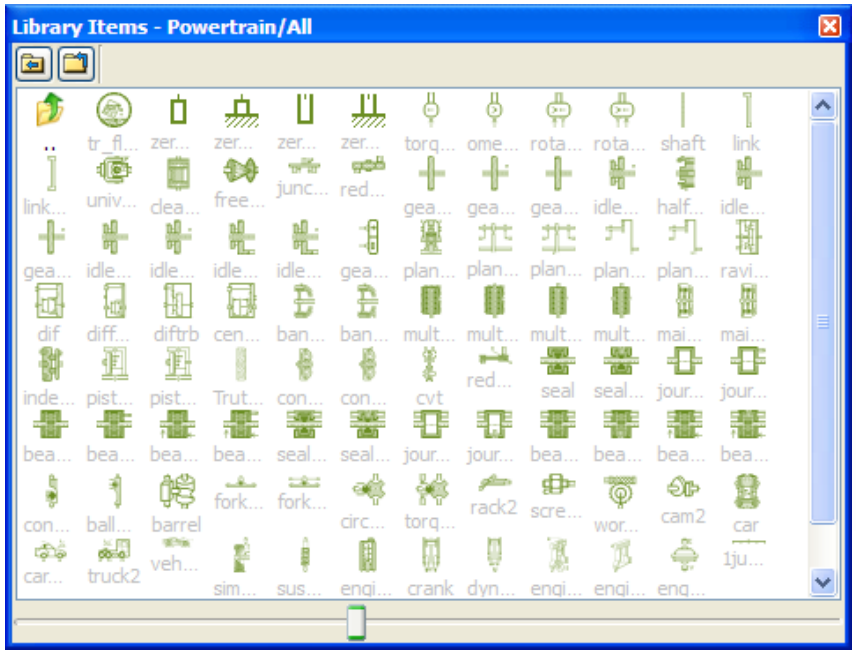
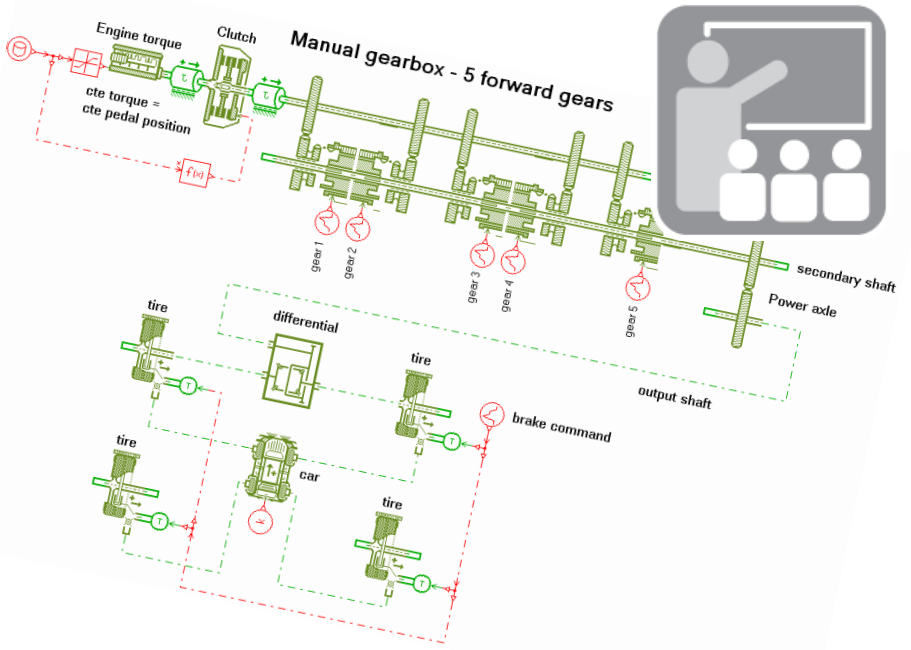
AME_TR2: Agenda

