arsenal research
An Enterprise of the Austrian Research Centers.

Simulation of Electric Machines and Drives using the Machines and the SmartElectricDrives Libraries
Part II

J.V. Gragger
arsenal research, Vienna

Mo. 03.03.2008

Room H5, Time 8:15 - 11:00

Contents

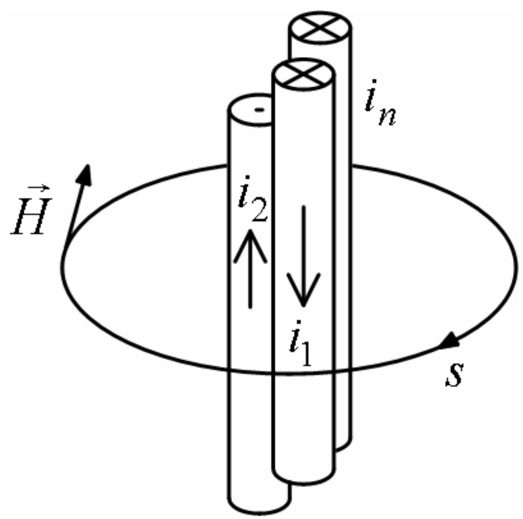
arsenal research
An Enterprise of the Austrian Research Centers.

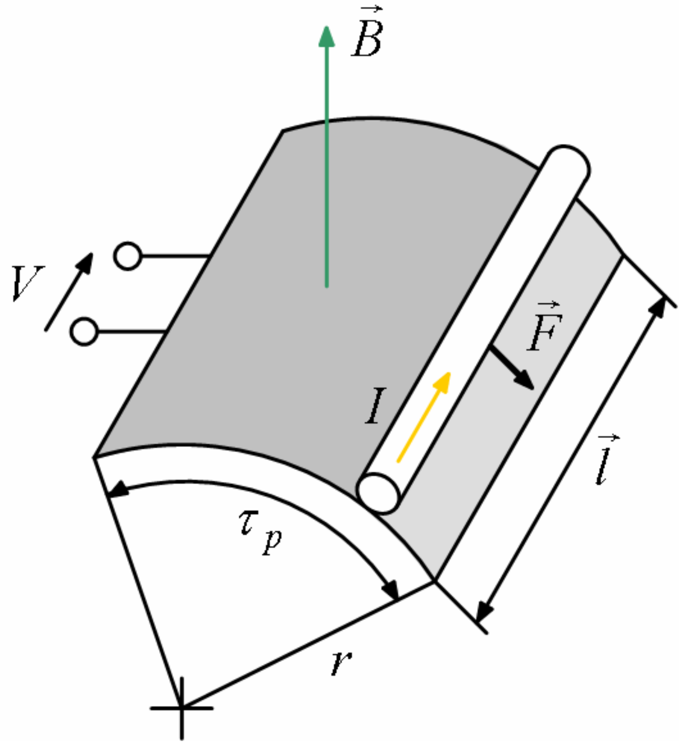
Contents

Contents

Basics and Terms of Electrical Engineering

Chapter 1

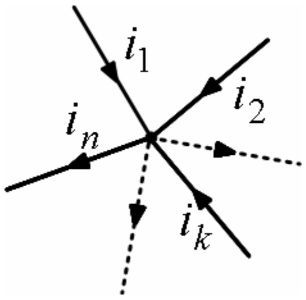




Kirchhoff's Laws

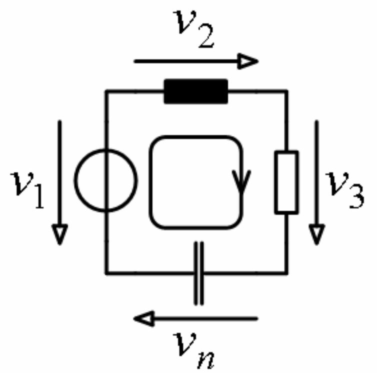
- The algebraic sum of all currents entering and exiting a node equals zero.

$$\sum_{k=1}^{n} I_k = 0 \qquad n = \text{number of currents}$$



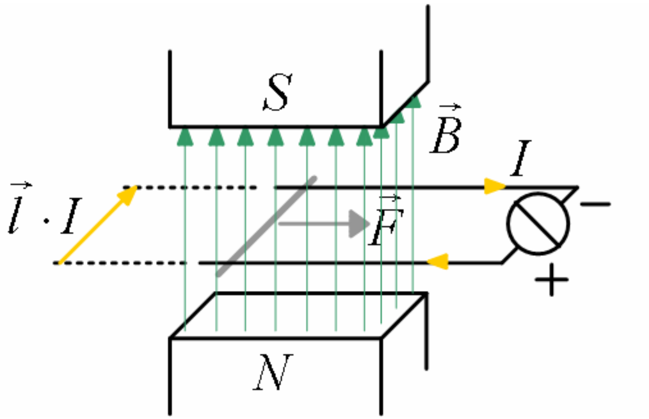
- The algebraic sum of all voltages in a loop equals zero.

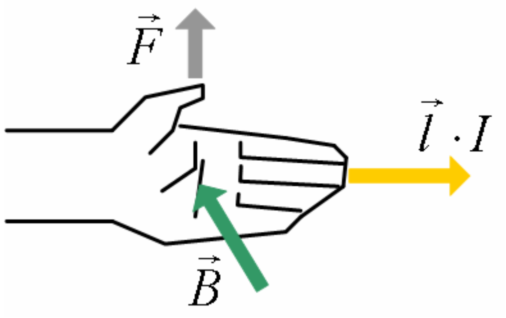
$$\sum_{k=1}^{n} V_k = 0 \qquad n = \text{number of voltages}$$



Lorentz Force

- Force on a current carrying wire in a magnetic field



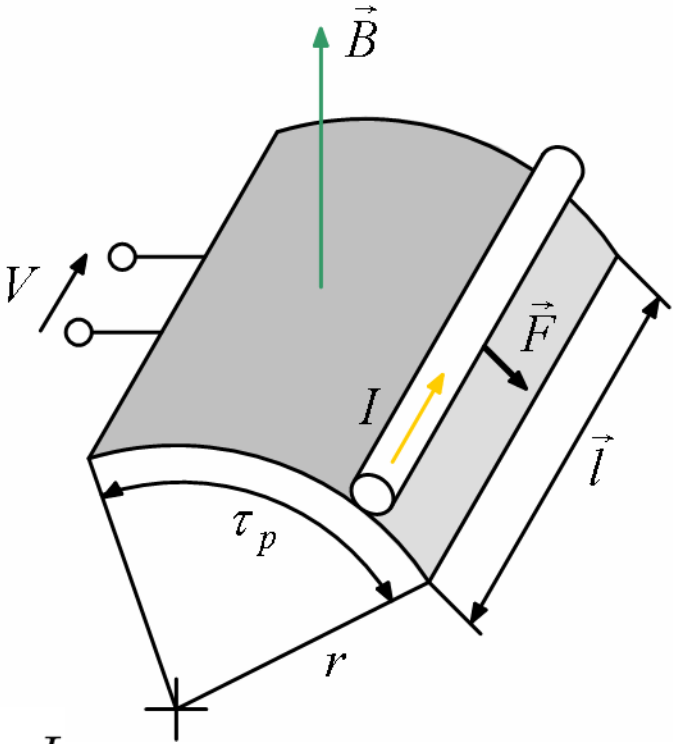


Left Hand Rule

$$\vec{F} = I \left(\vec{l} \times \vec{B} \right)$$

Principle of Electric Machines

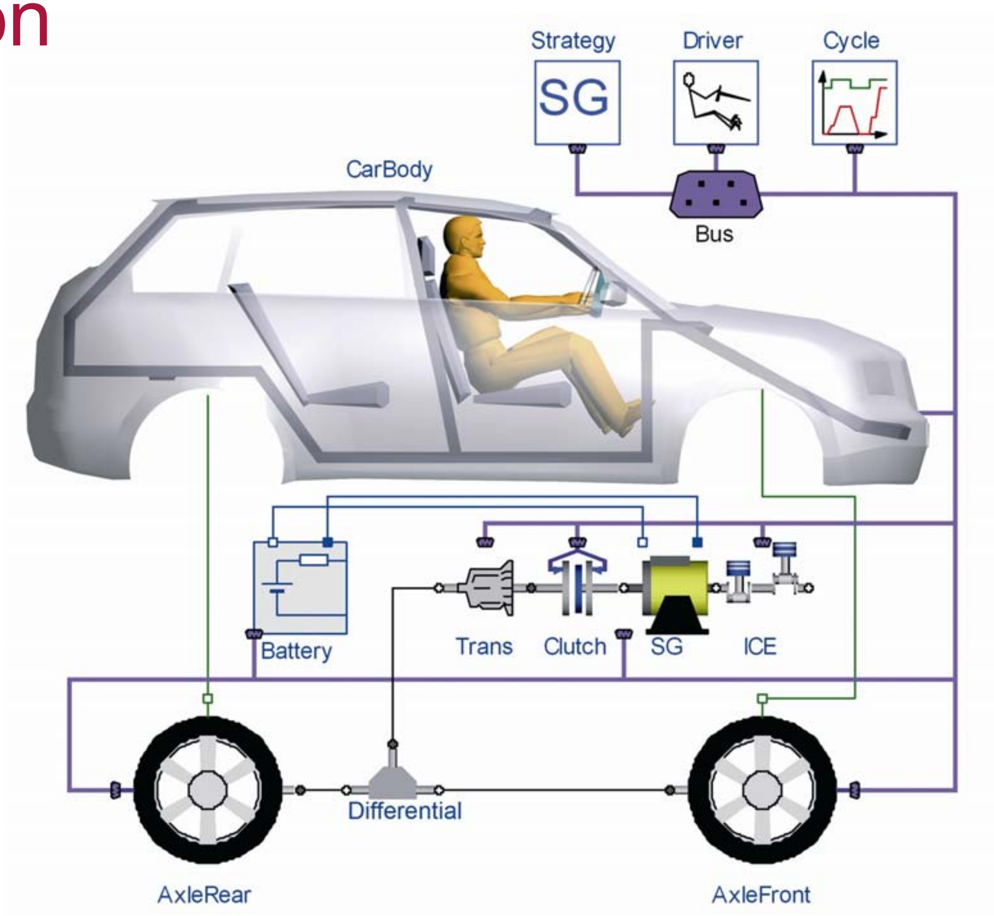
- Flux linkage
  - $\Psi = B \cdot \tau_p \cdot l$
- Speed
  - $v = r \cdot \Omega_m$
- Induced Voltage
  - $V = B \cdot l \cdot v = \frac{r}{\tau_p} \cdot \Psi \cdot \Omega_m$
- Torque
  - $T = \left| \vec{F} \times \vec{r} \right| = I \cdot B \cdot l \cdot r = \frac{r}{\tau_p} \cdot \Psi \cdot I$



arsenal research
An Enterprise of the Austrian Research Centers.

The SmartElectricDrives Library - Introduction

Chapter 2



arsenal research
An Enterprise of the Austrian Research Centers.

Overview

- Major components of the SED library
  - Asynchronous induction machines, permanent magnet synchronous induction machines, dc machines
  - Field oriented control, brushless dc control
  - Converters (ideal, switching), sources (batteries, supercaps, fuel cells)
- Application examples
  - Hybrid electric vehicles (HEVs), electric vehicles (EVs)
  - Starter / generator, electrically operated auxiliaries
  - Machine-tools and robotics
  - Paper mills, mining
  - Construction machinery, assembly lines
  - etc.

arsenal research
An Enterprise of the Austrian Research Centers.

Application Specific Drive Design I

Practical Considerations

- Various technologies (e.g. batteries, supercaps, fuel cells etc.)
- Matching the right components based on their specifications
- Maximizing the efficiency of the entire drive system
- Comprehensive analysis of dynamic effects
- Component security (Currents, Voltages, etc.)
- Controller calibration (Dynamic characteristics and static characteristics)

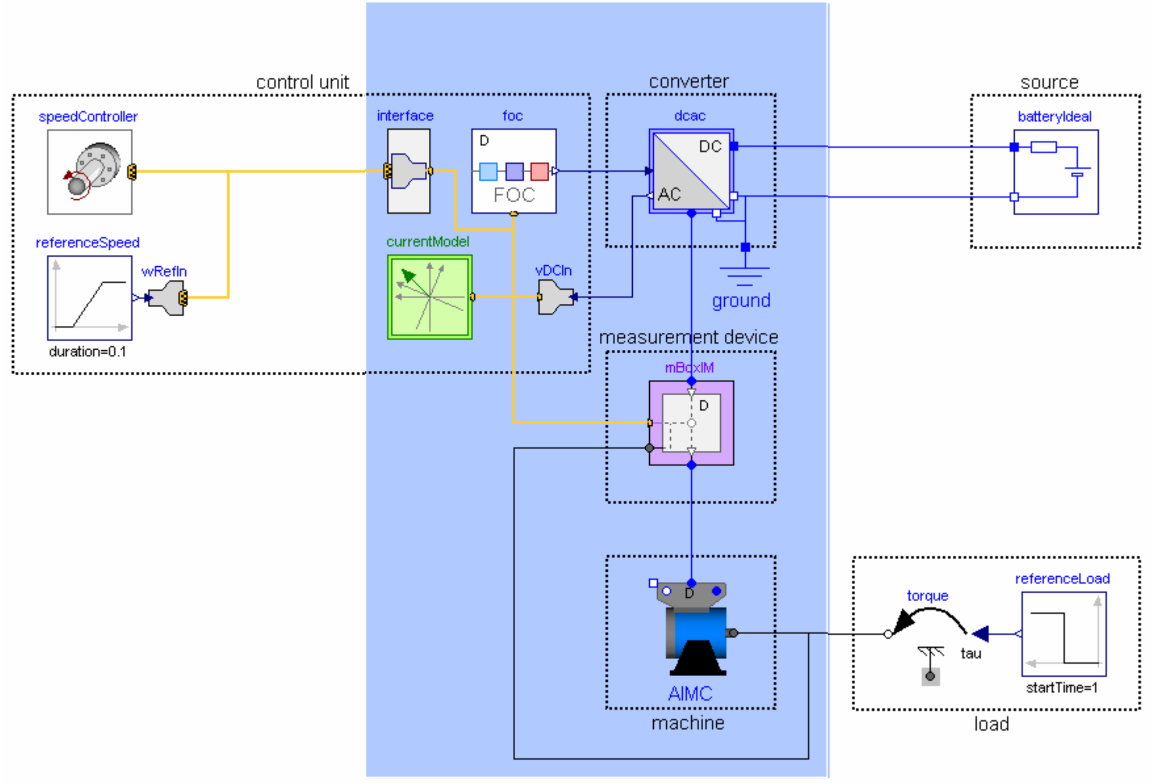
Application Specific Drive Design II

Software Requirements

- Hybrid systems
  - Simulation of mechanical and electrical components at the same time
  - User friendliness
- High processing effort
  - Definition of different layers of abstraction
- Short development cycles
  - Automation of development procedures with ‘Ready to use’ - models

