



Title: DEVELOPMENT OF AN ENERGY MANAGEMENT SYSTEM FOR FUEL CELL/LITHIUM-ION BATTERY HYBRID ELECTRIC VEHICLES

By

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Datasets: Electric vehicle parameters, fuel cell details, battery parameters, electric motor parameters, results

Appendix: Battery management system, EMS subsystem

Date : 15/11/2022

DATASETS

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1. Dataset A: Electric vehicle details

Figure 1: Drive cycle reference block FTP-75

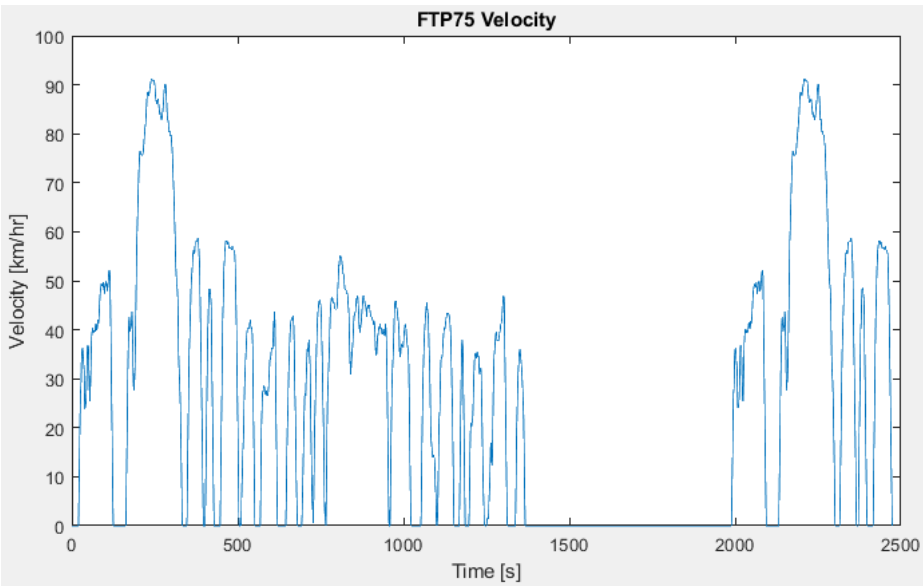


Table 1: Vehicle body parameters

Parameters	Values
Mass	1000 kg
Number of wheels per axle	2
Horizontal distance from CG to front axle	1.4 m

Horizontal distance from CG to rear axle	1.6 m
CG height above ground	0.5 m
Gravitational acceleration	9.81 m/s ²
Drag coefficient	0.25
Frontal area	2 m ²
Air density	1.18 kg/m ³

Figure 2: Longitudinal vehicle dynamics

Main
Drag
Pitch
Variables

Mass: 1000 kg

Number of wheels per axle: 2

Horizontal distance from CG to front axle: 1.4 m

Horizontal distance from CG to rear axle: 1.4 m

CG height above ground: 0.5 m

Externally-defined additional mass: Off

Gravitational acceleration: 9.81 m/s²

2. Dataset B: Fuel cell details

Table 2: Fuel cell stack parameters

Detailed parameters of the fuel cell stack	
Voltage at 0A and 1A [V ₀ (V), V ₁ (V)]	[150, 200]
Nominal operating point [I _{nom} (A), V _{nom} (V)]	[285.7, 350]
Maximum operating point [I _{end} (A), V _{end} (V)]	[345, 288]
Number of cells	65
Nominal stack efficiency (%)	50

Operating temperature (Celsius)	45
Nominal Air flow rate (lpm)	3000
Nominal supply pressure [Fuel (bar), Air (bar)]	[1.5, 1]
Nominal composition (%) [H2 O2 H2O (air)]	[99.95, 21, 1]

