Dynamic co-simulation of start stop starter motor solenoid using Matlab & Edyson

by
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Agenda:

1. Start-Stop function overview
2. Starter Motor – Basic components
3. Starter motor starting circuit
4. Solenoid mathematical model
5. Start-Stop solenoid functions
6. Problem statement
7. Approach used to solve the problem by co-simulation
8. Dynamic Interaction between Magnetic & System level domain
9. Robustness check for given variables
10. Results of co-simulation [Sample]

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1. Overview : Start-Stop function

Vehicle with manual transmission

When the vehicle comes to a stop the engine is immediately switched off when the gear lever is in neutral and the clutch pedal is released

Activating the clutch pedal once again restarts the engine automatically.

Vehicle with automatic transmission

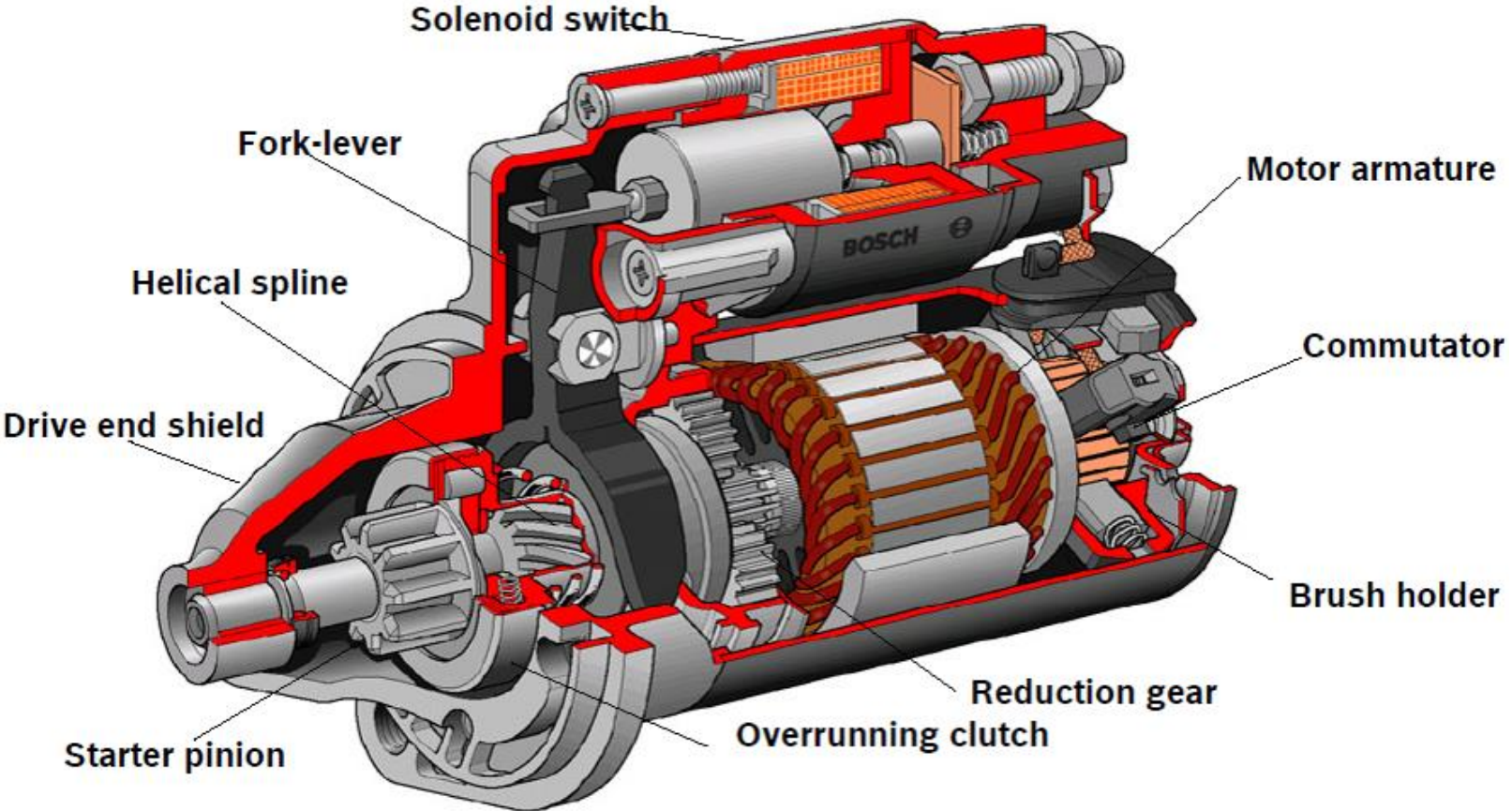After the brake pedal has been depressed, the engine is switched off as soon as the vehicle comes to a stop.