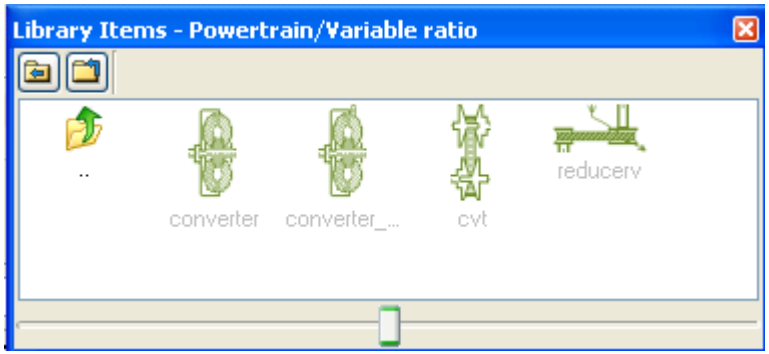
1. Introduction
2. Sign convention – T junction
3. End stop models – Rotary shafts
4. Friction models
5. Clutches – Brakes
6. Tire models
7. Gear trains - planetary gear train – idle gear models
8. Bearings
9. Thermal aspects in Powertrain components
10. Torque conversion elements (Torque converter – CVT)
11. Synchronizer
12. Contact models
13. Vehicle models
14. Engine models
15. 2D and 3D models





TR2 - Powertrain and Transmission modeling

10 – *Torque conversion elements*

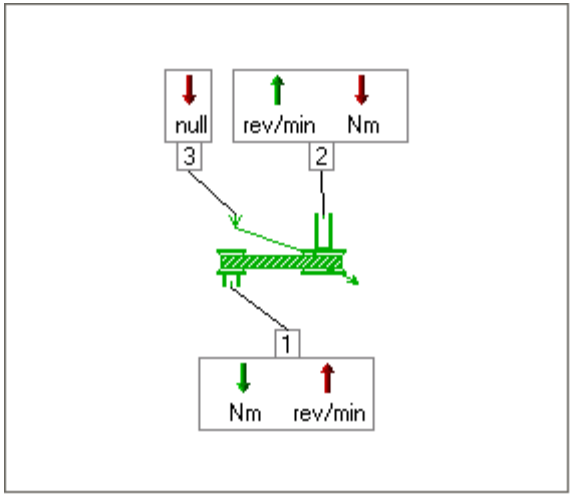


LMS ENGINEERING INNOVATION

Torque conversion elements: Agenda

1. **Simple ratio reducer model**
2. **Torque converter**
3. **CVT**

Simple ratio reducer model



- This a model of an ideal ratio reducer system (gear box, CVT, torque converter)
- The ratio is a signal input and can be changed during the simulation
- No parameter
- No losses