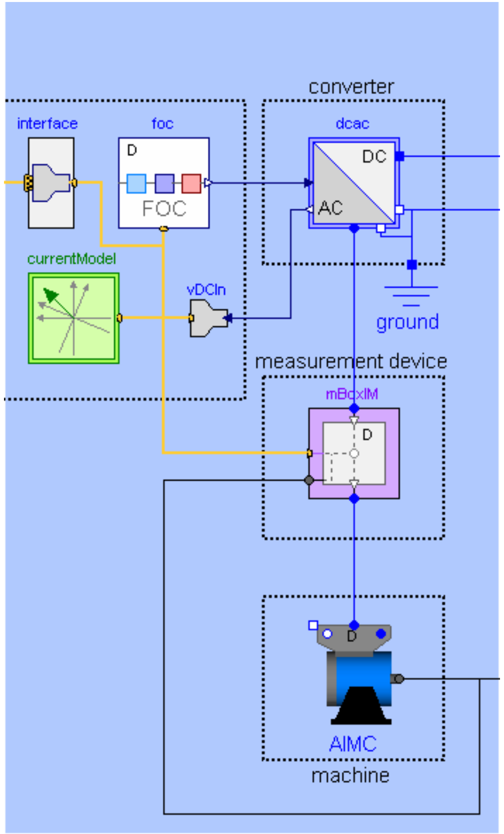
Components of Electric Drives

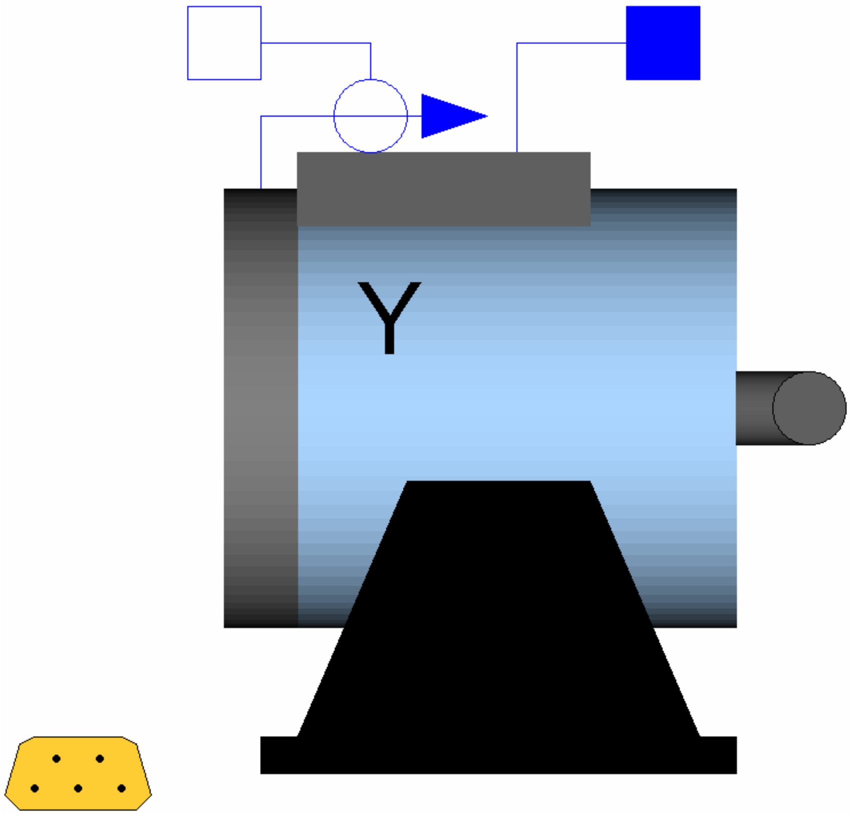
- Sources
- Converters
- Electric machines
- Measurement devices
- Control units
- Mechanical loads



arsenal research
An Enterprise of the Austrian Research Centers.

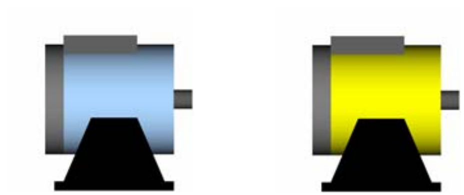
‘Ready to use’ Models



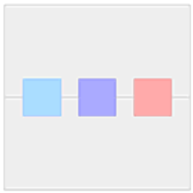


‘Ready to use’ Models

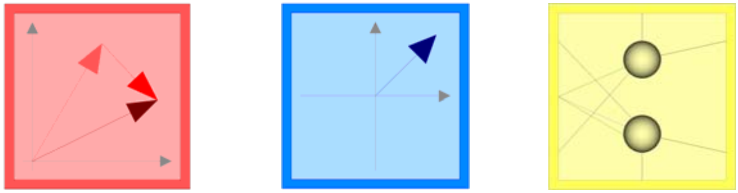
- Models of controlled machines



- Models of drive controllers

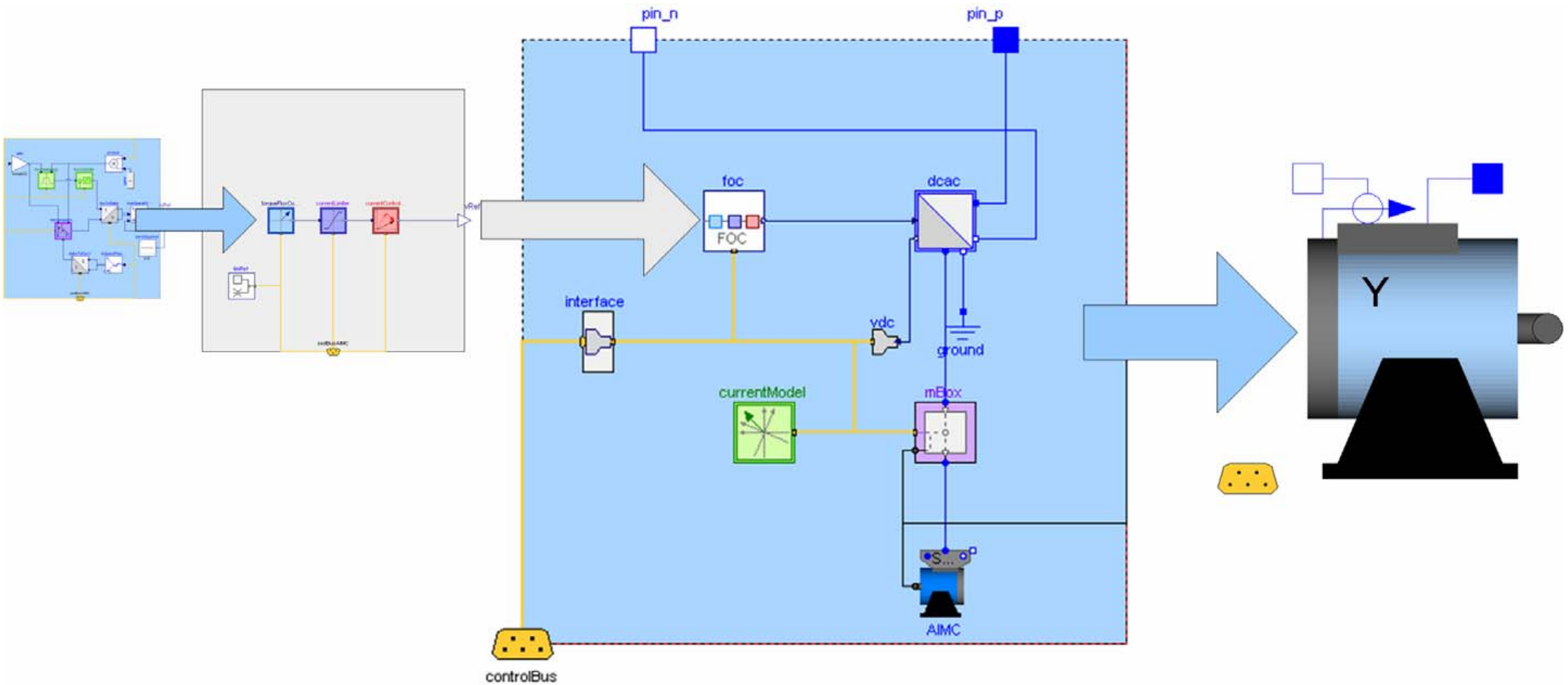


- Models of elementary controllers

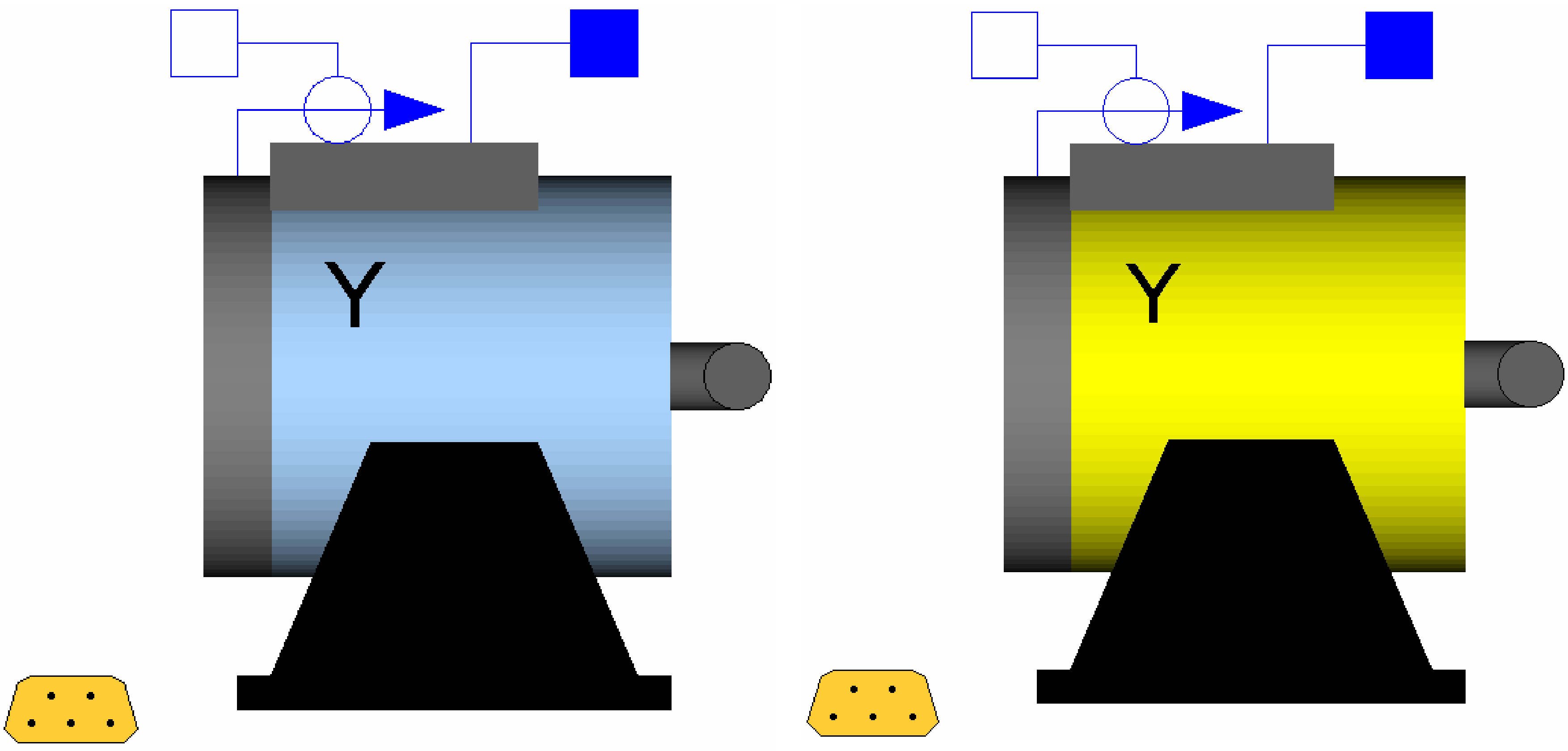


arsenal research
An Enterprise of the Austrian Research Centers.

Torque Controlled Induction Machine with Integrated Converter

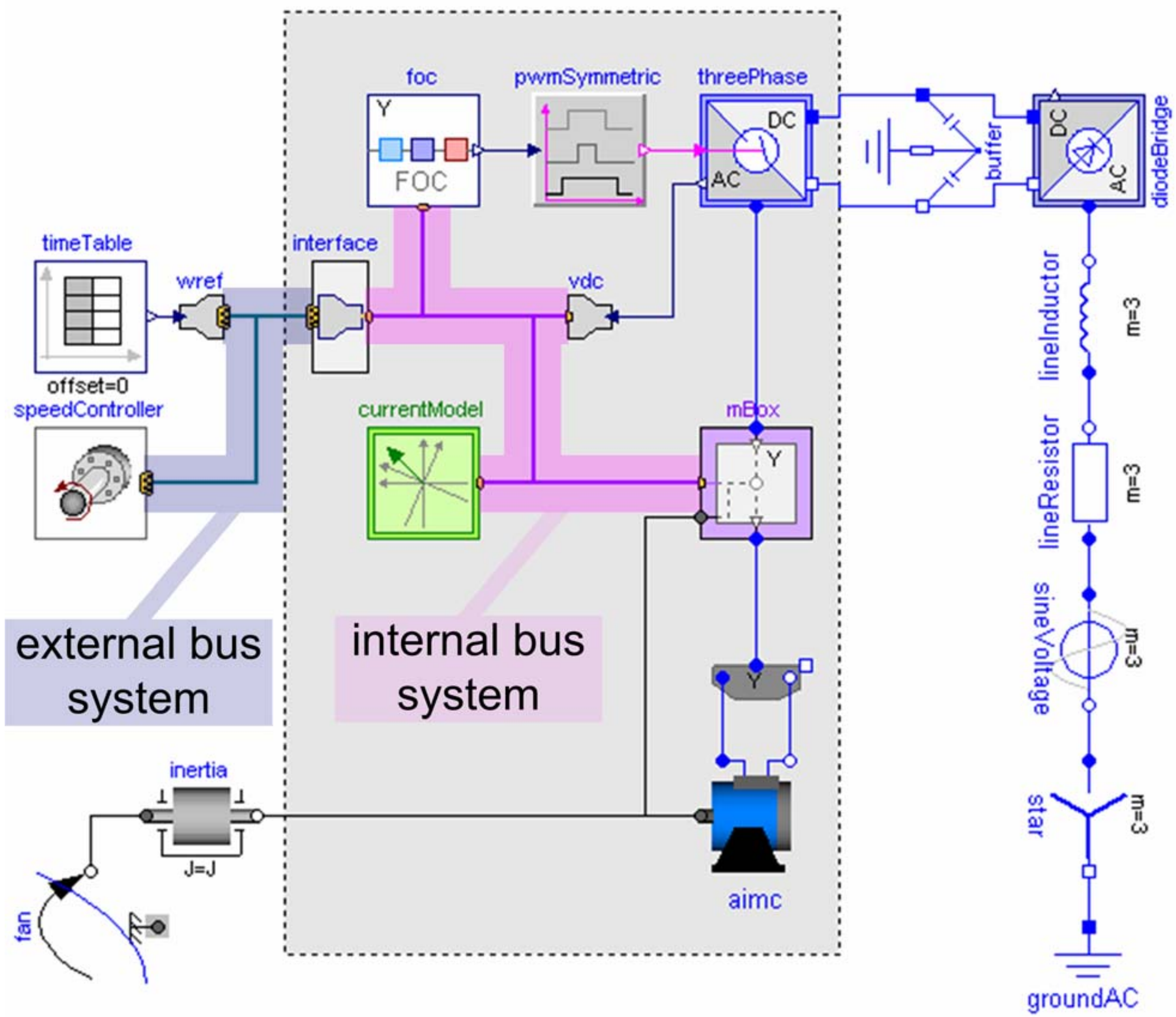


Connectors of the Controlled Machine Models



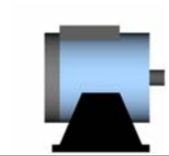
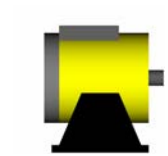
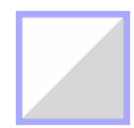
arsenal research
An Enterprise of the Austrian Research Centers.

Bus concept



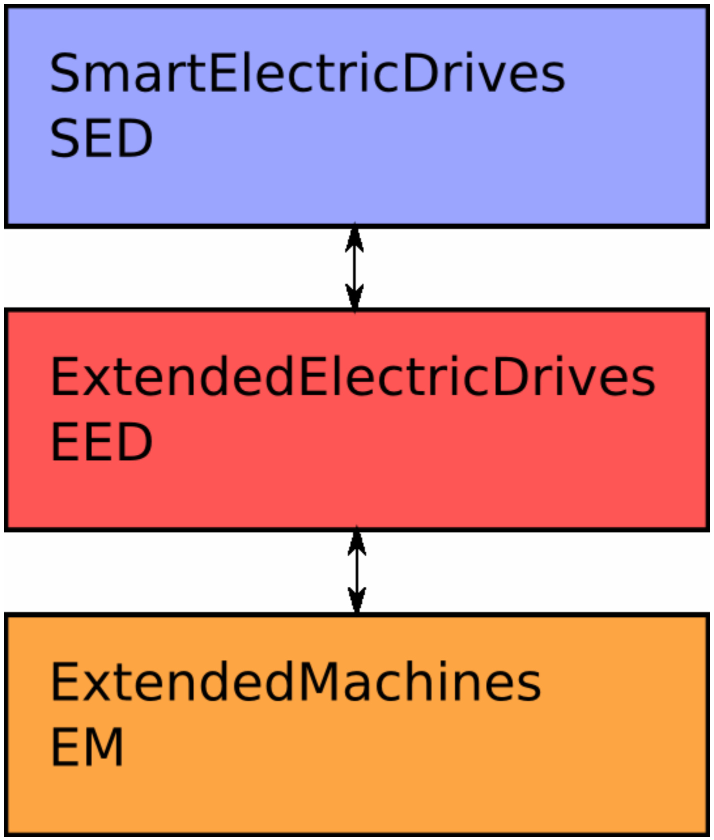
arsenal research
An Enterprise of the Austrian Research Centers.

