Key Developments for Supercapacitive Energy Storage : Power Electronic Converters, Systems and Control

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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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  - Adapting the voltage-level with transformers
  - Increasing efficiency with ZVT/ZCS Technology
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- Smoothed energy distribution for electric bus transportation
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  - Principle
  - Power requirements
- Conclusion

Introduction

- **Supercapacitors :**
  - **for energy storage**
  - **smoothing of strong and short time power solicitations**

Classical Electrolytic Capacitor
100’000 µF / 16V
E = 12.8J

ECDL Supercapacitor
800F / 2.5V
E = 2500J

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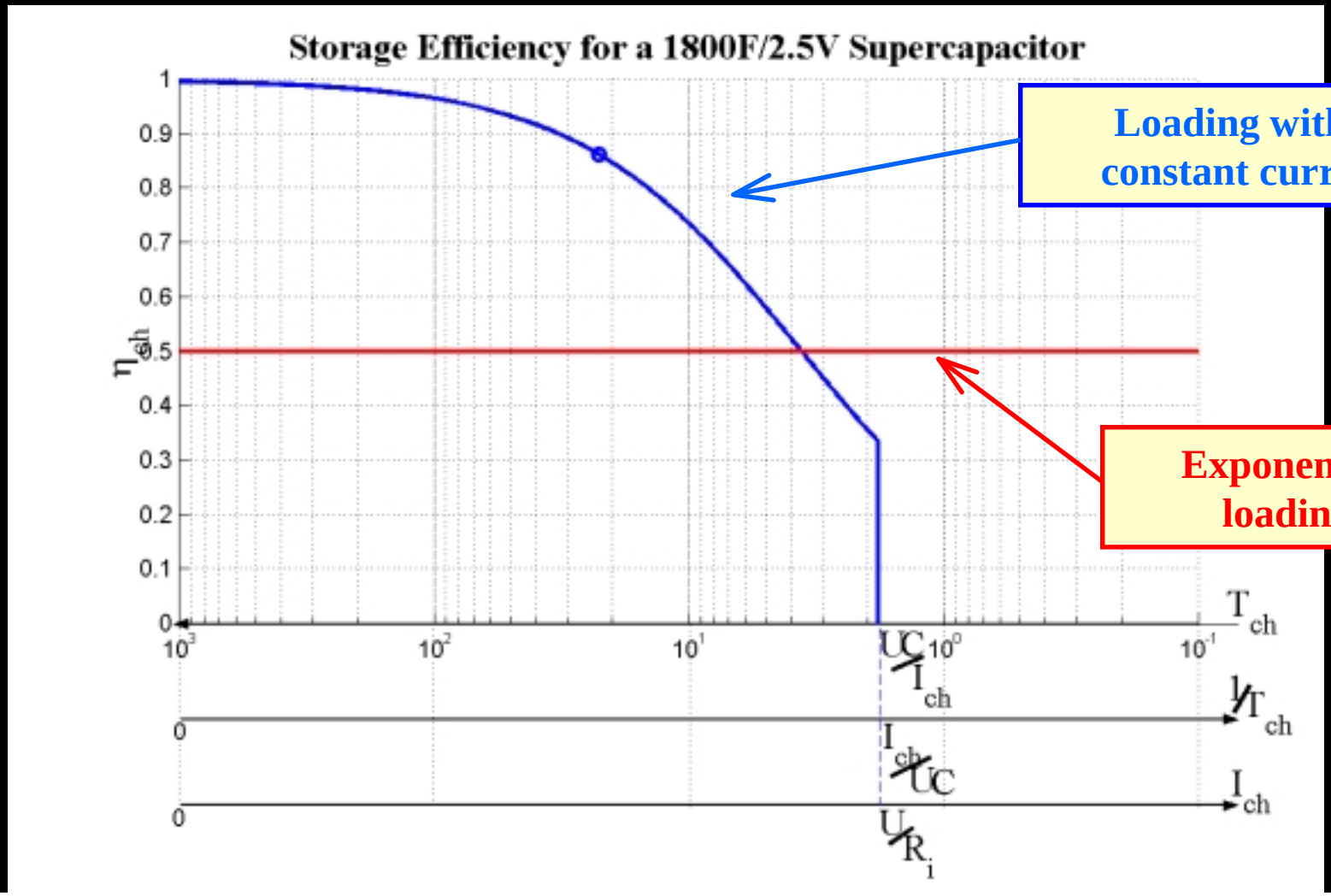
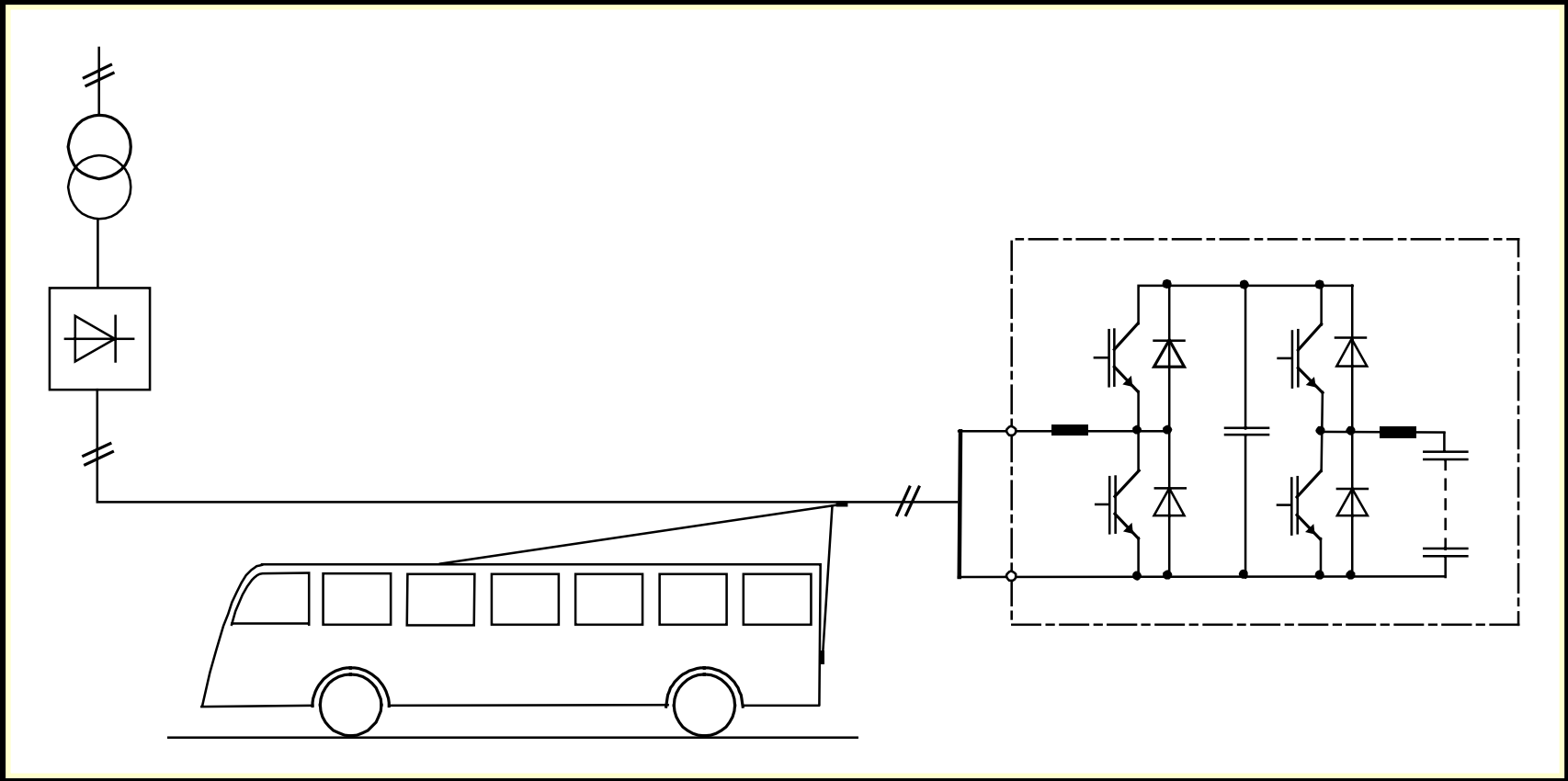
Introduction

