Cooperation and development annual conference EPFL
Workshop B: What technologies are suitable for the South?

Sustainable Energy Storage Technology for the South and the North

Prof. Alfred Rufer

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The North and the South: Similar problematic for a sustainable energy future ?

-From Centralized to Decentralized Generation? (North)

- The Rural Electrification (South)

- Integration of Renewable Sources (N & S)

A clear demand for electrical energy storage

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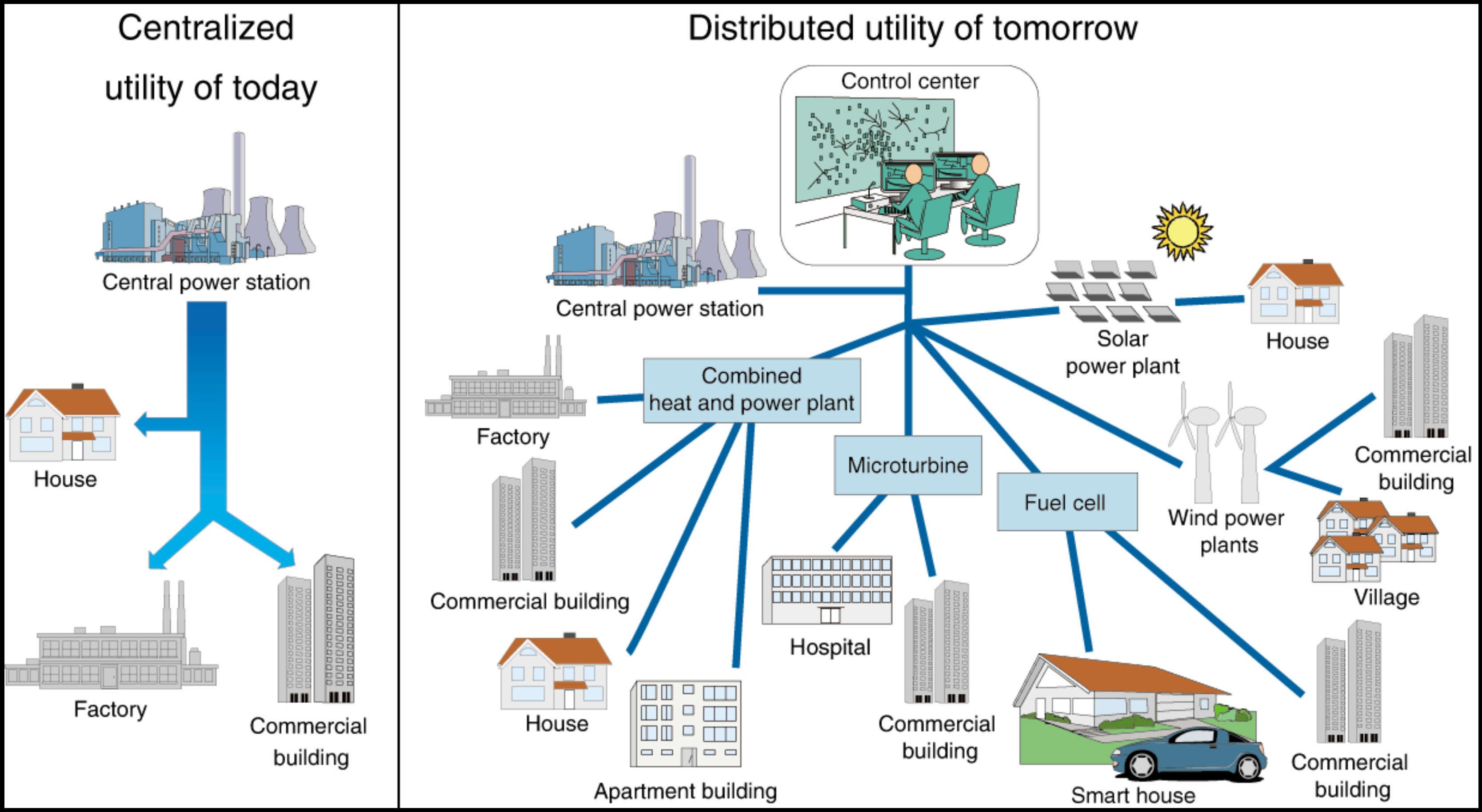
- **Electricity storage for DG (Decentralised Generation):**
  - **Stochastic generators can be made dispatchable for grid integration**
  - **Stochastic loads can be made compatible with grid disponibility**



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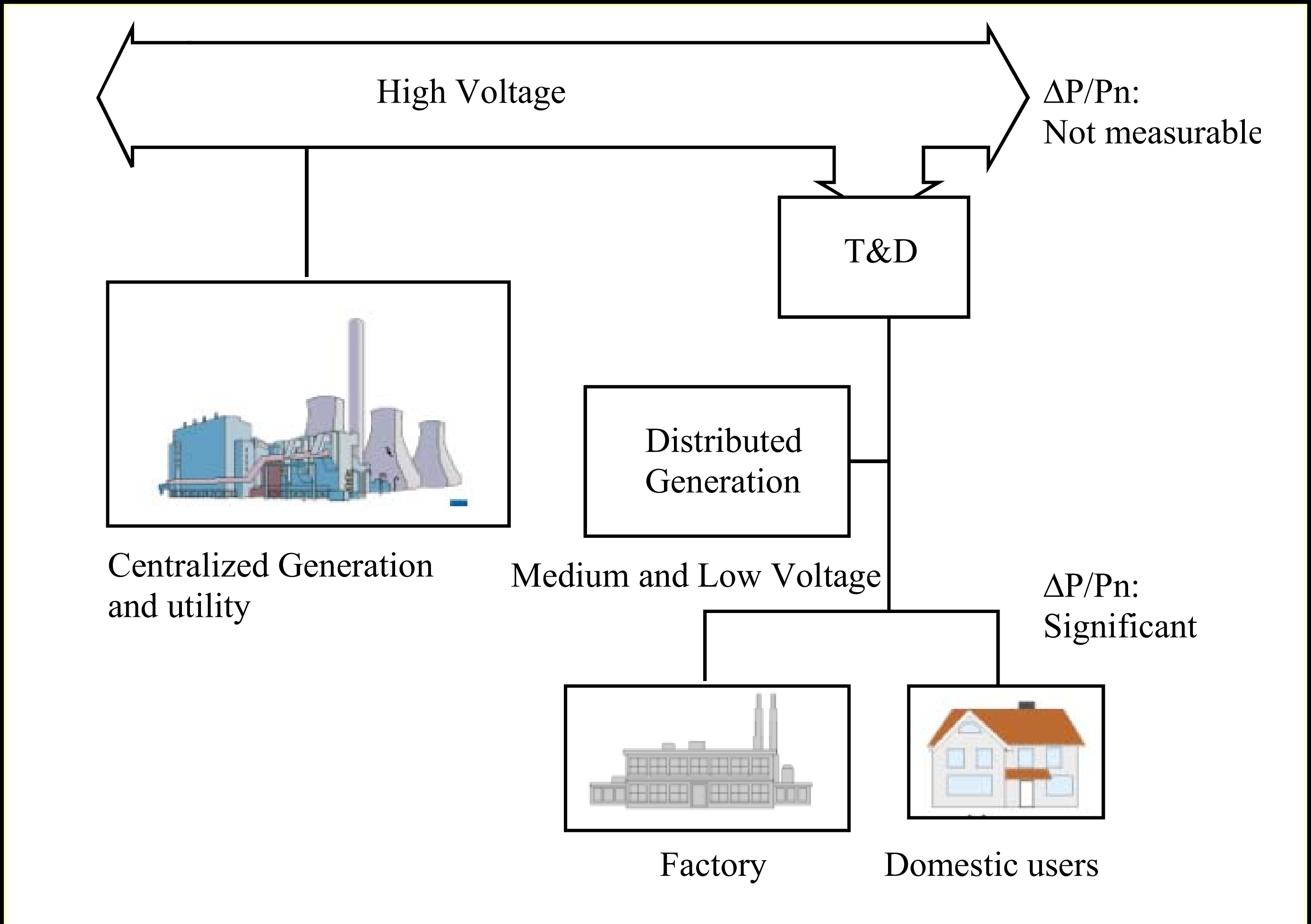
Power variations of loads and generators

