Inter IIT Tech Meet 9.0

BOSCH'S ELECTRIC VEHICLE SIMULATION

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Performance Baselining

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Target Parameters

Vehicle segment chosen:
Passenger Car (PC)

PC

Seats	4
Drive	Rear Wheel
Battery Type	Li-Polymer
Axle Ratio	1 (No differential)
CG Position, long	1260mm from front axle
CG Position, Vertical	546mm from ground
Mass Distribution	48:52 longitudinal

Mass (Curb Weight)	1200kg
Acceleration (0-100kph)	7.4 sec
Top Speed	135 kph
NEDC Range	160 km
Aerodynamic drag coeff	0.3
Area	2.05
Rolling resistance coeff	0.009
Starting gradability	25%
Wheel Radius	0.31

Max Torque @wheel	1531.4 Nm
Motor Max Torque(2)	190 Nm
Transmission Ratio	8.06
Coefficient of Friction	0.8
Max permissible tractive force	5817.02 N
Torque required @Max speed	193.17 Nm
Power Required @Max Speed	23.37 kW
Braking Distance(100kph - 0kph)	68 m

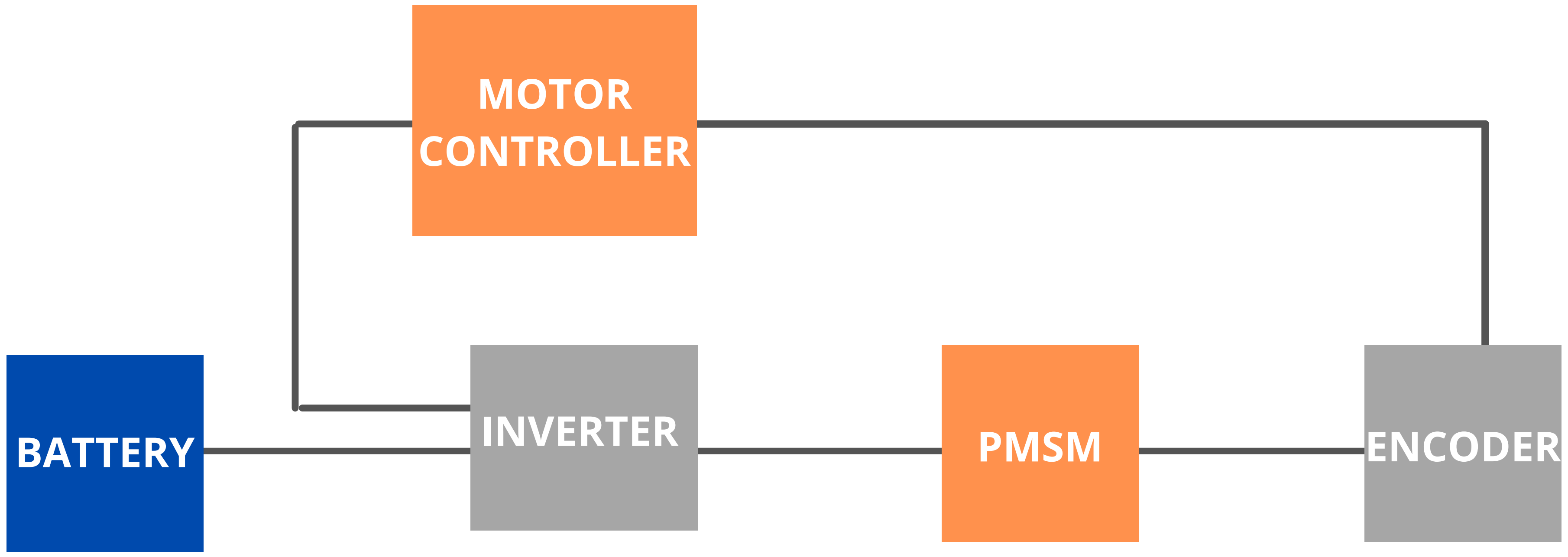
Model and Analysis

06

Target

- Output torque/Power at respective speeds of the motor
- Results of the achieved target performance parameters of the vehicle

Basic schematic



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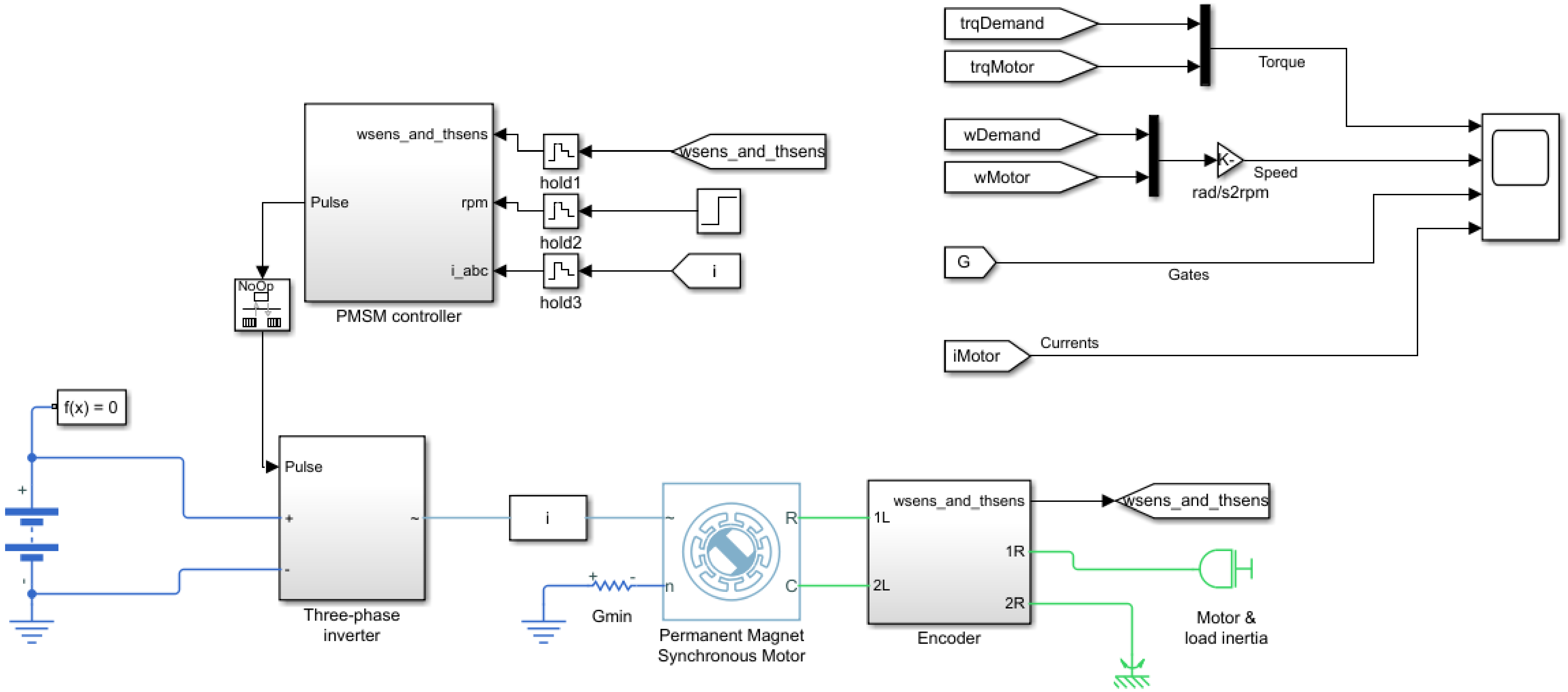
Motor and Motor Controller Model(1/2)



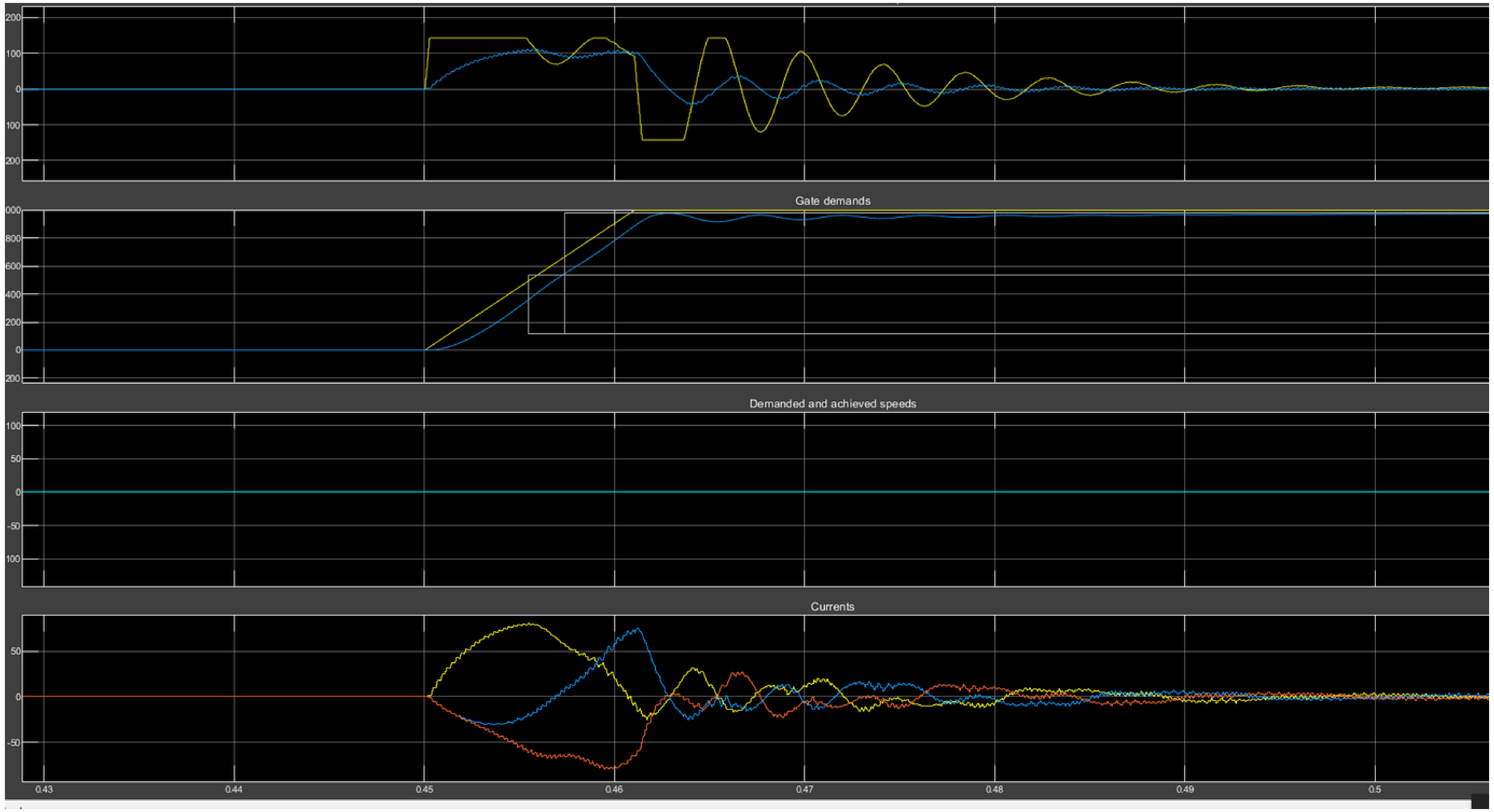
Simulink model [link]

Motor and Motor Controller Model(2/2)

MODEL IN BRIEF

Blocks ,subsystems and Functioning

PMSM Controller
Three Phase inverter
Three Phase current sensor
PMSM
Encoder
Battery
Motor and load inertia
PMSM Field-Oriented Control



Velocity control of a PMSM with step change in reference speed from 0 rpm to 1000rpm .