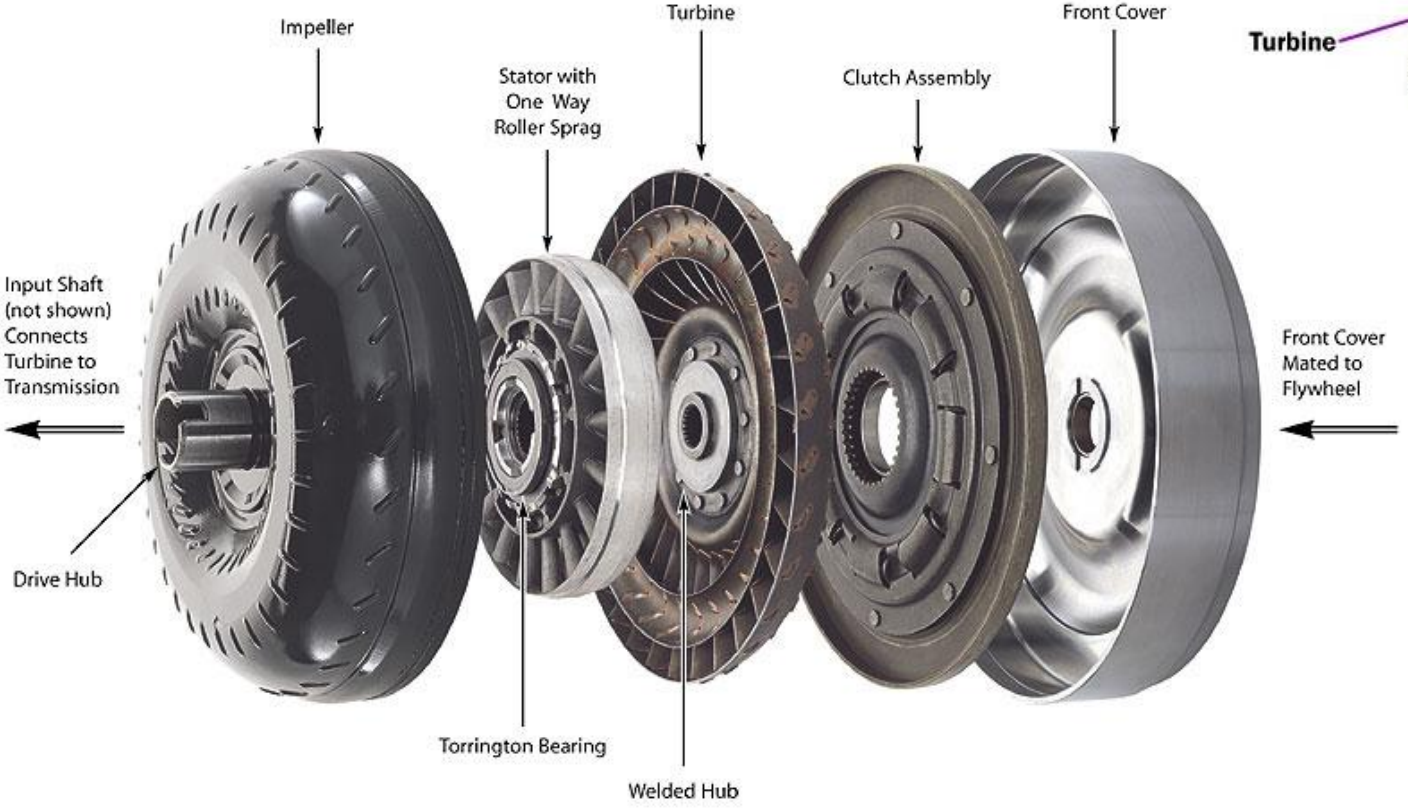
Torque conversion elements: Agenda

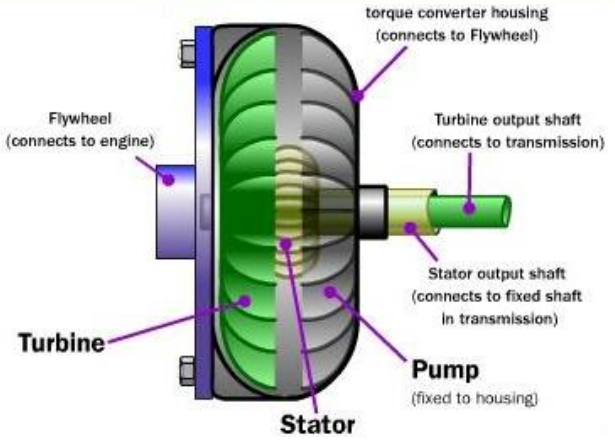
1. Simple ratio reducer model
2. Torque converter
3. CVT

