New Busbar Network Concepts Taking Advantage of Copper Collector Bars to Reduce Busbar Weight and Increase Cell Power Efficiency

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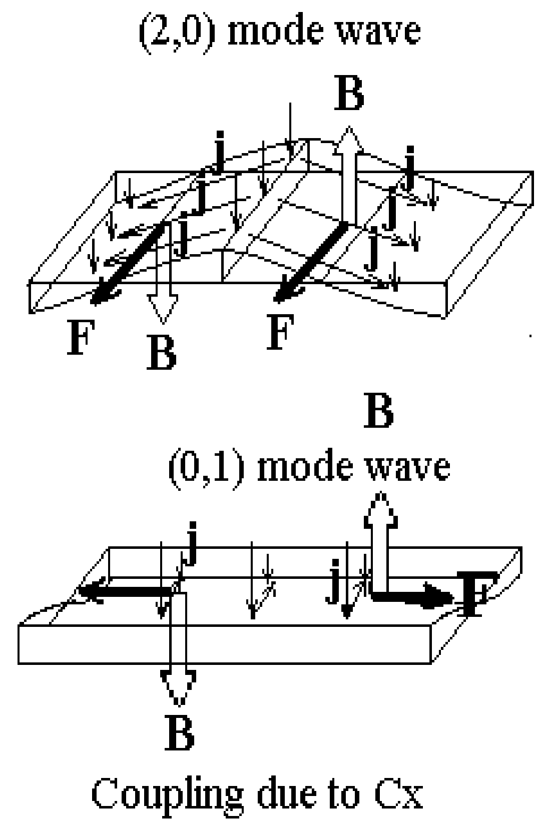
ICSOBA *Québec, 3 – 6 October 2016*

Plan of the Presentation

- **Introduction**
- **Usage of Copper Collector Bars**
- **Extracting 100 % of the cell current on the downstream side**
- **Busbar Network Designs Taking Advantage of 100 % Downstream Cell Current Extraction**
  - Reversed compensation current (RCC) busbar network
  - External compensation current (ECC) busbar network
- **Conclusions**

Introduction

- Cell stability influenced by magnitude of B_z in metal pad
- B_z is the vertical component of the magnetic fields
- C_x is the difference between the B_z positive value in one end of cell and the B_z negative value in the other end

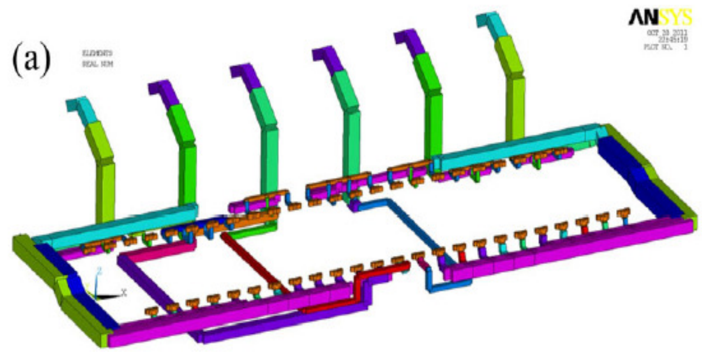


Ref: N. Urata, Wave Mode Coupling and Instability in the Internal Wave in the Aluminum Reduction Cells, TMS Light Metals 2005, pp 455-460.

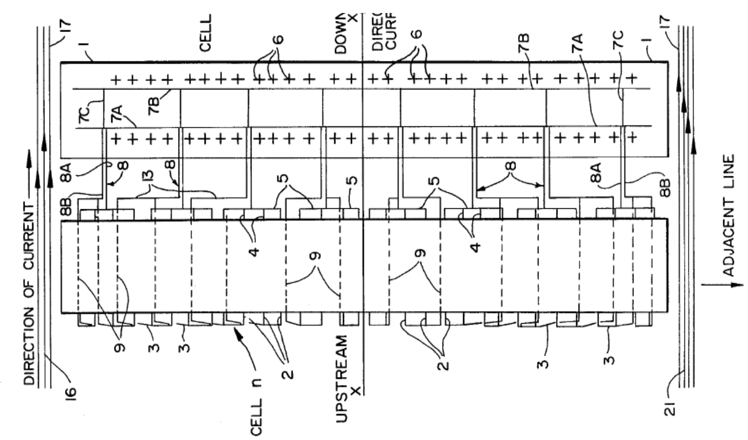
State of the art in busbar design

List of different type of busbar designs

- **I**nternal **C**ompensation **C**urrent (**ICC**)



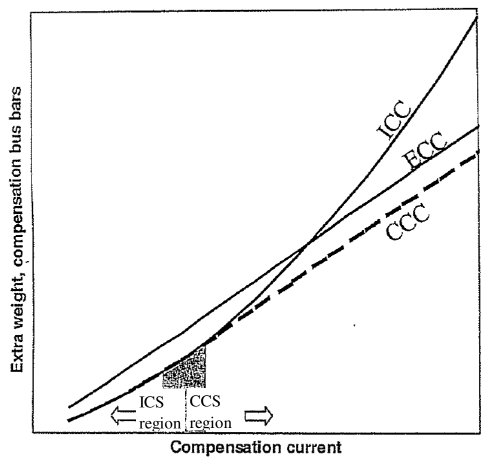
- **E**xternal **C**ompensation **C**urrent (**ECC**)



State of the art in busbar design

List of different type of designs

- **C**ombined types of **C**ompensation **C**urrent (**CCC**)



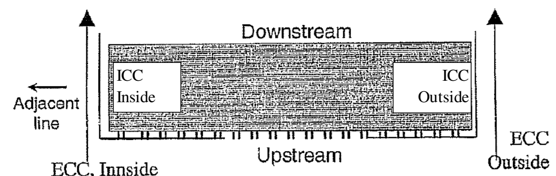
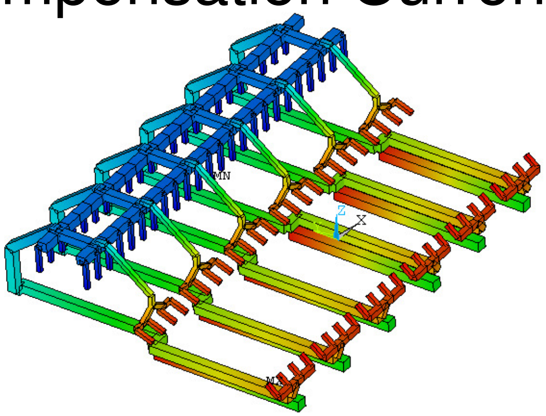


Figure 10.a

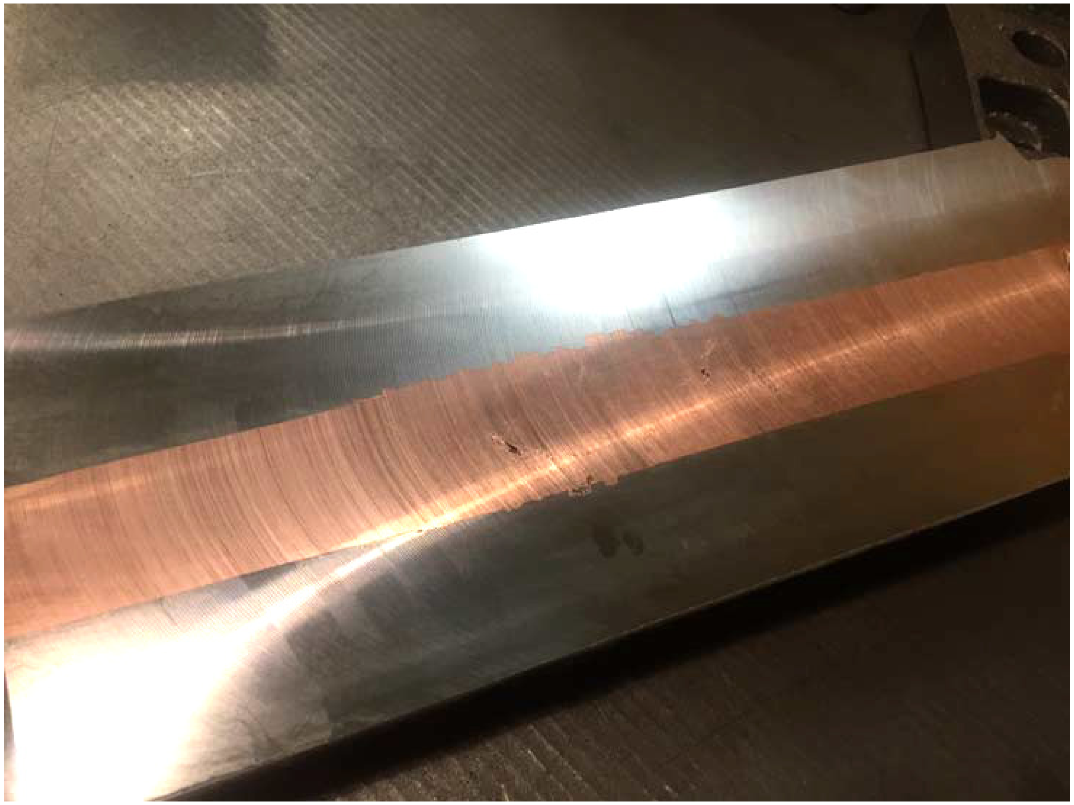
Figure 10.b

- **R**eversed **C**ompensation **C**urrent (**RCC**)