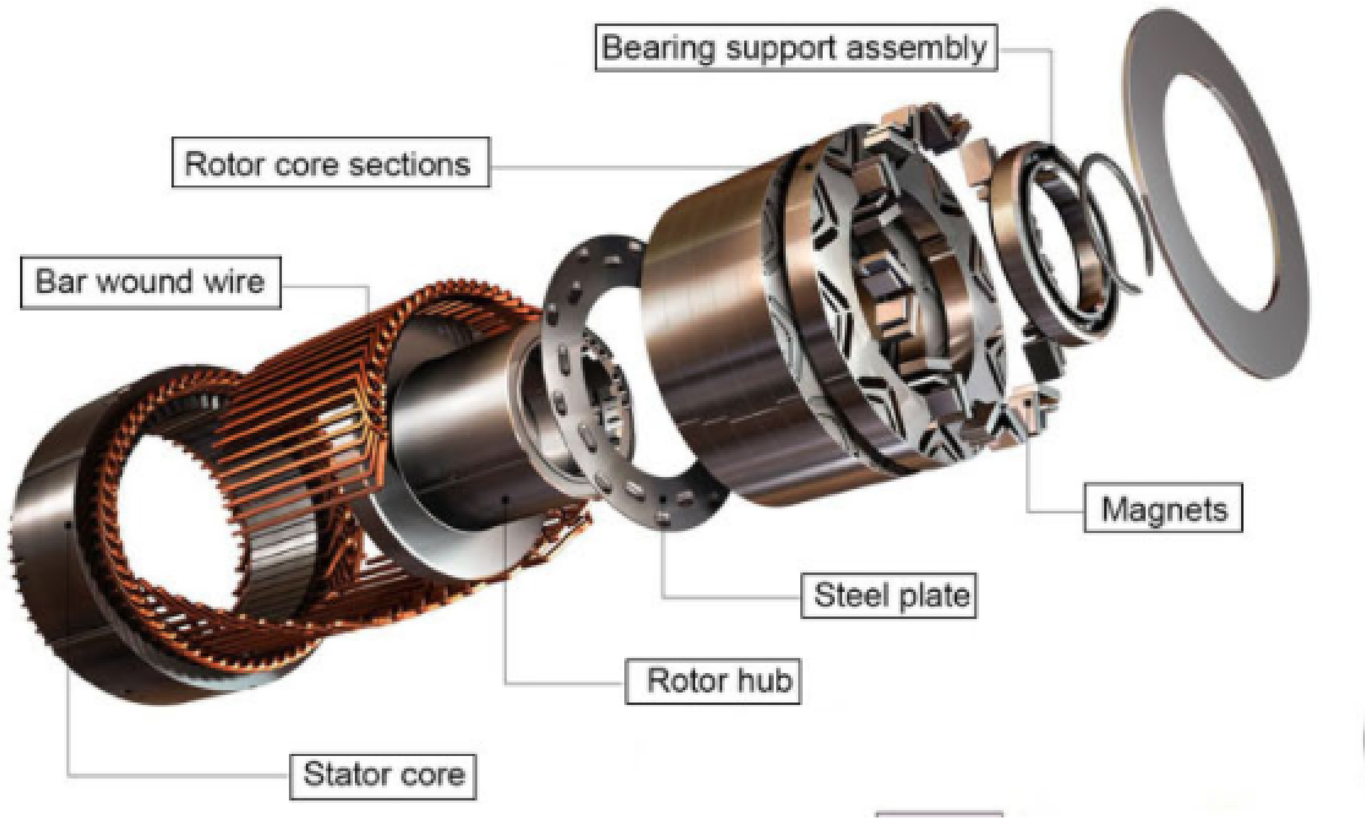
Graph-1: Demanded Torque(yellow) and Actual Torque(blue)
Graph-2: Demanded speed(yellow) and Actual speed(blue)
Graph-3: Six Pulses
Graph-4: Three current signals
Velocity control of a PMSM with step change in reference speed from 0 rpm to 1000rpm .

Results

Electric Drive Dimensioning

Motors

Equations used in motor modeling



$$T_e = T_l + J\, d\omega/dt + B\omega$$

$$V_d = R_s i_d + L_d di_d/dt - N\omega i_q L_q$$

$$V_q = R_s i_q + L_q di_q/dt + N\omega(i_d L_d + \lambda_m)$$

$$T_e = 1.5 N i_q (L_d i_d + \lambda_m) - i_d I_q I_q)$$

Where

Te = Electromagnetic Torque

Tl = Load Torque

J = Intertia of rotor

ω| = Rotor Speed

B = Viscous damping coefficient

Vd = d-axis voltage

Vq = q-axis voltage

Rs = Equivalent resistance of each stator winding

Ld = stator d-axis inductance

Lq = stator q-axis inductance

N = Number of pole pairs

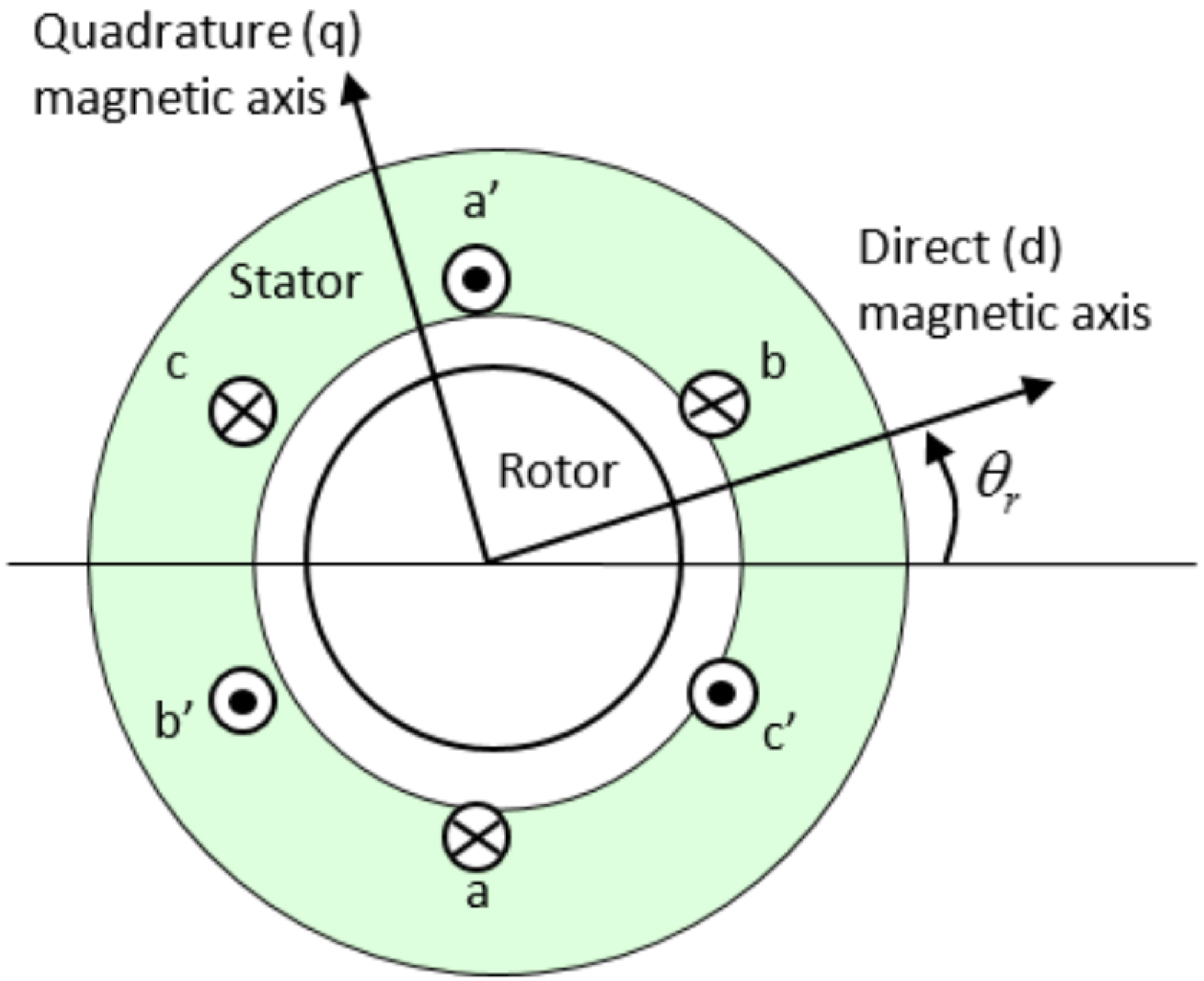
λ_m = Permanent magnet flux linkage

Id = d-axis current

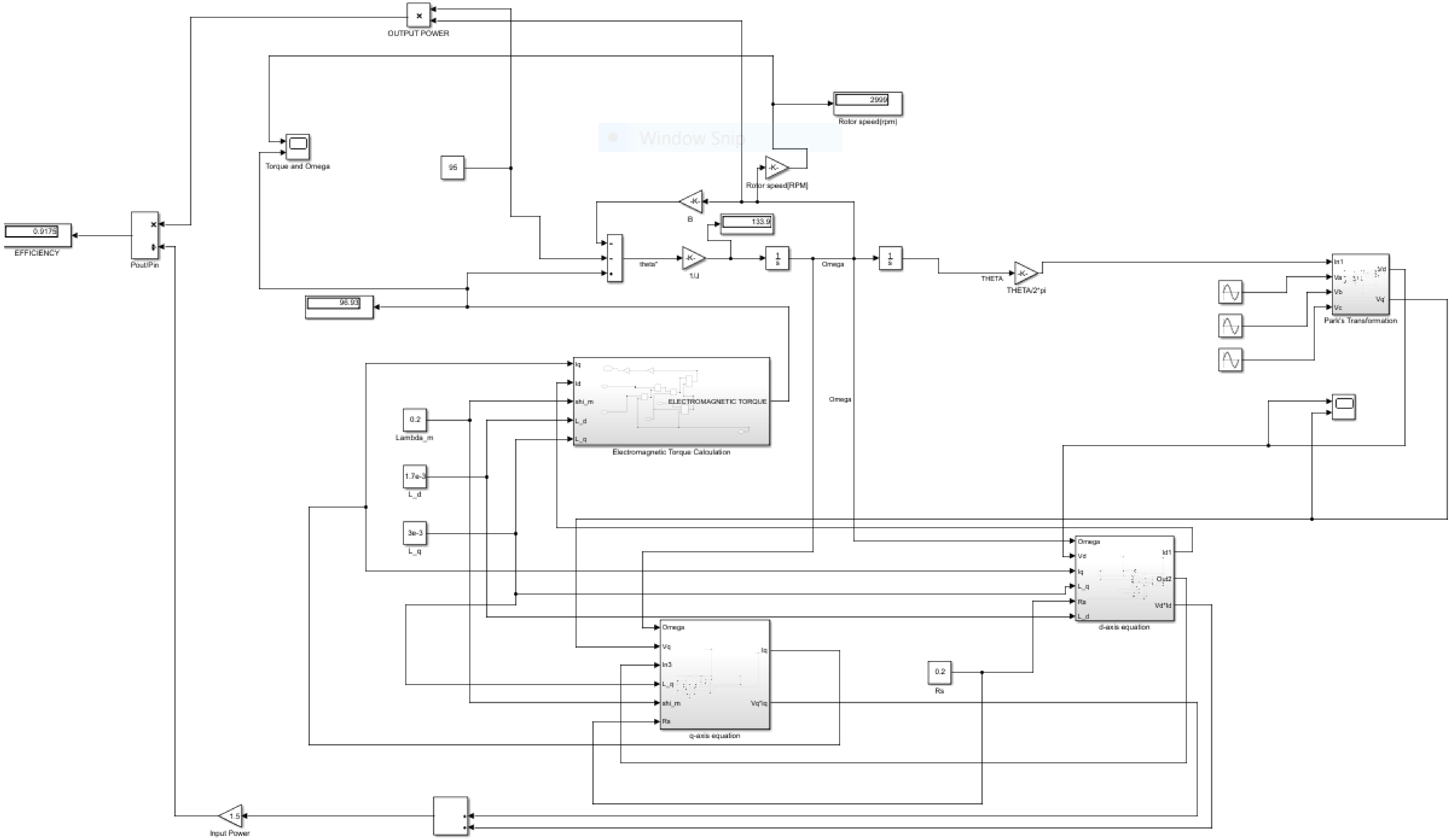
Iq = q-axis current

Technical Data of Motor

Maximal motor torque = 95Nm
Continuous motor torque = 45Nm
Maximal rotation speed = 3000rpm
Peak Motor power = 32Kw
Continuous motor power = 18Kw
Motor efficiency = 85-94%
Wire connection: star



