WEC-Sim Training Course

PRESENTED BY

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Advanced Features: PTO-Sim

What is PTO-Sim?

Purpose

- The equation of motion in the time domain for a floating body is:

$$m\ddot{x}(t) = F_{hs}(t) + F_{ext}(t) + F_{rad}(t) + F_{v}(t) + F_{pto}(t) + F_{m}(t) + F_{nh}(t)$$

Nonlinear hydrodynamic force

Mooring force

Power take-off force

Viscous force

Hydrostatic restoring force

Wave excitation & diffraction force (from BEM simulations)

Radiation force: added mass and radiation damping (from BEM simulations)

Usually the PTO is represented as a spring-damper system for simplicity:

$$F_{pto}(t) = -K_{pto}x(t) - c_{pto}\dot{x}(t)$$

What is PTO-Sim?

Purpose

- PTO-Sim
  - Is a package of detailed PTO models
  - Open-source
  - Integrated with WEC-Sim

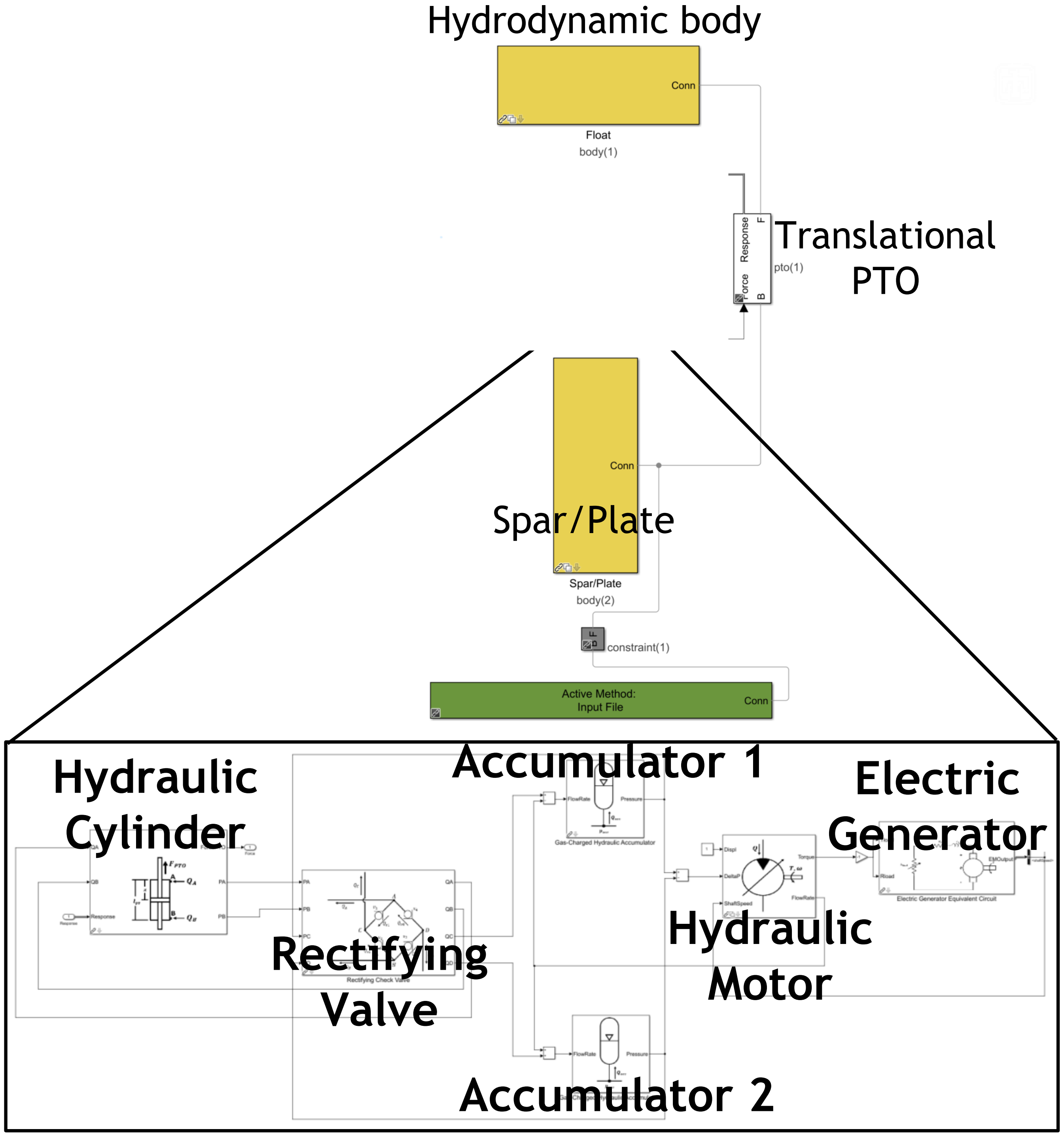
- PTO-Sim class includes models such as:
  - hydraulic cylinders
  - hydraulic accumulators
  - hydraulic motors
  - electric generators
  - hydraulic valves

- MATLAB toolboxes contain these models but at additional cost:
  - Simscape Hydraulics
  - Simscape Electrical

What is PTO-Sim?

