The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION
BARCELONA
17th-20th November 2013

Development of engine clutch control for parallel HEVs

November 19th, 2013

Joonyoung Park

Hyundai Motor Company

Organized by

Hosted by

In collaboration with

Supported by

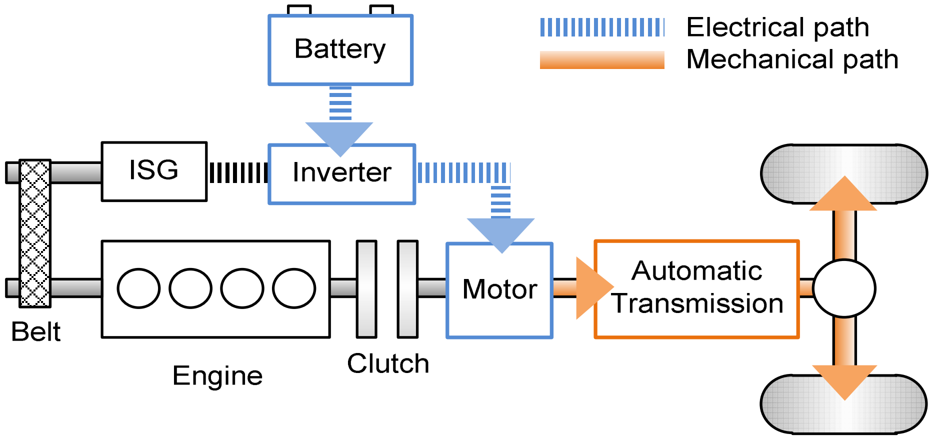
European Commission

Contents

- Introduction
- Clutch control for HEV mode changing
  - Syncronized engagement
  - Launch slip engagement
- Clutch variation learning
  - Offset, gain & linearity compensation
- Conclusion

Introduction

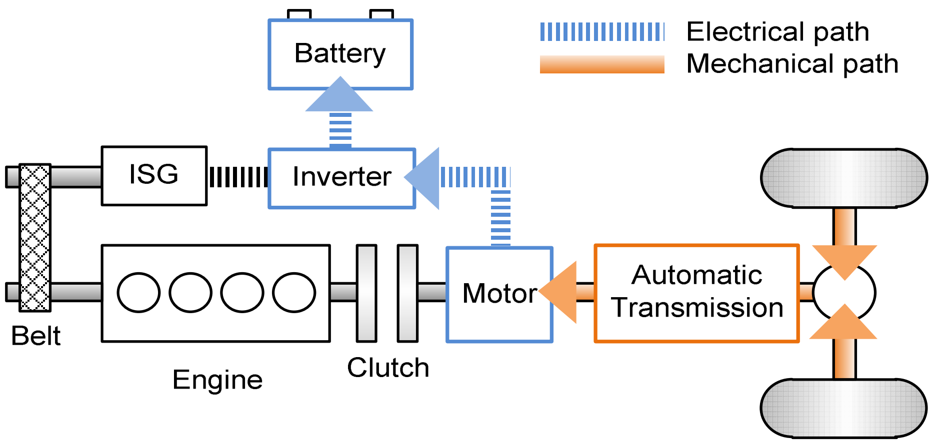
- Drivetrain configuration
  - Multiple operation modes are enabled by the clutch control



Pure electric mode

Introduction

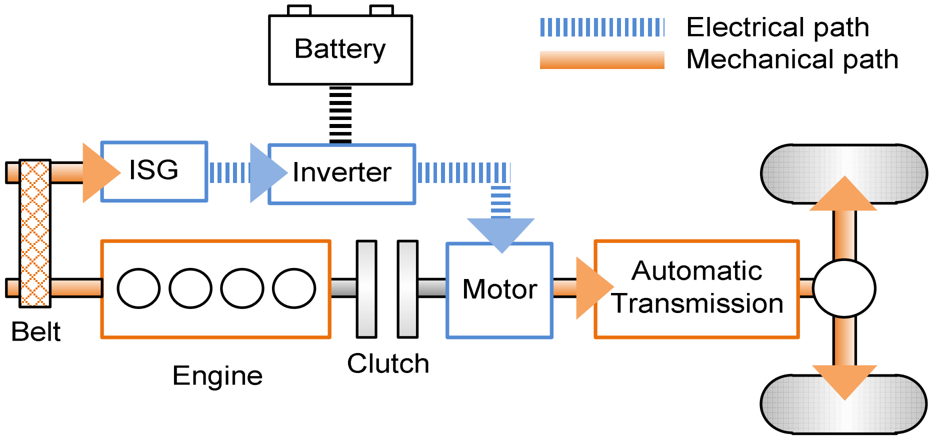
- Drivetrain configuration
  - Multiple operation modes are enabled by the clutch control



