ÚJV Řež, a. s.

Power Flow Problem in a Smart Grid with Hydrogen Storage Systems

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HydrogenDays

Essential Questions

- How does power engineering look at hydrogen storage systems?

- Could be hydrogen storage systems easy involved in all kinds of electrical grid (especially smart)?

Power Flow Problem

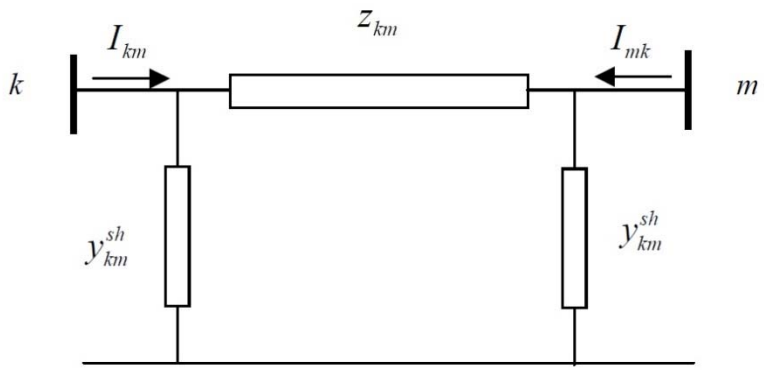
- **Ohm´s Law**
- **Two Kirchhoff´s circuits laws**
  - Current Law
  - Voltage Law
- **Non – linear problem**
  - Complex Impedance
    - Resistance
    - Capacity
    - Inductance
- **Power**
  - Active P (W)
  - Reactive Q (var)
  - Complex S (VA)
- **Power Factor = P / S**

Power Flow Problem

- **Generally**
  - Non – linear set of equations
  - f (x, u, p) = 0
    - x is vector containing the state variables
    - u is a vector with known control outputs
    - p is a vector of parameters
- **Mathematical methods**
  - Gauss – Seidel
  - Newton – Raphson
- **Four Variables**
  - Voltage Magnitude
  - Voltage Angle
  - Active Power
  - Reactive Power

Power Flow Problem

- **Transmission and Distribution Network**
  - Nodes
    - Three kind of nodes
      - Voltage controlled node
        - PU
      - Load node
        - PQ
      - Slack node
        - Uθ
  - Branches
- **Topology**
  - Admittance matrix



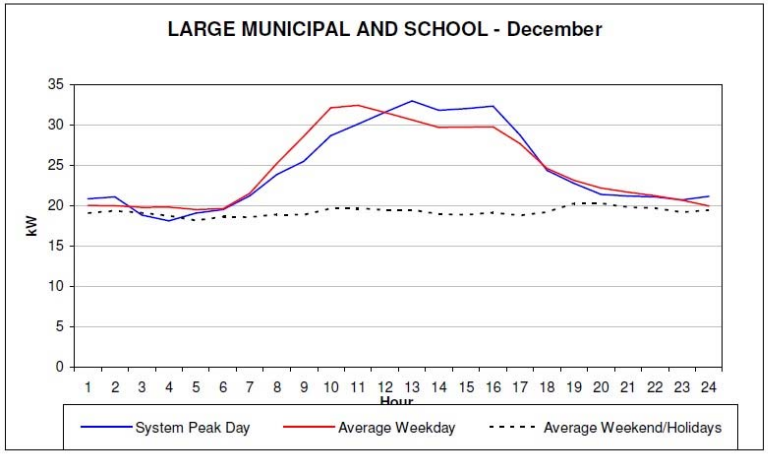
Power Flow Problem

$$P_k = U_k \sum_{m \in K} U_m (G_{km} \cos \theta_{km} + B_{km} \sin \theta_{km})$$

$$Q_k = U_k \sum_{m \in K} U_m (G_{km} \sin \theta_{km} - B_{km} \cos \theta_{km})$$

