Super Capacitor electrical and lifetime model development for low frequency current applications

Tom Turcksin

Mahdi Soltani, Joris Jaguemont, Ahmed Abdallh, Omar Hegazy, Peter Van den Bossche, Joeri Van Mierlo, Noshin Omar

outline

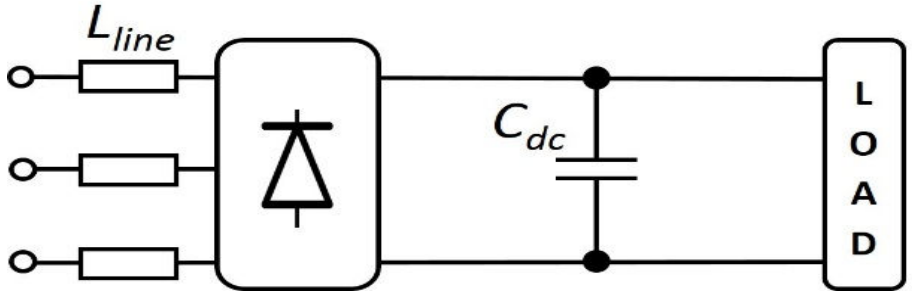
- Motivation
- Aging modelling principle
- Model components
- Characterization tests
- Experimental results
- Simulation results and discussion
- Conclusion

Motivation:

Energy recuperation helps to increase the efficiency of weaving loom machines

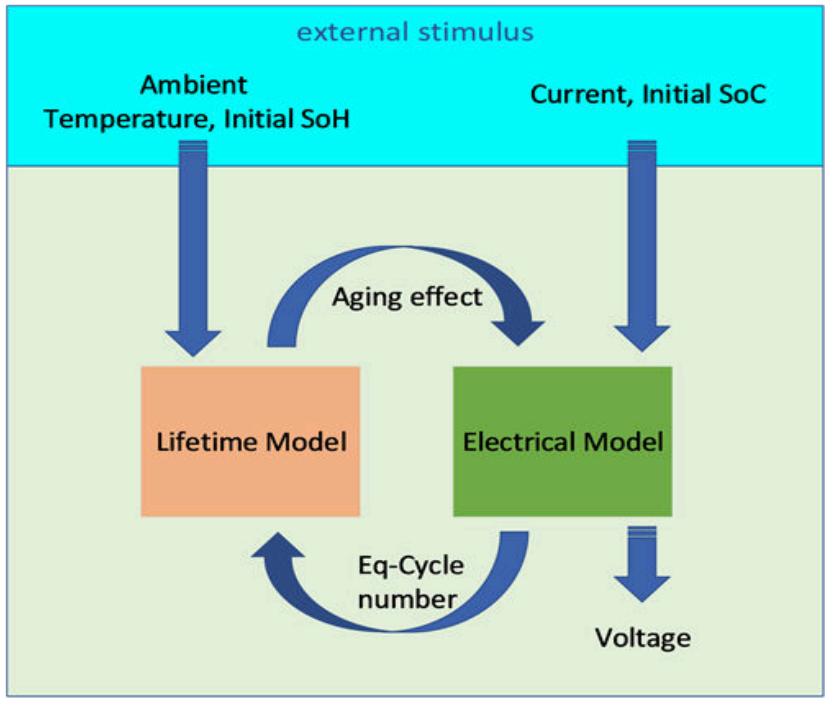
Energy storage methods:

- Send back to the grid → complex bidirectional converter
- Store in mechanical storage devices (spring, flywheel) → limited lifetime, limited storage capability
- Store electrically in Super-Capacitors → **Lifetime is questionable**