Regeneration mode

Introduction

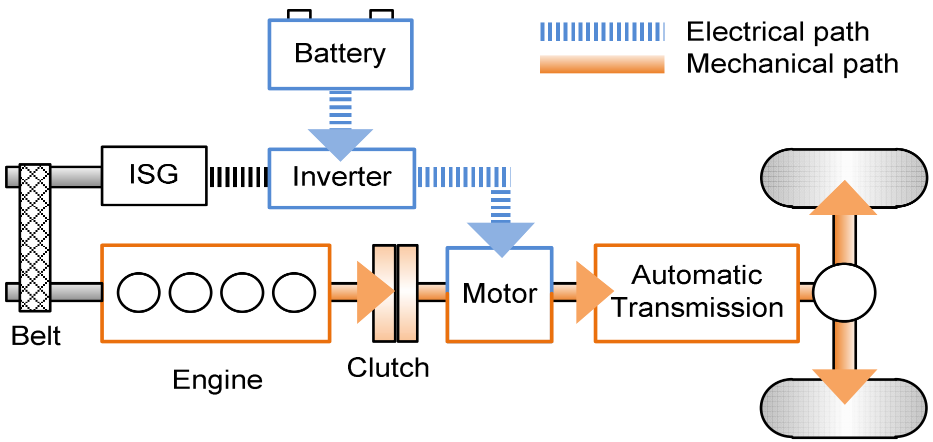
- Drivetrain configuration
  - Multiple operation modes are enabled by the clutch control



Series HEV mode

Introduction

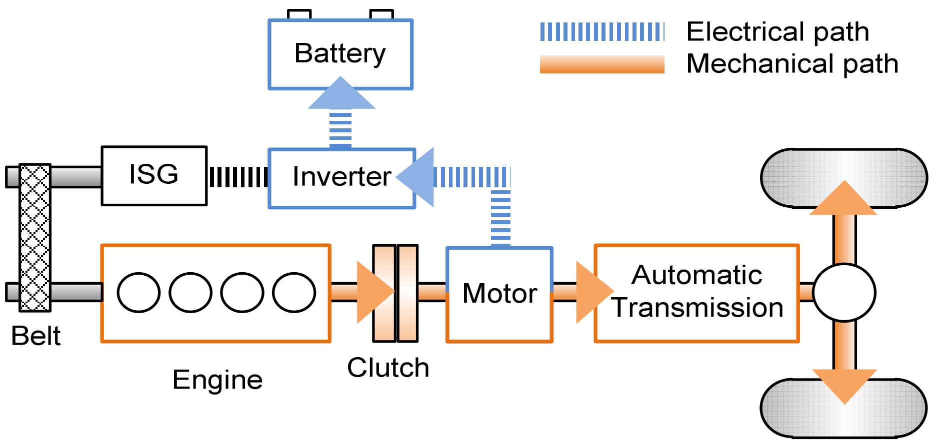
- Drivetrain configuration
  - Multiple operation modes are enabled by the clutch control



Parallel HEV mode (Assist)