Load Profile - Today

- **Only in general**
  - OTE, a.s.
    - Regions
  - Temperature involved
    - Daily
    - Monthly
    - Seasonly
    - Yearly
- **Typified load profiles**
  - Various groups
    - Factories
    - Residentials

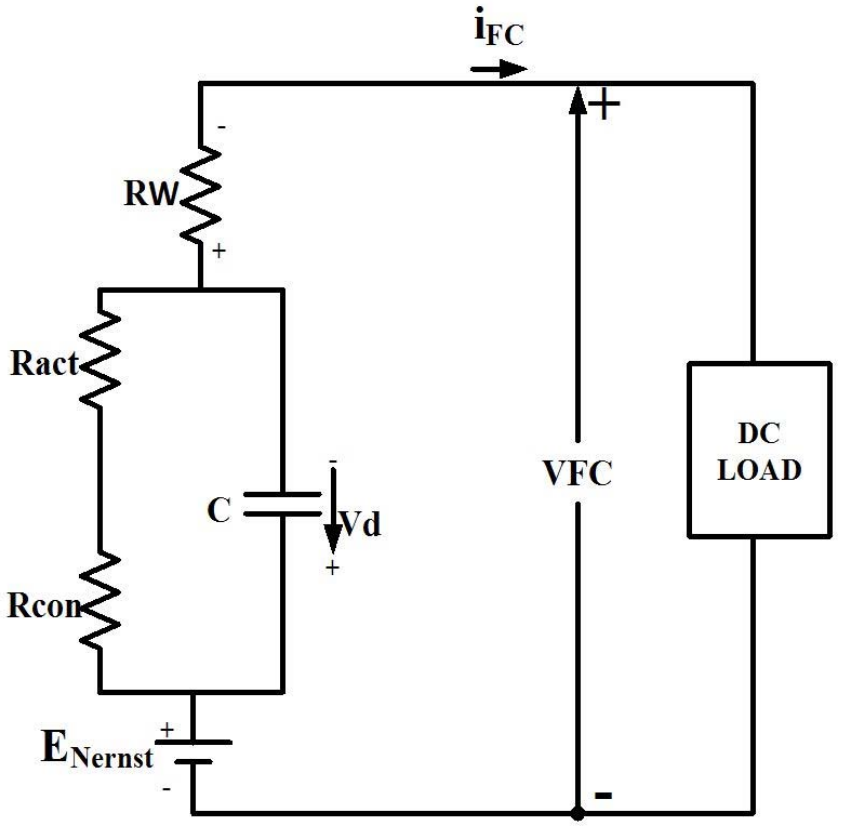


Load Profile – Smart Grid

- **Example**
  - City
    - Two districts
      - Workers´
      - Academic
  - Different load profiles for both districts
  - Students live their days differently than workers
- **Power engineers**
  - Could with a smart grid optimize power flow in different parts of
    - City
    - Region
    - Country
    - ???

Hydrogen Storage as a Node

- **Fuel cell**
  - Linearized polarization curve
  - Resistance
    - Only ohmic losses
- **No problem with reactive power and power factor**
  - But power engineer needs reactive power for regulation of voltage!



Hydrogen Storage as a Node

- **Ordinary power flow problem becomes more complex**
  - In each node the load profile must be involved
- **Each time interval a new instance of power flow problem**
  - Stability of the system must be guaranteed for the worst scenarios
- **Storage systems - and more complex again**
  - PQ node
  - Sometime as a load, sometime as a generator
    - Minus - load
    - Plus - generator
- **Very powerful IT technology must be used!**

Conclusion

- **It will not be easy to build a completely new and fully functional national smart grid with storage systems**
- **Deeper and more complex real – time calculations are needed!**
- **Such systems will be very vulnerable**
  - Destruction
  - Hacking
- **They will cost a lot of money**
  - Trillions of euro in the course of the next half of century!
- **But if all goes well, they will be a small step to paradise**
- **But if all went well, they would be a small step to paradise**
- **Which conditional do you prefer?**

THANK FOR YOUR ATTENTION

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