Aalto University
School of Engineering

Vehicle mechatronics
5 cr.
Introduction to QSS toolbox

Dr. Tatiana Minav

QuasiStatic Simulation toolbox (QSS)

+ Toolbox makes it possible for powertrain systems to be designed quickly and in a flexible manner
+ Calculate easily the fuel and energy consumption
+ Toolbox contains examples of a number of elements
+ QSS models are ideally suited for the optimization of the fuel consumption under various control strategies
- The quasi-static approach obviously is not suitable for the capture of dynamic phenomena
- Due to the purely backward modeling technique performance simulations cannot be done

Dynamic modeling

- Dynamic modeling is based on “correct” mathematical description of the system.
- Usually this means ordinary differential equations in state-space form
- Purpose is to accurately describe dynamic effects
- Dynamical modeling is computationally intensive and sometimes unnecessary accurate in capturing “slow” phenomena

Quasi-static modeling

- In QSS, time is broken down into finite amount of time steps *h,* in each of these time steps, system is interpreted as static system
- In QSS modeling, look-up tables and charts can be used (since they are static models)
- QSS approach is very useful for “slow” phenomena, such as fuel consumption during driving cycle
- QSS approach is computationally light, so it suits very well in designing control strategies and optimizing them

Quasi-static modeling

Vehicle in the plane – traditional approach:

System: $m \cdot \dot{v}_f(t) = F_a(t) - m_f \cdot g \cdot c_r - \frac{1}{2} \cdot \rho_L \cdot c_w \cdot A_f \cdot v_f^2(t)$

Cause: force $F_a(t)$

Effect: vehicle speed $v_f(t)$

Vehicle in the plane – QSS approach:

System: $m \cdot \dot{v}_f(t) = F_a(t) - m_f \cdot g \cdot c_r - \frac{1}{2} \cdot \rho_L \cdot c_w \cdot A_f \cdot v_f^2(t)$

Cause: $v_f(k \cdot h)$, i.e., speed given at certain times

Effects:

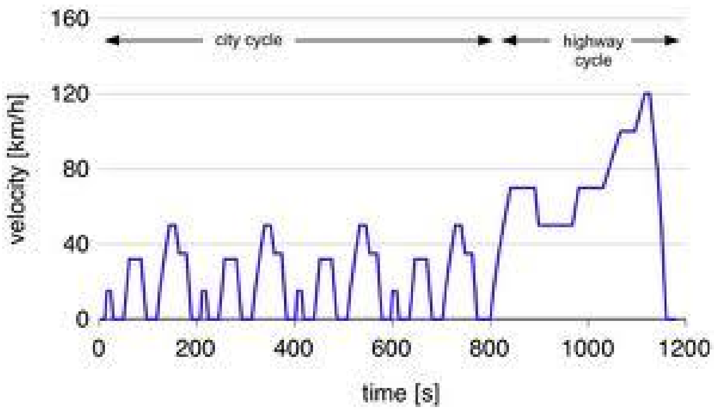
1. Mean speed $v_f(t) = (v_f(k \cdot h + h) + v_f(k \cdot h))/2$, $\forall t \in [k \cdot h, k \cdot h + h)$
2. Acceleration $\dot{v}_f(t) = (v_f(k \cdot h + h) - v_f(k \cdot h))/h$, $\forall t \in [k \cdot h, k \cdot h + h)$
3. Driving force $F_a(t)$ (constant in the interval $\forall t \in [k \cdot h, k \cdot h + h)$!)

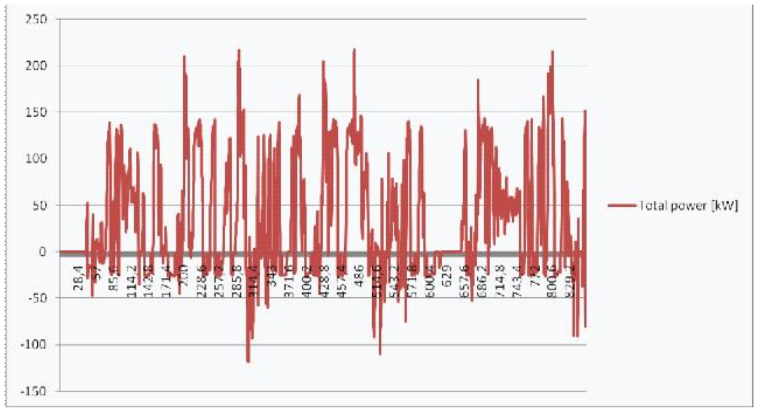
Backward modeling

- In backward modeling, load power for powertrain is calculated from the wheels towards the power sources (or from output to input)
- Load power or v/t-profile is a priori information
- Obviously backward modeling is a reversed concept of forward modeling (pedal to traction motor)
- Quasi-static modeling à backward modeling
  - or backward/forward modeling à ADVISOR
- Dynamic models à forward modeling