Figure 3: Characteristics of the PEMFC

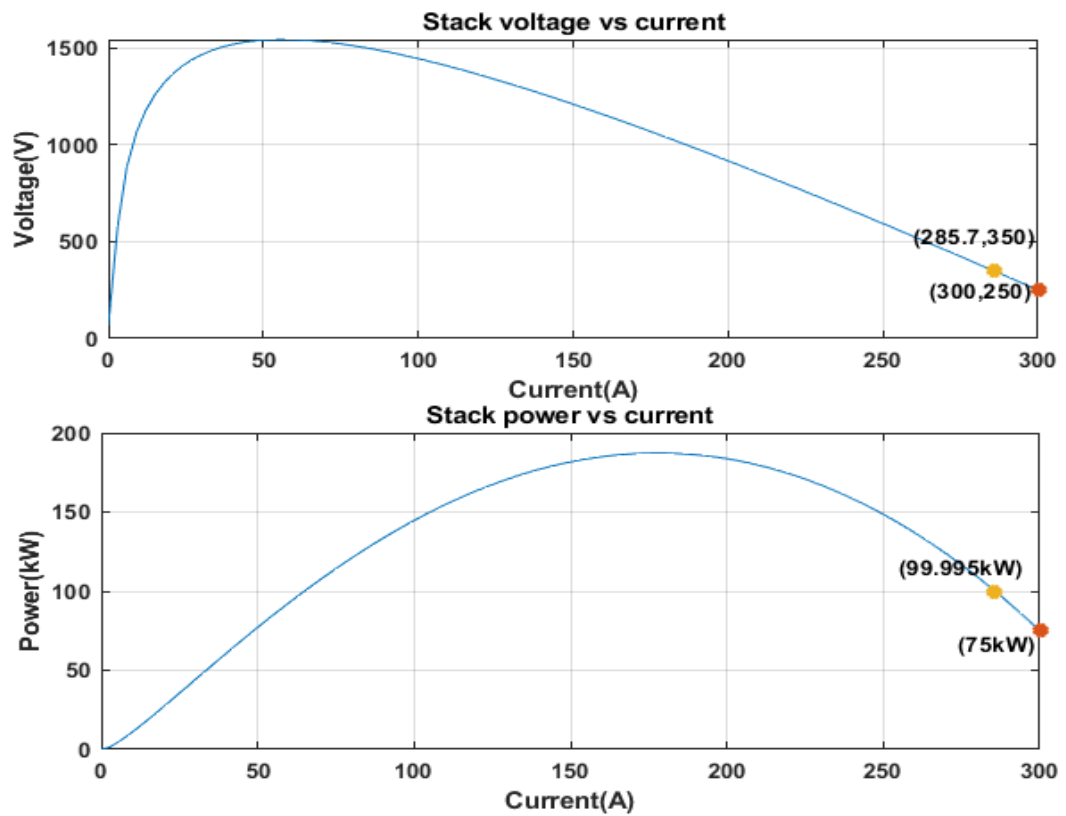


Table 3: Fuel Cell simulation parameters

Fuel cell stack nominal parameters	
Stack nominal power	100 kW
Stack maximum power	100.02 kW
Fuel cell resistance	0.00334 ohms
Nernst voltage of the cell [En]	1.1736 V

Hydrogen utilization (%)	8.056
Oxidant utilization (%)	9.199
Nominal fuel consumption	99.55 slpm
Nominal air consumption	236.9 slpm
Exchange current [i_o]	0.279055 A
Exchange coefficient [alpha]	0.001636

Table 4: Fuel Cell signal variation parameters

Fuel Cell signal variation parameters	
Fuel composition	99.95 %
Oxidant composition	21 %
System temperature (T)	318 K
Fuel supply pressure	1.5 bar
Air supply pressure	1 bar

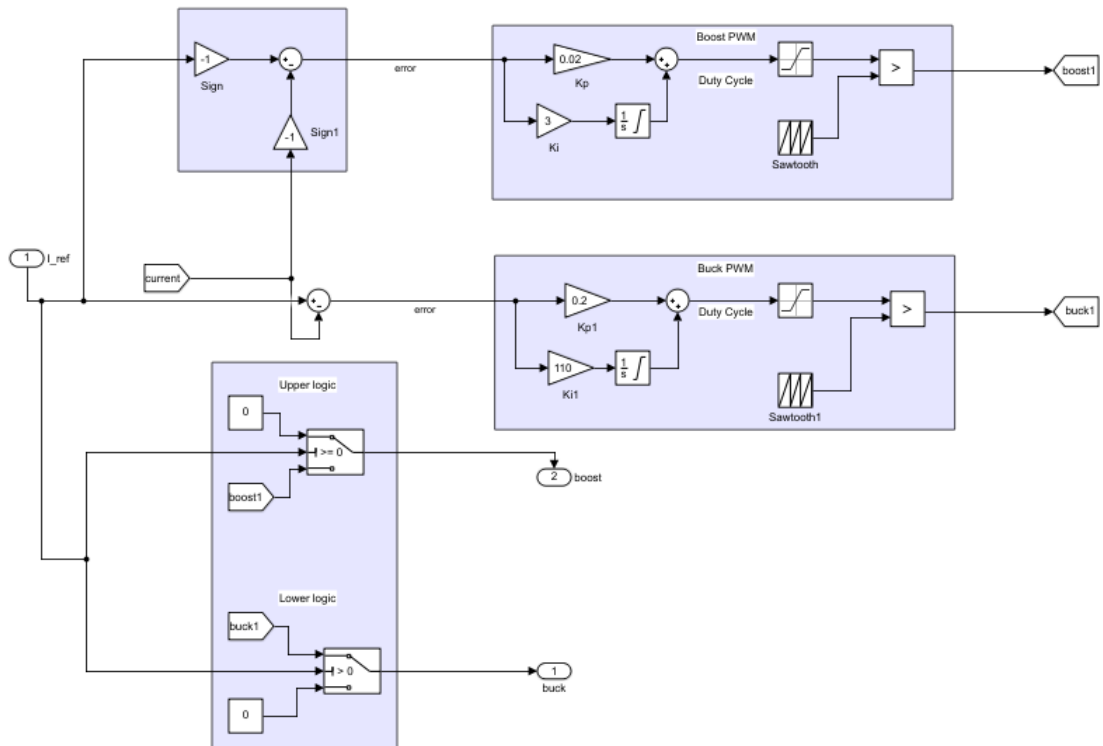
Table 5: Fuel cell DC-DC boost converter parameters

