ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

DCIS

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SIMULATION OF EV AND HEV IN A VEHICLE SIMULATOR BASED ON A DETAILED PHYSICAL MODEL

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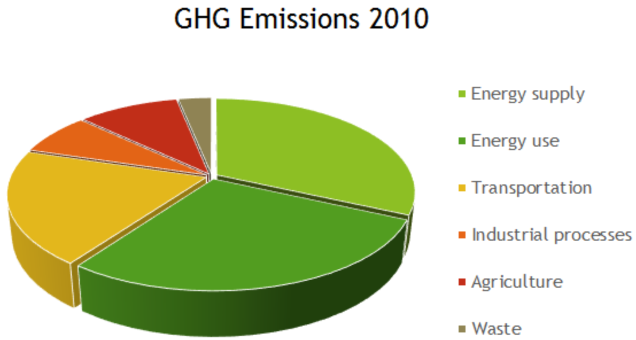
RICARDO

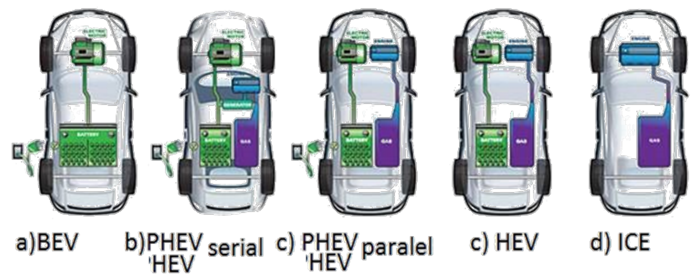
Content

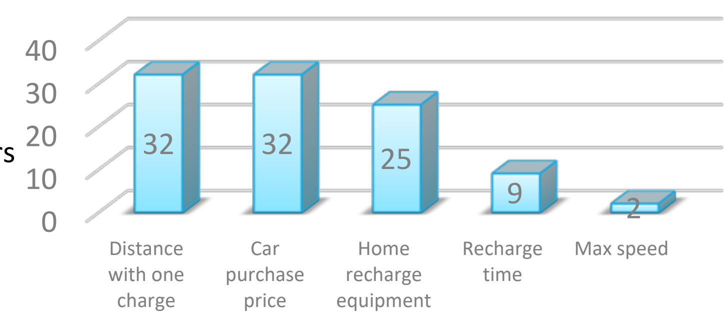
- Introduction of EV and HEV and their HMI
- Introduction to Modelica programming language and FMI as a tool to simulate EV
- Introduction to IGNITE
- Creation and validation of a model for simulation
- Integration into Vehicle Simulators
- Output of the simulation
- Example of the Use Case

Introduction

- Motivation
  - Transportation responsible for 19.7% of GHG
  - Where passenger cars responsible for 12% of this share
  - CO_2 emissions from Transport have risen 21% to 28% in 20 years.
  - It will rice if nothing is done
  - EU Directive Regulation CE/443
- Electric Vehicles and their benefits
  - Increase of efficiency (85%-95%)
  - Price and source of energy.
  - Pollutes less than gas-powered cars.
  - EV more reliable and require less maintenance
  - Using domestically-generated electricity
  - Utilize the existing electric grid.
  - Reduce pick load on network grid
- Why all vehicle ARE NOT electric
  - Range anxiety and lack of confidence in estimated range, and state of charge feedback
  - Problems with the process of charging, and reminding users to recharge
  - There are some concerns that electric vehicle driver information system is complexand heavy on information

