Power Smoothing and High-Power Fast Energy Exchange Between Storage Systems

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- Sequential distribution with double storage : “ le biberonnage”
  - Minimising the constraints on a power supply
  - Constraints on a power supply
  - Fast energy exchange
- Conclusion

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Supercapacitors as new energy storage components

- **Generalities :**

Supercapacitors are electrochemical double layer capacitors :

- **high energy storage density (but 10 times lower than batteries)**

  200F -- 2400F (compared to the classical 10000mF)

- **High instantaneous power (higher than batteries)**

The main parameters of supercapacitors are :

- **capacitance (200F ® 2400F)**
- **series resistor (limitation loading/unloading current)**
- **Maximum voltage : 2.5V**

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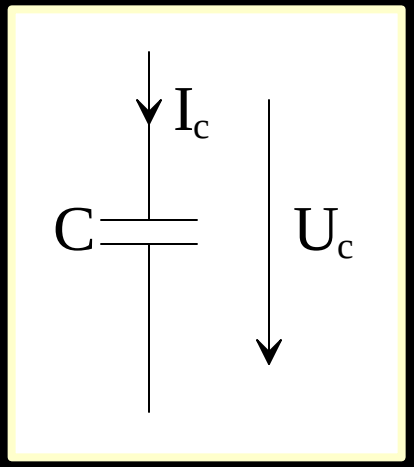
Supercapacitors as new energy storage components

- **Generalities :**



- **Fundamental relationship :**

$$I_c = C\frac{dU_c}{dt}$$

- **Energy storage :**

$$\varepsilon_c = \frac{1}{2}CU_c^{\,2}$$

The main properties of supercapacitors are :

- **the amount of the stored energy is bound to the square of its voltage**
- **a fast loading or unloading process needs a high current**
- **the loading and the unloading can be done with a high instantaneous power**

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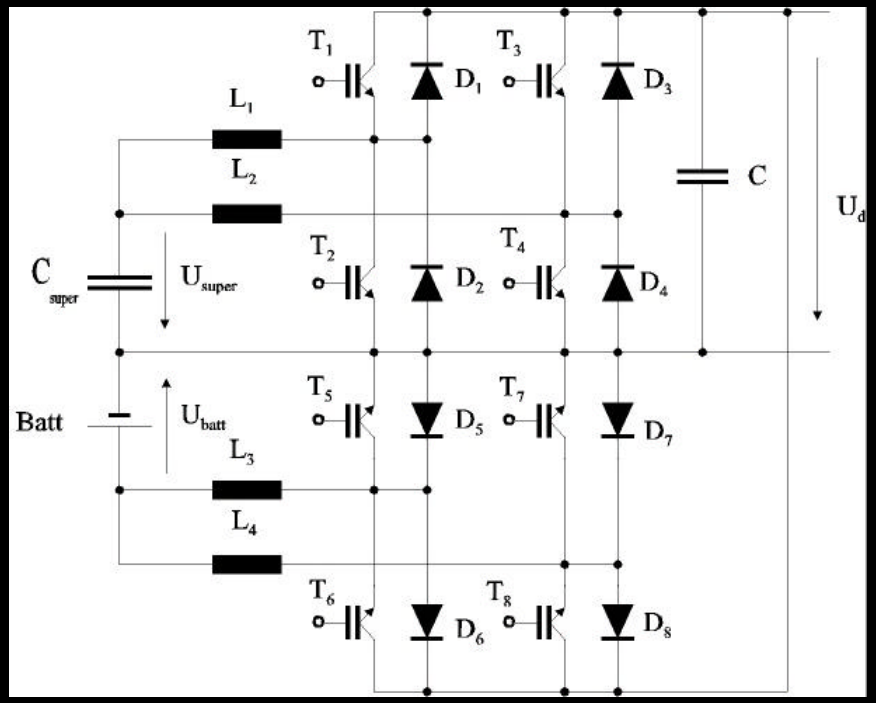
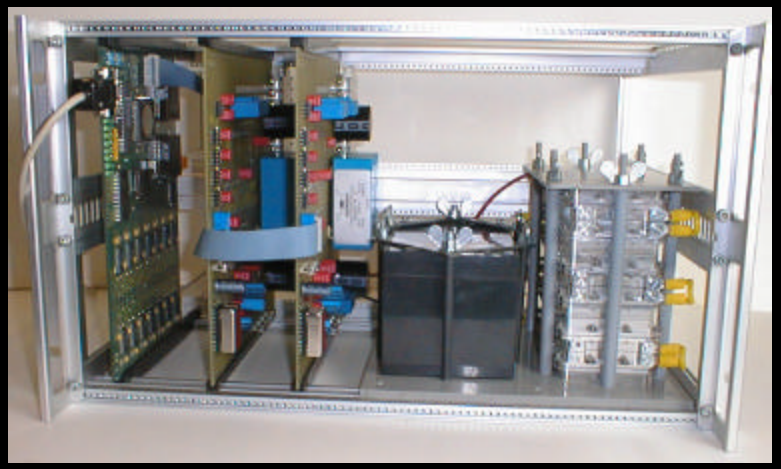
Supercapacitors as new energy storage components

- **Supercapacitors used as a complementary energy storage devices**

Idea : to use supercapacitors each time an energy source is not able to give the instantaneous power needed by a load :



- **batteries + supercapacitors**
- **fuel cells + supercapacitors**
- **...**



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Supercapacitors as new energy storage components