Workflow

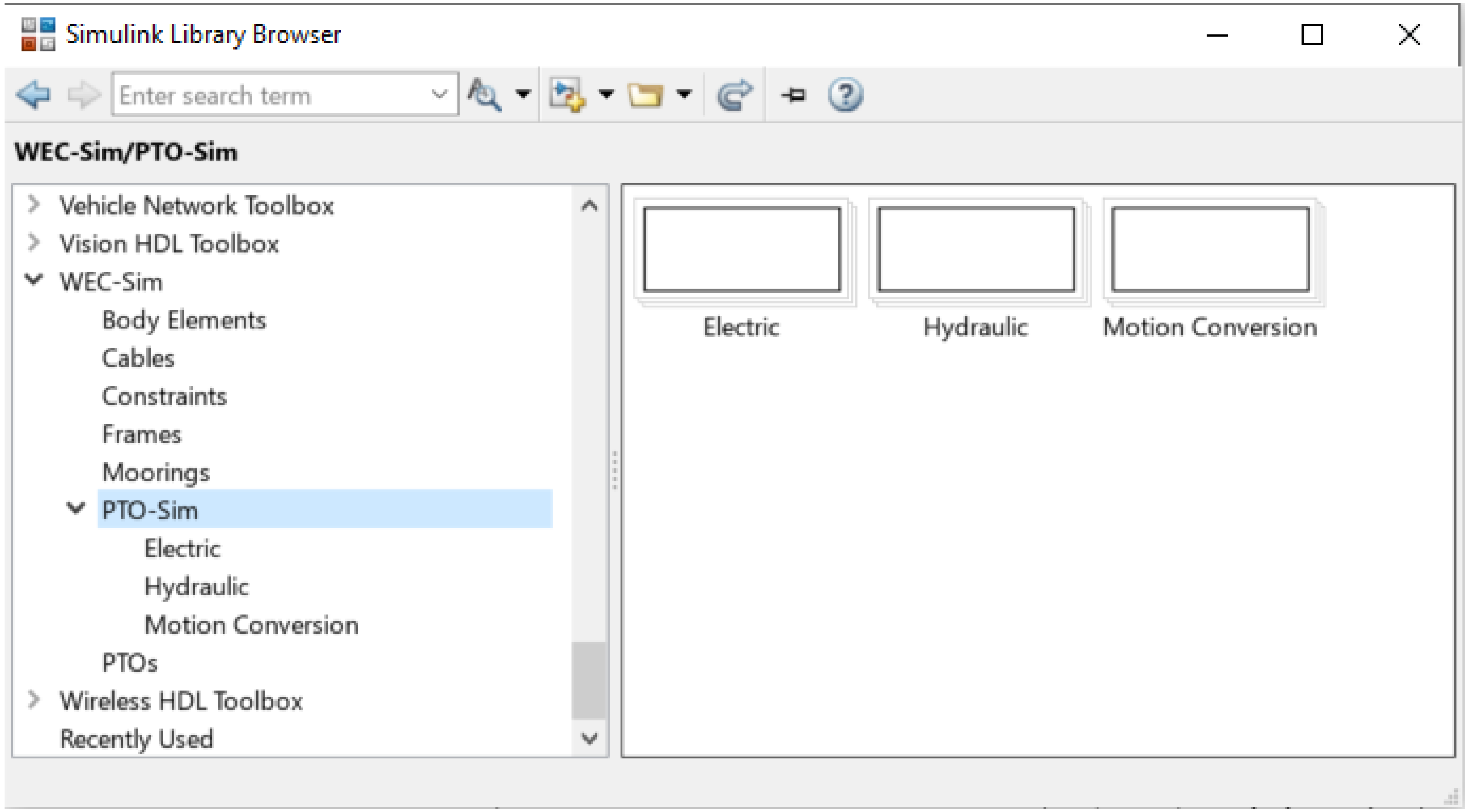
- Select appropriate PTO (rotational, translational)
- Create a subsystem for your detailed PTO model. The input is the response and the output is either the force or the torque in the PTO.
- The subsystem can be edited depending on the desired level of detail.



PTO-Sim Blocks

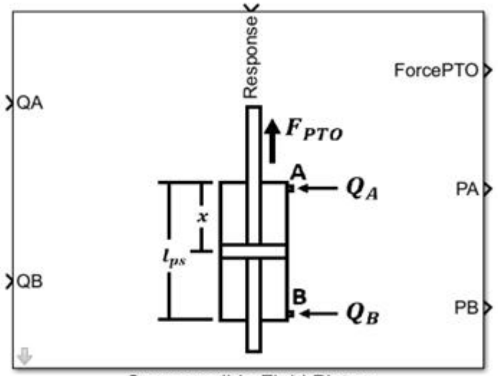
- PTO-Sim has a library with ten blocks grouped in three different categories:

PTO-Sim Library
Block
Electric Generator
Hydraulic cylinder
Hydraulic accumulator
Rectifying check valve
Hydraulic motor
Linear crank
Adjustable rod
Check valve
Direct drive linear generator
Direct drive rotary generator