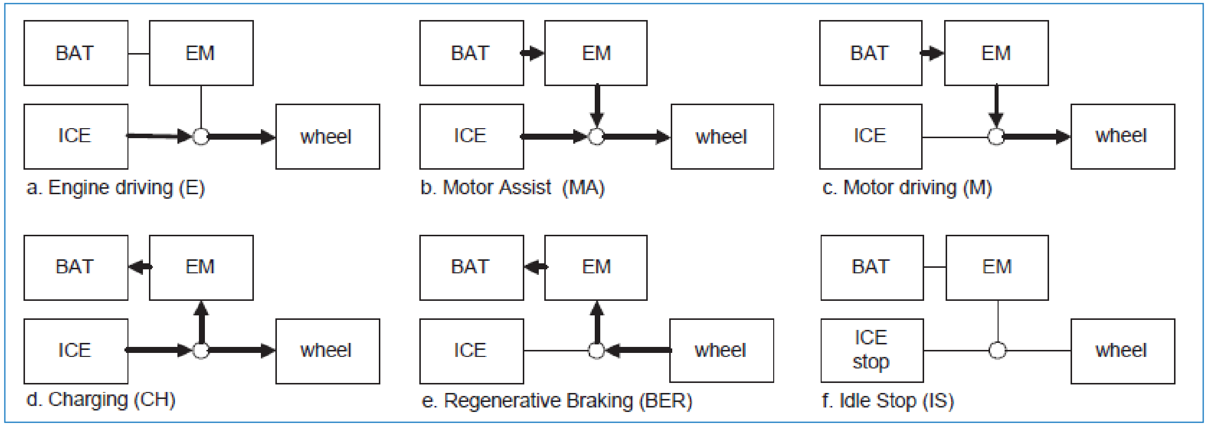






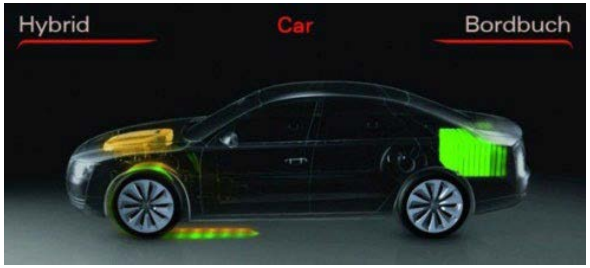
P2 HYBRID SELECTED ARCHITECTURE

- Energy-loss reduction
  - Stop-start system
- Energy recovery and reuse
  - Braking energy is not wasted
- Electric motor assist during acceleration
  - Motor is assisting ICE during acceleration
- Vehicle with high-efficiency operation control
  - To use the electric motor when the engine's efficiency is low and by generating electricity when efficiency is high



Modern approach to HMI for EV

- Maximally similar to ordinary ICE
  - Analog gauges with pointers
  - Power in/out gauge
  - Battery state of charge indicator SoC
  - Range information
  - READY’ indication
- Different gauge Location and use of additional portable devices
  - Power flow displays
  - Extended navigation features
  - Eco-feedback interfaces -feedback



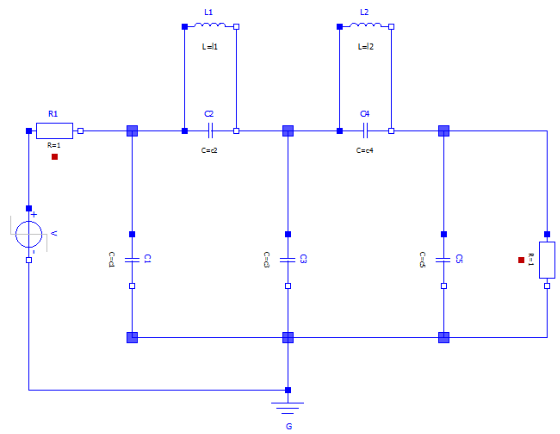
- EV and HEV HMI design requirements
  - The system should not be limited in functionality compared to ICE vehicles
  - The system should improve user's safety and comfort.
  - The system should help to deal with energy shortage.
  - The system should be attractive and intuitive.