LMS® ENGINEERING INNOVATION

Variable Torque Components

Torque Converter

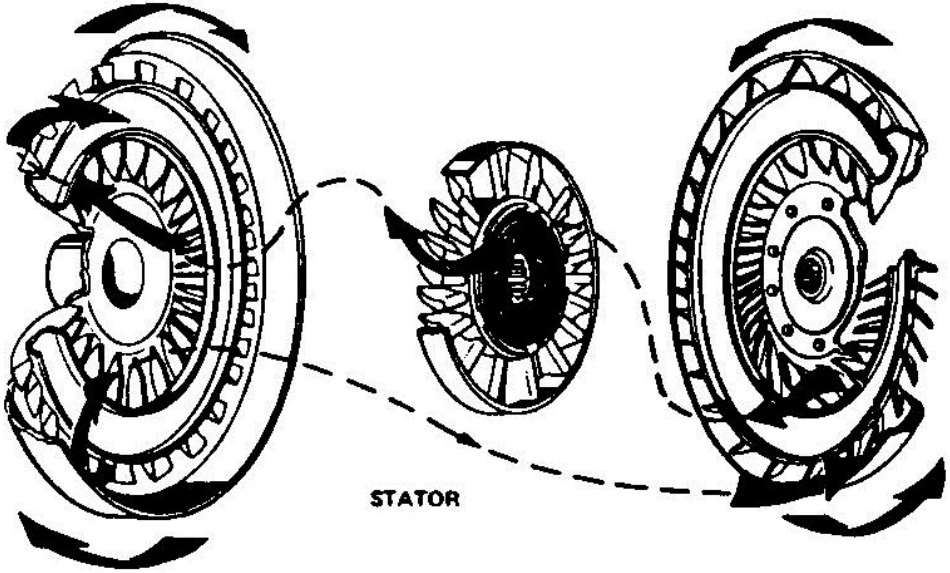


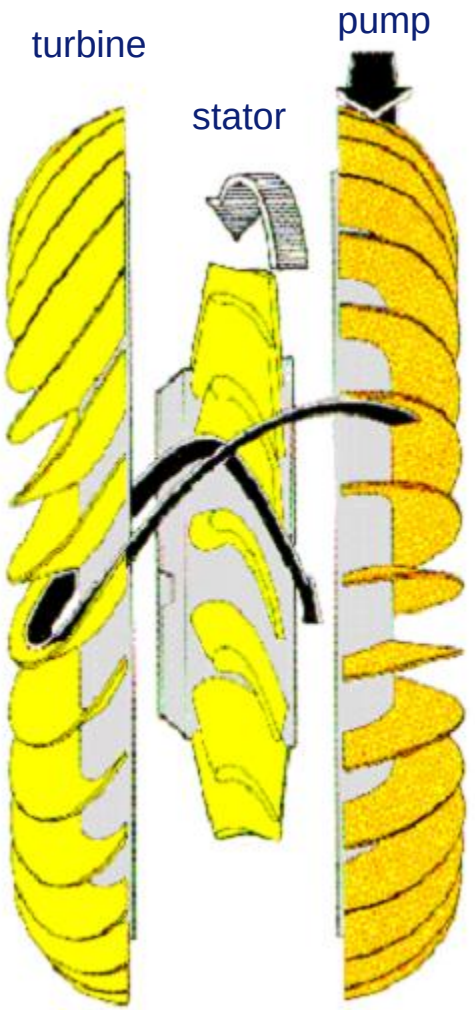


LMS® ENGINEERING INNOVATION

Variable Torque Components

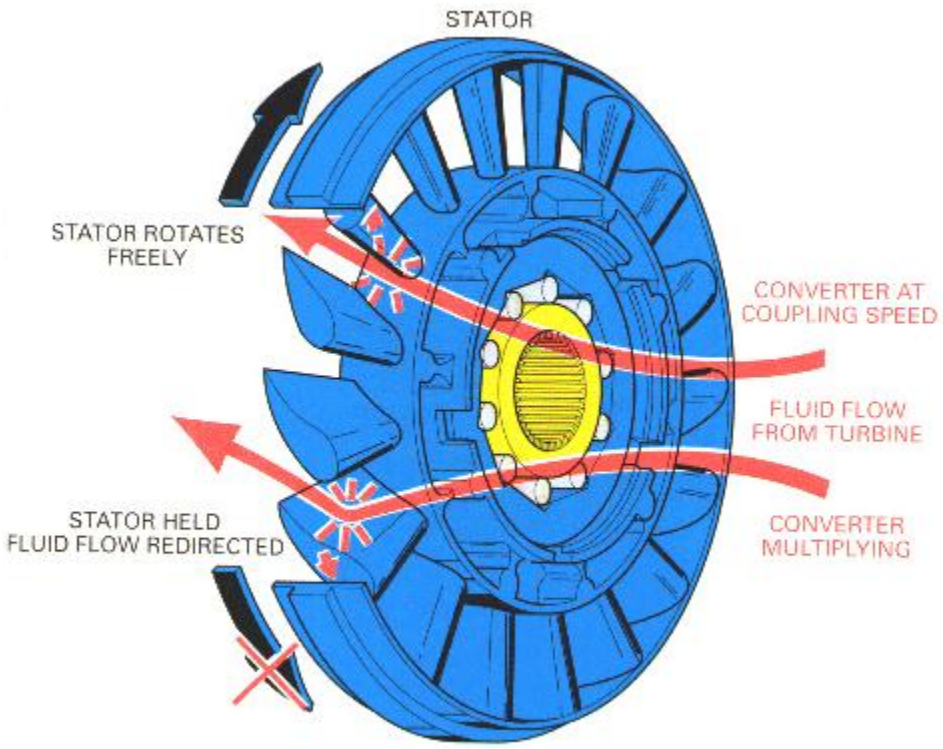
