evs 27

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# Analyse of Clutch-brake System Control Based on Experimental Tests and Applied in Hybrid Power Train

Antoni Szumanowski, Zhiyin Liu, Pawel Krawczyk

*Warsaw University of Technology (Poland)*

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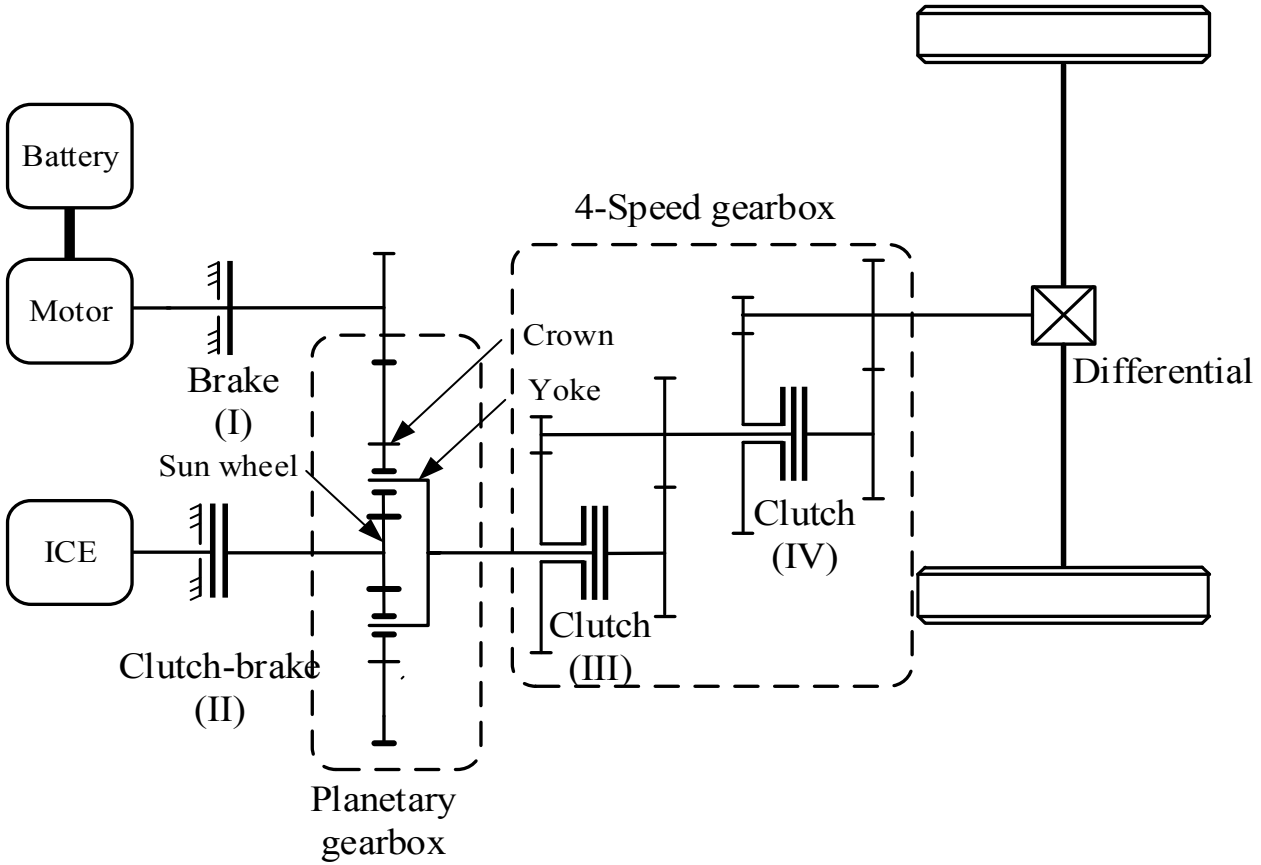
# Contents

# Targets of research

1. Modeling of hybrid power train with clutch-brake system
2. Modeling of control
3. Verification of  power train with clutch-brake system based on laboratory bench test