Input voltage	350 V
Output voltage	400 V
Input Power	100 kW
Duty cycle	12.5 %
Switching frequency	40 kHz
Critical Inductance	13 μ H
Critical Capacitance	19.5 μ F
Output Resistance	3.2 Ω

Table 6: DC/DC bidirectional converter parameters

Battery voltage	144 V
DC bus voltage	400 V
Input Power	30 kW
Duty cycle	64 %
Switching frequency	100 kHz
Inductance (L_{min})	5.9 μ H
R_H	7.96 Ω
ΔV_H	1.0295
Capacitance	320 μ F

Figure 4: Bidirectional converter controller



3. Dataset C: Battery parameters

The battery is rated at 30 kW which is approximately 33.3% of the power supply capacity when compared to the fuel cell. The Li-ion battery parameters are presented in Table 7.

Table 7: Battery specifications

Parameter	Value
Chemistry	Li-ion
Nominal Voltage	144 V
Nominal capacity	208.3 Ah
Nominal Power	30 kW
Initial battery SoC	90 %
Response time	1 s
Nominal temperature	25 °C

4. Electric motor (EM) details

The Permanent magnet synchronous motor is a 100 kW with a nominal no-load speed of 4000 rpm while other parameters are shown in Figure 5

Figure 5: Permanent magnet synchronous motor details

Electrical Torque	Power Supply	Mechanical
Model parameterization: By motor ratings ▼		
Rated mechanical power:	100	kW ▼
Rated speed:	4000	rpm ▼
Rated RMS line-to-line voltage:	400	V ▼
Rated supply frequency:	60	Hz ▼
Rated RMS line current:	250	A ▼

