Cours CIVIL 469 - Synthesis of the course, **week #05** (19.03.2025), 2h theorical +2h exercises

1. **High-head schemes (including those without storage)**
    - Characteristics
    - Typical powerplant layouts
        - Waterway typologies
        - Free-surface flow waterways (canals, tunnels, conduits running in free-surface)
            - Characterized by mild slopes and flow controlled by downstream at the forebay /headpond
            - Flow runs at near critical velocities in near-uniform flow for minimum slope for a large range of discharges
            - Velocities are within 1-2 m/s.
            - Any change in flow rate resulting from manoeuvring of a gate/valve at the powerhouse will travel upstream in the penstock and will generate a down/up surge in the forebay.
        - Pressurized flows waterways
            - Controlled by downstream until full gate opening, any slope, rough turbulent subcritical flow, section optimised considering construction costs (which increase with increasing diameter) and economic losses due to energy losses (which decrease with increasing diameter), approx. ≤ 3-4 m/s
            - Tunnels
            - Shafts
            - Penstocks / pressurized conduits
        - Powerhouse typologies: surface, shaft, underground
        - Surge chambers
        - Purpose
        - Topographical constraints
    - Power and energy yield
    - Energy coefficient or WEC
    - Operation duration at rated discharge and operation modes
        i. From base load to peak load
        ii. The role of storage
        iii. Repowering
    - Examples
        - Grande Dixence HPPs (GD)
        - Oberhasli HPPs (KWO) – Gadmenwasser (without seasonal storage)
        - Oberhasli HPPs (KWO) – Haasliaare (with seasonal storage)

2. **Pumped storage**
    a. **Definition**
    b. **Potential**
        i. Global Greenfield Pumped Hydro Energy Storage Atlas | ANU RE100 Group
        ii. ANU RE100 Map
    c. **Typologies**
        i. Open PSP
        ii. Semi-open/closed PSP
        iii. Closed-loop PSP

d. Typical operation cycles

i. Daily, weekly, weekend, seasonal
ii. Dependency on reservoir morphology
iii. Drawdown ranges (elevation range and advance/retreat range)
iv. Drawdown rates (limitations)
    1. Safety concerns
    2. Reservoir slope stability concerns
    3. Public access vs. restricted access
    4. ~~Compatibility with multi-purpose use of the reservoir (e.g. Sihlsee/SY)~~

e. Challenges of power grid operation

i. Challenge 1: Balance/Arbitrage
    1. Guarantee continuous balance between production & demand

ii. Challenge 2: Modulation
    1. Integration of different power production centers with different characteristics (scale, reaction time, inertia)
    2. Demand side management vs. Production side management

iii. Challenge 3: provide affordable power & sufficient cost coverage
    1. Facilitate integration of solar and wind
    2. Solar and wind as renewable endogenous power production sources

iv. Inertia of spinning machines
    1. Synchronous behaviour
    2. Deviations from synchronous behaviour
        a. Due to flow discharge variations
        b. Due to variation in resistant inertia (power grid)

v. Large-scale power grids
    1. Interconnexion
    2. Space & time scale of reaction to an unplanned power supply disturbance

vi. Examples
    1. Linthal
    2. Vianden
    3. Grimsel 2
    4. Nant de Drance

3. Exercise 2

- Short-cycle, semi-open loop PSP scheme