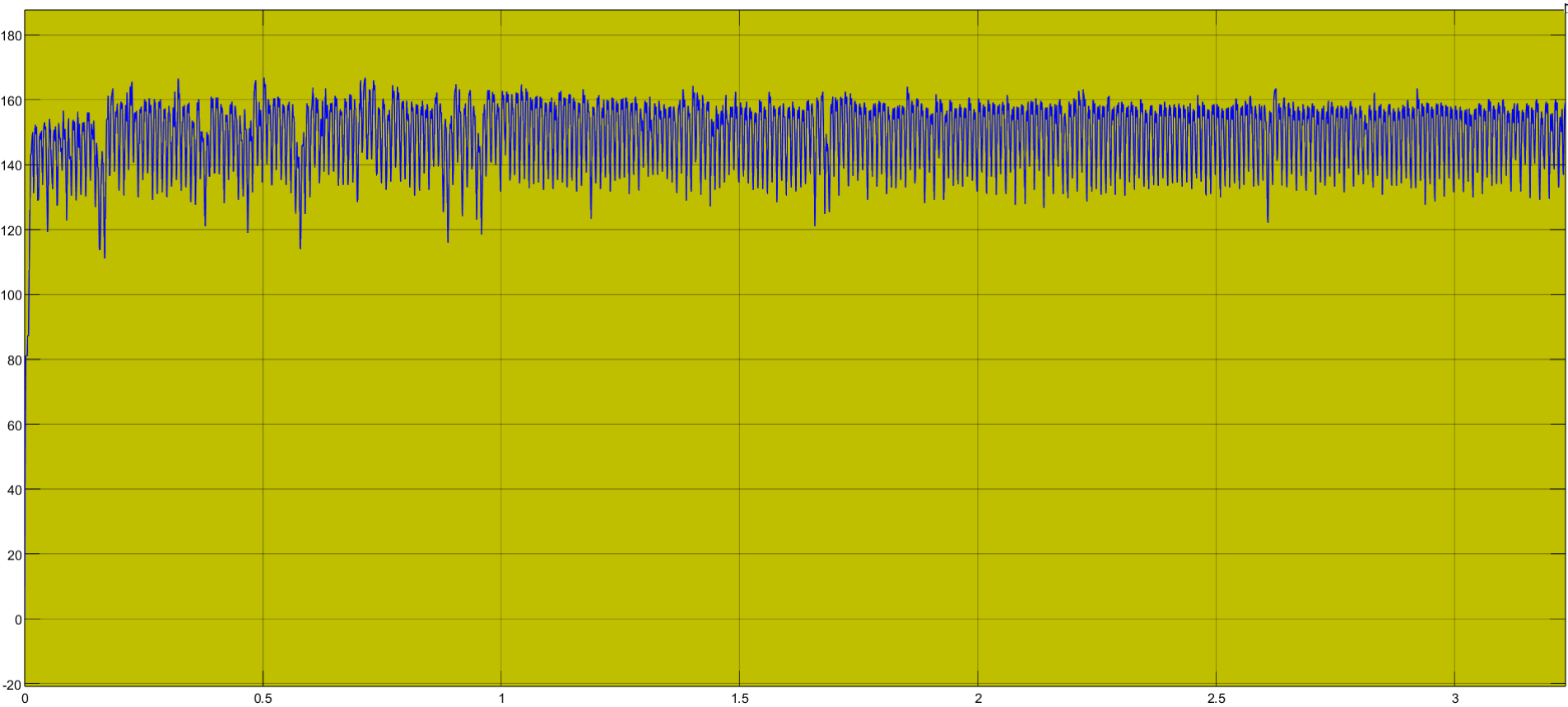


CLOSED LOOP SVM INVERTER











Thank you !