

## 1. Background and Motivation

- Planetary Gearbox (PG) is an essential component of a hybrid powertrain and most of hybrid electric vehicles (HEV) incorporate PG to interconnect various powertrain components.
- Increasing the number of PGs from 1 to 2 improves fuel consumption, but there is a lack of available literature to systematically define the optimal number of PGs. This study aims to understand the effect of the number of PG in HEVs' fuel economy over a driving cycle.

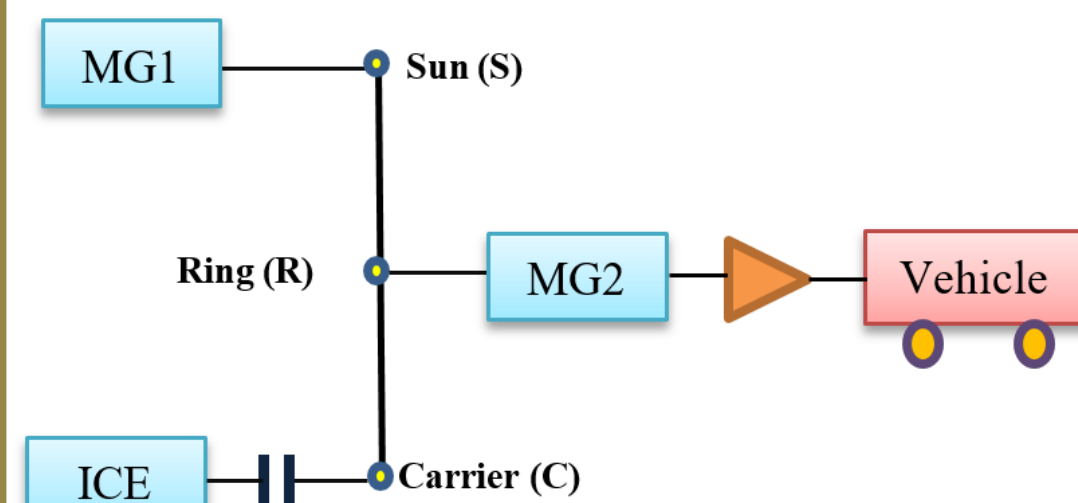
## 2. Objectives

- To study the effect of increasing the number of PGs in a hybrid powertrain.
- To model a hybrid powertrain using dSpace ASM and Simulink for one, two and three PGs.
- To fix the component size and energy management strategy.

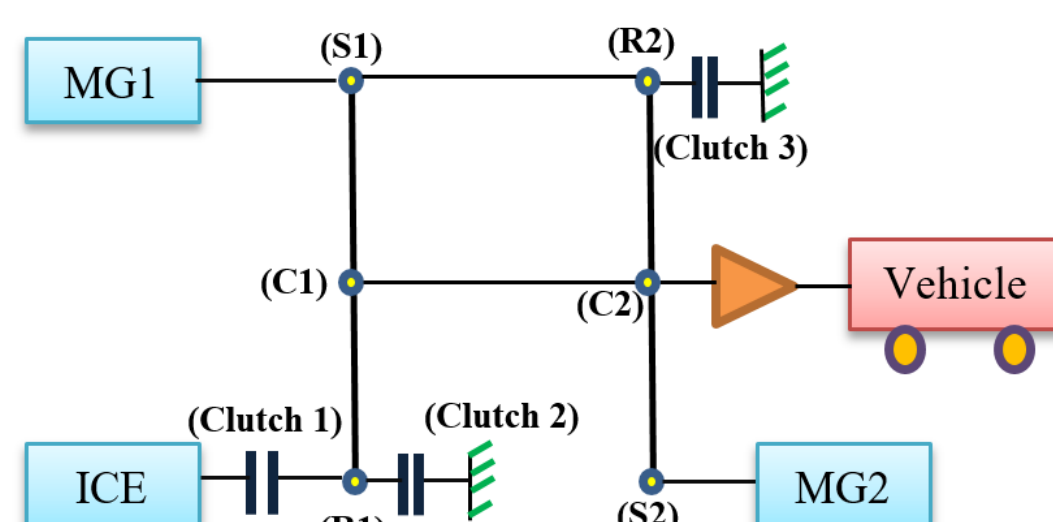
## 3. Model Description

- Model have been developed for 1,2 and 3PGs. Input split configuration has been chosen and fixed for all the three models. Configuration of hybrid powertrains are shown below:

1PG Configuration



2PG Configuration



3PG Configuration

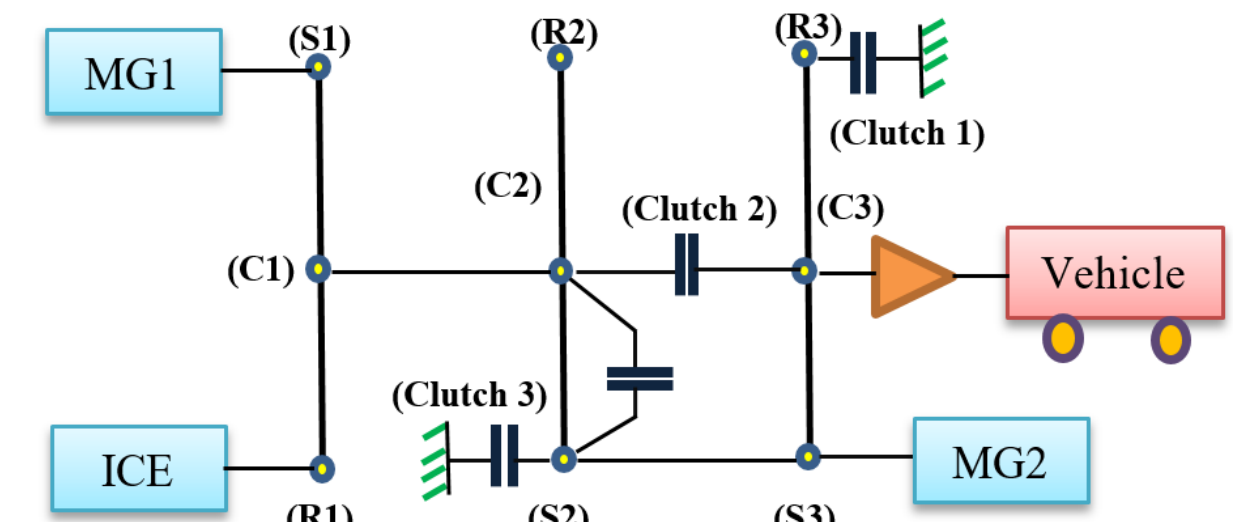
