Pumped Storage Hydropower Plants Modeling in the Power Systems Research

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TECHNOLOGY

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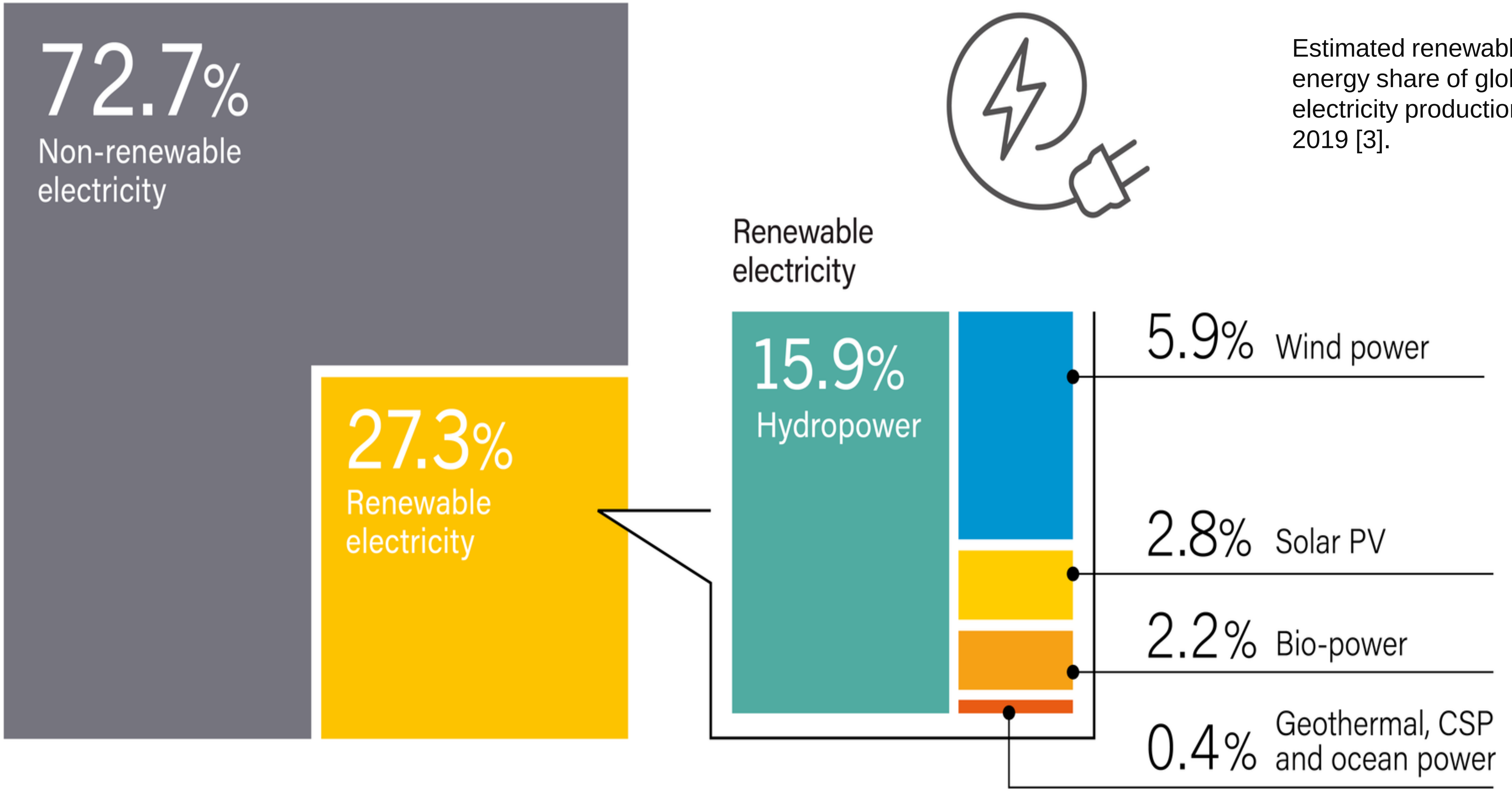
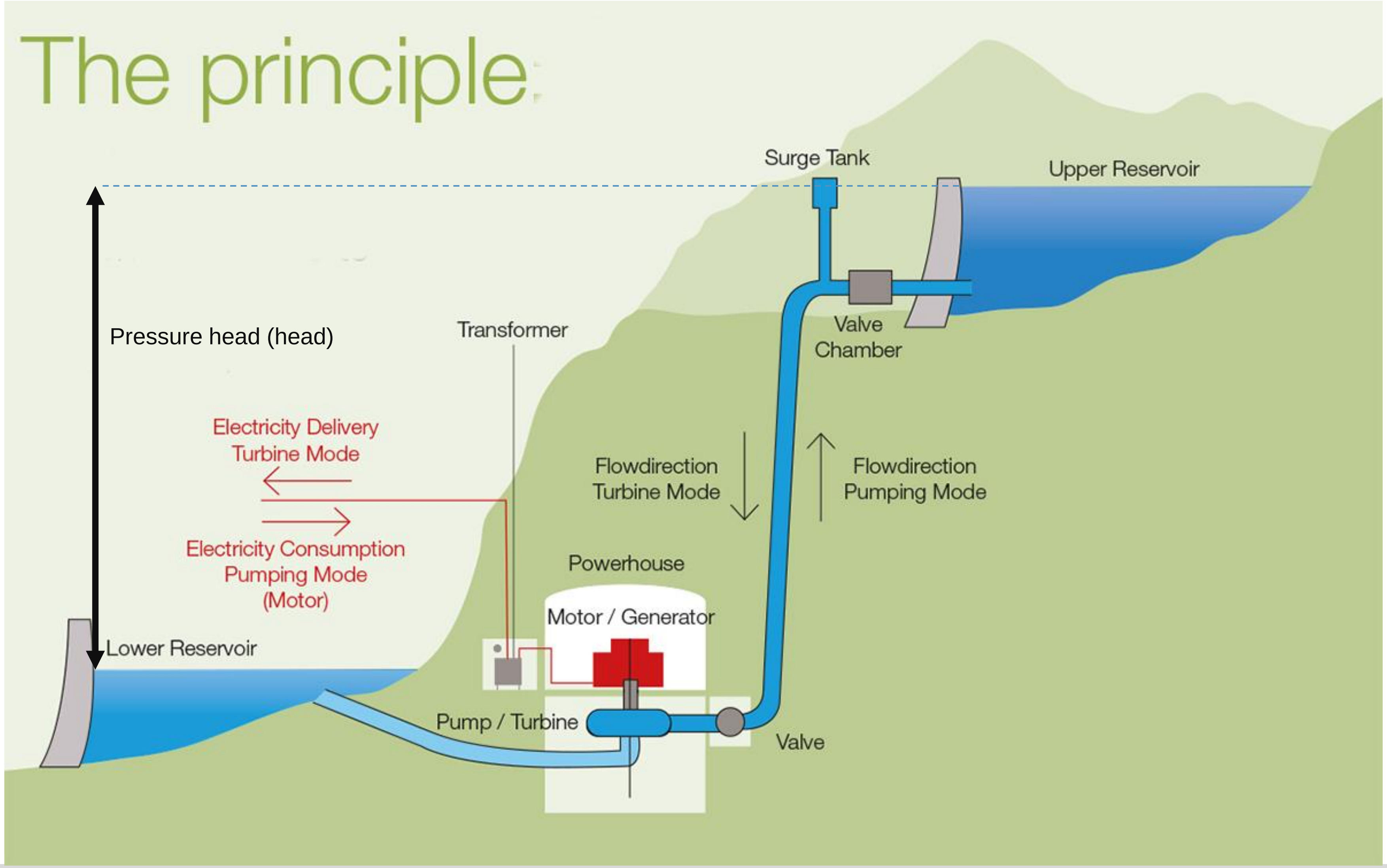