Introduction

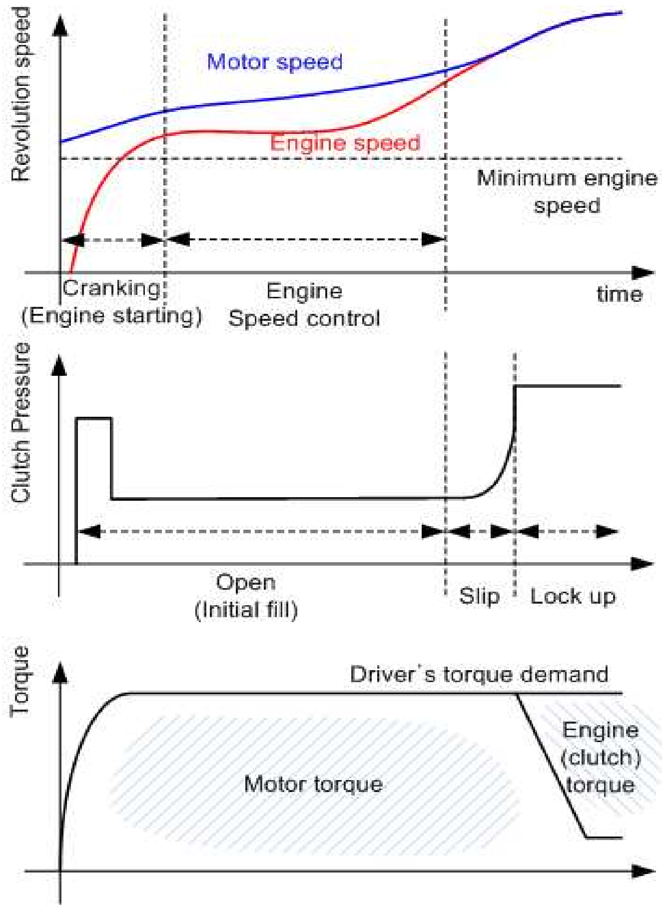
- Drivetrain configuration
  - Multiple operation modes are enabled by the clutch control



Parallel HEV mode (Charge)

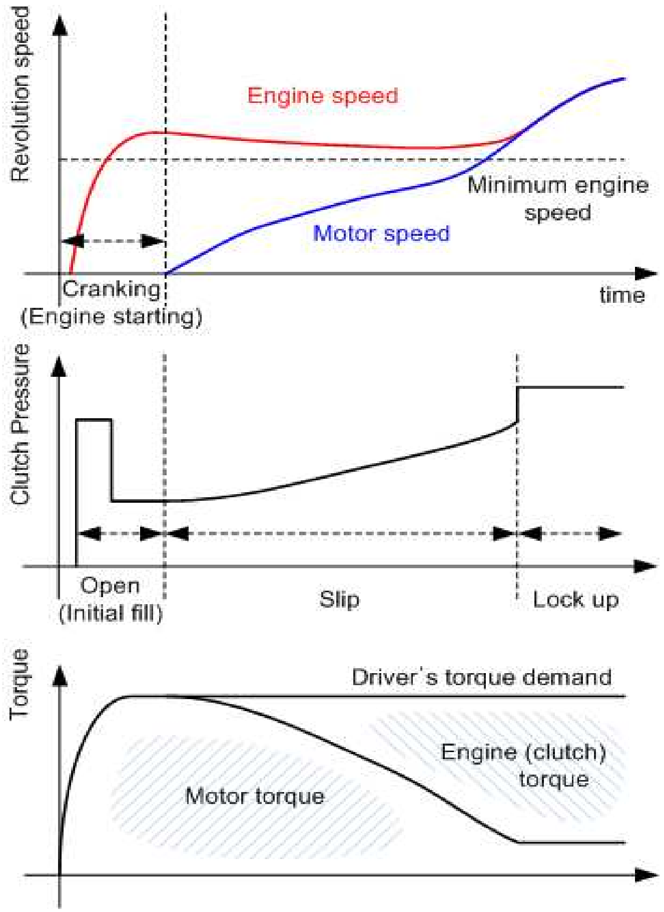
Clutch control for HEV mode changing

- Synchronized engagement
  - The engine & motor are synchronized before starting engaging
  - Minimum slip ensures drivability & durability
  - The vehicle is driven only by the motor before full engagement