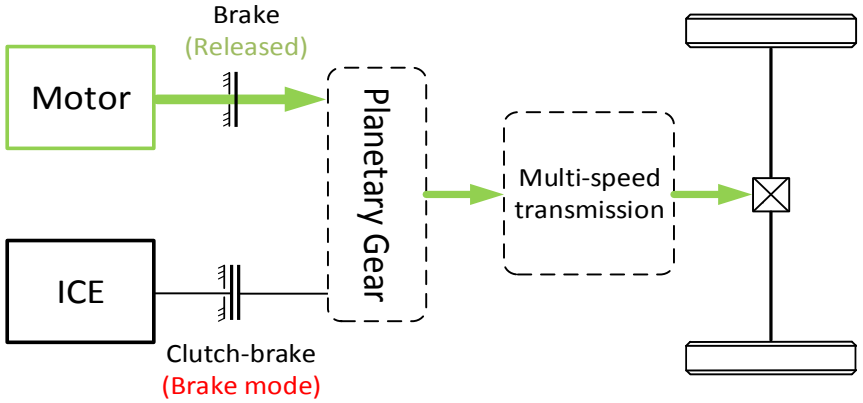
# Introduction of CHPTD



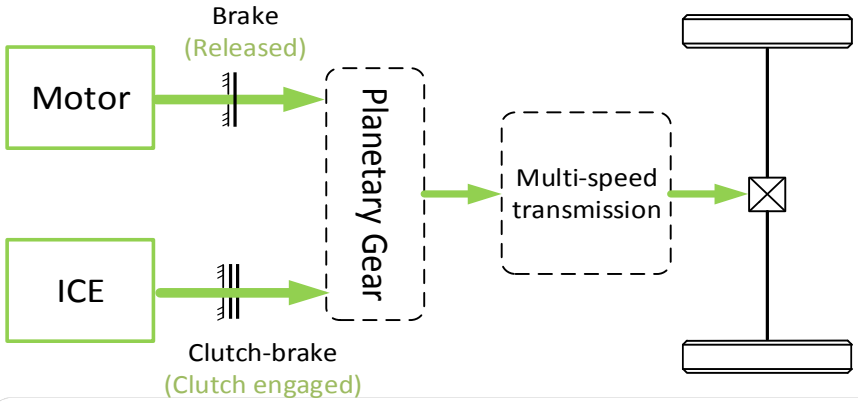

The newly improved Compact Hybrid Planetary Transmission Drive

# Introduction of CHPTD

## Pure electric mode




## Hybrid mode

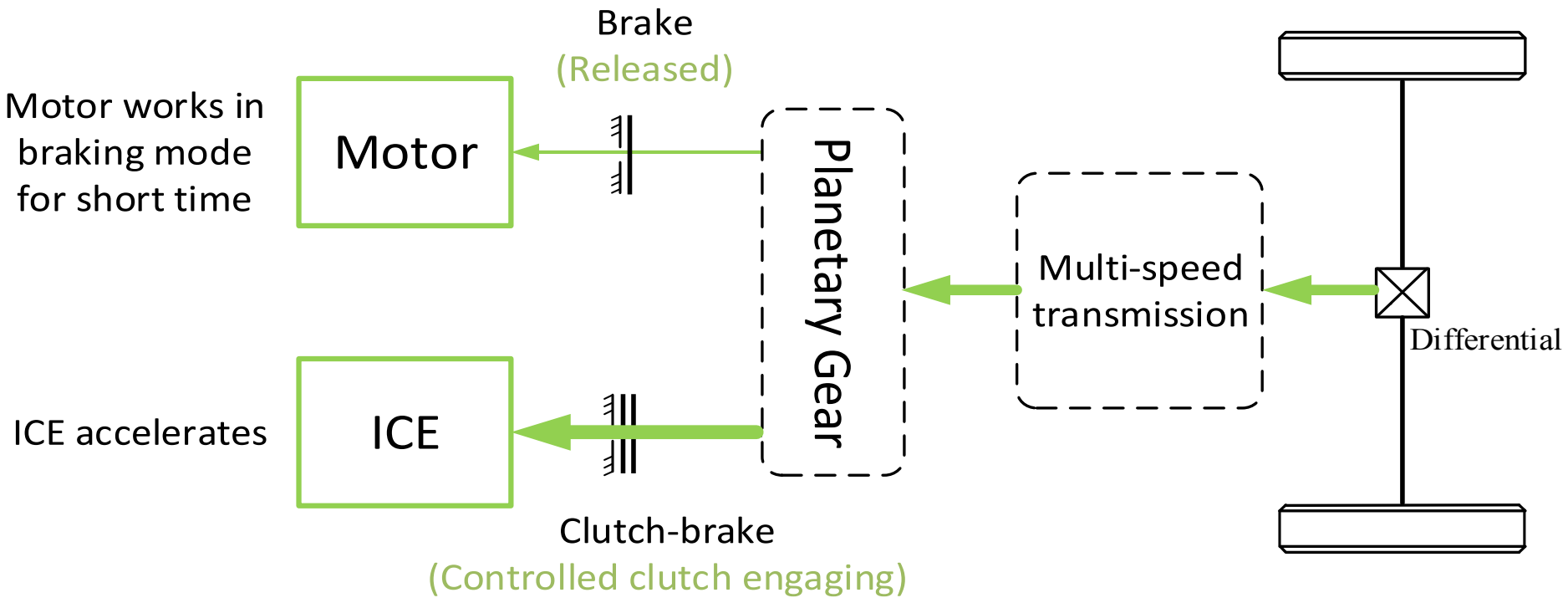



By cooperating with proper control method, clutch/brake system can reduce the degree of freedom of planetary transmission from 2 to 1, which means the drivetrain could work in different modes.

| Operation mode of plug-in hybrid powertrain | Control signal of clutch/brake systems | |
|---|---|---|
| | *Brake I** | *Clutch/Brake II*** |
| Pure electric drive and regenerative brake | off | off |
| Pure engine drive | on | on |
| Hybrid drive | off | on |
| Engine charge battery (when vehicle stop) | off | off |

# Introduction of CHPTD

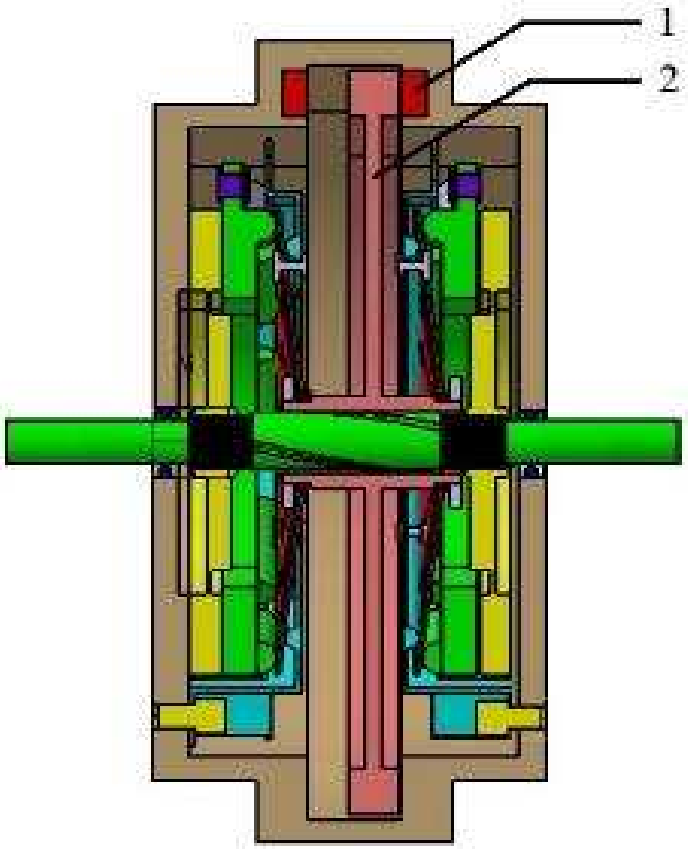
## ICE starting without additional starter motor



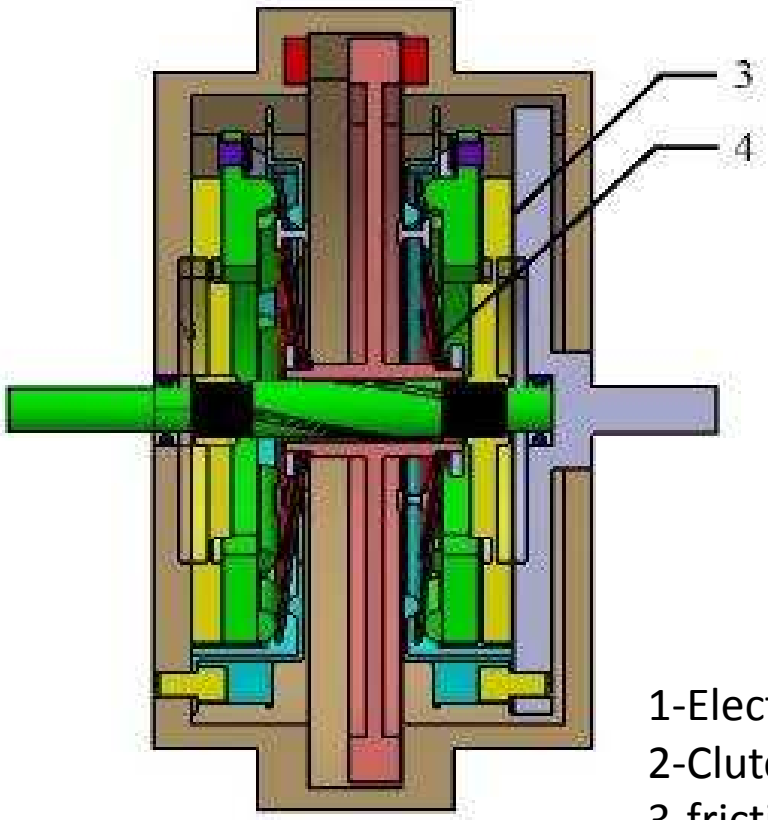
# Why controllable clutch-brake system?

