MANITOBA HVDC RESEARCH CENTRE,
a Division of Manitoba Hydro International Ltd.

Machine Modeling and Power System Study Applications

November 02, 2017

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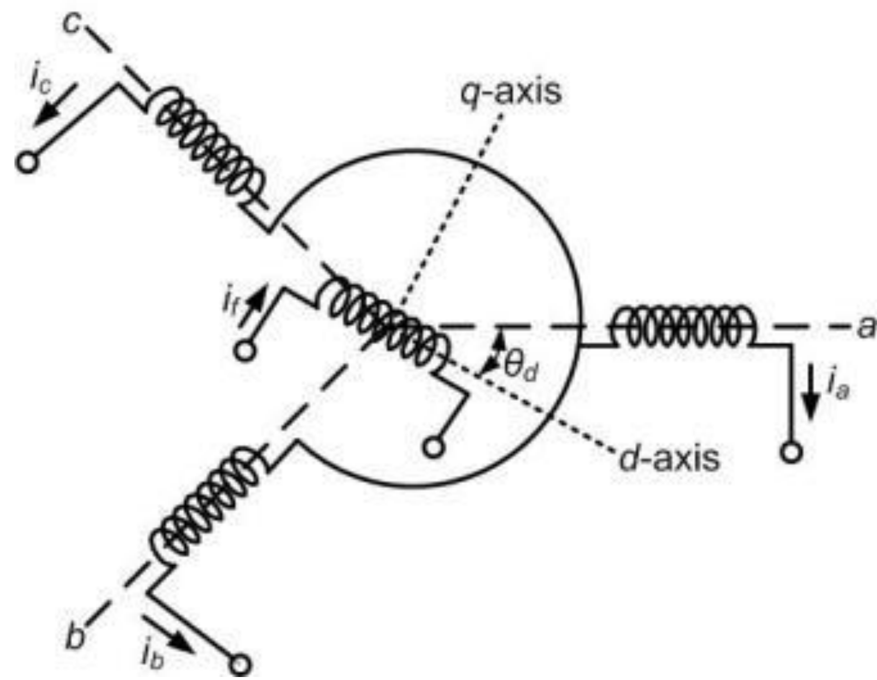
Outline - Machine Modeling and Applications

- Mathematical representation of machine windings and rotor dynamics
- Machine models and controls models available in PSCAD
- Setting up a PSCAD simulation case
    - Synchronous machine (initialization of machine and control models)
    - Induction machine (starting example)
- Illustration of Simulation examples
    - Synchronous machine under black start conditions
    - Voltage flicker due to compressor load driven by a synchronous machine
    - Sub synchronous resonance and torsional interactions
    - Voltage dips due to induction motor starting and mitigation options
    - Applications in wind generation (DFIG)
    - Synchronous condenser application to improve wind farm FRT performance
    - PM machine in wind generation
- Internal faults simulation other enhancements to standard models

Machine windings and the mathematical representation



Machine windings and the mathematical representation

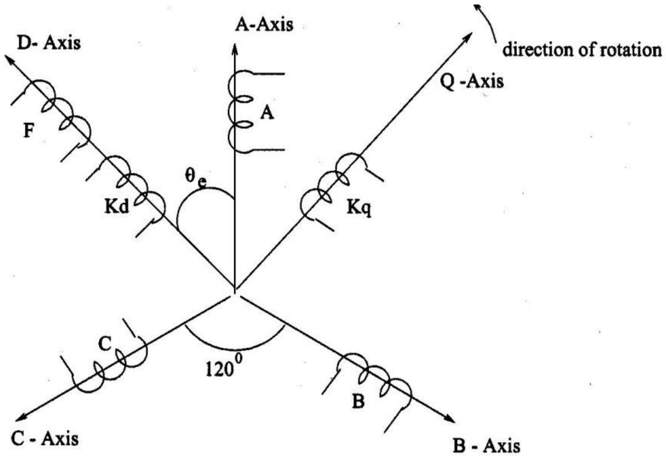


Figure 2.1: Representation of the machine coils and the direction of their magnetic axes