Torque Converter





Variable Torque Components

Torque Converter

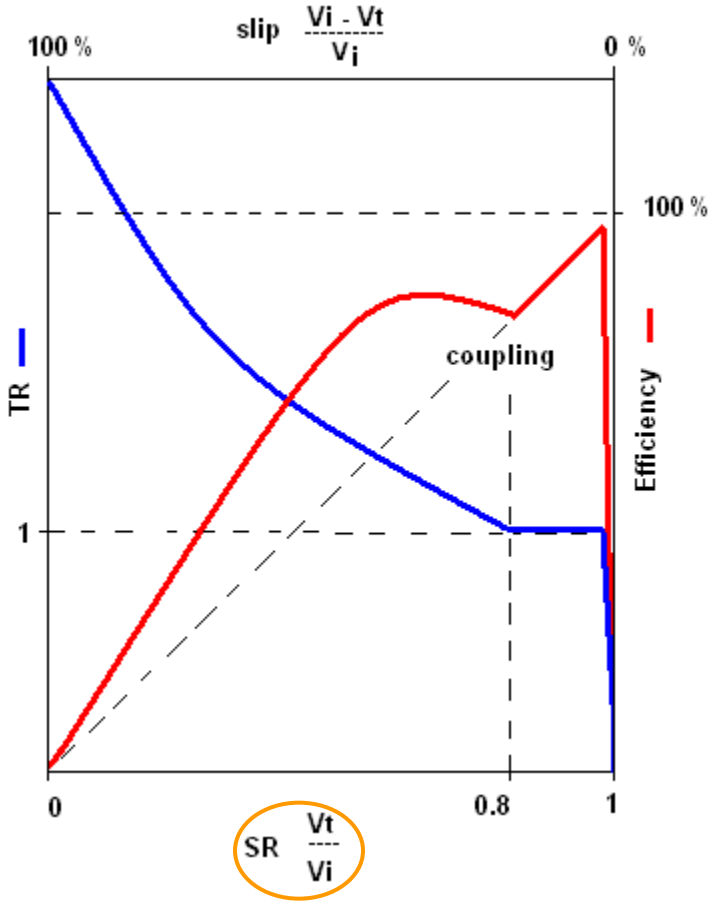


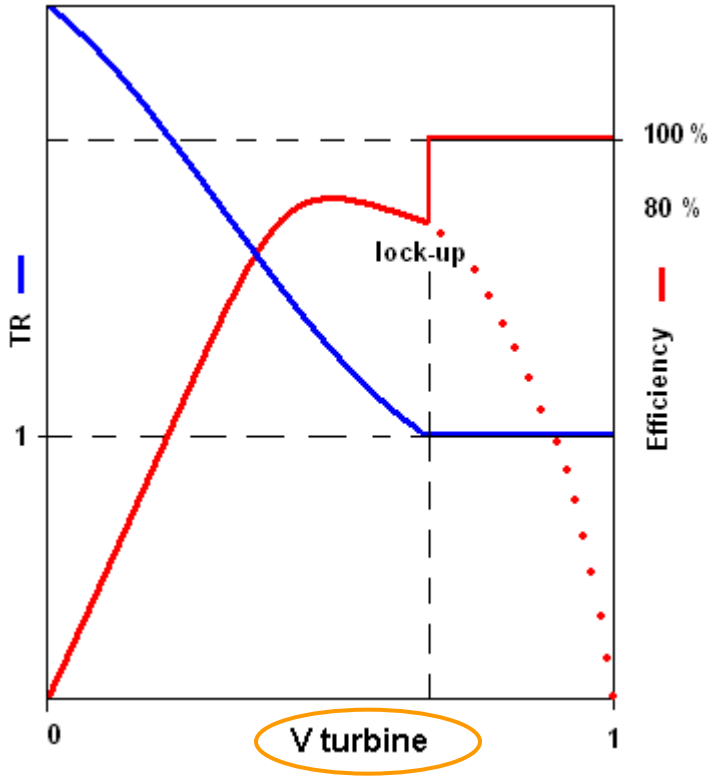
3 stages

- stall (stator fixed)
- acceleration (stator free)
- direct drive (lock-up)

