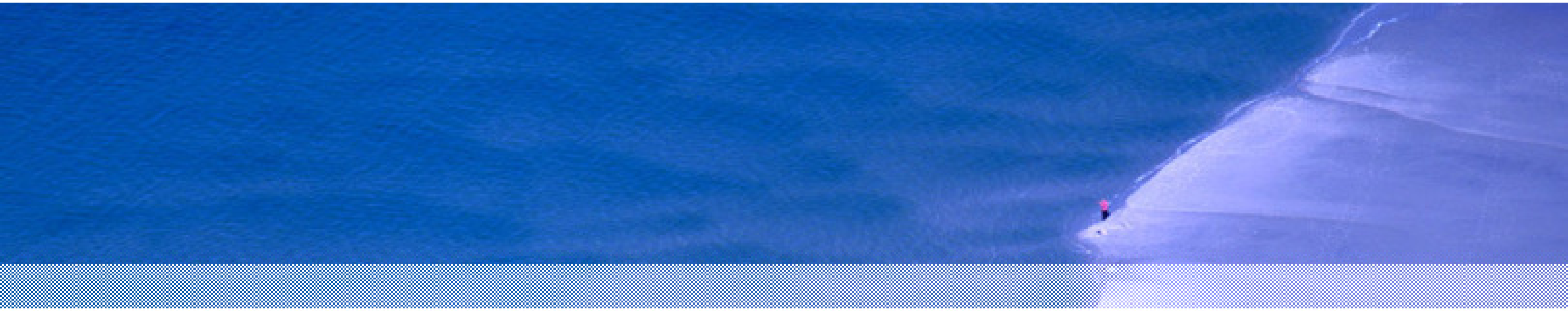

MODELLING THERMAL DYNAMIC RESPONSE TO A 3-HOUR TOTAL POWER SHUTDOWN EVENT

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Introduction

- **In the past, energy costs accounted for about 30% of total production costs. With the changes in the power market in Europe and elsewhere over the last 10 years, this share has risen in some cases to more than 50%. Power costs in smelter exceeds 50€/MW.**

- **Under these conditions, power could become a trading asset for the aluminium industry.**

- **Partly, actual power contracts contain clauses for power supply reduction and buyback. This have to be carefully considered with regard to the pot technology, i.e.**
  - not harming pot life in the long term
  - making gains on the power market in the short term

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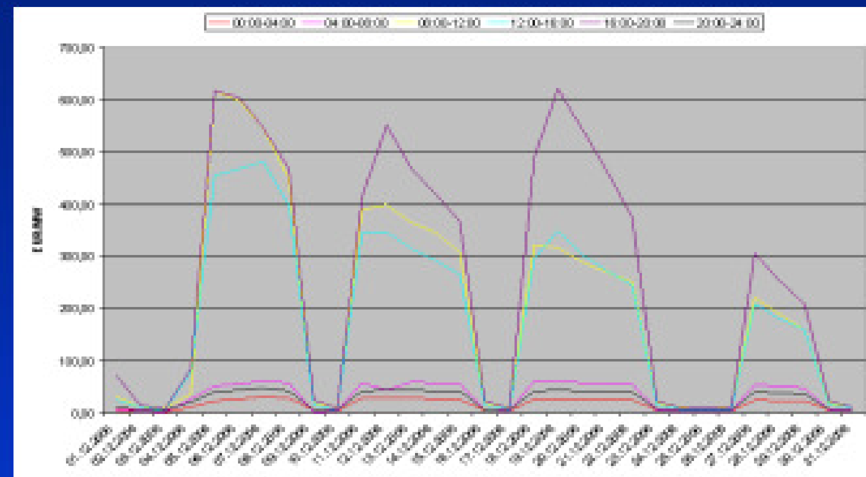
Power Modulation

- **Weekly power price on the spot market at European Energy Exchange (EEX) reached e.g. 500€/MW in Dec 2006.**
- **What are the technical challenges executing Power Modulation up to Hibernation and Swing Lines?**



- Power modulation events, however, affect the smelting process by stopping production, disturbing the chemical and heat balance and reducing pot life.
- To better understand the thermal and chemical impact in a pot during power cut back or modulation a dynamic lump model can be used as cell simulator to predict the pot behavior and estimate the economical impact.