- **The correct C-storage strategy :**



Voltage drop compensation for weak distribution of energy

- **Principle : example of trolley-busses**



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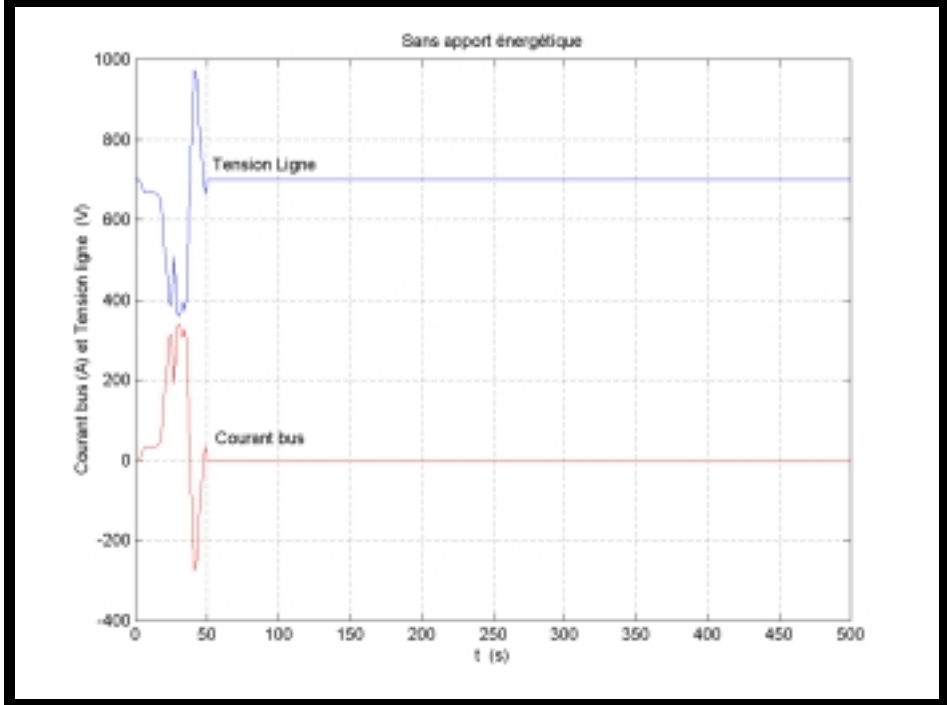
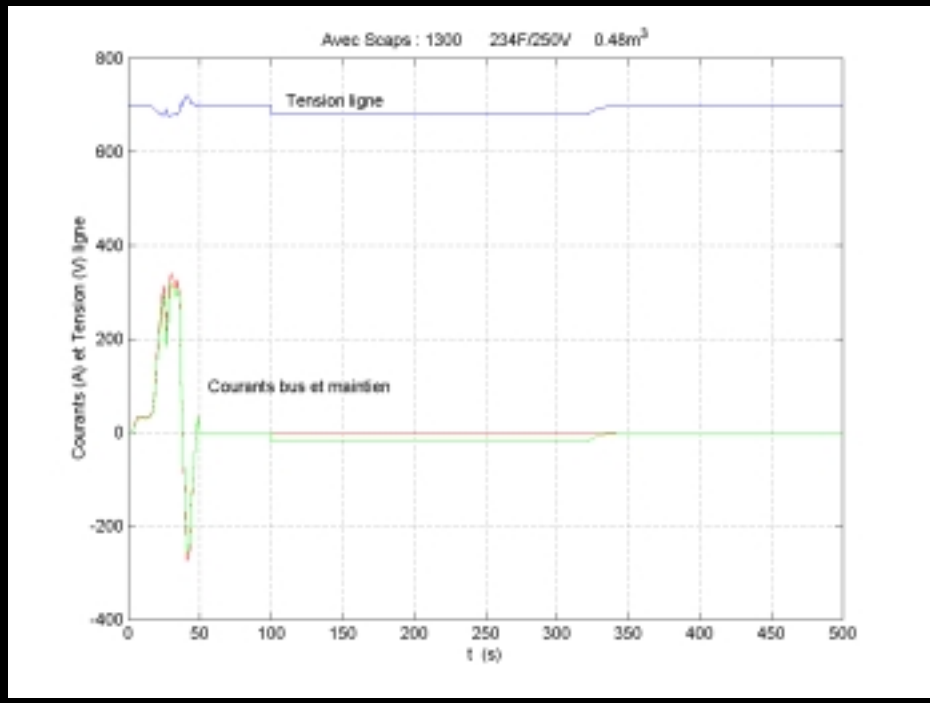
Voltage drop compensation for weak distribution of energy

- **Principle : Start of the bus with/without compensation**



Start without compensation

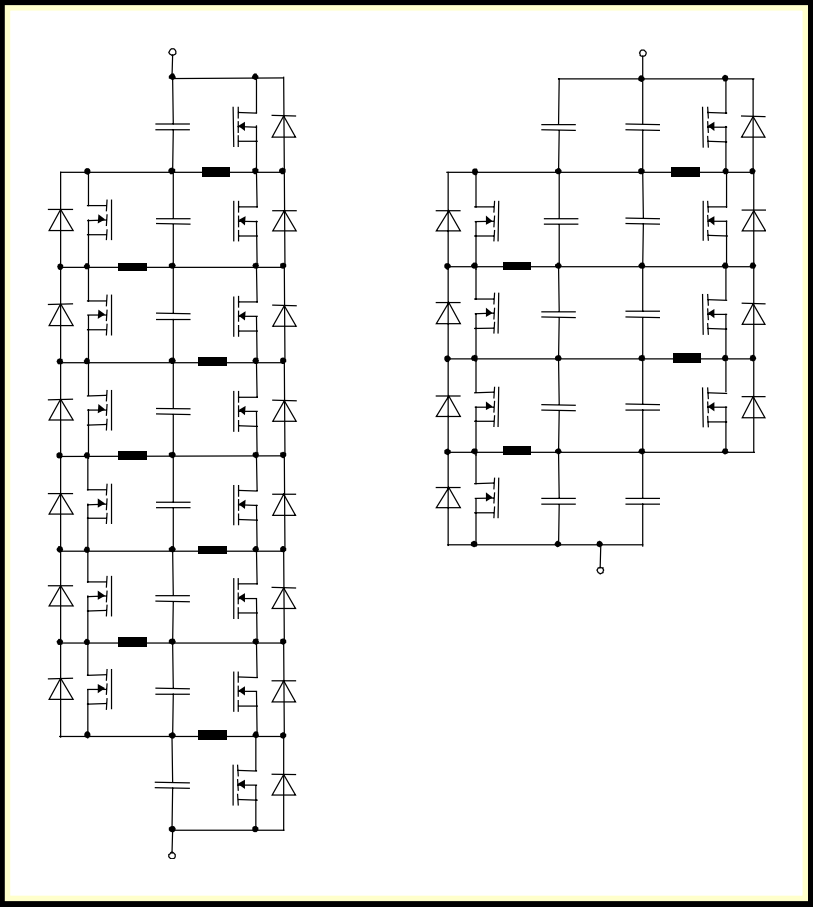


Start with active DC-compensator

Voltage drop compensation for weak distribution of energy

- **Organising the series/parallel connections of the cells :**
  - **Topologies of storage tanks with <u>active voltage equalising</u> (leiwww.epfl.ch /Publications/2000)**