Estimated renewable energy share of global electricity production in 2019 [3].

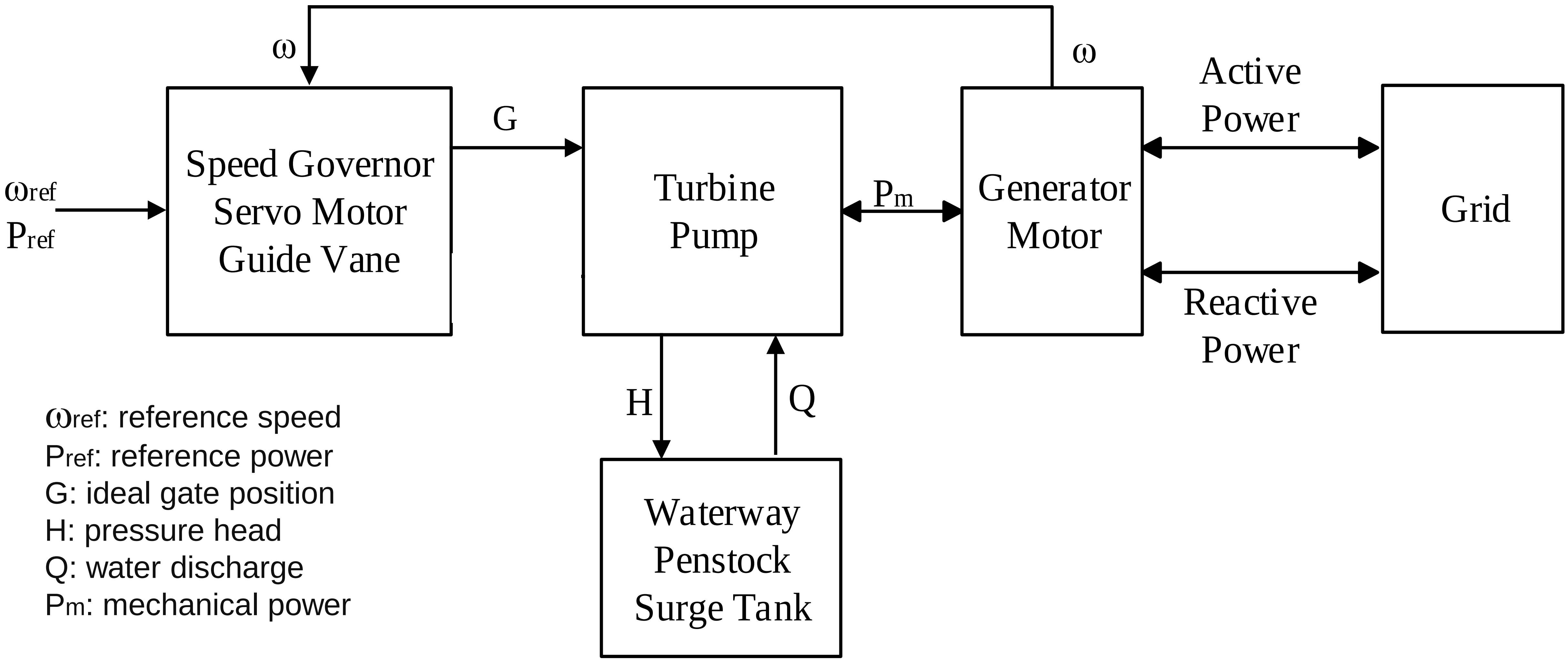
ELECTRICAL POWER SYSTEMS TU GRAZ

Principle of pumped storage hydropower plants



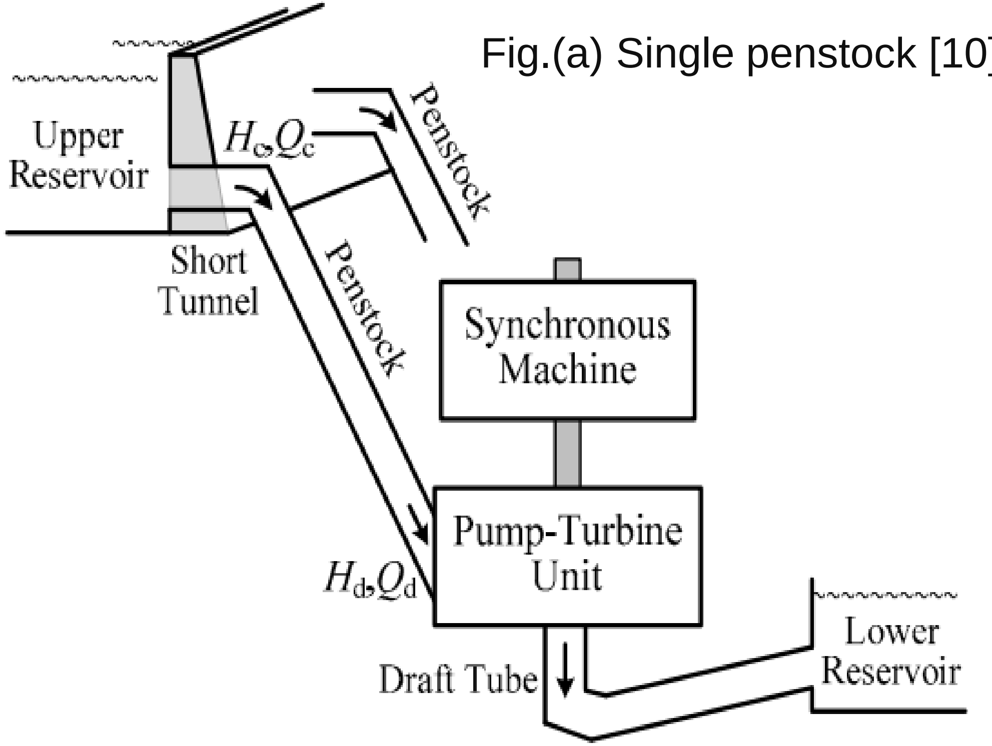
Principle of pumped storage hydropower plants [2]