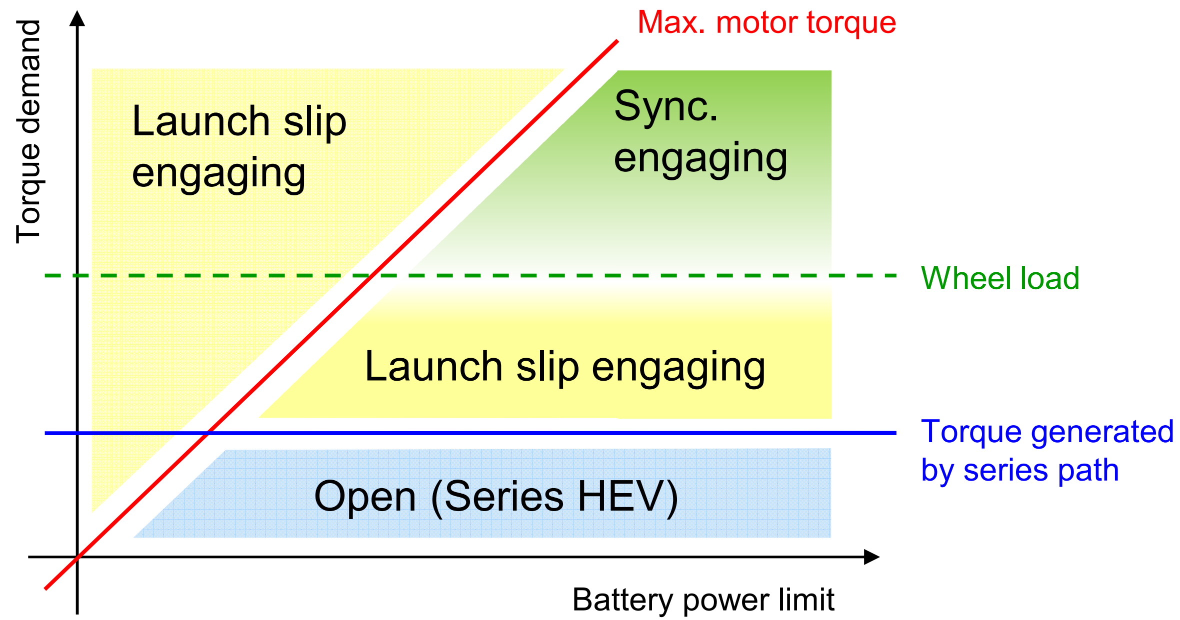
Clutch control for HEV mode changing

- Launch slip engagement
  - Engine torque is transferred through clutch slip
  - The vehicle can be driven by both engine & motor before full engagement
  - Precise hydraulic control is imperative