$$[v] = [R][i] + d/dt[L][i]$$

$$L_A = L_1 + L_2 + L_3 \mathrm{Cos}\,(2\theta)$$

$$M_{AF} = f(\theta)$$

Synchronous Machine Equations in d-q reference frame

Stator Side

$$V_d = R_s . i_d + \frac{d}{dt}\lambda_d(t) - \lambda_q(t) . w_r$$

$$V_q = R_s . i_q + \frac{d}{dt}\lambda_q(t) + \lambda_d(t) . w_r$$

$$V_0 = R_0 . i_0 + \frac{d}{dt}\lambda_0(t)$$

Rotor Side

$$E_f = R_f . i_f + \frac{d}{dt}\lambda_f(t)$$

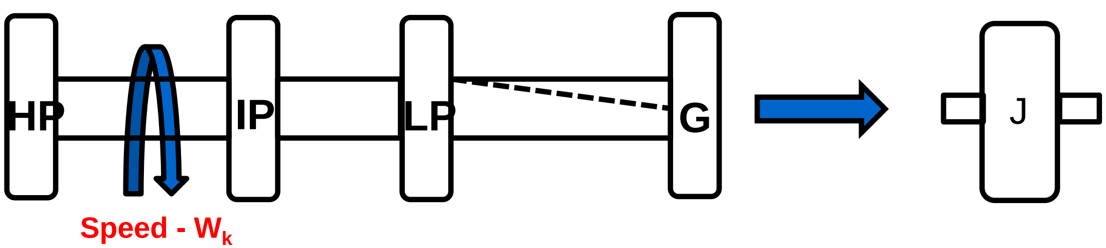
$$0 = R_{kd} . i_{kd} + \frac{d}{dt}\lambda_{kd}(t)$$

$$0 = R_{kq1} . i_{kq1} + \frac{d}{dt}\lambda_{kq1}(t)$$

$$0 = R_{kq2} . i_{kq2} + \frac{d}{dt}\lambda_{kq2}(t)$$

Dampers – 2 on Q-axis

Mechanical rotation



$$T_m - Te = J\frac{d\omega}{dt} + B\omega$$

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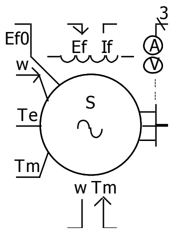
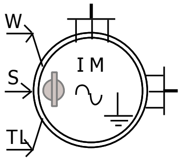
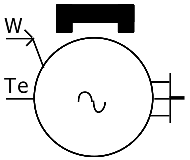