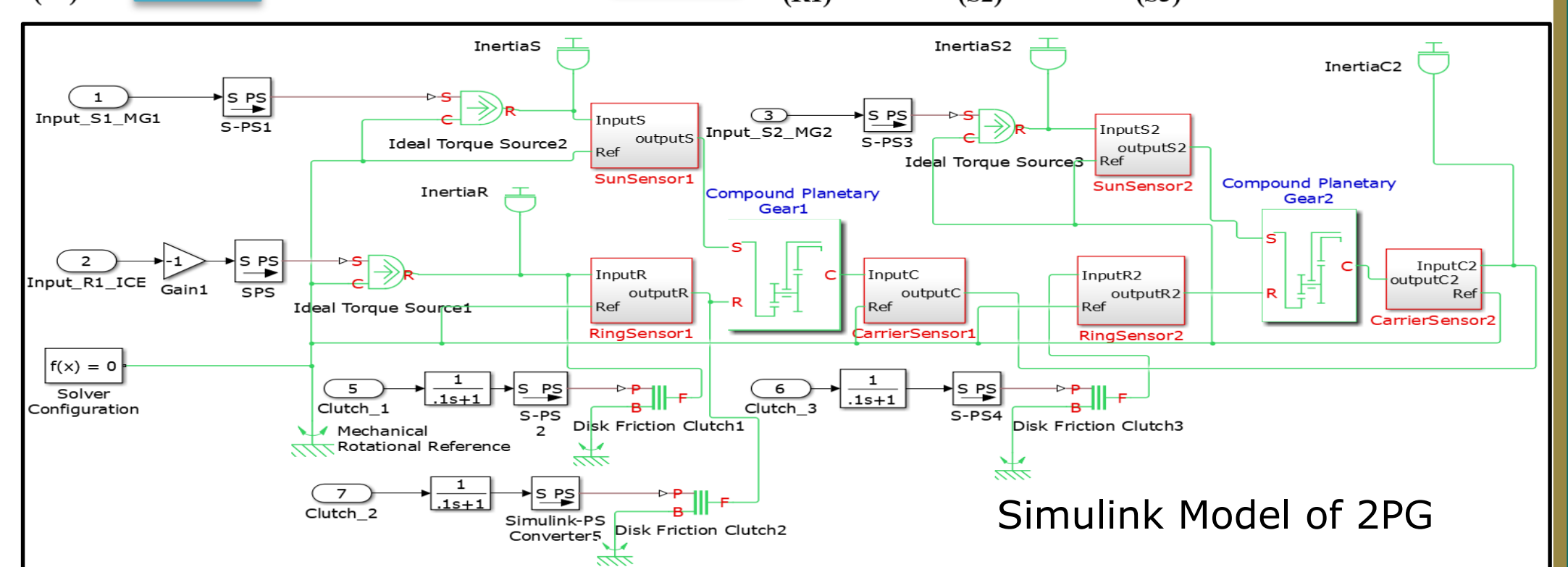
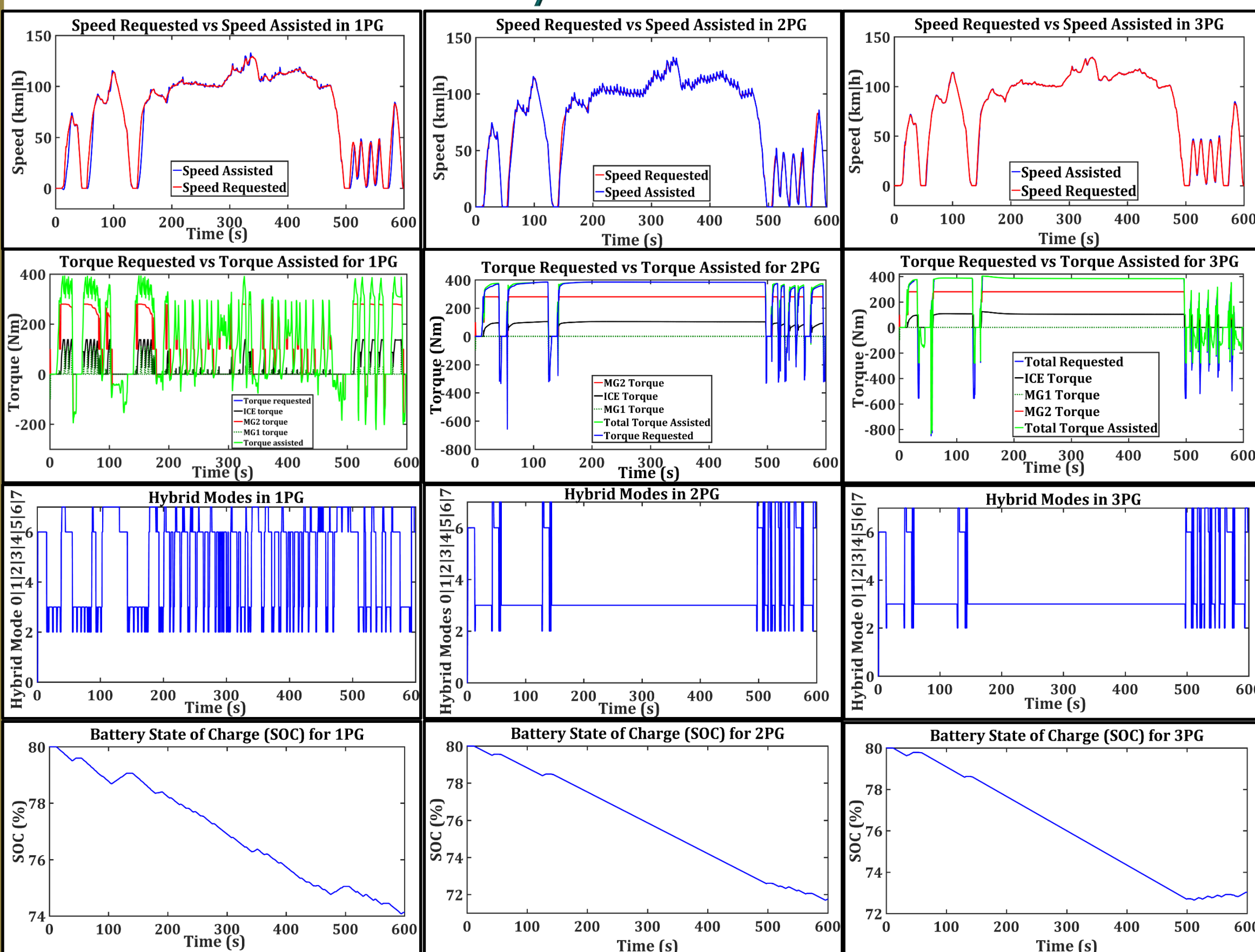