  - The system should not limit a user in drive style.
  - The system should provide a functionality to improve vehicle energy consumption
  - Information provided by HMI should be trustworthy, and consistent
- How to evaluate such a complex system.
  - A complex simulation tool is needed
  - A tool create and adjust Control strategy of EV
  - A complex evaluation tools are needed
  - User safety and integrity of results should be preserved

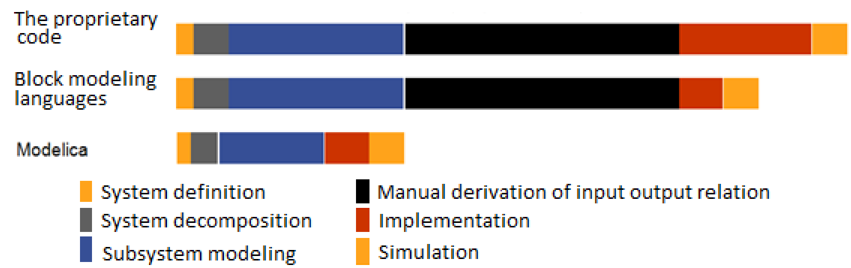
Evaluation on a Vehicle Simulators can be a solution

MODELICA INTRODUCTION

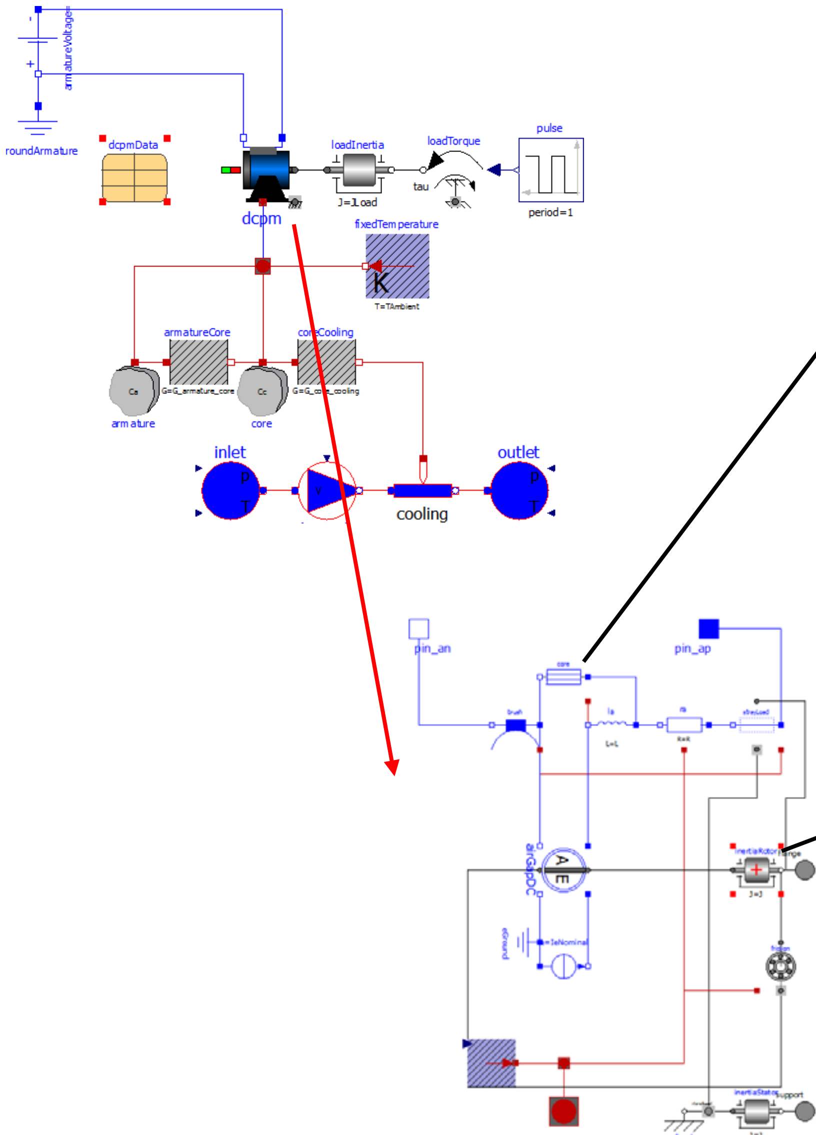
- *"Modelica is really an ideal language for modeling the behavior of engine systems in nearly any engineering domain"*
- **High-level, declarative, object oriented** language for describing mathem behavior.
- Allow the description of continuous and discrete behavior framed in the context of system of hybrid **differential-algebraic** equations.
- Describe the behavior of different types of engineering components
- Components can then be combined into subsystems, systems or even architectures
- Supports both physical design and control design in a single language