5. Dataset D: Results

Figure 6: Fuel cell stack voltage, current and efficiency

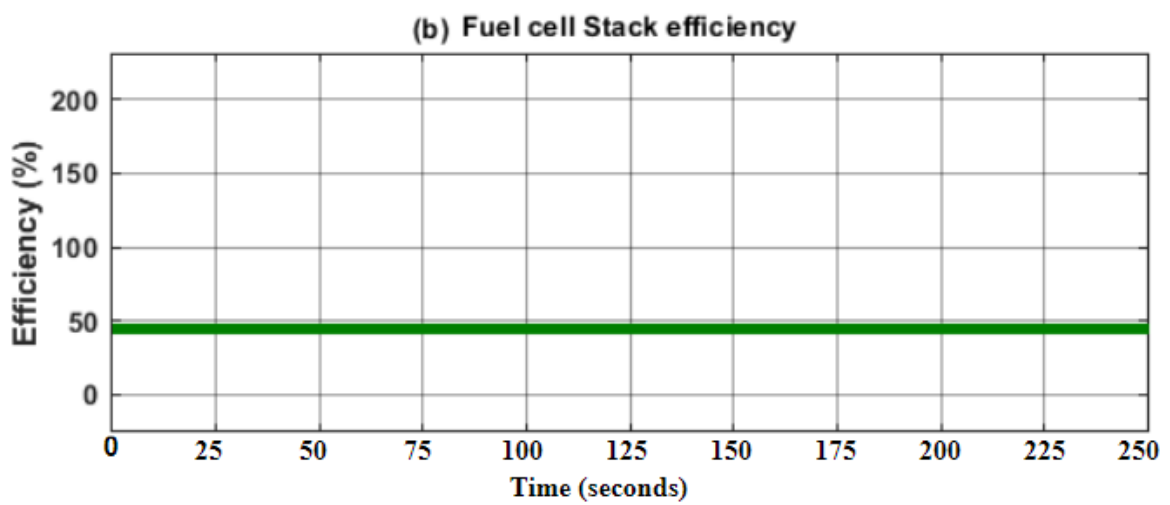
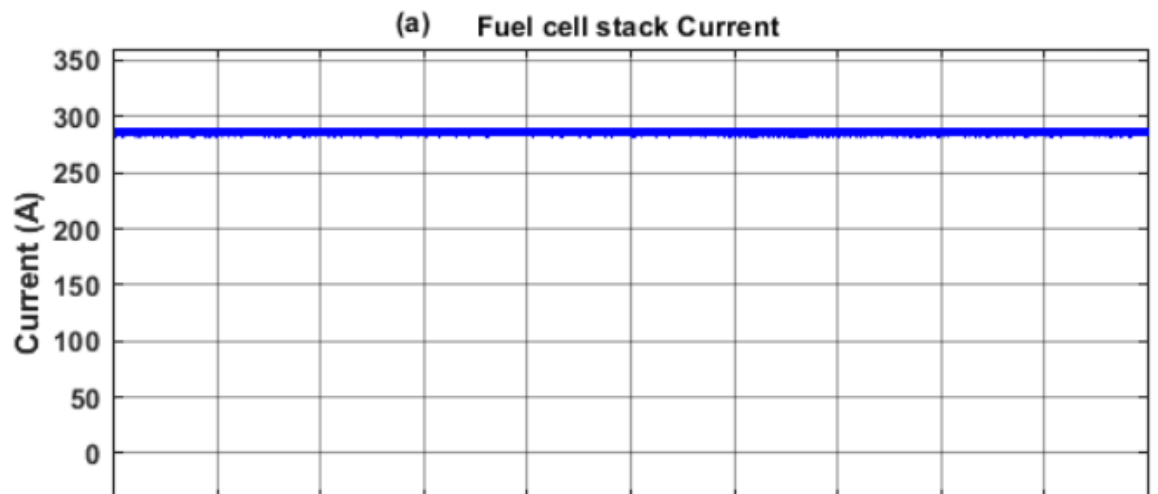
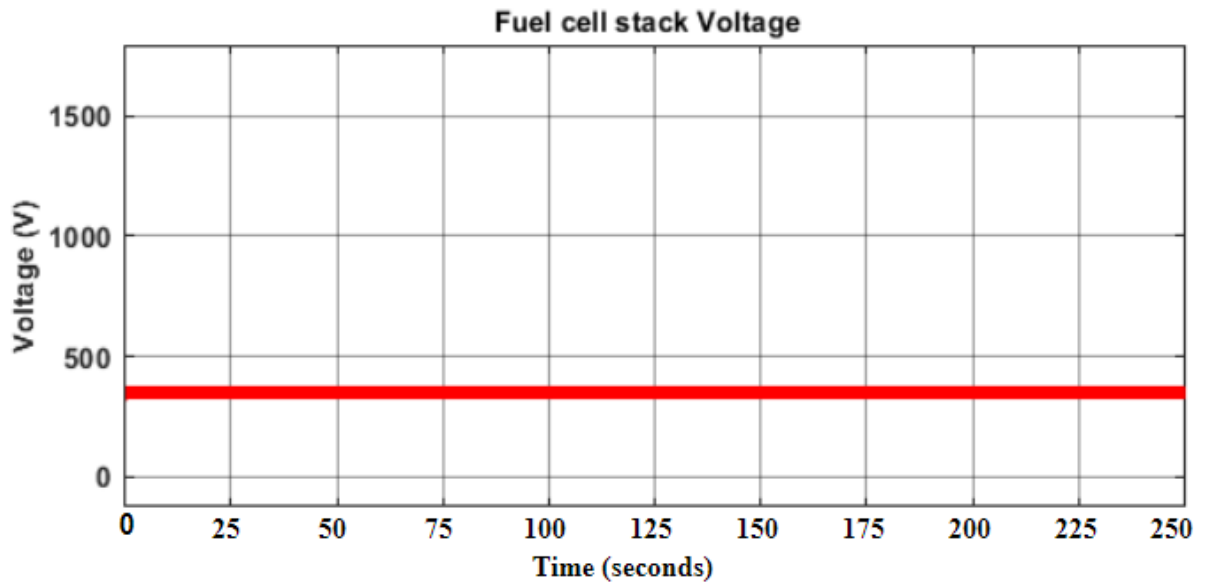