Different levels of abstraction

Models of controlled machines	Electrical transients and mechanical transients	
	Quasi stationary models (only mechanical transients)	
Converters	Power balance	
	Ideal switches	
	Real switches (coming soon)	

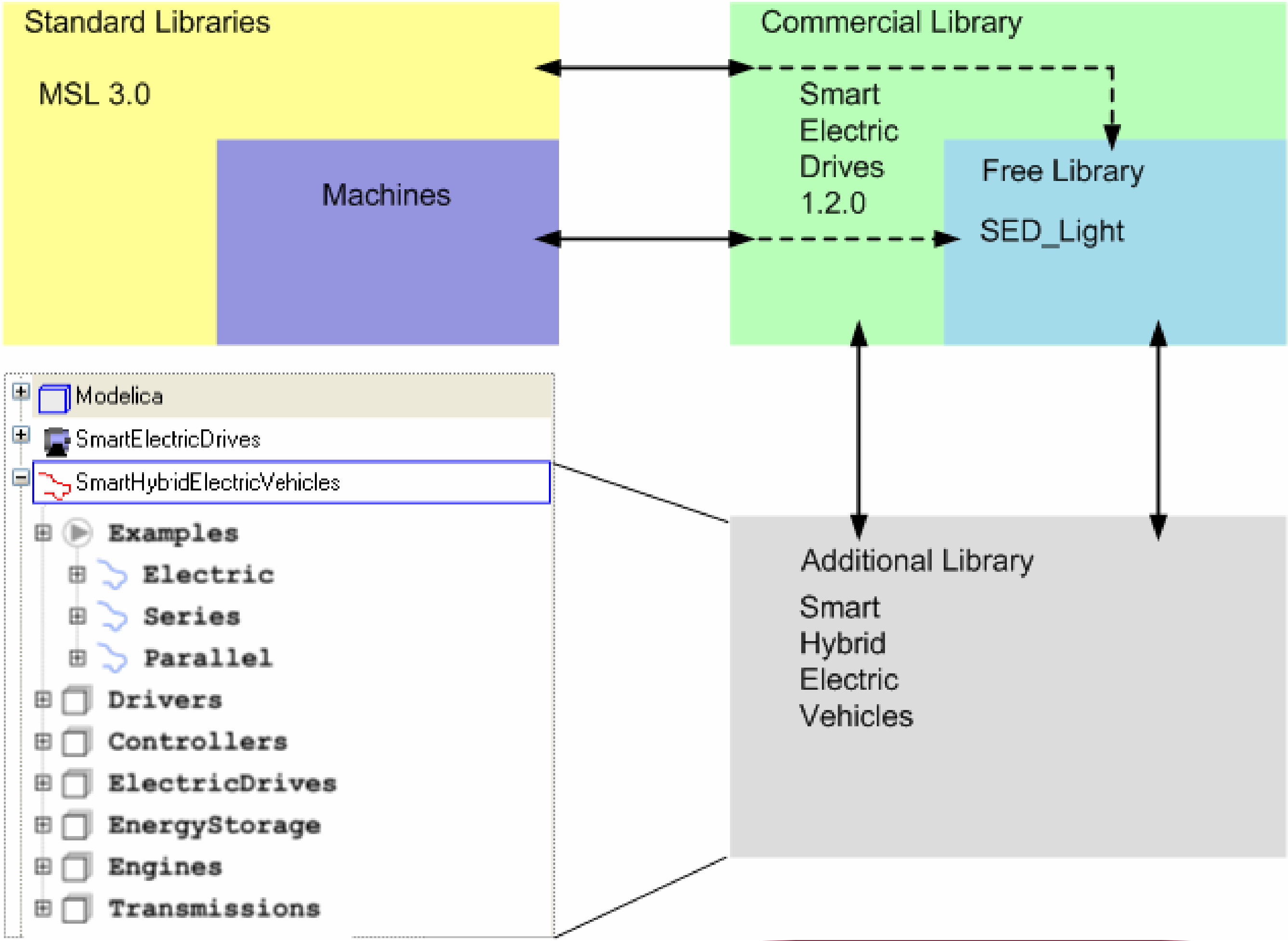
Outlook

- Various number of phases of stator and rotor
- Asymmetric phase windings enable consideration of stator / rotor failures
- Saturation effects (induction / synchronous / dc machines)
- Deep bar effect of squirrel cage rotors (induction machines)
- Iron losses (hysteresis losses, eddy losses)
- Supplementary and friction losses
- Thermal models of induction machines



arsenal research
An Enterprise of the Austrian Research Centers.

Outlook



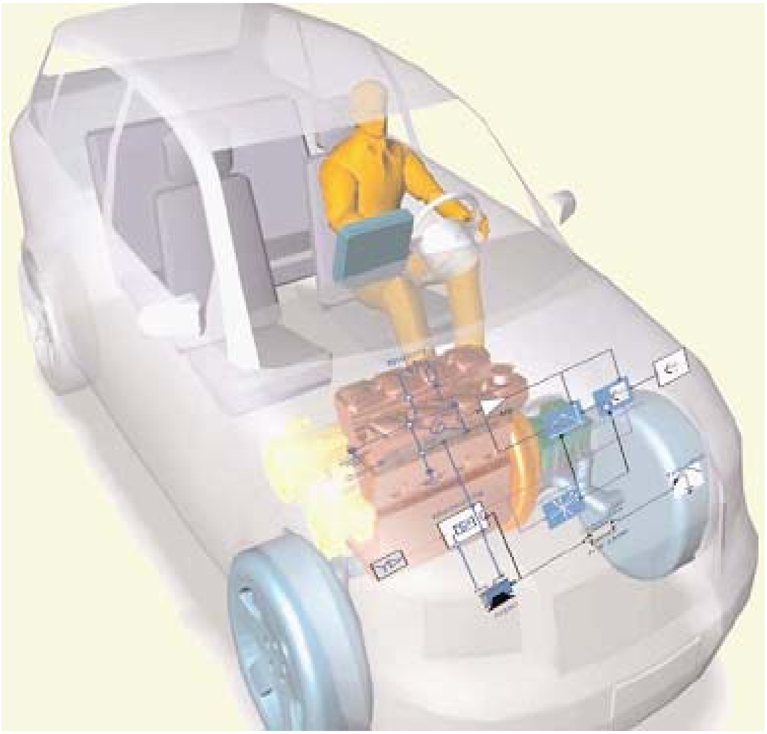
Key Advantages of the SED library

- Comprehensive library for electric drive simulation in automotive applications
- Applicable for hardware in the loop (HIL) and real time simulations
- ‘Ready to use’ models
- Controller parameter estimation functions for easy controller handling
- Models at different layers of abstraction
- SED bus concept for easy coupling with other Dymola libraries
- Many examples, extensive documentation and intelligible SED library structure

arsenal research
An Enterprise of the Austrian Research Centers.

SED library – novelties

- SmartElectricDrives 1.2.0 – available now!
- Opened source code ~90 %
- SED light version for free – available since end of October!
- Additional HEV examples
  - SmartHybridElectricVehicles library coming soon (in combination with the SED library)



Comparison SED library vs. SED light library

SED library

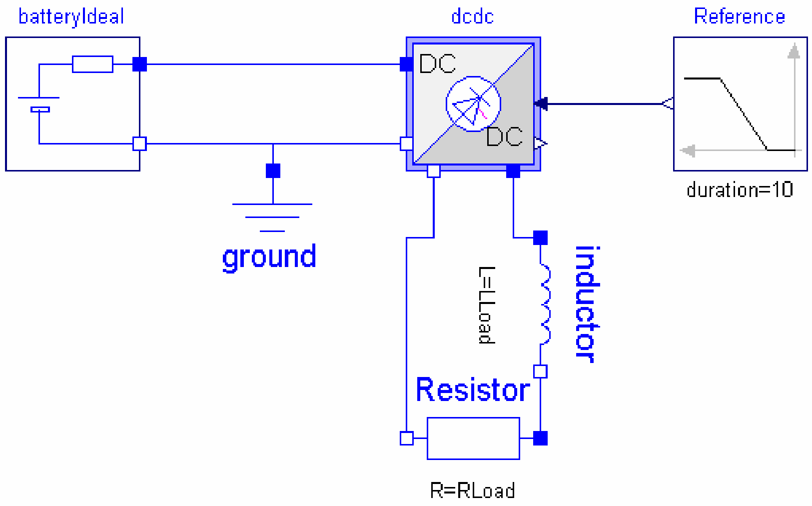
- Sources
  - batteries, supercaps, fuel cells
- Converters
  - ideal, switching
- Electric machines
  - transient & quasi stationary models
  - asynchronous induction machines
  - permanent magnet synchronous induction machines
  - dc machines
- Control units
  - field oriented control, brushless dc control
- Electrical loads

SED light library version

- Sources
  - batteries
- Converters
  - restricted selection
- Electric machines
  - transient & quasi stationary models
  - dc machines
- Electrical loads
  - restricted selection

DC Circuits

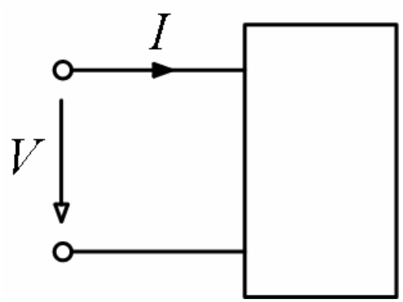
Chapter 3



arsenal research
An Enterprise of the Austrian Research Centers.

Pulsating DC-Circuits

- Reason: power electronics with periodic behavior



$$p(t) = V \cdot I$$

$$P = \frac{1}{T}\int_0^T p(t)dt$$

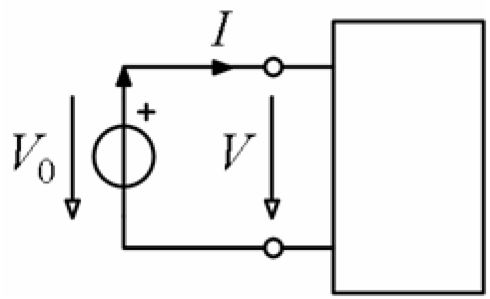
- Characteristic quantities for periodic signals
  - Average values:

$$\overline{V} = \frac{1}{T}\int_0^T V(t)dt$$

$$\overline{I} = \frac{1}{T}\int_0^T I(t)dt$$

Pulsating DC-Circuits

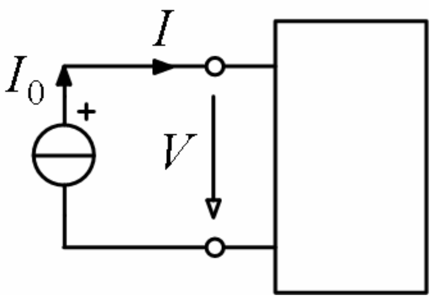
- Special cases
  - Constant voltage



$$P = V_0 \cdot \overline{I}$$

$$V = V_0$$

  - Constant current

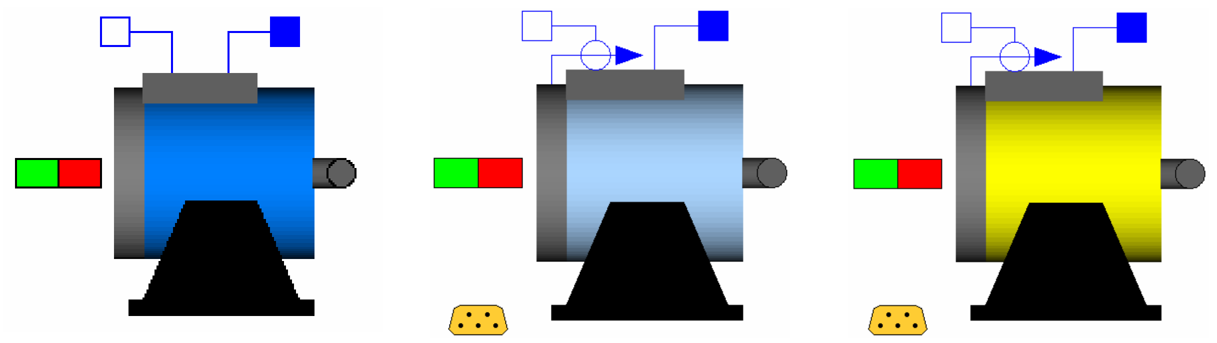


$$P = \overline{V} \cdot I_0$$

$$I = I_0$$

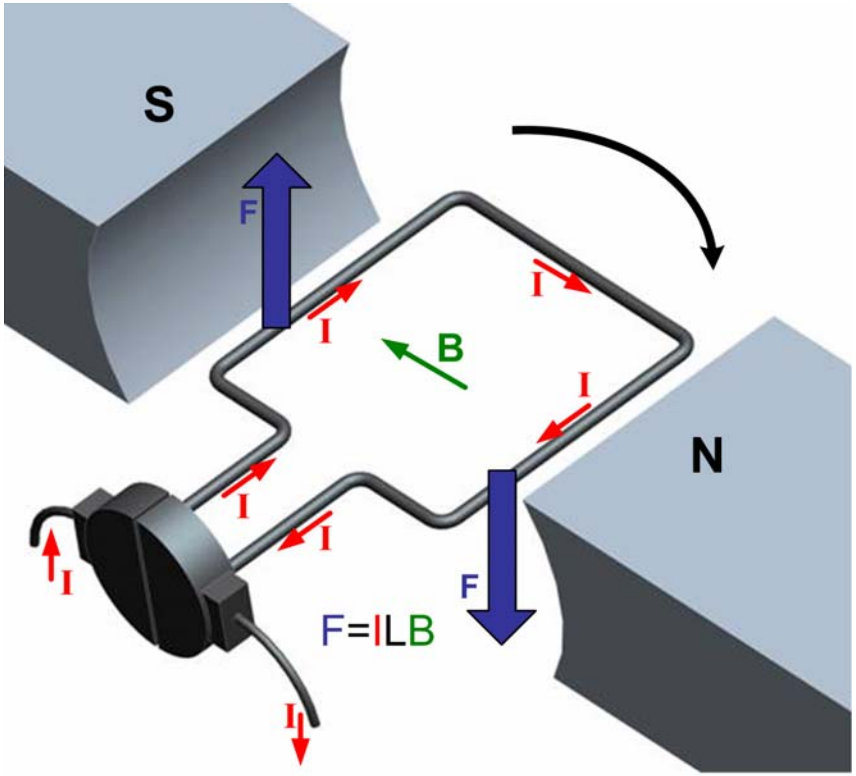
DC Machines

Chapter 4



Principle

- The stator magnet creates a homogeneous magnetic field
- Opposite current direction in the proximity of the poles
- Same torque at all wires in the armature
- Commutator works as a mechanical rectifier