Usage of Copper Collector Bars

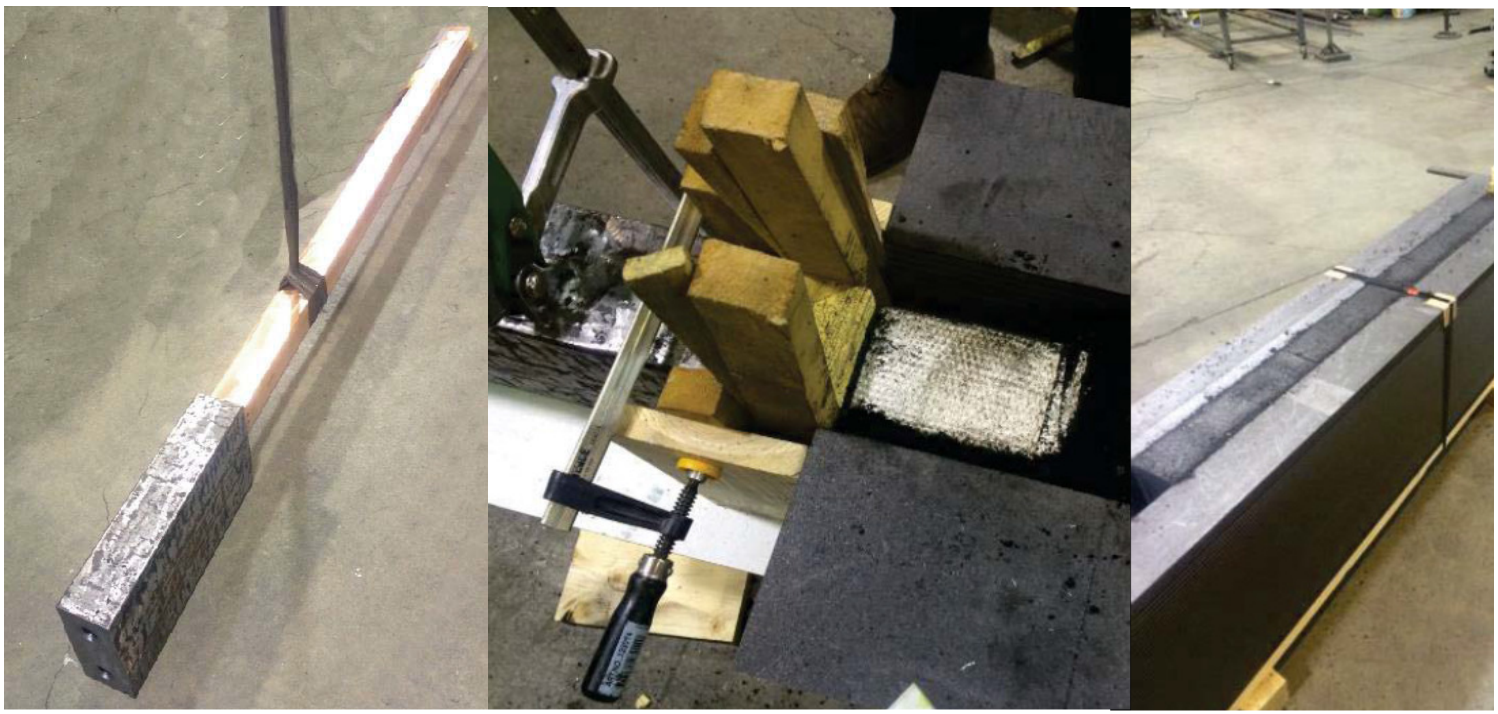
- Storvik AS publication at the ISCOBA 2015 conference is presenting a technology for casting copper inserts into steel



Ref: Dag Sverre Sæsbøe, Storvik high conductivity anode yoke with copper core, Proceedings of 33rd International ICSOBA Conference, , Dubai, UAE, 29 November – 1 December 2015, Paper AL23, Travaux No. 44, 717-726.

Usage of Copper Collector Bars

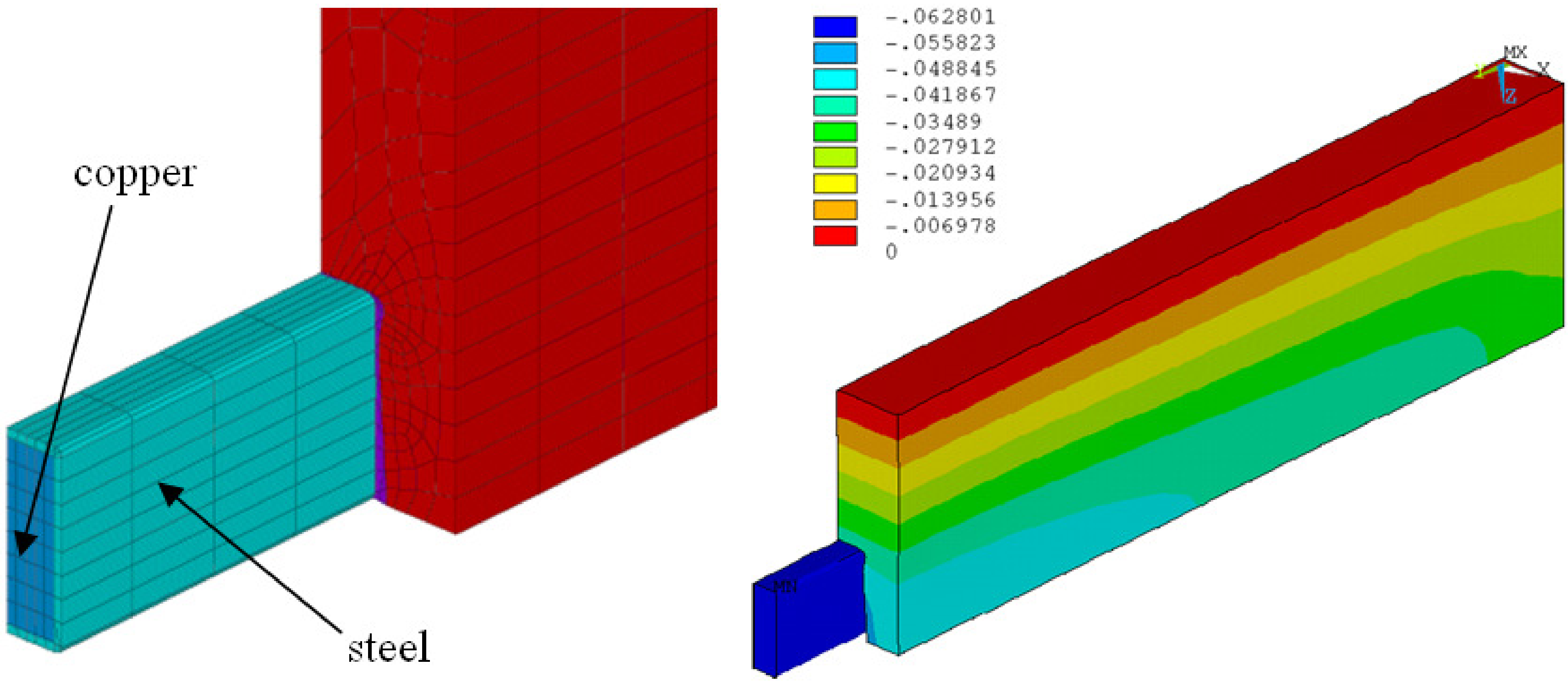
- At the TMS 2016 conference KAN-NAK advocated that copper collector bars do not even need to be protected by a steel shell and rodded to the block with cast iron



Ref: R. von Kaenel and al., Copper Bars for the Hall-Héroult Process, TMS Light Metals 2016, 903-908.

Usage of Copper Collector Bars

- In its 2011 ALUMINIUM article, the author presented a 500 kA cell design using massive collector bar inserts, covering 76 % of steel collector bar cross-section



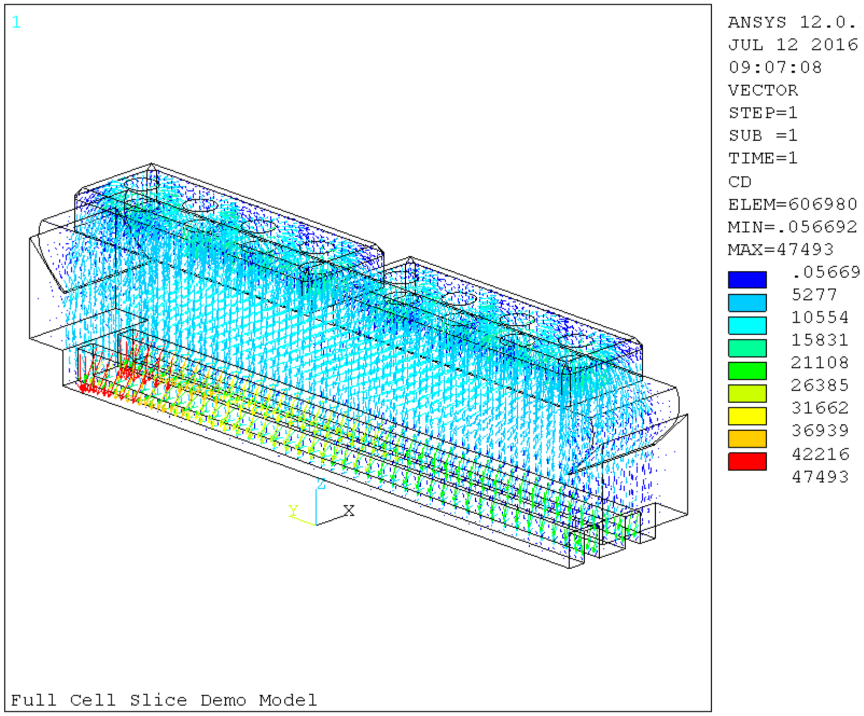
Ref: M. Dupuis and V. Bojarevics, Retrofit of a 500 kA cell design into a 600 kA cell design, ALUMINIUM 87(1/2), 2011, 52-55.