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Modelling tools

Requirements of the models:

- **The model must accurately represent the key behaviors of the process to be modeled.**
  - Thermo-electric behavior of all solids
  - Realistic heat loss scenario including ledge formation
  - Feeding and solution effects
  - Chemical response on Fluoride feeding and ledge formation
  - Impact of pot control and operation
- **The model must be limited to a manageable size / complexity in order to keep both its development and computation time affordable.**

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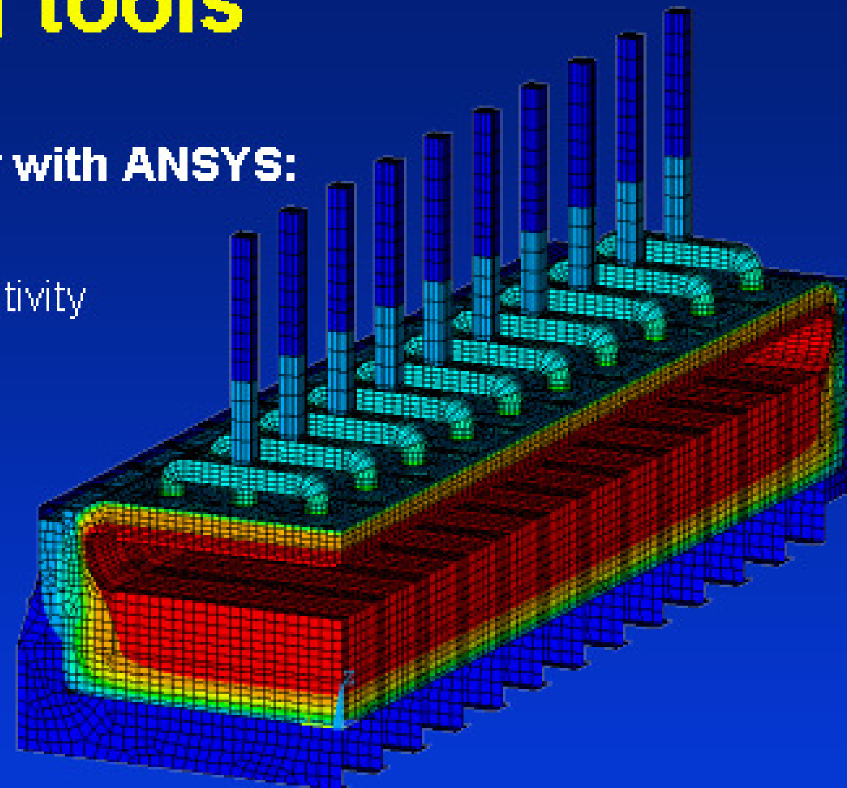
Modelling tools

Modelling of the thermo-electric behaviour with ANSYS:

- **3D finite element models**

  Realistic joule heat generation, thermal conductivity and heat losses well established



But, liquid phase missing:

- Bath with feeding, deposit and dissolution effects not implemented
- Local electro-chemical behaviour even
- Also without these features too long computational time for running transient operational cases

Modelling tools

Integral approach more promising:

- **1D lump models: Dyna/Marc**

To model the reduction process, 36 differential equations are solved using the Euler numerical scheme.

To evaluate the required first order derivative of the 36 variables, a large number of derived variables are calculated in sub models using published literature equations. These equations are required to solve the heat and mass balance of the process and to evaluate the ACD evolution and the amperage fluctuation.

Cell controller events like Resistance control and Feeding control handled depending to the associated state of the cell in the model.

Pot states like normal operation, anode effect, metal tapping and anode change are included to cover the operation disturbance on the reduction process.