- With clutch-brake system, the operation modes of power train can be changed.
- Dynamic control of the clutch engagement time and torque capacity results in smooth and fast ICE start.
- Better efficiency and less abrasion of clutch.

# Zero steady-states electrical energy consumming clutch-brake system in CHPTD



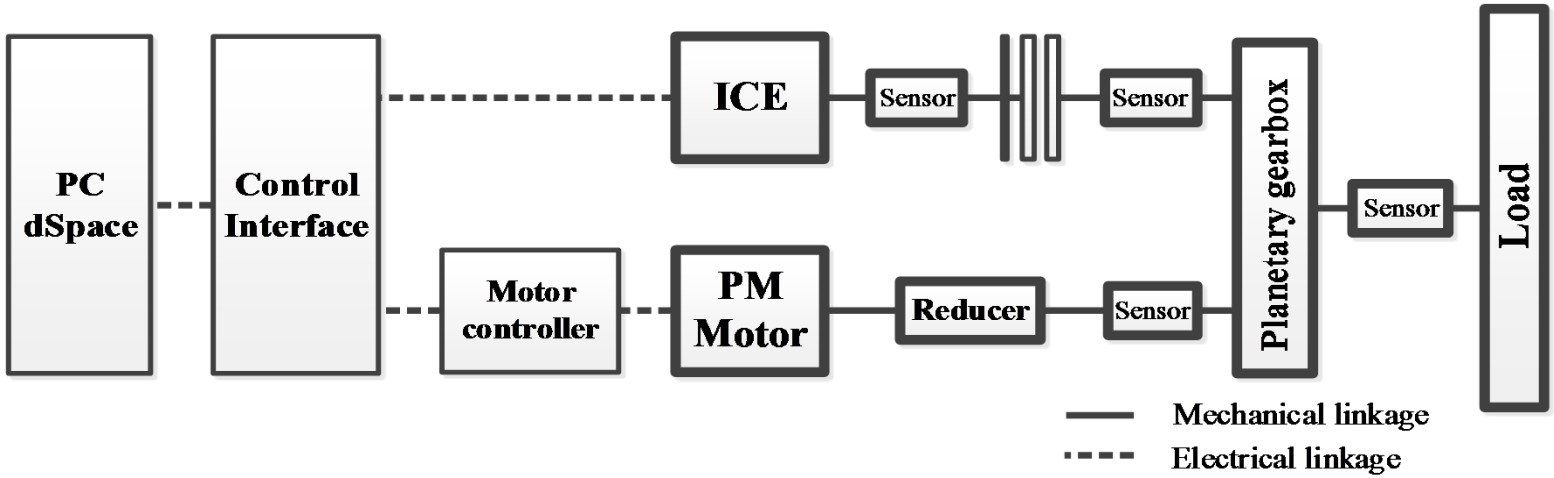

Brake I



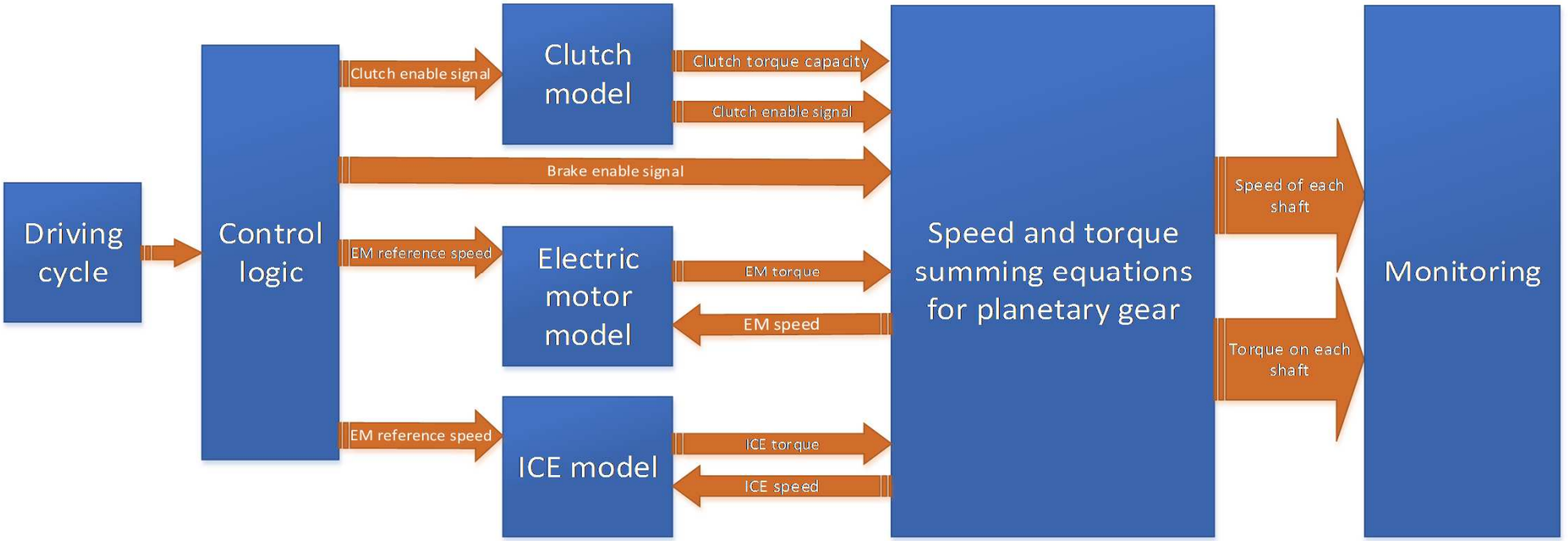

Clutch/Brake II

1-Electromagnetic actuator
2-Clutch release plate
3-friction plate
4-diaphragm spring