CauerLowPassAnalog





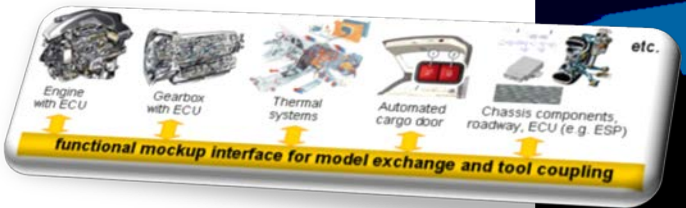
MODELICA SIMPLE EXAMPLE



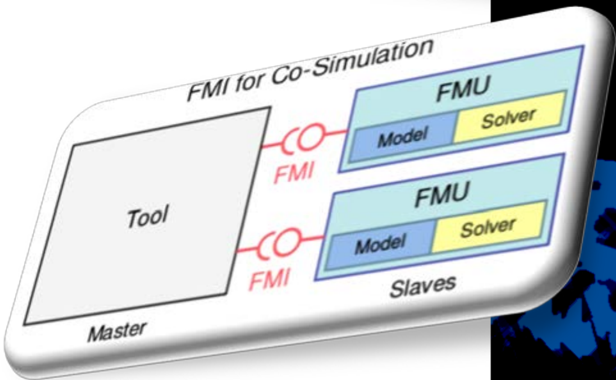

```
class Basic.Resistor
  Real v "Voltage drop between the two pins";
  Real i "Current flowing from pin p to pin n";
  Real p.v "Potential at the pin";
  Real p.i "Current flowing into the pin";
  Real n.v "Potential at the pin";
  Real n.i "Current flowing into the pin";
  parameter Real T "Fixed device temperature if useHeatPort = false";
  Real LossPower"Loss power leaving component via HeatPort";
  Real T_heatPort "Temperature of HeatPort";
  parameter Real R "Resistance at temperature T_ref";
  parameter Real T_ref = 300.15 "Reference temperature";
  parameter Real alpha = 0.0 "Temperature coefficient of resistance";
  Real R_actual "Actual resistance" ;
equation
  R_actual = R * (1.0 + alpha * (T_heatPort - T_ref));
  v = R_actual * i;
  LossPower = v * i;
  v = p.v - n.v;
  0.0 = p.i + n.i;
  i = p.i;
  T_heatPort = T;
  p.i = 0.0;
  n.i = 0.0;
end Basic.Resistor;
```

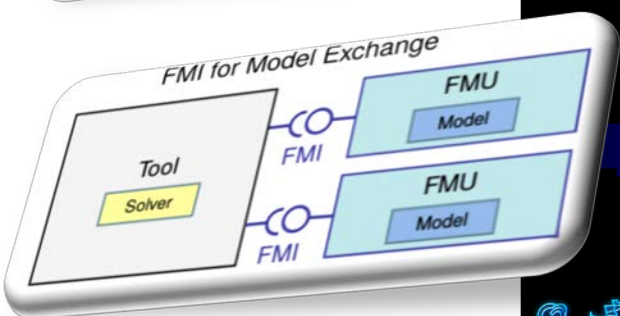
```
class Components.Inertia
  Real flange_a.phi "Absolute rotation angle of flange";
  Real flange_a.tau "Cut torque in the flange";
  Real flange_b.phi "Absolute rotation angle of flange";
  Real flange_b.tau "Cut torque in the flange";
  parameter Real J "Moment of inertia";
  Real w "Absolute angular velocity of component (= der(phi)
  Real a "Absolute angular acceleration of component (=
equation
  flange_a.phi= flange_b.phi;
  w = der(phi);
  a = der(w);
  J * a = flange_a.tau + flange_b.tau;
  flange_a.tau = 0.0;
  flange_b.tau = 0.0;
end Components.Inertia;
```