Synchronous Machine

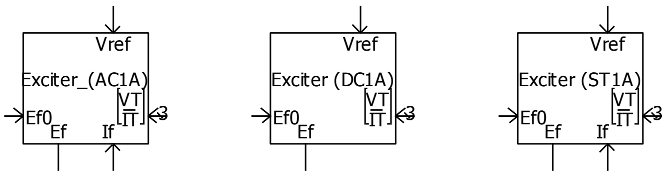


Induction Machine

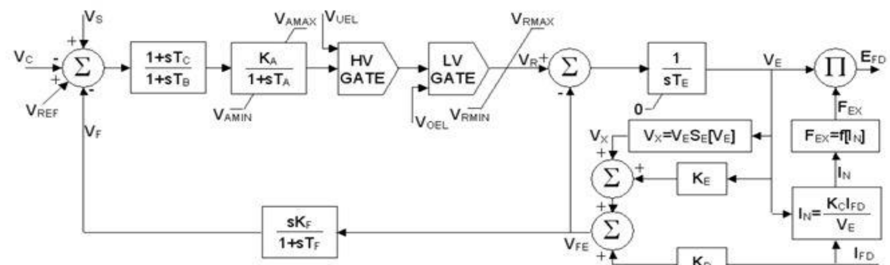


Permanent Magnet Machine

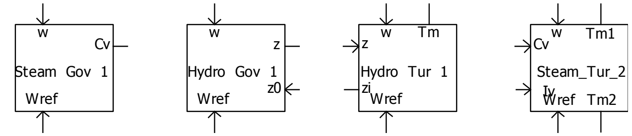
Exciter models



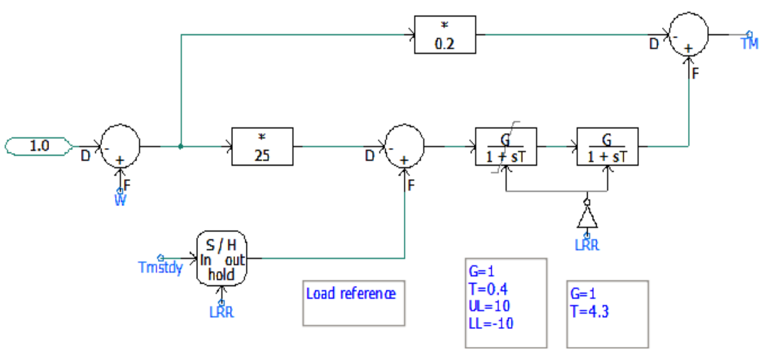
IEEE Standard exciter type AC1A



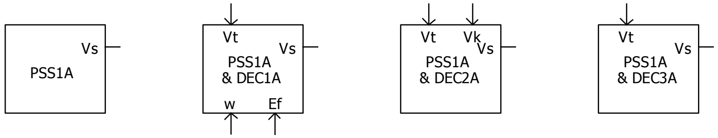
Governor/Turbine models



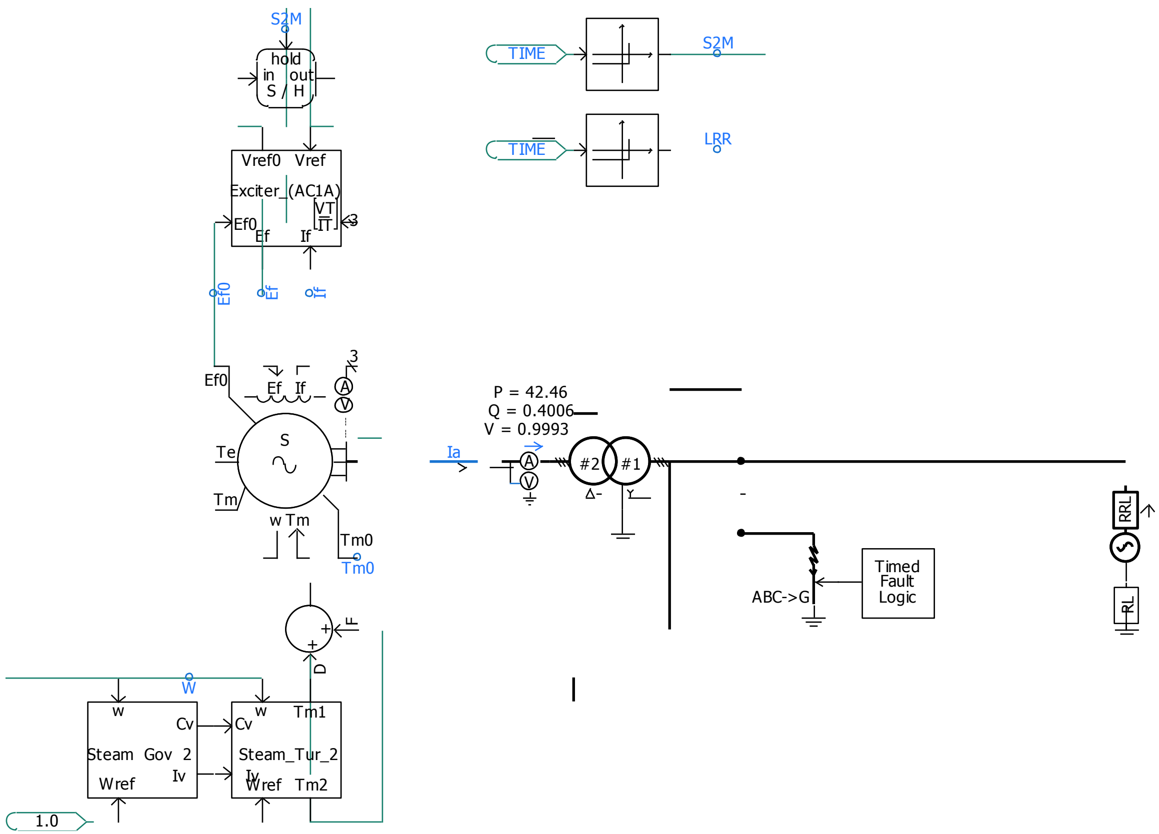
Non standard generator control systems



PSS models

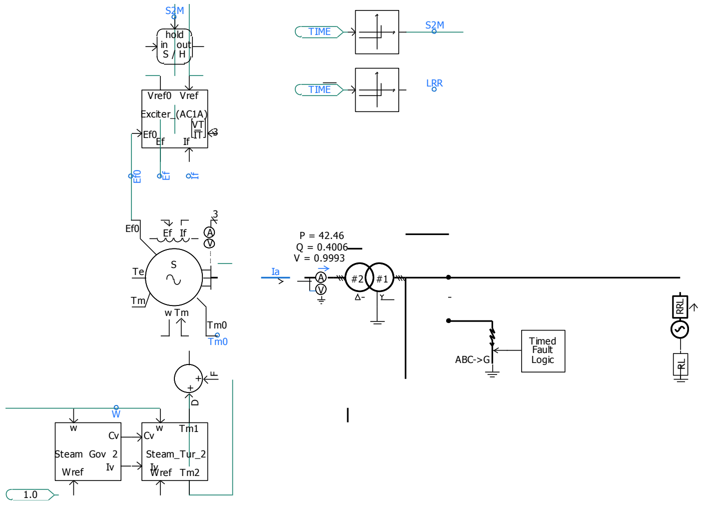