- **Supercapacitors used as main energy storage devices**
  - **First applications (small size supercapacitors)**
    - **IC memories**
    - **microcomputer**
    - **…**
  - **Large size supercapacitors**
    - **hand tools**
    - **telecommunications**
    - **medicinal domain (defibrillator, …)**
    - **UPS**
    - **Starting of engines**

Electric vehicle

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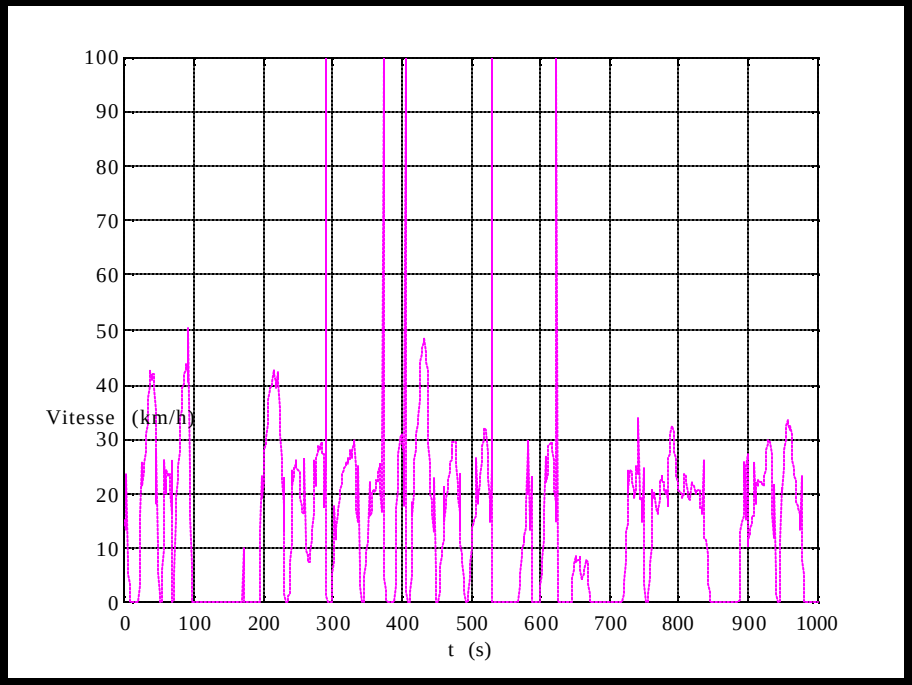
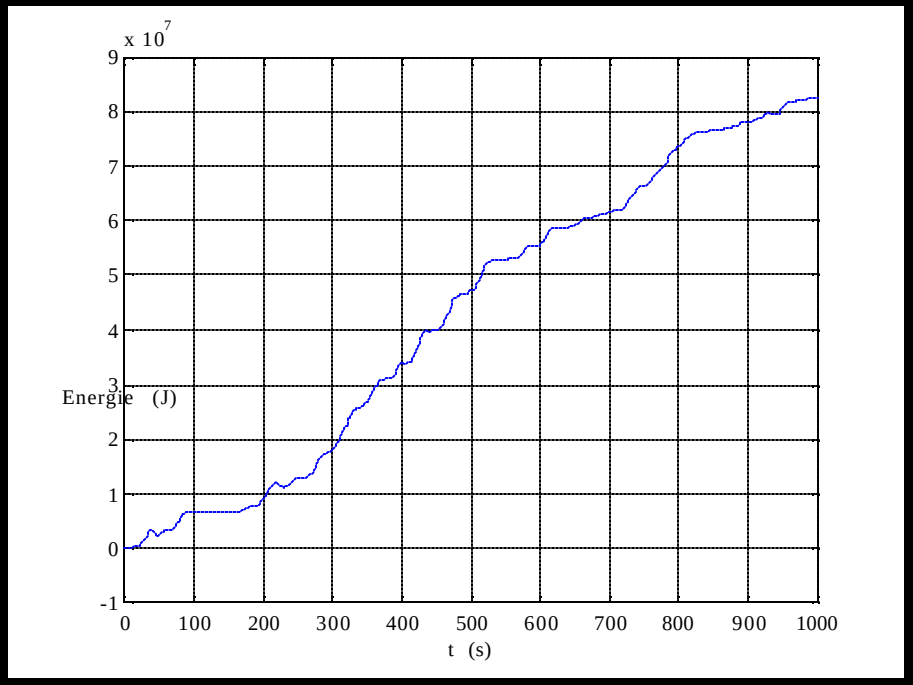
Powering a bus with supercapacitors

- **Supercapacitors used as main energy source**
  - **Are supercapacitors able to store enough energy for a powering a bus ?**





From “Bellerive” to “St François”
5km / 120m

The needed energy is 84MJ (23.3kWh)