FMI INTRODUCTION



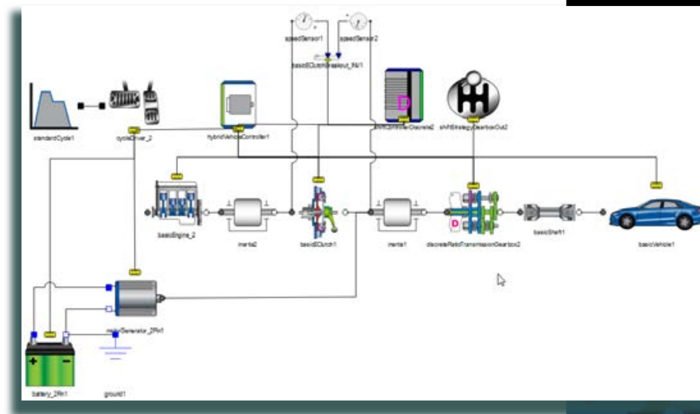
- *"The Functional Mockup Interface (FMI) is a tool independent standard for the exchange of dynamic models and for co-simulation. "*
- The primary goal is to support the exchange of simulation models between suppliers and OEMs
    - Different data formats
    - Different domains
- Platform dependent implementation(.DLL,.SO) - FMI API
    - Can be integrated in to C code directly (20 C functions)
    - PyFMI (JModelica) Python interface
    - Other .NET, Excel, Matlab
    - More then 100 tools already using it including IGNITE, Adams, CATIA, SimulationX and etc.

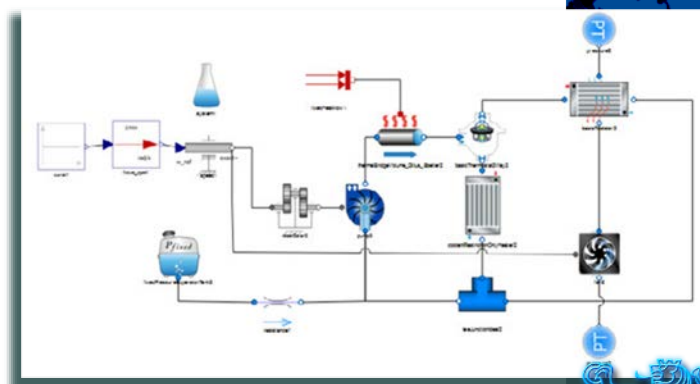




IGNITE RICARDO

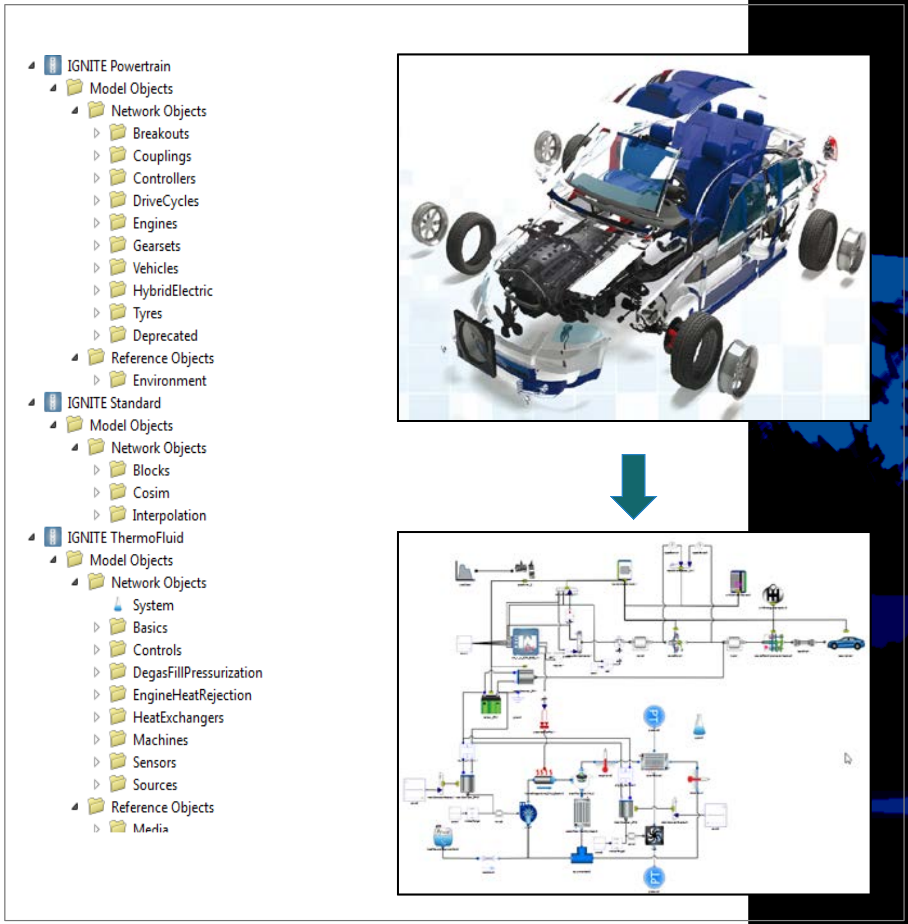
- **IGNITE** is a physics-based system simulation package focused on complete vehicle system modeling and simulation.
  - Provides hybrid-electric and full electrical vehicle system modeling capabilities
  - Flexible controls integration - development of hybrid controls systems
  - Battery thermal modeling
  - Detailed e-machine modeling
  - Posibility to integrate thermal systems modeling (performance issues)
  - Combined vehicle / thermal system simulation, Battery TM, and Motors and engine cooling circuits, AVAC systems
  - Models can be imported as FMU for Co - Simulation