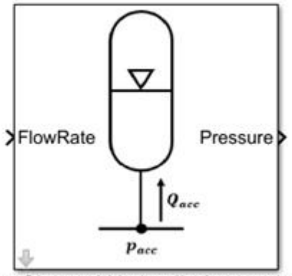


PTO-Sim Blocks

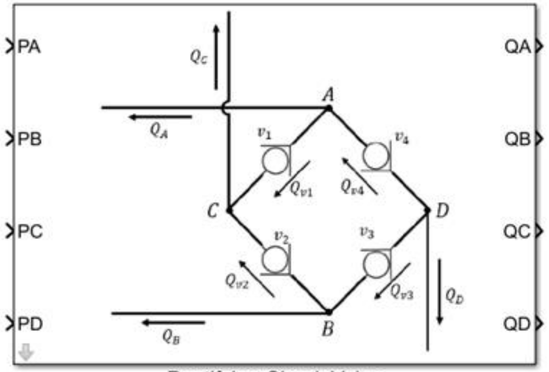
Hydraulic



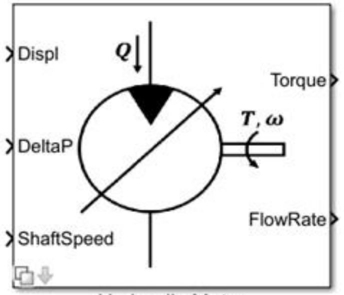
Compressible Fluid Piston



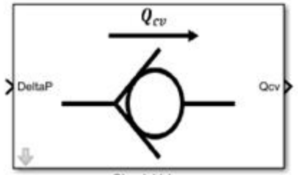
Gas-Charged Hydraulic Accumulator



Rectifying Check Valve

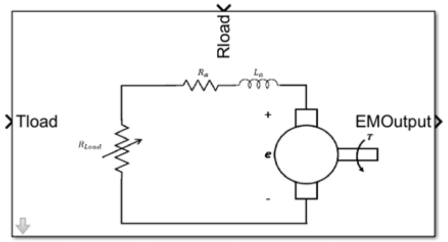


Hydraulic Motor

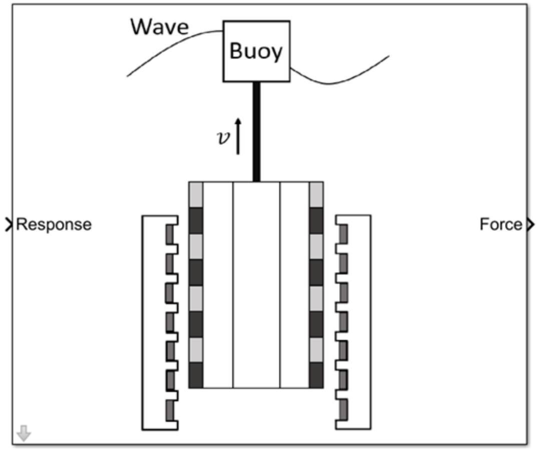


Check Valve

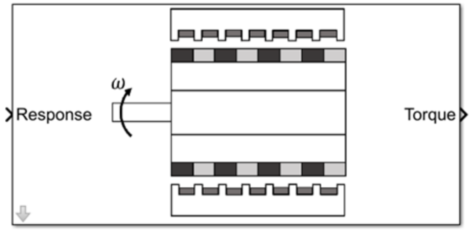
Electric



Electric Generator Equivalent Circuit

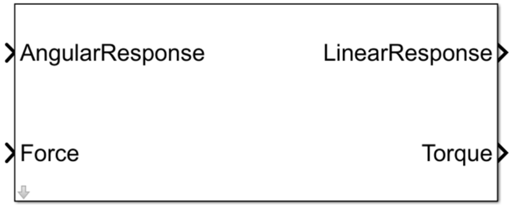


Direct Drive Linear Generator