The Equivalent Circuit

- Armature current I_a
- Main flux Φ
- Induced voltage

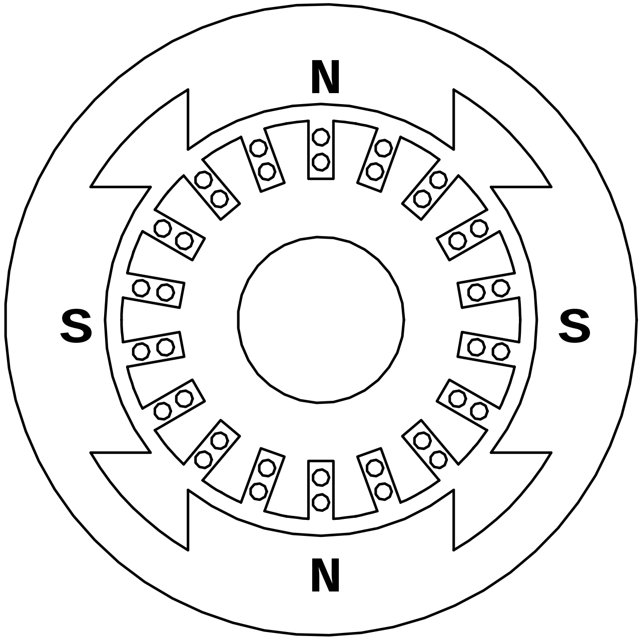
$$V_i = k \cdot \Phi \cdot \Omega_m$$

- Torque

$$T = k \cdot \Phi \cdot I_a$$

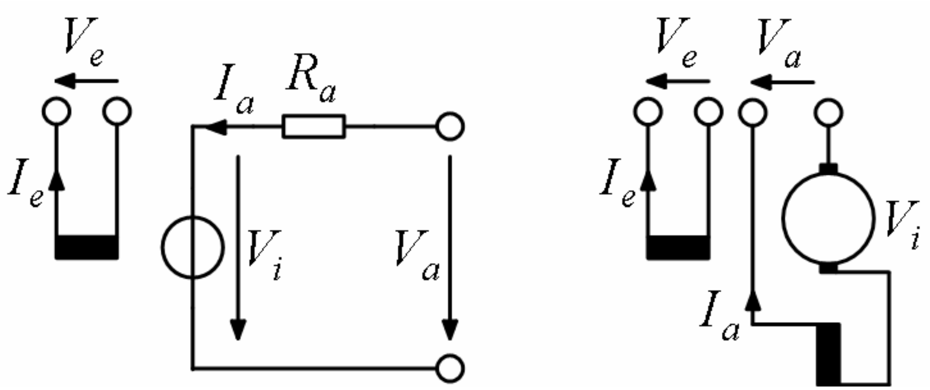
- Mechanical power

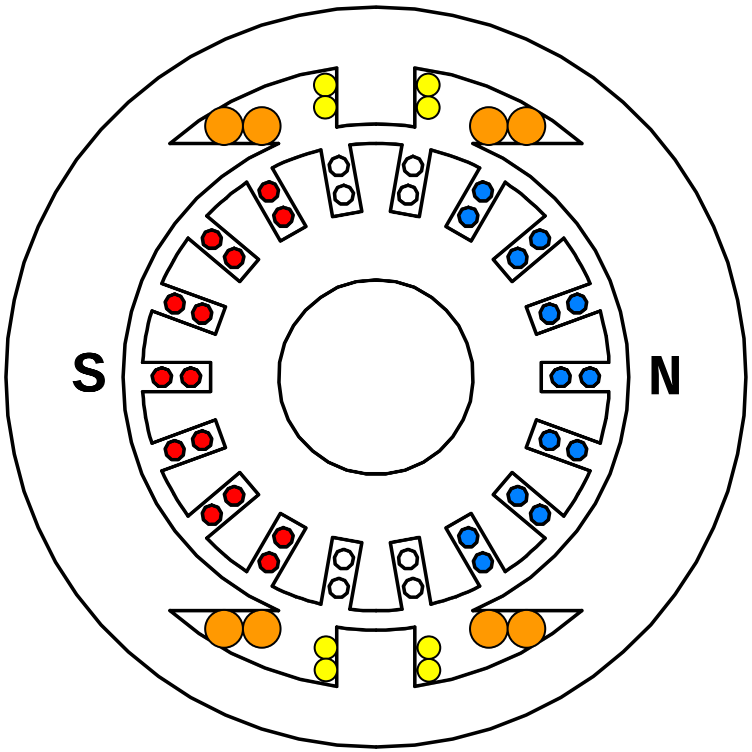
$$P_m = V_i \cdot I_a = T_{el} \cdot \Omega_m$$



The Equivalent Circuit – Steady State Operation

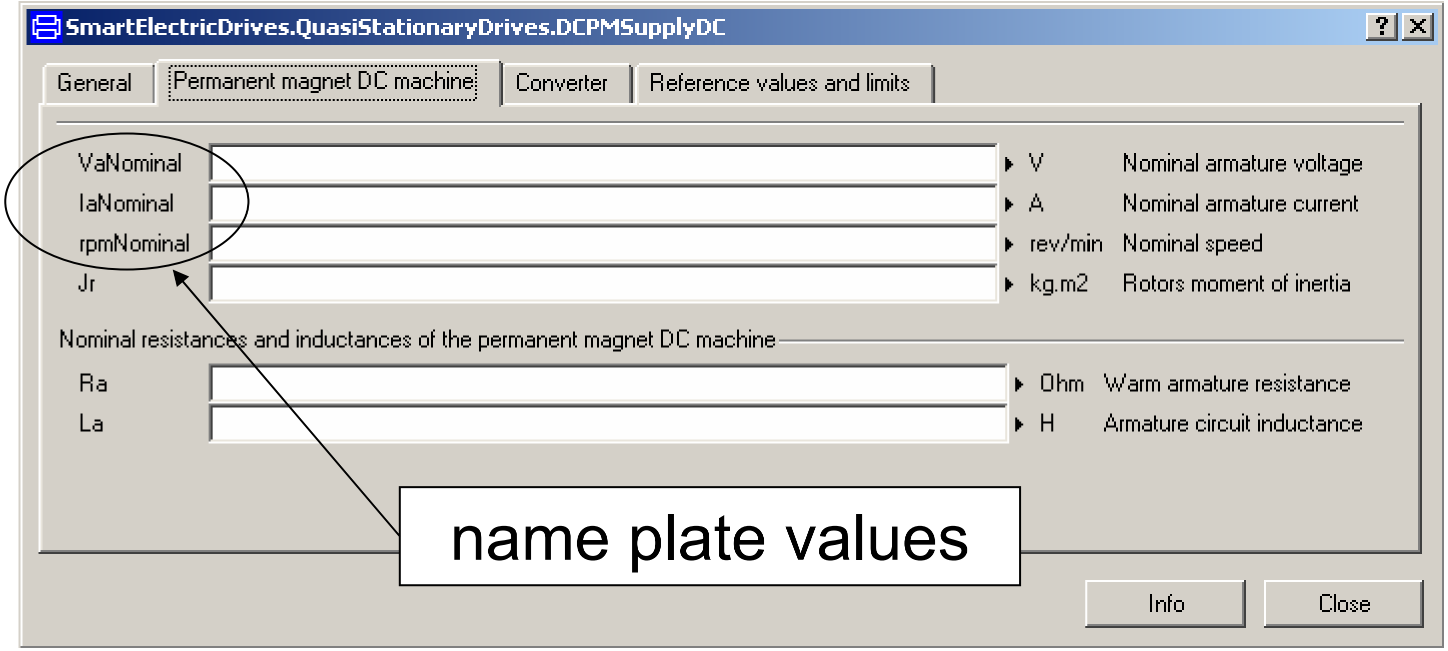
- Electrical excitation $\Phi \propto I_e \quad V_i \propto \Phi \cdot \Omega_m$
- Armature circuit
- Excitation circuit (excitation current)
- Commutating poles





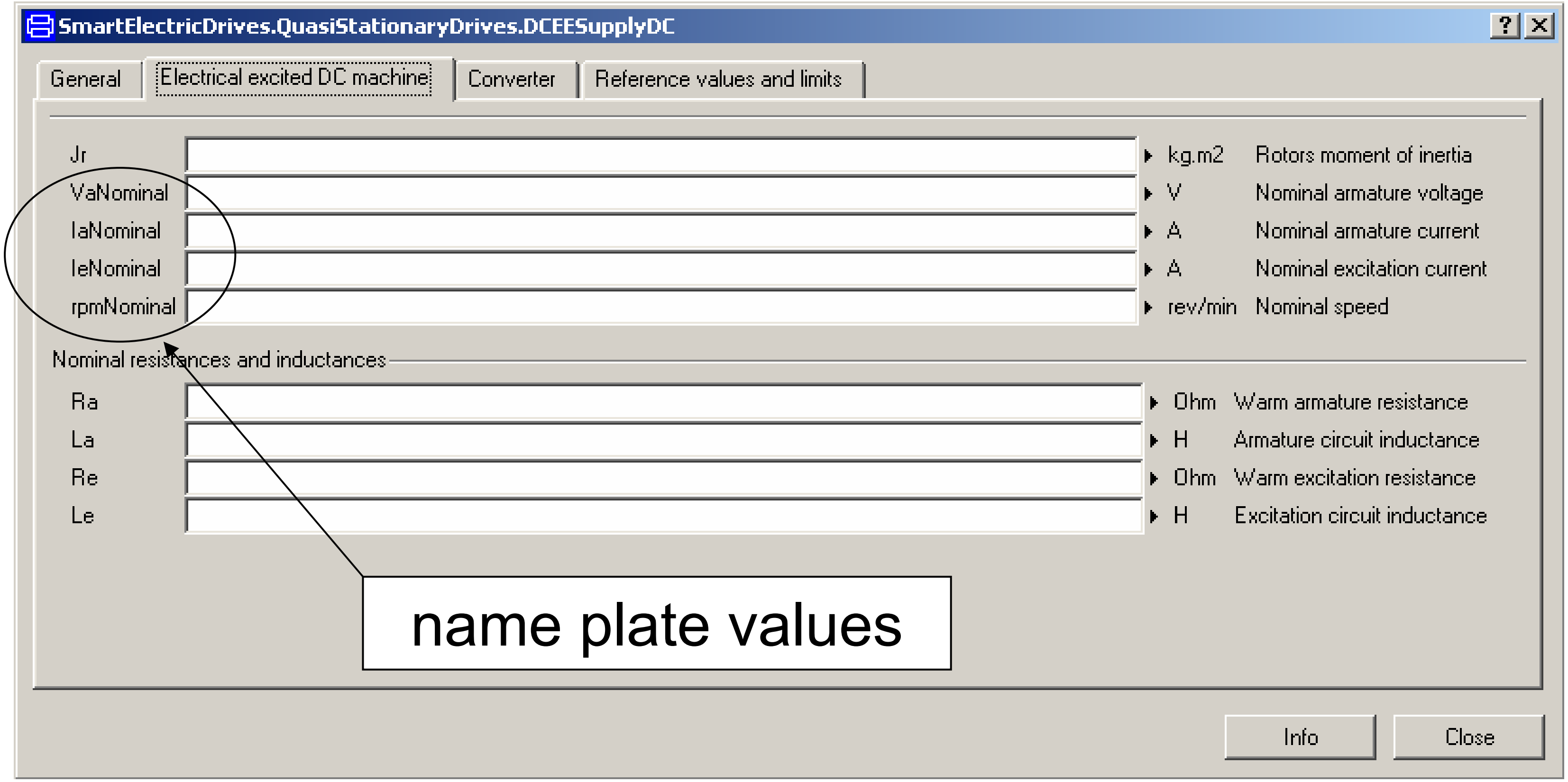
arsenal research
An Enterprise of the Austrian Research Centers.

Parameter List of the DCPM – Machine Model



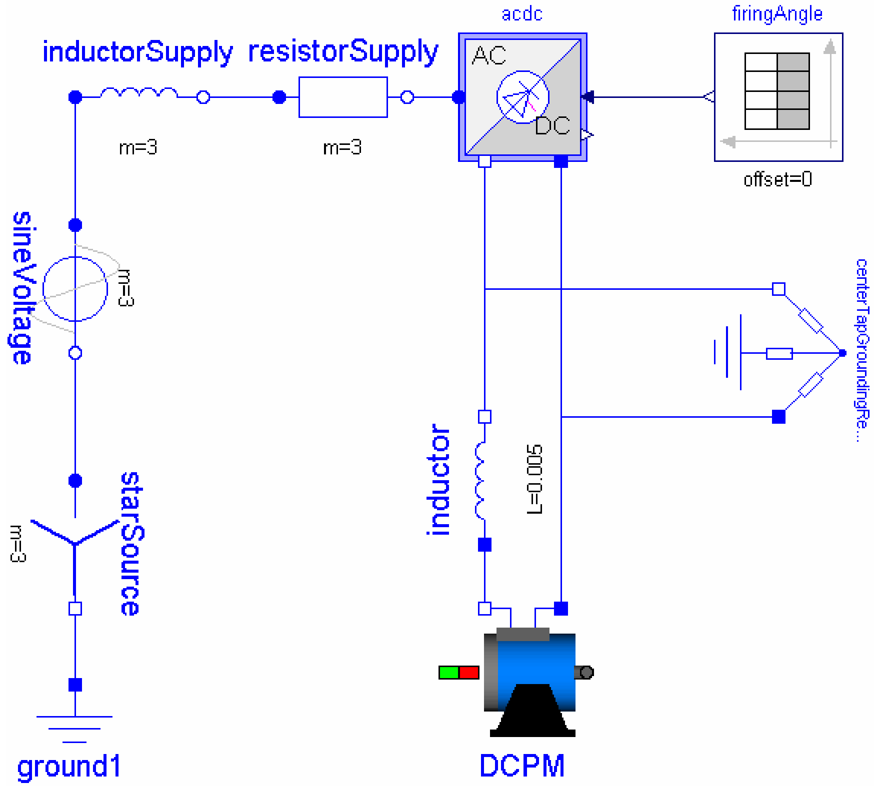
arsenal research
An Enterprise of the Austrian Research Centers.

Parameter List of the DCEE – Machine Model



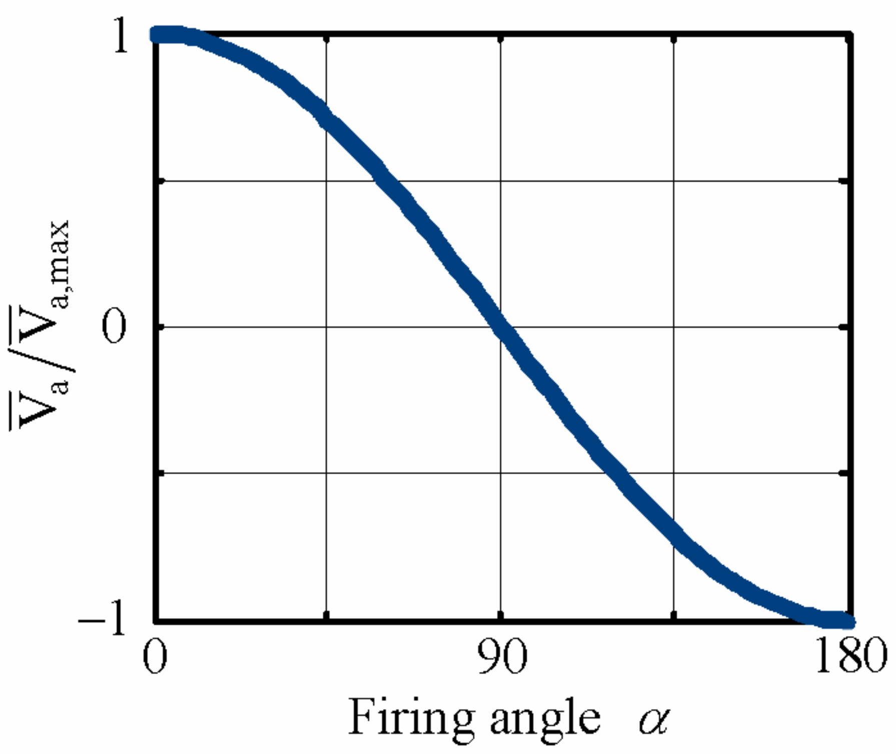
arsenal research
An Enterprise of the Austrian Research Centers.