Moving the generators from a smooth high power level to a « noisy » distribution level: « seeing » the load variations



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A very important subject (for North and South):

Electric Energy Storage

2 Main areas :

Storage for Power Generation

Examples:

- Photovoltaic plants
- Wind generators
- Starting of micro-turbines

Storage for Power Utilisation

Examples:

- Automotive, Trains
- Elevators, Problematic loads

The storage technologies:

What properties?

What problems?

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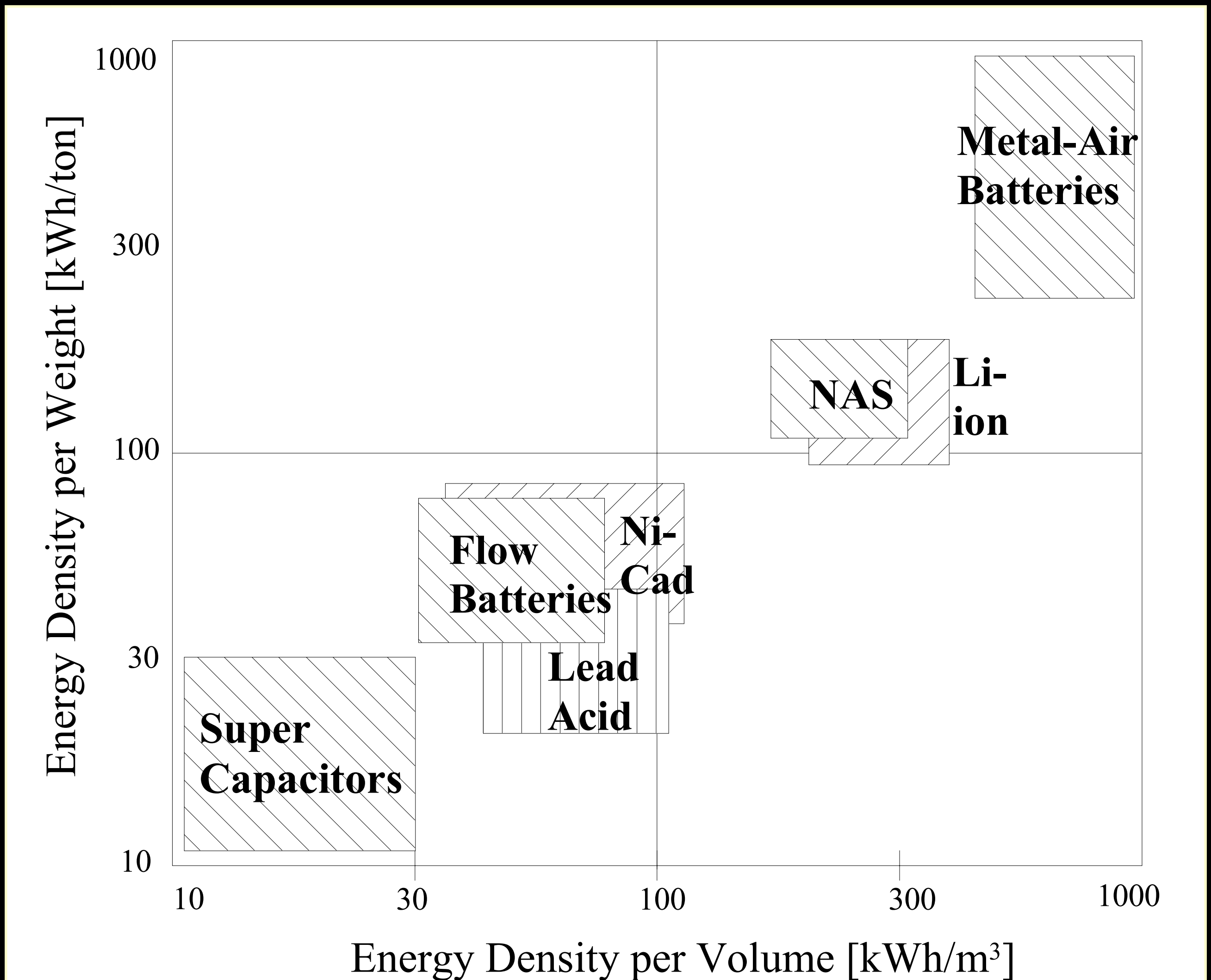
Energy density of different storage systems (Courtesy: Electricity Storage Association