Motor Simulink Model



Simulink model [link]()

Motor Parameters

Stator d-axis inductance(Ld) = 1.7mh

Stator q-axis inductance(Lq)=3mh

Resistance of each stator winding(Rs)=0.15ohm

Inertia of Rotor(J)= 0.01kgm^2

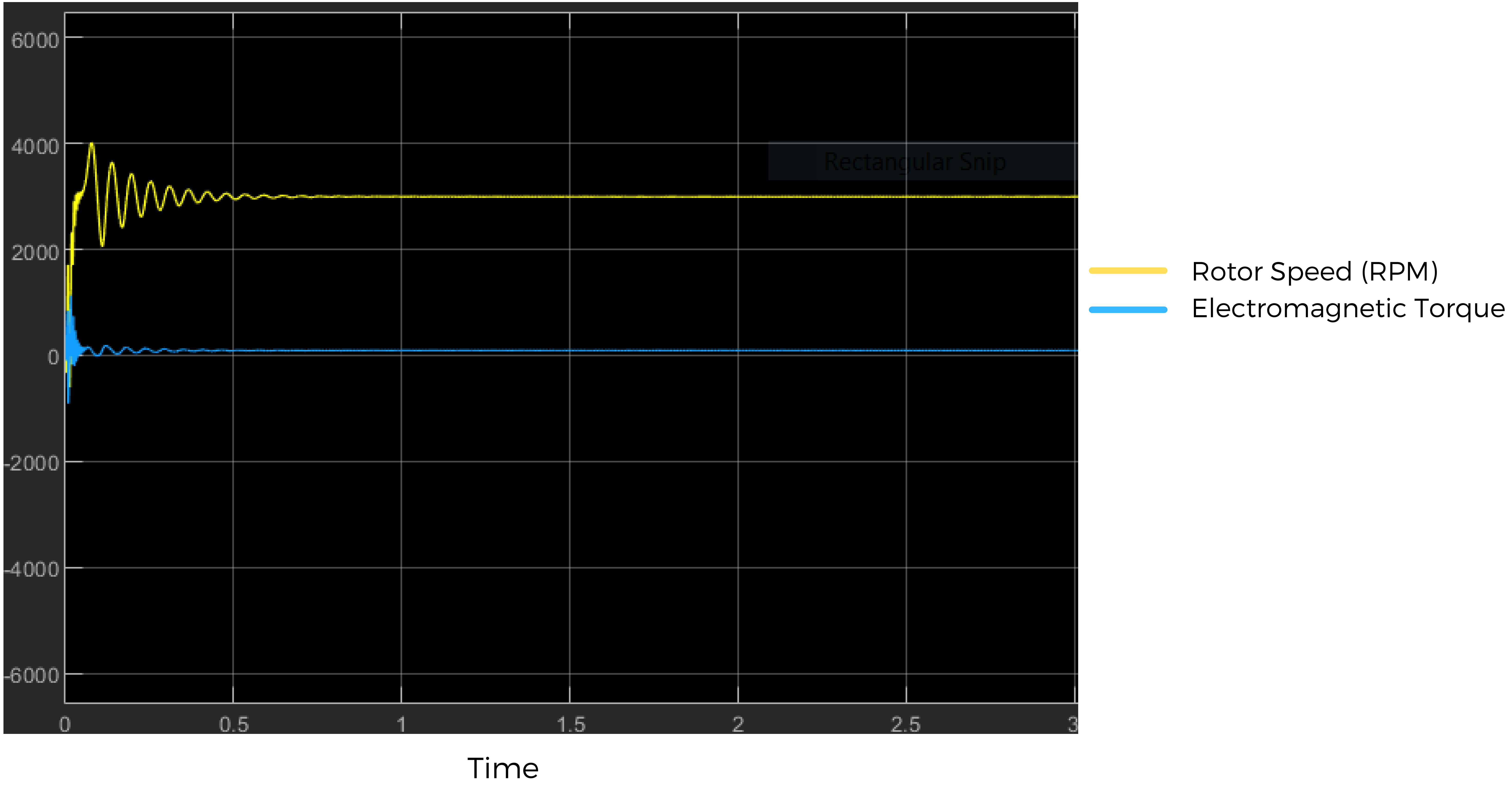
Viscous damping coefficient(B)=0.001889Nms

Flux linkage = 0.2205weber

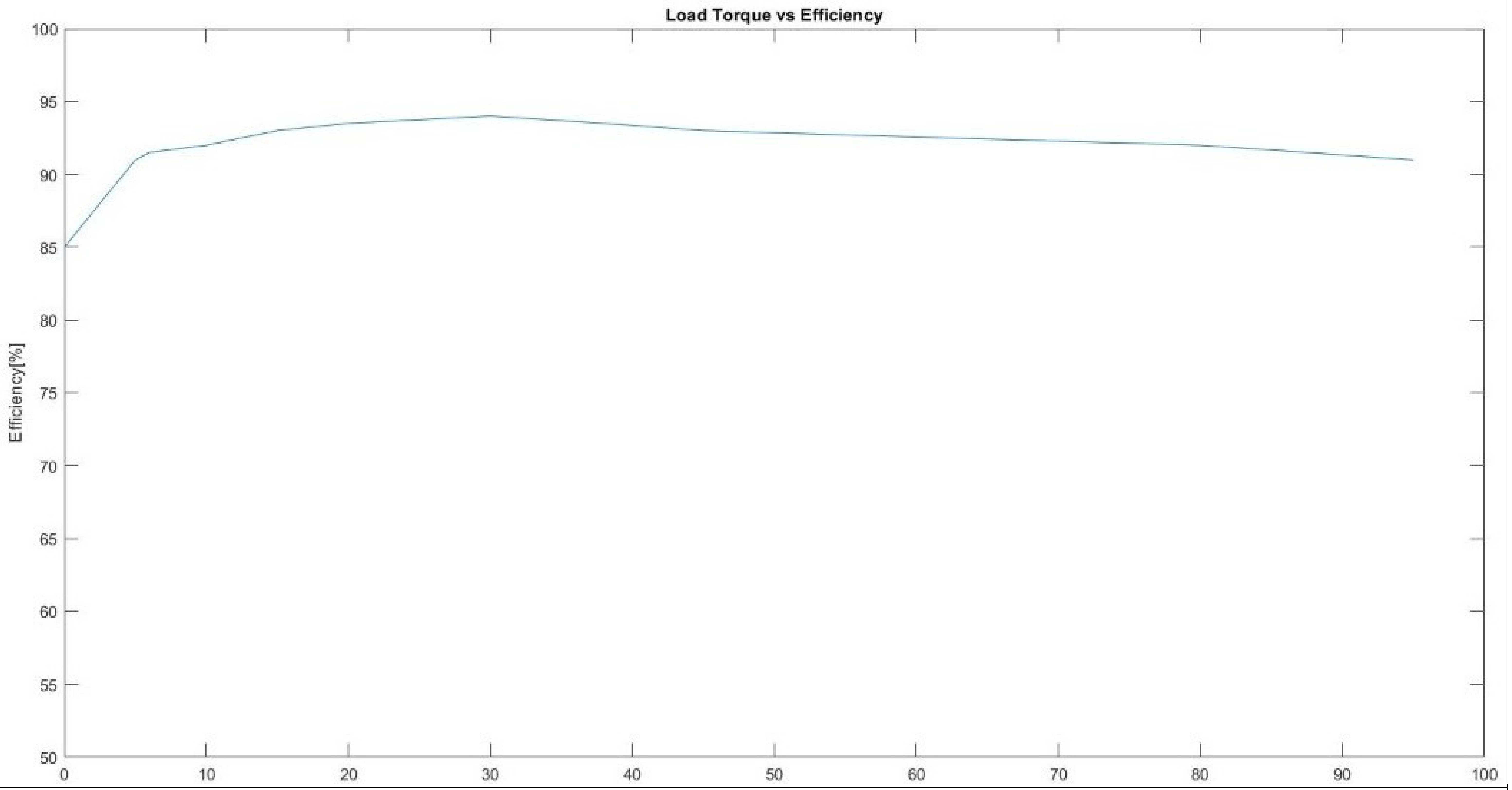
Number of pole pairs(N) = 4

Rotor type: Round

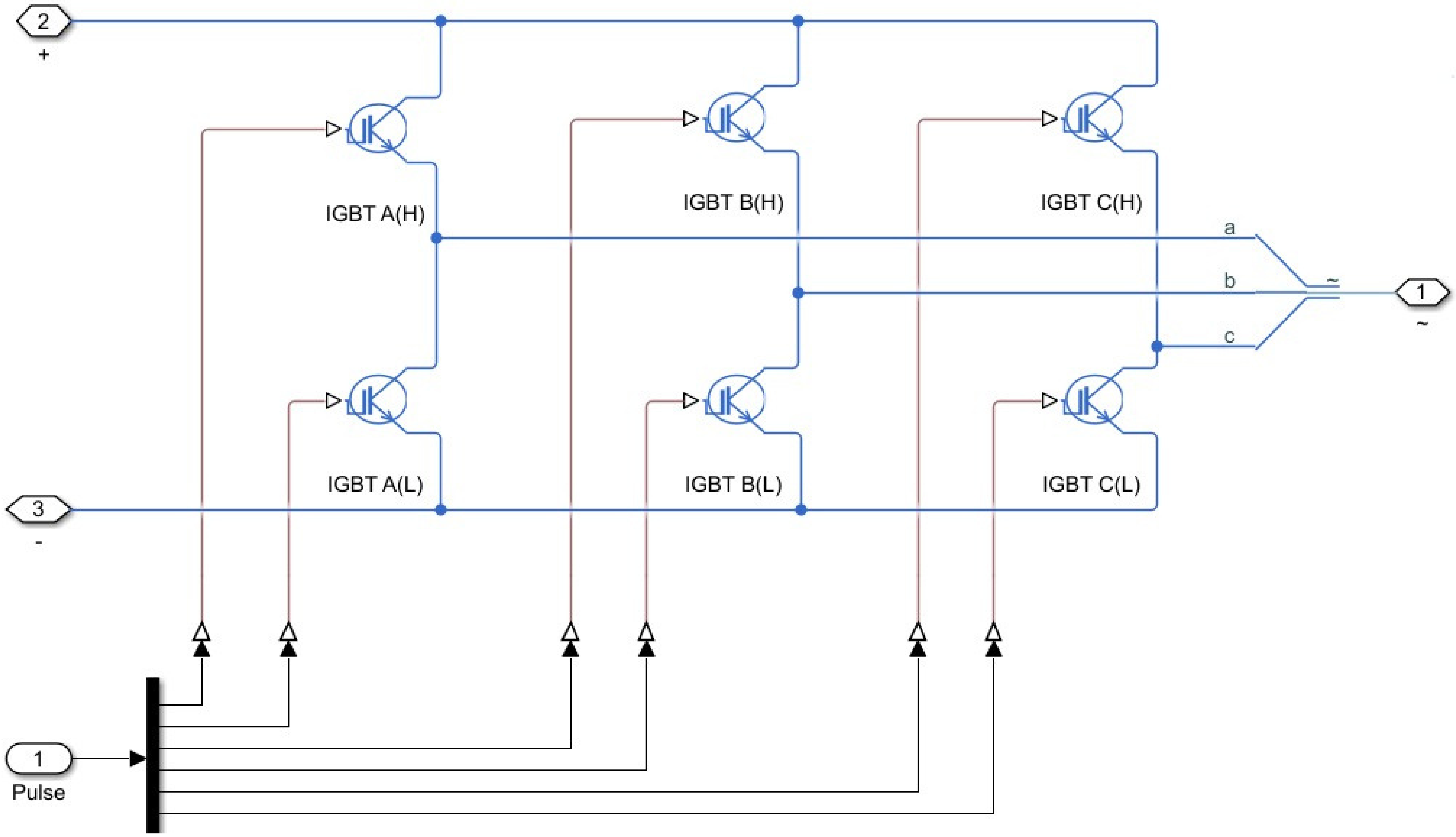
Electromagnetic Torque and Rotor speed at constant Load Torque vs Time