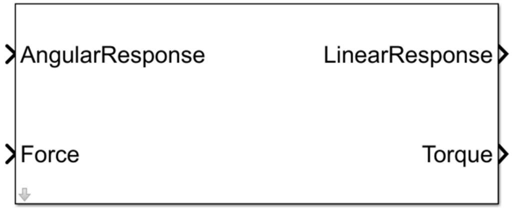


Direct Drive Rotary Generator

Motion Conversion



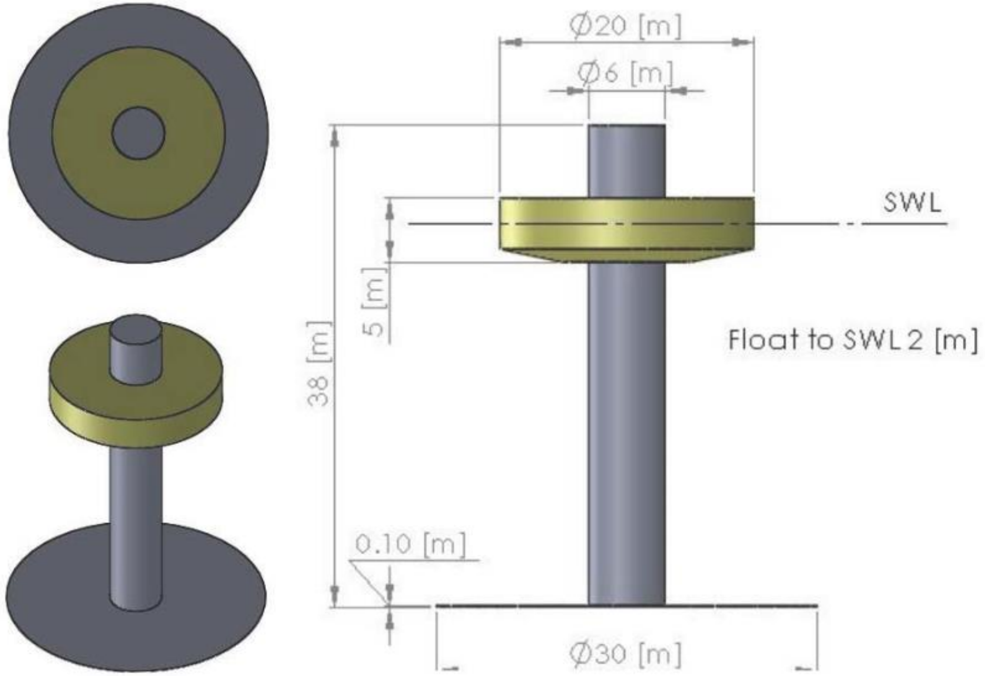
Rotary to Linear
Adjustable Rod



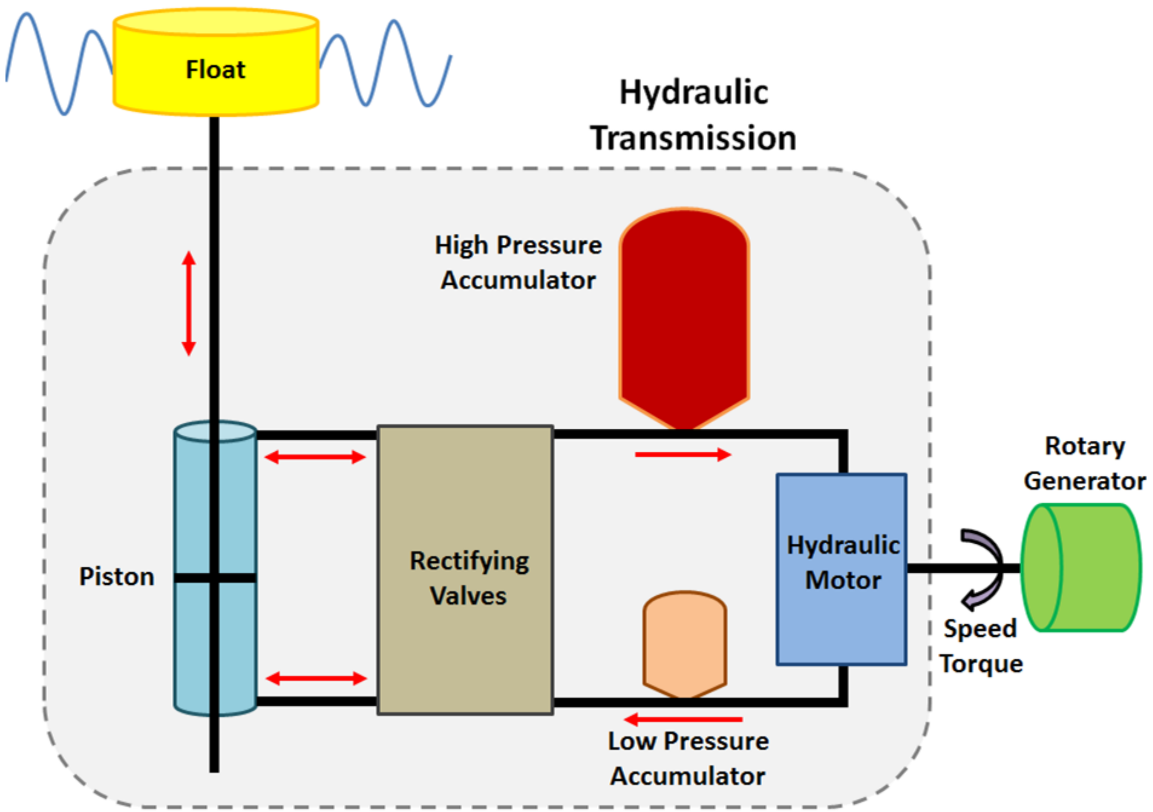
Rotary to Linear
Crank

Examples

RM3 with hydraulic PTO

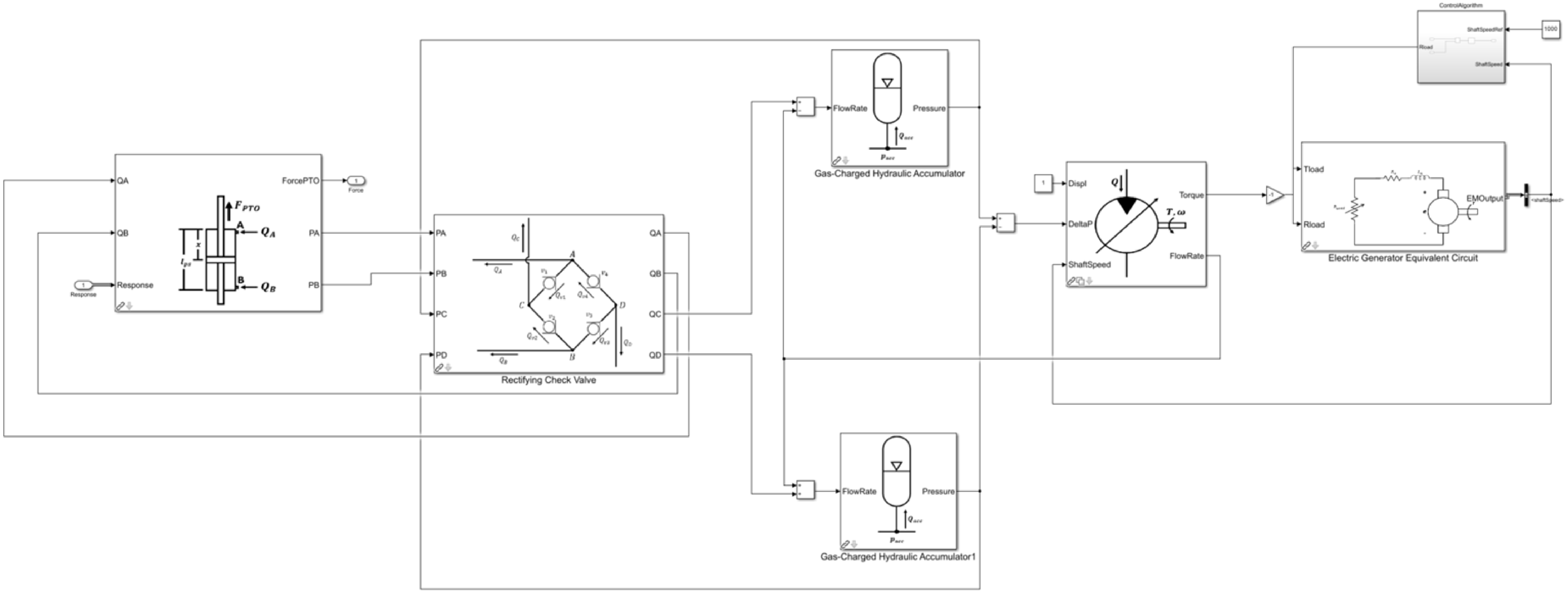


Two body point absorber



Hydraulic PTO

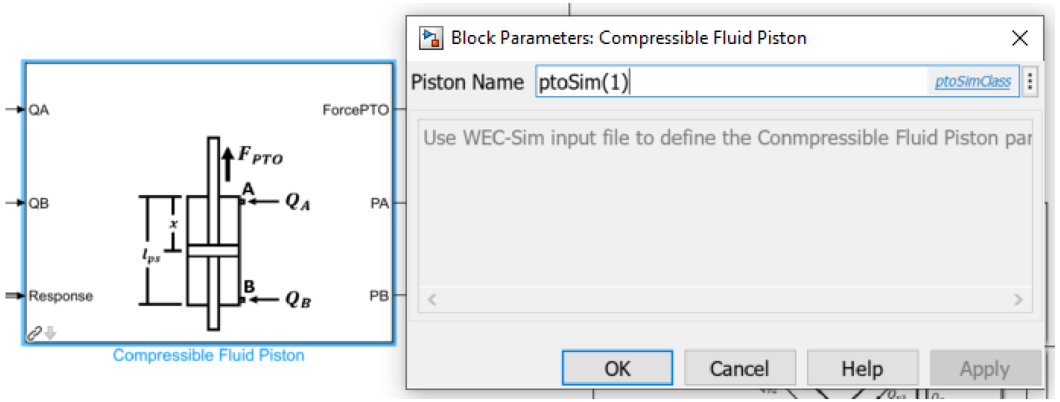
Examples



QA
QB
Response
ForcePTO
PA
PB
Force
PC
PD
QC
QD
Rectifying Check Valve
FlowRate
Pressure
Gas-Charged Hydraulic Accumulator
Gas-Charged Hydraulic Accumulator1
Displ
DeltaP
ShaftSpeed
Torque
FlowRate
Tload