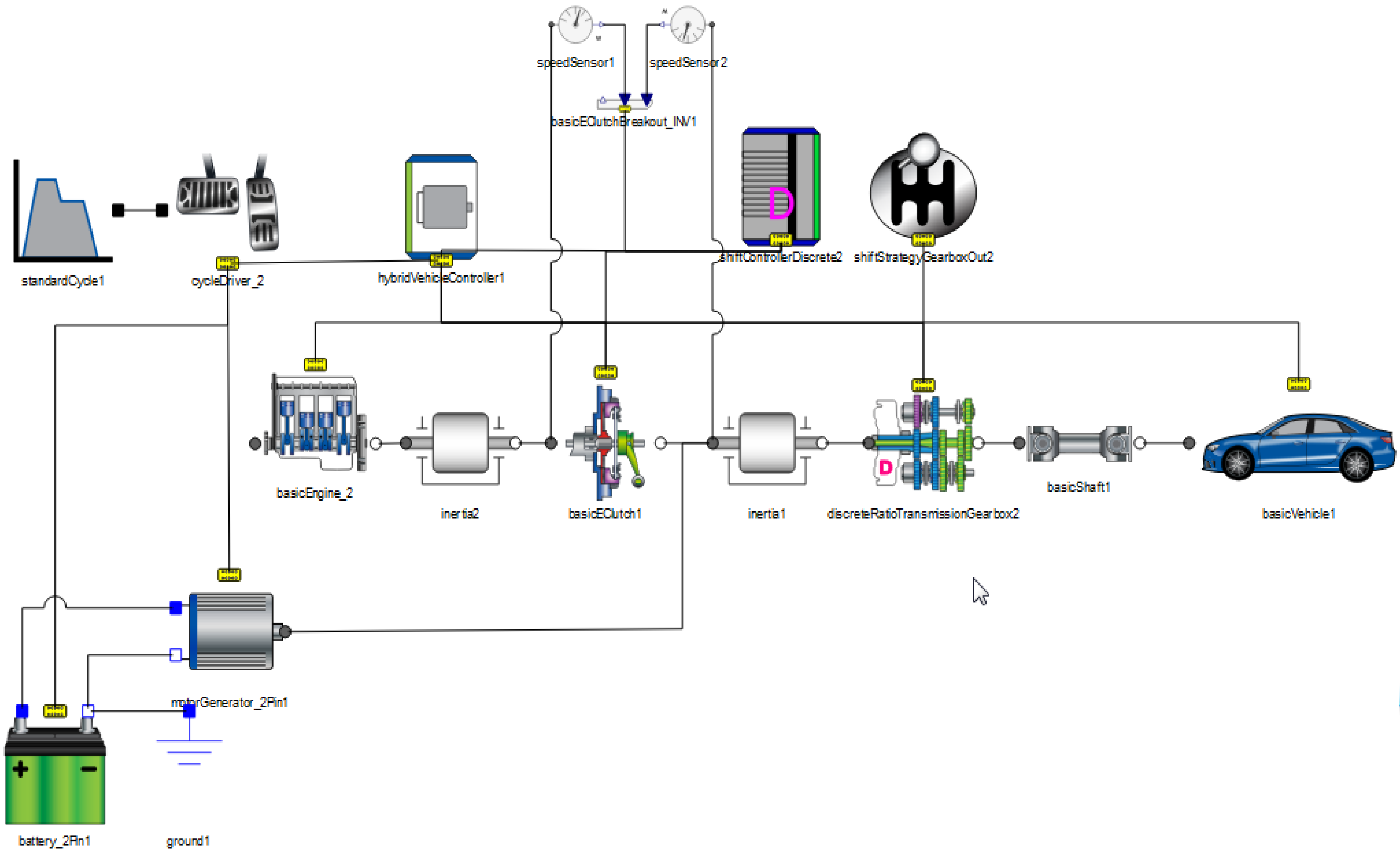


IGNITE Model Creation

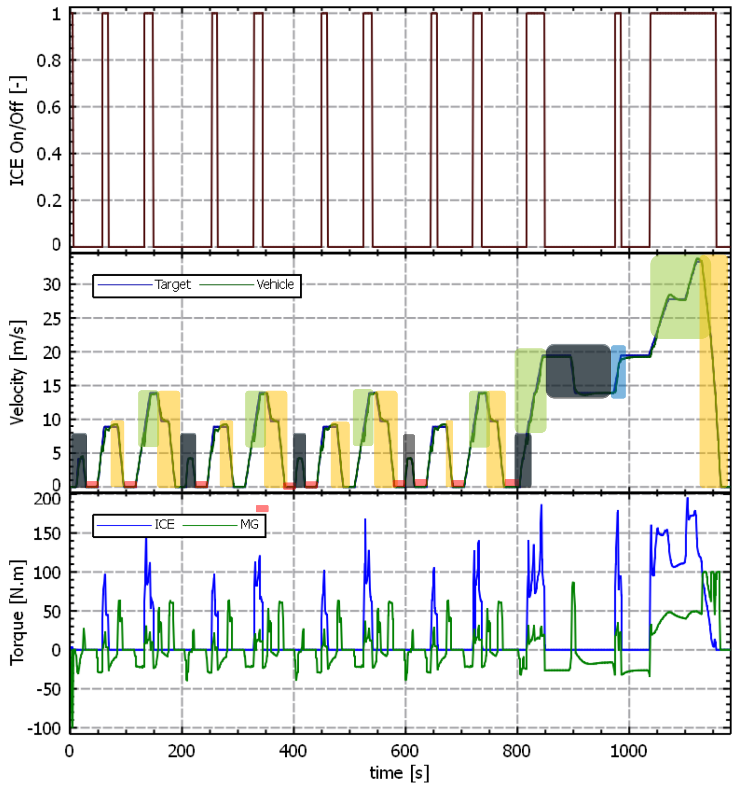
- IGNITE model development
  - Collect all necessary vehicle information (tires, aerodynamics, mass, …)
  - Collect powertrain information (gear efficiencies, shifting maps, engine maps, electrical machine and battery characteristics, …)
  - Build the model by using IGNITE libraries:
    - Powertrain
    - Standard
    - ThermoFluid
    - Modelica Standard Library
  - Create a user library if necessary



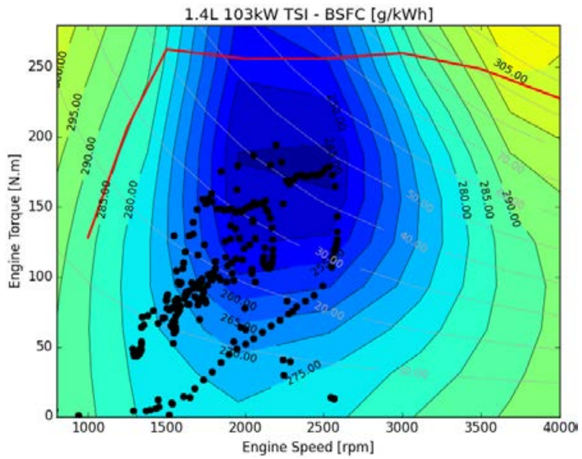
IGNITE model of P2 hybrid



IGNITE Model Results Verification HEDC



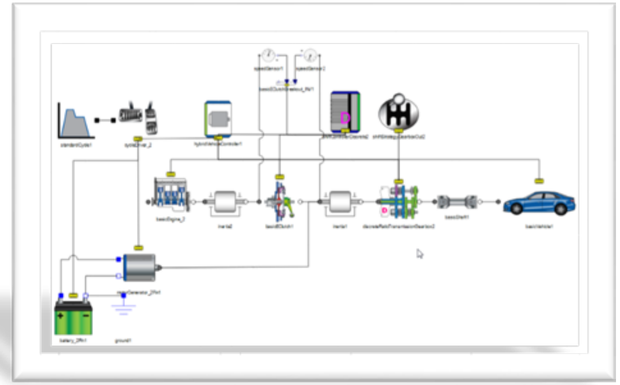
- Pure EV Mode
- Load Averaging/Generation Mode
- Electric Boost
- Regenerative Braking
- Stop Start