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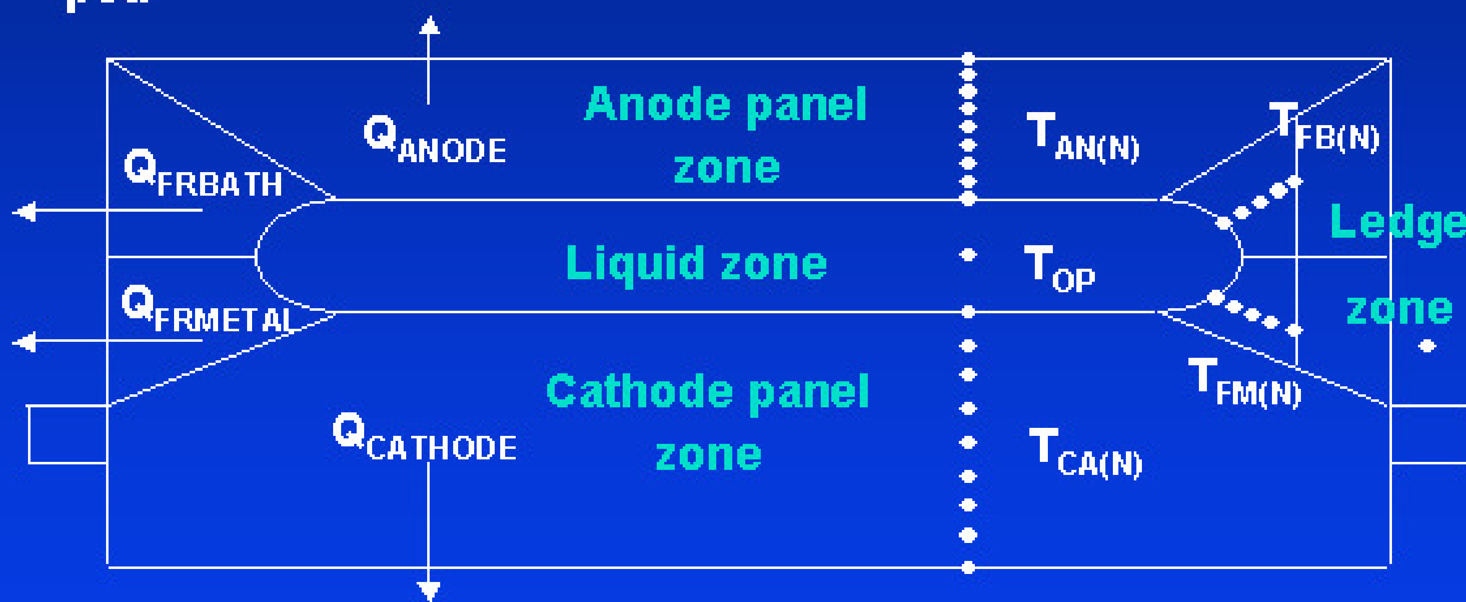
Modelling tools

Thermal set-up:

5 Zones representing the thermal behaviour from heat generation, thermal conductions to heat loss for the whole pot.



Local effects can not be covered with this approach.

Example

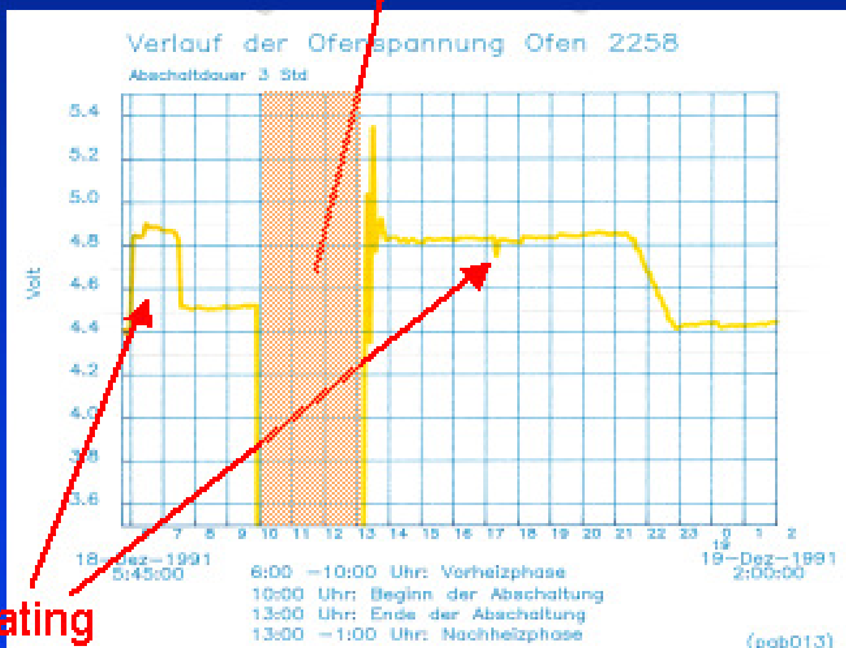
- 240 kA cell technology (Töging, 1991)