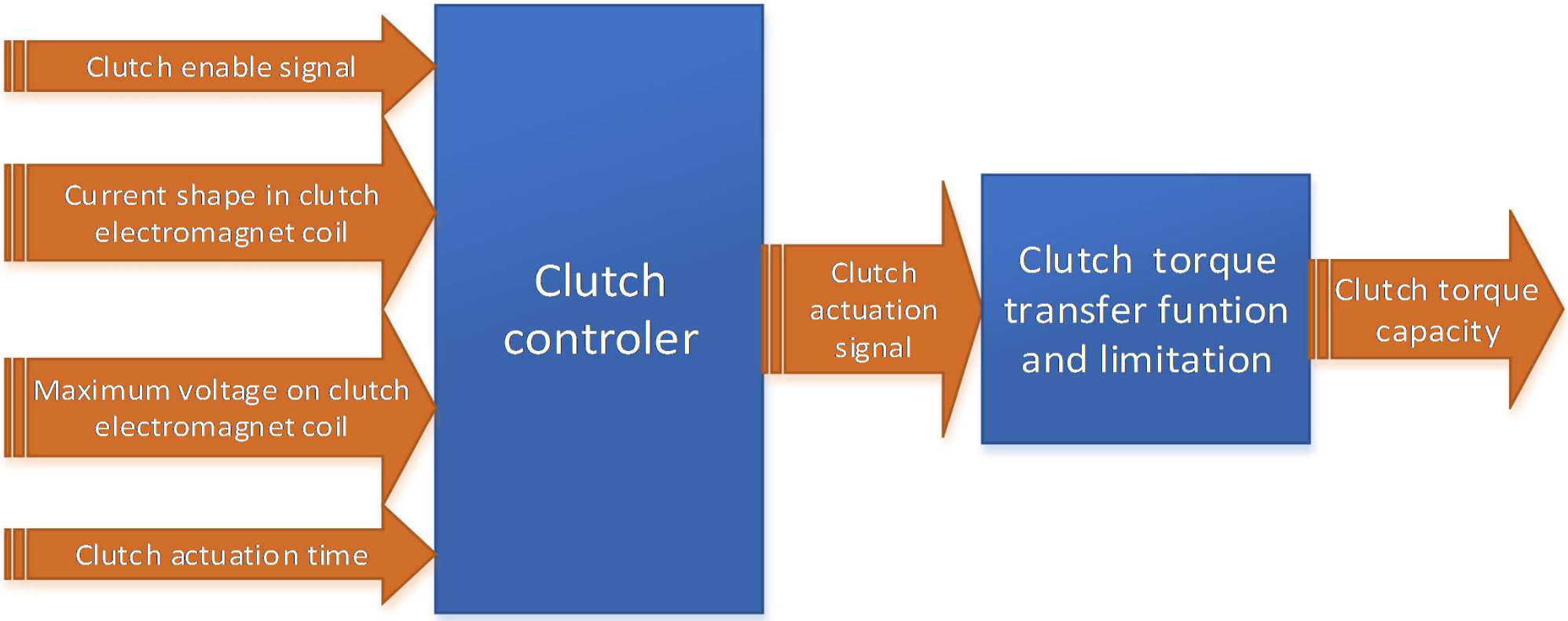
# Laboratory stand of CHPTD



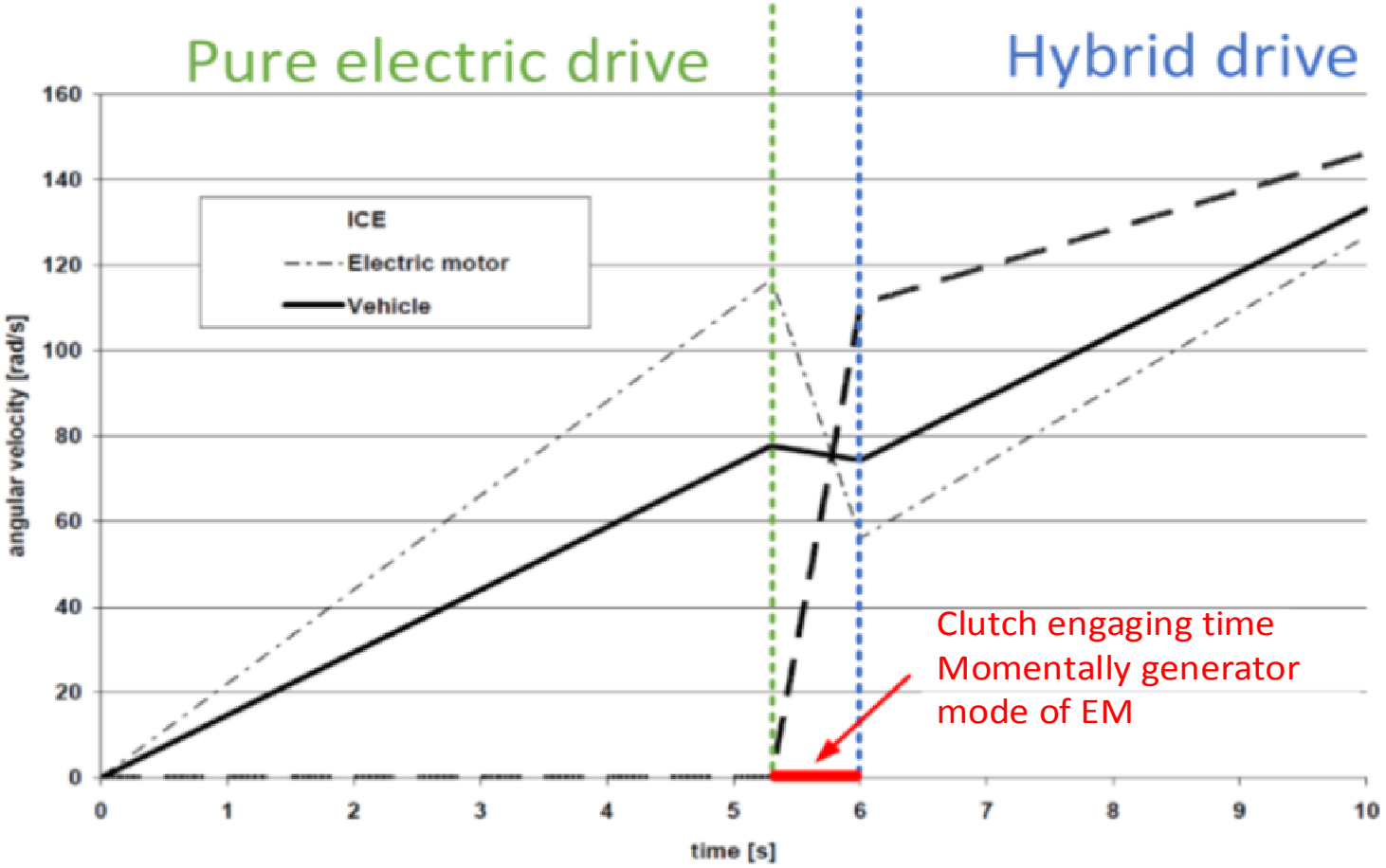
# Simulation model based on laboratory stand