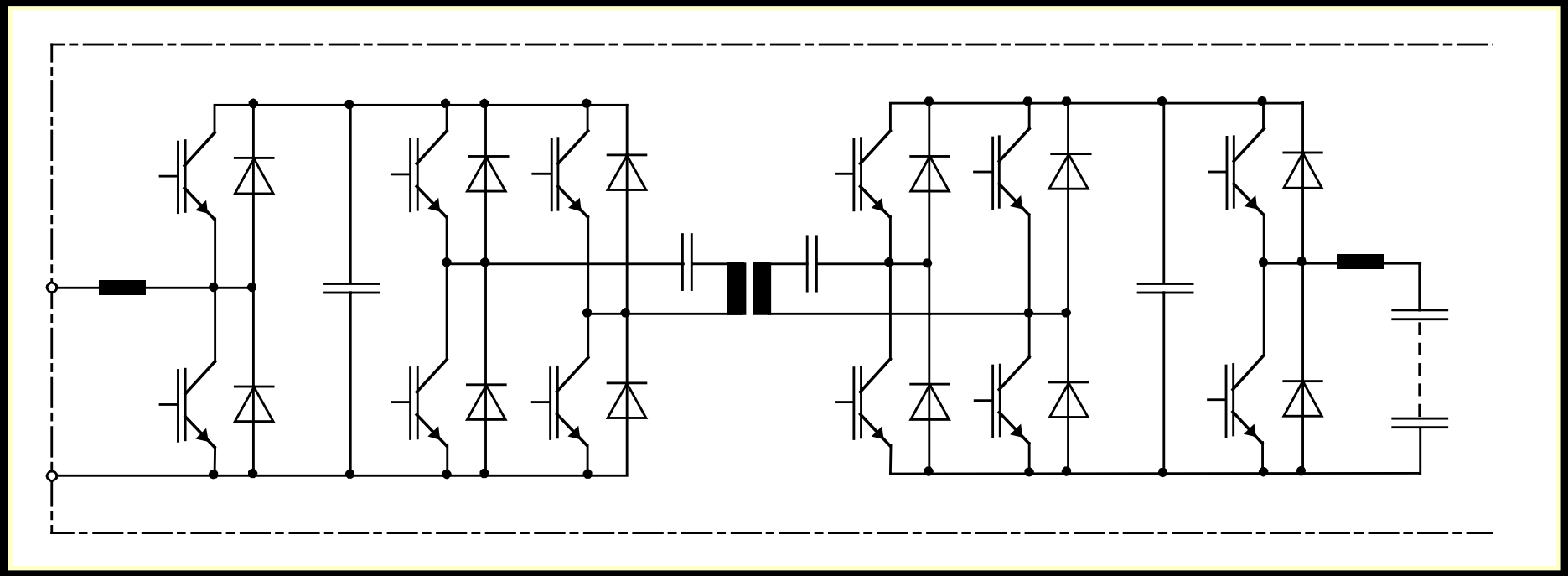
Series organisation



Series/parallel organisation

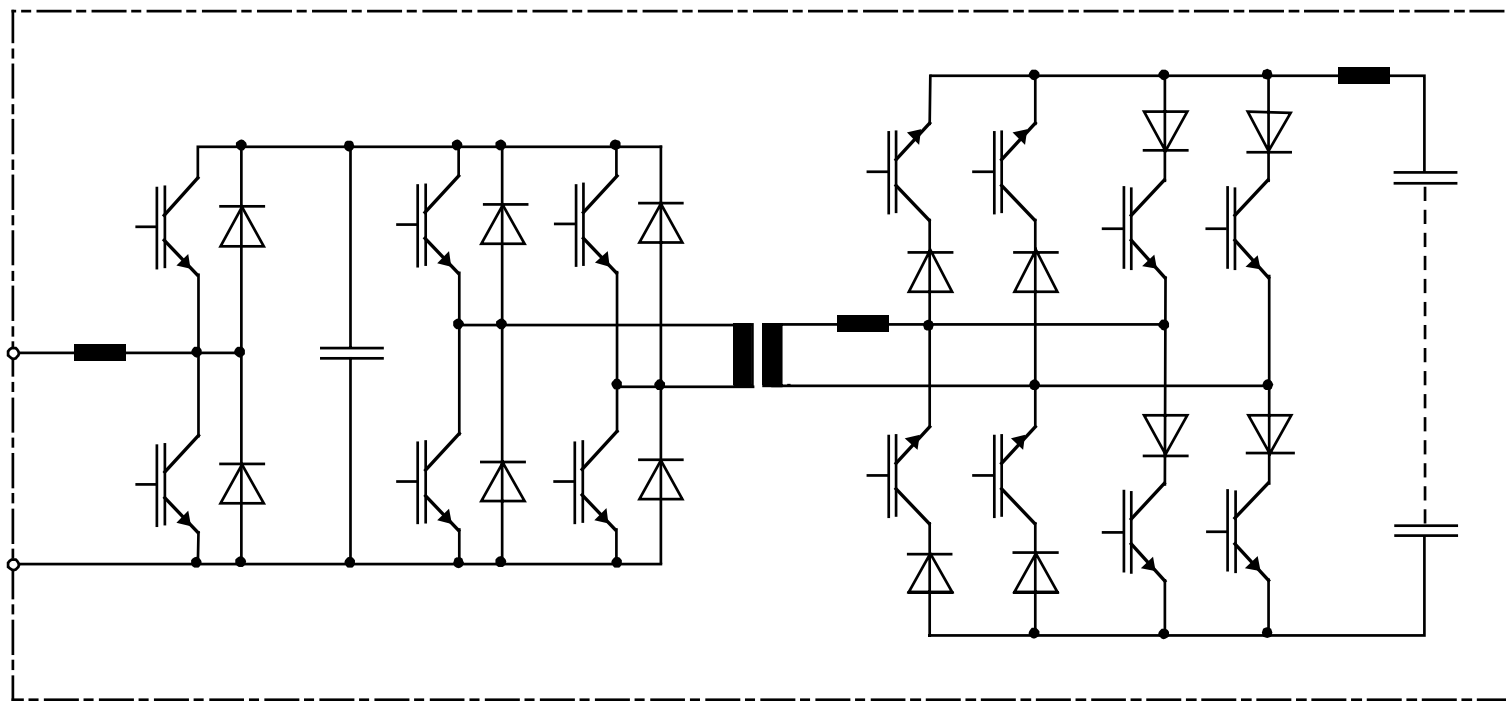
Voltage drop compensation for weak distribution of energy

- **Adapting the voltage-level with transformers**
  - **Voltage adaptation with an intermediary AC-link with MF-transformer**
  - **topology with resonant mode**