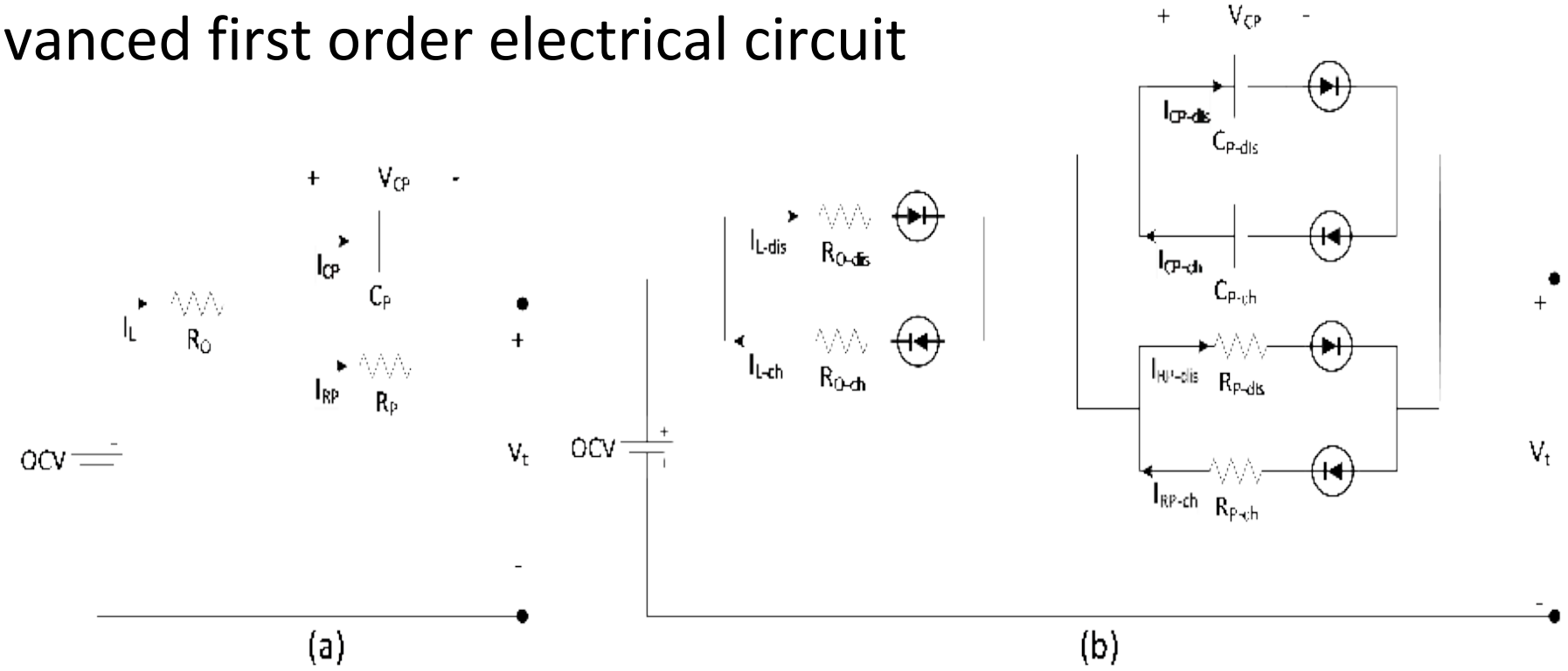
Aging modeling principle

- Electrical model === voltage variation with current and temperature
- Lifetime model === capacity and resistance evolution with time and cycle



Model components

- An advanced first order electrical circuit



$$\dot{V}_{cp} = -\frac{V_{cp}}{R_P C_P} + \frac{I_L}{C_P}$$

$$V_t = V_{ocv} - I_L R_O - I_{RP} R_P$$

Model components

- Lifetime model

  End of life == capacity falls to 80% and resistance increases to 200%

  Capacity degradation coefficient:

  capacity correction factor → $CCF = 1 - Q_{loss}$

  $$Q_{usable} = Q_{initial} \times CCF$$

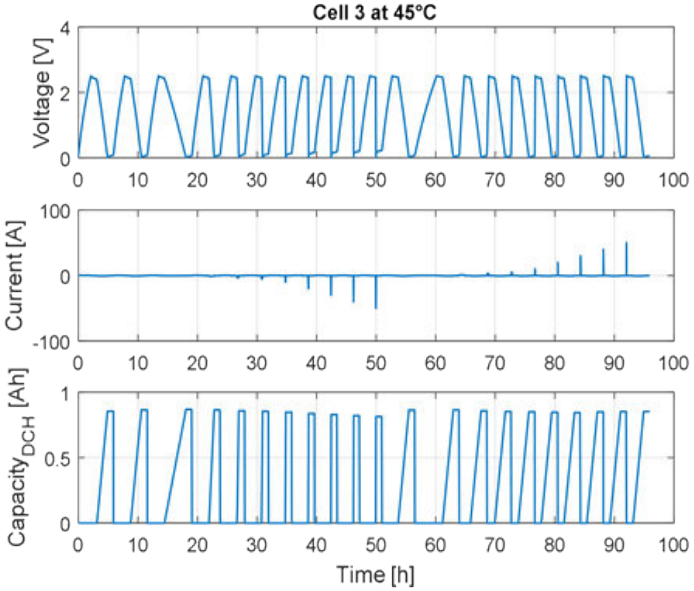
  resistance increase coefficient:

  resistance correction factor → $RCF = 1 + R_{increment}$

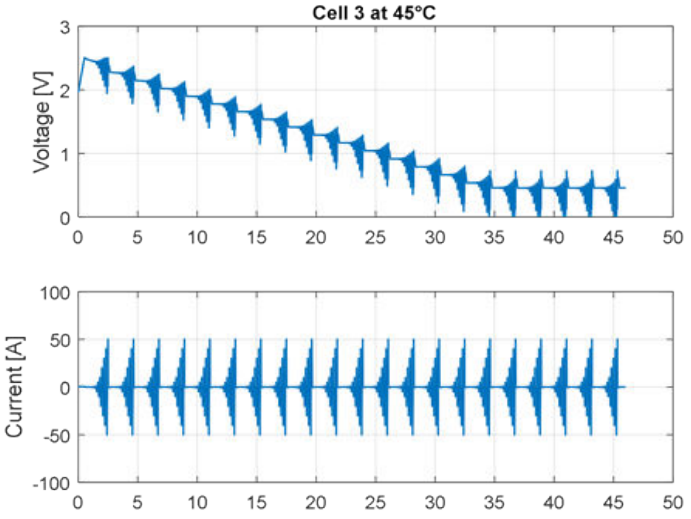
  $$R_{available} = R_{initial} \times RCF$$

Characterization tests

- OCV test → to calculate the open circuit voltage
- Capacity test → for SOC calculation