Modeling of pumped storage hydropower



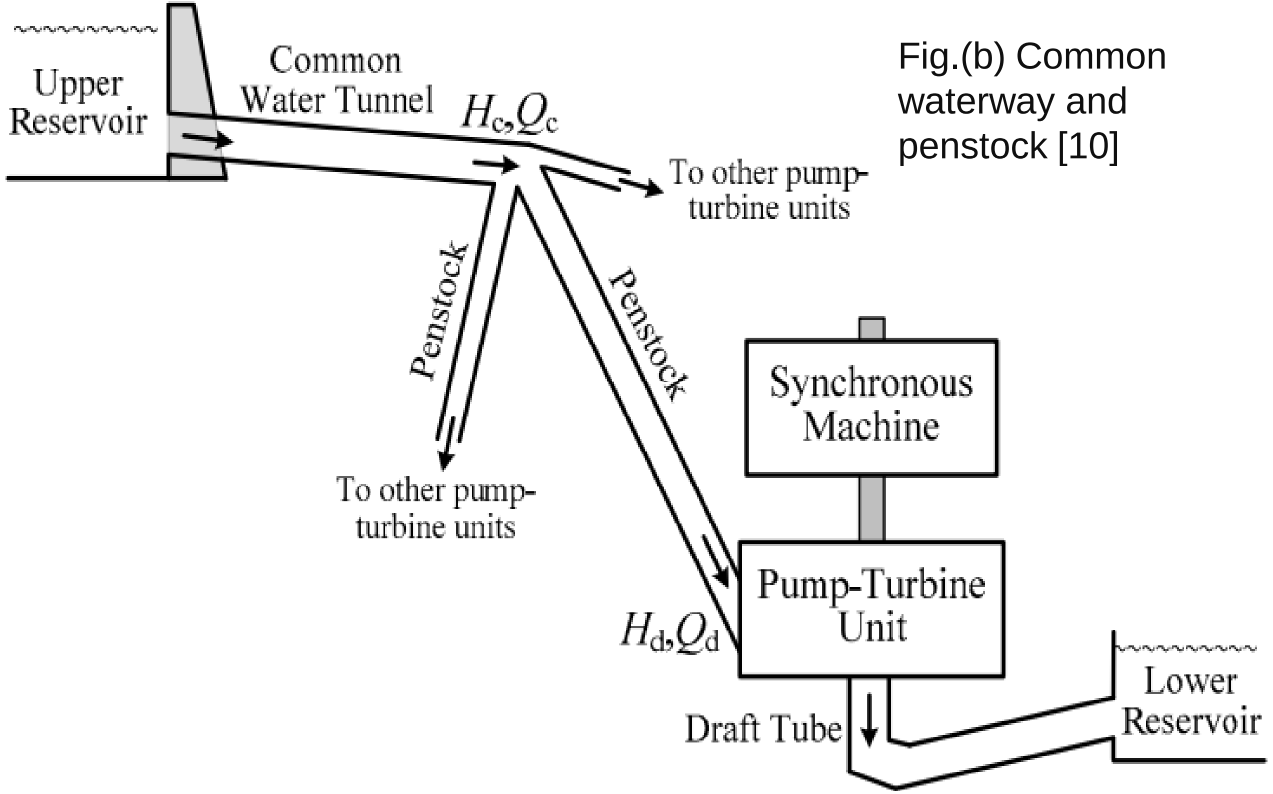
ω_{ref}: reference speed
P_{ref}: reference power
G: ideal gate position
H: pressure head
Q: water discharge
P_m: mechanical power

Modeling of pumped storage hydropower



(a)

Fig.(a) Single penstock [10]



(b)

Fig.(b) Common waterway and penstock [10]

Hc: Dynamic head at the junction of Tunnel and penstock
Qc: Dynamic flow at the junction of Tunnel and penstock

Hd: Dynamic head established by Pump-Turbine unit
Qd: Dynamic flow established by Pump-Turbine unit