Efficiency Vs Load Torque



Inverter Simulink Model



Simulink model link

Inverter

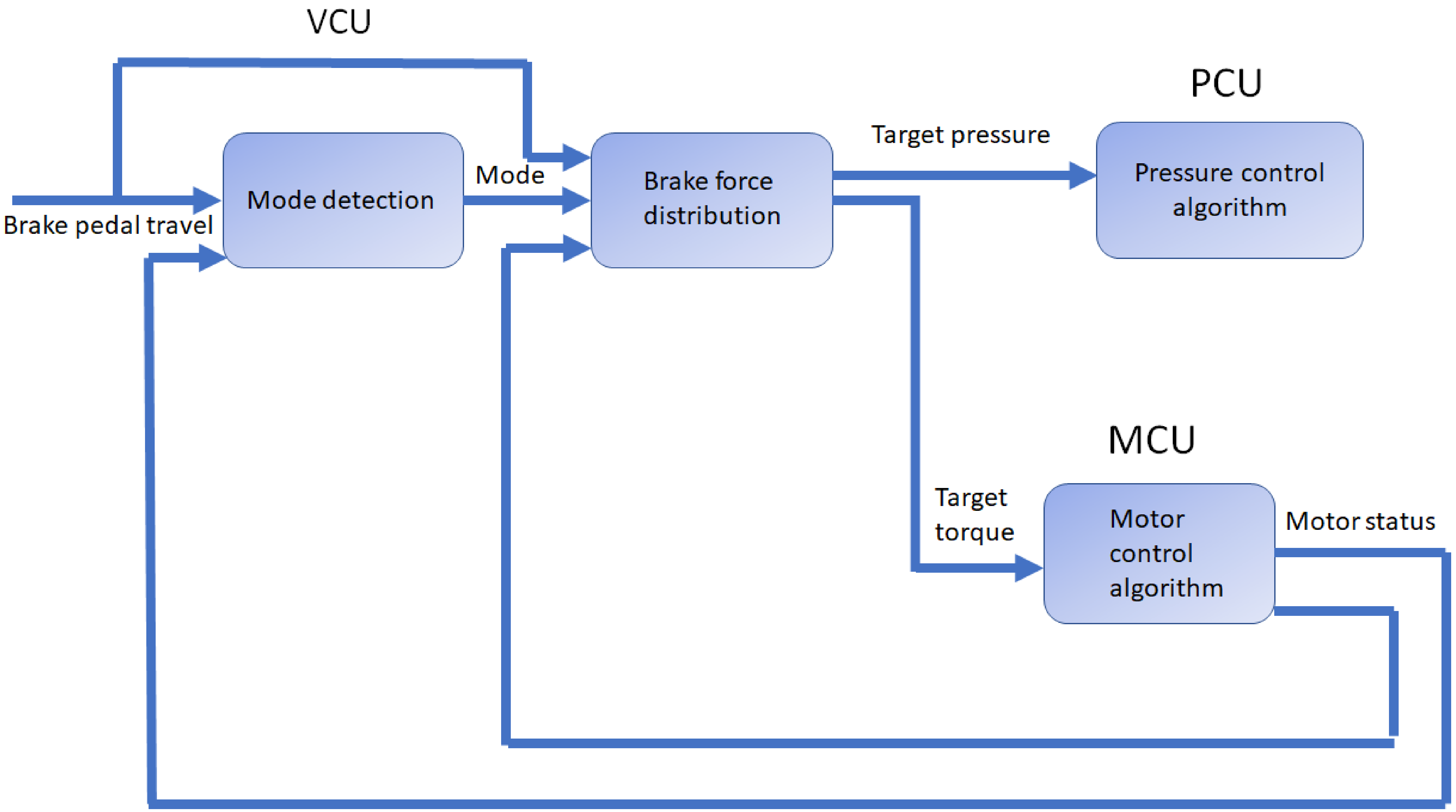
A three-phase inverter converts a DC input into a three-phase AC output. Its output delayed by an angle of 120° so as to generate a three-phase AC supply.

Specifications:

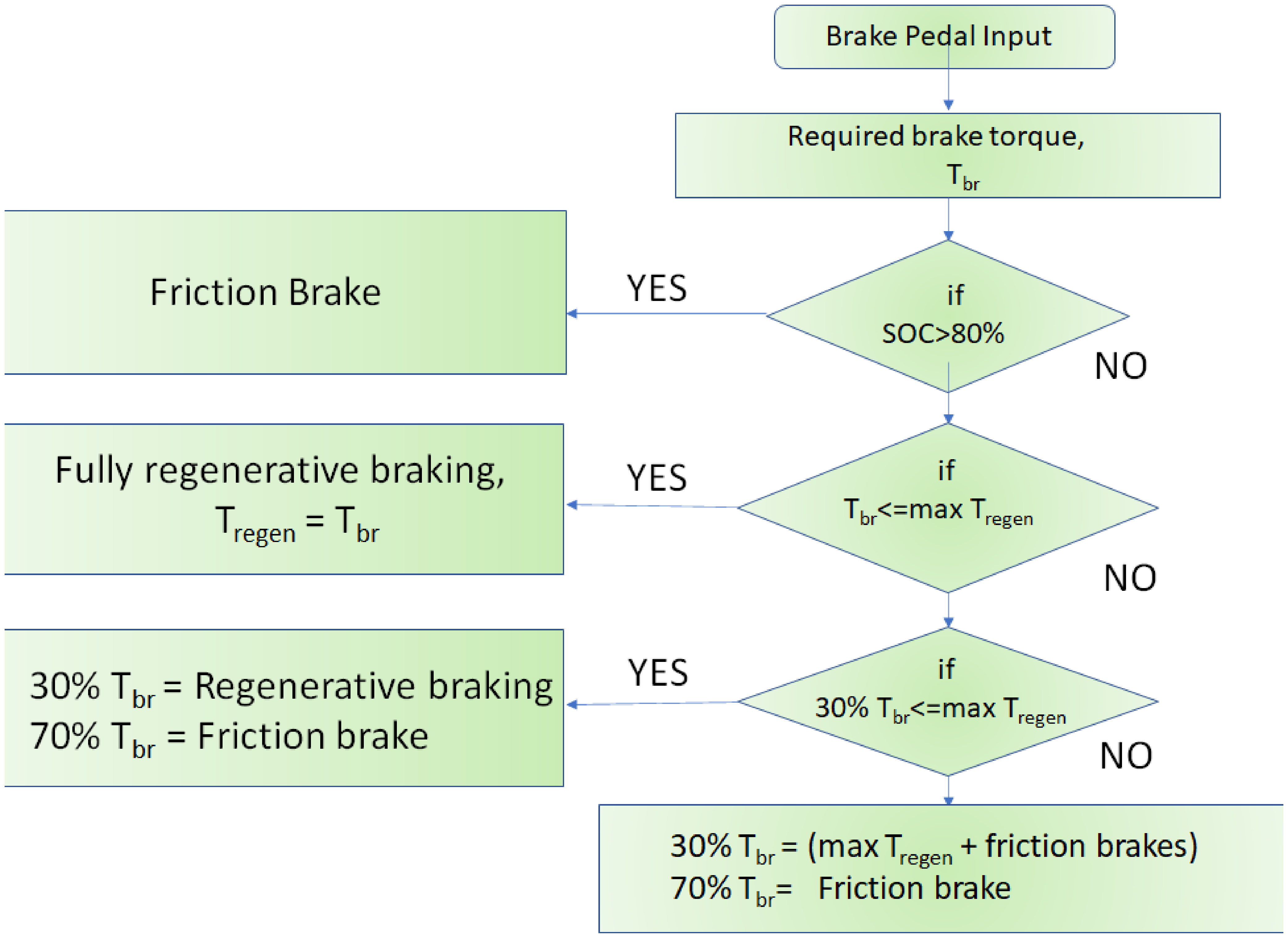
- Input Voltage: 333VDC
- Frequency: 50HZ
- Efficiency: >92%
- Power Factor: 0.85-1.00
- Using IGBT Diode to ensure fast switching speed
- Ambient Temperature -15 to 55 °C