- HPPC test → for Ro, Rp and Cp calculation

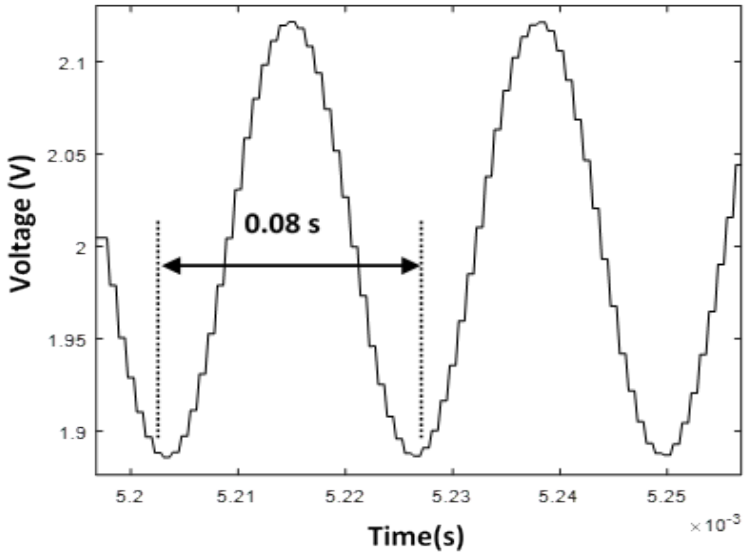


$$\dot{V}_{cp} = -\frac{V_{cp}}{R_P C_P} + \frac{I_L}{C_P}$$

$$V_t = V_{ocv} - I_L R_O - I_{RP} R_P$$

Experimental results

- Current profile (80A p-p, 12 Hz) is applied at 80% SoC at (25 and 40°C)



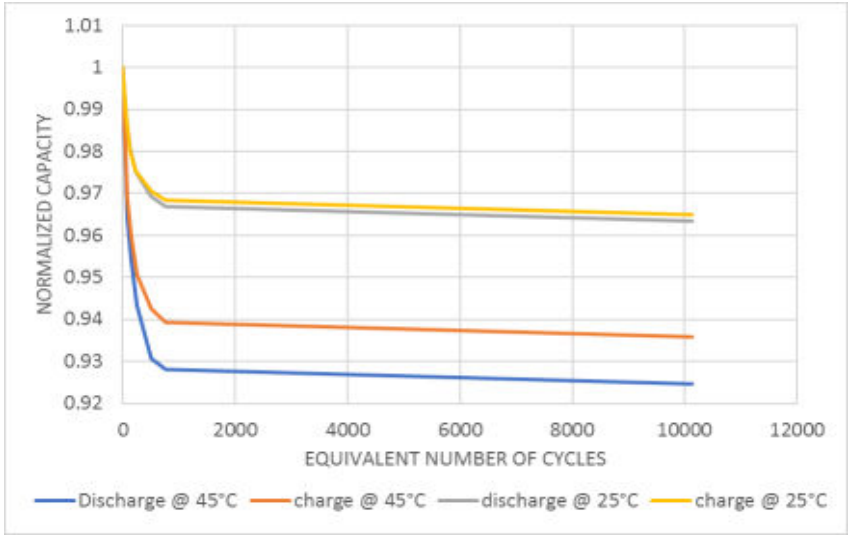
- Characterization tests are performed every 700 Kcycles

Experimental results

- Capacity degradation trend

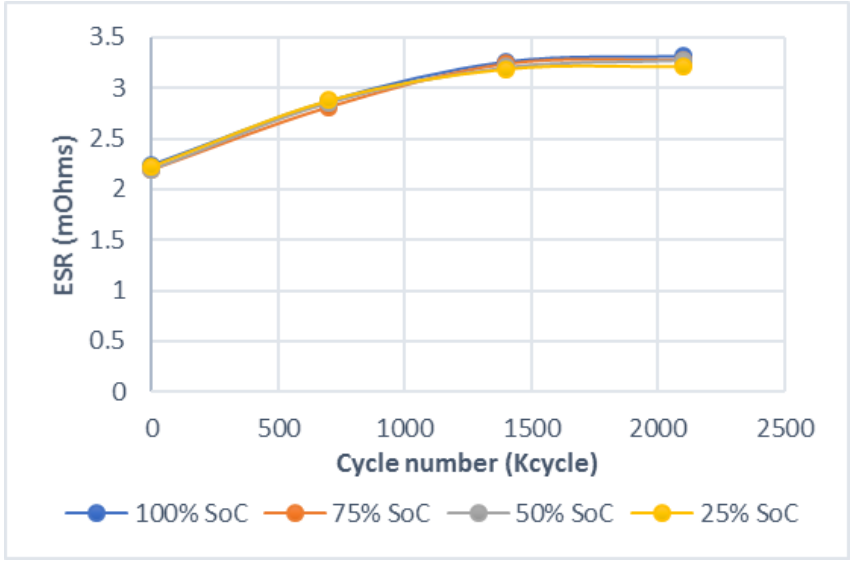
  different trend for charge and discharge