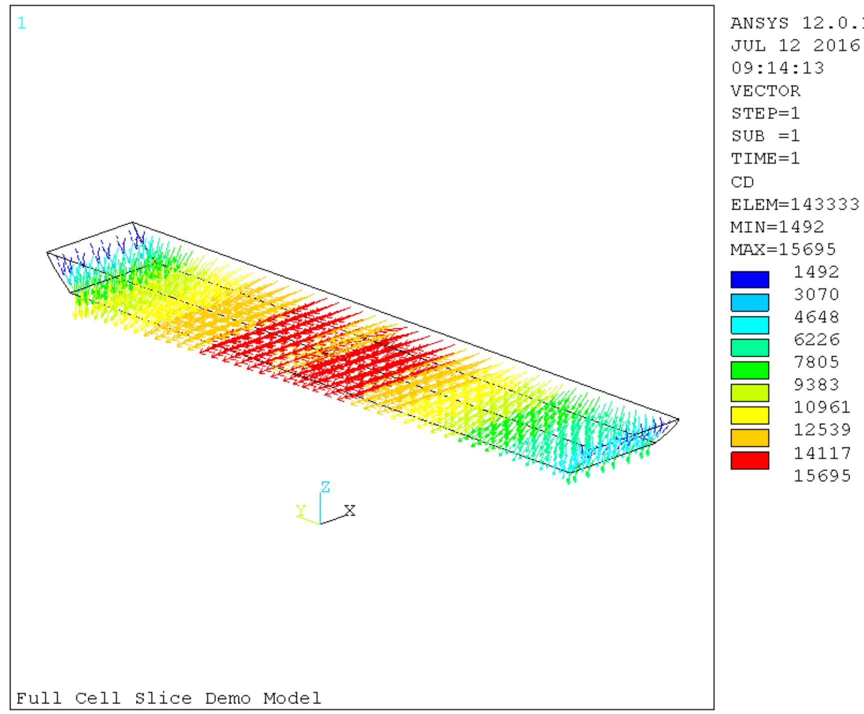
Extracting 100 % of the cell current on the downstream side

- With the usage of copper collector bars, 100 % of the cell current can be extracted on the downstream size without generating excessive horizontal current in the metal pad or generating excessive cathode voltage drop

- In order to test this idea, the 3D thermo-electric model previously used for the 2011 ALUMINIUM article was adapted keeping exactly the same lining design and collector bar size

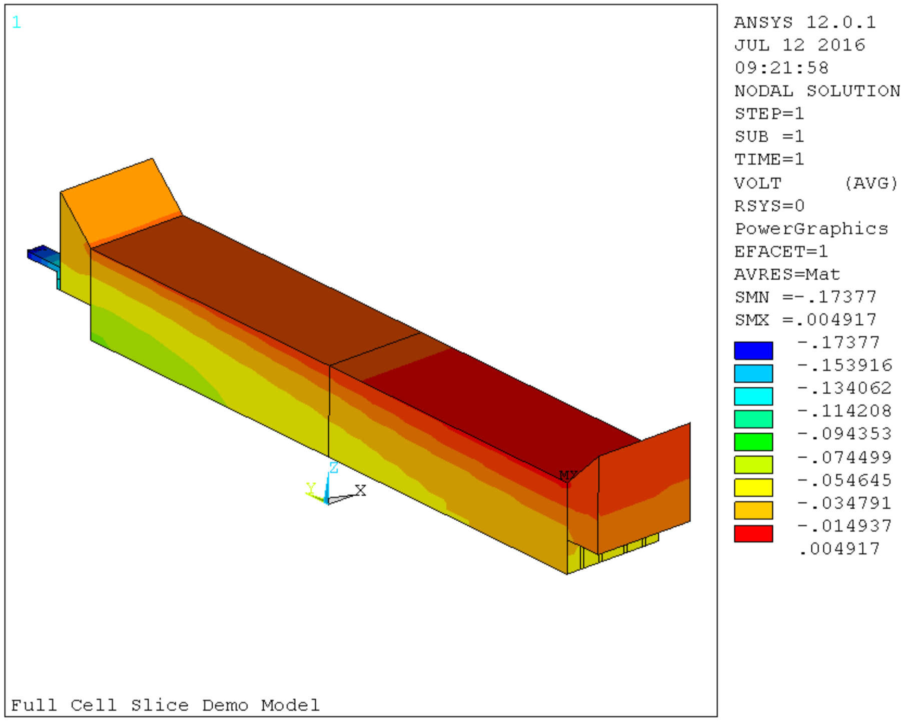
Extracting 100 % of the cell current on the downstream side

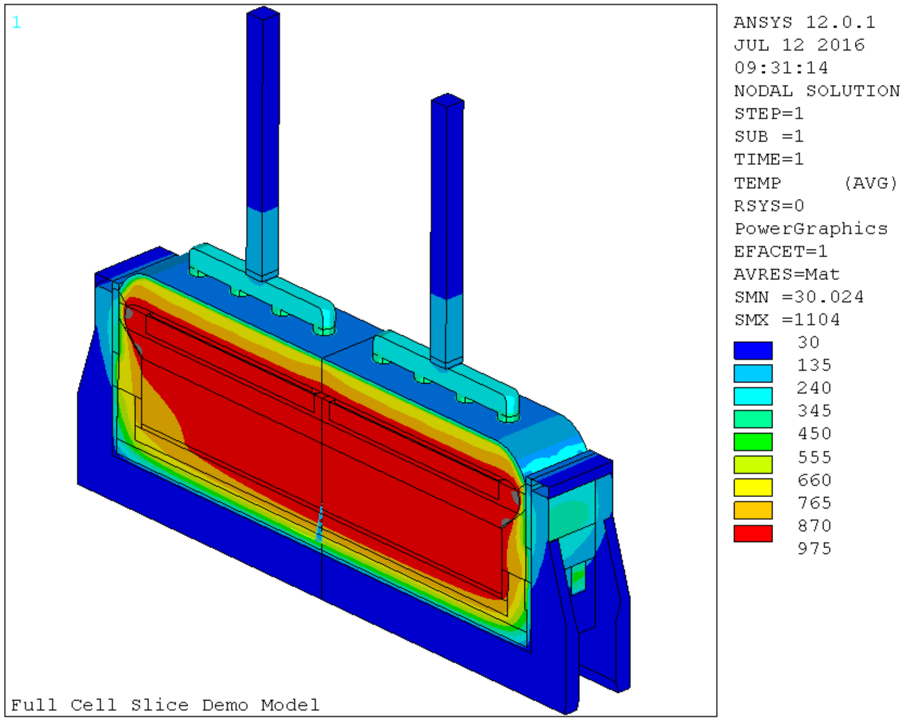




Thermo-electric model with current density in the whole domain (left) and in the metal pad only (right)

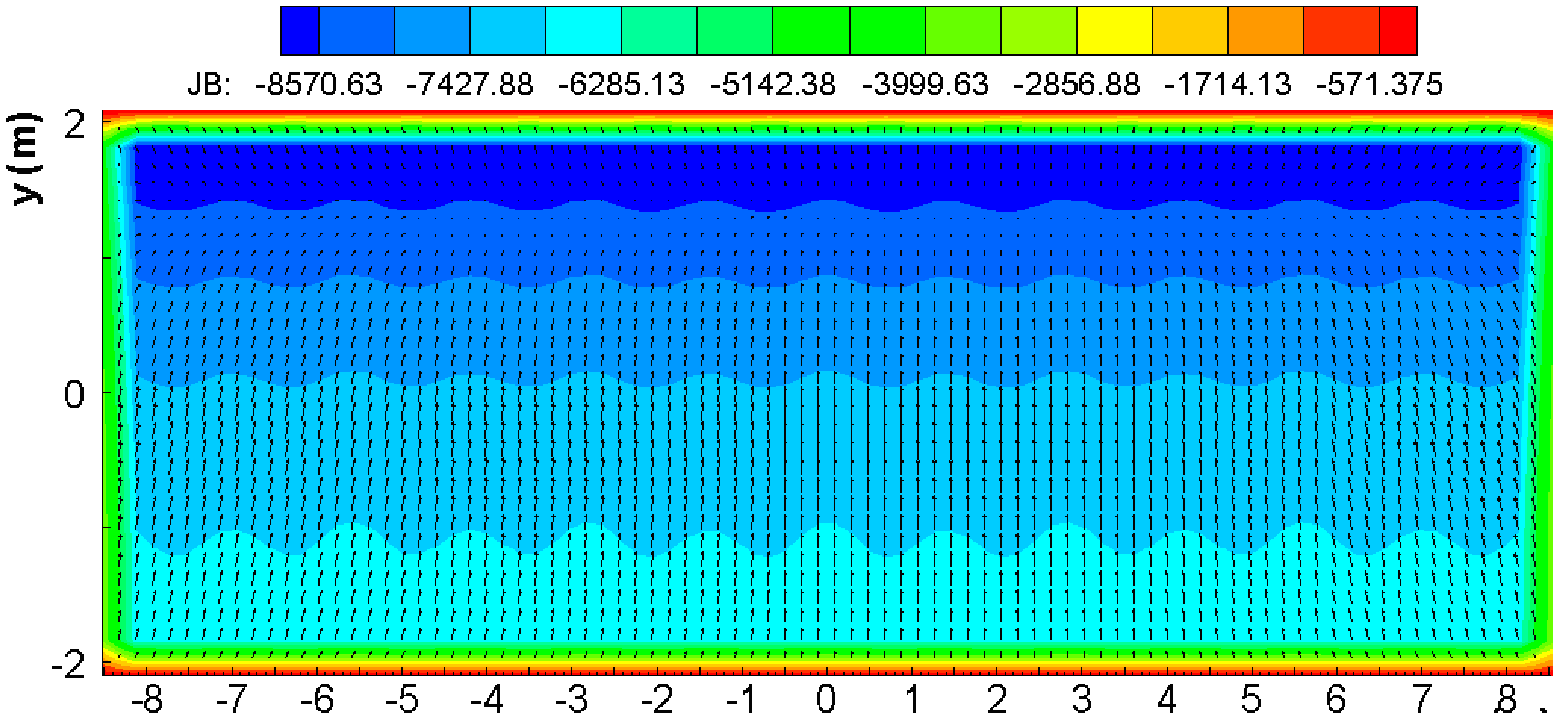
Extracting 100 % of the cell current on the downstream side