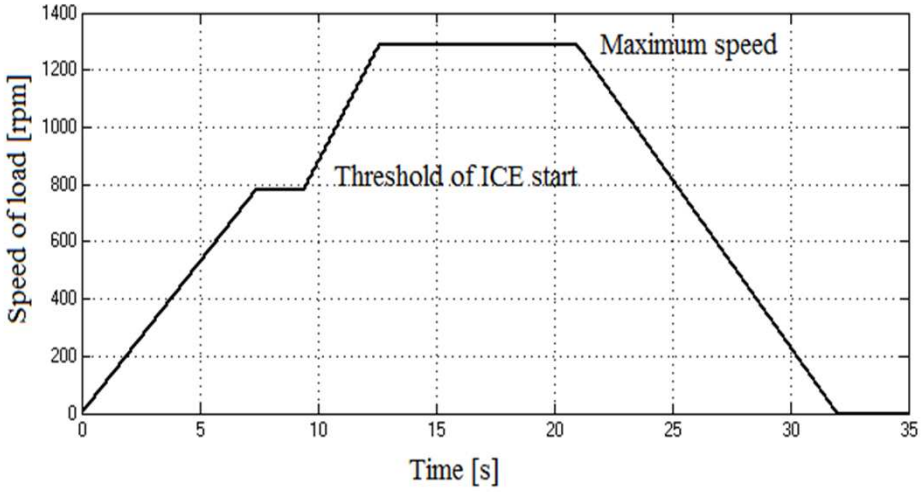
# Simulation model of clutch unit and its controler



# Clutch engaging with operation modes



# Speed control basic algorithm in power train




## Pure electric start

$$\omega_{em} = \frac{1+k_p}{k_p} i_{reducer} \omega_{load}$$

## Hybrid drive

$$[\omega_{ice\_\min}, \omega_{ice\_\max}] \qquad \omega_{ice} = a\omega_{load} + b$$

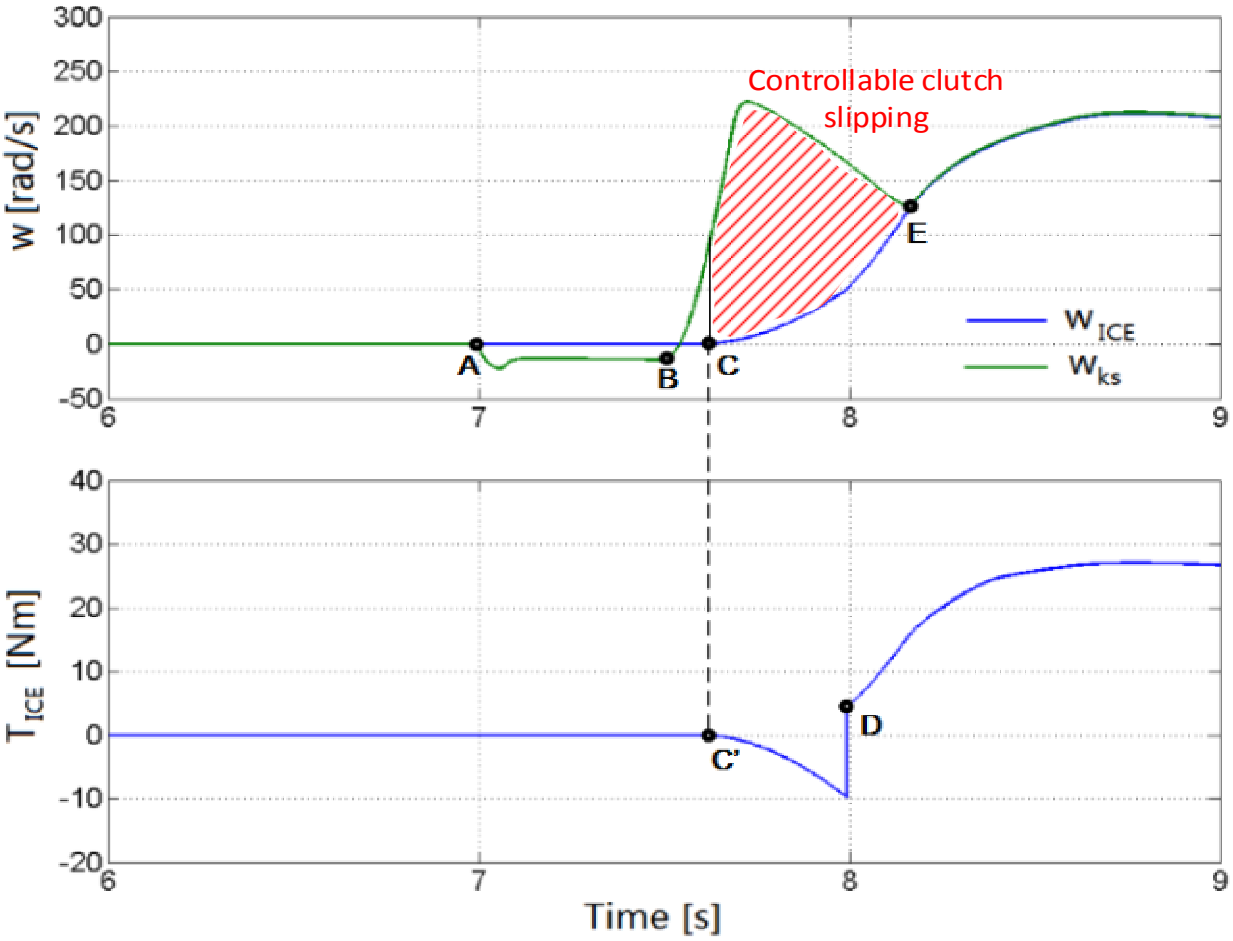
$$\begin{cases} \omega_{ice} = \omega_{ice\_\min} \\ \omega_{load} = \omega_{load\_Th} \end{cases} and \begin{cases} \omega_{ice} = \omega_{ice\_\max} \\ \omega_{load} = \omega_{load\_\max} \end{cases}$$

$$\omega_{ice} = \frac{\omega_{ice\_\max} - \omega_{ice\_\min}}{\omega_{load\_\max} - \omega_{load\_Th}} \omega_{load}$$

$$+(\omega_{ice\_\max} - \frac{\omega_{ice\_\max} - \omega_{ice\_\min}}{\omega_{load\_\max} - \omega_{load\_Th}} \omega_{load\_\max})$$