When the brake pedal is released, the engine restarts rapidly and reliably
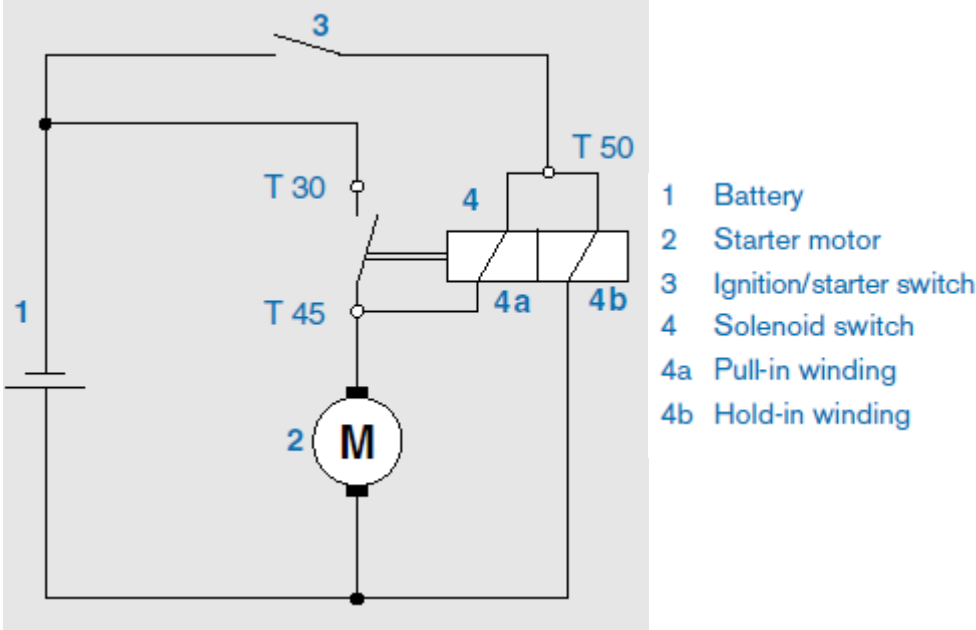
Reduction of fuel & CO_2 up to 8%

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2. Starter Motor – Basic components

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3. Starter Motor starting circuit

General Starting circuit

1 Battery
2 Starter motor
3 Ignition/starter switch
4 Solenoid switch
4a Pull-in winding
4b Hold-in winding

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4. Solenoid mathematical model

The solenoid behaviour is characterized by using Simscape language.

It has electrical pins on left side which are input(P) and ground(N).

It has input pin on right side which accepts magnetic flux.