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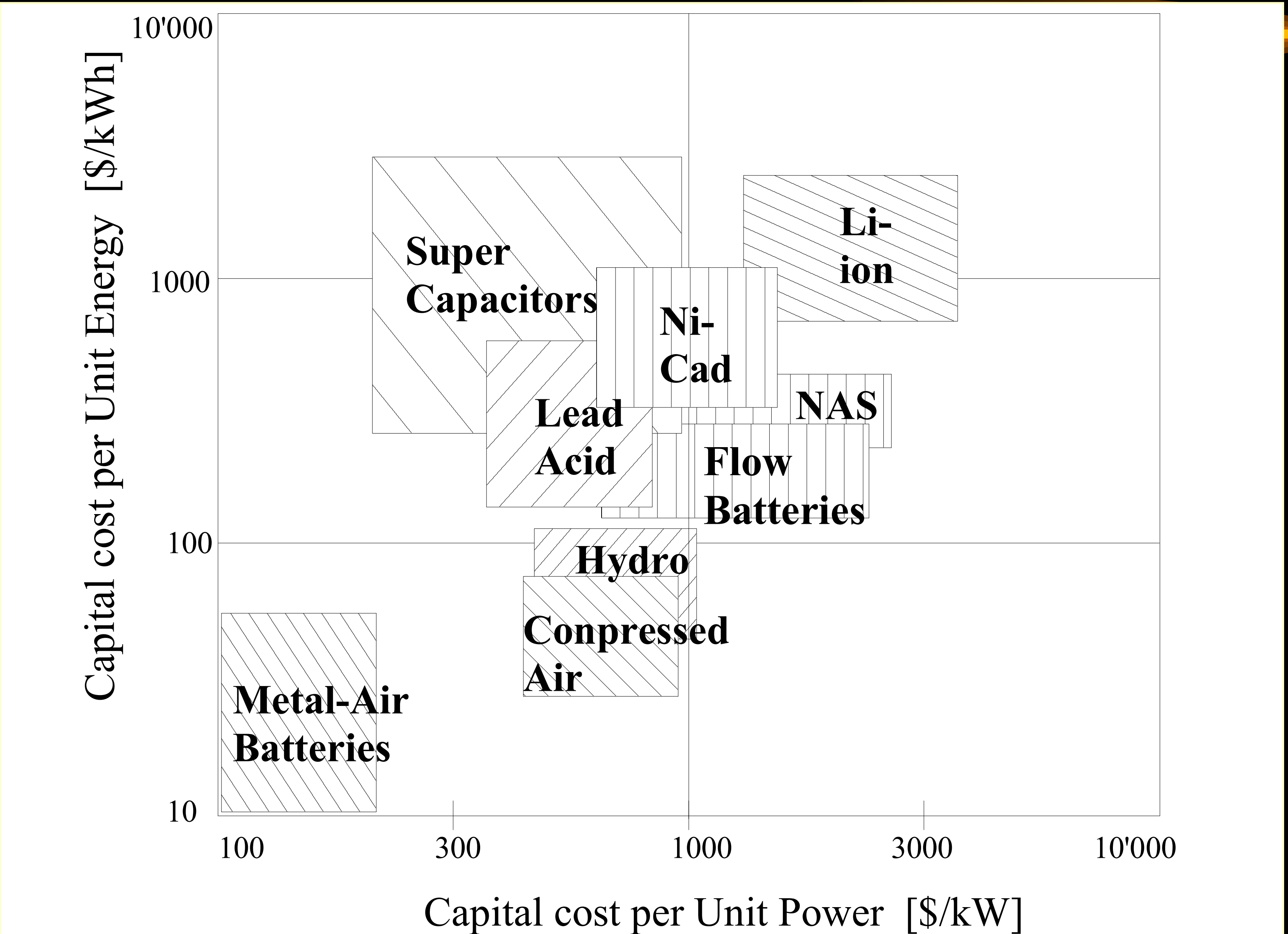
Capital costs (Courtesy: Electricity Storage Association)



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Life cycles and efficiencies

Storage system	Life [cycles]	Efficiency [%]
Pumped Hydro	75 Years	70-80
Compressed air	40 Years	
Flow Batteries	1500-2500	75-85
Metal-Air	100-200	50
NAS	2000-3000	89
Other advanced batteries	500-1500	90-95
Lead-Acid	200-300	75
Supercapacitors	10'000-100'000	93-98

Electric energy storage:

Additional criteria:

- Environmental impact!!

- How to recycle

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Energy storage BESS

Nickel-Cadmium Battery 40 MW 13MWh

Golden Valley Electric Association (Alaska)   13'760 Battery Cells, End of 2003

Energy storage with high life-cycle and low environmental impact, alternative solutions to classical batteries

A new research project at EPFL-LEI
has already partners in the South
(needs for financial support)

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CAES
(Compressed Air Energy Storage)

Prof. A. Rufer

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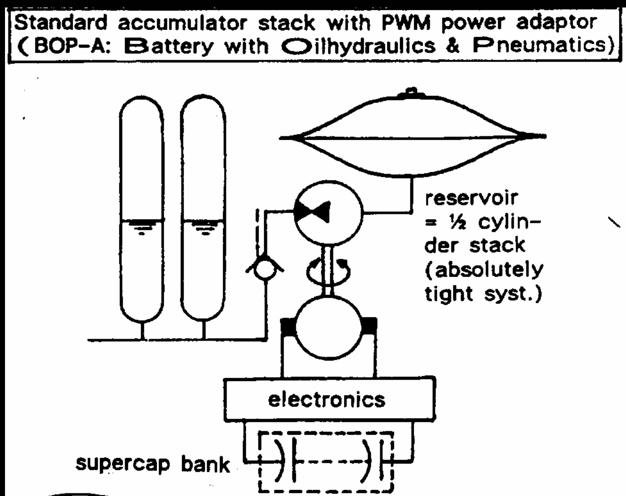
Two main Families of CAES Technologies:

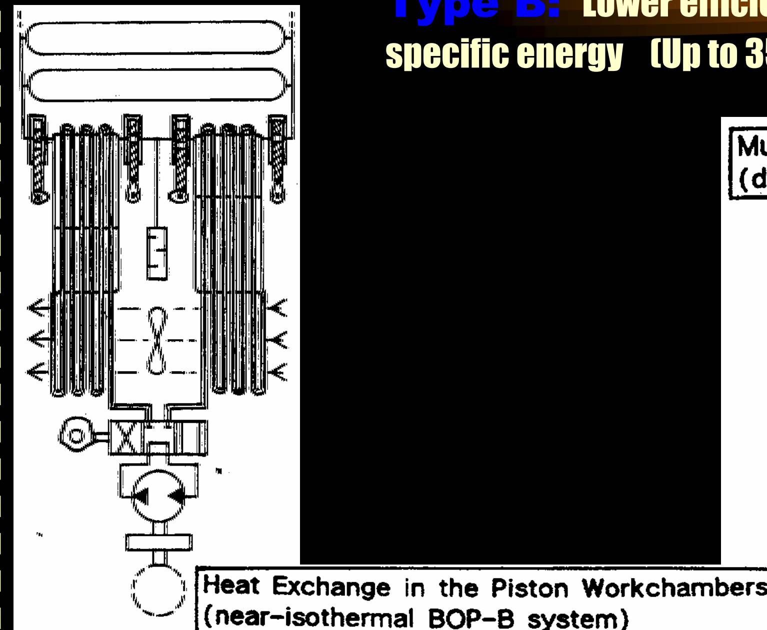
- Volumetric machines with Vessel storage
- Kinetic machines with Underground storage