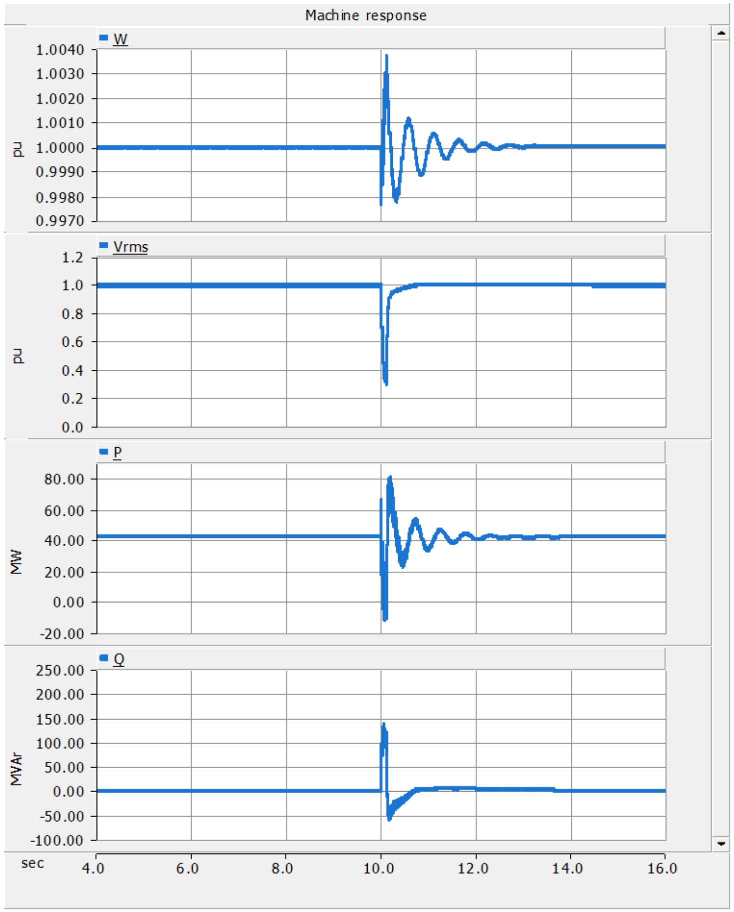
Simulation setup – Synchronous machine



Parameter		Thermal units typical values
Sator leakage Inductance	X_l	0.1-0.2
Synchronous reactances	X_d	1.0-2.3
	X_q	1.0-2.3
Transient Reactance	X'_d	0.15-0.4
	X'_q	0.3-1.0
Subtransient Reactance	X''_d	0.12-0.25
	X''_q	0.12-0.25
Transinet OC time constant	T'_{do}	3.0-10.0 s
	T'_{qo}	0.5-2.0 s
Subtransient OC Time constant	T''_{do}	0.02-0.05 s
	T''_{qo}	0.02-0.05 s