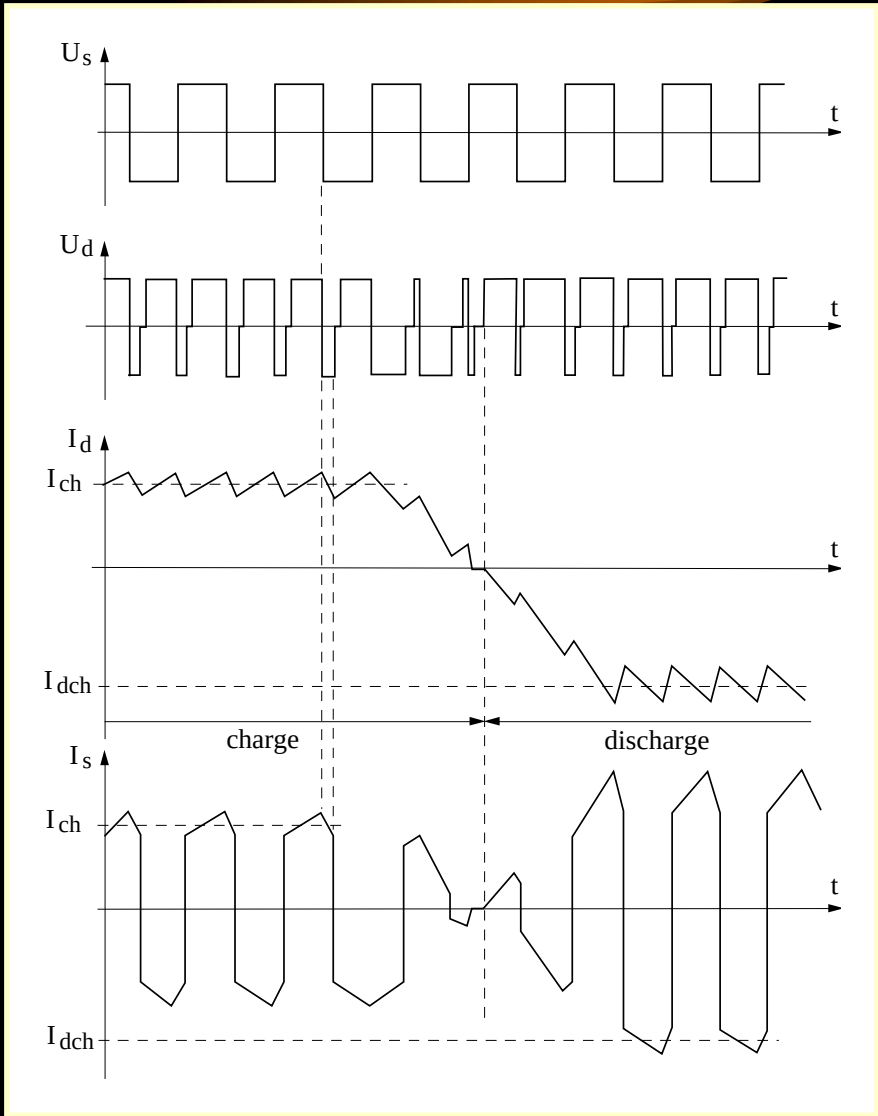
Voltage drop compensation for weak distribution of energy

- **Increasing efficiency with ZVT/ZCS Technology**
  - **Topology : MF-AC-link with ZVT/ZCS converters**



Voltage drop compensation for weak distribution of energy

- **Increasing efficiency with ZVT/ZCS Technology**
  - **Modern soft-commutated converters with AC link at medium frequency**



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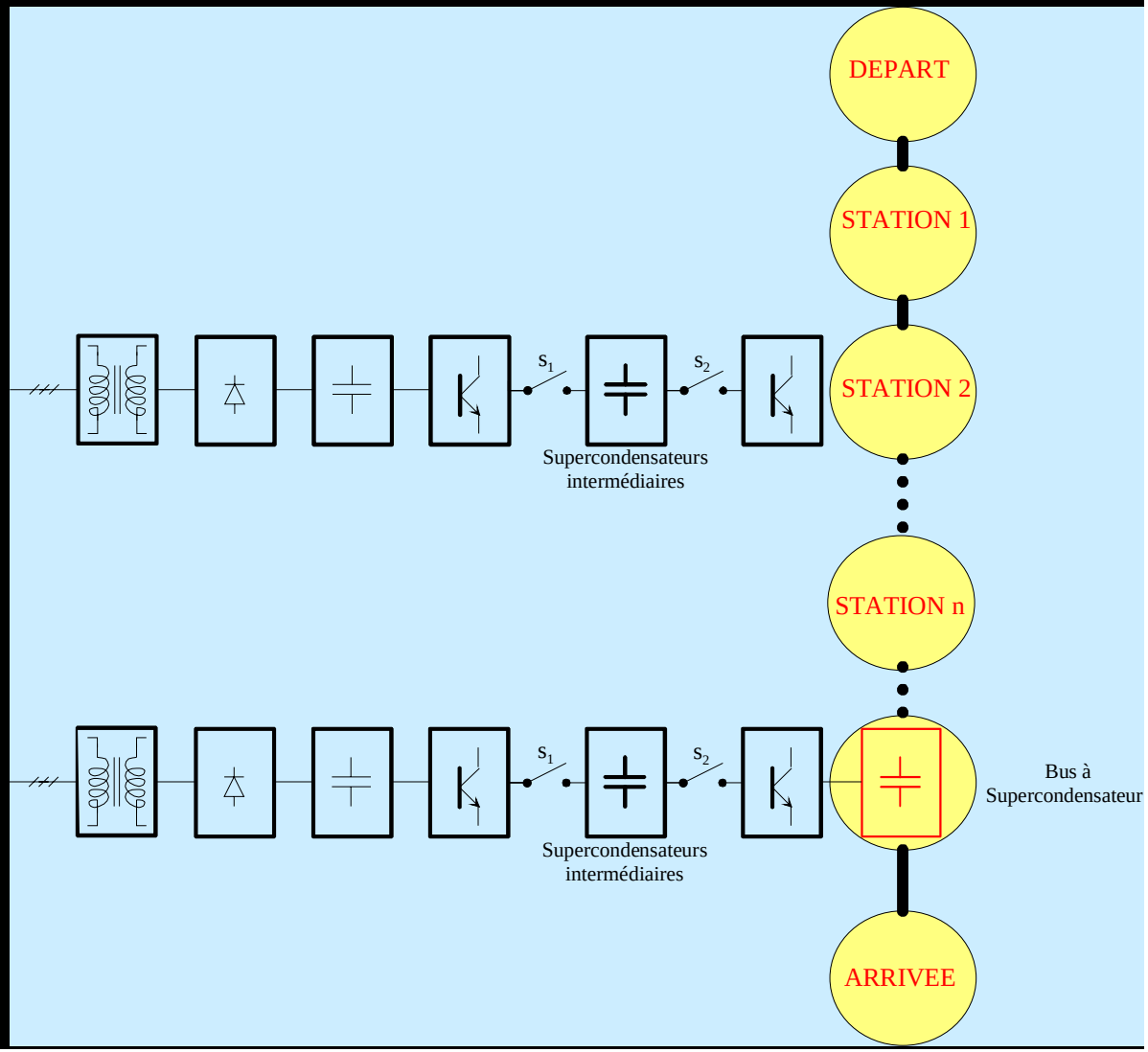
Smoothed energy distribution for electric bus transportation

Principle :

when loading the mobile supercapacitors, the energy is taken from fix supercapacitors

to prepare the coming of the next bus, the fix supercapacitors have to be re-loaded :