19900 Scaps (1800F) / 7.46m^3 / 7.96T

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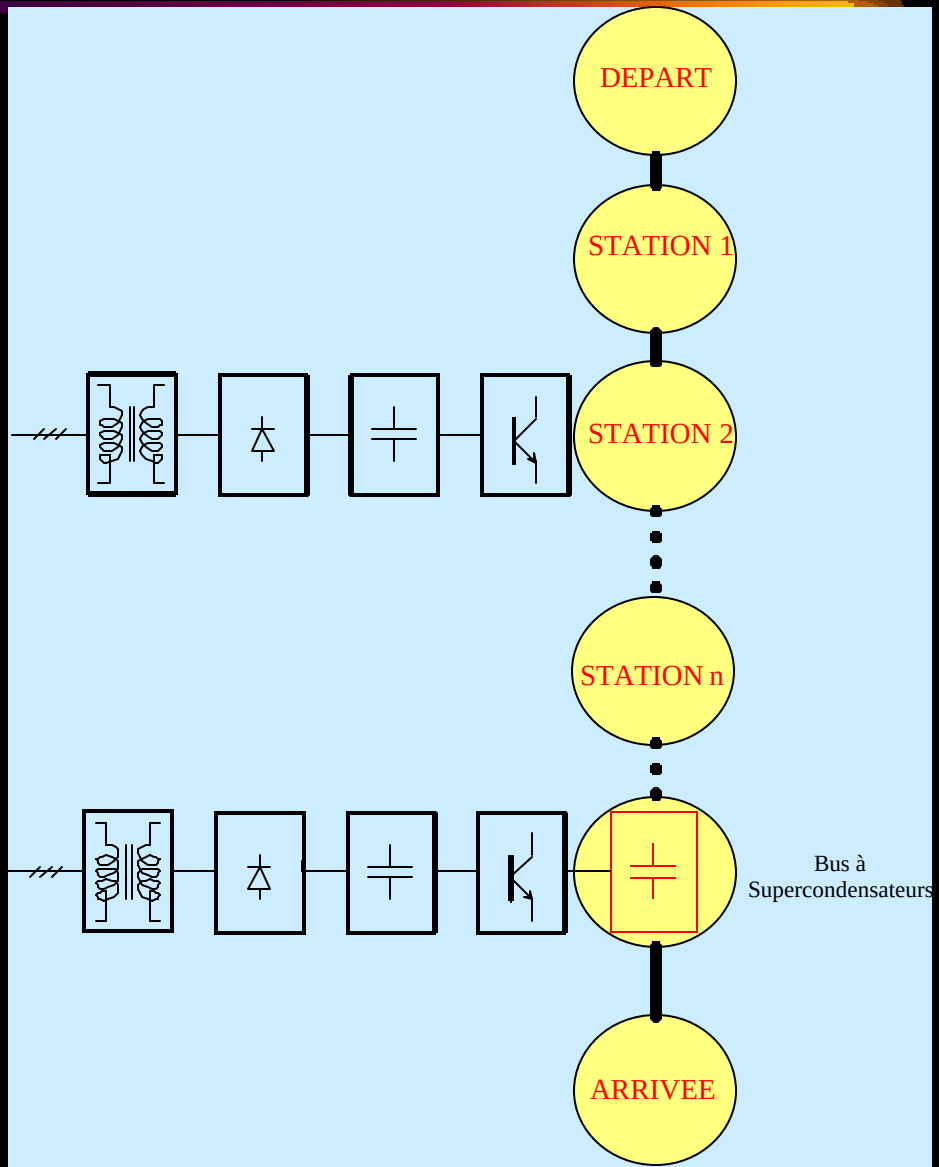
Powering a bus with supercapacitors

- **Supercapacitors used as main energy source**
  - **Supercapacitors are not able to store enough energy for a complete run**
  - **Some intermediary re-loading stages have to be defined**



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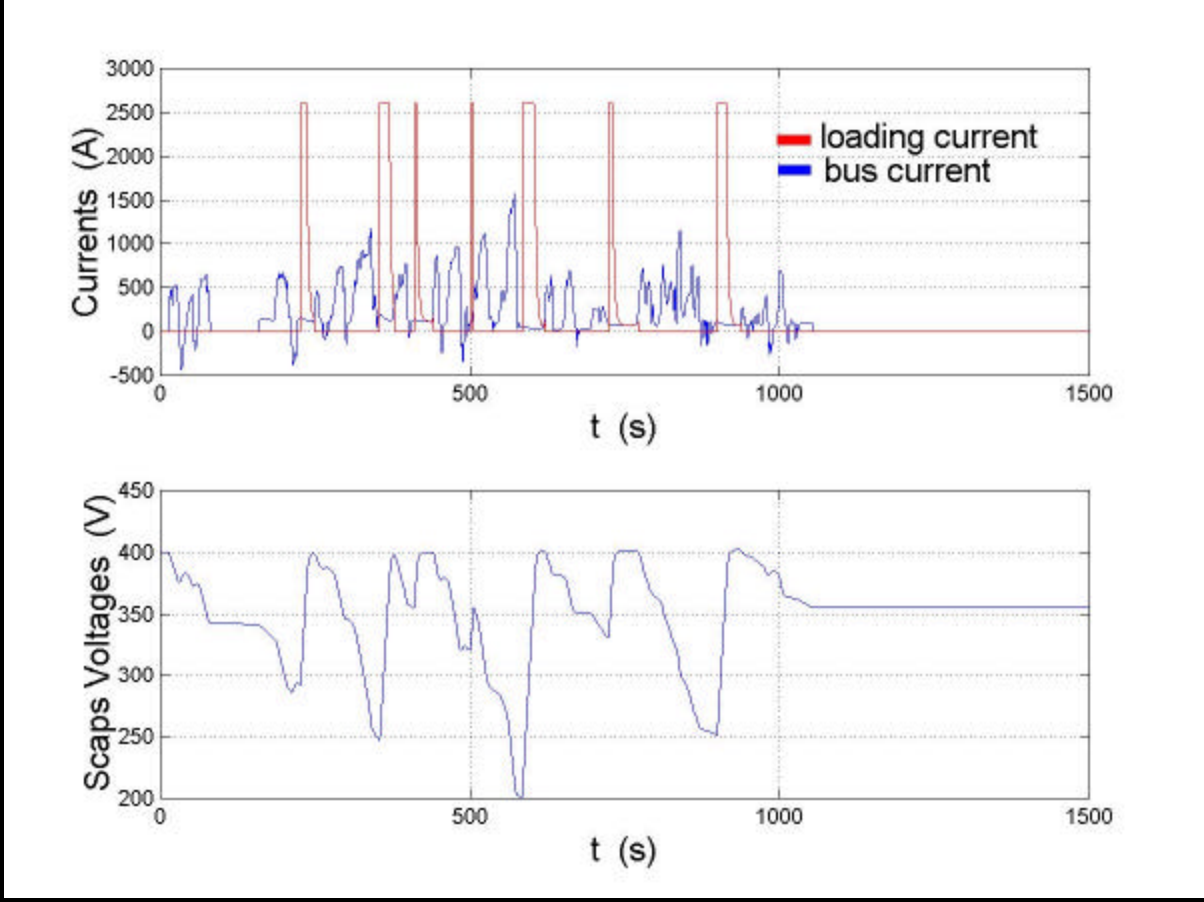
Powering a bus with supercapacitors