Rload
EMOutput
Electric Generator Equivalent Circuit
ControlAlgorithm
ShaftSpeedRef
ShaftSpeed
1000

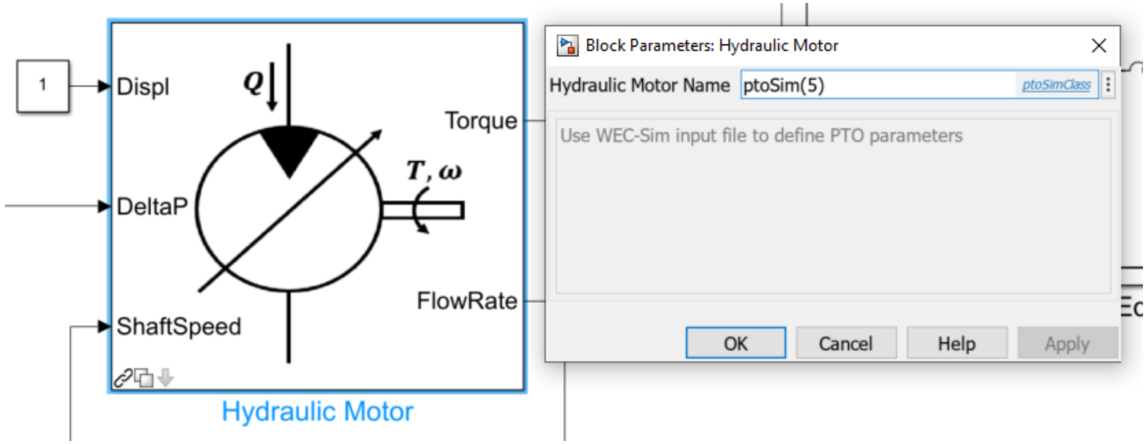
Examples

Hydraulic Cylinder




```
%Hydraulic Cylinder
ptoSim(1) = ptoSimClass('hydraulicCyl');
ptoSim(1).hydPistonCompressible.xi_piston = 3;
ptoSim(1).hydPistonCompressible.Ap_A = 0.0378;
ptoSim(1).hydPistonCompressible.Ap_B = 0.0378;
ptoSim(1).hydPistonCompressible.bulkModulus = 1.86e9;
ptoSim(1).hydPistonCompressible.pistonStroke = 6;
ptoSim(1).hydPistonCompressible.pAi = 2.1333e7;
ptoSim(1).hydPistonCompressible.pBi = 2.1333e7;
```