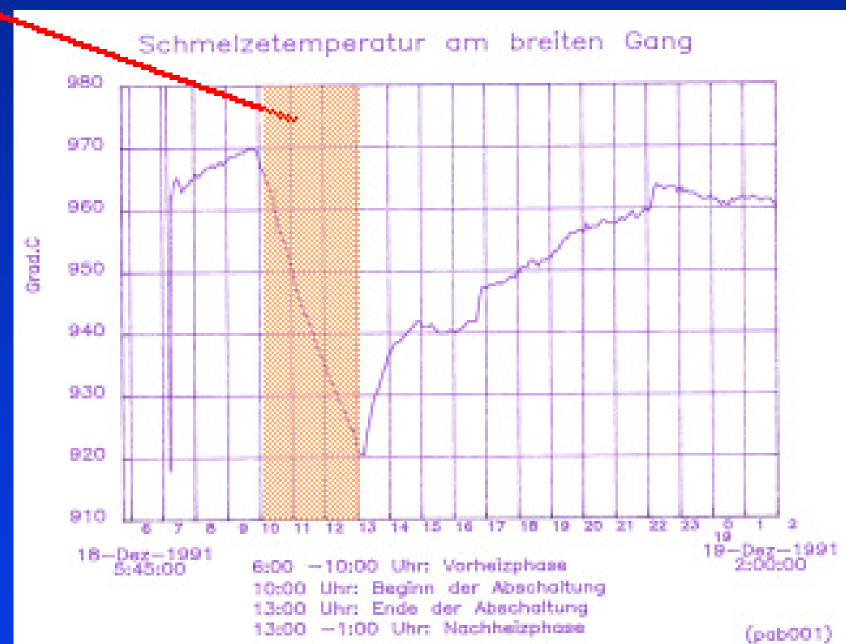
Several shut down scenarios were carried out, when it was decided to direct the hydro-electric power from the Töging smelter's own dam into the power grid.

Example

- Thermal response: Voltage curve and continuous temperature reading

Power shutdown duration





Heating phase

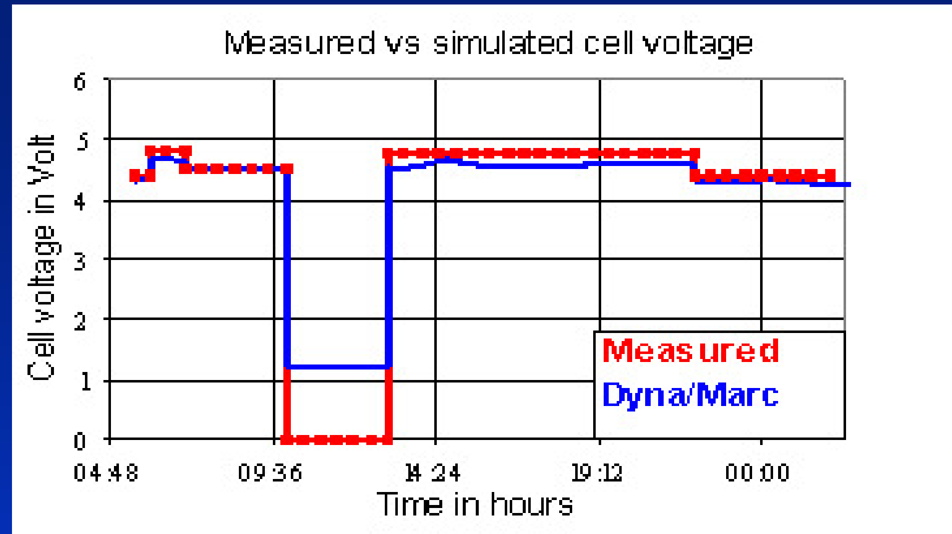
Simulation results

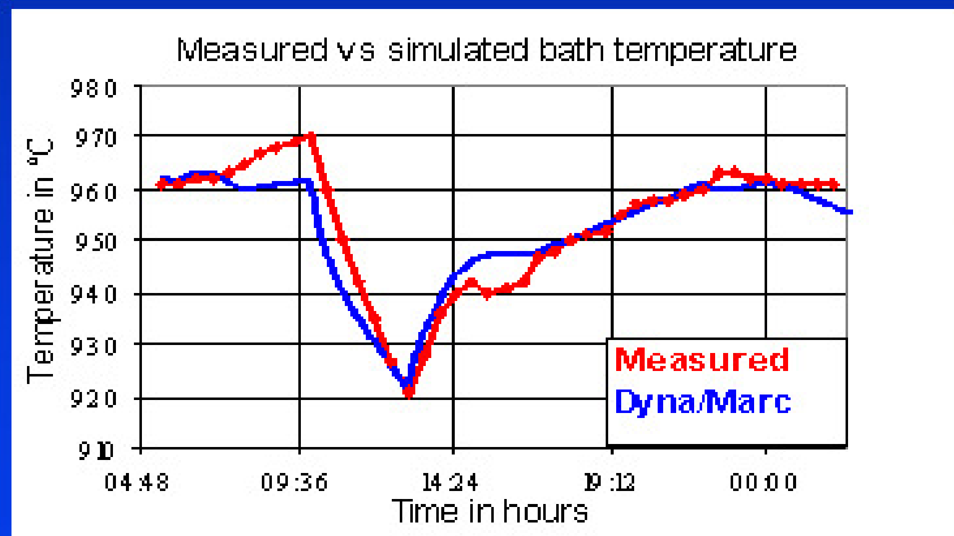
- **After adjusting the thermal and chemical response of the cell in the model,**