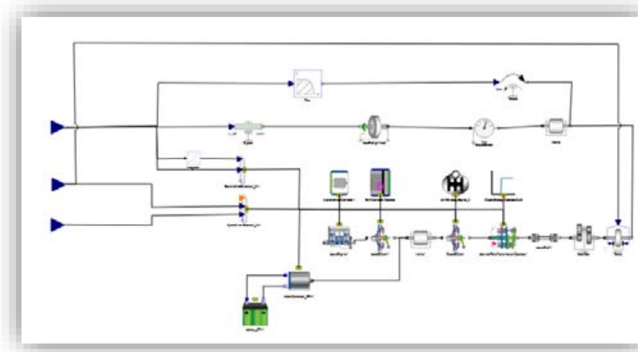


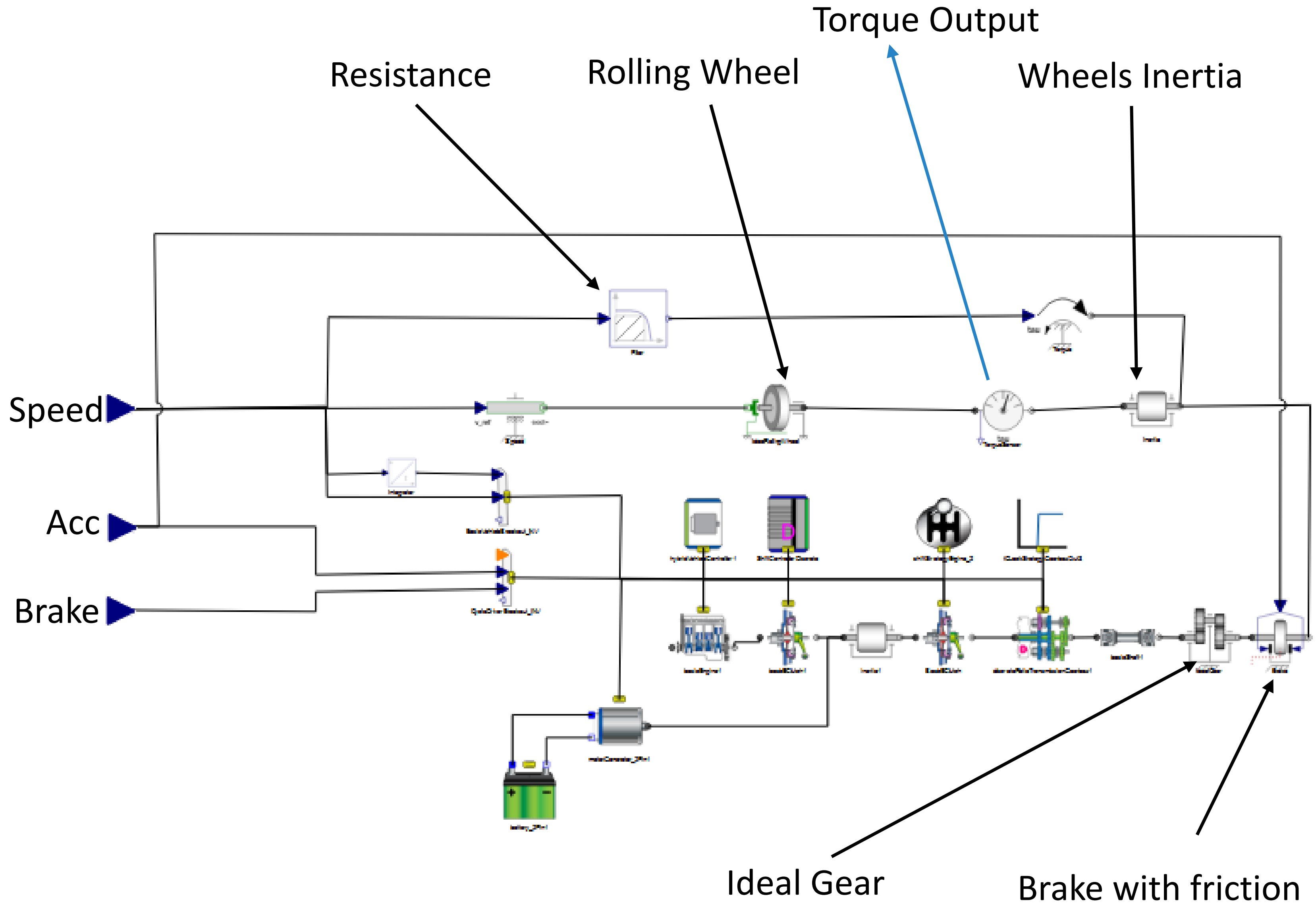
Fuel Economy: 4.3 L / 100 km
CO2 equivalent: 100 g/km

Model integration

- Driver Cycle – replaced with direct Real input:
  - Acceleration pedal (Acc Demand)
  - Brake pedal (Brake Demand)
  - Vehicle velocity
- Torque transferred directly to wheels minus air, rolling resistance (additional element is added)
- Grade resistance is calculated by Master Physical Engine (Bullet or ODE physical engine)