$$\omega_{em} = \frac{(1+k_p)\omega_{load} - \omega_{ice}}{k_p} i_{reducer}$$

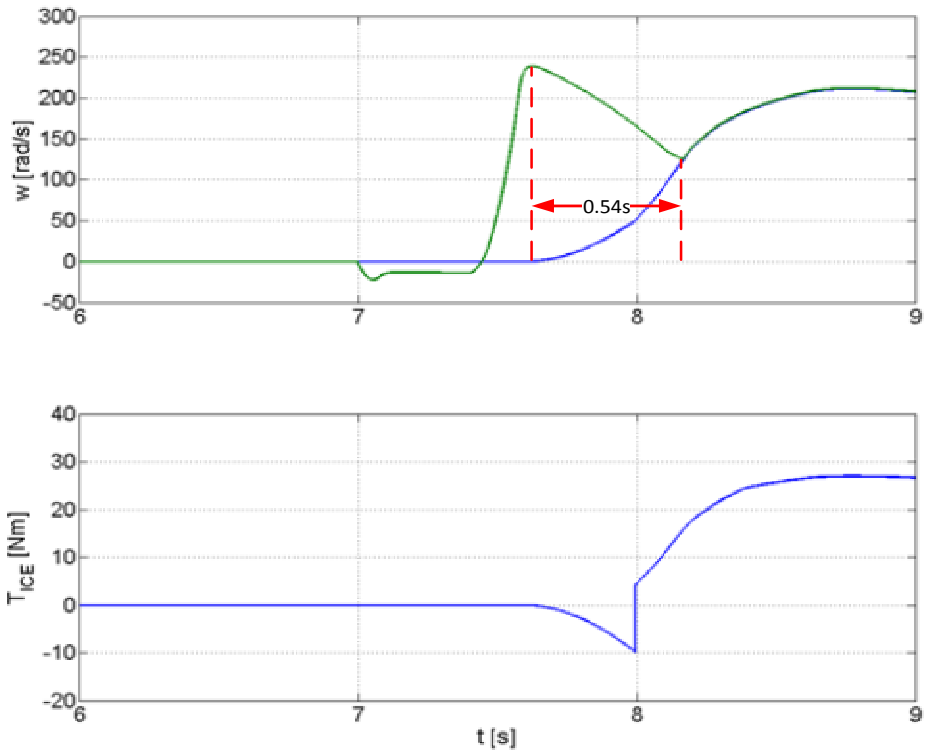
# Simulation results of ICE start

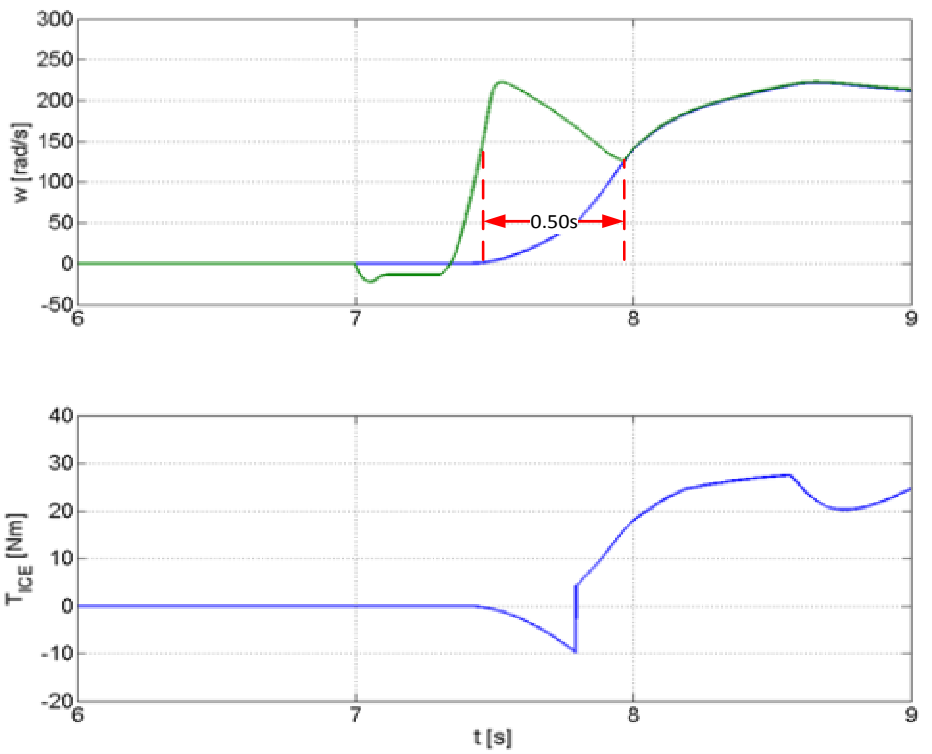



- Point A: Brake of sun shaft is released.
- Point B: The negative torque is generated on ring of planetary by braking the PM motor - the sun shaft is accelerating positively.
- Point C: The clutch on sun shaft is engaging with ICE shaft.
- Point C' to D: ICE shaft keeps accelerating while ICE has resistance torque.
- Point D: When ICE speed is over the threshold of starting, ICE starts and generates positive torque.
- Point E: Speed of sun shaft is synchronized to the ICE shaft, which means the clutch is fully engaged.

# Simulation results

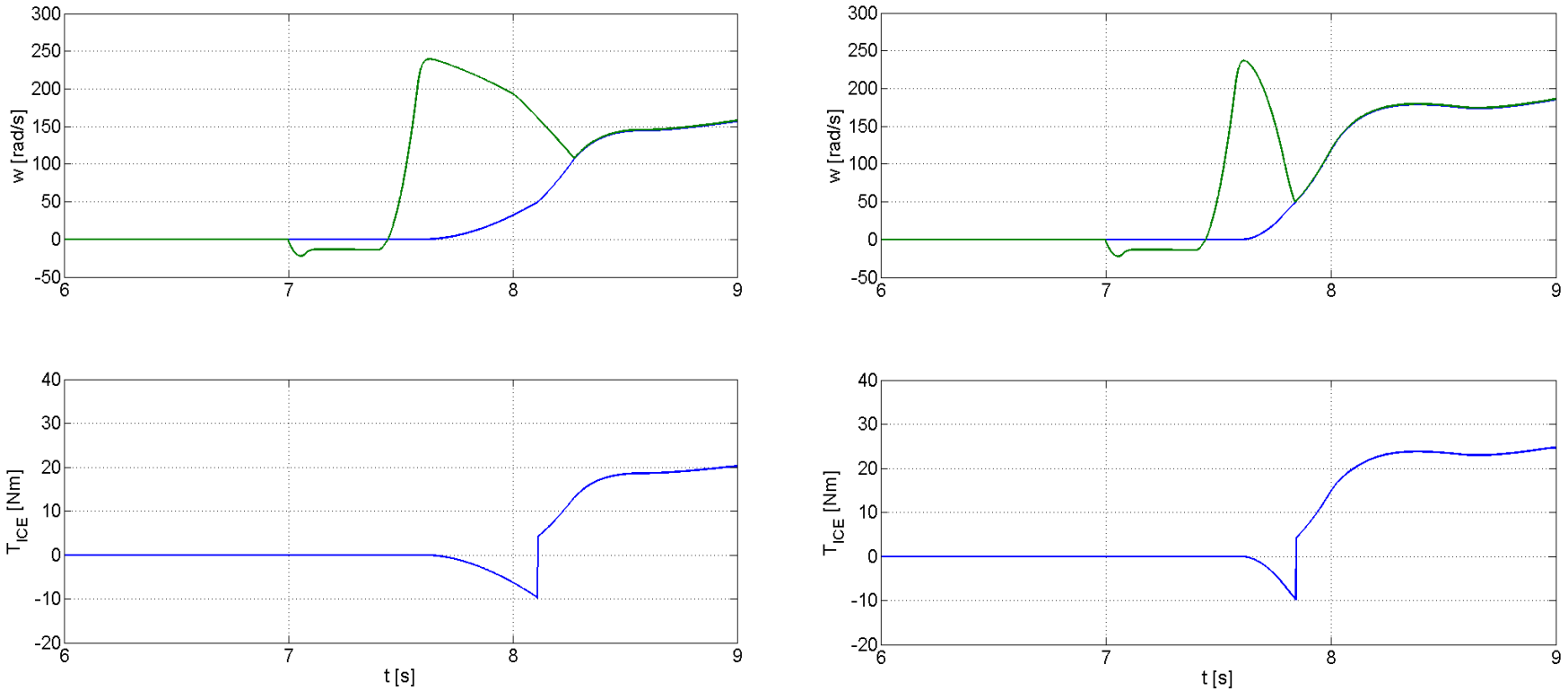
## Influence of different timing of electric motor braking and clutch engaging