- **Supercapacitors used as main energy source :**
  - **7 loading stations**
  - **4160 supercapacitors 1800F/2.5V**
    - **26x160 series connected**
    - **total energy : 23.4MJ (6.5kWh)**
    - **operational energy : 17MJ (4.75kWh)**
    - **Time for loading : 20s**
    - **Current for loading : 2.6kA**
    - **1.6m³ / 1.7T**



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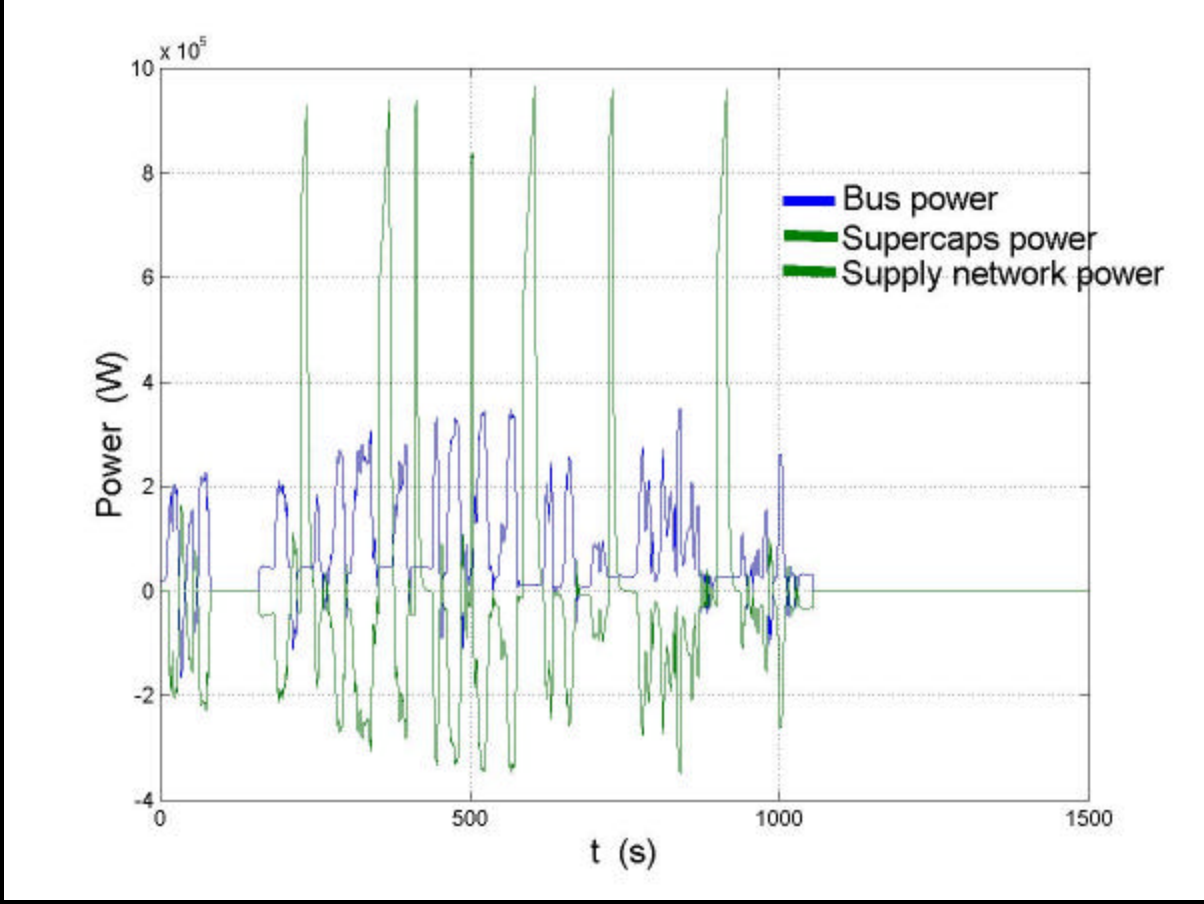
Powering a bus with supercapacitors

- **Constraints on the power supply network :**
  - **The power absorbed by the bus is the mirror of the power provided by the supercapacitors**
  - **The loading of the supercapacitors needs to absorb high magnitude power on the network :**
    - **1MW x 7 times x 20s**