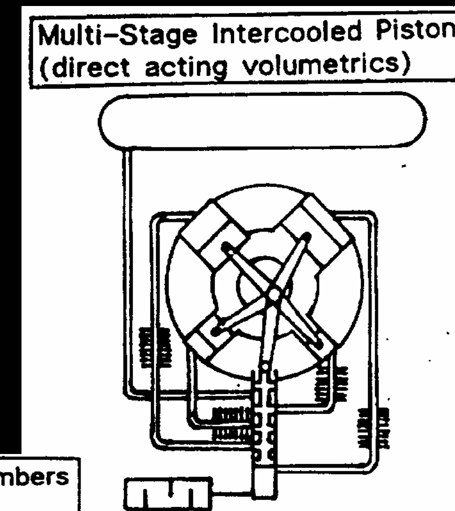
Type A: Premium efficiency compensated by low specific energy (< 3Wh/l)

Type B: Lower efficiency but higher specific energy (Up to 35Wh/l @ 300bar)

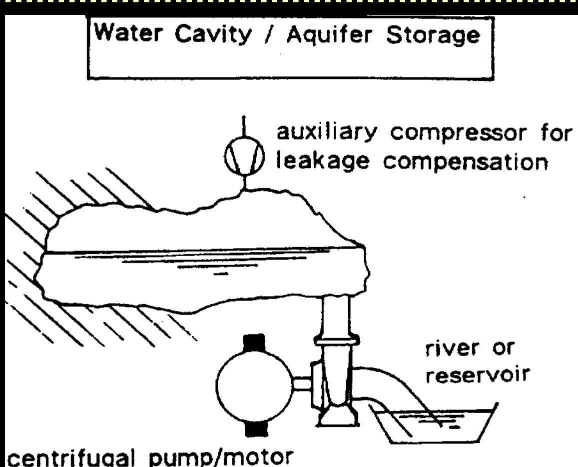
Volumetric

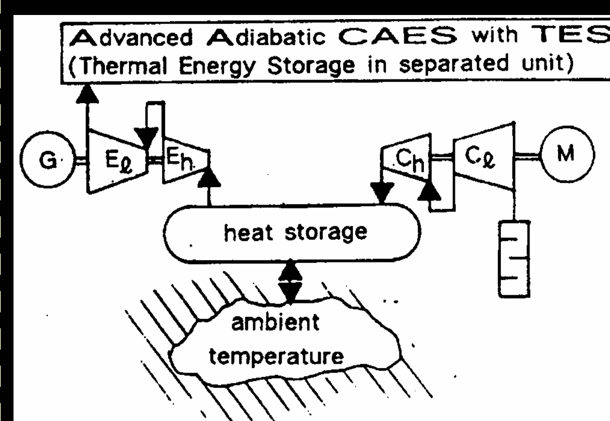


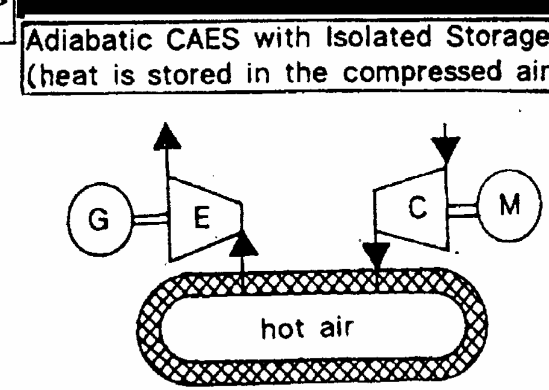




Kinetic







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CAES with vessel storage (small CAES)

- Use of Air Motor / Compressor to drive an electric generator
- Use of Hydraulic Motor/Compressor (higher efficiency,0.89 one way)
- Low cost tank, easy to recycle technique, low aging phenomena
- Competitive storage capability:

1,75-3,3Wh/kg and 1,6 Wh/L	(Liquid piston)
23-50Wh/kg and 24 Wh/L	(Interface system)

- Several specific problems to be solved (interdisciplinary)
  Examples:
  Operating point of the air or oil motor with an acceptable value of efficiency
  Thermodynamic conditioning