Battery Dimensioning and Optimization

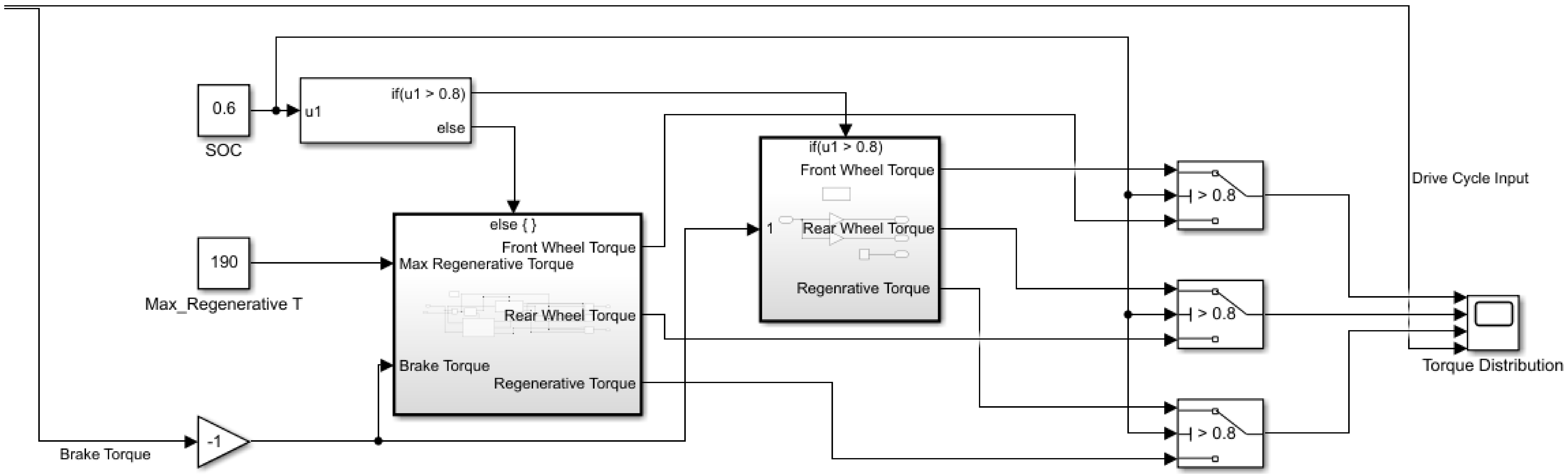
Regenerative Braking



Brake Torque Distribution Strategy

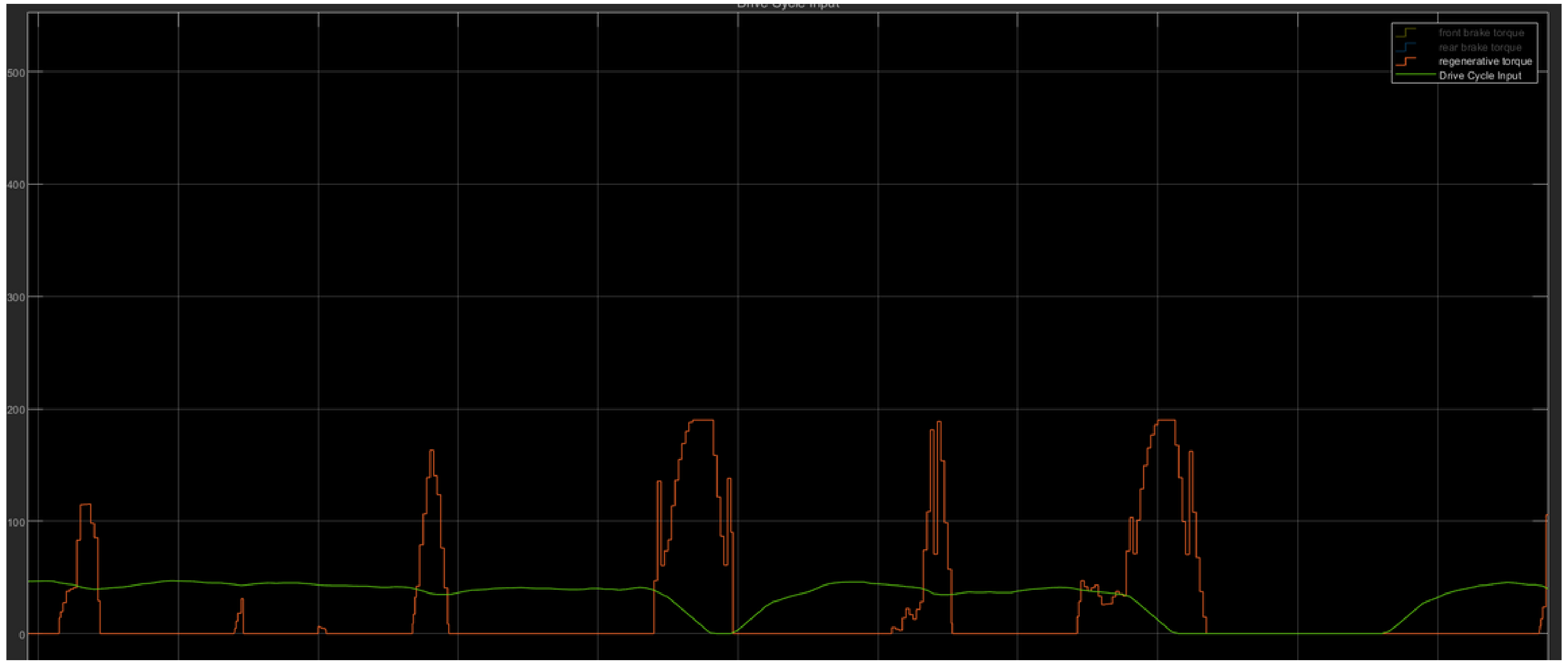


Regenerative Braking

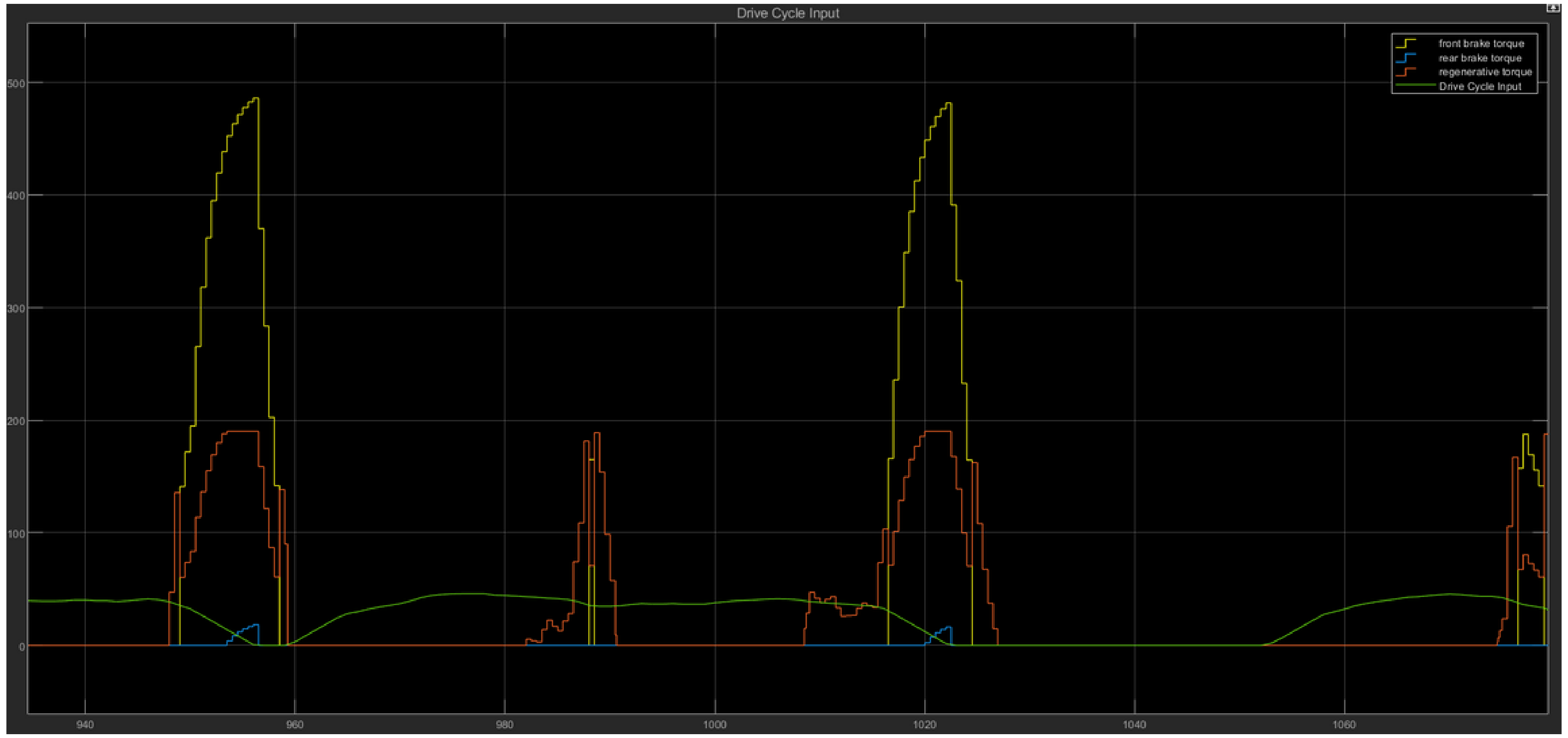


Simulink Model Link

Braking Torque vs Time as well as drive cycle

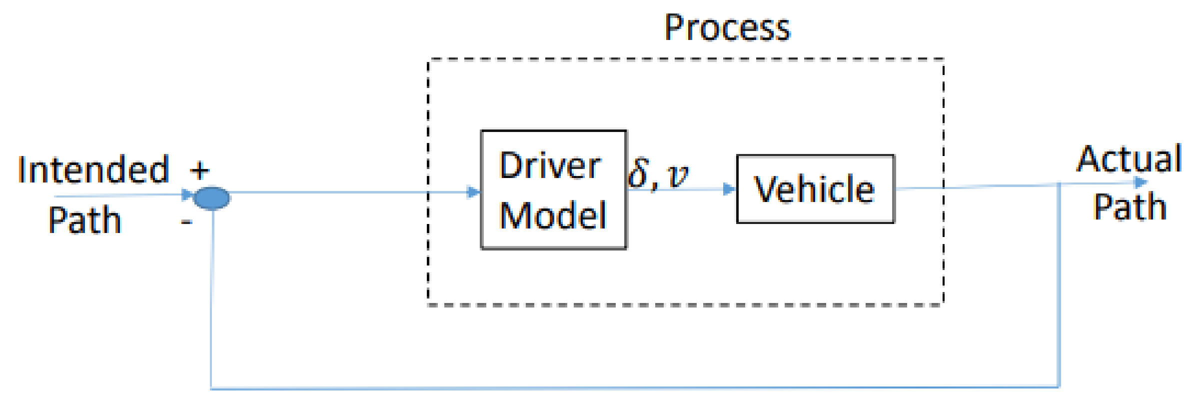


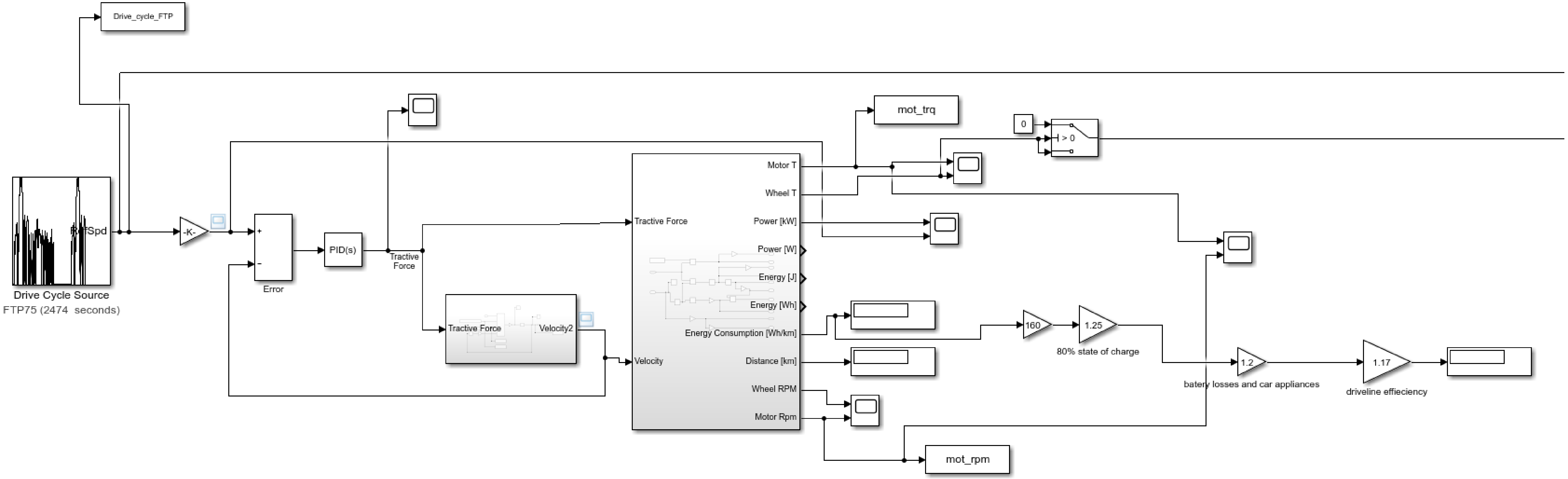
The first figure shows the regenerative torque



The second figure shows the front and rear wheel torques as well

Simulink Model





Simulink model [link]

Battery Sizing

The function of the high voltage (HV) battery in an electric car is as an electrical energy storage system in the form of direct-current electricity (DC). On getting a signal from the controller, the battery will stream DC electrical energy to the inverter, converting it into a 3 phase AC wave that is to be used to drive the motor.
We have used a Lithium-Polymer (Li-Po) rechargeable battery as a reference for calculating different parameters.