Thermo-electric model voltage drop (left) and temperature (right)

Extracting 100 % of the cell current on the downstream side

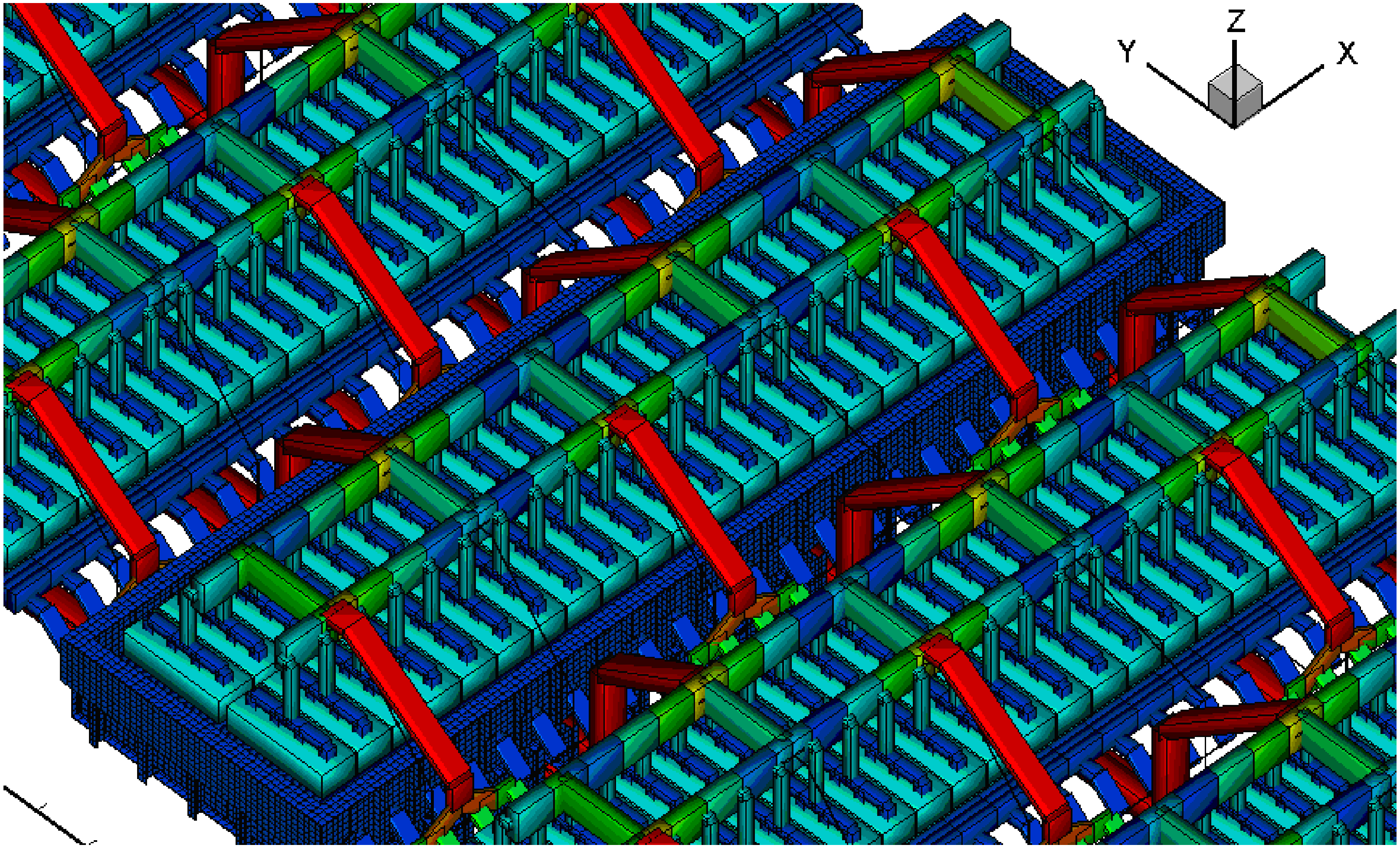


Electric current density at the cell bottom

Current density calculated with MHD-Valdis. Contours: current density entering the cathode block. Arrows: Horizontal current density in the metal pad.

Busbar Network Designs Taking Advantage of 100 % Downstream Cell Current Extraction

Reversed Compensation Current (RCC) busbar network



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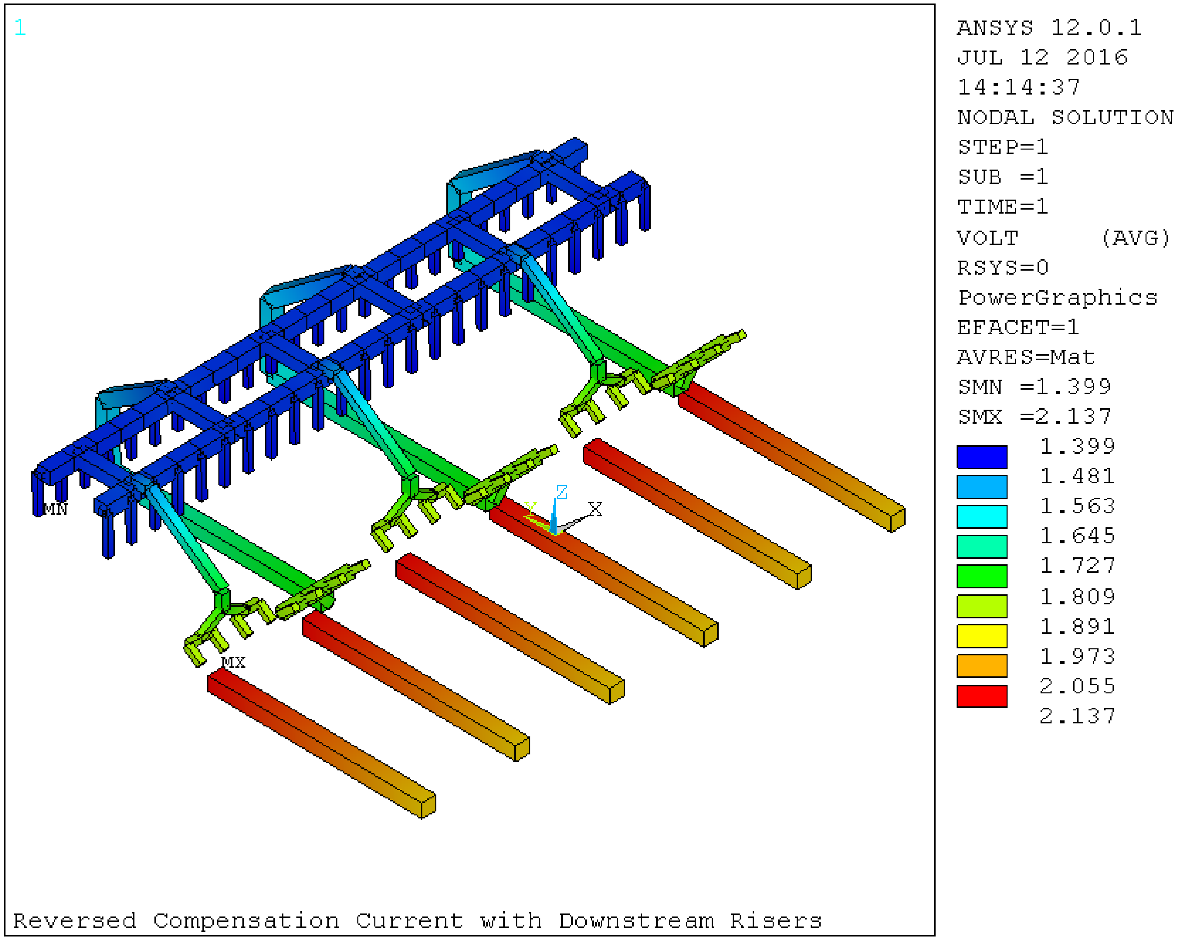