Modeling of pumped storage hydropower

Elastic water dynamic:

$$H_c = H_{s1} - Z_{ht}Q_c\tanh(sT_{et})$$

$$H_d = H_{s2} + H_c\,\mathrm{sech}(sT_{ep}) - Z_{hp}Q_d\tanh(sT_{ep})$$

$$Q_c = Q_d\cosh(sT_{ep}) + \frac{1}{Z_{hp}}H_d\sinh(sT_{ep})$$

$$Q_c = \sum_{i=1}^{N} Q_{di}\cosh(sT_{ep}) + \frac{1}{Z_{hp}}H_{di}\sinh(sT_{ep})$$

Rigid water dynamic:

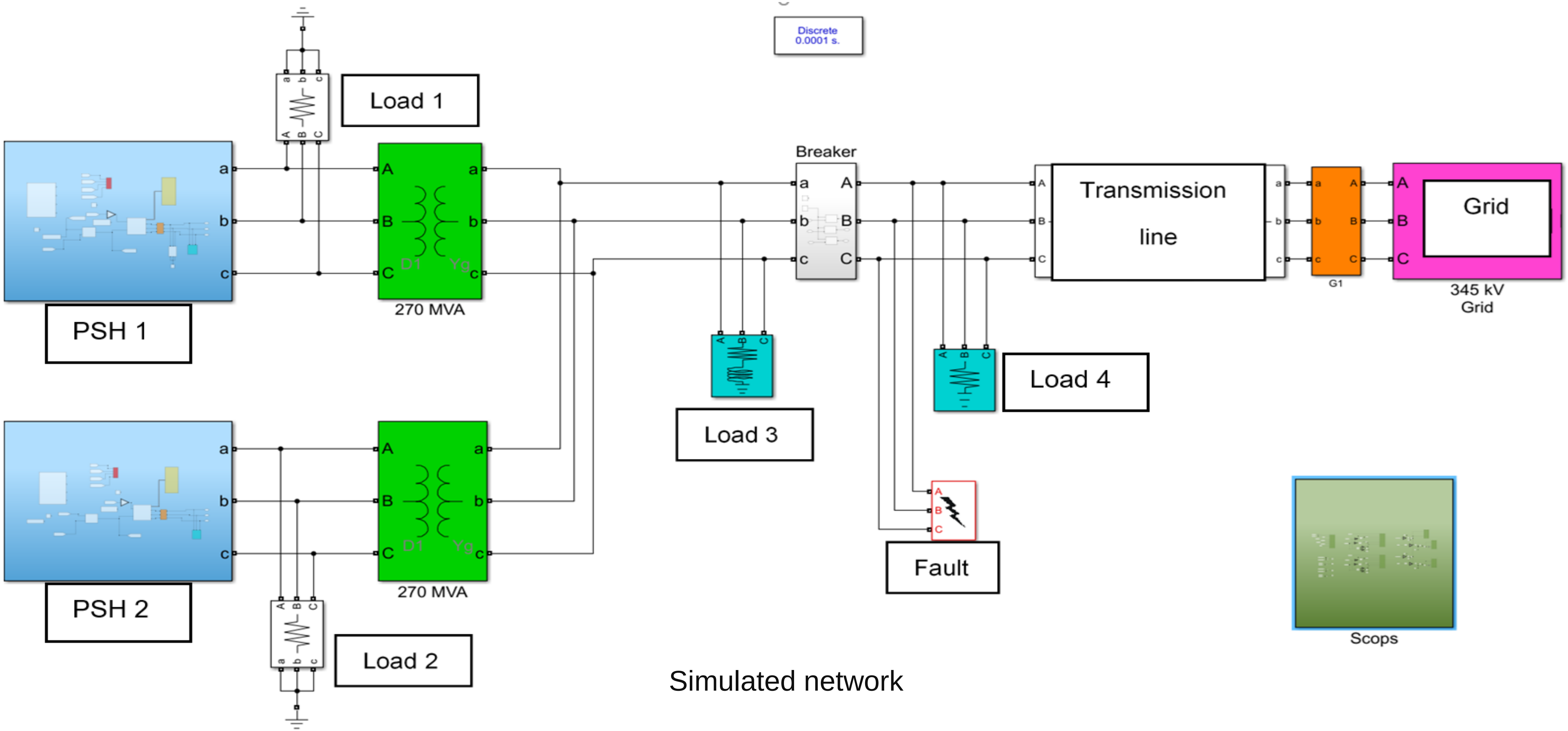
$$T_e \Rightarrow 0$$

$$Q_c = Q_d = \frac{1}{sZ_{hp}T_{ep}}(H_s - H_d) - \frac{Z_{ht}T_{et}}{Z_{hp}T_{ep}}Q_c$$