Three Phase Thyristor Bridge



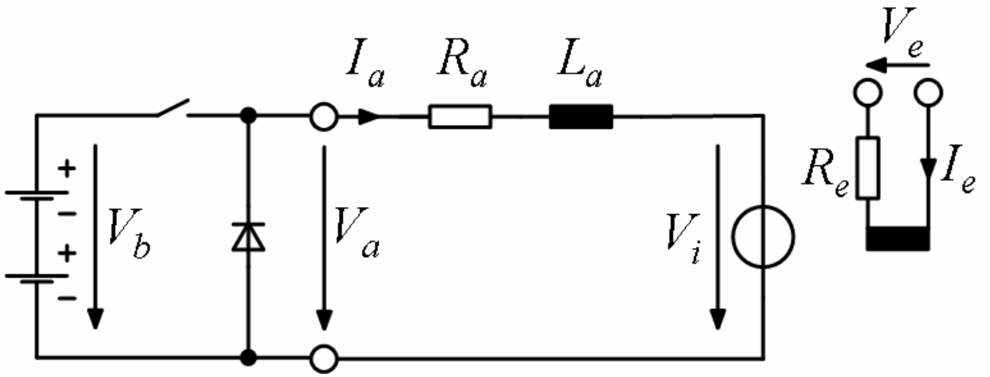
Three Phase Thyristor Bridge

- Voltage harmonics
- Current harmonics
  - Continuous mode
  - Discontinuous mode
- Through-conduction

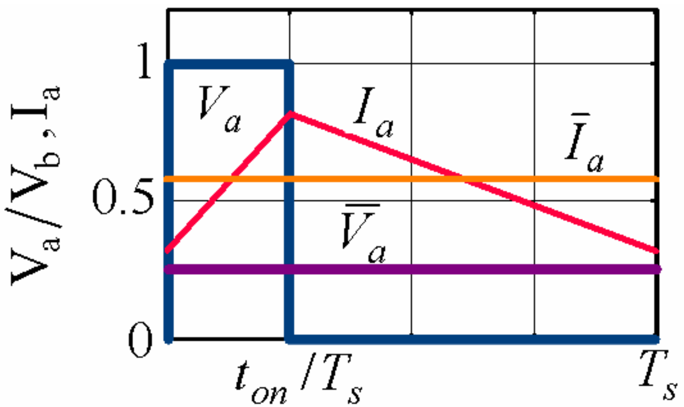


Chopper

- DC supply
- Step down converter
  - $V_a = D \cdot V_s$
  - $D = \frac{t_{on}}{T_s}$



- Electric switches
- Free wheeling diode



T_s:...switching periode

Chopper Models in the SED Library

- Power balance model
  - low computing effort

- Ideal switching model
  - events
  - iteration
  - computing effort dependent on switching frequency

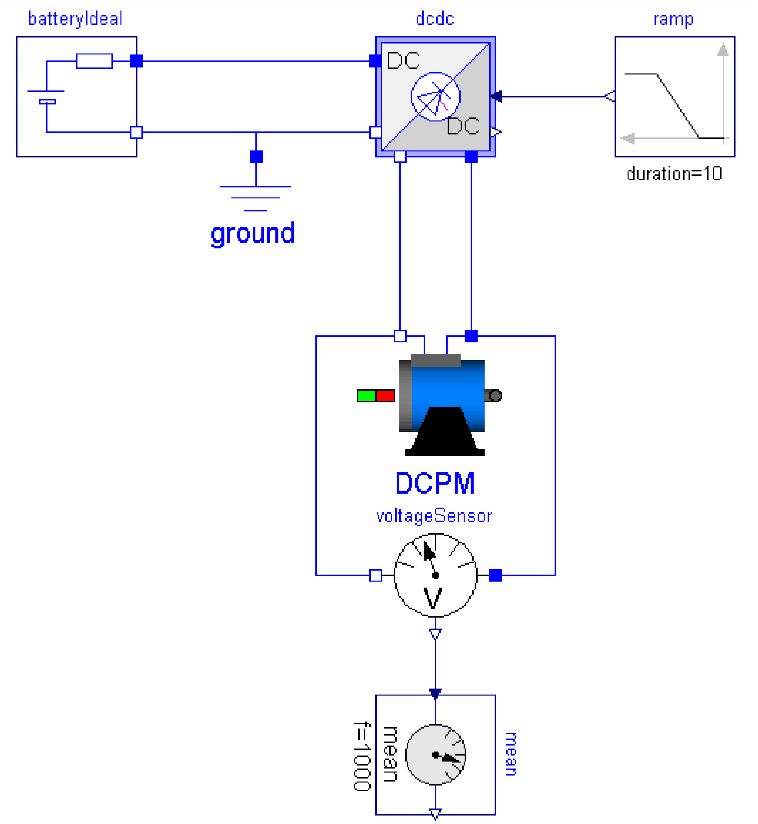
Examples with a Chopper and a DC Machine

Exercise 1

arsenal research
An Enterprise of the Austrian Research Centers.

SED Example – Chopper03

- Given:
  - Battery voltage = 100V
  - Reference voltage:
    $$\frac{dv}{dt} = \frac{100V}{10s} \qquad V_{Max} = 100V$$
  - Chopper frequency = 1000Hz
- Display: $i_a(t),\ v_a(t),\ \overline{I}_a,\ \overline{V}_a,\ \omega_m(t)$
  - Add an inertia
  - Add a load step



arsenal research
An Enterprise of the Austrian Research Centers.

Chopper03: Component Paths

- SmartElectricDrives.Sources.Batteries.BatteryIdeal
- Modelica.Electrical.Analog.Basic.Ground
- SmartElectricDrives.Converters.IdealSwitching.DCDC.Chopper
- Modelica.Blocks.Sources.Ramp
- Modelica.Electrical.Machines.BasicMachines.DCMachines. DC_PermanentMagnet
- Modelica.Electrical.Analog.Sensors.VoltageSensor
- SmartElectricDrives.Sensors.Mean

Chopper03: Parameter Settings

- BatteryIdeal
  - VCellNominal = 100V
  - ICellMax = 150A
  - RsCell = 0Ω
  - ns = 1
  - np = 1
- Chopper
  - f = 1000Hz
  - IConverterMax = 150A
  - VDC = 100V
- Ramp
  - height = 100
  - duration = 10s
- DCPM
  - Nominal values
- Mean
  - f = 1000Hz
  - yStart = 0
- Simulation time
  - t = 15s

arsenal research
An Enterprise of the Austrian Research Centers.

Chopper03: System Analyses

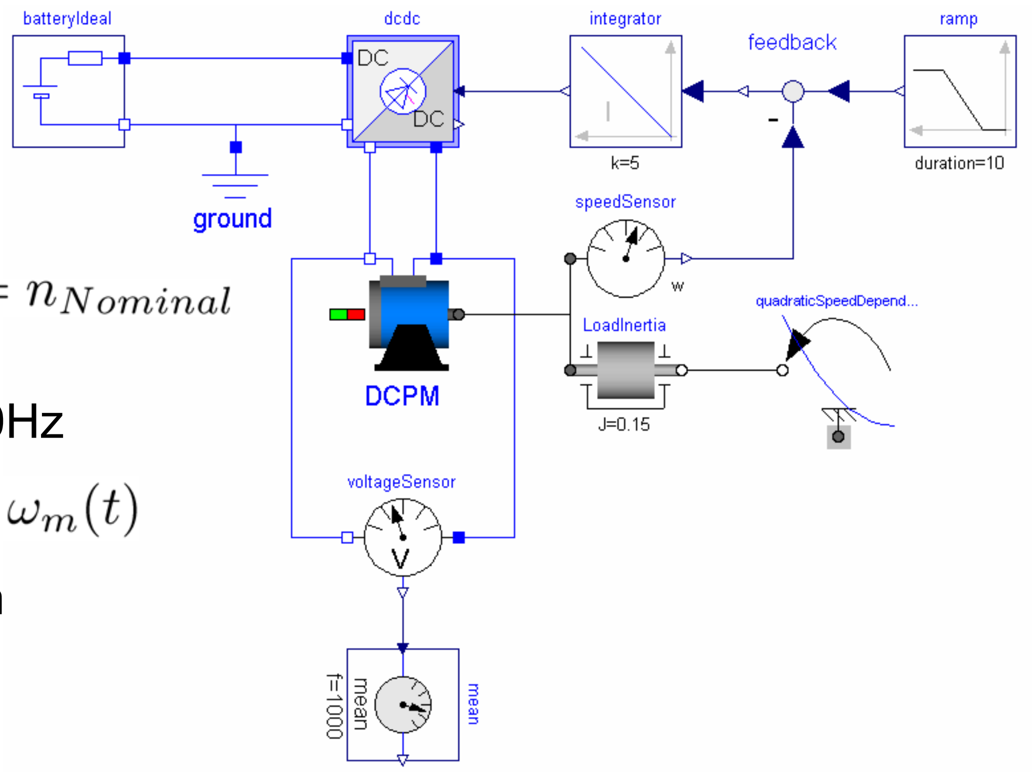
- Inertia added, J = 0.5kgm^2
  - **Compare:** batteryIdeal.IPackage, DCPM.w_mechanical, DCPM.ia
  - The armature current increases
  - The shaft acceleration is delayed
  - The battery current drain increases
- Load added, T = -60Nm @ 0.5s; J = 0kgm^2;
  - **Compare:** batteryIdeal.IPackage, DCPM.w_mechanical, DCPM.ia

SED Example – Chopper04

- Given:
  - Battery voltage = 100V
  - Reference speed:

$$\frac{dn}{dt} = \frac{1425rpm}{10s} \quad n_{Max} = n_{Nominal}$$

  - Chopper frequency = 1000Hz
- Display: $i_a(t),\ v_a(t),\ \overline{I}_a,\ \overline{V}_a,\ \omega_m(t)$
  - Change the integrator gain



Chopper04: Component Paths

- SmartElectricDrives.Sources.Batteries.BatteryIdeal
- Modelica.Electrical.Analog.Basic.Ground
- SmartElectricDrives.Converters.IdealSwitching.DCDC.Chopper
- Modelica.Blocks.Continuous.Integrator
- Modelica.Blocks.Math.Feedback
- Modelica.Blocks.Sources.Ramp
- Modelica.Mechanics.Rotational.Sensors.SpeedSensor
- Modelica.Electrical.Machines.BasicMachines.DCMachines. DC_PermanentMagnet
- Modelica.Mechanics.Rotational.Inertia
- Modelica.Mechanics.Rotational.QuadraticSpeedDependentTorque
- Modelica.Electrical.Analog.Sensors.VoltageSensor
- SmartElectricDrives.Sensors.Mean

Chopper04: Parameter Settings

- BatteryIdeal
  - VCellNominal = 100V
  - ICellMax = 150A
  - RsCell = 0Ω
  - ns = 1
  - np = 1
- Chopper
  - f = 1000Hz
  - IConverterMax = 150A
  - VDC = 100V
- Integrator
  - k = 5
- Ramp
  - height = 149
  - duration = 10s
- DCPM
  - Nominal values
- Inertia
  - J = 0.15kgm^2

Chopper04: Parameter Settings

- QuadraticSpeedDependentTorque
  - TauNominal = -63.66Nm
  - wNominal = 149 rad^-1
- Mean
  - f = 1000Hz
  - yStart = 0
- Simulation time
  - t = 15s

Chopper04: System Analyses

- Integrator gain changed; k = 1, simulation time = 2s
  - **Compare:** DCPM.w_mechanical, DCPM.ia, dcdc.vRef
  - The armature current decreases
  - The shaft acceleration is delayed
  - The reference voltage raise is delayed

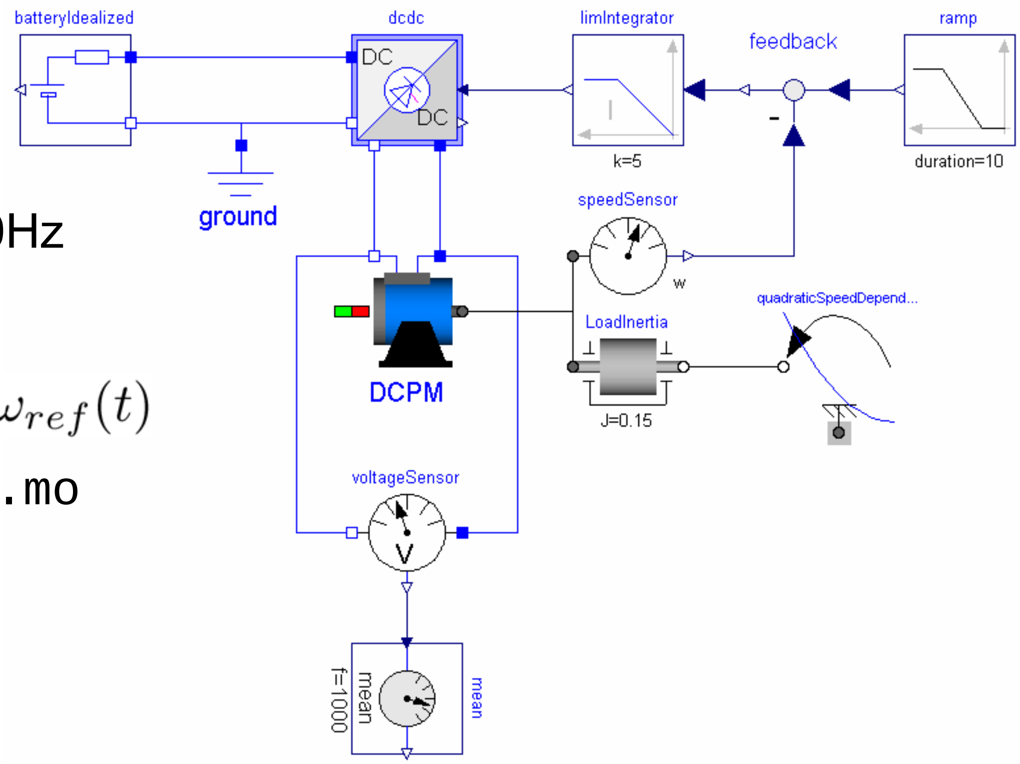
arsenal research
An Enterprise of the Austrian Research Centers.

SED Example – Chopper05

- Given:
  - Reference speed : as in Chopper04
  - Chopper frequency = 1000Hz
- Display:

$i_a(t),\ v_a(t),\ \overline{I}_a,\ \overline{V}_a,\ \omega_m(t),\ \omega_{ref}(t)$

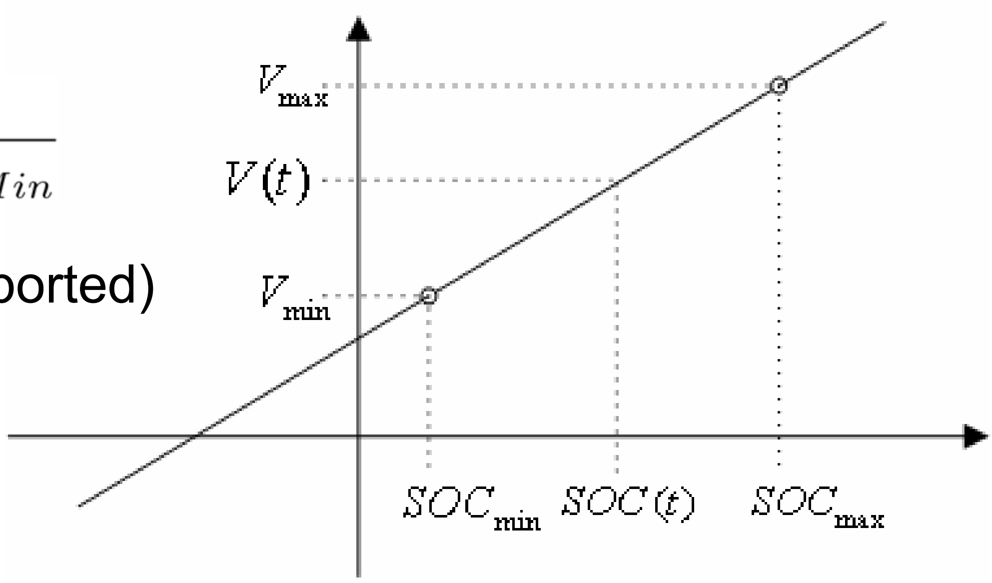
  - Use `batteryIdealized.mo`
  - Check SOC
  - Add battery cells
  - Change the controller limit



arsenal research
An Enterprise of the Austrian Research Centers.