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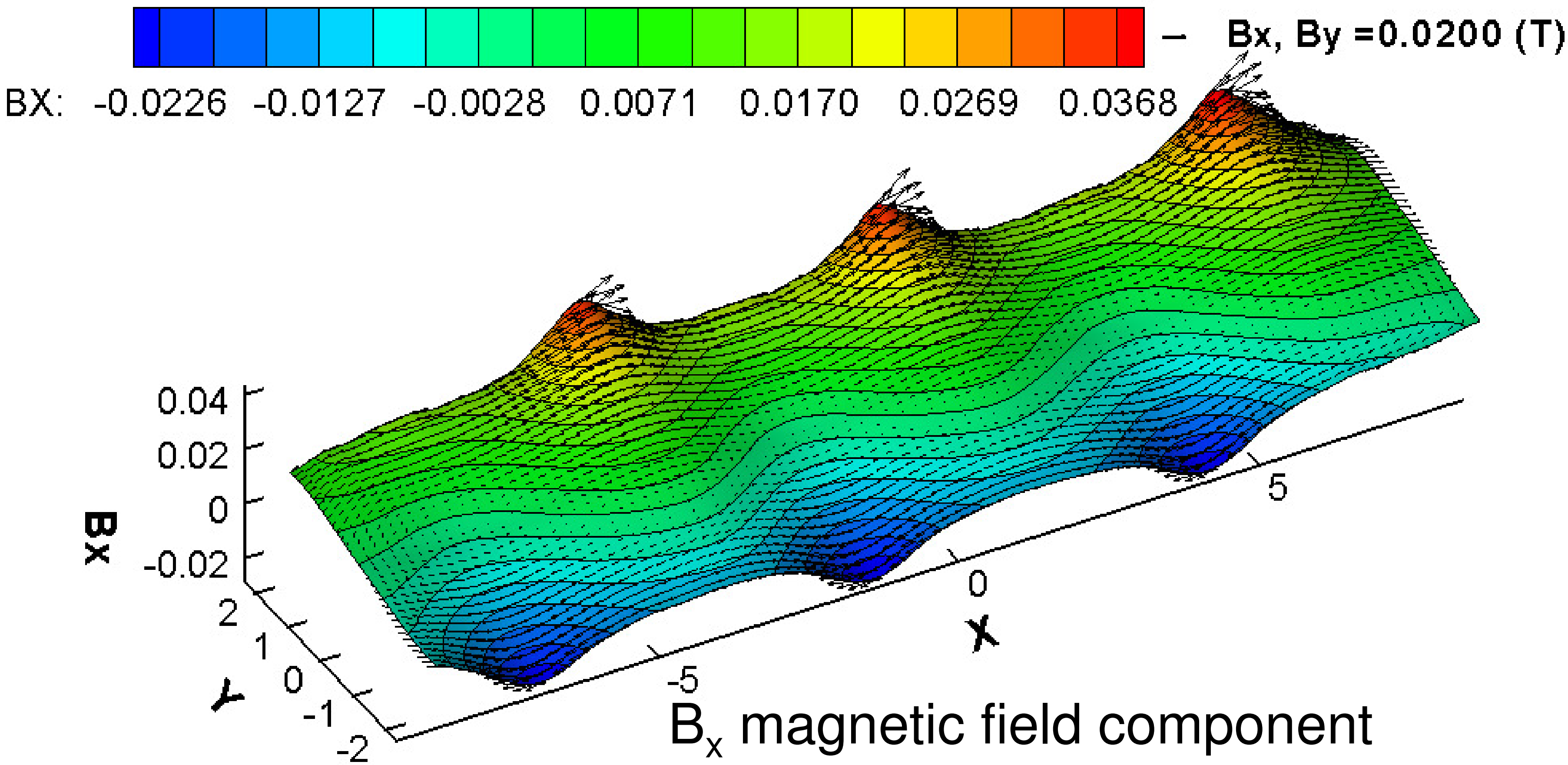

B_x magnetic field component

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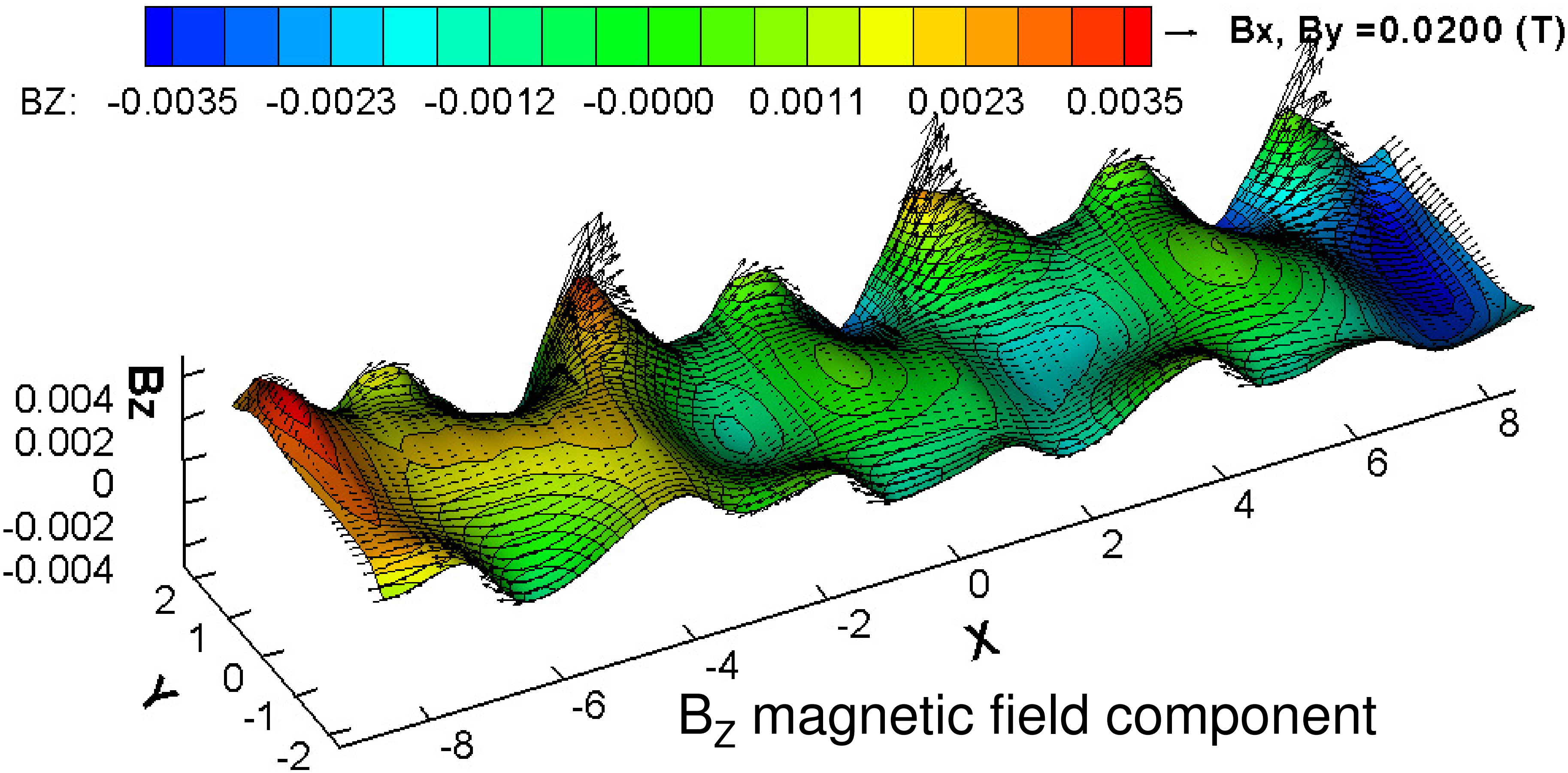

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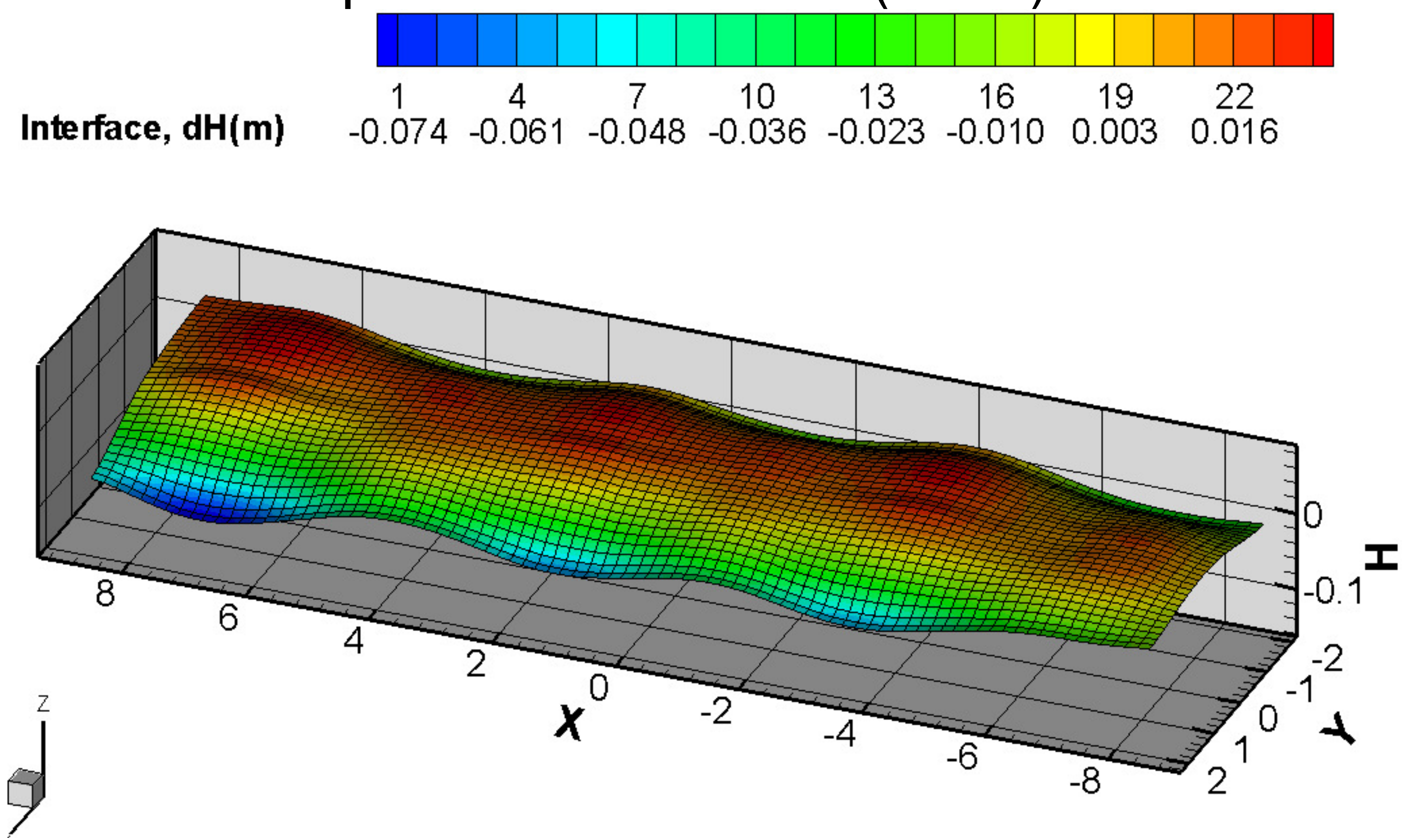