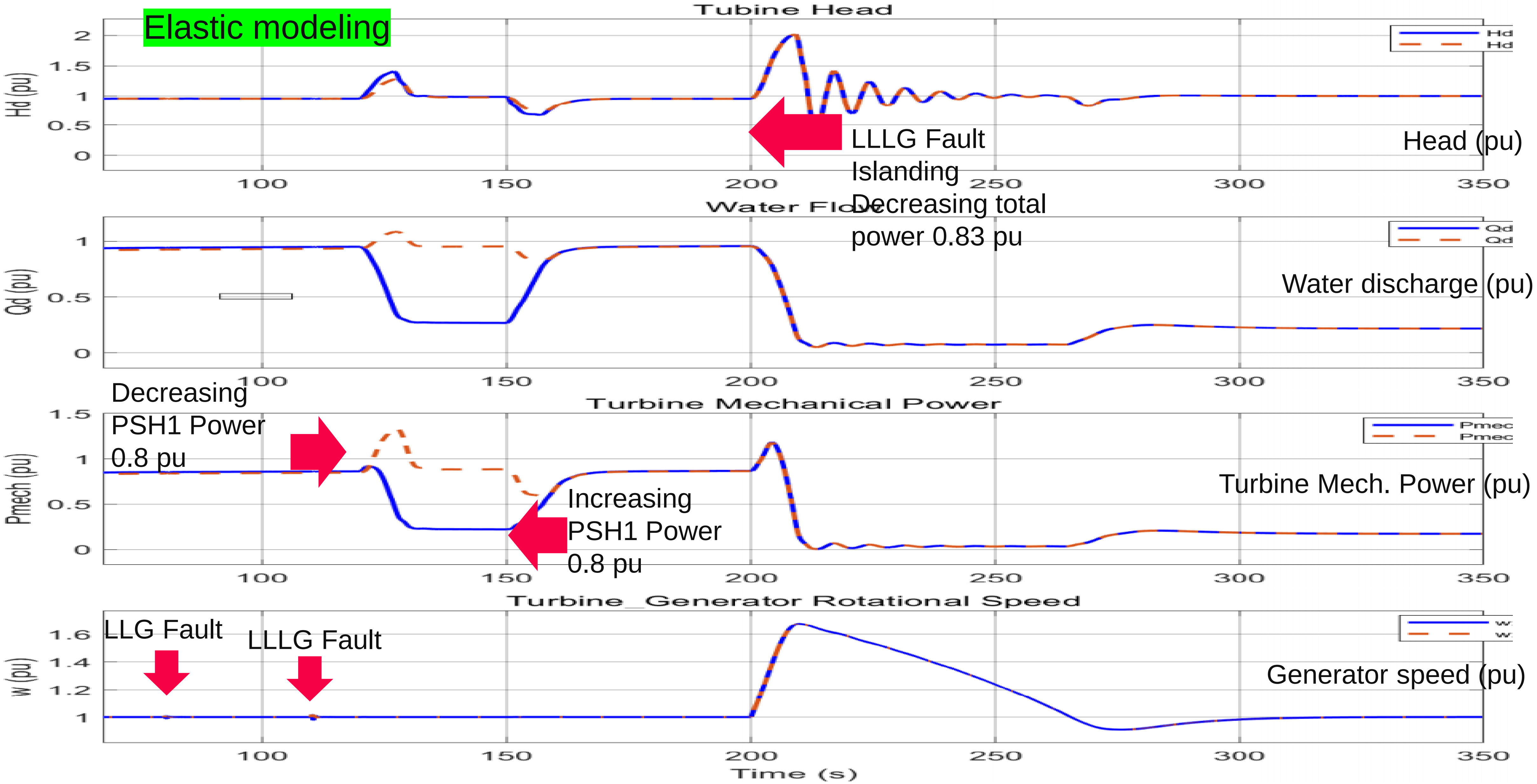
$$T_{wt} = Z_{ht}T_{et}, \quad T_{wp} = Z_{hp}T_{ep}$$