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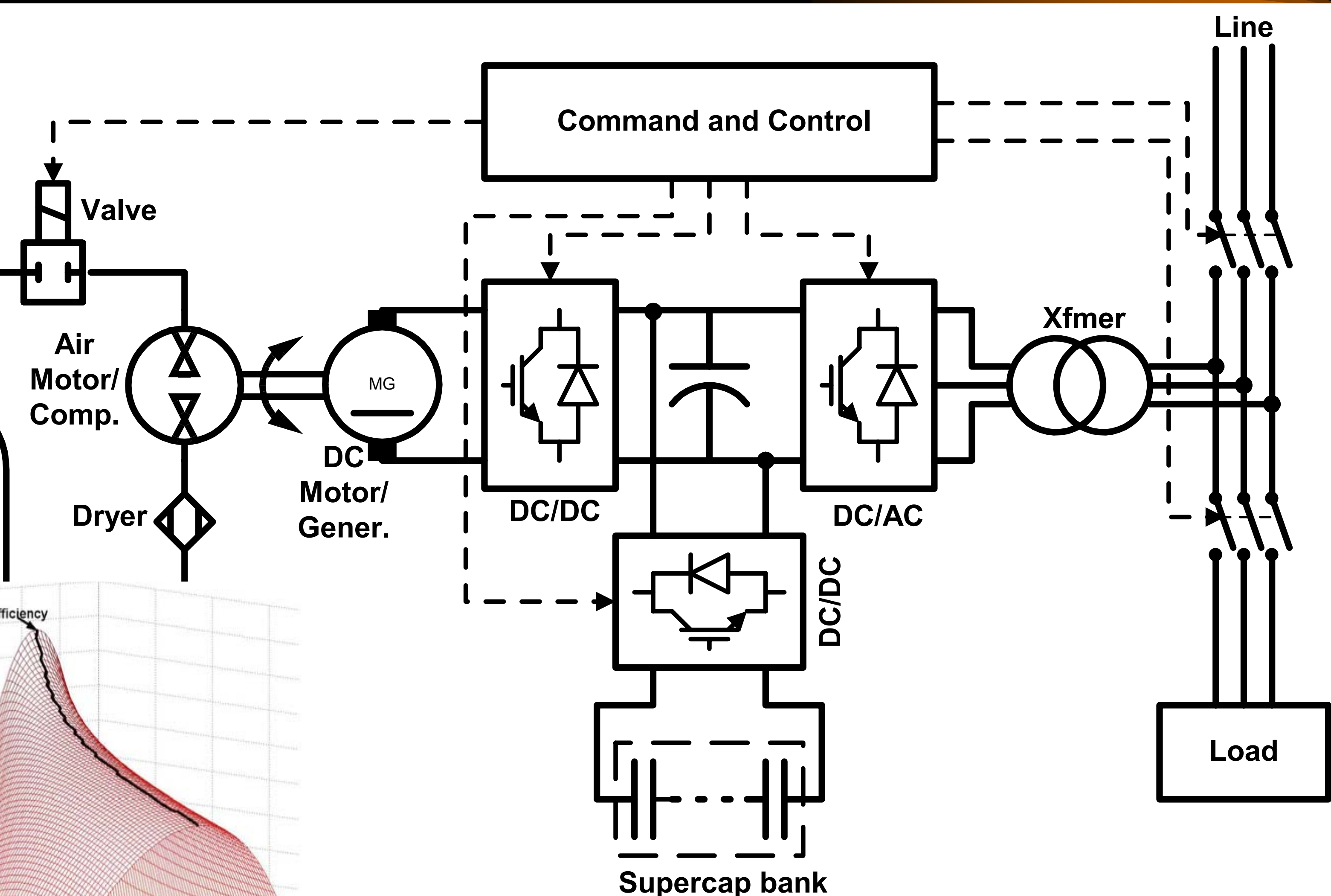
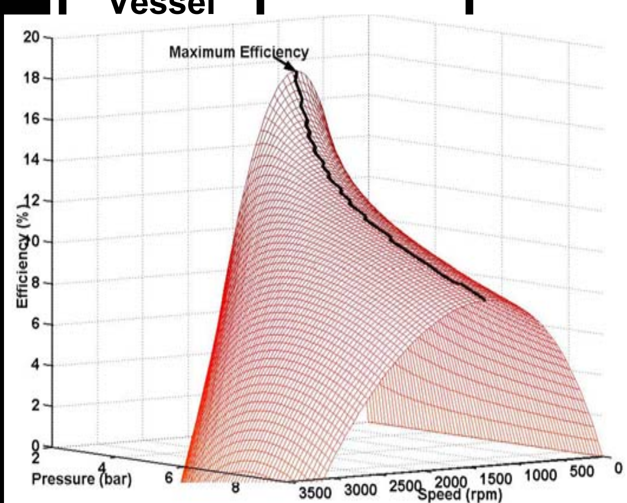
UPS-System with Air Motor/Compressor





MEPT: Maximum efficiency point tracking

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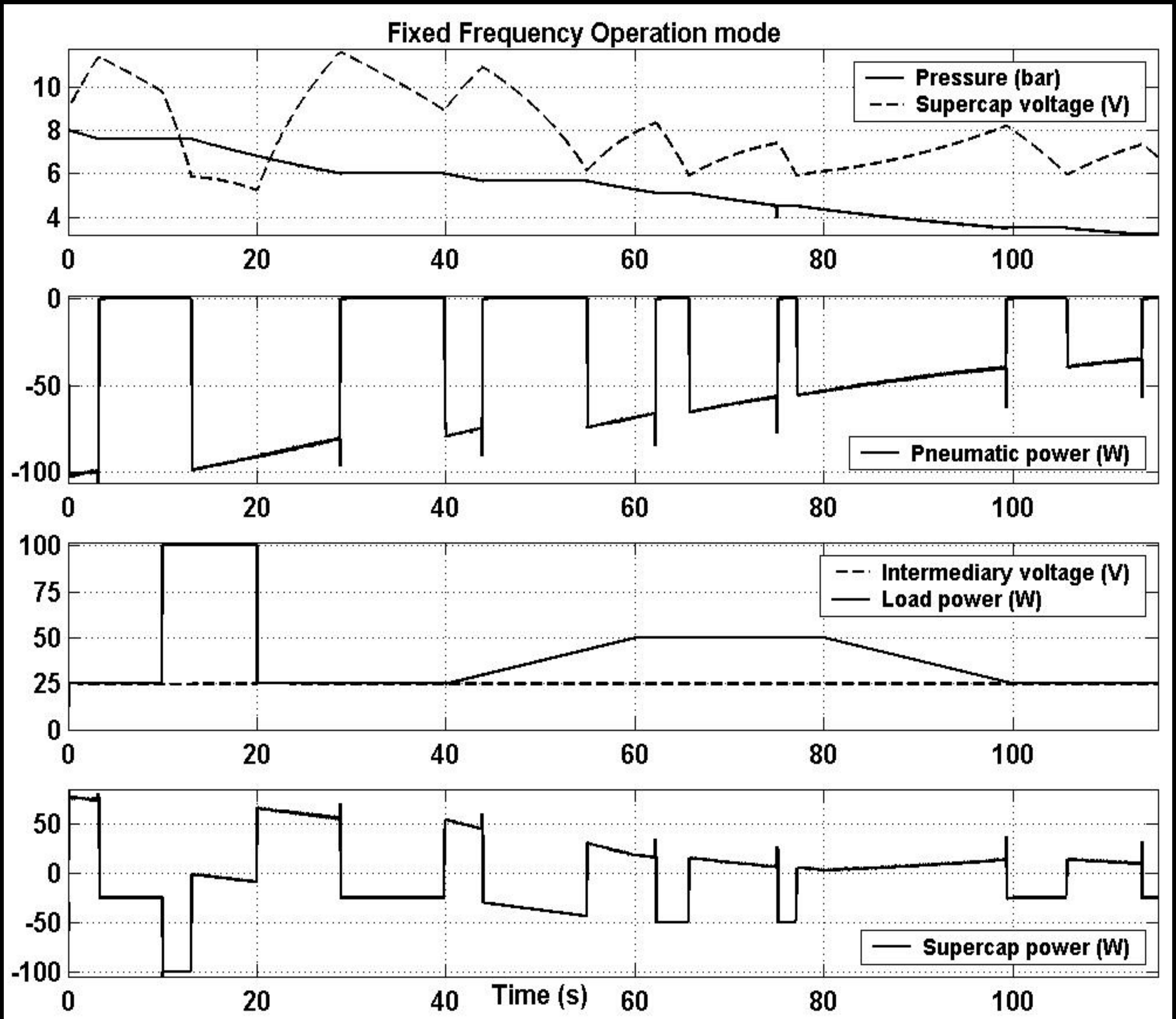
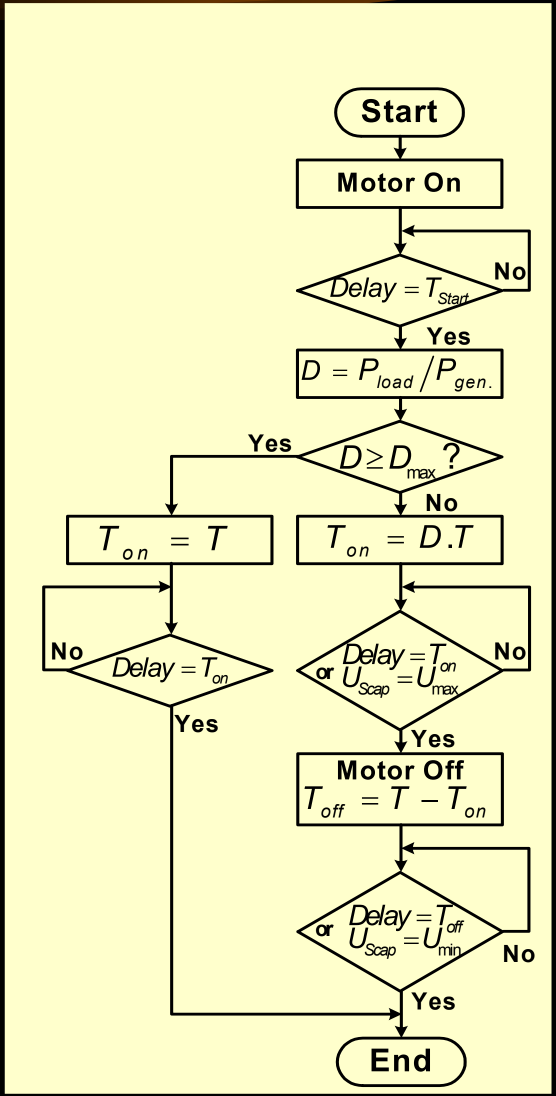
Two PWM operation modes are possible:

- Free oscillation PWM (FO-PWM)
- Fixed frequency PWM (FF-PWM)



Flow diagram of FF-PWM



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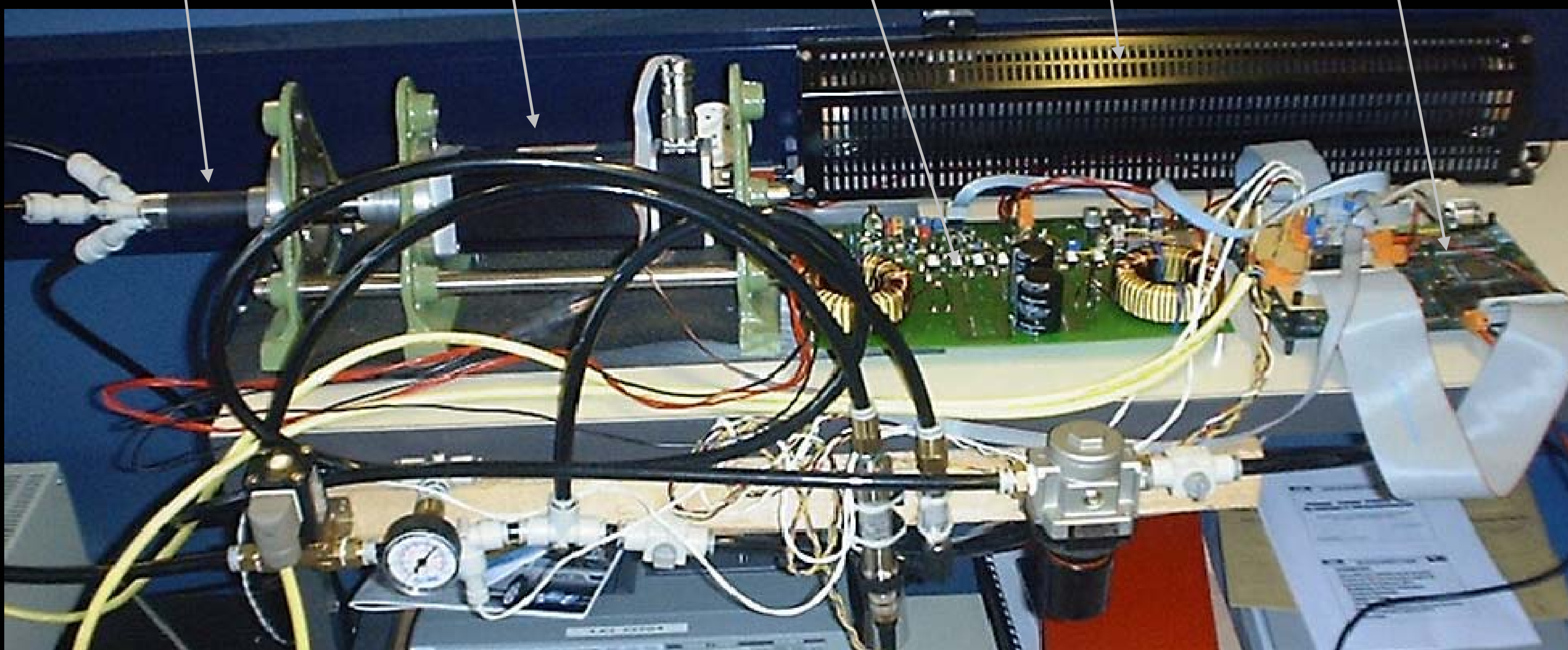
Maximum Efficient Point Tracking (MEPT)