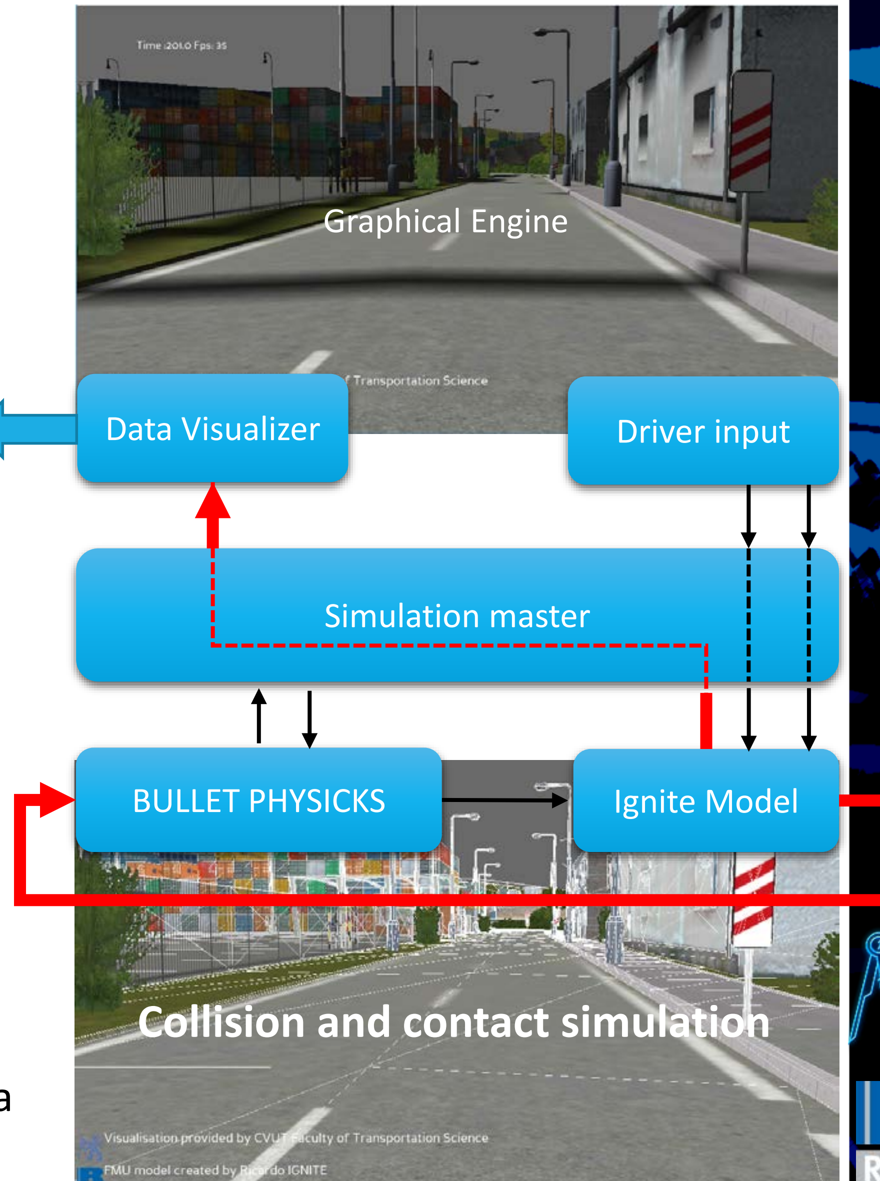





Torque Output
Resistance
Rolling Wheel
Wheels Inertia
Speed
Acc
Brake
Ideal Gear
Brake with friction

MOVING TO 3D

- Scenario, Bullet / ODE physics
  - Collision control
  - Mesh wheel- road contact point simulation
  - Gravity effect and suspension
  - Bullet Vehicle model
- IGNITE FMU
  - Powertrain simulation
  - Air and Rolling resistance
  - All calculated variables transmitted via we
- Master –Slave algorithm synchronization

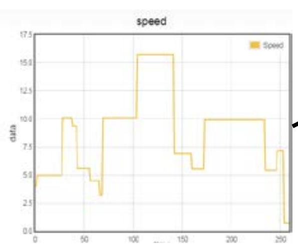


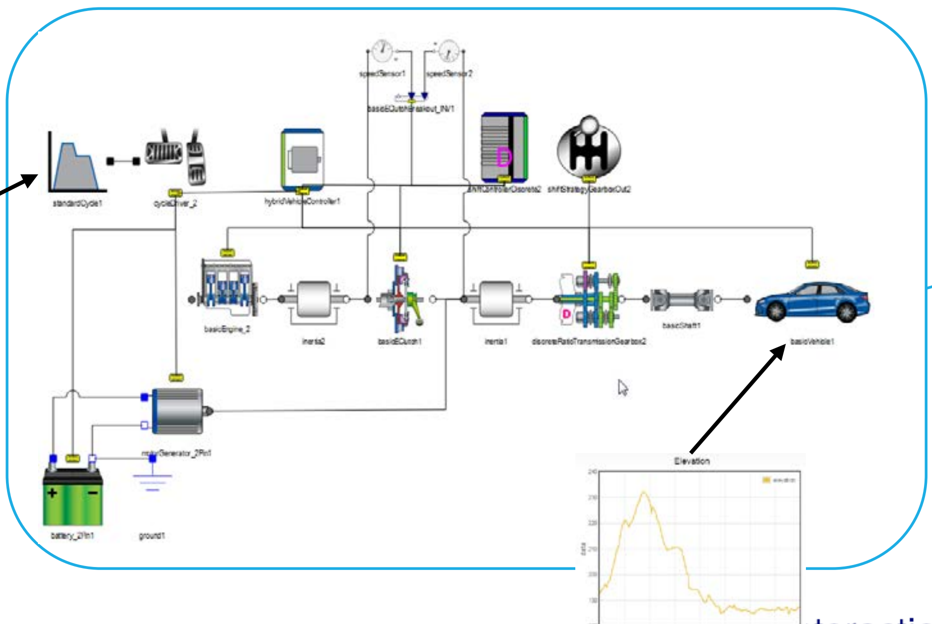
What do we get as an output

- What we obtained
  - State of the charge
  - Energy Flow
  - Mode of operation
  - Instant ad cumulative fuel and energy consumption
  - Temperature (engine, battery, motors, inCabine)
  - All the internal data (Torques, Forces, Voltages Currents and etc.)
- What can be implemented more
  - Predictive fuel and energy consumption
  - Estimated range based on history
  - Dynamic consumption maps
  - Estimation of driver efficiency (“Green driver” reward)
- All the date available on request for visualization
  - UDP, WebSocket Communication Protocol
  - Additional Software can be used to simulate an EV Gauges

Predict Energy consumption Use Case

- Use same IGNITE model
- Obtain “ahead” elevation profile (EP)
  - Feed EP as a terrain profile for the model
- Obtain “ahead” speed limits (SL)
  - Introduce some randomness
  - Feed SL as a Cycle for Cycle Driver
- Run simulation in parallel (5-10 sec)
- Obtained SoC profile can be used to predict Vehicle range on a rout or several routes





Design of experiment and Evaluation of the HMI

- Possible scenarios
  - Limited SoC with and without predictive algorithms
  - “Green driver” rewards effects.
  - Energy Flow display usability.
- Measured parameters
  - Driver eye sight (position of the sight on the gauge)
  - Region of interests (which gauges are of interest)
  - Gauge check frequency
- Driver acceleration and deceleration rate
- Questionnaires

Referenses

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