It has output pin which produces total ampere-turns (AT) depending up on the dynamic current.
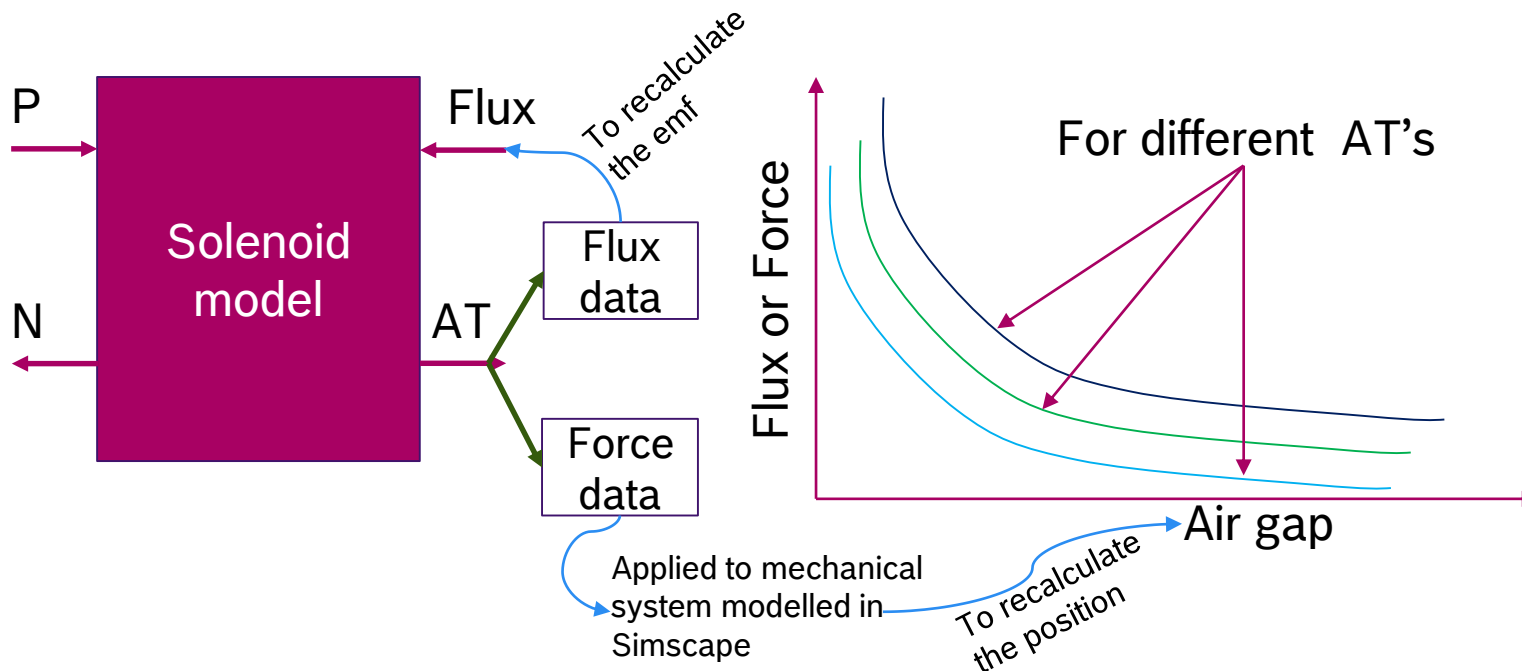

The magnetic force and flux lookup tables need position and ampere turns as input in order to get relevant force and flux data for next simulation time steps.

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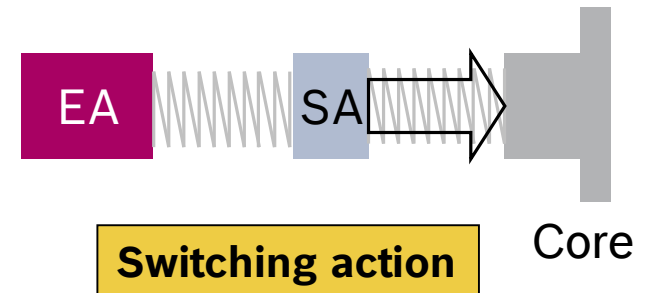
5. Start−Stop Solenoid functions

▶ **Function Engage Only**

  ▶ Pull the engage armature to the switching armature

  ▶ Keep the switch armature in rest position

  ▶ Energize only engage winding

EA SA

Engagement action   Core
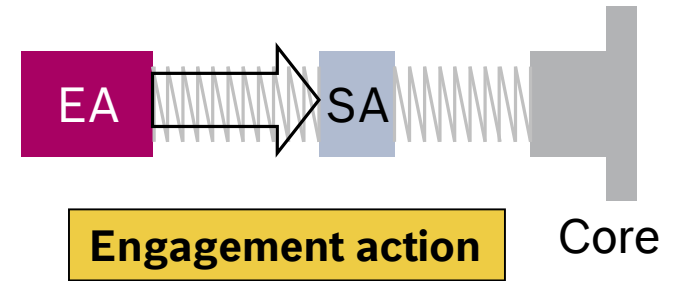
> **Both the actions can be performed independently in order to fulfil the requirement of CoM [Change of Mind] conditions**

▶ **Function Switch Only**

  ▶ Pull switch armature to the magnetic core

  ▶ Keep the engage armature in rest position

  ▶ Energize only switch winding

EA SA

Switching action   Core

▶ **Function key start**

  ▶ Engagement action should follow the switching action.