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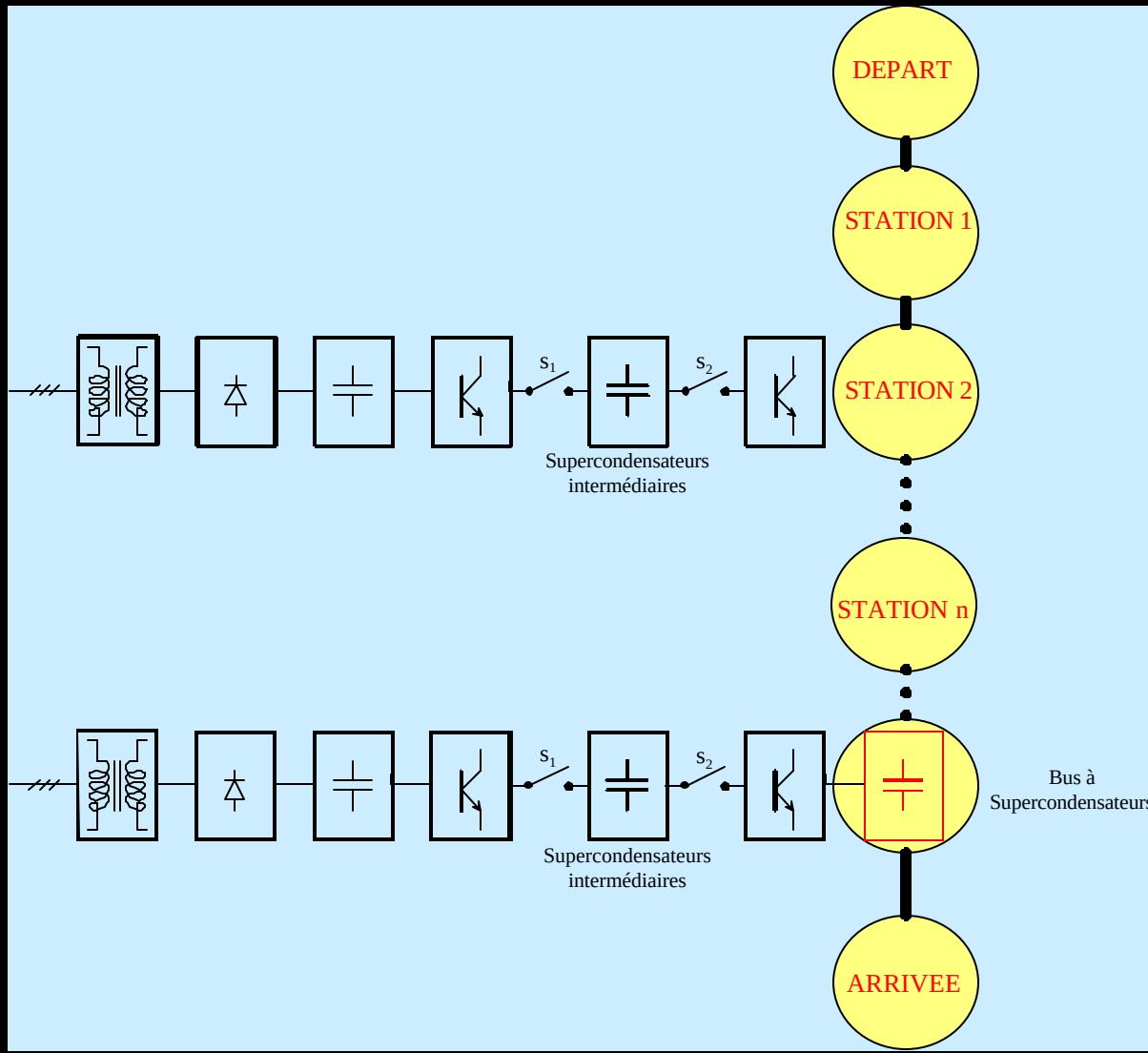
Sequential distribution with double storage (le biberonnage)