Towards Oil-hydraulics & Pneumatics systems for higher efficiency

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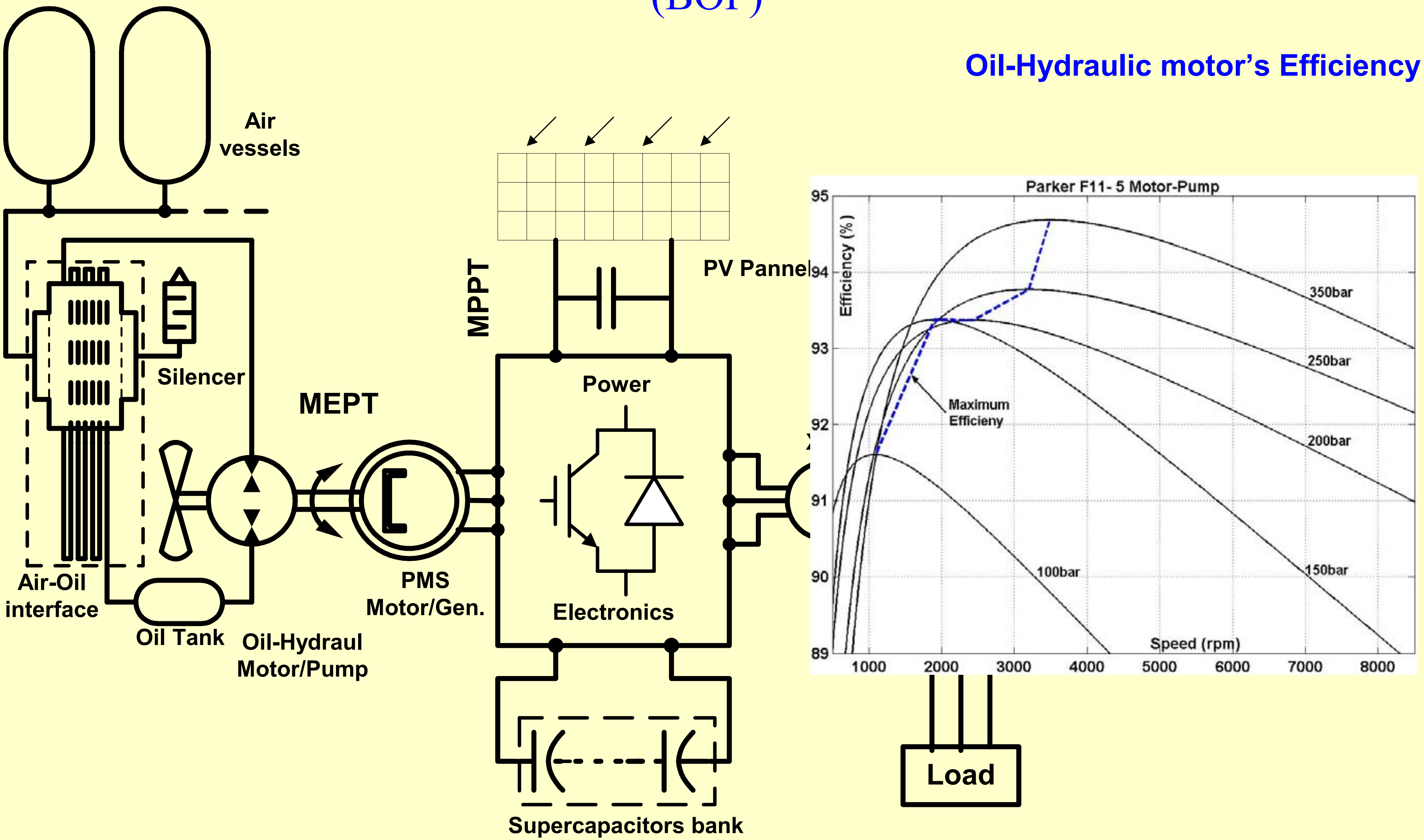
Possible configuration of a PV station with Oil - hydrauPneumatic Battery (BOP)



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Small CAES

A much higher efficiency with hydraulic machines

2 different approaches:

1: The “liquid piston”

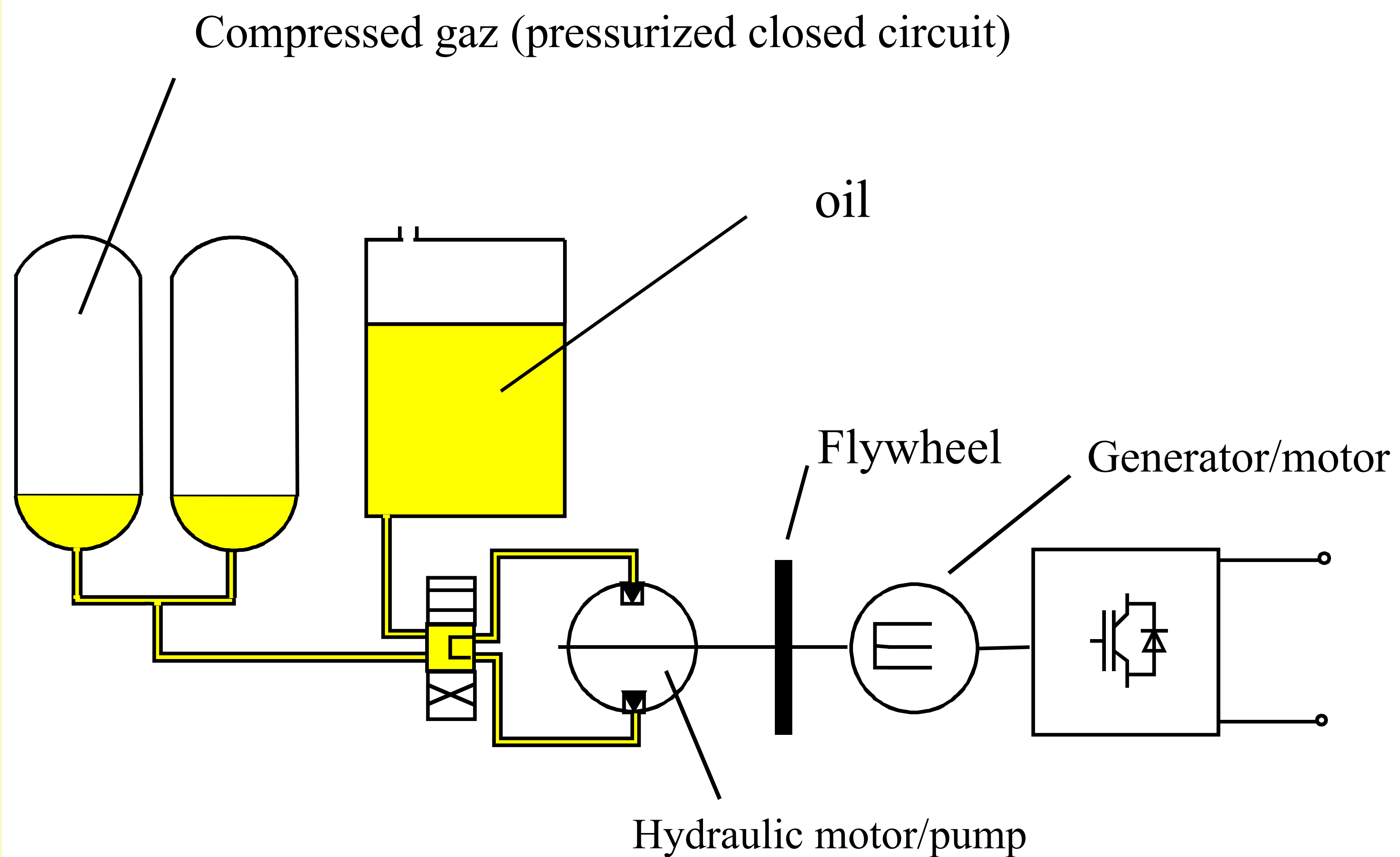
Injection of oil in a pre-pressurized vessel (Nitrogen)