  different trend for different temperature



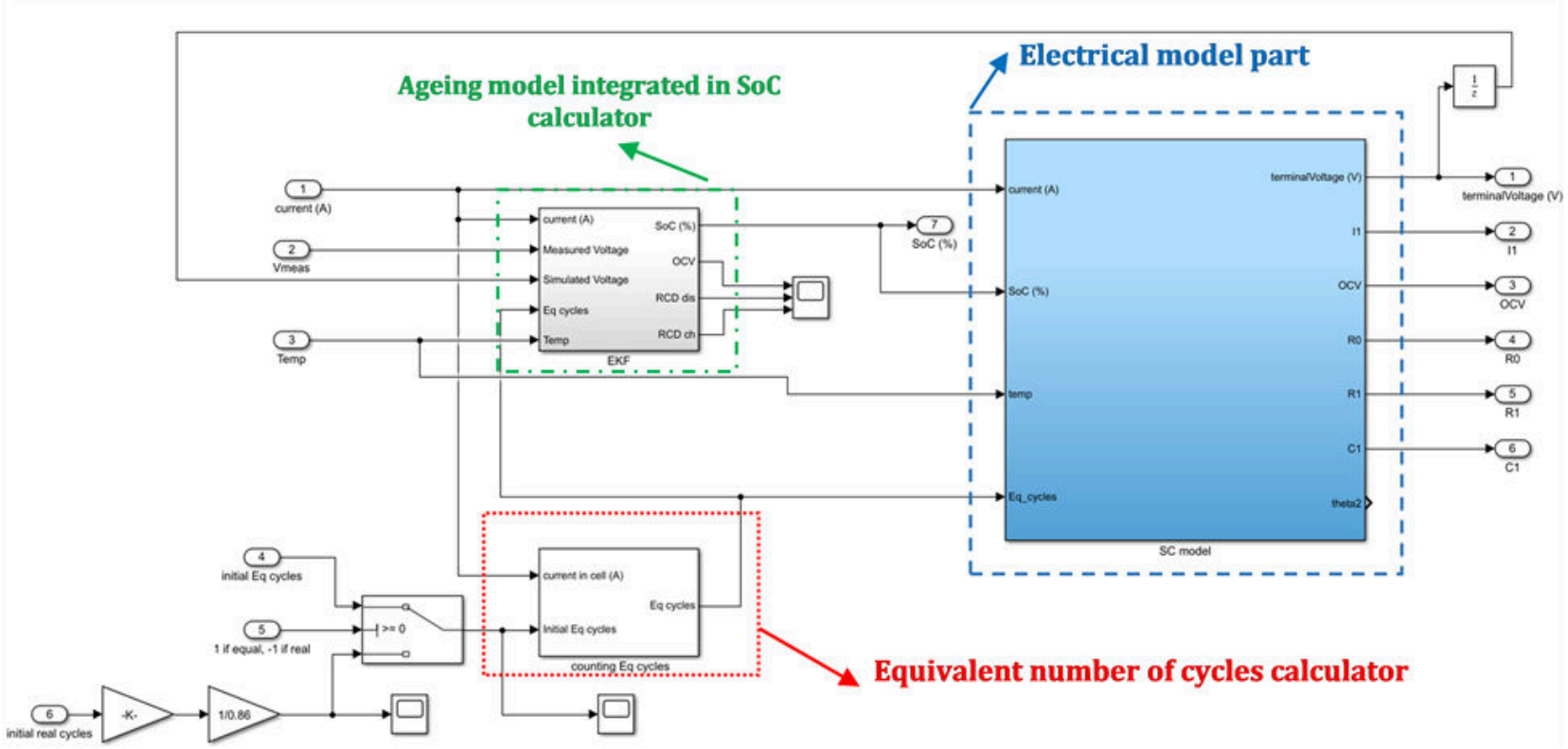
- Resistance evolution trend

  resistance at higher SoC increases more



Simulation results

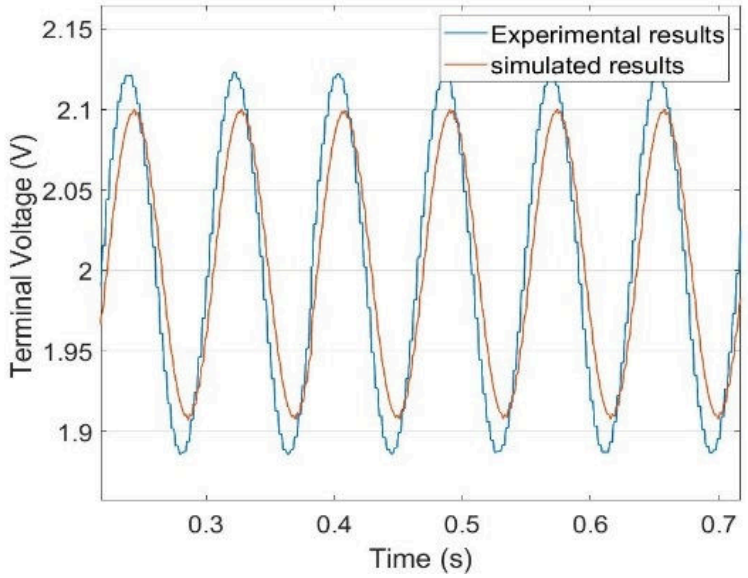
- The electrical and lifetime model are implemented in Matlab/Simulink

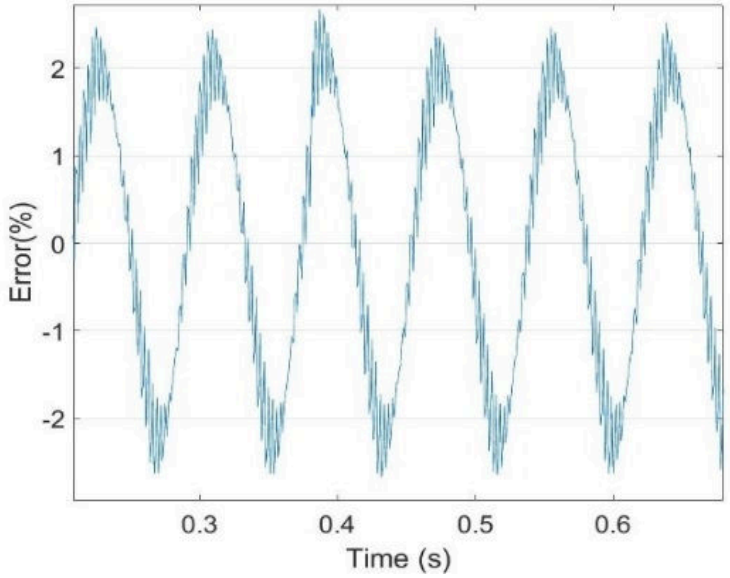


Simulation results

- Load profile is applied to the model and the error is calculated

$$error\% = 100\% \times \frac{V_{measured} - V_{simulated}}{V_{measured}}$$





conclusion

- End of life @ 25 °C is 500 million cycles = 15 Khours
- Cycling at high temperature accelerates the capacity degradation
- Cycling at high SoC, accelerates the resistance growth
- Cycling at 12Hz, accelerate aging process

  (nominal lifetime is more than 35 Khours)
- Model error is $\pm$ 2.5%.

Question?

Thank you for your attention

Tom Turcksin

Mahdi Soltani, Joris Jaguemont, Ahmed Abdallh, Omar Hegazy, Peter Van den Bossche, Joeri Van Mierlo, Noshin Omar (mahdi.Soltani@vub.be)