- 10mn instead of 20s
- the power absorbed on the network is low



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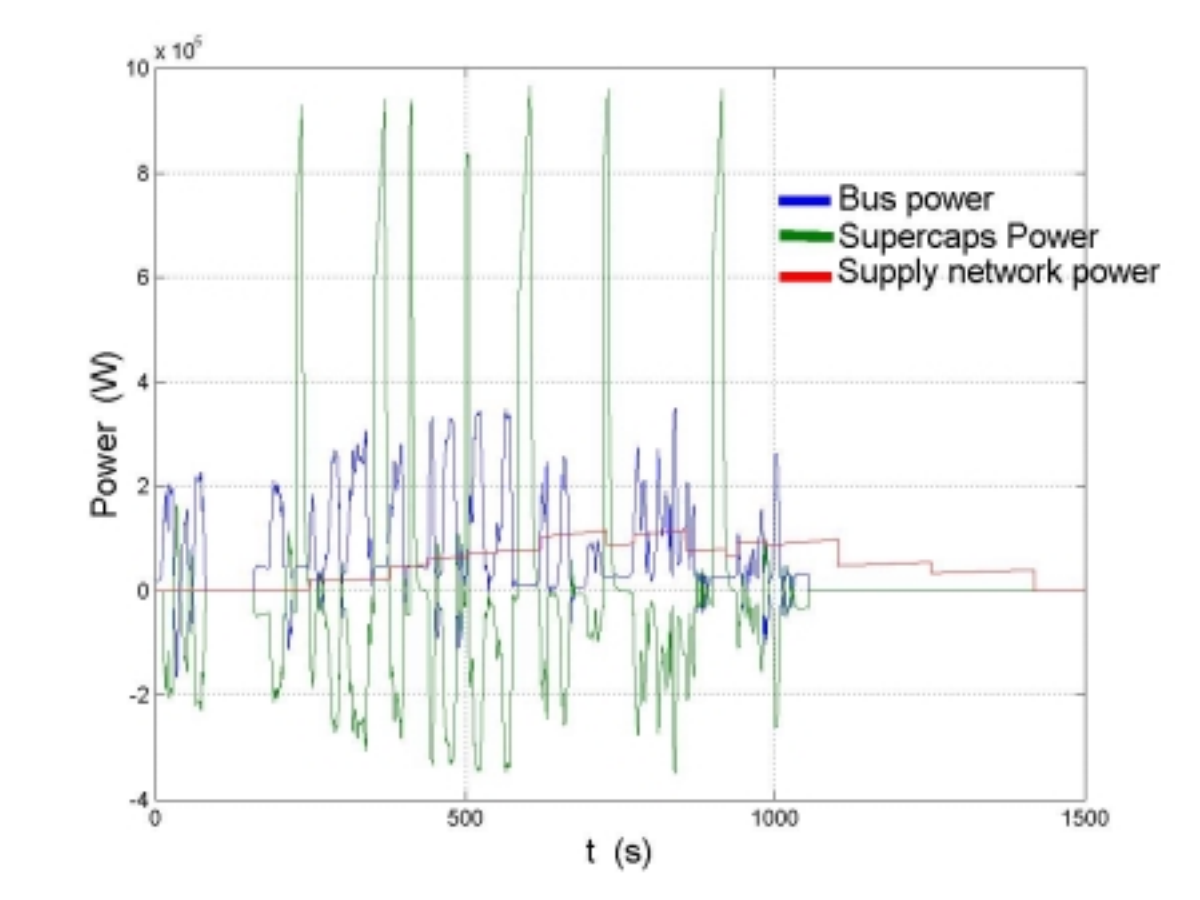
Smoothed energy distribution for electric bus transportation

- **Principle : minimising constraints on a power supply**
  - **The power provided by the network is the sum of the low power absorbed by each loading station**
  - **The power provided by the network is the real mean power needed by the bus**
  - **The power provided by the network is less than 100kW**



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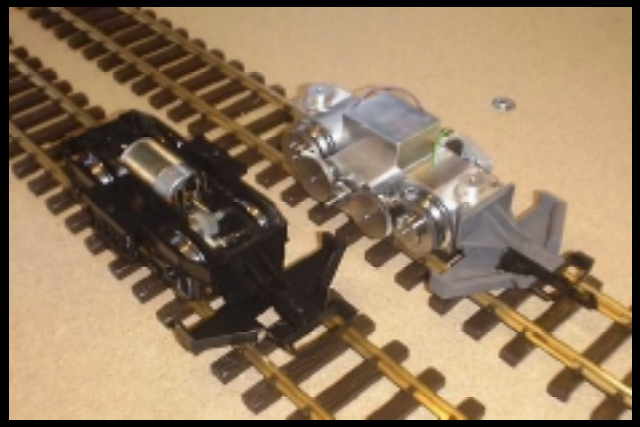
Smoothed energy distribution for electric bus transportation

- **Principle :**
  - **prototype for experimental validation**



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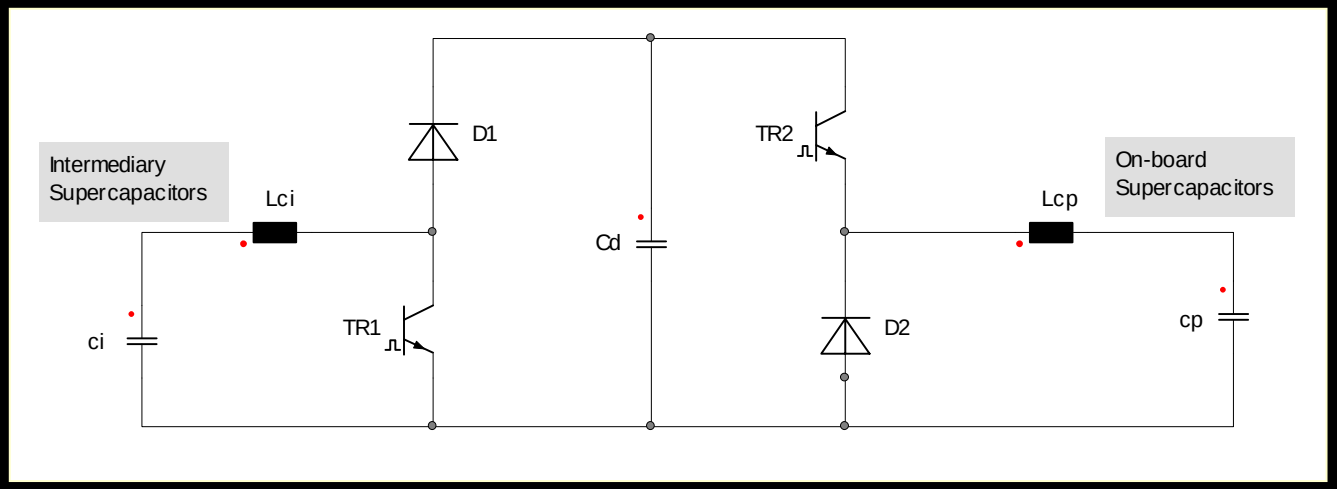
Smoothed energy distribution for electric bus transportation

- **Fast energy exchange between supercapacitive tanks :**



  - **Double stage power converter to limit the variations of the current provided/absorbed by the supercapacitors**
  - **Main design criteria :**
    - **the instantaneous power provided by the fix supercapacitors must correspond to the power absorbed by the on-board supercapacitors**
    - **The maximum exchange power is fixed by the stack which is able to provide/absorb the lowest power**

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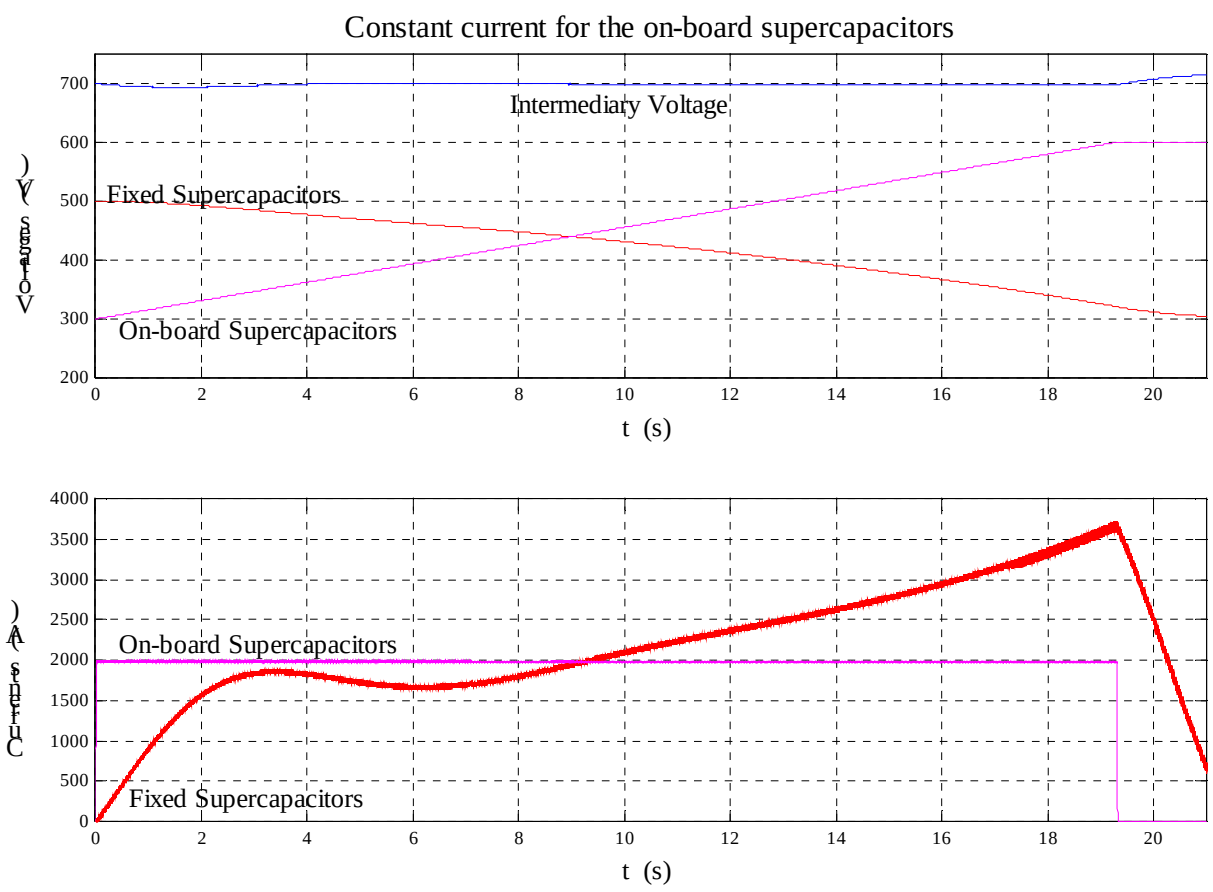
Smoothed energy distribution for electric bus transportation