Steady-state bath-metal interface deformation

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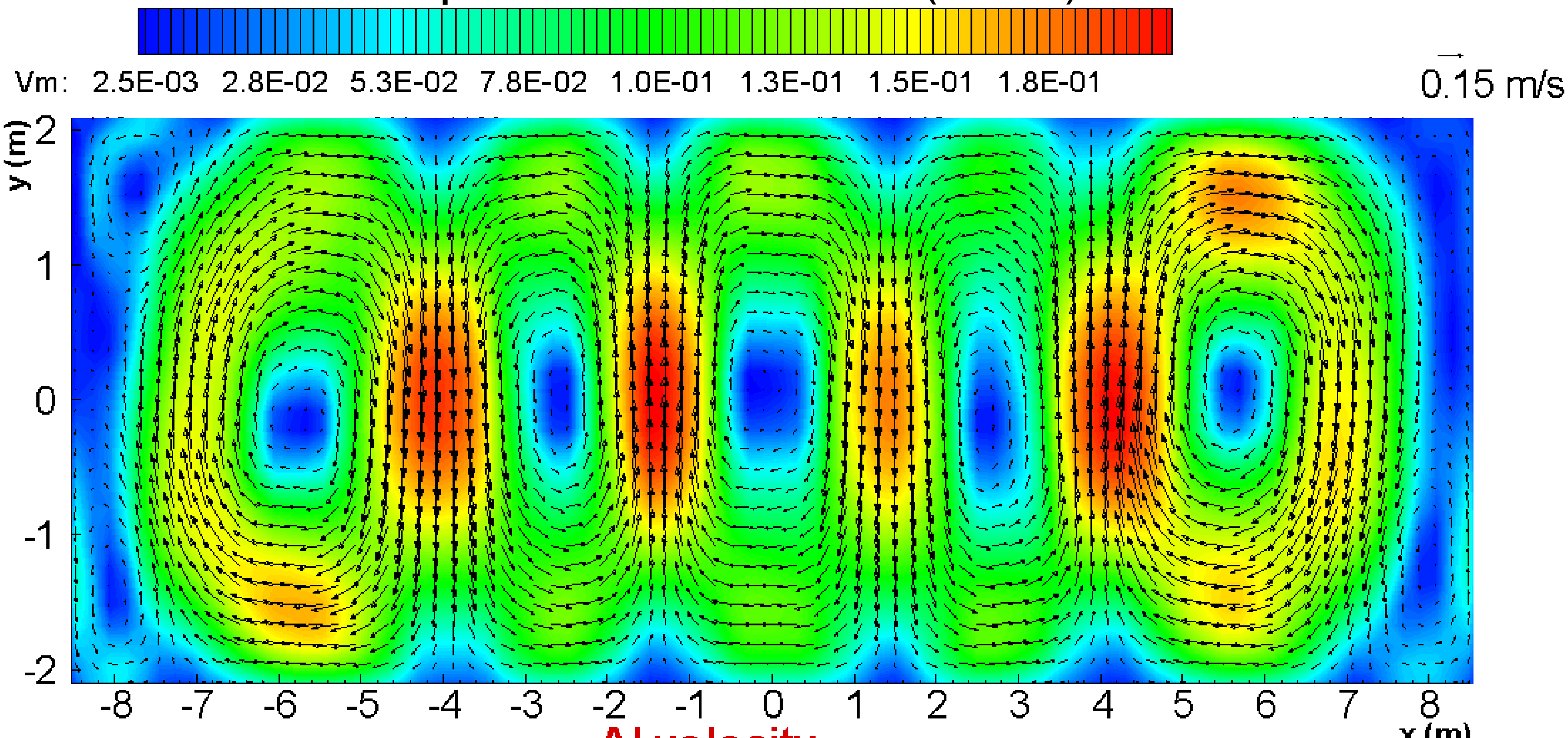


Al velocity

Steady-state metal pad flow velocity field

Busbar Network Designs Taking Advantage of 100 % Downstream Cell Current Extraction

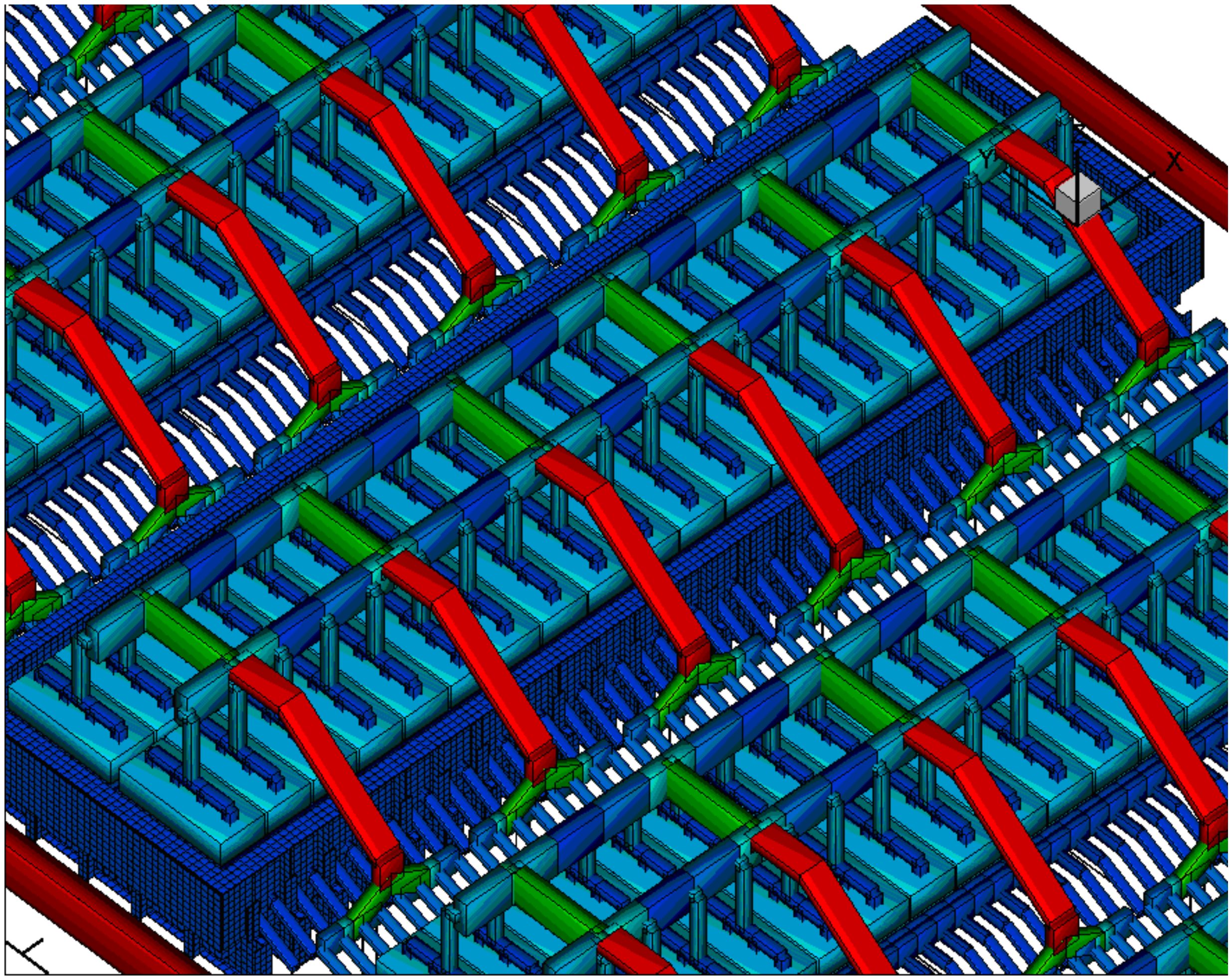
Reversed Compensation Current (RCC) busbar network

- As for the cell energy consumption of that 500 kA cell design with that new cathode design using copper collector bars extracting 100 % of its current on the downstream side and using this revised alternating anode risers RCC busbar configuration is predicted to run at 12.4 kWh/kg while operating at the same 3.5 cm ACD reported in [1].

Ref: [1] M. Dupuis and V. Bojarevics, Retrofit of a 500 kA cell design into a 600 kA cell design, ALUMINIUM 87(1/2), 2011, 52-55.