Table 1. Specification of Chevrolet Volt 2<sup>nd</sup> Generation

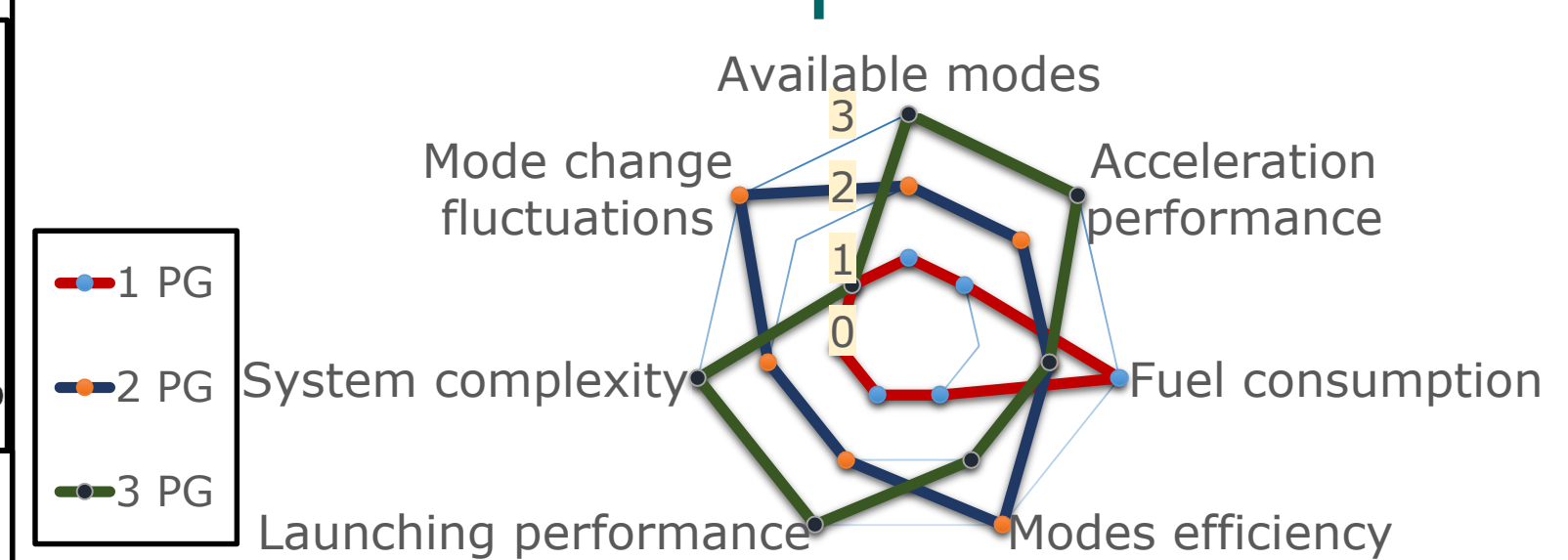
Parameters	MG1	MG2	ICE
Max Speed (rpm)	10000	8000	5000
Max Torque (Nm)	118	280	142@4000rpm
Max. Power (kW)	58	87	75
Battery Size (kWh)	18.4kWh, Max Power 120kW		
Planetary Gear Ratio (R:S)	2.6:1 (1PG)		
	2.6:1 (1 <sup>st</sup> PG) 2:1 (2 <sup>nd</sup> PG)		
	2:1 (1 <sup>st</sup> PG) 2:1 (2 <sup>nd</sup> PG) 2:1 (3 <sup>rd</sup> PG)		
Final Drive Ratio	3.95		
Vehicle Mass (kg)	1600		



## 4. Results: Drive cycle used is US06



## 5. Radar Map for all PGs



## 6. EMS and Modes Explanation

- The Energy Management Strategy used is a simple rule based strategy, where torque requested is assisted by max torque of the components. Also EMS is kept same for all the 3 models.
  - Modes are from 0-7 and the explanation is given below
- 0 - Load point shift
  - 1 ICE - Internal combustion engine only
  - 2 Boost Mode (BM)\_A - MG1 and MG2 together assist the torque
  - 3 BM\_B - MG2 and ICE together assist the torque demand
  - 4 BM\_C - MG1 and ICE together assist the torque demand
  - 5 BM\_D - MG1, MG2 and ICE together assist the torque demand
  - 6 EC - MG2 only assist the torque demand
  - 7 - Recuperation

## 7. Conclusions

- 1PG with smaller component size (42kW ICE, 60kW MG2 and 42kW MG1) shows better mode selection, torque assistance and fuel consumption of 214.79gm which is 21.79% less as compared to 1PG configuration with bigger components. Therefore use of 1PG recommended for comparatively smaller component sizes.
- Vehicle can follow speed profile more accurately for increased number of PGs.
- Fuel consumption is for 1PG, 2PG and 3PG is 261.6gm, 245.305 and 242.42gm respectively for the cycle of 600s or 10mins.
- 3PG shows only an improvement of 1.2% fuel economy compared to 2PG for fuel consumption therefore 2PG can be the best candidate for HEV powertrain in order to reduce system complexity.
- The acceleration performance of the vehicle is increased from 1PG to 2PG and 3PG. Vehicle can achieve an acceleration of 0-72km/h in 6.7seconds using 3PG, in 7.25seconds using 2PG and 8seconds using 1PG. Therefore for quick acceleration application 3PG can be used.