- **Fast energy exchange between supercapacitive tanks :**
  - **Constant current for the on-board supercapacitors**



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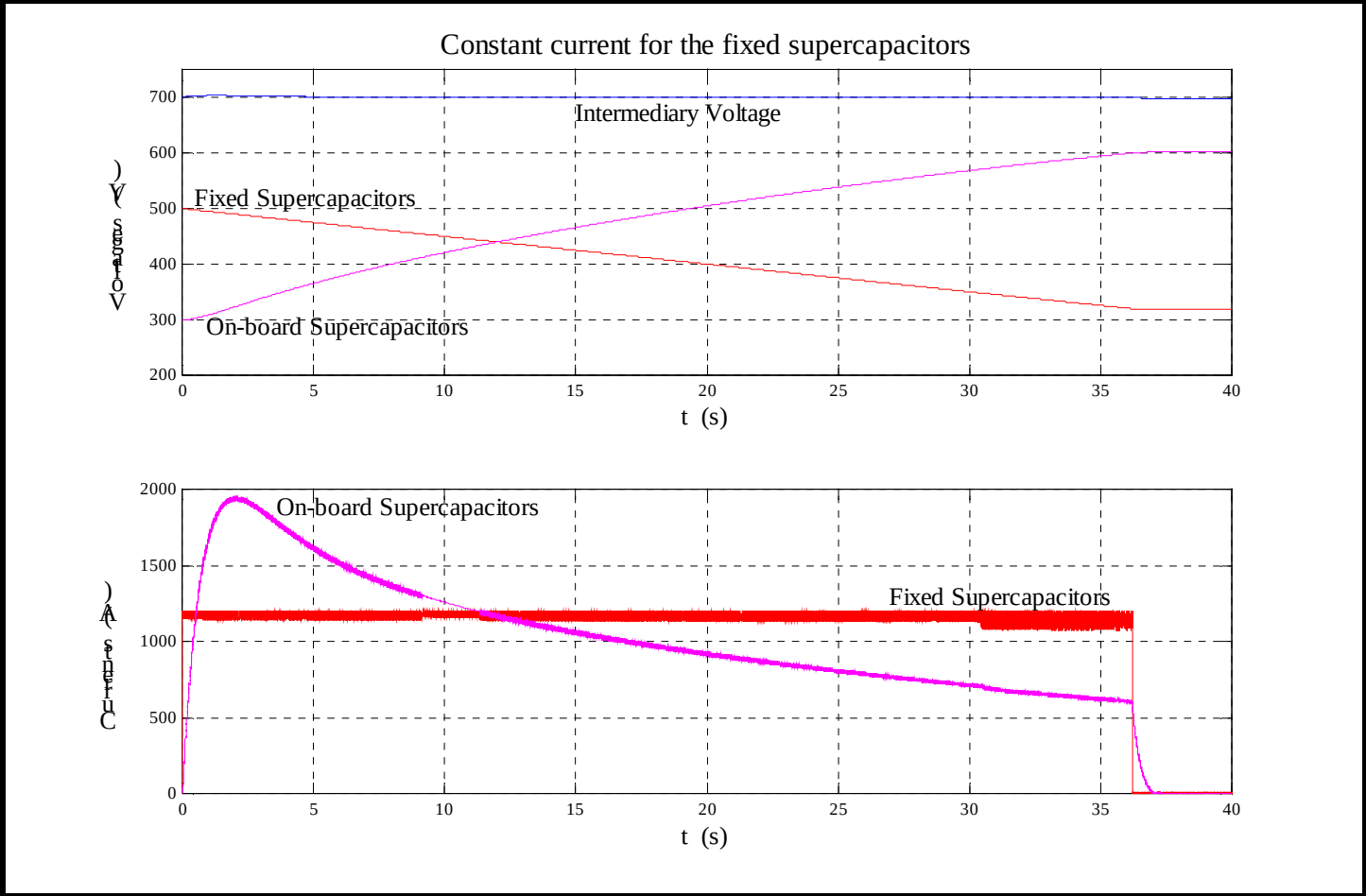
Smoothed energy distribution for electric bus transportation

- **Fast energy exchange between supercapacitive tanks :**
  - **Constant current for the fixed supercapacitors**



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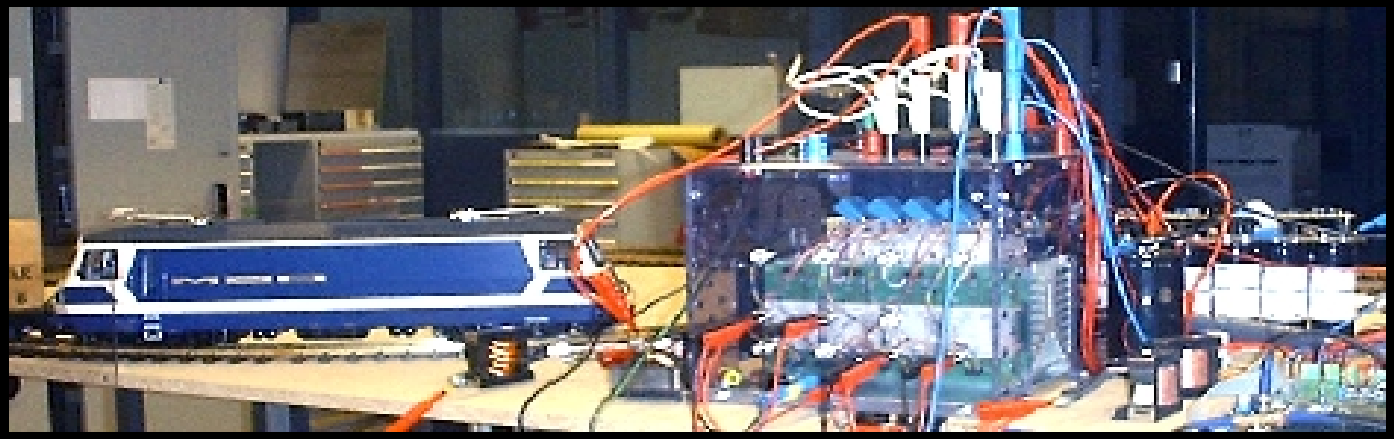
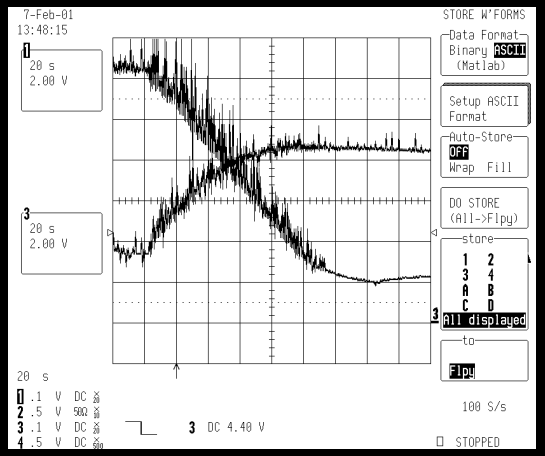
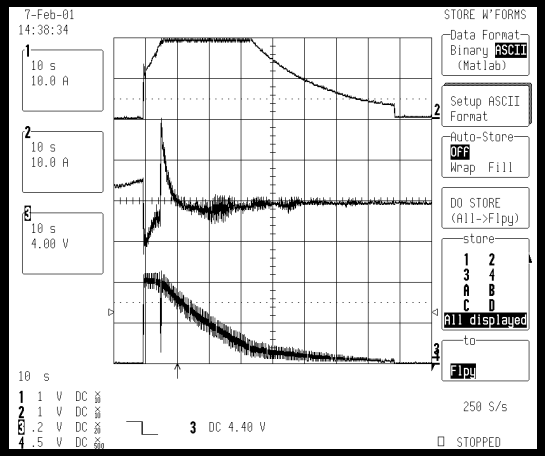
Smoothed energy distribution for electric bus transportation