Busbar Network Designs Taking Advantage of 100 % Downstream Cell Current Extraction

External compensation current (ECC) busbar network



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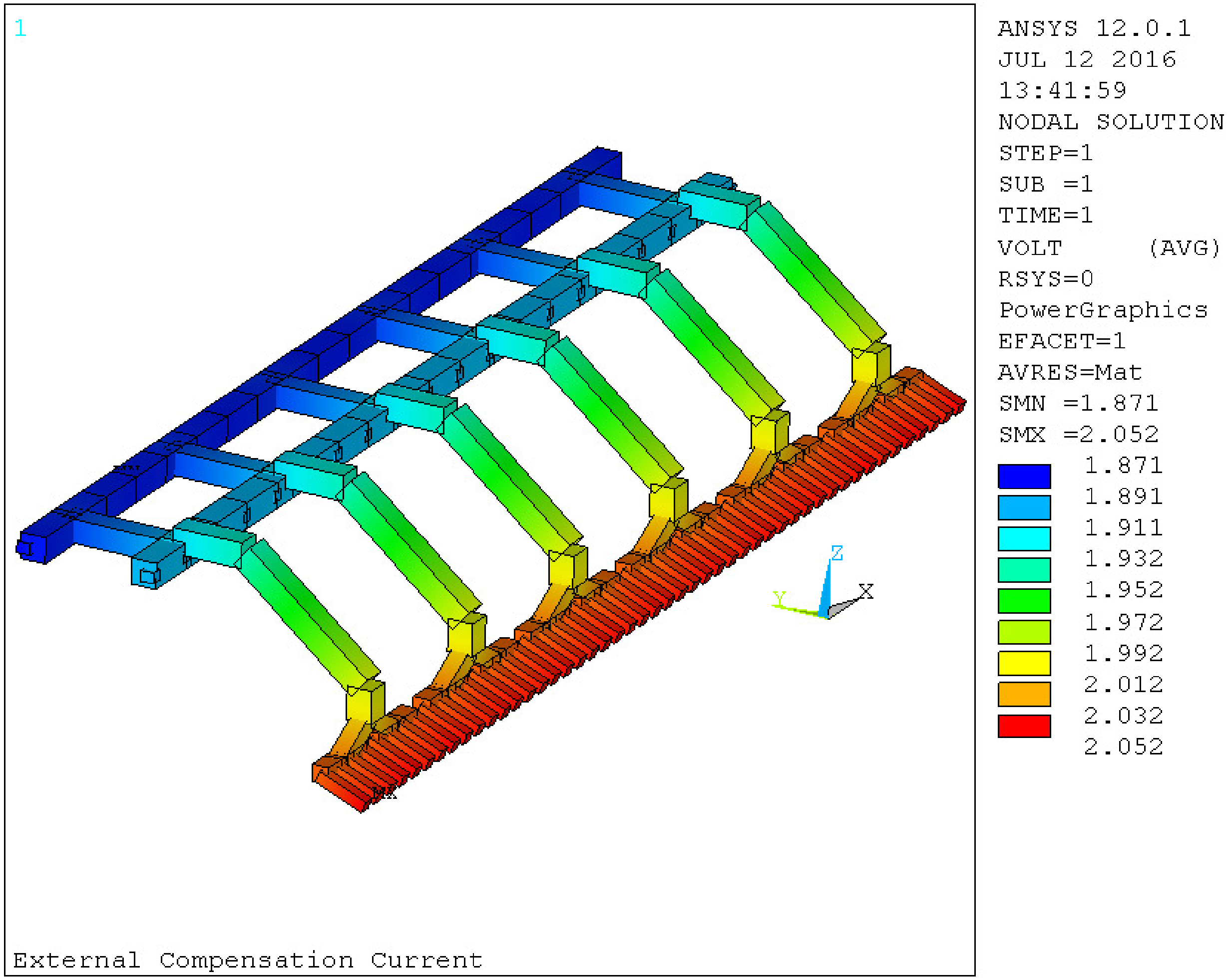

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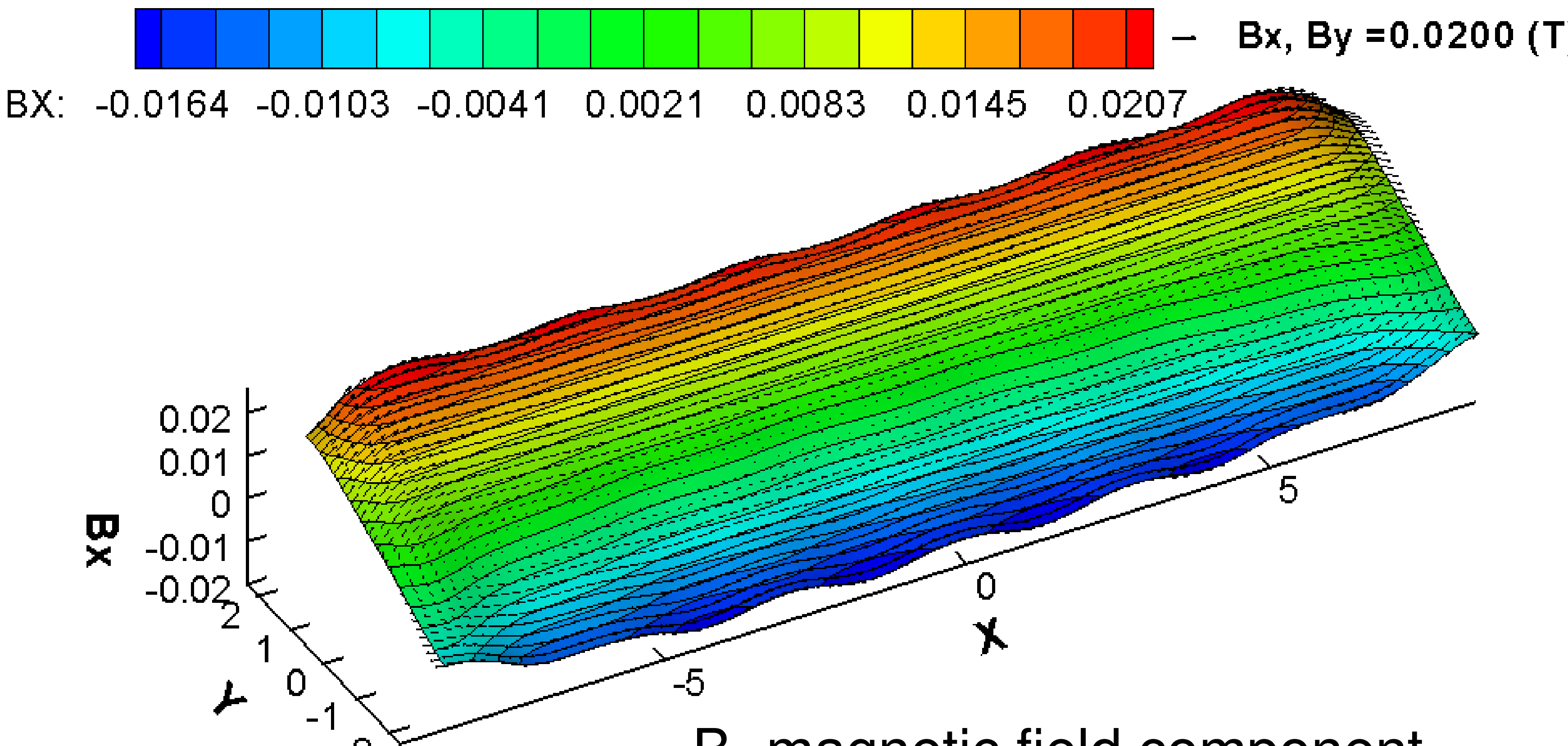