Specifications:

- Voltage: 333 V
- Nominal voltage: 3.7 V
- Peak power: 35 KW
- Battery Size: 32 KWh
- Peak current: 105 A
- Cell capacity: 10.5 Ah
- Battery capacity: 96 Ah
- Max Continuous Discharge Current: 157.5A
- Total cells: 900
- Cells in series: 90
- Cells in parallel: 10

Electrical Architecture

Subsystem Overview

Tractive System

- Battery Pack
- Inverter
- Motors
- Motor Controller
- Measurement Points
- DC-DC Converter
- Charging System
- Overcurrent Protection

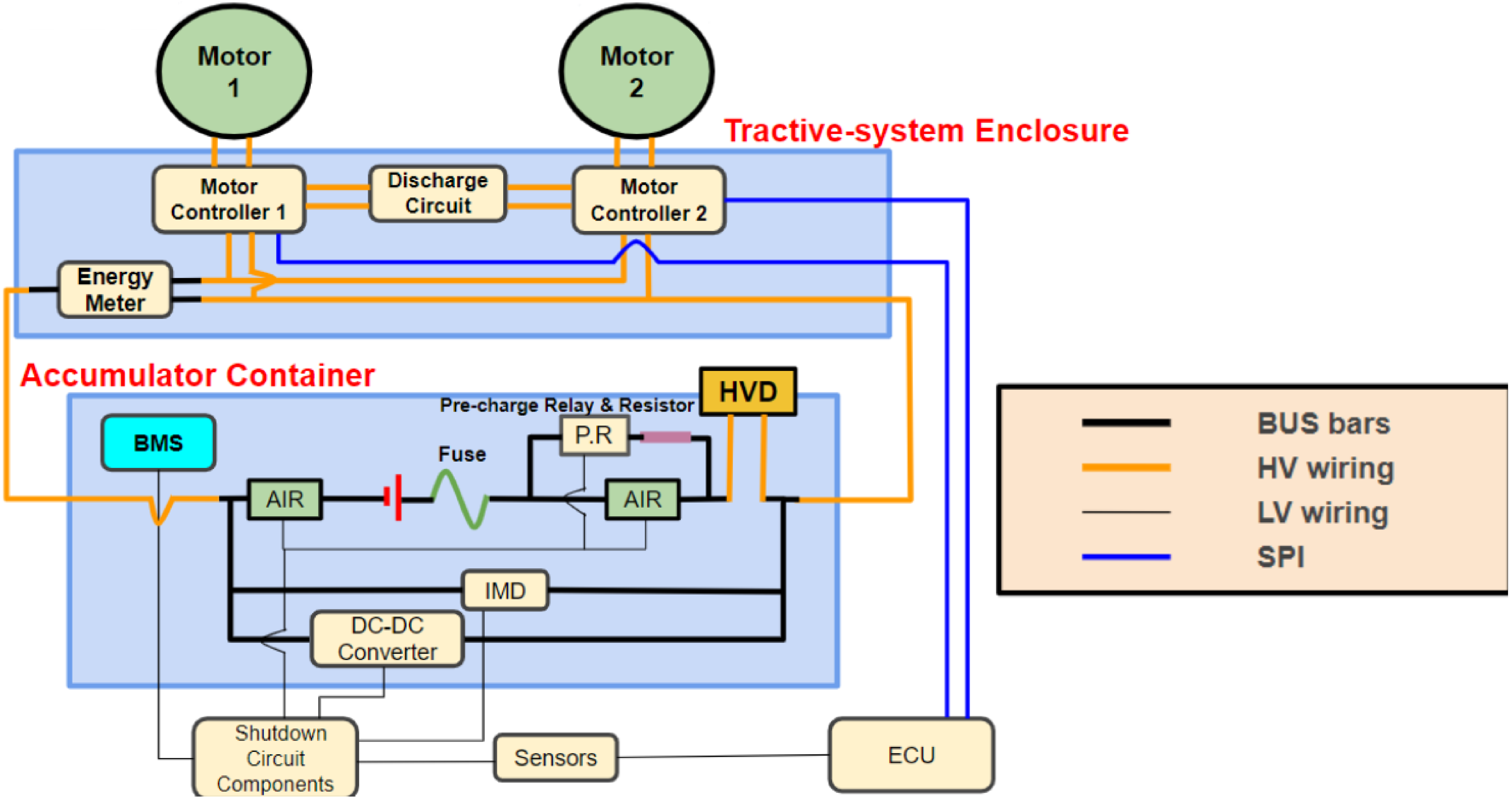
Low Voltage System

- BSPD
- Vehicle Control Units
- Torque Encoder
- Buck COnverter
- BMS
- IMD
- IMD/BMS Latch
- TSAL
- Pre-charge circuit
- Discharge circuit
- Shutdown system interlocks
- Sensors

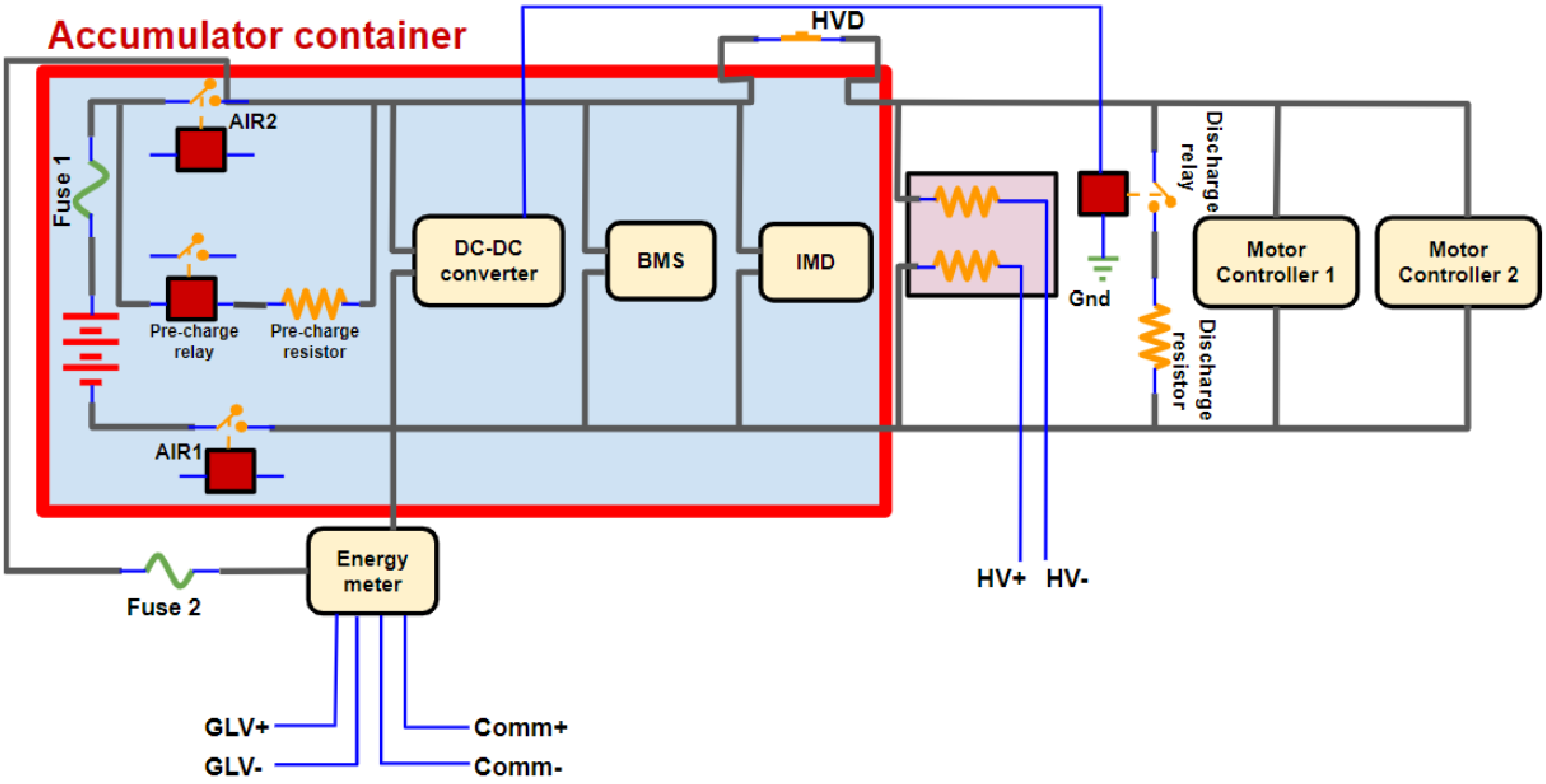
Non-Electrical System

- Intertia Switch
- Shutdown Button
- Overall grounding and insulation

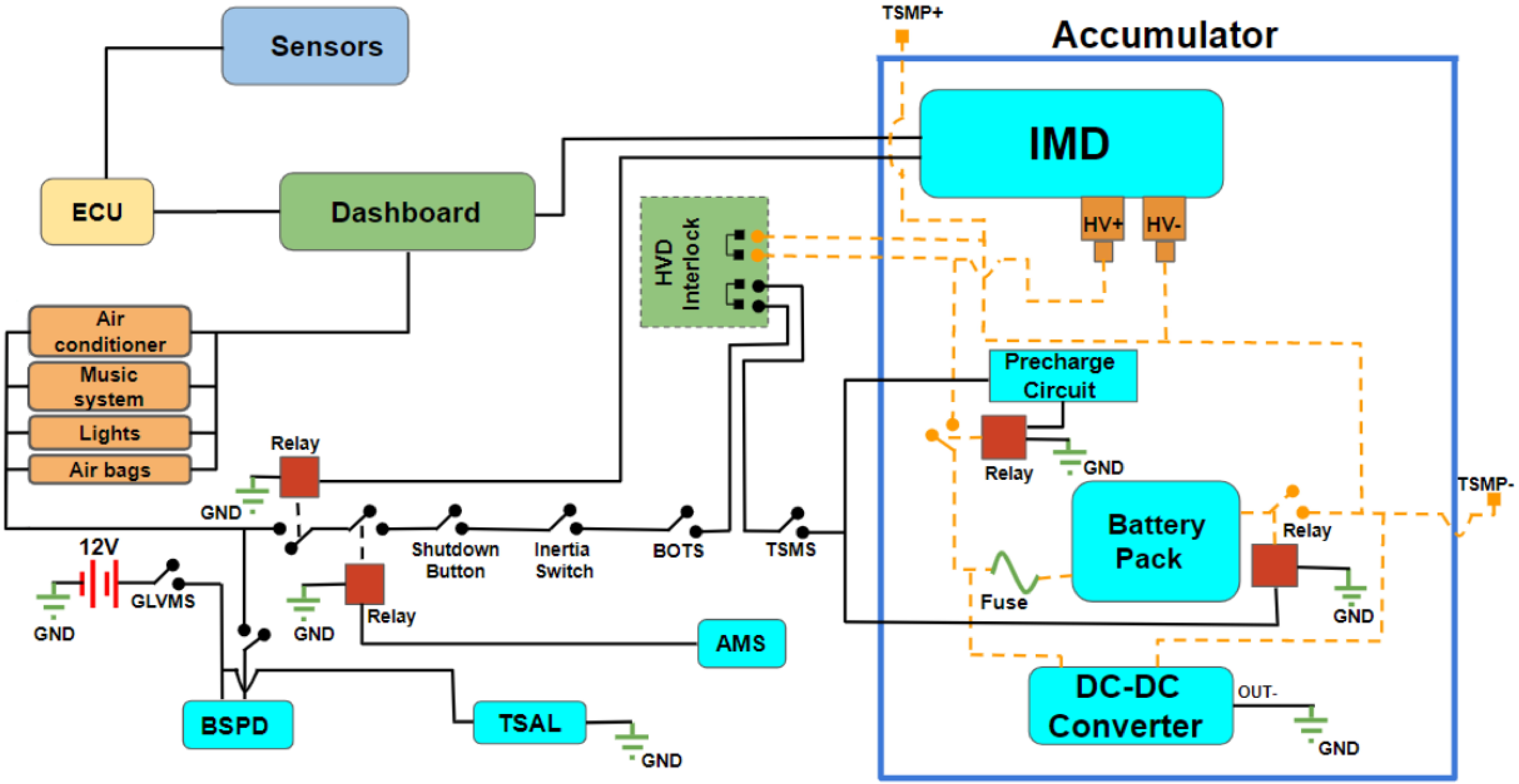
Block Level Representation of Systems



HV Wiring


Accumulator container
HVD
AIR2
Fuse 1
Pre-charge relay
Pre-charge resistor
DC-DC converter
BMS
IMD
AIR1
Gnd
Discharge relay
Discharge resistor
Motor Controller 1
Motor Controller 2
HV+
HV-
Energy meter
Fuse 2
GLV+
GLV-
Comm+
Comm-

LV Wiring



Sensors
ECU
Dashboard
Air conditioner
Music system
Lights
Air bags
Relay
GND
12V
GLVMS
GND
Relay
GND
Shutdown Button
Inertia Switch
BOTS
TSMS
HVD Interlock
AMS
BSPD
TSAL
GND
TSMP+
Accumulator
IMD
HV+
HV-
Precharge Circuit
Relay
GND
Battery Pack
Relay
GND
TSMP-
Fuse
DC-DC Converter
OUT-
GND

AUXILIARY FEATURES

Now a days, luxurious features are a very common thing in any passenger car. We are also installing some of those auxiliary features in our design.