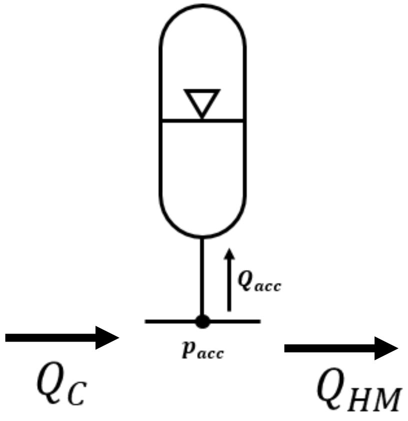
Hydraulic Motor



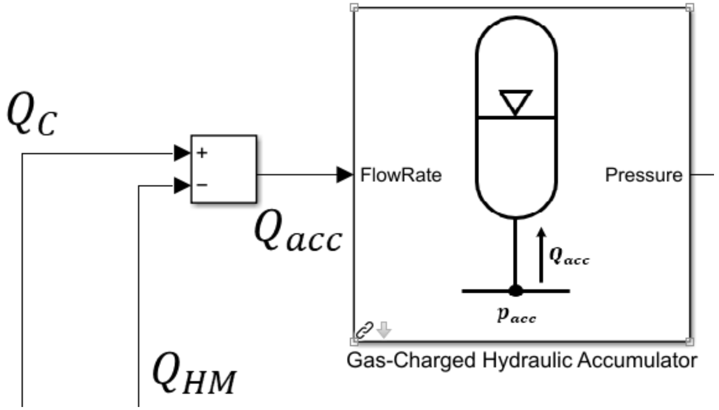

```
%Hydraulic Motor
ptoSim(5) = ptoSimClass('hydraulicMotor');
ptoSim(5).hydraulicMotor.effModel = 2;
ptoSim(5).hydraulicMotor.displacement = 120;
ptoSim(5).hydraulicMotor.effTableShaftSpeed = linspace(0,2500,20);
ptoSim(5).hydraulicMotor.effTableDeltaP = linspace(0,200*1e5,20);
ptoSim(5).hydraulicMotor.effTableVolEff = ones(20,20)*0.9;
ptoSim(5).hydraulicMotor.effTableMechEff = ones(20,20)*0.85;
```