Variable Torque Components

Stall, acceleration and coupling stages

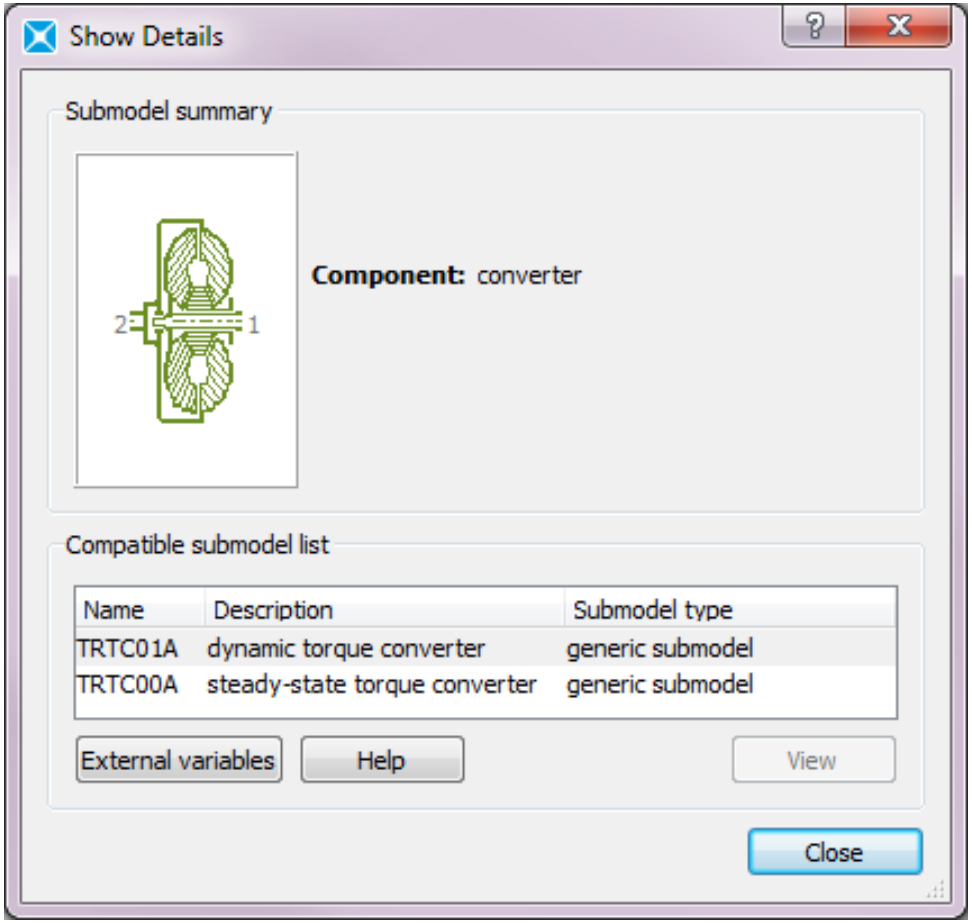




Variable Torque Components

The library models

- Level 0:
  - Steady-state torque converter.
- Level 1:
  - Dynamic torque converter.