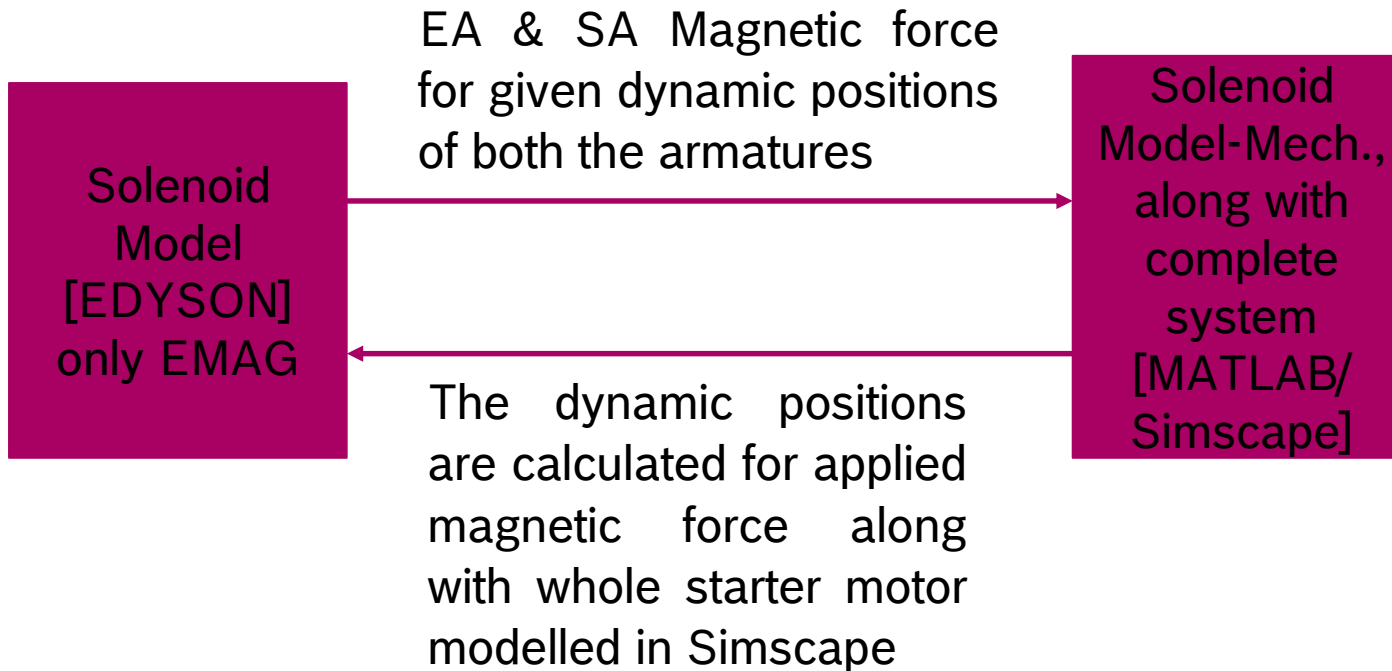 ▶ Both the windings need to be energized appropriately.

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6. Problem statement

- The look up table method holds good for single moving armature against stationary magnetic core.

- If there are two movable armatures the generation of force and flux data tables will become more complex since we do not have fixed reference frame for EA because SA can also move with in its design space. Similarly for SA we should also know the dynamic position of EA in-order to calculate the net magnetic force acting on SA.