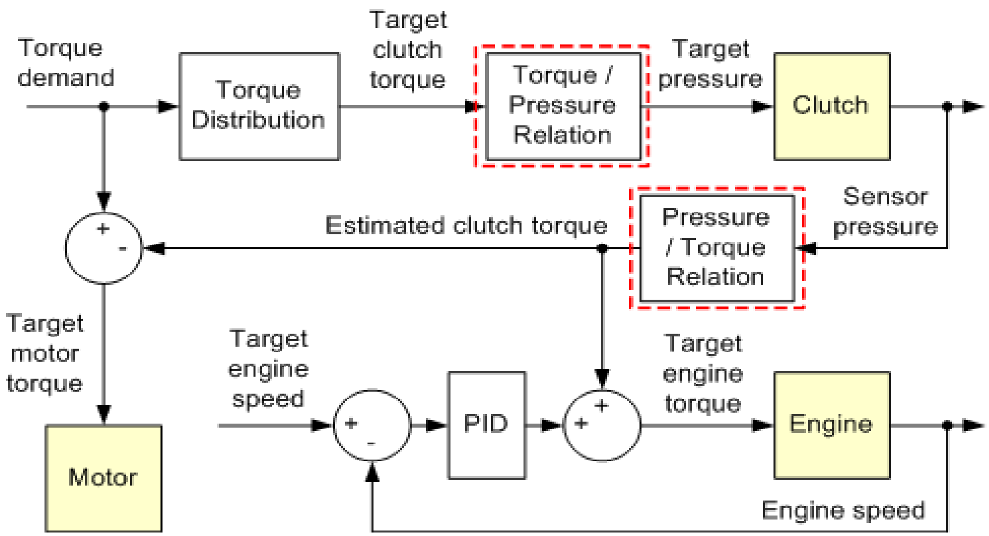
Clutch control for HEV mode changing

- Criterion for selecting engagement methods



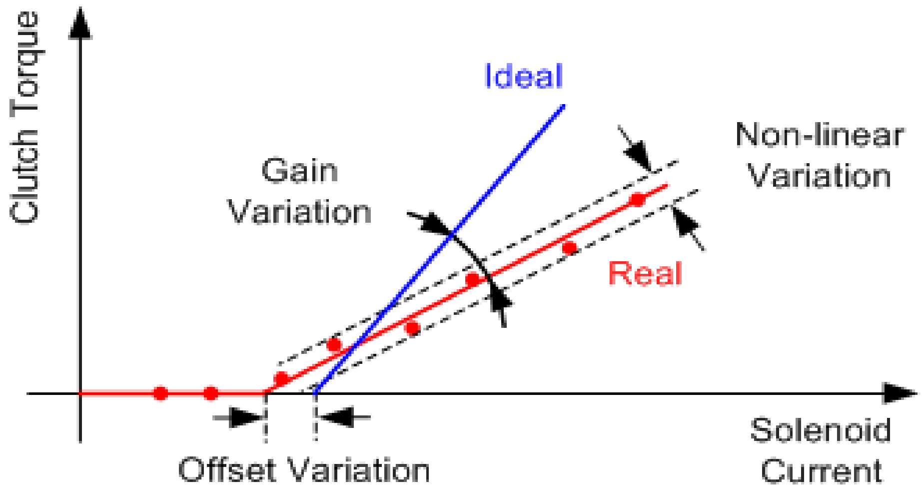
Clutch control for HEV mode changing

- Control scheme for Launch slip engagement
  - Accurate clutch torque model is required for engine speed stability & linear acceleration