- **Minimising constraints on the power supply :**
  - **when loading the main supercapacitors, the energy is taken on 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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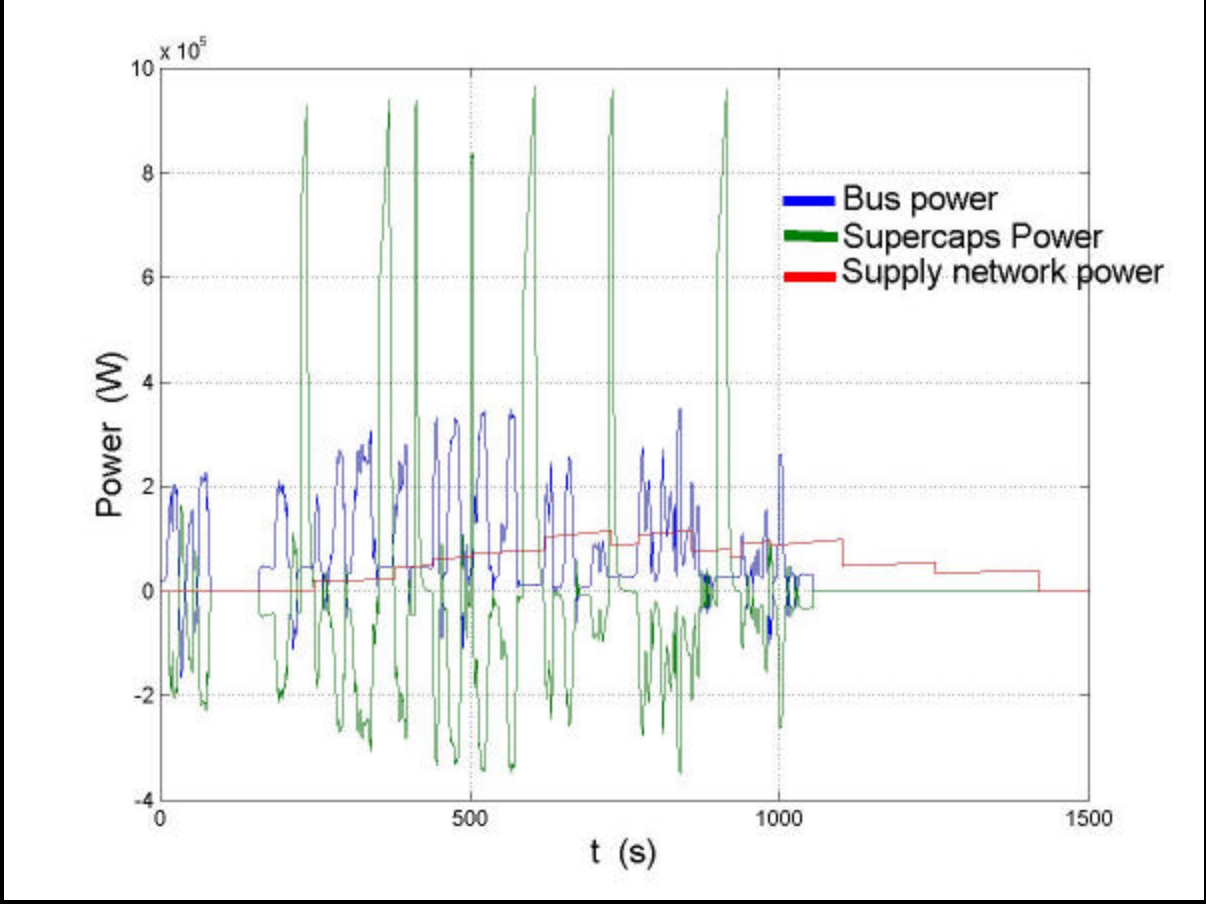
Sequential distribution with double storage (le biberonnage)

- **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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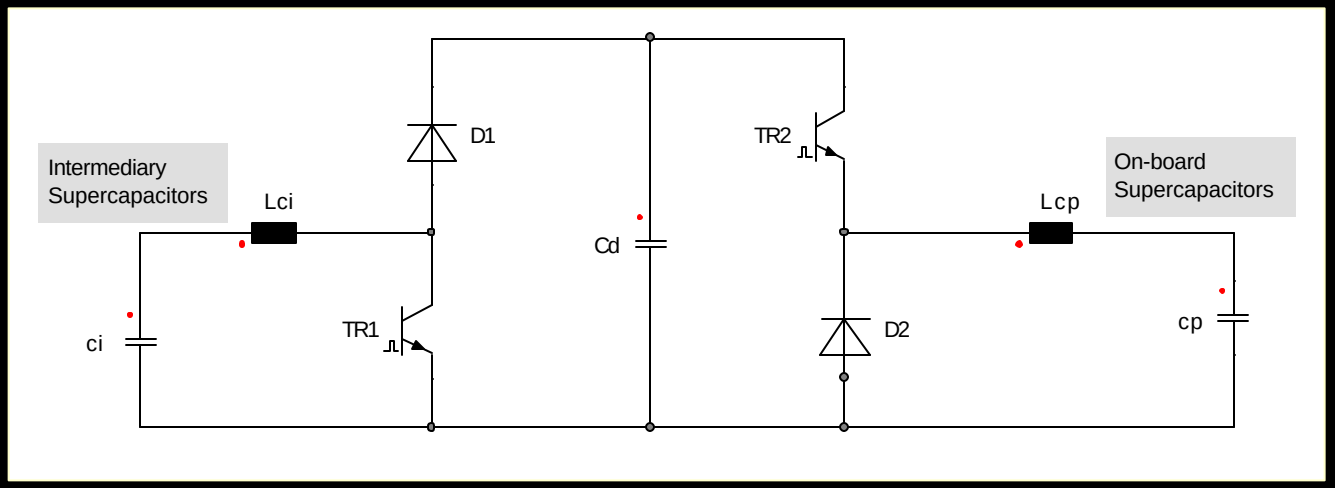
Sequential distribution with double storage (le biberonnage)