Chopper05: Battery Model Parameterization

- Fictitious capacitance
  - $$C = \frac{Q_{CellNominal}}{V_{CellMax} - V_{CellMin}}$$
- Limits (simulation may be aborted)
  - $V_{CellMax}$
  - I_{Max}
- Total electric charge
  - $Q_{PackageNominal} = Q_{CellNominal} \cdot n_p$
- Total serial resistance
  - $$R_{sPackage} = R_{sCell} \cdot \frac{n_s}{n_p}$$



Chopper05: Battery Model Parameterization

- Overall charging/discharging energy efficiency
  - heat losses due to the serial resistor (current dependent)
  - charge losses
- Overall charging/discharging efficiency always refers to a specific charging/discharging current ICellChargeDischarge.
- Maximum possible efficiency of the battery without considering charge losses

$$efficiency_{Max} = \frac{(V_{CellMin} + V_{CellMax} - 2 \cdot R_{sCell} \cdot I_{CellChargeDischarge})}{(V_{CellMin} + V_{CellMax} + 2 \cdot R_{sCell} \cdot I_{CellChargeDischarge})}$$

arsenal research
An Enterprise of the Austrian Research Centers.

Chopper05: Component Paths

- SmartElectricDrives.Sources.Batteries.BatteryIdealized
- Modelica.Electrical.Analog.Basic.Ground
- SmartElectricDrives.Converters.IdealSwitching.DCDC.Chopper
- Modelica.Blocks.Continuous.LimIntegrator
- Modelica.Blocks.Math.Feedback
- Modelica.Blocks.Sources.Ramp
- Modelica.Mechanics.Rotational.Sensors.SpeedSensor
- Modelica.Electrical.Machines.BasicMachines.DCMachines. DC_PermanentMagnet
- Modelica.Mechanics.Rotational.Inertia
- Modelica.Mechanics.Rotational.QuadraticSpeedDependentTorque
- Modelica.Electrical.Analog.Sensors.VoltageSensor
- SmartElectricDrives.Sensors.Mean

Chopper05: Parameter Settings

- BatteryIdealized
  - QCellNominal = 36000C
  - VCellMin = 1V
  - VCellMax = 1.5V
  - SOCMin = 0.5
  - SOCMax = 0.8
  - SOCInit = 0.8
  - ICellMax = 100A
  - RsCell = 0.003Ω
  - Efficiency = 0.75
  - ICellChargeDischarge = 50A
  - ns = 66
  - np = 1
- Chopper
  - f = 1000Hz
  - IConverterMax = 150A
  - VDC = 100V
- Integrator
  - k = 5
  - outMax = 100
- Ramp
  - height = 149
  - duration = 10

Chopper05: Parameter Settings

- DCPM
  - Nominal values
- Inertia
  - J = 0.15kgm^2
- QuadraticSpeedDependentTorque
  - TauNominal = -63.66Nm
  - wNominal = 149 rad^-1
- Mean
  - f = 1000Hz
  - yStart = 0
- Simulation time
  - t = 15s

arsenal research
An Enterprise of the Austrian Research Centers.

Chopper05: System Analyses

- The supply voltage decreases due to battery discharge
  - **Display:** dcdc.vRef, batteryIdealized.vPackage; ramp.y, DCPM.w_mechanical; DCPM.ia; batteryIdealized.SOC;
  - To reach the desired speed the battery parameters must be changed. → ns = 100
- Controller limit changed; outMax = 1000
  - **Compare:** dcdc.vRef, batteryIdealized.vPackage; ramp.y, DCPM.w_mechanical; DCPM.ia;
  - Without limiting the integrator the reference voltage would unnecessarily increase.

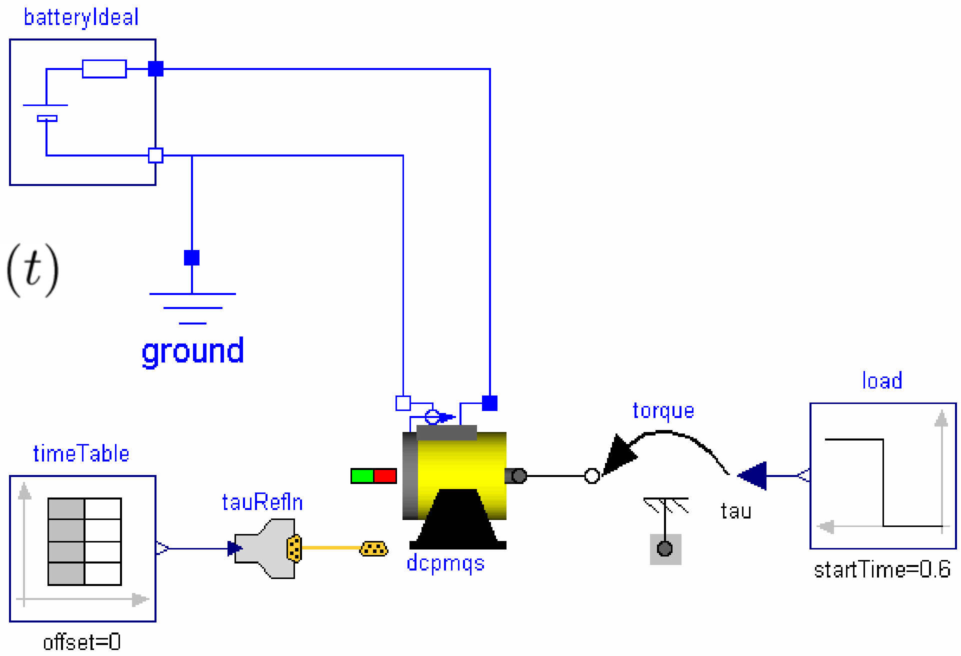
arsenal research
An Enterprise of the Austrian Research Centers.

SED Example – DCPMQS01

- Torque controlled DCPM
  - Battery voltage = 120V
- Display:

$$i_a(t),\ v_a(t),\ \omega_m(t),\ \tau_{el}(t),\ \tau_{ref}(t)$$

  - Check current limits
  - Check voltage limits



DCPMQS01: Component Paths

- SmartElectricDrives.Sources.Batteries.BatteryIdeal
- Modelica.Electrical.Analog.Basic.Ground
- Modelica.Blocks.Sources.TimeTable
- SmartElectricDrives.QuasiStationaryDrives.DCPMSupplyDC
- Modelica.Mechanics.Rotational.Torque
- Modelica.Blocks.Sources.Step

DCPMQS01: Parameter Settings

- BatteryIdeal
  - VCellNominal = 1.5V
  - ICellMax = 400A
  - RsCell = 0.004Ω
  - ns = 80
  - np = 2

- DCPMQS
  - Jr = 0.15
  - VaNominal = 100V
  - IaNominal = 100A
  - rpmNominal = 1425rpm
  - (wNominal = 149s^-1)
  - (TauNominal = 63.66Nm)
  - Ra = 0.05Ω
  - La = 0.0015Ω
  - TiConverter = 0.001s
  - vMachineMax = 1.1*VaNominal
  - iMachineMax = 1.5*IaNominal
  - IConverterMax = 2.5*IaNominal

DCPMQS01: Parameter Settings

- TimeTable
  - [0, 0; 0.2, 0; 0.2, TauNominal/2; 0.4, TauNominal/2; 0.8, TauNominal/2; 0.8, TauNominal; 1, TauNominal]
  - Optional: [y = y(redeclare type SignalType = Modelica.SIunits.Torque)]
- Step (load)
  - height = -TauNominal/2
  - startTime = 0.6s
  - Optional: [add modifier: y(redeclare type SignalType = Modelica.SIunits.Torque)]
- Simulation time
  - t = 1s

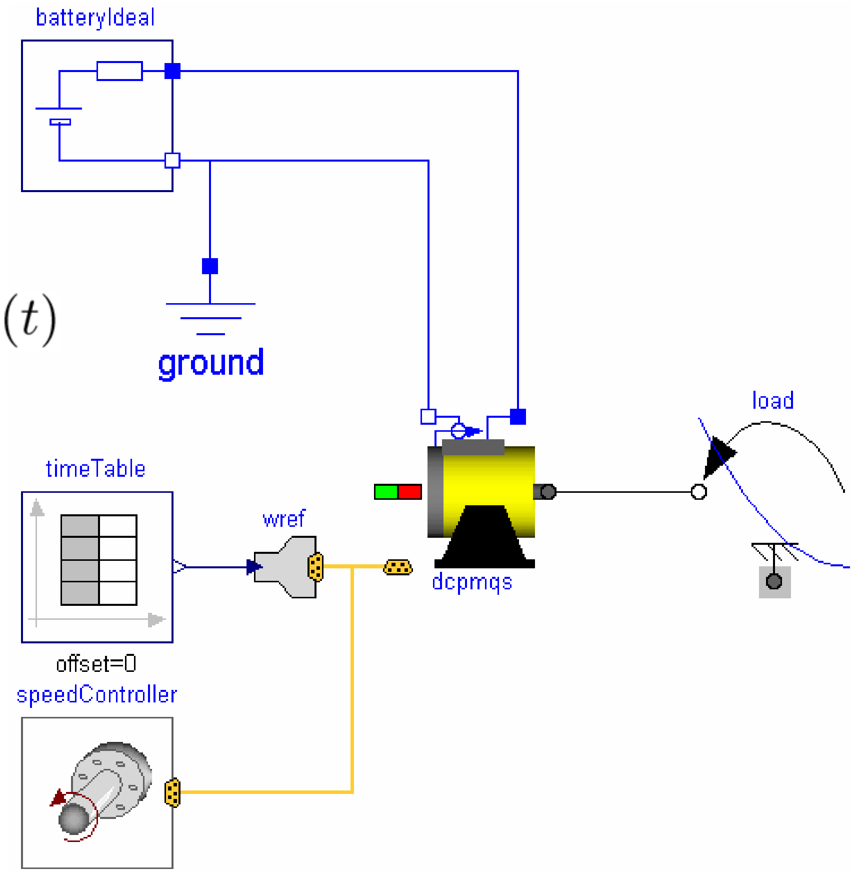
DCPMQS01: System Analyses

- The electric torque follows the reference torque instantly.
  - **Display from dcpmqs.controlBus:** vMachine, vMachineMax, iMachine, iMachineMax, wMechanical, tauRef
  - **Display furthermore:** dcpmqs.tauElectrical
- Current limit changed; IMachineMax = 0.8*IaNominal
  - **Compare:** dcpmqs.controlBus.iMachine, dcpmqs.tauElectrical;
  - The electric torque gets limited.
- Voltage limit changed; VMachineMax = 0.7*VaNominal
  - The electric torque settles to a value only opposing the load torque.

arsenal research
An Enterprise of the Austrian Research Centers.

SED Example – DCPMQS02

- DCPM Water pump drive
  - Battery voltage = 120V
  - Speed controlled
- Display: $i_a(t), v_a(t), \omega_m(t), \omega_{ref}(t)$
  - Check current limits
  - Check voltage limits
  - Check Torque limit



DCPMQS02: Component Paths

- SmartElectricDrives.Sources.Batteries.BatteryIdeal
- Modelica.Electrical.Analog.Basic.Ground
- Modelica.Blocks.Sources.TimeTable
- SmartElectricDrives.Interfaces.BusAdaptors.WRefIn
- SmartElectricDrives.QuasiStationaryDrives.DCPMSupplyDC
- Modelica.Mechanics.Rotational.QuadraticSpeedDependentTorque
- SmartElectricDrives.ProcessControllers.SpeedController
- SmartElectricDrives.AuxiliaryComponents.Functions.
parameterEstimationDCPMControllers

arsenal research
An Enterprise of the Austrian Research Centers.

DCPMQS02: Parameter Settings

- BatteryIdeal
  - VCellNominal = 1.5V
  - ICellMax = 400A
  - RsCell = 0.004Ω
  - ns = 80
  - np = 2
- DCPMQS
  - Jr = 0.15
  - VaNominal = 100V
  - IaNominal = 100A
  - rpmNominal = 1425rpm
  - (wNominal = 149s^-1)
  - (TauNominal = 63.66Nm)
  - Ra = 0.05Ω
  - La = 0.0015Ω
  - TiConverter = 0.001s
  - vMachineMax = 1.1*VaNominal
  - iMachineMax = 1.5*IaNominal
  - IConverterMax = 2.5*IaNominal

DCPMQS02: Parameter Settings

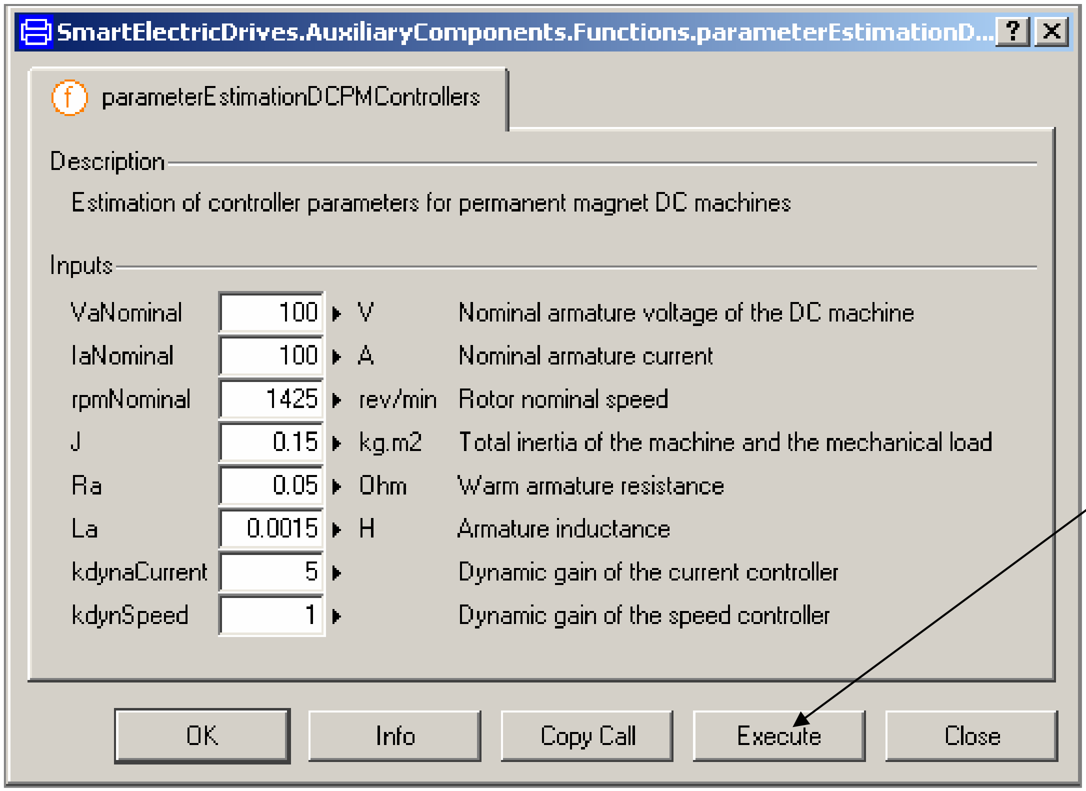
- TimeTable
  - table=[0, 0; 0, 0; 0.2, wNominal/2;1, wNominal/2; 1.2, wNominal; 2, wNominal]
- QuadraticSpeedDependentTorque
  - TauNominal = -63.66Nm
  - wNominal = 149 rad^-1
- parameterEstimationDCPMControllers
  - kdynaCurrent = 5
  - kdynSpeed = 1
  - (Not available in SED light)
- Speed Controller
  - kpSpeed = 29.3
  - TiSpeed = 0.024s
  - TauMax = 1.2* TauNominal = 76Nm
- Simulation time
  - t = 2s

arsenal research
An Enterprise of the Austrian Research Centers.