Examples

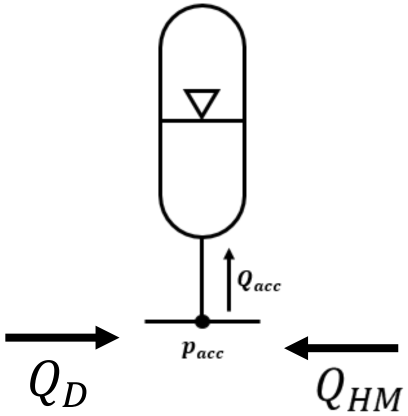
High Pressure Accumulator



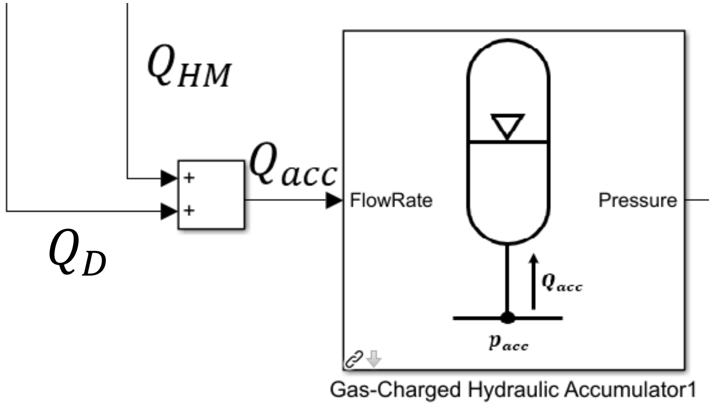
$$Q_{acc} = Q_c - Q_{HM}$$



Low Pressure Accumulator

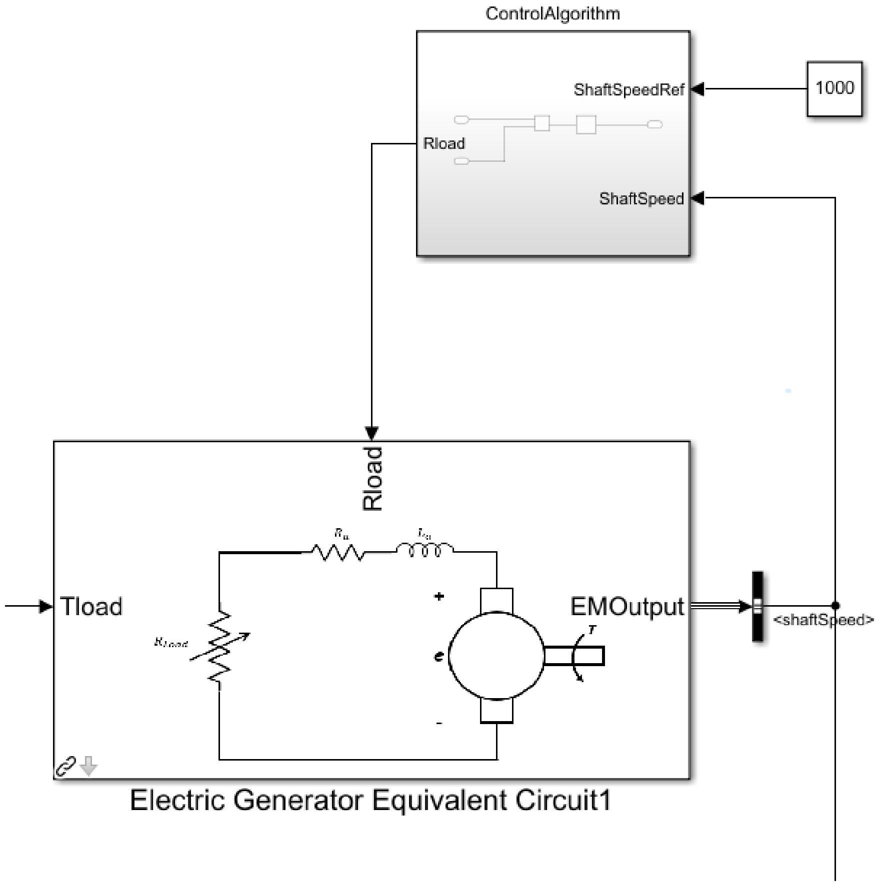


$$Q_{acc} = Q_D + Q_{HM}$$



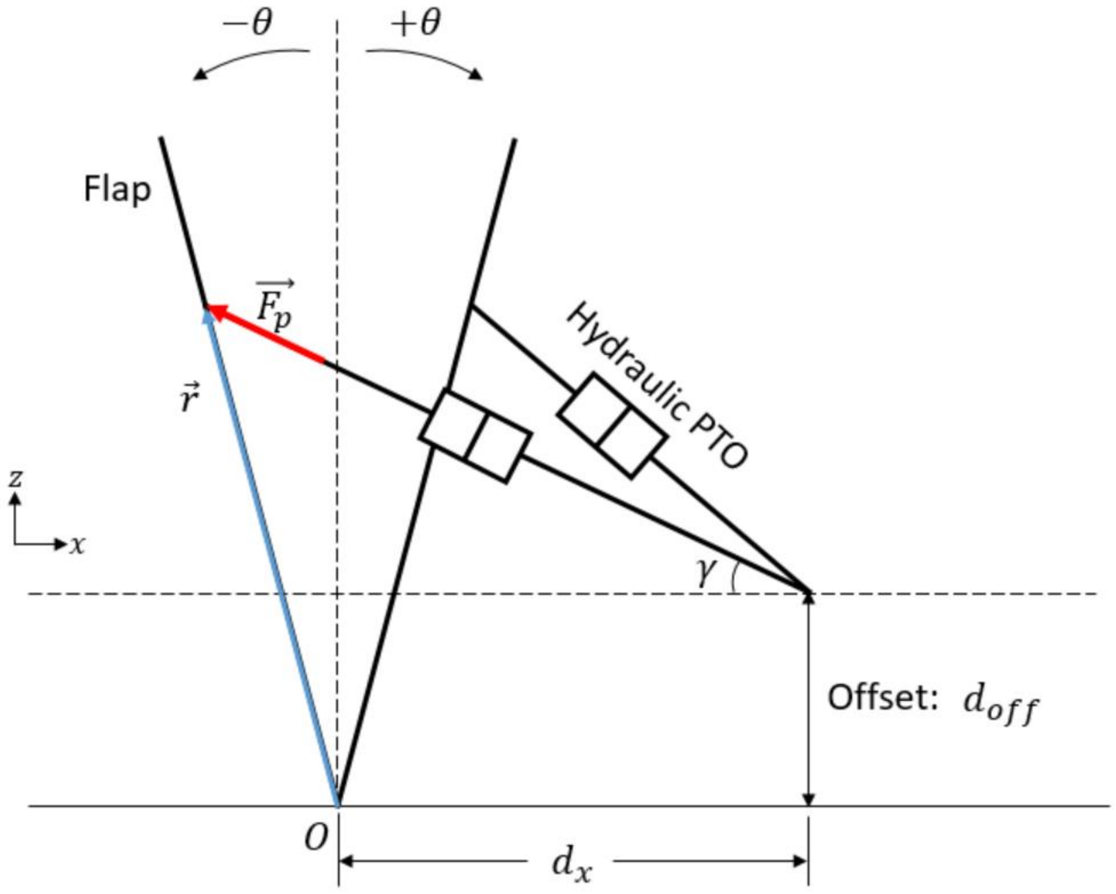
Examples

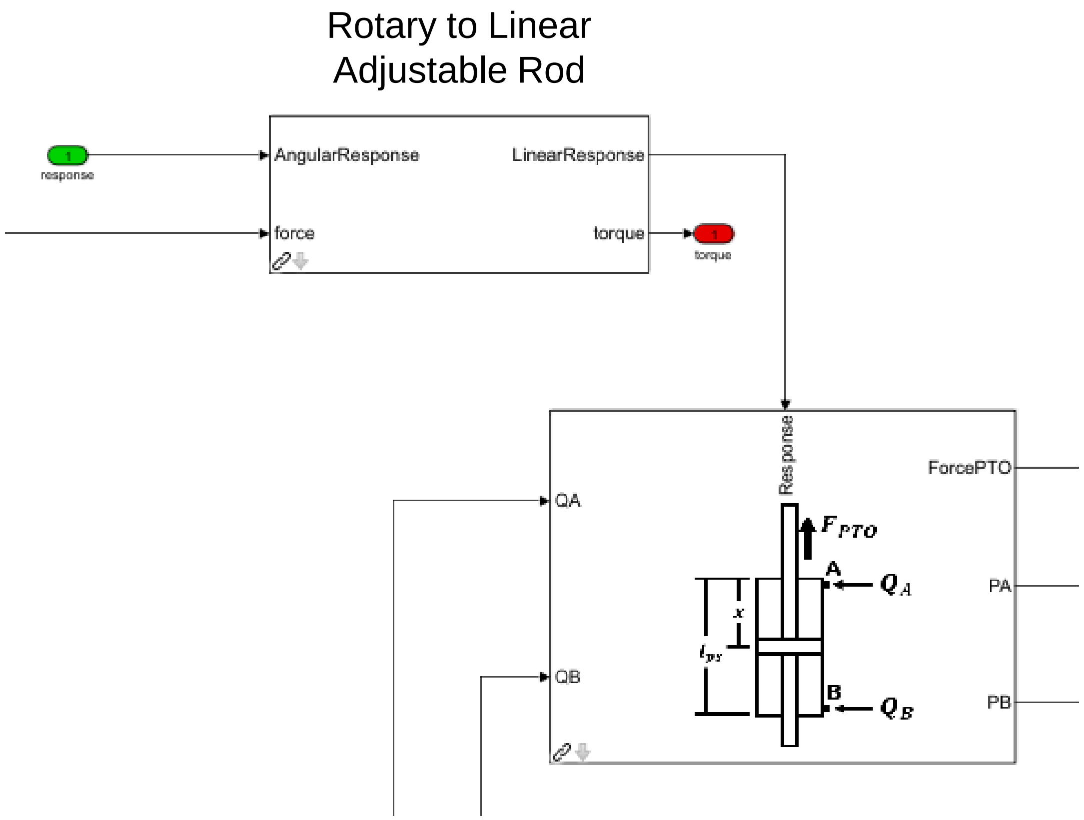
Electric generator and shaft speed control



- R_{Load} represents the load in the generator
- In this example, R_{Load} is used to control the shaft speed.