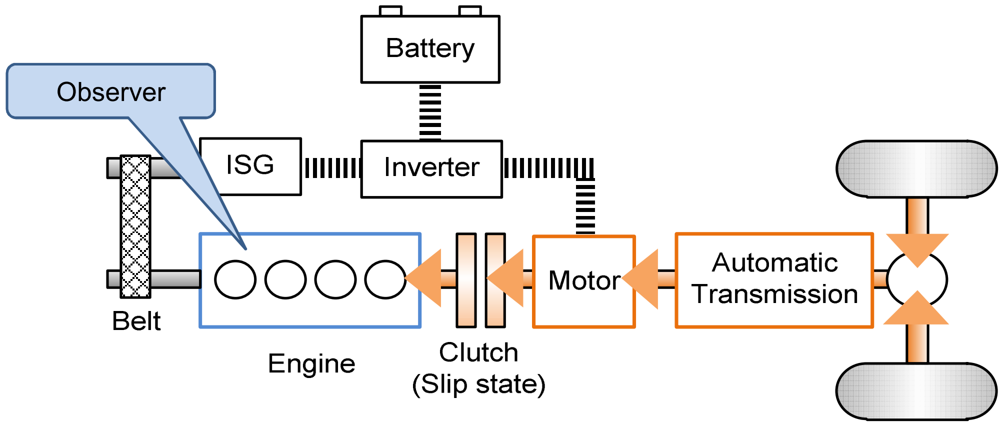
Clutch variation learning

- Clutch variation on pressure & torque domain



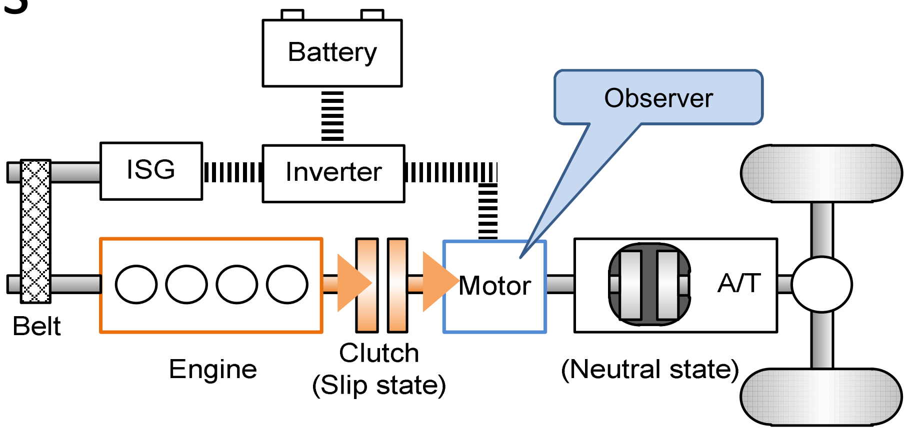
Clutch variation learning

- Conventional approaches based on engine torque
  - Inaccurate due to engine torque error
  - Easily distorted by external disturbances



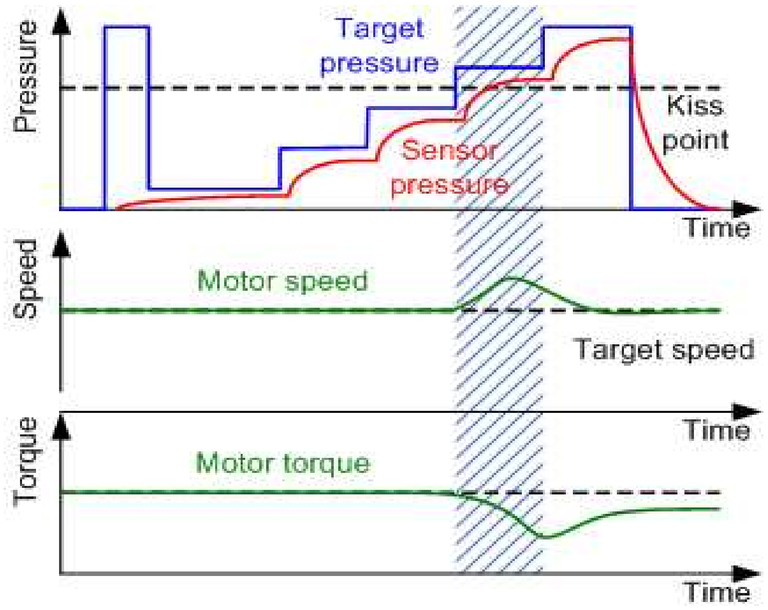
Clutch variation learning

- Proposed method based on motor torque
  - Compensate all variation terms accurately (Offset, Gain & Linearity)
  - Activated in parking/neutral state immune to disturbances



Clutch variation learning

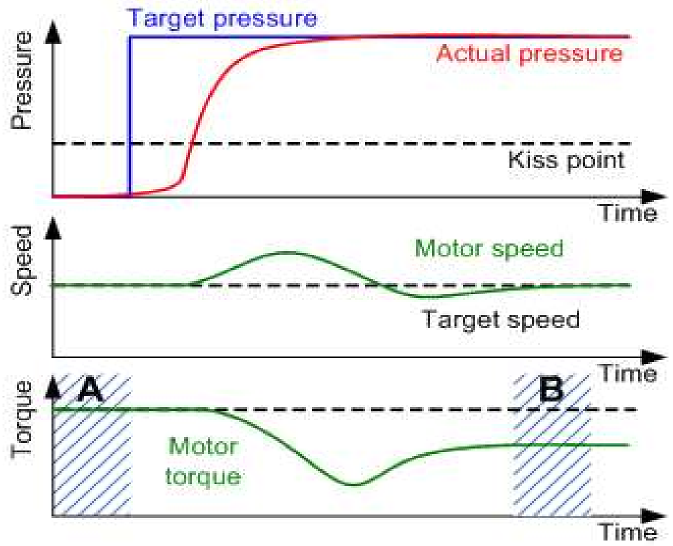
- Offset learning
  1) Control the engine & motor to have different speed
  2) Increase clutch pressure in step wise
  3) Observe motor state change to detect the kiss point