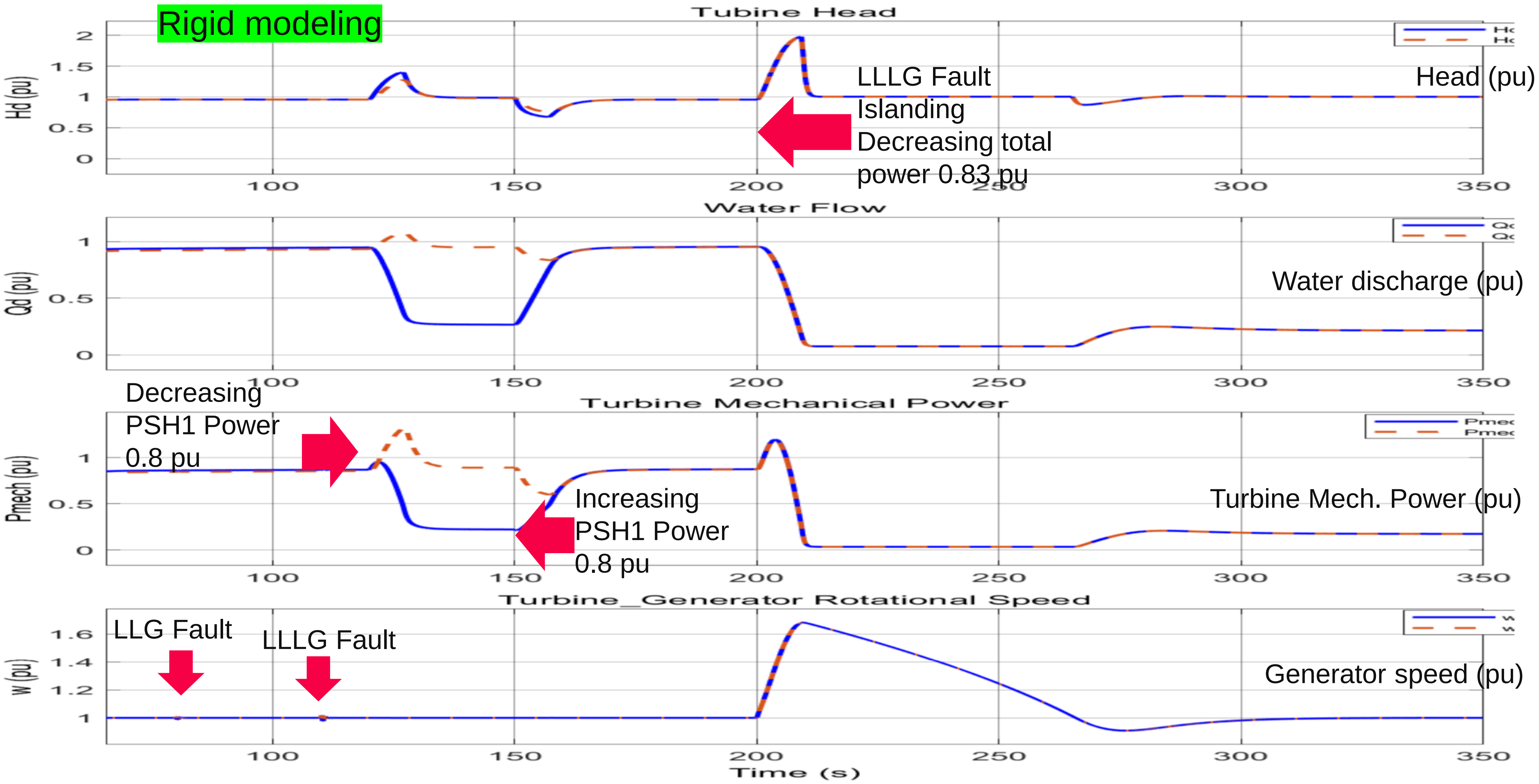
$$Q_d = \frac{1}{s(T_{wp} - T_{wt})}(H_s - H_d)$$

Modeling Pumped storage hydropower plants:



Simulated network


Elastic modeling
Tubine Head
Hd (pu)
Hd
Hd
LLLG Fault
Islanding
Decreasing total
power 0.83 pu
Head (pu)
Water Flow
Qd (pu)
Qd
Qd
Water discharge (pu)
Decreasing
PSH1 Power
0.8 pu
Turbine Mechanical Power
Pmech (pu)
Pmec
Pmec
Increasing
PSH1 Power
0.8 pu
Turbine Mech. Power (pu)
Turbine_Generator Rotational Speed
w (pu)
w
w
LLG Fault
LLLG Fault
Generator speed (pu)
Time (s)