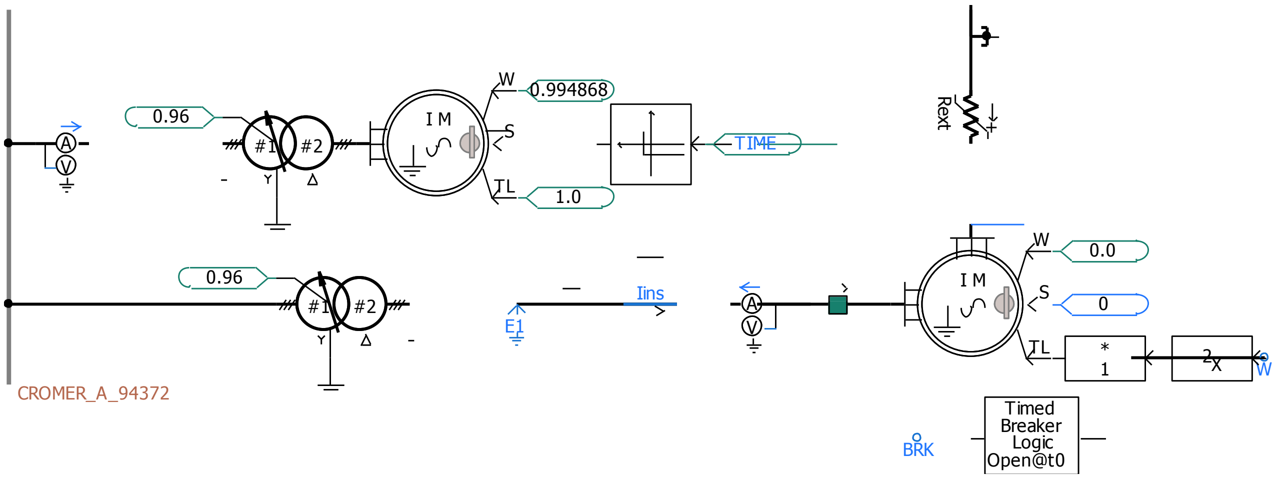
Simulation setup – Synchronous machine

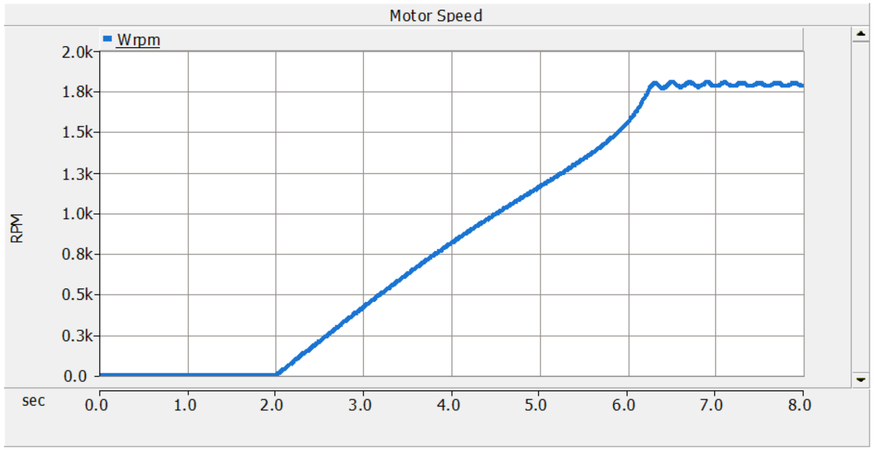




Technical note available on how to set up the machine model and controls

Simulation setup – Induction machine





Technical note available on how to set up the machine model and controls

Simulation examples

Simulation examples