EVS 27 — The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION — BARCELONA 17th-20th November 2013

Clutch variation learning

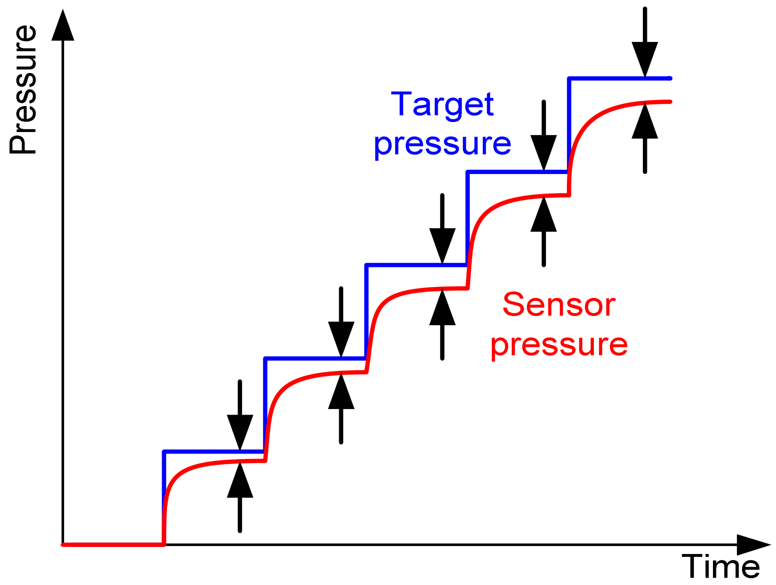
- Gain learning
  1) Control the engine & motor to have different speed
  2) Increase clutch pressure above the kiss point
  3) Compare motor torque and model torque to update the gain term



$$k = \frac{\textbf{Motor torque}}{\textbf{Model torque}} = \frac{A - B}{\mu \cdot N}$$

Clutch variation learning

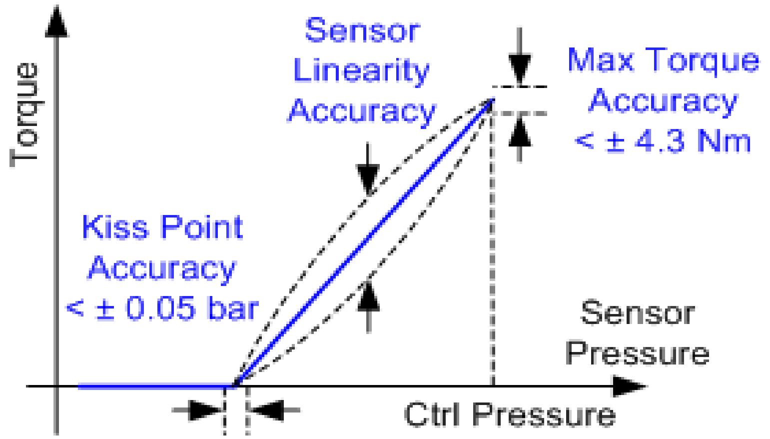
- Linearity learning
  1) Apply target pressure in step wise for the whole control range
  2) Extract error between the target & sensor values for every steps
  3) Build up correction map with the errors



EVS27 — The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION — BARCELONA 17th-20th November 2013