- **Fast energy exchange :**



  - **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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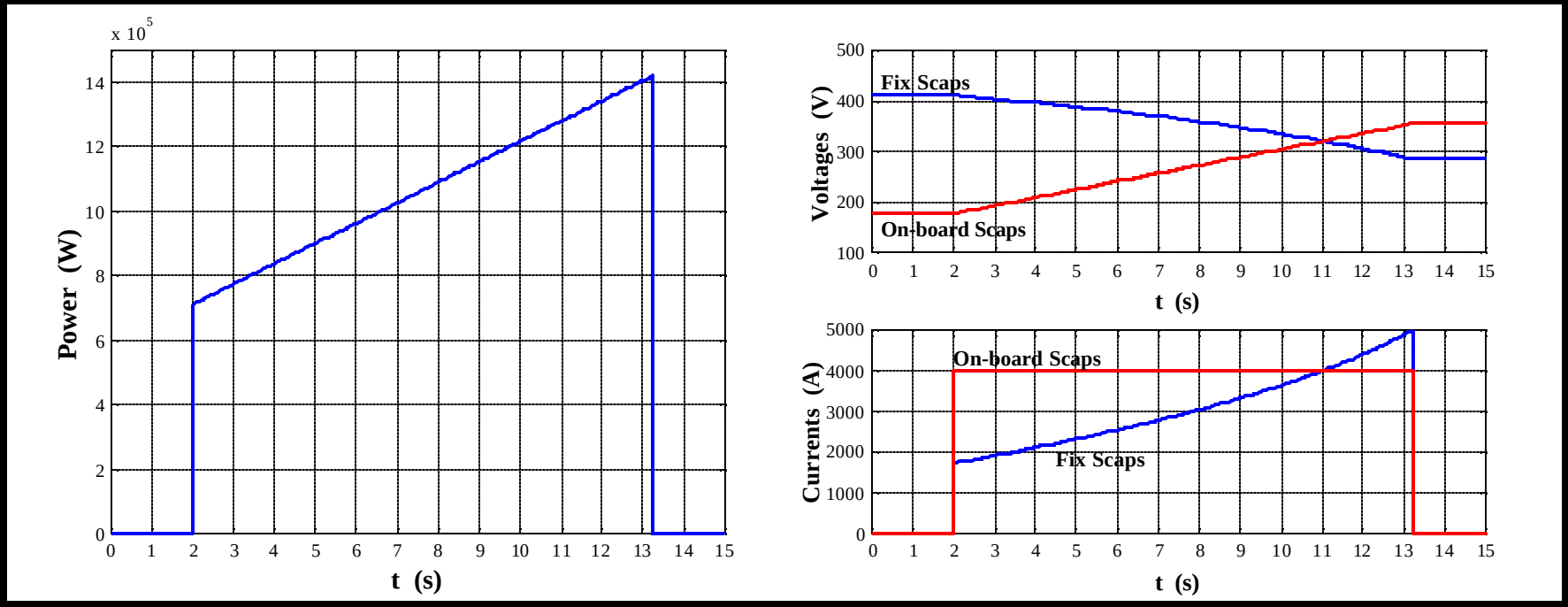
Sequential distribution with double storage (le biberonnage)

- **Fast energy exchange :**
  - **Various energy transfer processes :** Constant current for the on-board Scaps



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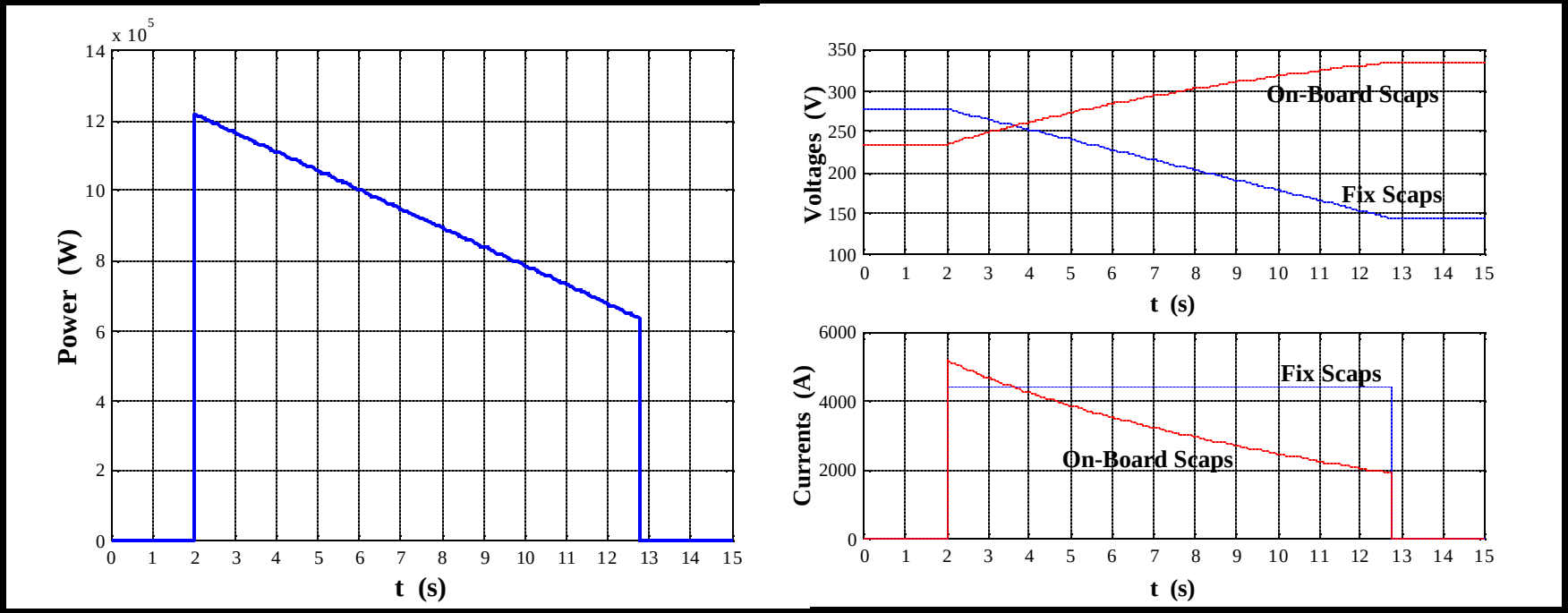
Sequential distribution with double storage (le biberonnage)

- **Fast energy exchange :**
  - **Various energy transfer processes :** Constant current for the fix Scaps