- **Fast energy exchange between supercapacitive tanks :**







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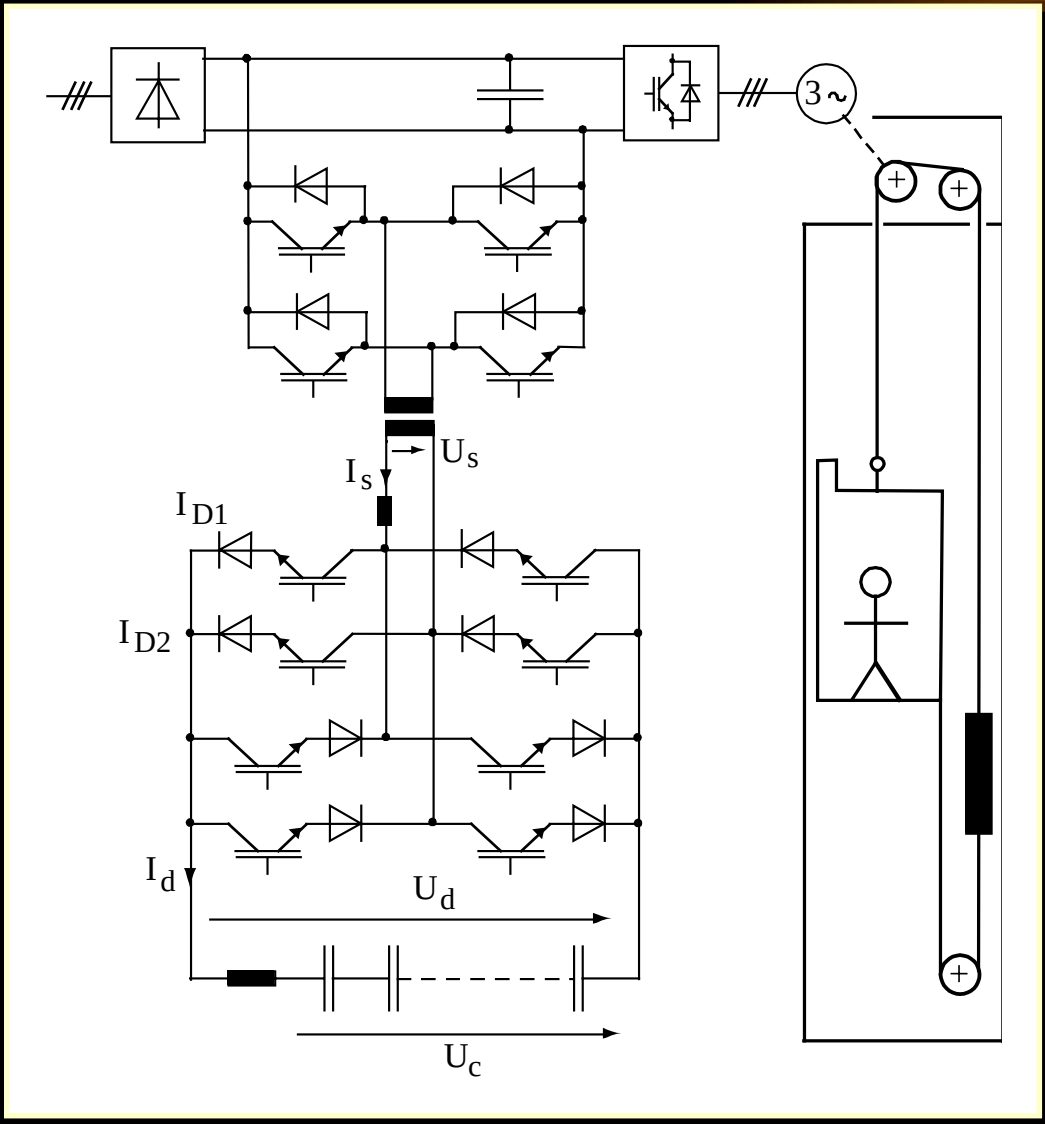
Load-equalising for elevators

- **Principle**



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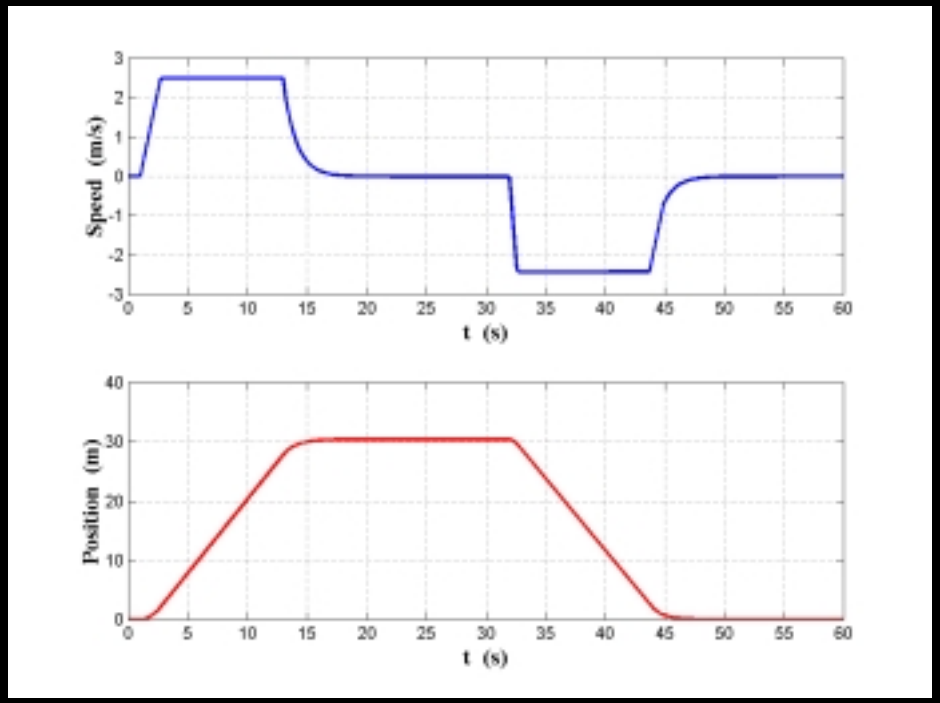
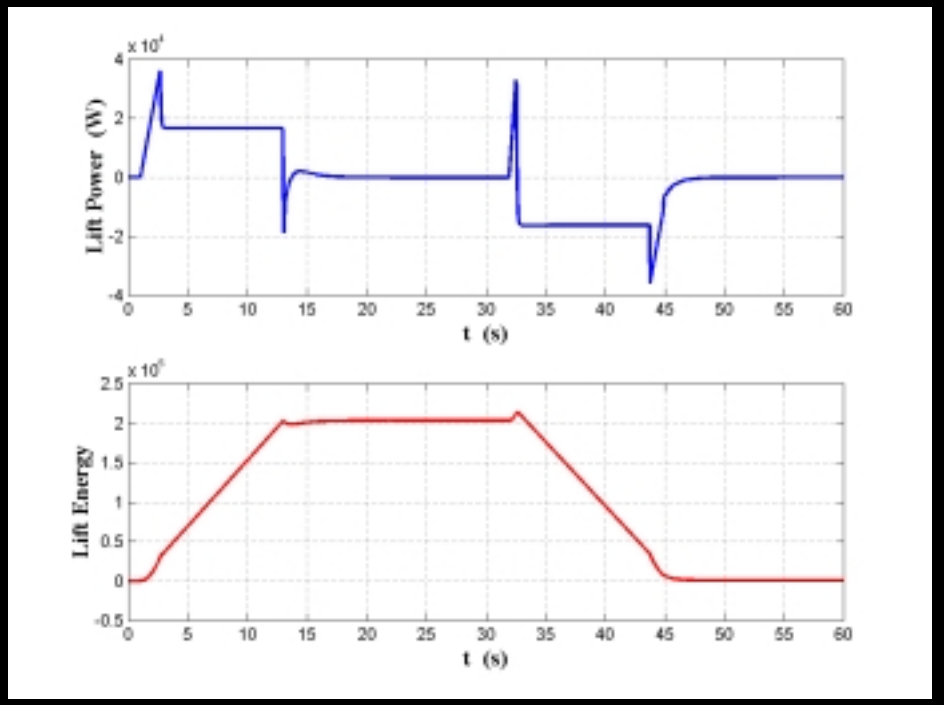
Load-equalising for elevators