  which is not quite easy 15 years after carrying out the trail,

  a good correspondence was found with the measurement.

- **Open points**
  - Battery effect of cell
  - Stronger heating effect





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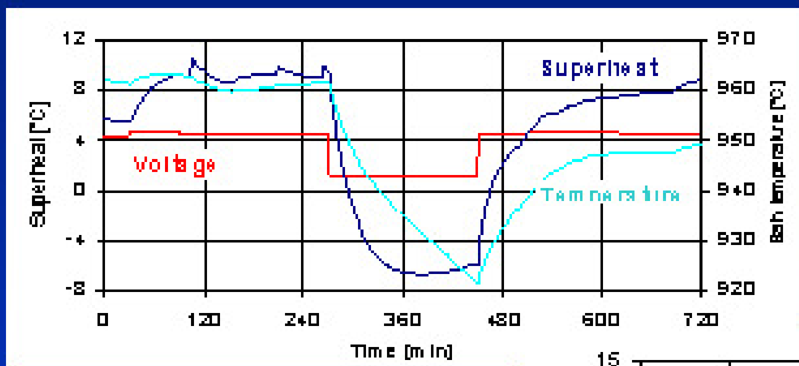
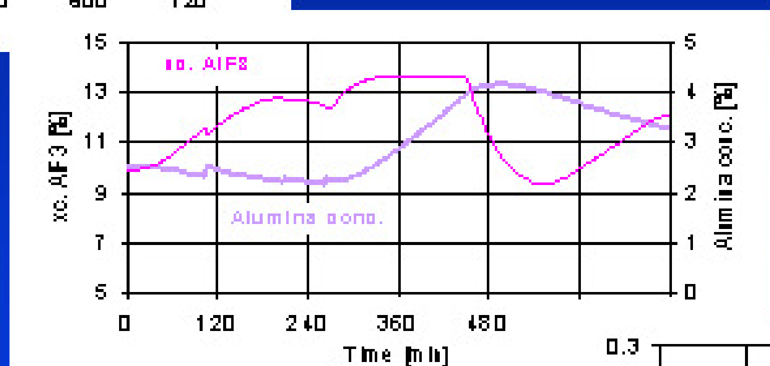
Simulation results

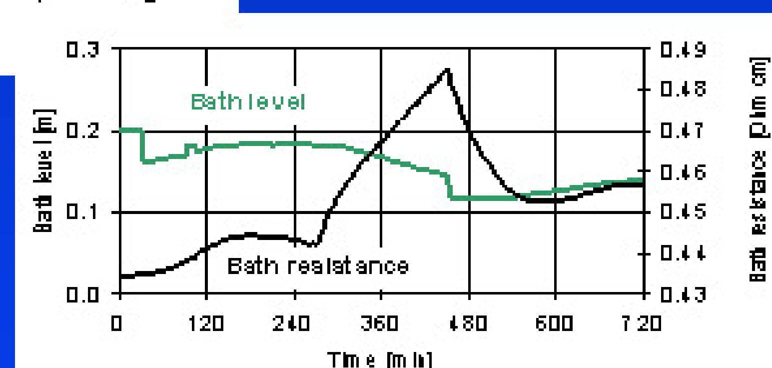
- **Adjusted model allows to look into pot behaviour during power shutdown:**



Super heat shows much fast response on the voltage than bath temperature



AlF3 concentration is rising with the ledge formation.



Temperature drop in the bath shows strong impact on bath resistance resulting in reduced ACD.

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Conclusion

- **This model validation exercise highlights both the strengths and weaknesses of mathematical modelling:**
  - a well calibrated and, hence, well validated model is able to represent the complex dynamic behaviour of a Hall-Héroult aluminium electrolysis cell accurately.
  - Such a model can help to plan and execute strategies for power modulation, reduce specific power costs and ensure stable pot operation and extended pot life.