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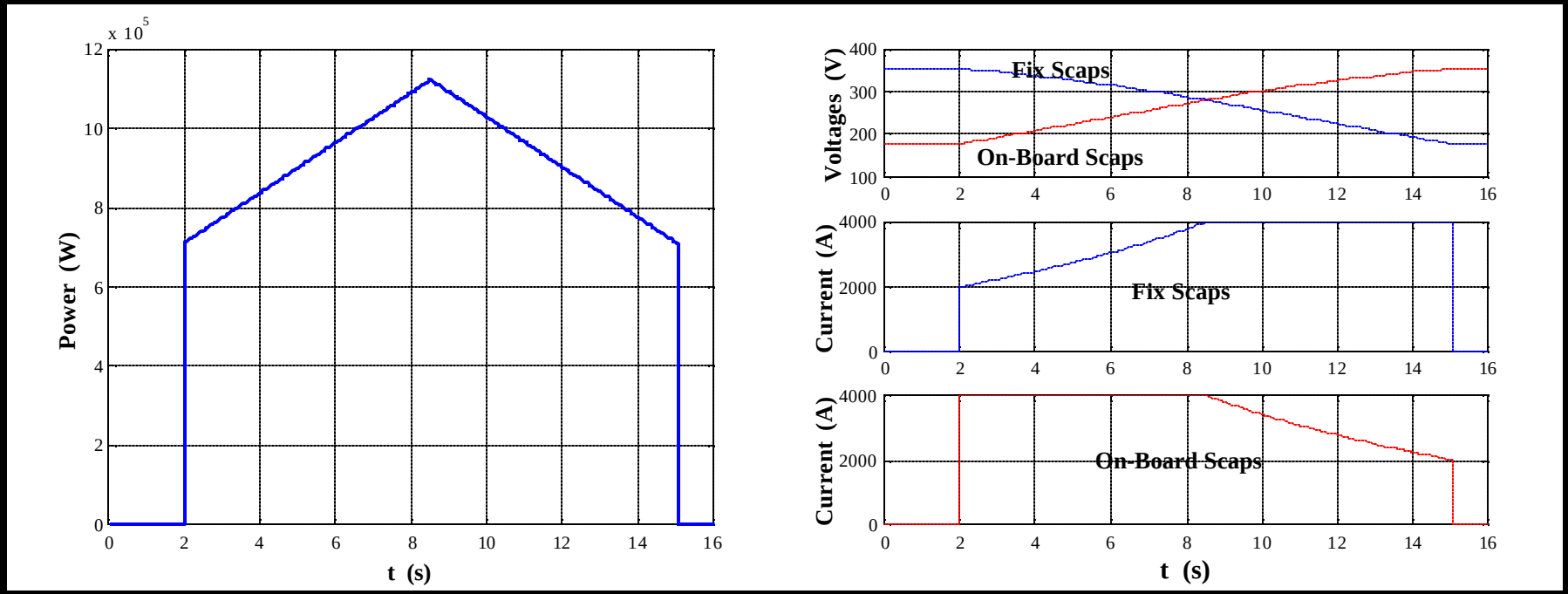
Sequential distribution with double storage (le biberonnage)

- **Fast energy exchange :**
  - **Various energy transfer processes :** hybrid solution



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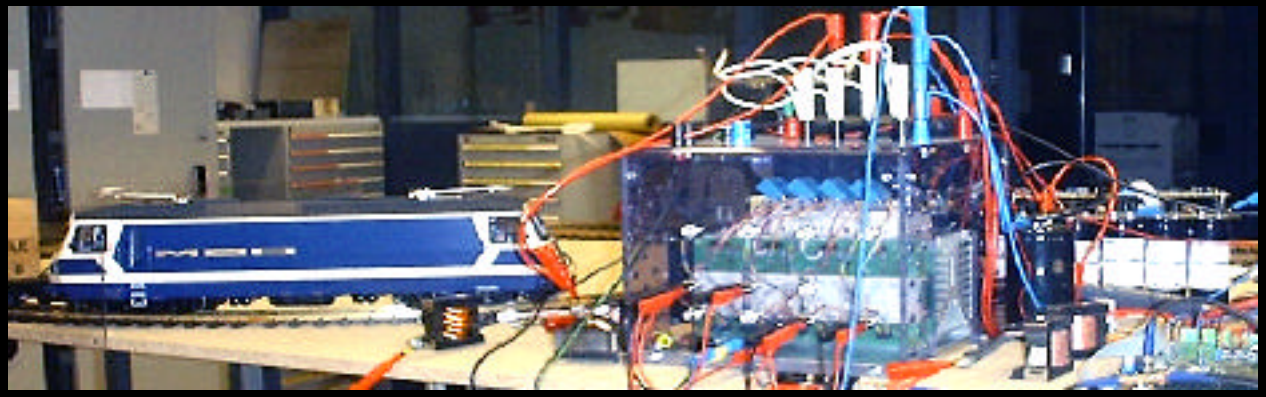
Sequential distribution with double storage (le biberonnage)

- **Fast energy exchange :**
  - **Experimental validation**



Video

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Conclusion

- **Supercapacitors are components for energy storage**

- **Because they are able to provide/absorb high instantaneous power, they are considered as power sources :**
  - **Used as main power source**
  - **Used as energy buffer, to limit power constraints on an energy source (batteries, fuel cells, power network, …)**

- **Main difficulties for high power applications**
  - **Number of supercapacitors (price…)**
  - **Efficiency (low voltages, high currents...)**
  - **Connections (from the fix supercapacitors to the on-board supercapacitors)**
  - **Pollution from EMC effects ...**