- Illustration of Simulation examples
  - Synchronous machine under black start conditions
  - Voltage flicker due to compressor load driven by a synchronous machine
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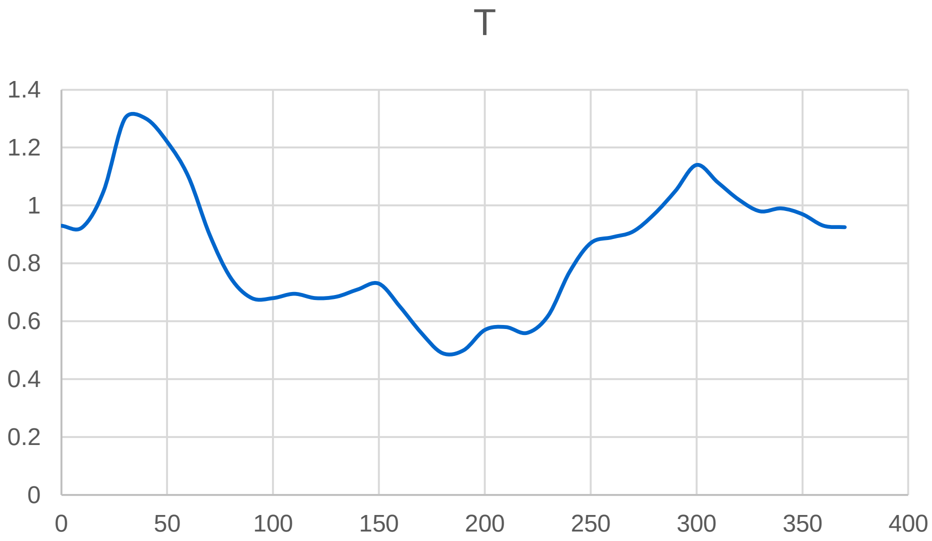
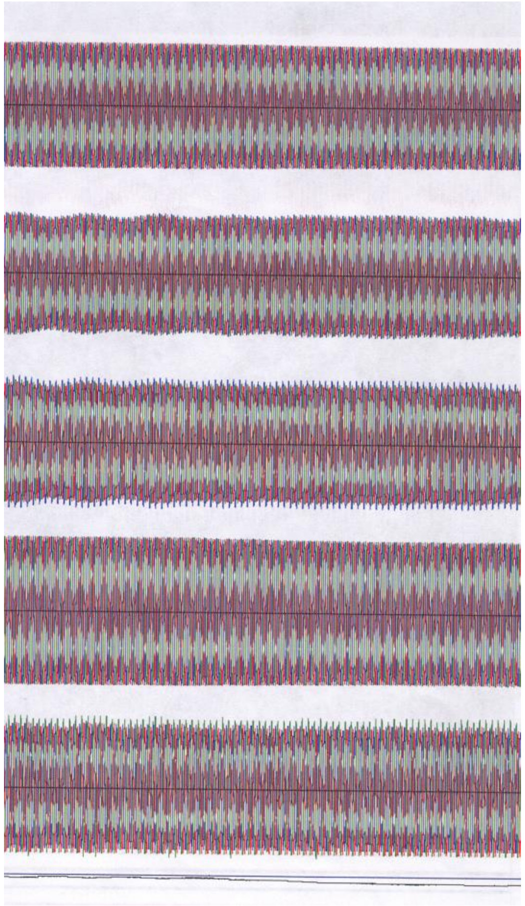
Example: Flicker due to a synchronous motor driven compressor