Figure 7: Power distribution using the down-sampled drive cycle

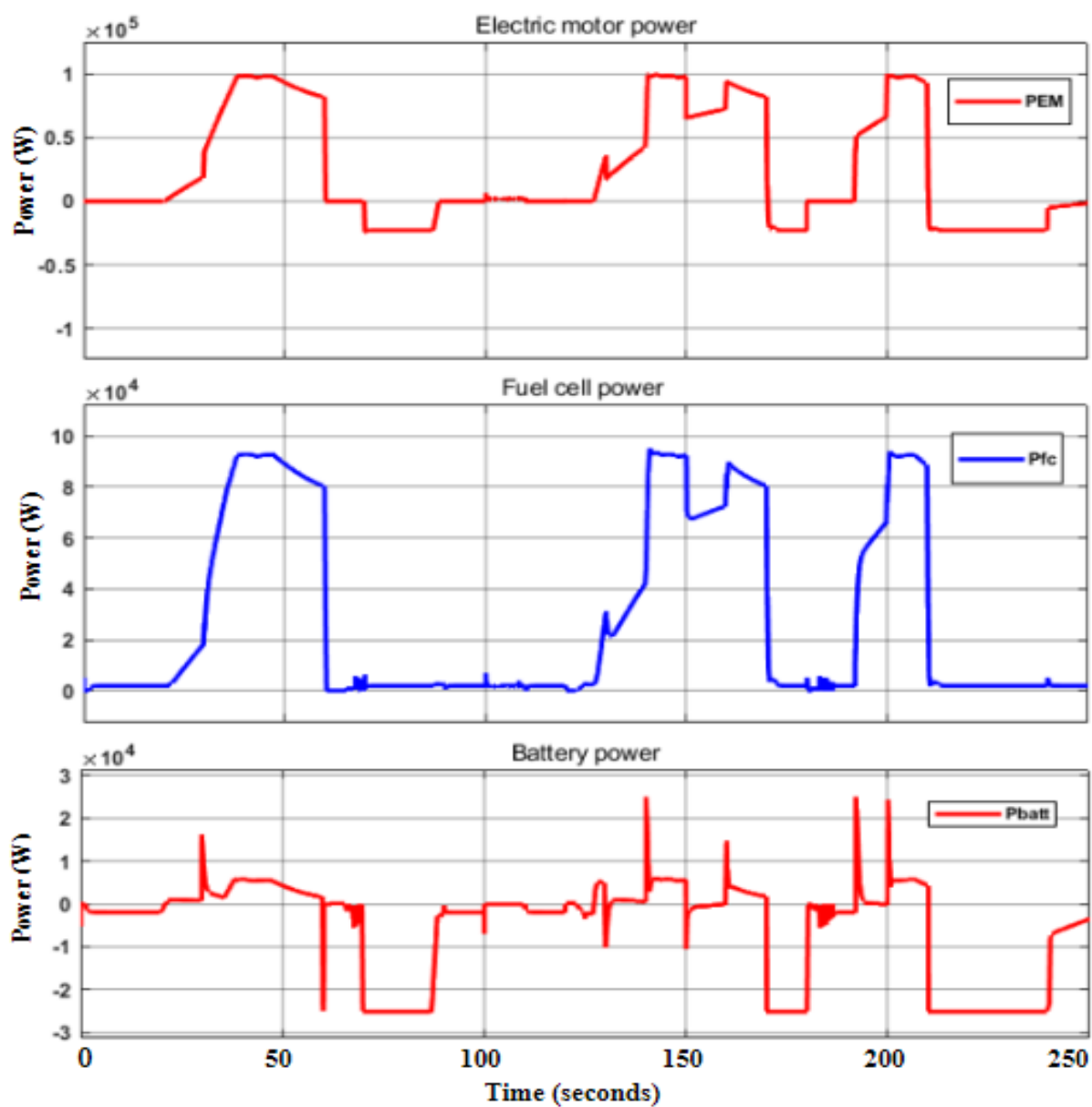


Figure 8: Electromagnetic torque, Rotor speed, Mechanical power, Current, Voltage