Driving cycle

- Driving cycle is a presentation of the vehicle behavior as function of time
- Term “Driving cycle” is commonly used with road vehicles and is in form of speed vs. time



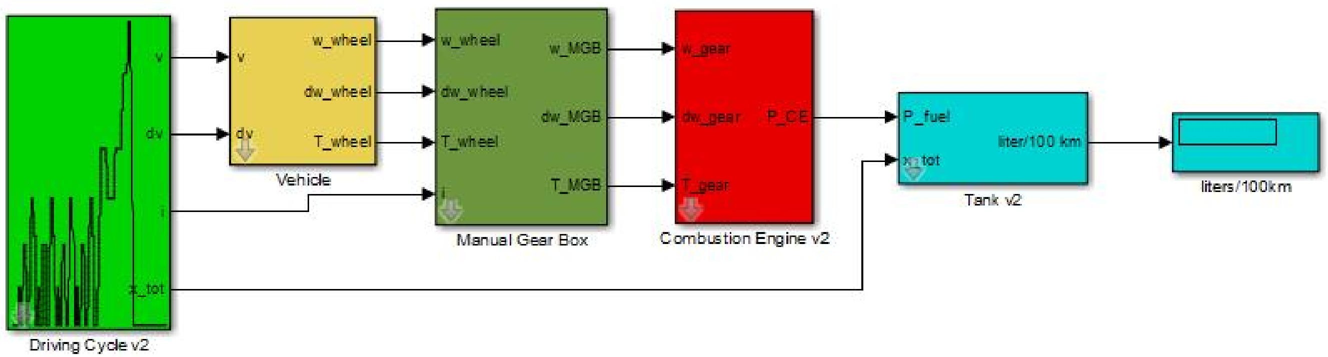


QSS Toolbox introduction

- Original Toolbox developed by ETH Zurich
  - Folder *“QSS_Original”*
  - Manual in Folder “Documentation”
- Modified models and data for this course
  - Folder *“QSS_Aalto”*
  - Models of conventional, electric and series hybrid vehicles
  - Predefined vehicle data in each model and component
  - Updated model library *“qss_tb_library_aalto.mdl”*
  - Modified component models in reference to the original models
    - Battery, engine, generator, fuel cell and control for hybrid vehicle
    - Two additional driving cycles (SC03 and US06)

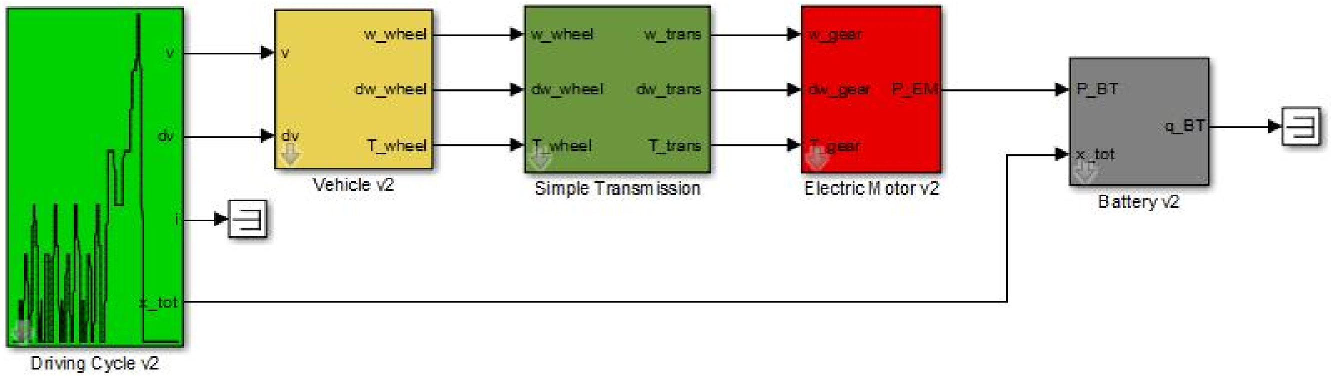
Conventional vehicle model

- Fuel consumption simulations with gasoline and diesel engine
- Engine size can be scaled by changing the engine displacement
  - Minimum size: 1.4 liter
- Gearbox gear ratios can be optimized with script “MasterOptiGear”