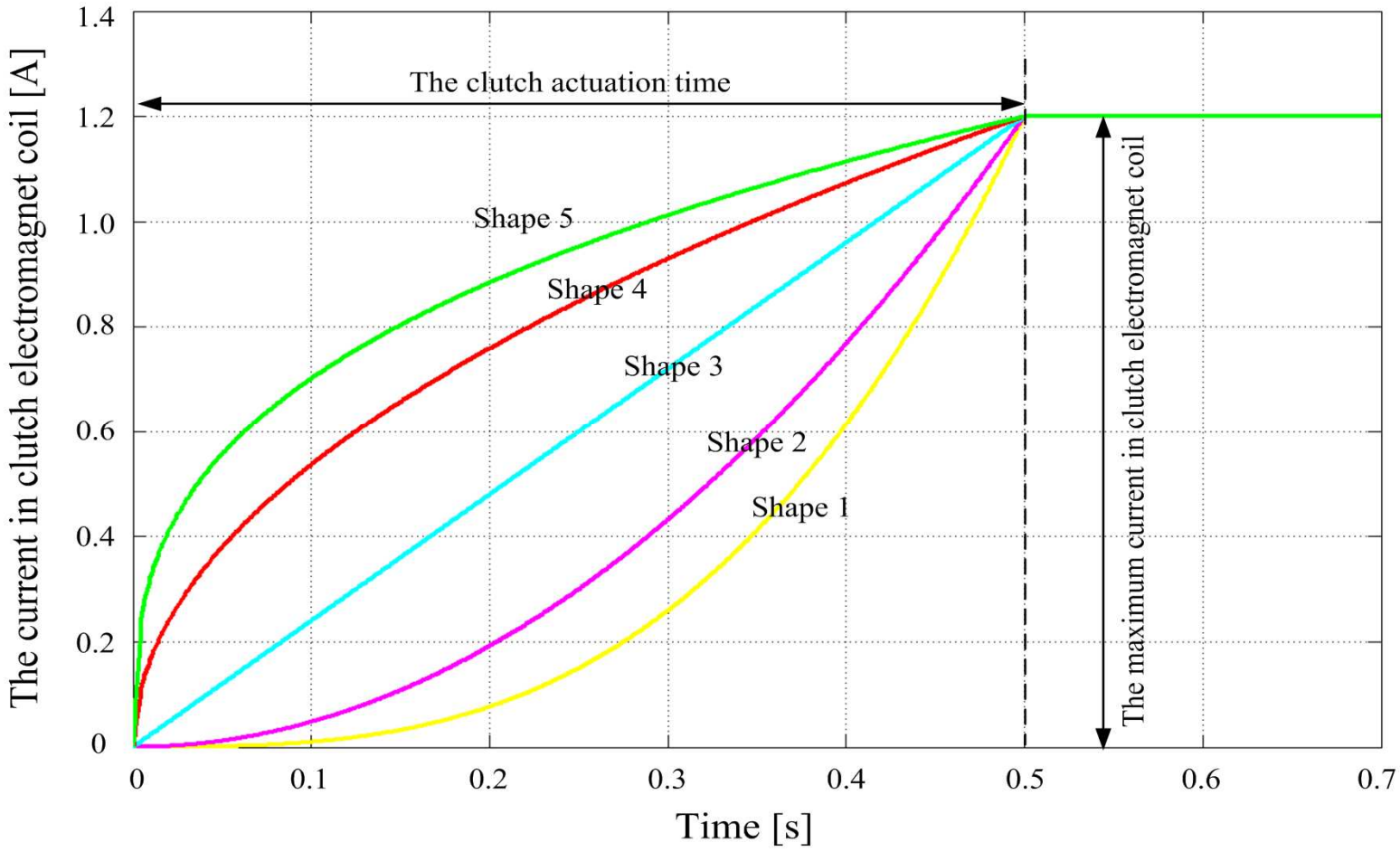



# Simulation results

## Influence of Different clutch actuation time

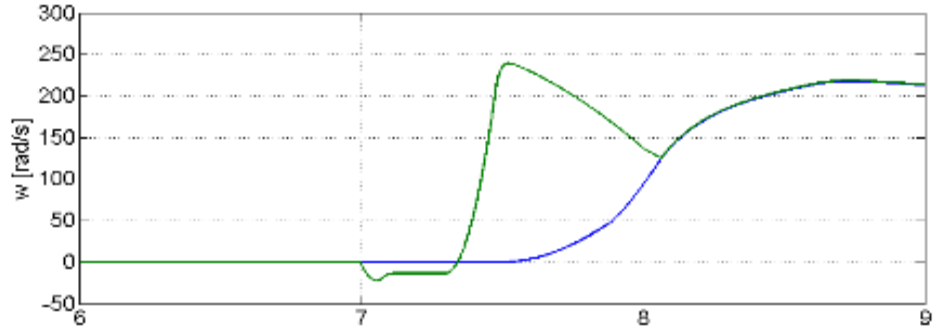


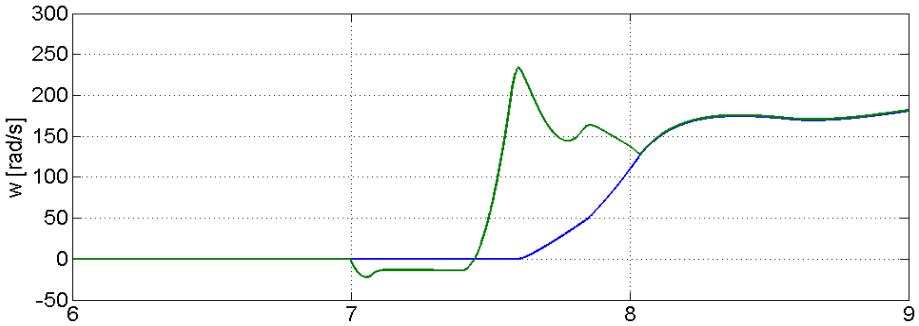
# Simulation results

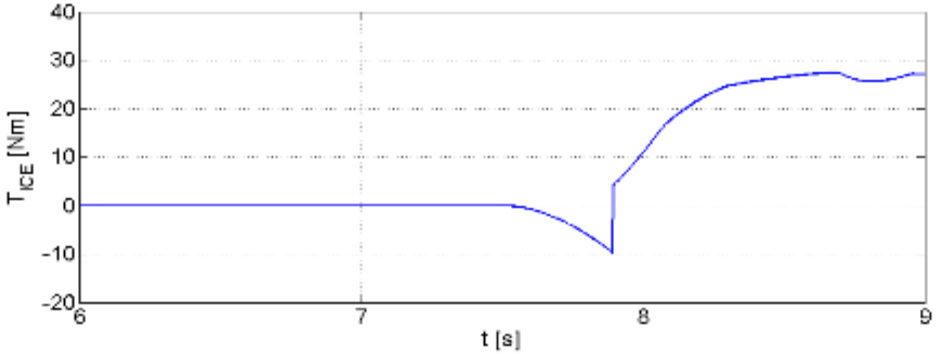


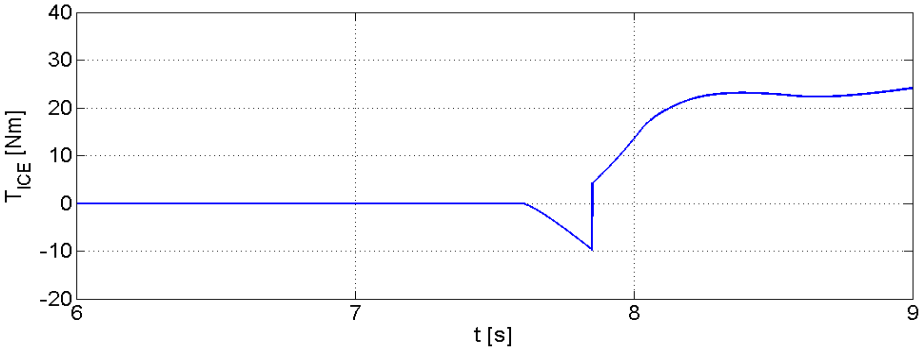
# Simulation results

## Influence of different shapes of increasing current in clutch electromagnet coil

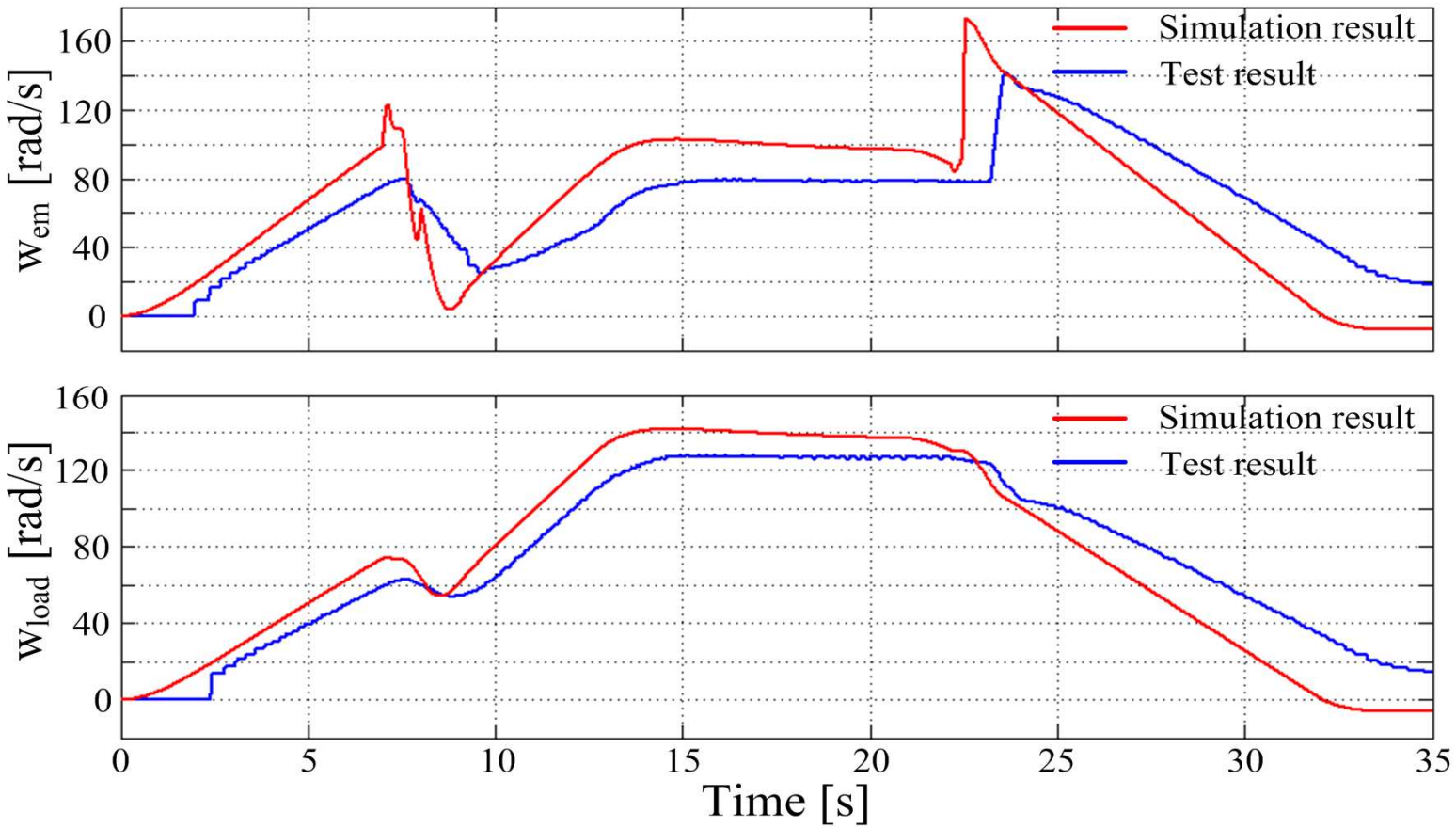


# Comparison of simulation and bench test results



# Conclusions

- Special clutch-brake system design is necessary for proper hybrid planetary power train operation;
- Proper control strategy for clutch is designed;
- Both different timing of electric motor braking and clutch engaging and current in clutch electromagnet coil could strongly influence the engine start performance which are proved by simulation results.
- The bench test results verify that the simulation model could simulate the behaviours of laboratory stand correctly.

# Thank you for attention!

Email: asz@simr.pw.edu.pl

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