Rigid modeling
Tubine Head
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Decreasing total
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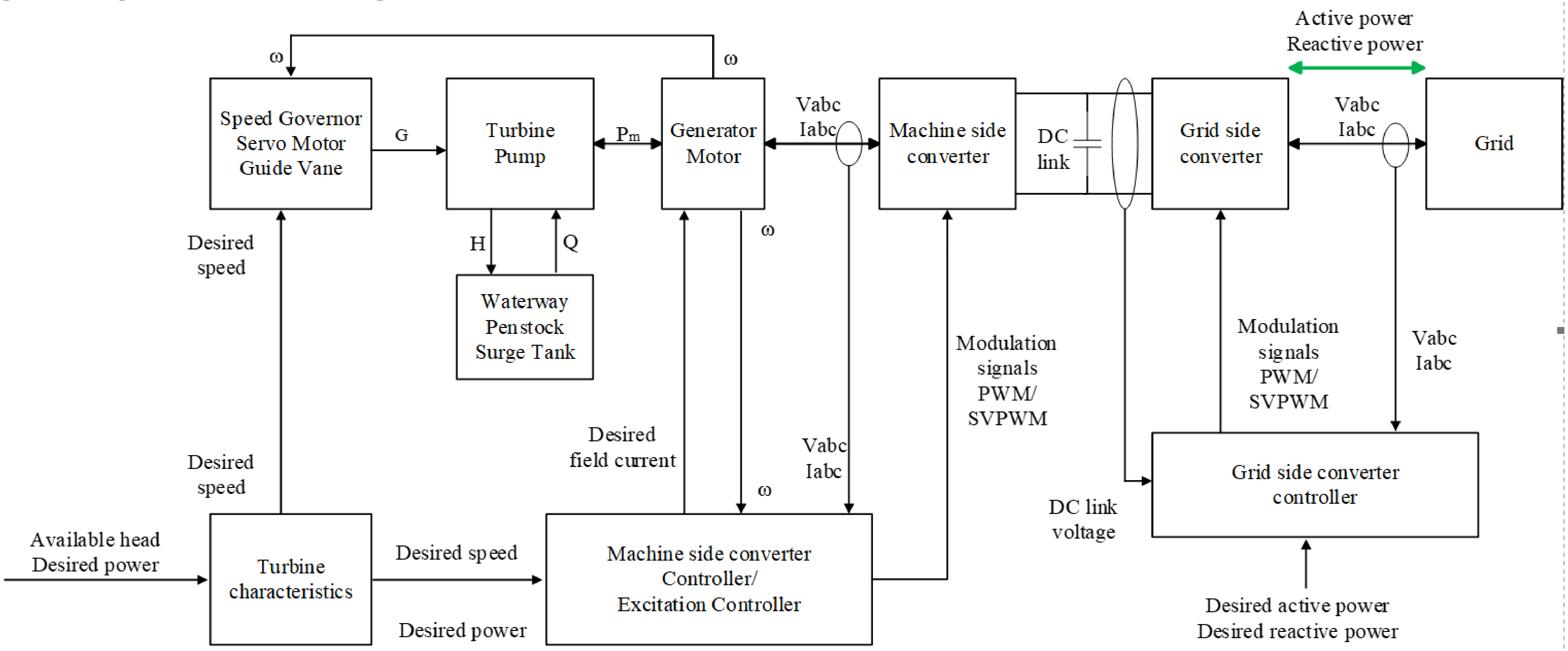
w (pu)
LLG Fault
LLLG Fault
Generator speed (pu)
Time (s)

Further steps and outlook of this research

- Effect of one variable speed hydropower (EESM) on the fixed speed unit in the same power plant with common water way.
- Effect of two different variable speed hydropower units e.g. EESM, DFIM, PMSM on each other considering common water way.
- Possibility to operate as the primary frequency control unit
- Supporting /compensating wind-PV generation by variable speed hydropower (EESG)
- Implementing the simulation models in the power hardware in the loop (PHIL) lab observe the prototype power

General concept for control and model a variable speed pumped storage unit:



Power hardware in he loop (PHIL) lab

References

1. https://www.hydropower.org/iha/discover-facts-about-hydropower
2. https://www.andritz.com/products-en/hydro/products/pumped-storage
3. REN21 2020 (https://www.ren21.net/gsr-2020/chapters/chapter_01/chapter_01/#sub_5)
4. Leopold Ruppert, Robert Schürhuber, Bernhard List, Alois Lechner, Christian Bauer, "An analysis of different pumped storage schemes from a technological and economic perspective", Energy, Volume 141, 2017, Pages 368-379.
5. https://twitter.com/EASE_ES/status/1442788673884405762

Thank you for your attention