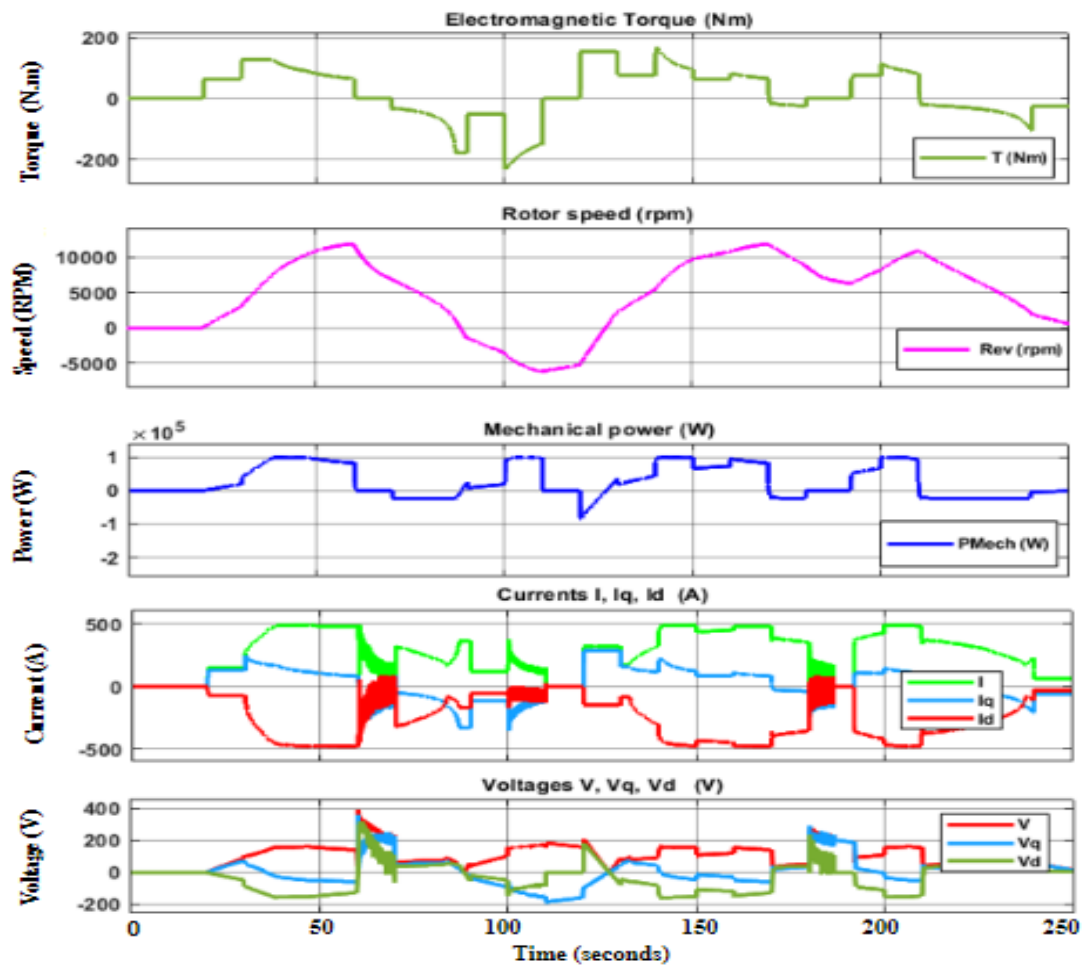


Figure 9: Schematic Editor

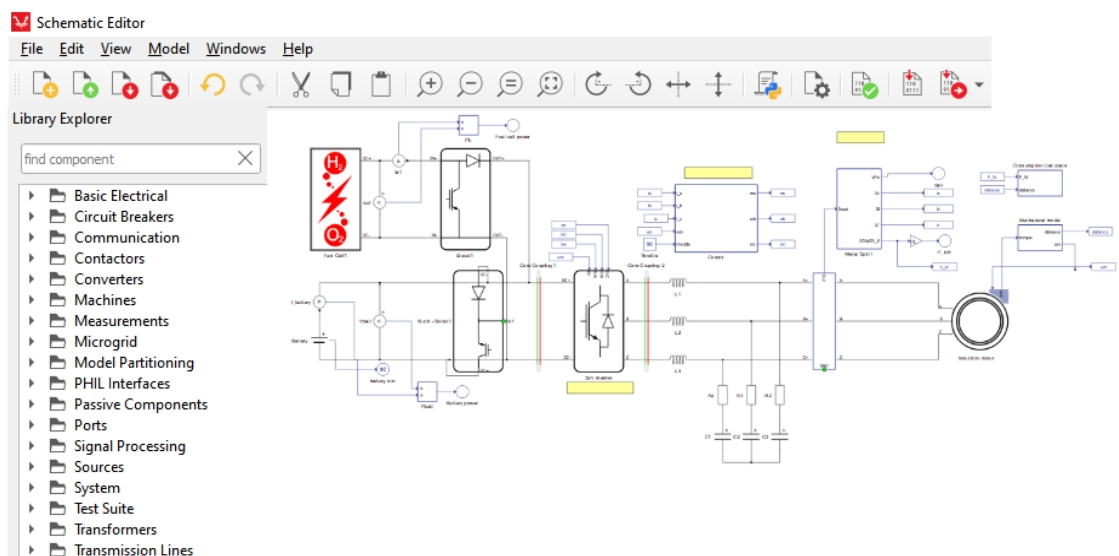


Figure 10: Components allocation according to responsible computing unit