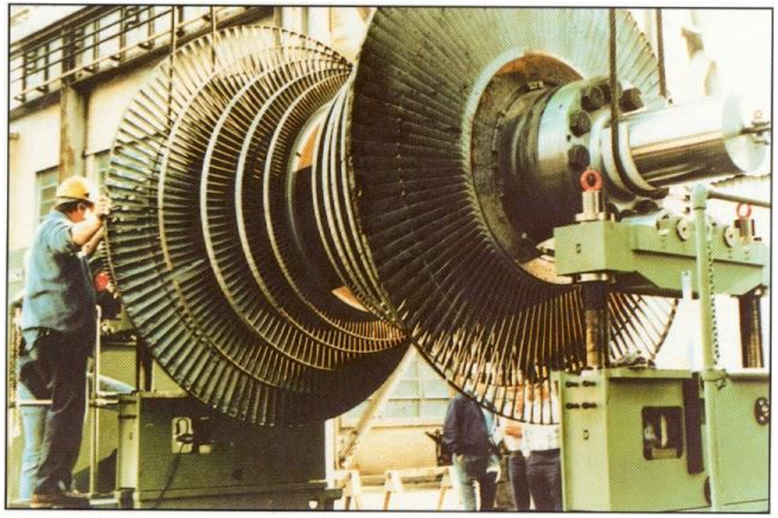
Compressor load torque characteristics

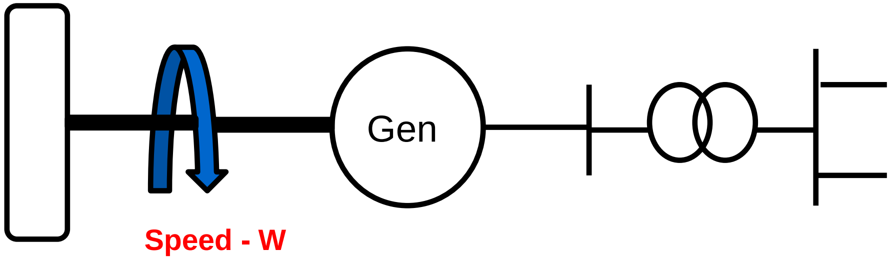


Voltage flicker measured at transmission level



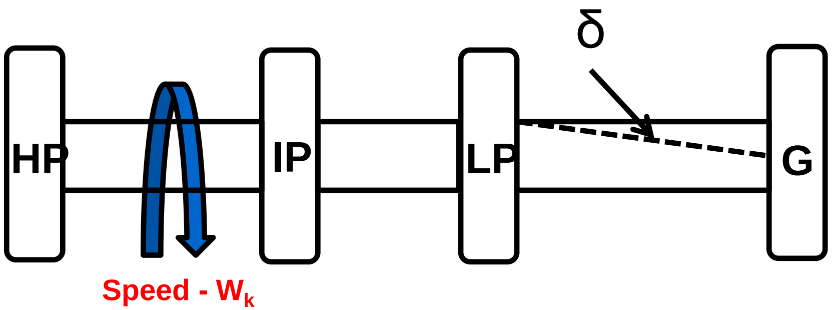
Example: SSTI studies - Mechanical shaft-mass system

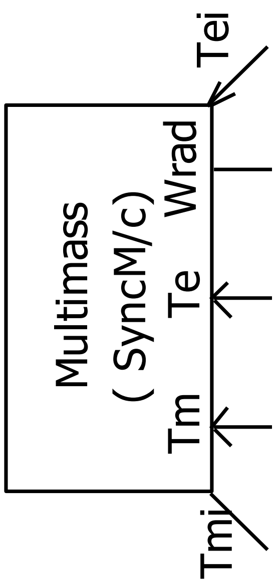




- Rotor of a Turbine Generator is a complex system of masses connected by shaft sections
- The total length can be as much as 50 m.
- A single lumped inertia representation is typically considered in system transient stability studies
  - Assumption: Rigid shafts

Mechanical shaft-mass system





- Torsional Interaction studies require a more detailed representation of the shaft (compared to lumped mass representation)
  - A Multi-Mass representation
    - Main rotor components represented as separate (rigid) masses
    - The masses are connected to each other with ‘elastic’ shaft sections

Thank you