Variable Torque Components

Level 0: Steady state torque converters

Impeller shaft

Turbine shaft

Variable Torque Components

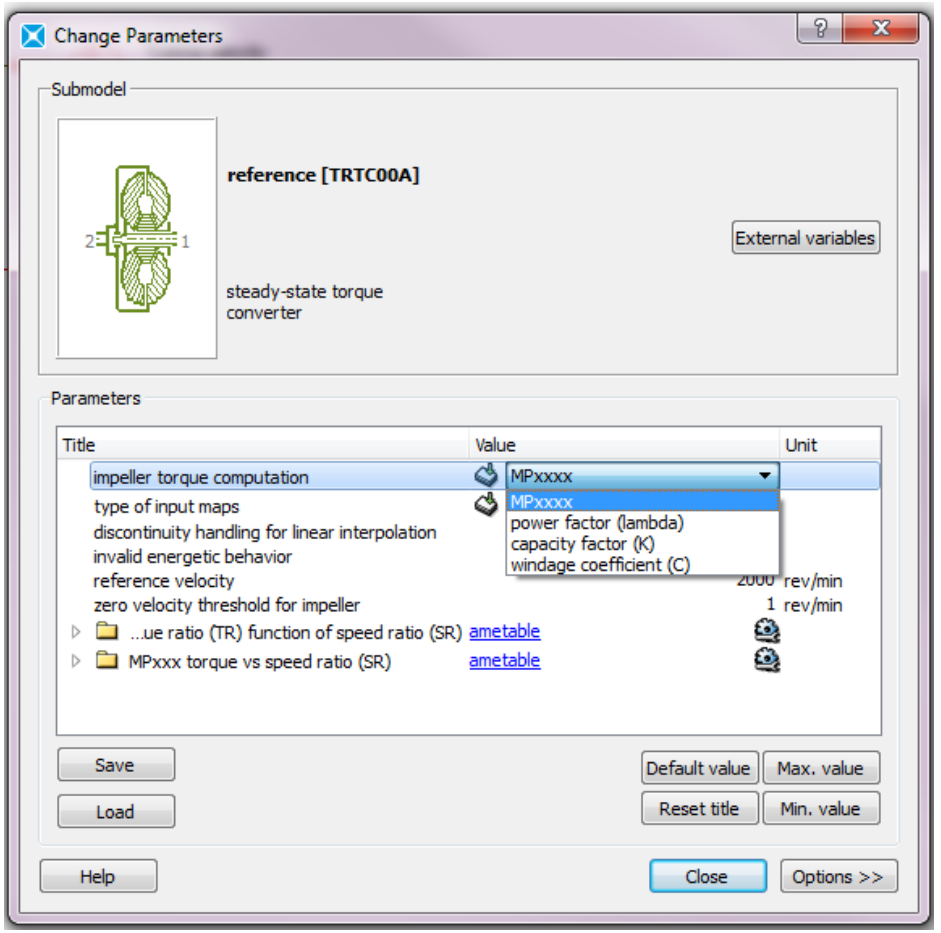
- Submodel TRTC00A: level0

External variables

- Computation of impeller torque: an enumeration enabled choosing between 4 methods (table formats): MPxxxx factor: impeller torque at fixed velocity xxxx rpm
  - lambda factor: power factor
  - K factor: capacity factor
  - C factor: windage coefficient
- Computation of turbine torque: A map defining the Torque Ratio (TR) function of the speed ratio (SR) is used

$$TR = \frac{T_{turbine}}{T_{impeller}} \qquad SR = \frac{\omega_{turbine}}{\omega_{impeller}}$$

Model parameters



Variable Torque Components

Torque at the impeller Ti can be defined by one of the following equation:

- **MPxxxx torque equation:**

$Ti = (MPxxxx(SR) / \omega ref^{2}) . Nimpeller^{2} . si$

with

ωref: reference fixed velocity [rad/s]

- **λ: Power factor equation:**

$Ti = (\rho . Dh^{5} . \lambda(SR) . \pi^{2} / 900) . Nimpeller^{2} . si$

with

ρ: oil density [kg/m**3]

Dh: hydraulic diameter [m]

- **K: capacity factor equation:**

$Ti = (10 . K(SR)^{-2}) . Nimpeller^{2} . si$

- **C: windage coefficient equation:**

$Ti = (C(SR)) . Nimpeller^{2} .si$

$si = tanh(2 . N_{impeller} / Nz)$

with: *Nz*: zero impeller rotary threshold [rpm]

enables to get a smooth transition on the impeller torque when the sign of the impeller velocity changes

Variable Torque Components

$$\eta = \frac{T_{turbine} \times \omega_{turbine}}{T_{impeller} \times \omega_{impeller}} = TR \times SR$$

Notes:

- 0 <= SR <= 1 (even for overrun)
- $\omega_{impeller}$ has to be greater than zero
- SR = 1 → TR = 0 (without lock-up)
- η_{max} ~ 95 – 98 % (without lock-up)

Variable Torque Components

Level 1: Dynamic torque converter

Impeller shaft

Turbine shaft

Variable Torque Components

Submodel TRTC01A: level1

- Use this submodel when dynamics are significant up to 50 Hz (modeled by physical equations and no table data).
- The model takes into account:
  - Inertias of turbine, impeller, stator and fluid.
  - Fluid friction.
  - Shocks losses.
  - Influence of system geometry on fluid effects.
  - One way clutch for the stator.
- Parameters are only physical ones.