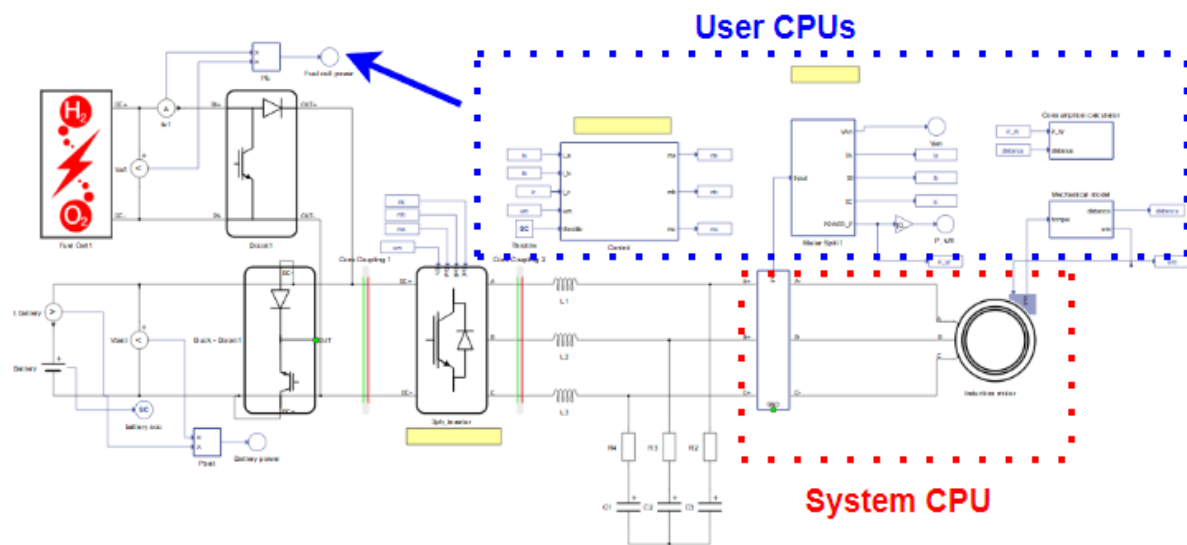


Figure 11: EV powertrain control system

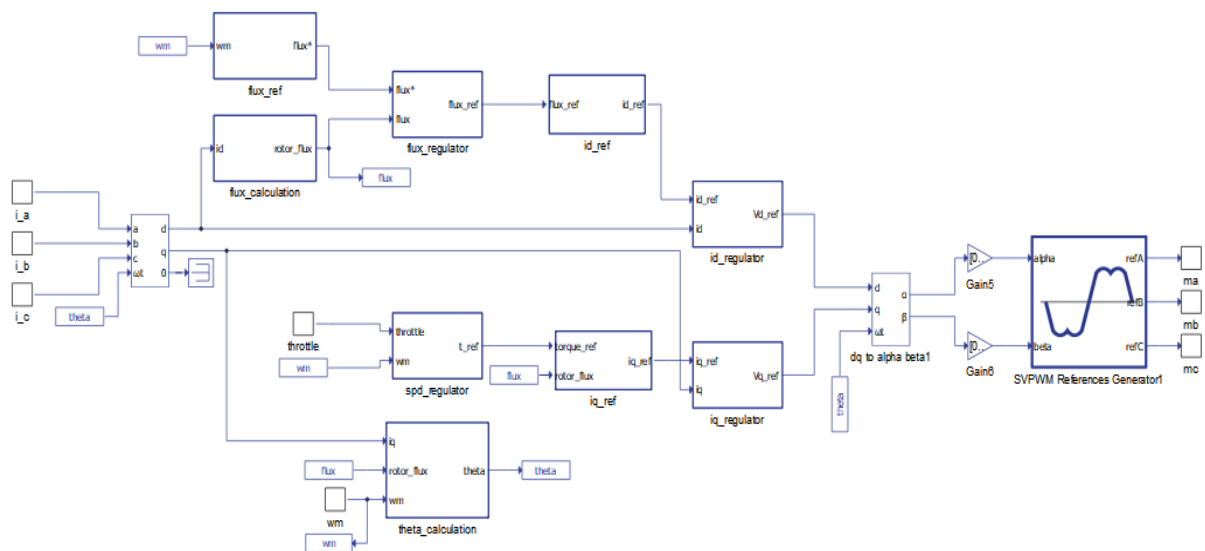
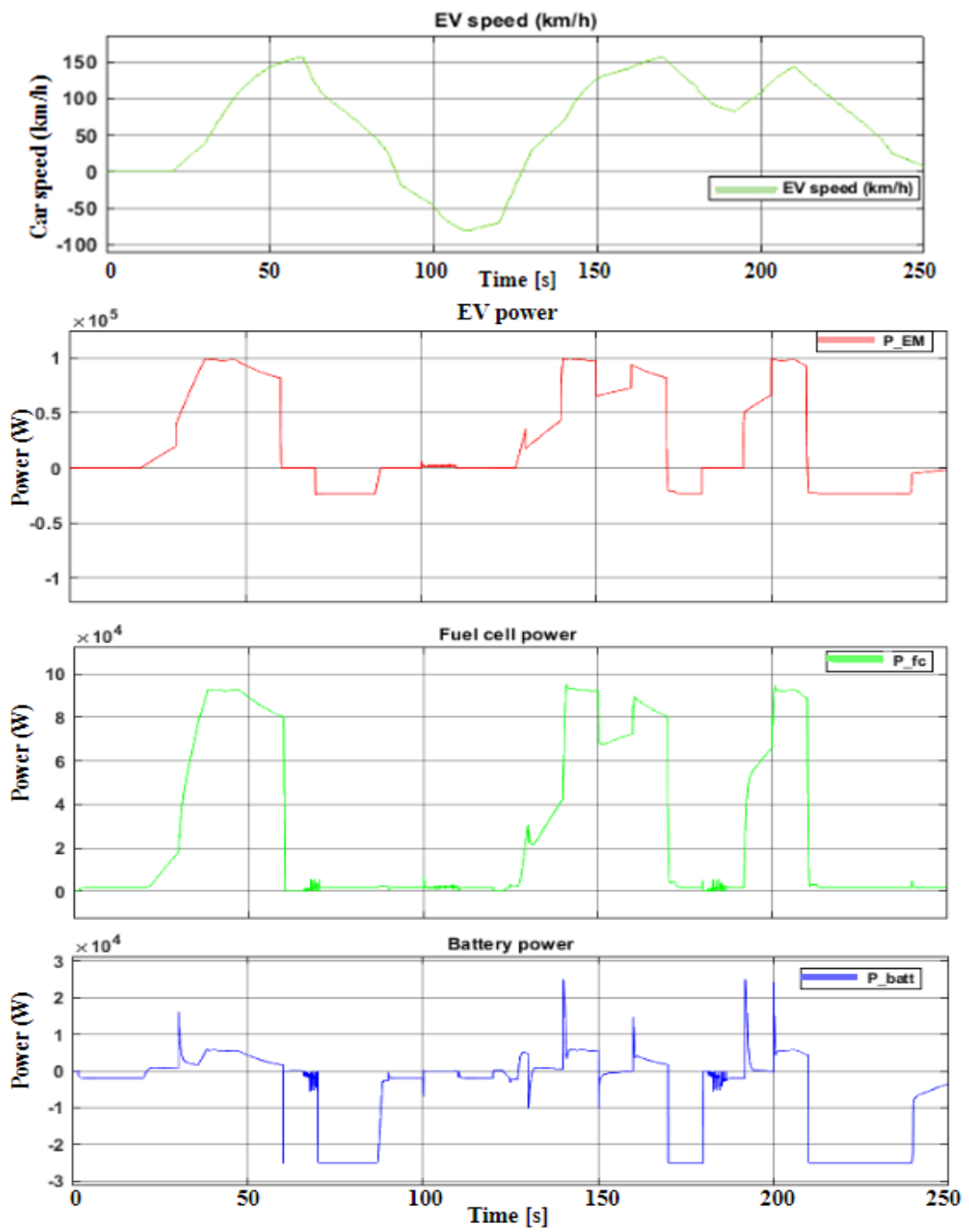