Not available in SED light

Using the Parameter Estimation Function

- parameterEstimationDCPMControllers



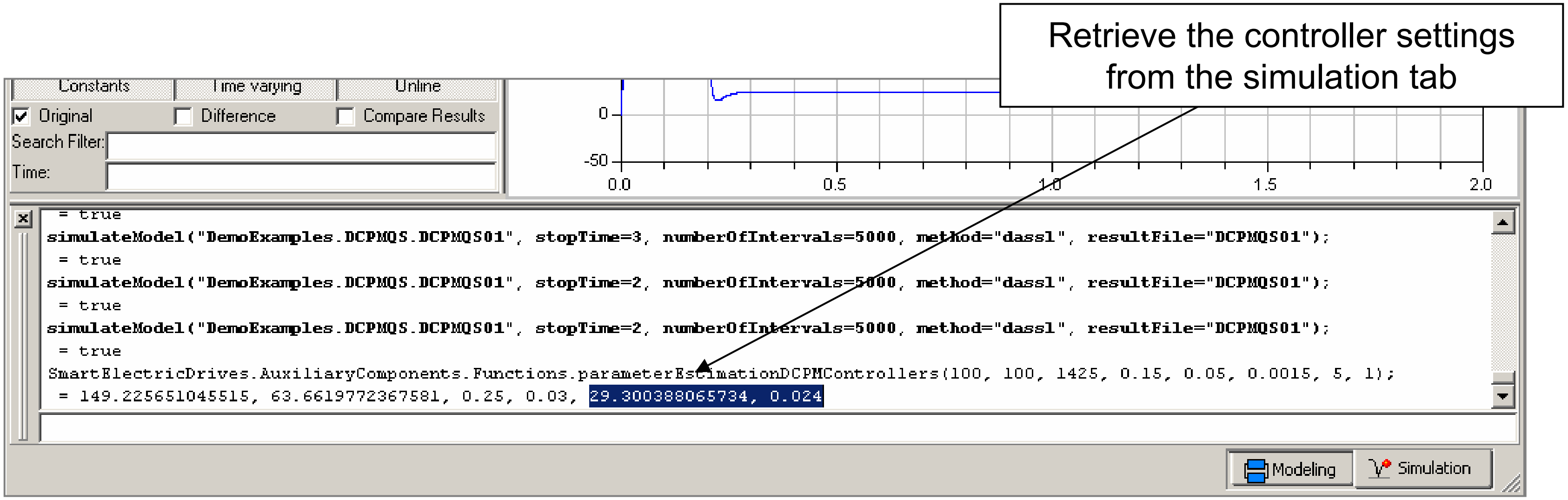
Generate controller settings

arsenal research
An Enterprise of the Austrian Research Centers.

Not available in SED light

Using the Parameter Estimation Function

- parameterEstimationDCPMControllers(VaNominal, IaNominal, rpmNominal, J, Ra, La, kdynaCurrent, kdynSpeed) = wNominal, TauNominal, kpaCurrent, TiaCurrent, kpSpeed, TiSpeed



DCPMQS02: System Analyses

- The machine does not reach the desired acceleration close to wNominal.
  - **Display from dcpmqs.controlBus:** vMachine, vMachineMax, vDC, iMachine, iMachineMax, wMechanical, wRef, tauRef
  - **Display furthermore:** speedController.TauMax
  - The torque limit TauMax is too low.
  - Increase TauMax and IMachineMax

arsenal research
An Enterprise of the Austrian Research Centers.

Exercise

Conversion of a conventional vehicle to a hybrid electric vehicle with a starter-generator

Software requirements:

SmartElectricDrives

SmartHybridElectricVehicles

PowerTrain

Dymola

arsenal research

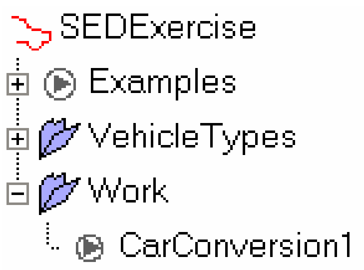
An Enterprise of the Austrian Research Centers.

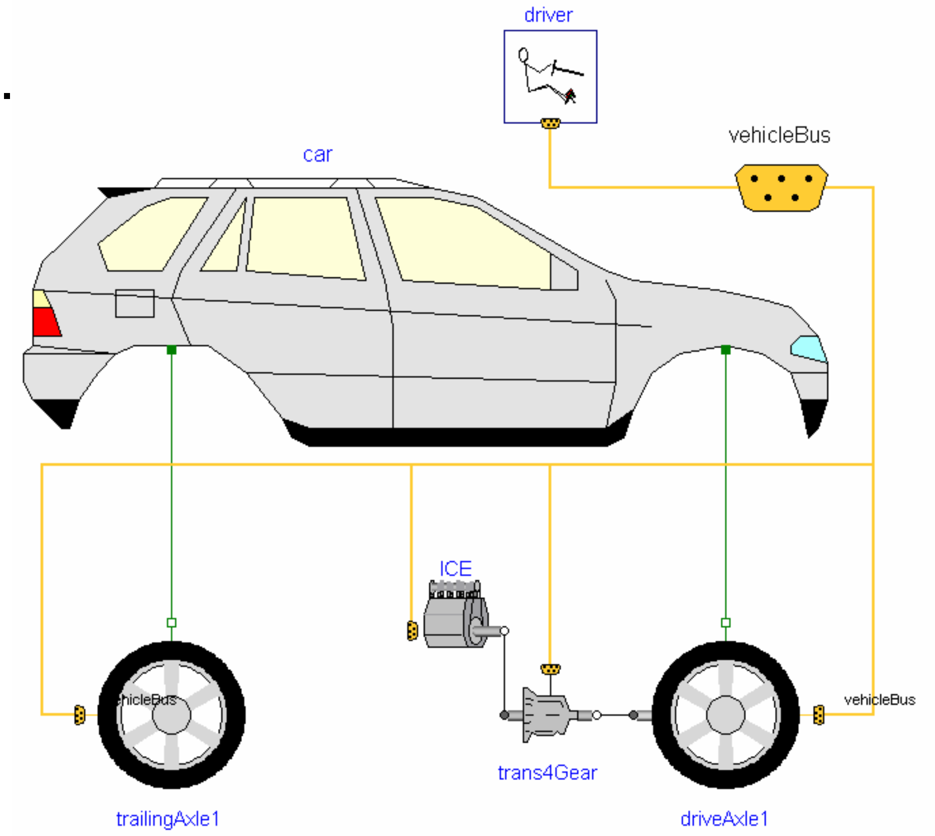
Work steps

- Take the conventional vehicle simulation
- Delete the unfit components
- Add the electrical components
- Add the automatic gearbox and the new controller
- Change the driver settings
- Connect the physical connectors
- Connect the signal bus connectors
- Run the simulation and assess the results

Take the conventional vehicle simulation

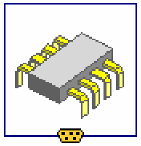
1. The conventional car model can be found in **SEDExercise.Examples.ConventionalCars. ConventionalCar**.
2. Duplicate this model.
3. Call it **CarConversion1**.
4. Insert it in package **SEDExercise.Work**.



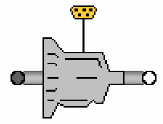


Delete the unfit components

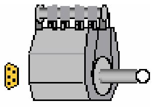
- Delete the components:
  - **Controller**

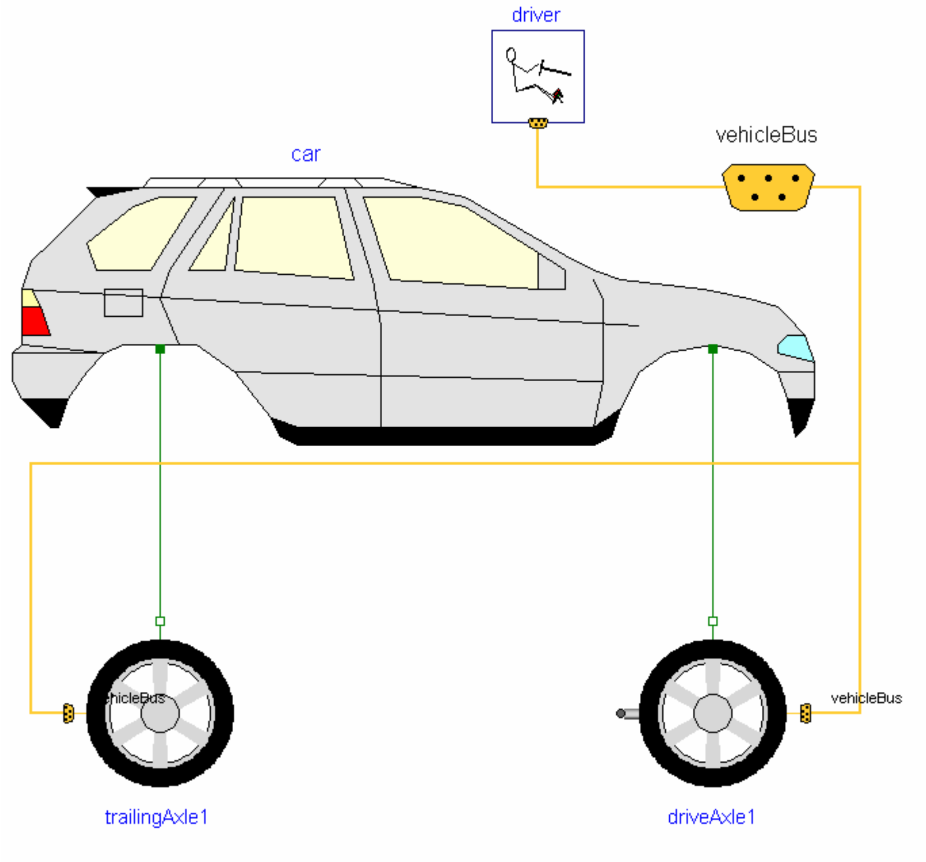


  - **Trans4gear**



  - **ICE**



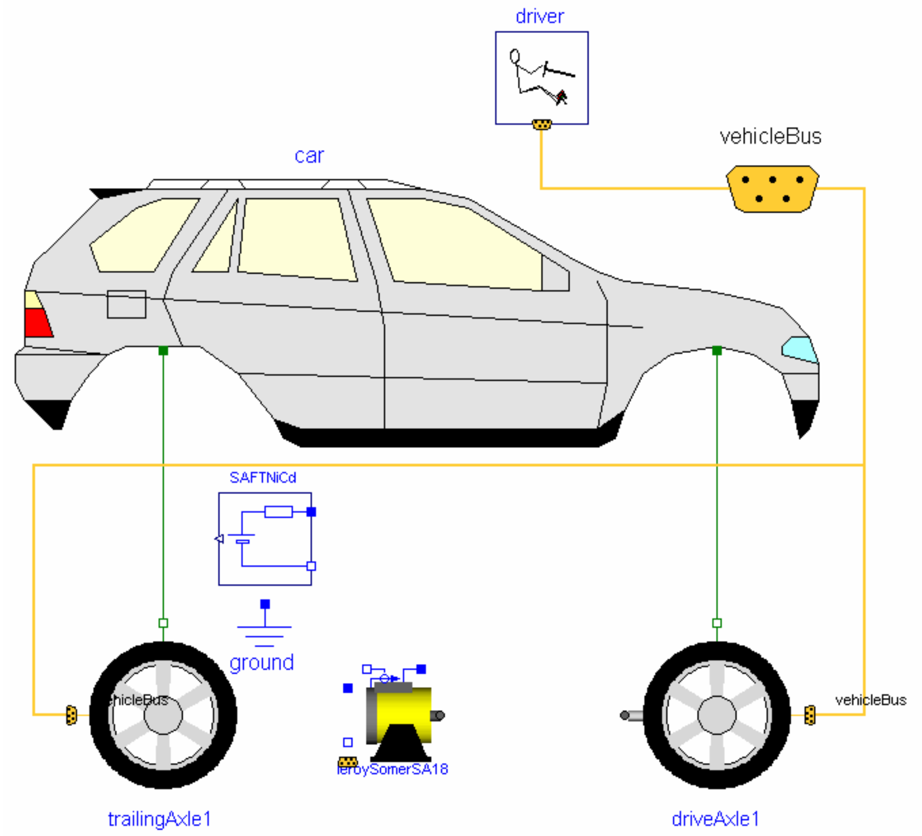


arsenal research

An Enterprise of the Austrian Research Centers.

Add the electrical components

- Component paths:
  - SmartElectricDrives.QuasiStationaryDrives.DCEESupplyDC
  - SmartElectricDrives.Sources.Batteries.BatteryIdealized
  - Modelica.Electrical.Analog.Basic.Ground



Parameters settings of the drive model

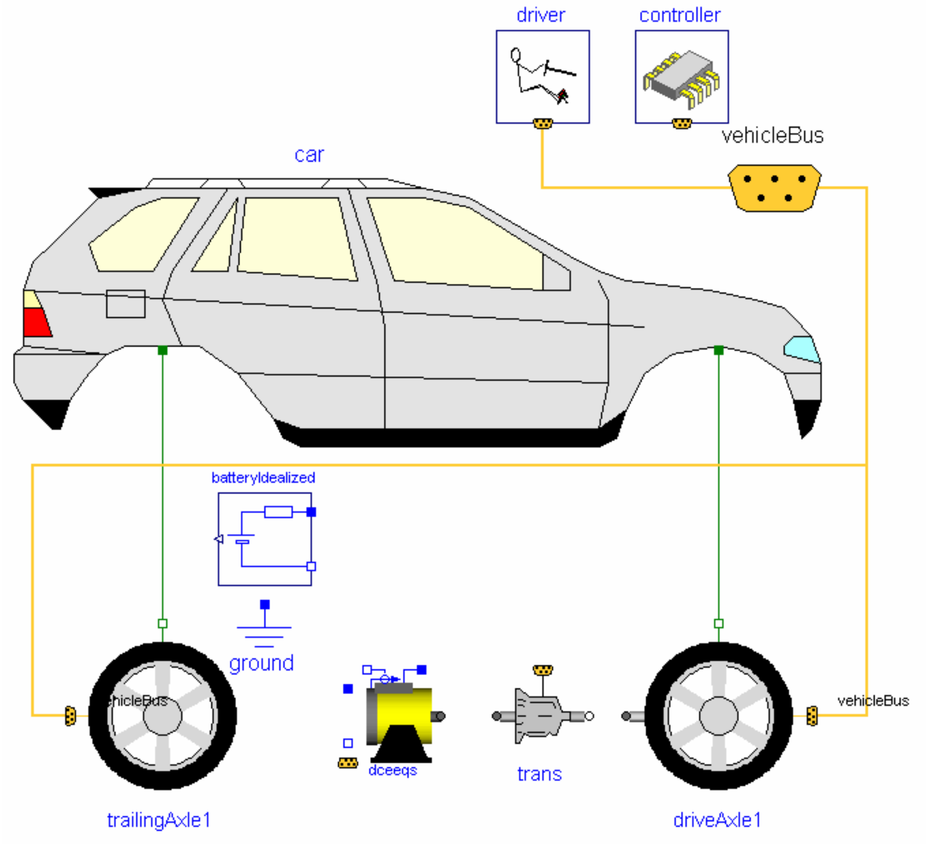
- DCEEQS
  - VaNominal = 162 V
  - IaNominal = 110 A
  - IeNominal = 9.5 A
  - rpmNominal = 1650 rpm
  - Jr = 0.2 kgm^2
  - Ra = 0.23 Ω
  - La = 0.007 H
  - Re = 12.63 Ω
  - Le = 1.263 H
- DCEEQS
  - TiConverter = 0.001 s
  - vMachineMax = 162 V
  - iMachineMax = 220 A
  - fluxLevel = 0.9
  - IConverterMax = 200 A
  - ieMax = 19 A
  - IeConverterMax = 19 A

Parameters settings of the battery model

- BatteryIdealized
  - QCell = 360000 C
  - VCellMin = 5.288 V
  - VCellMax = 6.315 V
  - SOCMin = 0
  - SOCMax = 1
  - SOCInit = 1
  - ICellMax = 150 A
  - RsCell = 0.0004 Ω
  - efficiency = 0.8
  - ICellChargeDischarge = 100 A
  - ns = 27
  - np = 1

Add the new gearbox and the new controller

- Component paths:
  - SmartHybridElectricVehicles.VehicleTypes.ElectricCars.PeugeotPartnerLike.Controllers.TorqueControllerEDrive
  - SmartHybridElectricVehicles.VehicleTypes.ElectricCars.PeugeotPartnerLike.AuxiliaryComponents.CVTideal



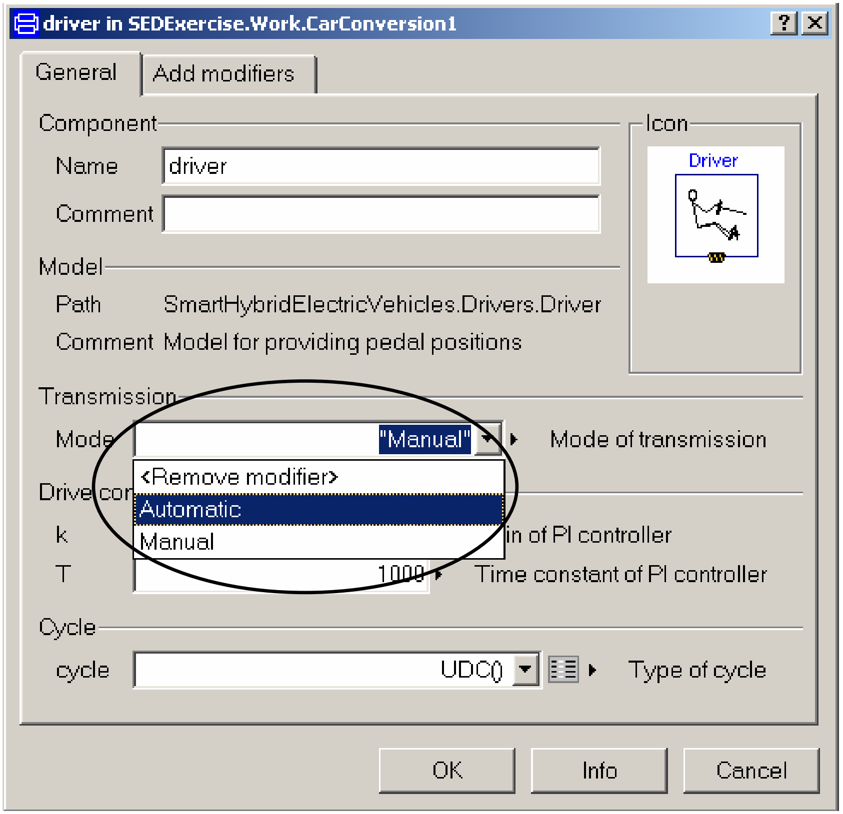
Parameters settings of the gearbox model

- CVTideal
  - ratioMax = 2.88
  - ratioMin = 0.62
  - Jin = 0.01 kgm^2
  - Jout = 0.01 kgm^2

arsenal research
An Enterprise of the Austrian Research Centers.