- Air-conditioner
- Music system with USB/AUX/Radio/Bluetooth
- Lights
- Airbags

Key Components

TRACTION BATTERY PACK

- Type: Rechargeable Lithium Polymer(Li-Po) battery
- Voltage: 333 V
- Nominal voltage: 3.7 V
- Peak current: 105 A
- Peak power: 35 KW
- Battery Size: 32 KWh
- Battery capacity: 96 Ah

INVERTER

It converts the DC current from battery pack into 3-phase AC current, for driving the electrical motor.

- Input Voltage: 333 VDC
- Frequency: 50 Hz
- Power factor: 0.85-1.00
- Efficiency: >92%
- Fan-cooling methodology

MOTOR

- 3-phase PMSM
- Dual motor configuration [rear-wheel drive]
- Max input voltage: 320V
- maximum power of each motor is limited using the controller at peak power of 35 KW
- Cooling methodology: enclosed in a casing which also serves the purpose of cooling jackets

Key Components

GLV BTTERY

It is the usual 12V battery, which is used to provide electricity to power the vehicle accessories (lightings, multimedia, etc).

DC DC CONVERTER

It converts the high voltage DC power from the battery into low-voltage(12V).

BUCK CONVERTER

- It steps down the 12V DC power from the GLV battery to 5V, which powers all the sensors and ECU.
- Input voltage: 12V
- Nominal output voltage: 5V

Charging System

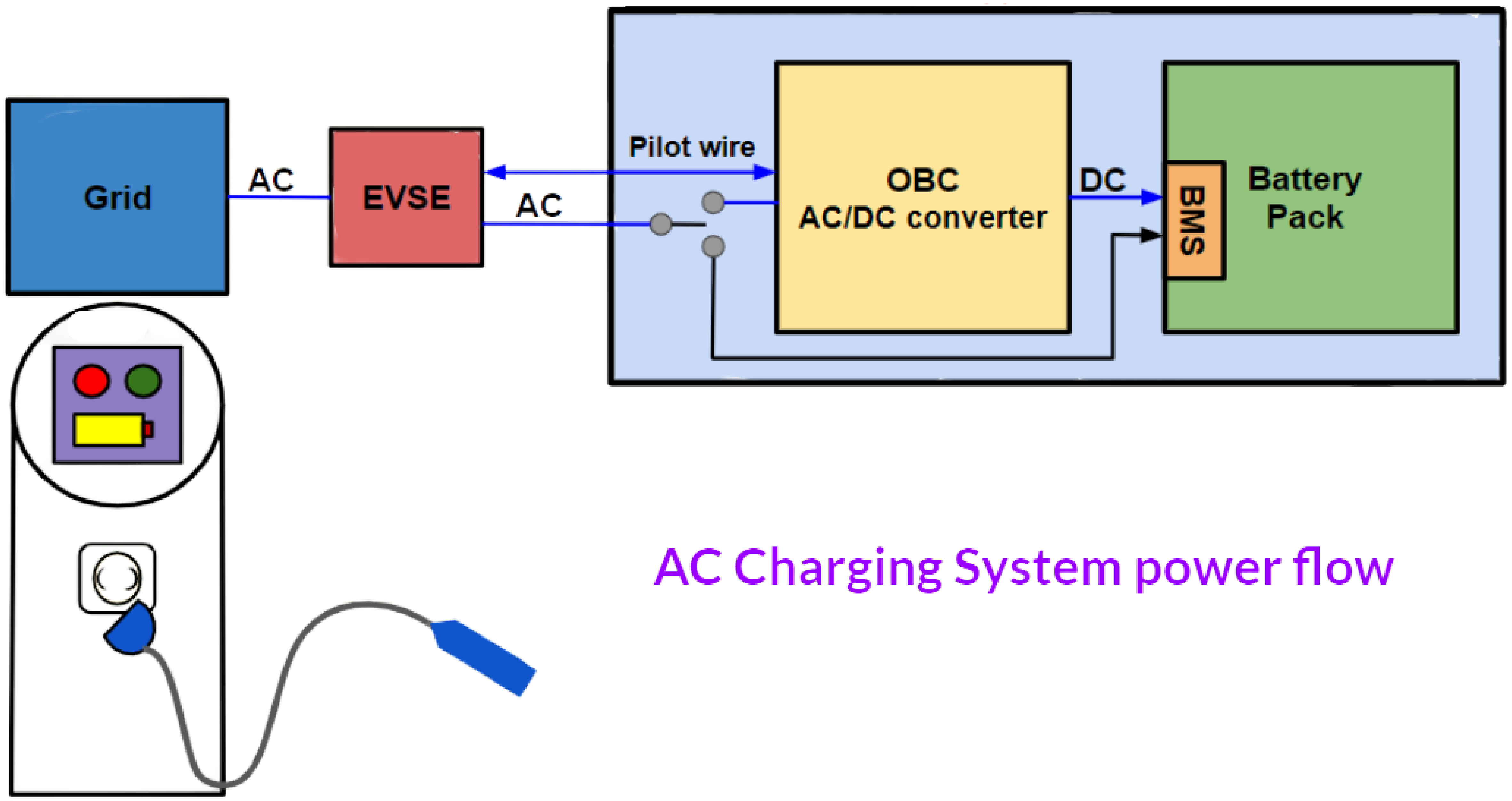
Charger

We are using an onboard charger(OBC). It gets AC electricity from outside sources and stores this energy in the battery by converting it into DC electricity.

Charge-port

It enables the connection of the vehicle to an external power supply.