Advantages: No thermodynamic problems because of quasi-isothermal operation

Drawback: requests a large volume because of the needed oil reservoir

Challenges: High efficiency by low load
- Power-electronics
- Control
- Additional storage

BOP System (Batterie Oléohydraulique et Pneumatique) « liquid piston »



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Small CAES

A much higher efficiency with hydraulic machines

2: The "interface system"

Injection of external air in a pre-pressurized vessel via a reciprocating hydro-pneumatic interface

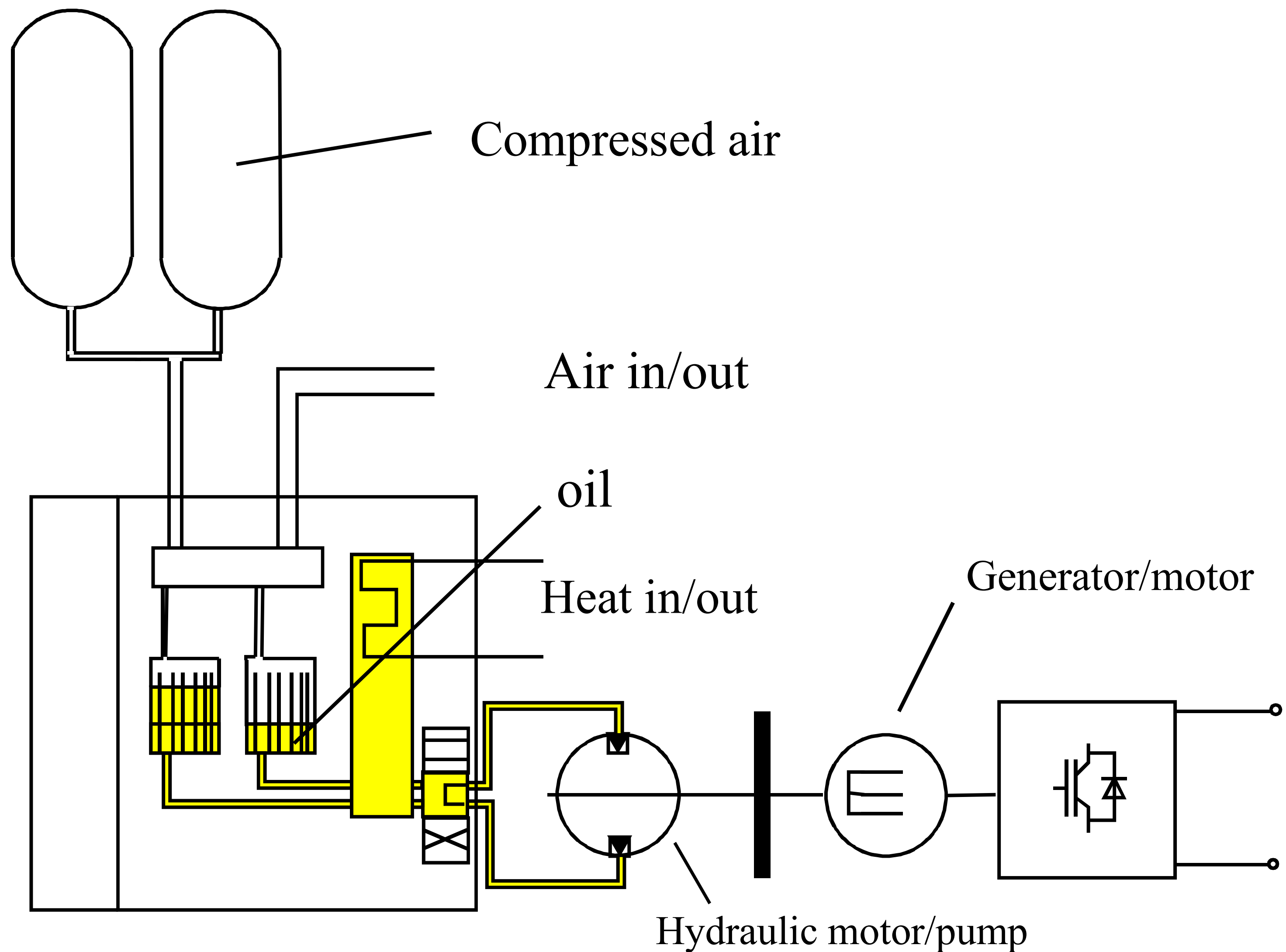
Advantages: Low oil volume requested, "only air" in the vessel

Drawback: Respect of thermodynamic conditions inside of the interface

Challenges: Thermodynamic exchangers inside of the interface, High efficiency by low load

- Power-electronics
- Control
- Additional storage

BOP System with reiprocating interface



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Conclusions

- Rural Electrification and Decentralized Generation need both sustainable storage technologies
- Electrochemical solutions for energy storage are often not acceptable and not sustainable (economically, environmentally)
- Alternative solutions can compete, based on reversible phenomena from physics
- What are the synergies between classical and mature (but cheap) hydropneumatics and modern power-electronics and control ?
- Can they be made « economically » compatible with the market (What market) ?
- They are « long term » devices, easy to recycle, also reparable.