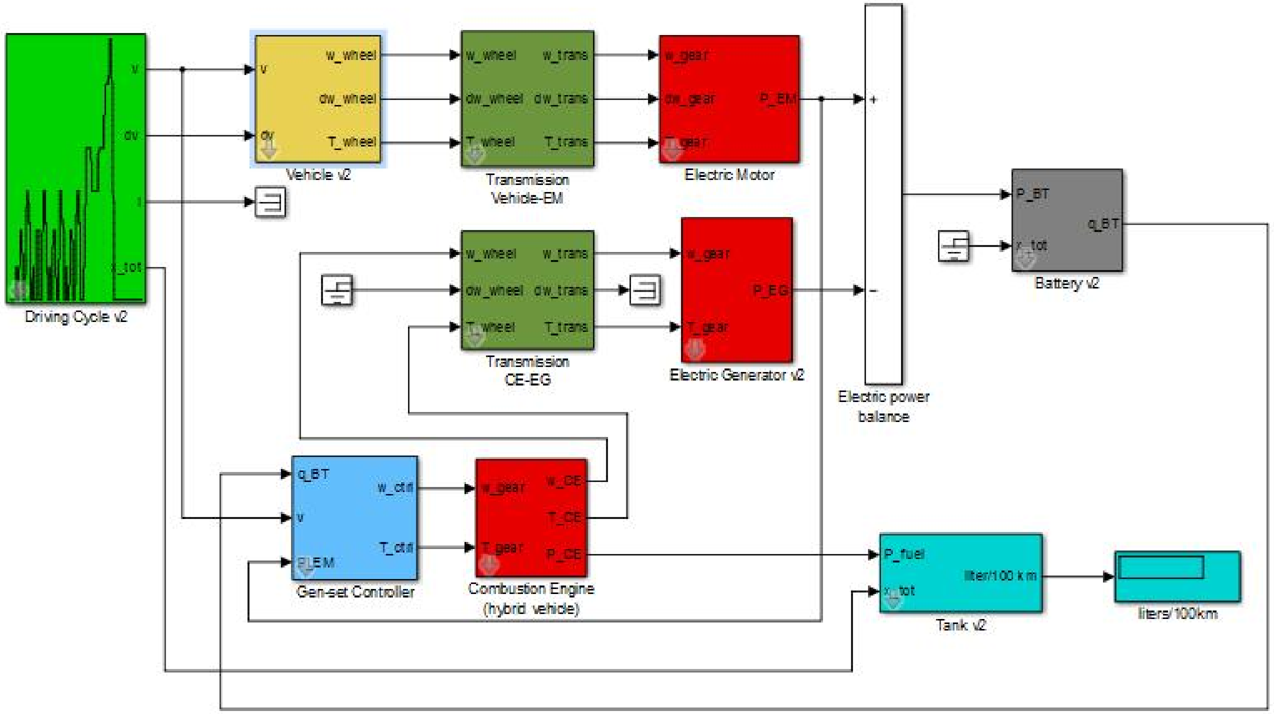


Electric vehicle model

- Energy consumption simulations with different types of batteries
- Electric traction motor size can be scale by the scaling factor
  - Minimum size: factor of 3.5
- Battery model is parameterized the way that simulations should be done by running the script *“QSS_simulation.m”*



Series hybrid vehicle model



Series hybrid vehicle model

- Energy consumption simulations with different size of battery and gen-set
- Electric traction motor size can be scale by the scaling factor
  - Minimum size: factor of 3.5
- Battery size can be defined in terms of cells in series and parallel
- Predefined battery initialization files
- Gen-set size can be scaled by changing the engine displacement
  - The size of the generator scales automatically based on the engine size
- The gen-set control is based on the vehicle speed and battery state of charge
  - The output control power is calculated based on the maximum power limit of the engine and the battery state of charge

Fuel cell and supercapacitors

- There are predefined component models also for fuel cell and supercapacitors in the library
- Fuel cell model is parameterized to correspond commercial fuel cell stack: *Hydrogenics HyPM HD 30*
- Fuel cell model can replace the gen-set combination
  - Gen-set: engine – gear reduction - generator
- Supercapacitor model can be used in the place of the battery

Instructions for simulations

1. Download the toolbox file (QSS_TB_Aalto.zip) from MyCourses
   – Under weekly exercises: Simulation toolbox
2. Unzip the content of the file
3. Start Matlab
4. Add all the folders of the toolbox in Matlab path
   - Click right mouse button over the folder **QSS_TB** and choose "Add to Path" and then "Select Folders and Subfolders"
5. Open the model called *"qss_example_conv.mdl"*
6. Simulate the model from Simulink
7. For Electric vehicle model, script *"QSS_Simulation.m"* needs to be run in Matlab for parameter initialization

Additional information

- For any modifications of the models, create your own directory where you can save your models and keep the Toolbox files unmodified
- For each model there is a predefined plotting script
  - Called “plot_example_<type_of_the_vehicle>.m” à e.g. for electric vehicle it is called “plot_example_electric.m”
- Additional information of the vehicle and component default parameters as well as the output variables of the models can be found in
  - “Additional documentation for QSS Toolbox.pdf”