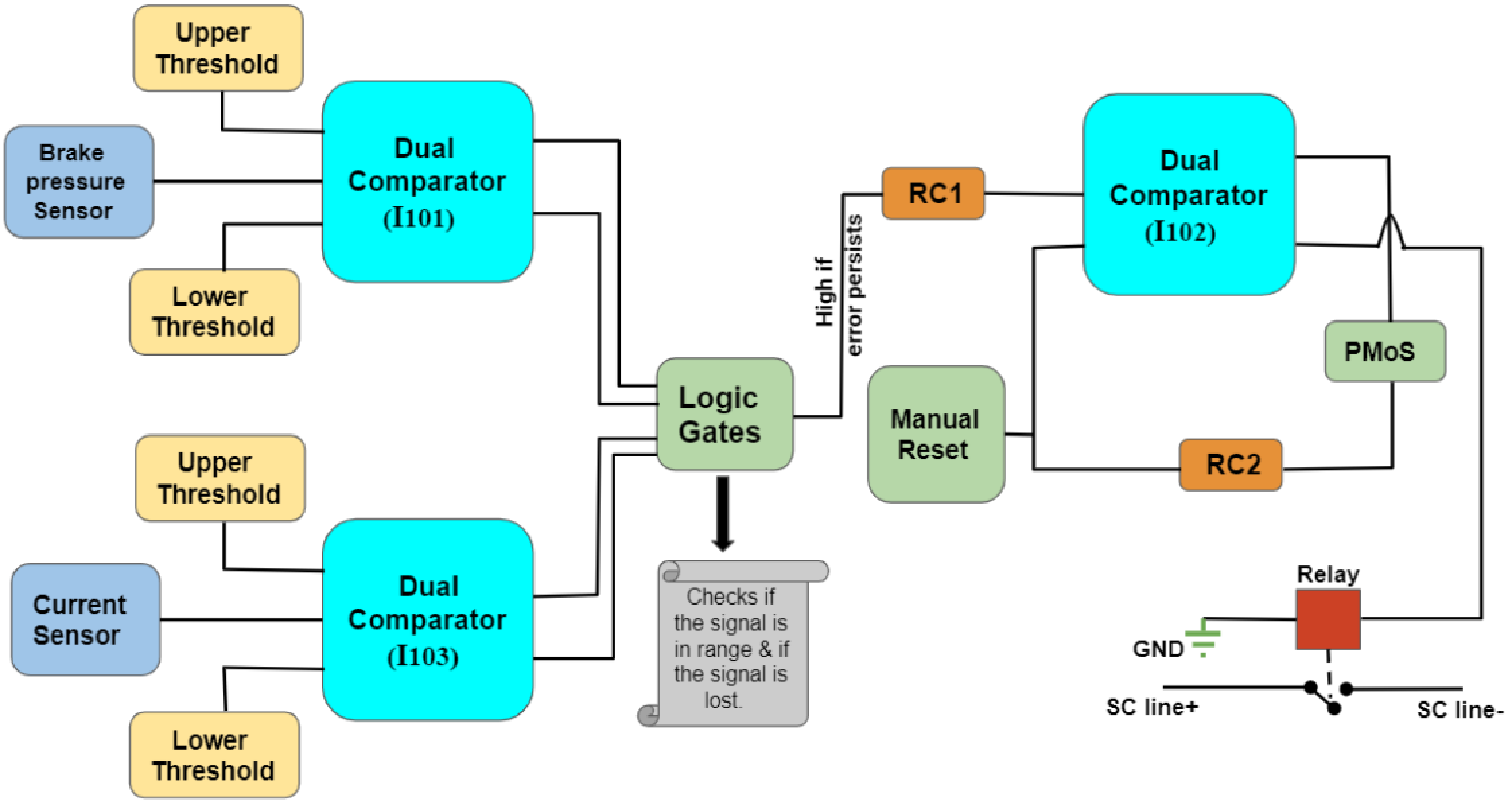
Level 1 and 2 Charging Station



AC Charging System power flow

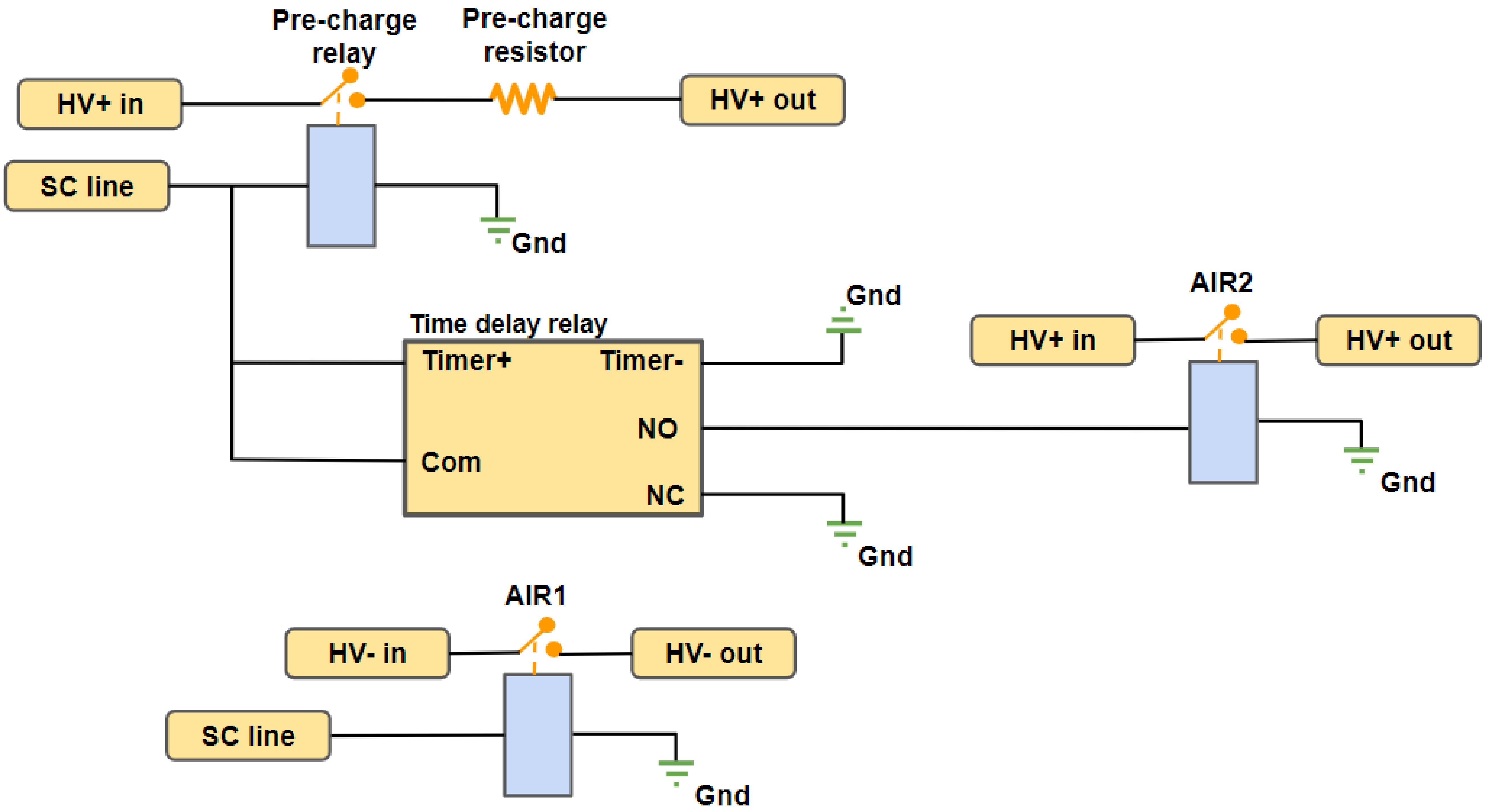
BSPD

It latches the Tractive system from the battery by opening the shutdown circuit whenever accelerator pedal and brake pedal are applied simultaneously beyond a certain limit.



Pre-charge circuit

This circuit ensures that the motor controller capacitor is pre-charged before closing the second AIR. It uses an SPST relay AIR1 and an SPDT time delay relay with a delay time set, after which SPST relay AIR2 is powered.



DISCHARGE CIRCUIT

This circuit discharges the motor controller capacitors if the TS accumulator is disconnected. It consists of a DPDT relay and a discharge resistor wired parallel to the accumulator.

BMS

It monitors the temperature, voltage, and current of the battery.

IMD

It opens the shutdown circuit in case of any insulation fault between low voltage and high voltage, that is if the resistance between GLV and HV drops below the response resistance of IMD.

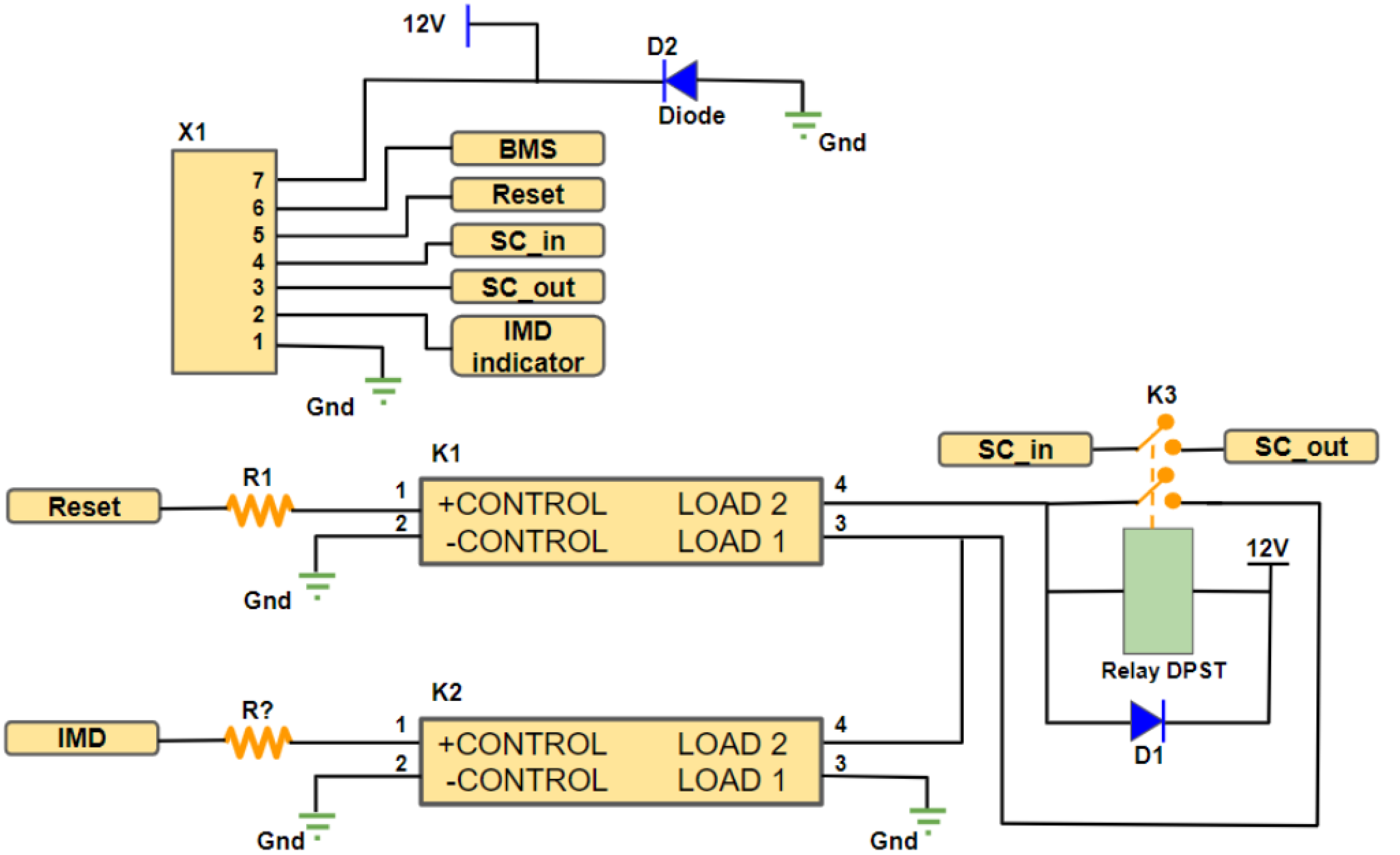
MAIN FUSE

Specifications:

- Voltage rating: 460 VDC
- Current rating: 40 A

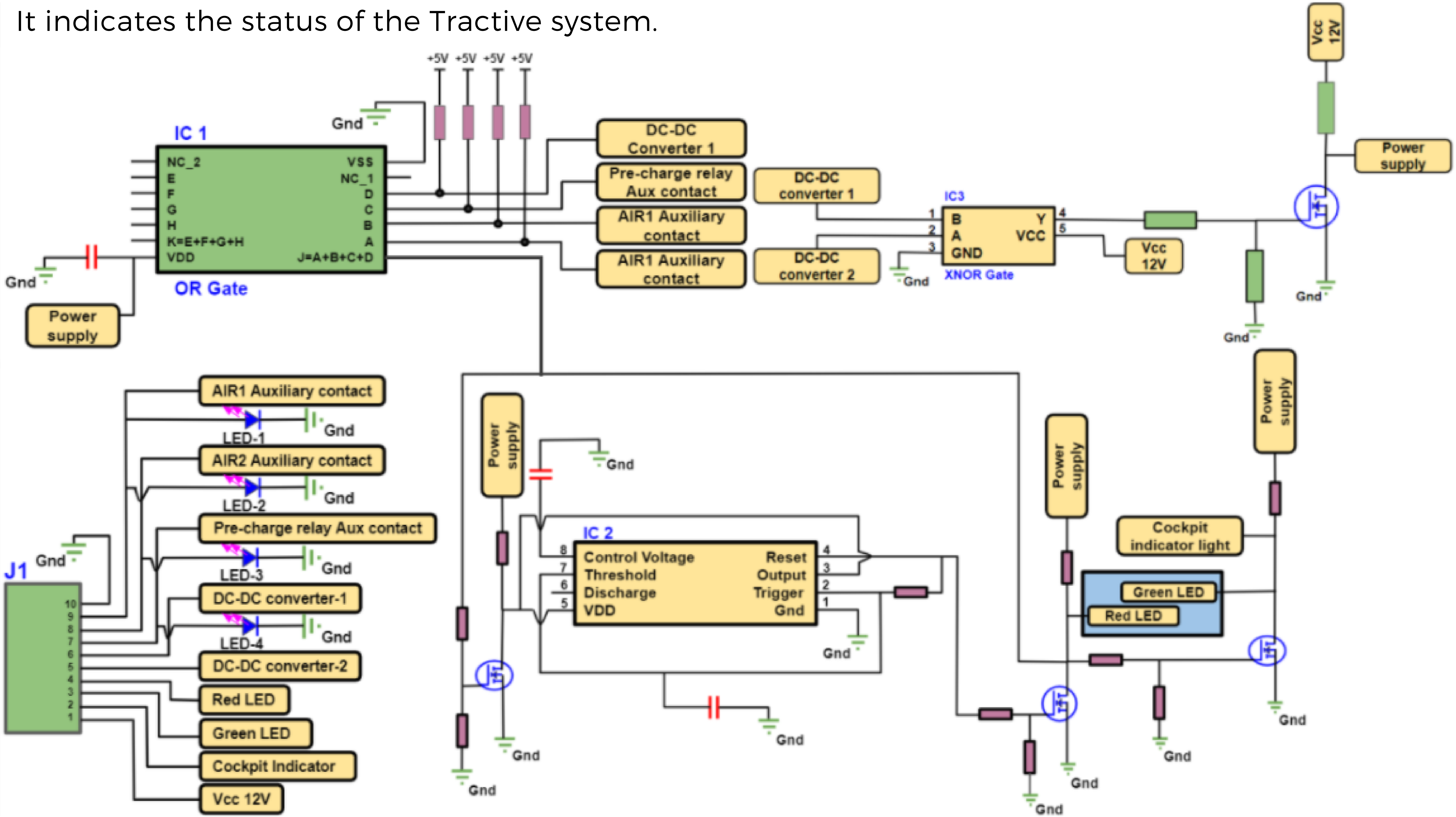
Latching Circuit

It is designed such that if the BMS or IMD throws a fault, the shutdown circuit latches off.



TSAL

It indicates the status of the Tractive system.



Sensors

1. **Accelerometer**

   It detects the magnitude and direction of acceleration of the vehicle.

   It is positioned near the centre of gravity of the vehicle.

2. **Acceleration Pedal Position Sensor (APPS)**

   It transmits the position of the accelerator pedal.

   It is installed to the accelerator pedal.

3. **Brake Pedal Sensor**

   It is installed to the brake pedal.

4. **Brake System Pressure Sensor**

   It measures the high pressures in automotive braking systems.

   It is installed in the T-joint of the brake circuit.

Sensors

5. Current Sensor

It detects the current in a wire coming from the accumulator.

It is installed with the wires of the accumulator.

6. Wheel Speed Sensor

It detects the wheel speed of a vehicle .

It is installed to the drive shaft.

7. Temperature Sensor

It measures the temperature of the cell.

It is installed to the negative terminal of the cell.

8. Steering Angle Sensor

It determines the direction in which the driver wants to steer. It is installed to the steering shaft.