- **Example : simulations regarding a real system**
  - **car weight : 720kg, counter weight : 1440kg, load : 1400kg**

Speed, Position for a 10-floors up/down run



Power and Energy for a 10-floors up/down run



The needed energy is 220kJ (61Wh)

Load-equalising for elevators

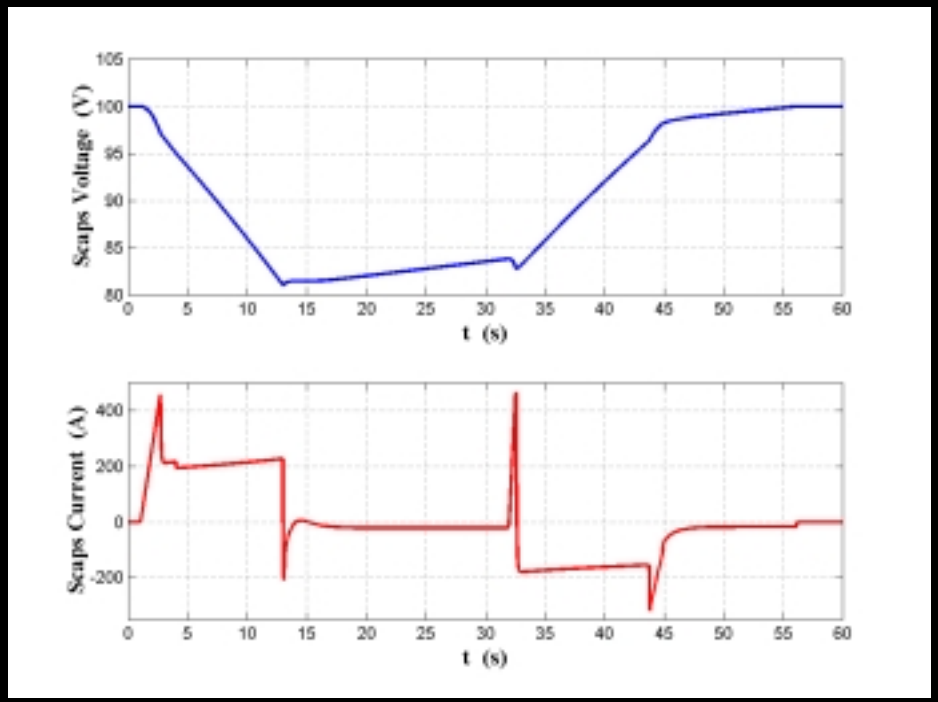
- **Example : simulations regarding a real system**
  - **Number of needed supercapacitors (theoretical) :**
    - **77 Scaps 1800F/2.5V**
    - **Energy available : 220kJ (61Wh) if the voltage is kept over 70% of the maximum**
    - **Total stored energy : 433kJ (120Wh)**
  - **For practical reasons :**
    - **120 Scaps 1800F/2.5V are chosen (55% more than needed)**
      - **⇒ to avoid any over-value for the Scaps current**
      - **⇒ to offer versatility in the energy management of the system**
    - **Available energy : 330kJ (92Wh) if the voltage is kept over 70% of the maximum**
    - **Total stored energy : 675kJ (187Wh) Ctot = 135 F /100 V**

Final choice : 3x40 series connected Scaps (1800F/2.5V) (48kg, 45l)

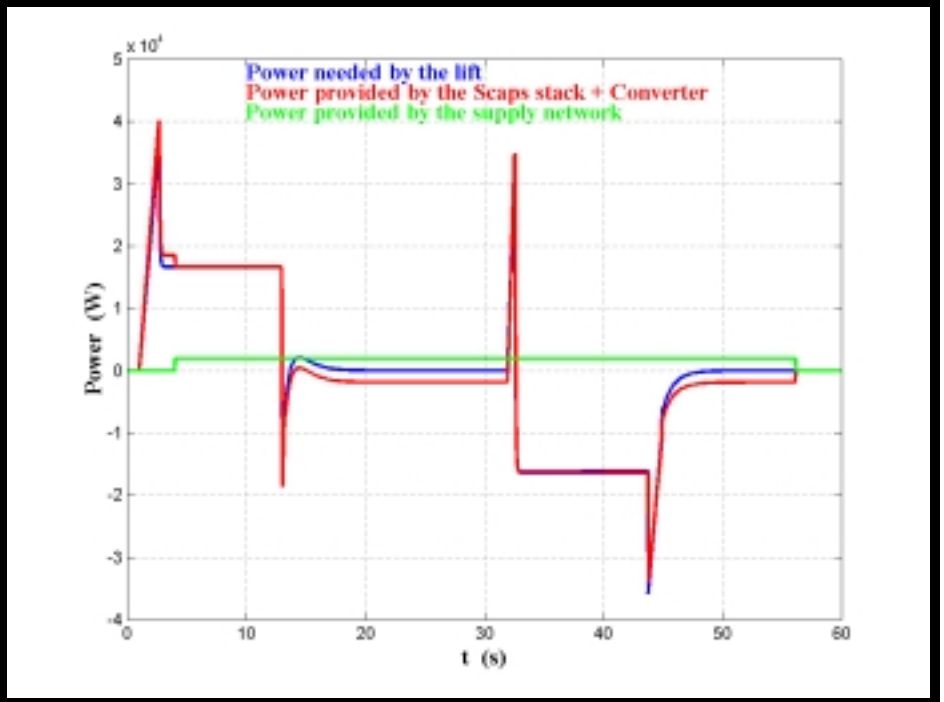
Load-equalising for elevators

- **Example : simulations regarding a real system**
  - **The power provided by the network has to compensate the losses of the lift drive**

Scaps voltage/current (10-floors up/down run)



Powers for a 10-floors up/down run



Conclusions

- **Supercapacitors appear as new and powerful components**
- **Typical applications with typical requirements (non constant voltage) :**
  - **special development and optimal design :**
    - **for the associated power electronics converter**
    - **for the design of the storage tanks**
- **Supercapacitors are able to be used**
  - **as energy sources for storage**
  - **as energy buffers in case of strong fluctuations and peak power demand**
- **Supercapacitors enable the development of many new feeding concepts, understanding separately the notion of "energy" and "power"**