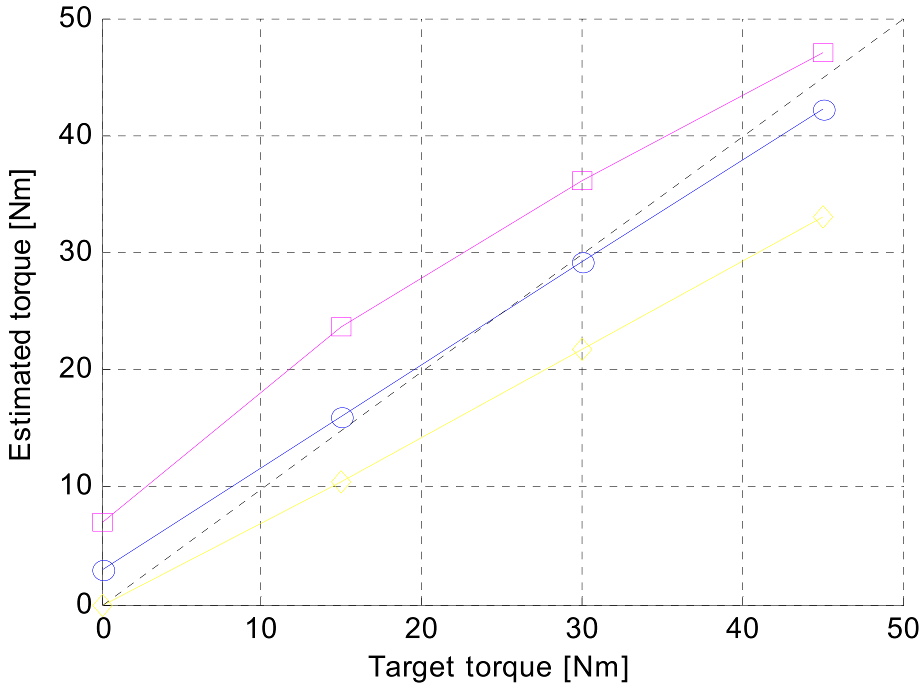
Clutch variation learning

- Effectiveness of the learning
  - Pressure & torque relation can be identified for whole control range
  - Accuracy is guaranteed in the level of the motor accuracy & sensor linearity

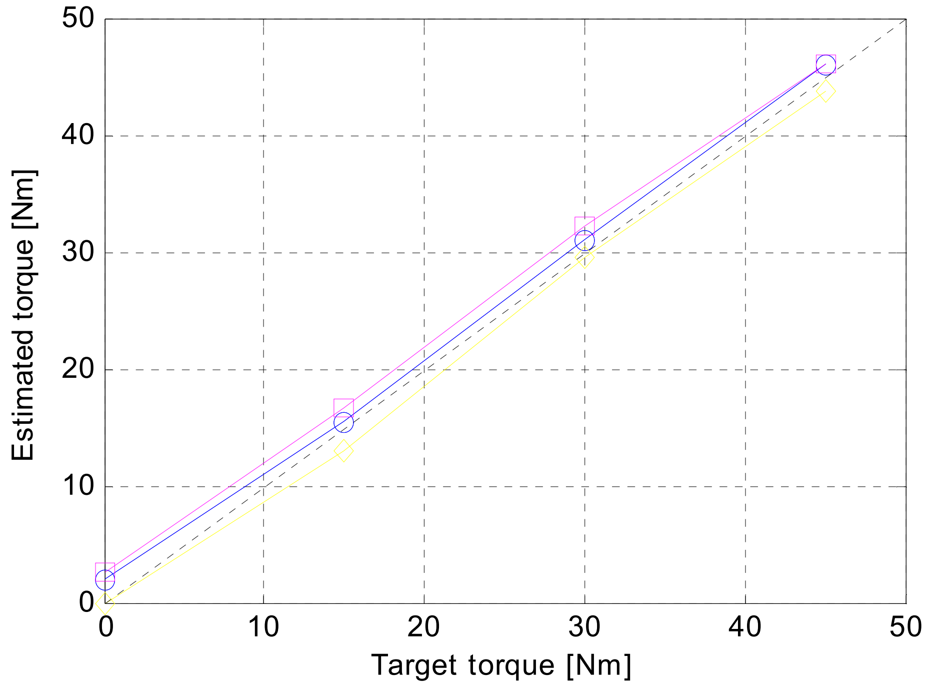


Clutch variation learning

- Learning results



Before correction



After correction

Summary

- Clutch control strategy was developed to change operation modes of a parallel HEV
  - Synchronized / Launch slip engagement
  - Criterion for selecting the adequate method
- Learning algorithm was proposed to compensate the variation of the HEV clutch
  - Employing the motor as an observer for accuracy
  - Compensating offset, gain & linearity variations