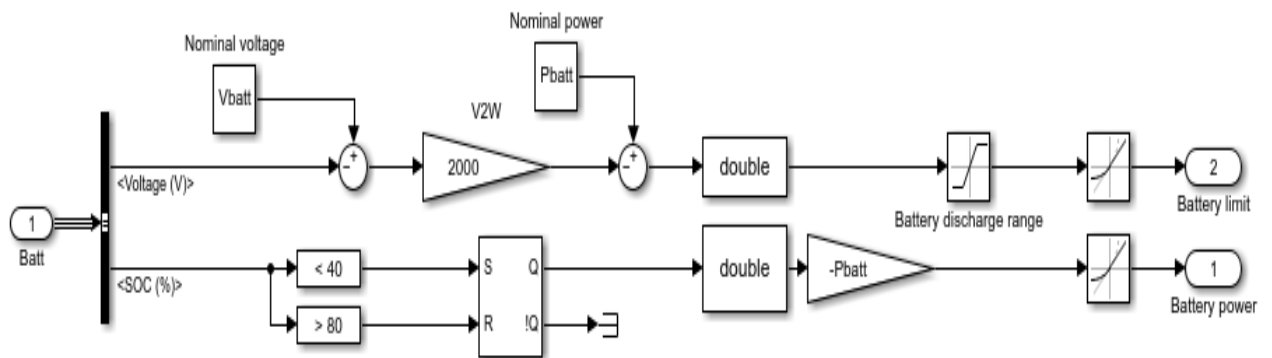


Figure 12: Down-sampled drive cycle Experimental result under Typhoon HIL



APPENDICES

Appendix 1: Battery management system



Appendix 2: EMS subsystem