Change the driver settings

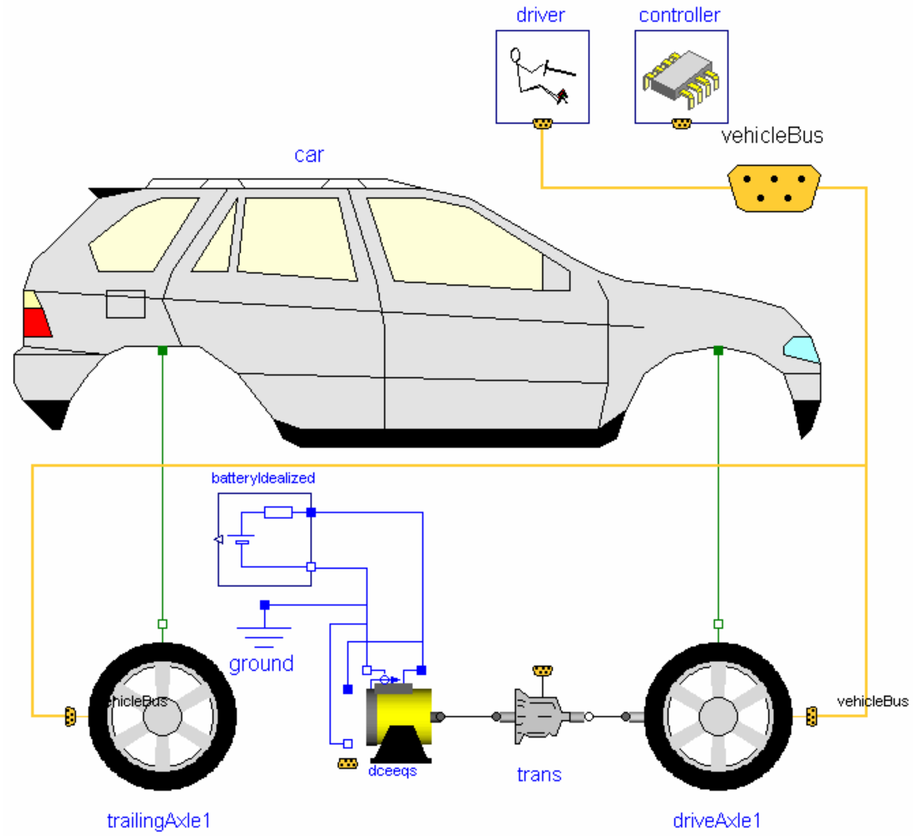
- Since the old gearbox had to be operated manual and the new gearbox is automatic it is necessary to change the corresponding parameter setting to **'Automatic'** in the driver model.



arsenal research
An Enterprise of the Austrian Research Centers.

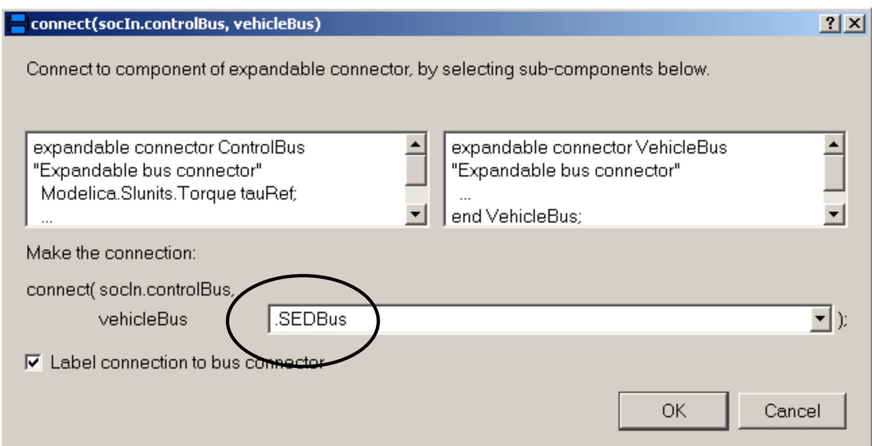
Connect the physical connectors

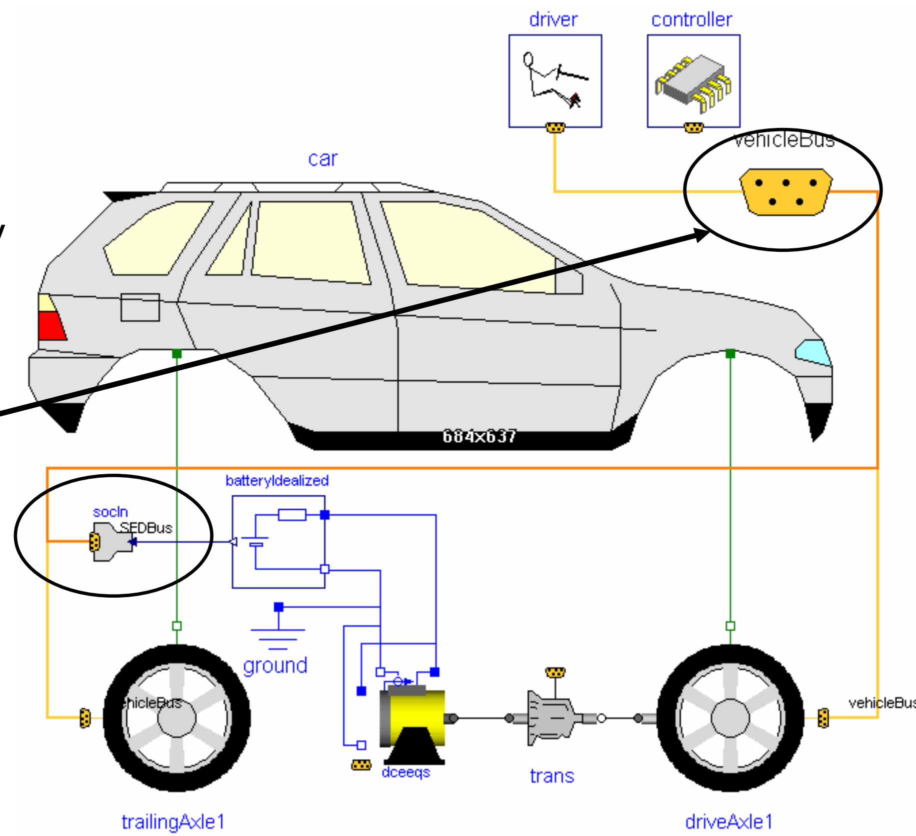
- Note that the excitation circuit of the DC machine may be connected to the same DC link circuit as the armature circuit.
- The shaft of the DC machine may be connected via the gearbox to the front axle of the vehicle.



Connect the signal bus connectors (1)

- Take the model **SmartElectricDrives. Interfaces.BusAdaptors.SOCIn** and connect it to the battery model.
- Connect this model with the vehicleBus by indicating the embedded bus system **'SEDBus'.**

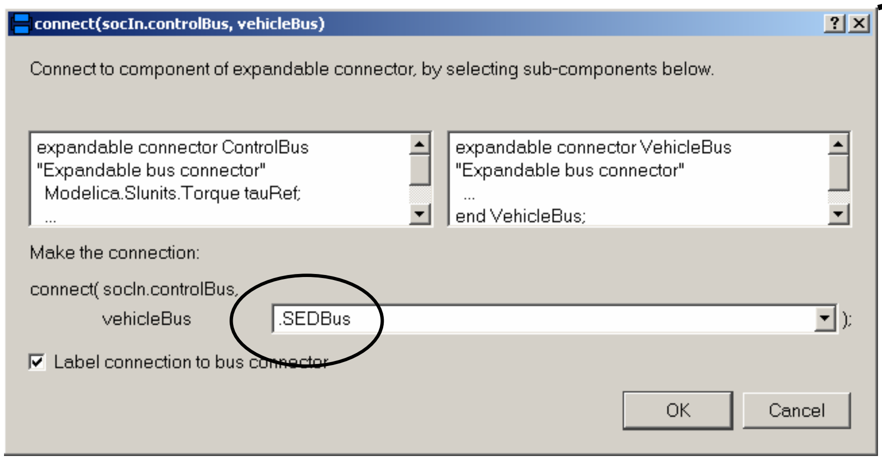


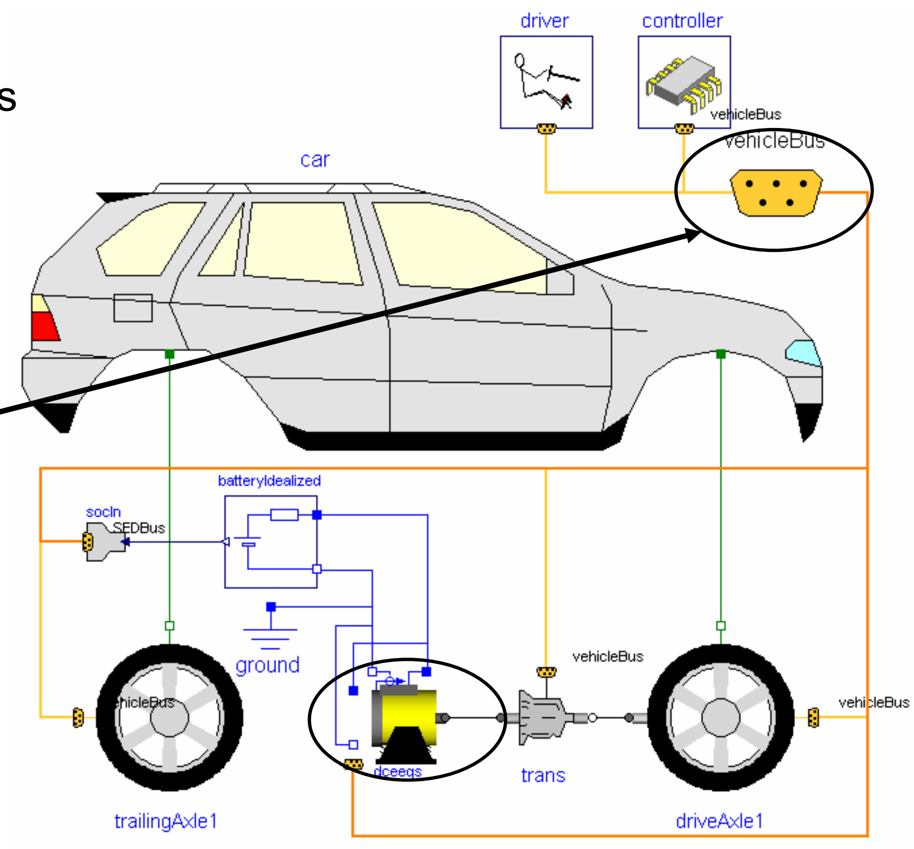


arsenal research
An Enterprise of the Austrian Research Centers.

Connect the signal bus connectors (2)

- Connect the drive model ‘dceeqs’ with the vehicleBus by indicating the embedded bus system **‘SEDBus’.**
- Connect the controller model and the gearbox model with the vehicleBus on the top level (no specific indication).

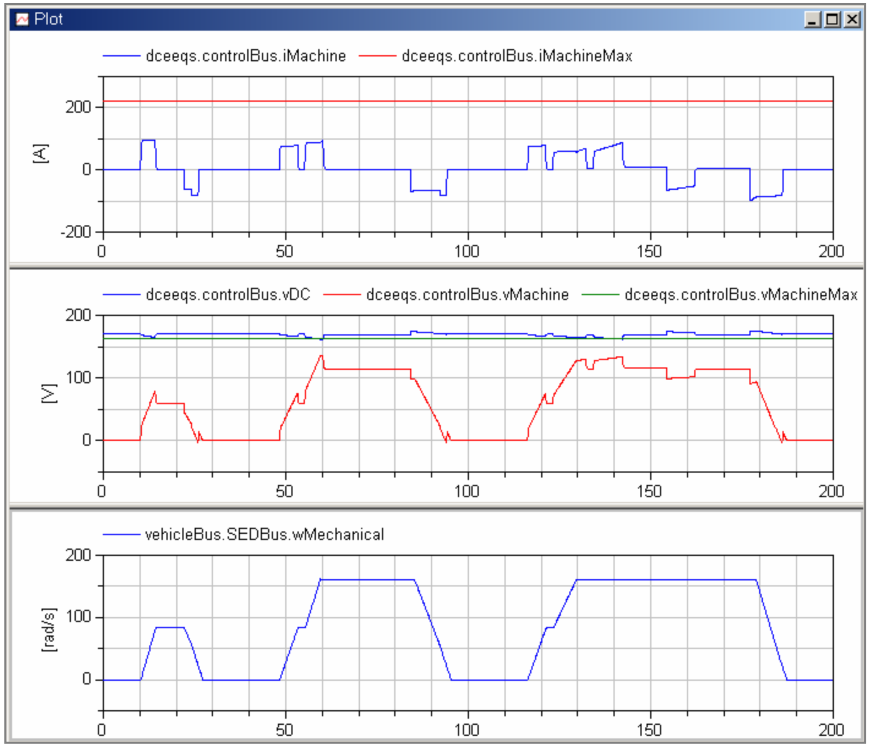




arsenal research
An Enterprise of the Austrian Research Centers.

Run the simulation and assess the results

- Compare the urban drive cycle (UDC) and the full load drive cycle at 120km/h.
- The full load drive cycle at 150 km/h is not applicable for this model.
  - **Display:** v, vRef
  - **The most important machine parameters can be found in dceeqs.controlBus:** iMachine, iMachineMax, vMachine, vMachineMax, vDC, wMechanical
  - **Display furthermore:** batteryIdealized.SOC



Thank you for the attention.

mail: sed@arsenal.ac.at

web: www.arsenal.ac.at

phone: +43-50-550 6282

fax: +43-50-550 6595

arsenal research
An Enterprise of the Austrian Research Centers.

The SmartElectricDrives library

A powerful tool for electric drive simulation