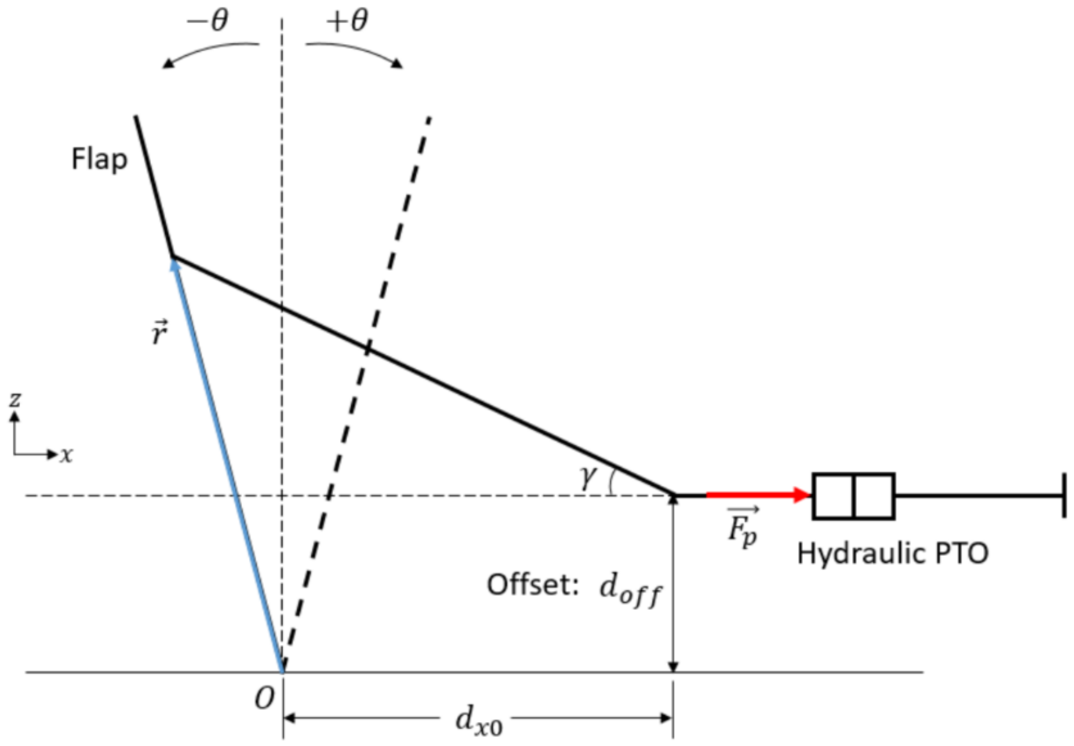
OSWEC
Hydraulic cylinder connected to an adjustable rod

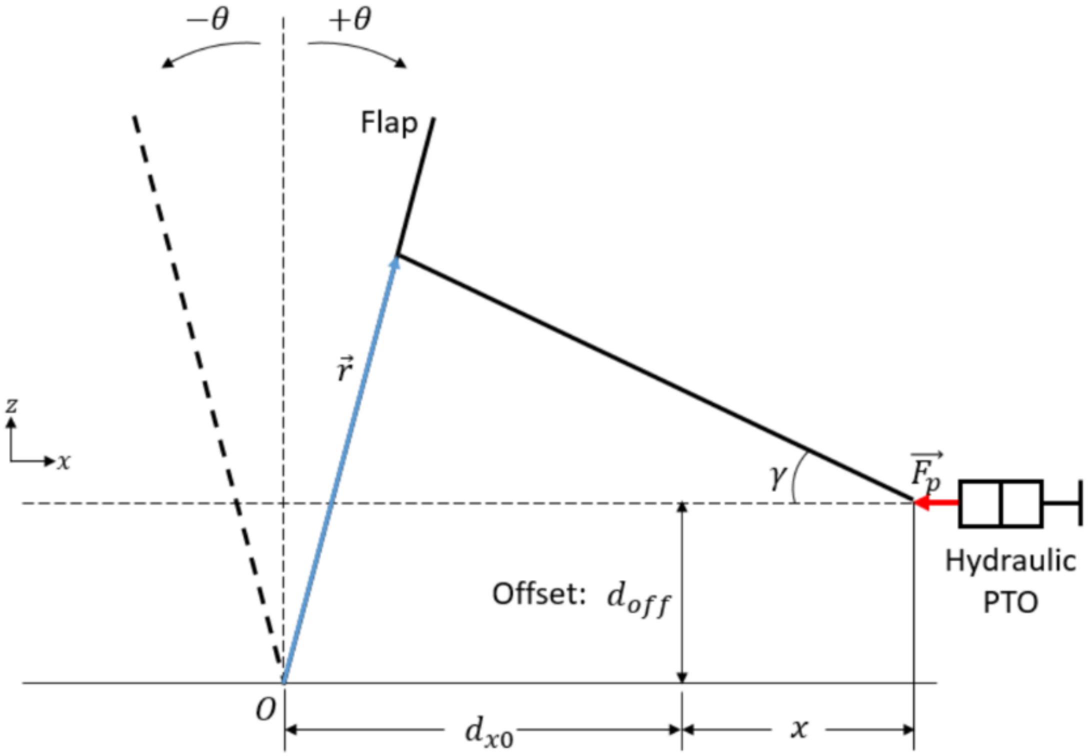




Examples

OSWEC
Hydraulic cylinder rod connected to a slider-crank mechanism





Thank you!

All previous webinar materials and recordings are available online:

http://wec-sim.github.io/WEC-Sim/webinars.html

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