- The complexities are
    - When engage winding is energized for engagement action, the switch armature dynamic position should be known.
    - When switch winding is energized for switching action, the engage armature rest position should be known.
    - During key start , engage windings will be energized first and with time delay switch winding will be energized, depending up on the positions of armatures and net magnetic force balance the armatures will move relatively and together towards fixed magnetic core.
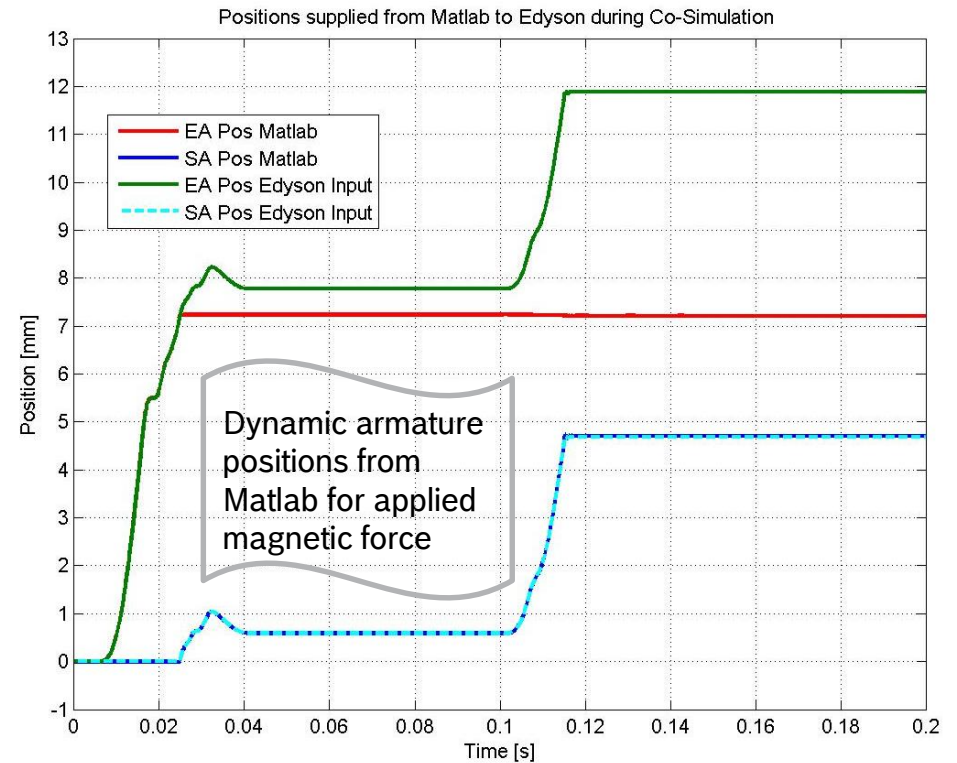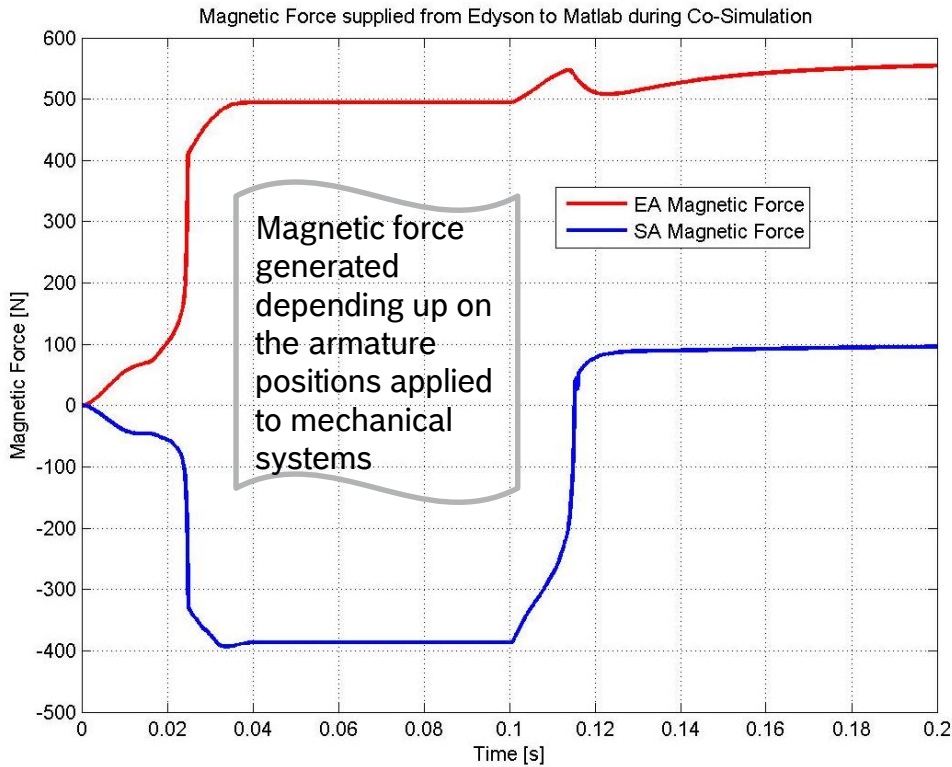
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7. Approach used to solve the problem

Co-simulation is the efficient way to solve this problem…

	EA & SA Magnetic force for given dynamic positions of both the armatures →	
Solenoid Model [EDYSON] only EMAG		**Solenoid Model-Mech., along with complete system [MATLAB/ Simscape]**
	← The dynamic positions are calculated for applied magnetic force along with whole starter motor modelled in Simscape	

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8. Dynamic Interaction between Magnetic & System level domain

Magnetic force generated depending up on the armature positions applied to mechanical systems

Dynamic armature positions from Matlab for applied magnetic force

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9. Robustness check

Pinion to Ring gear distance

Temperature
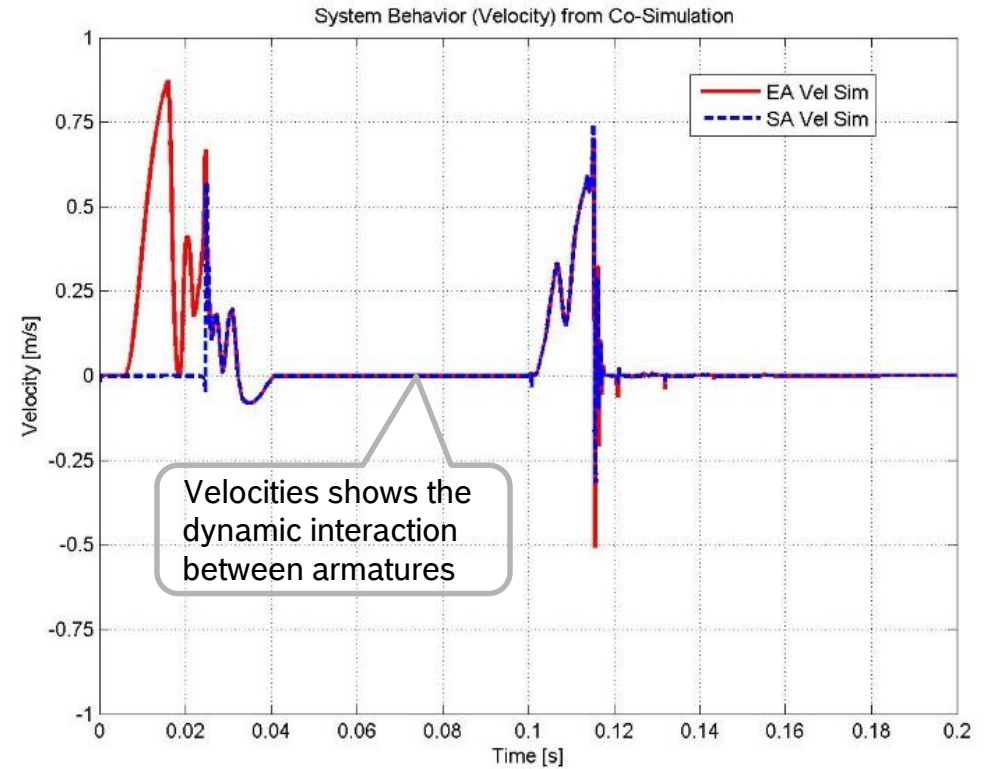
Power net conditions

Friction

Magnetic force

Spring force

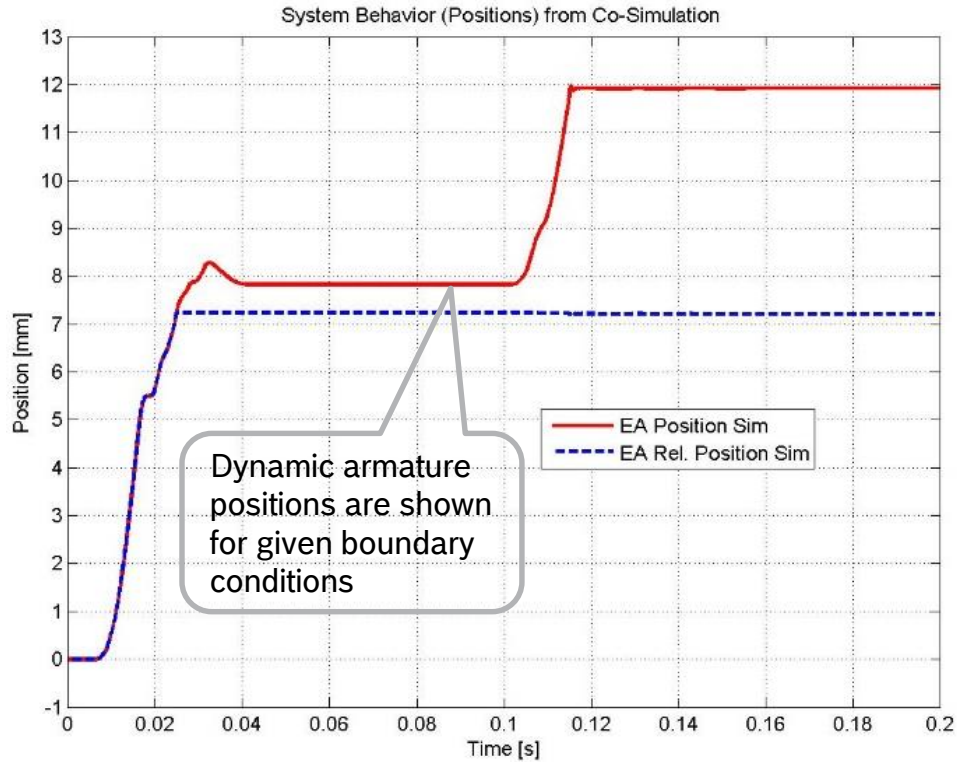BOSCH
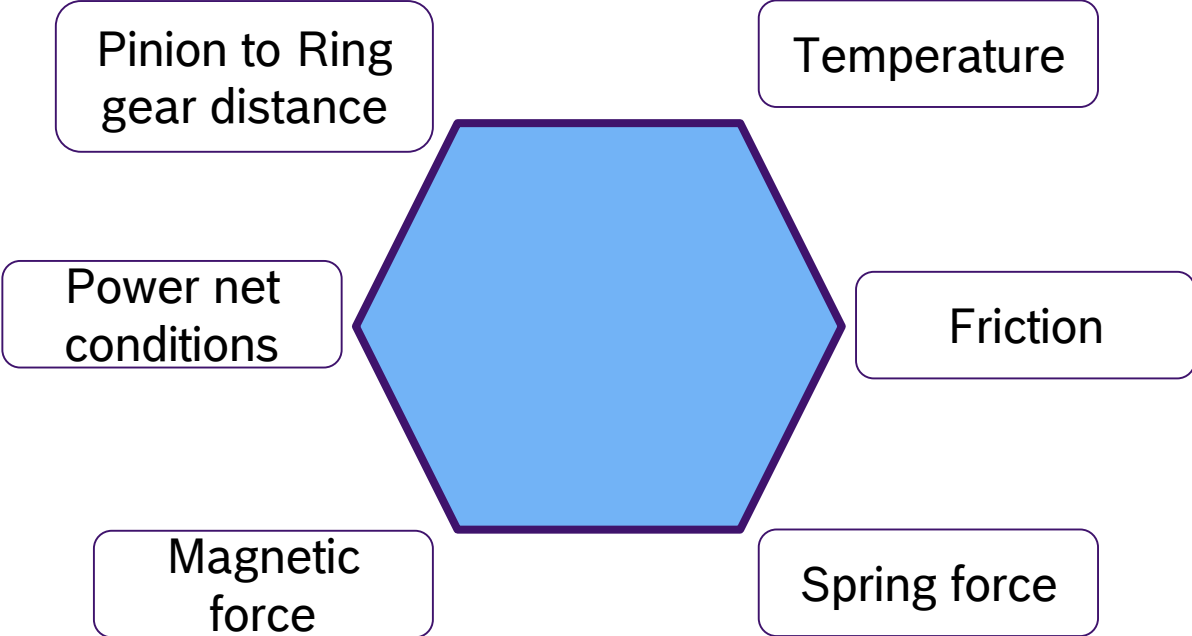
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10. Dynamic Co-Simulation Results

System Behavior (Positions) from Co-Simulation

Dynamic armature positions are shown for given boundary conditions

System Behavior (Velocity) from Co-Simulation

Velocities shows the dynamic interaction between armatures

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Thank you and have a nice day

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