B_x magnetic field component

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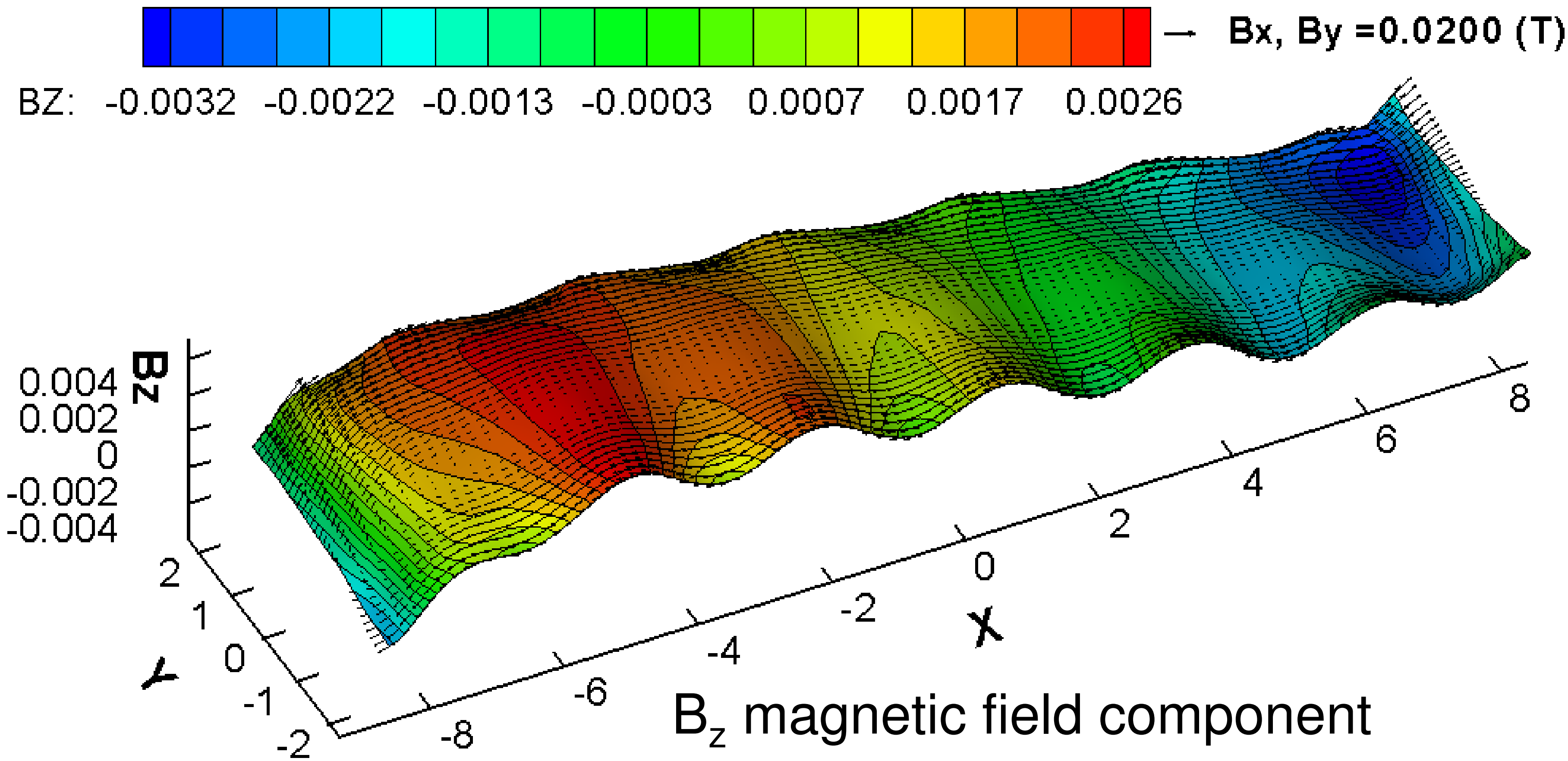

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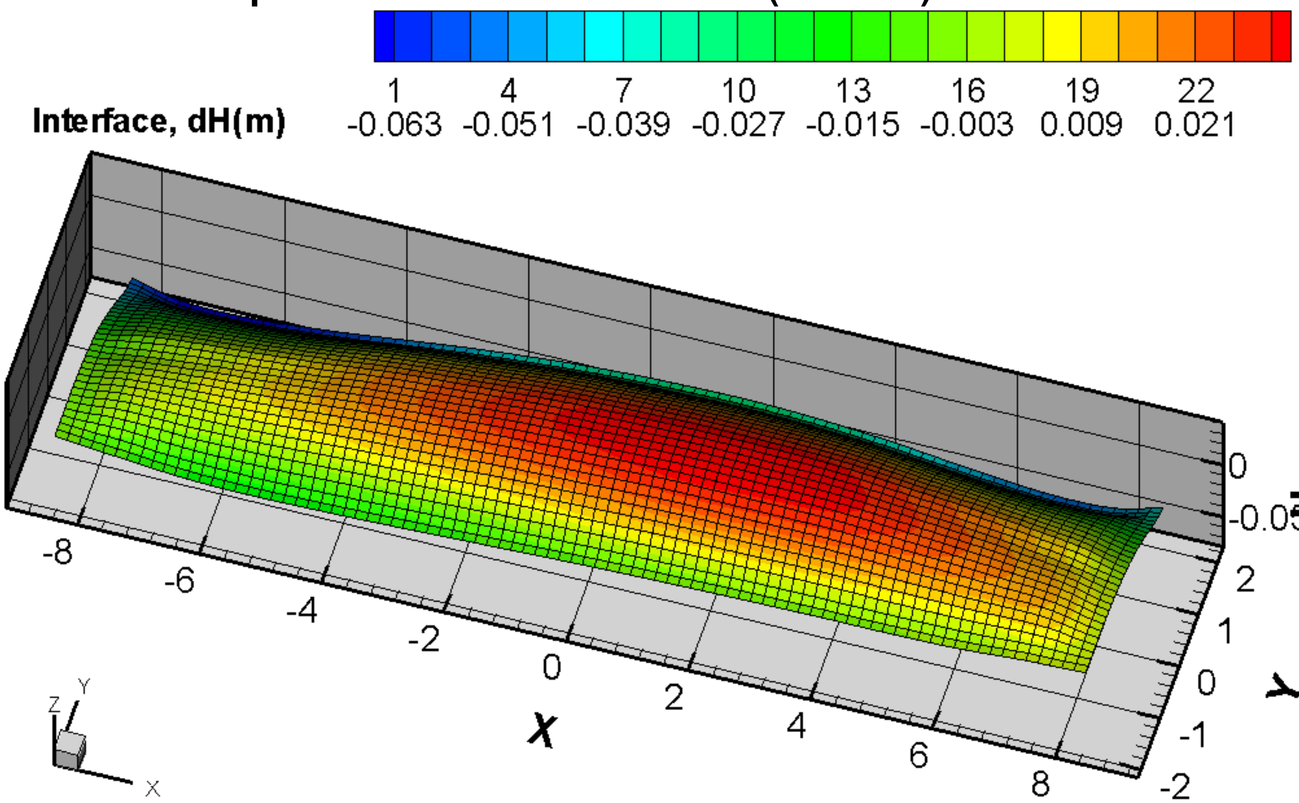

Steady-state bath-metal interface deformation

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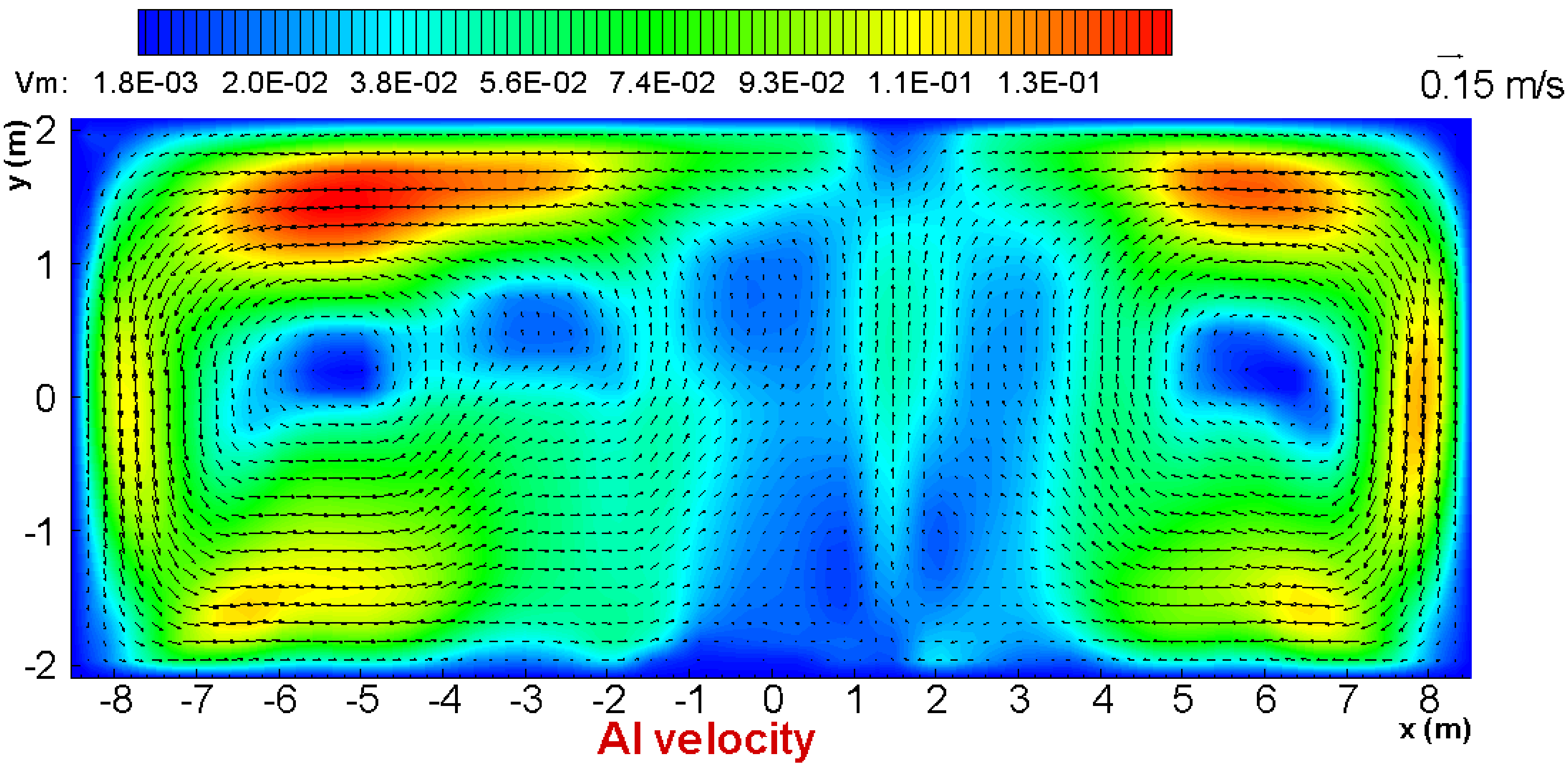


Steady-state metal pad flow velocity field

Busbar Network Designs Taking Advantage of 100 % Downstream Cell Current Extraction

External compensation current (ECC) busbar network

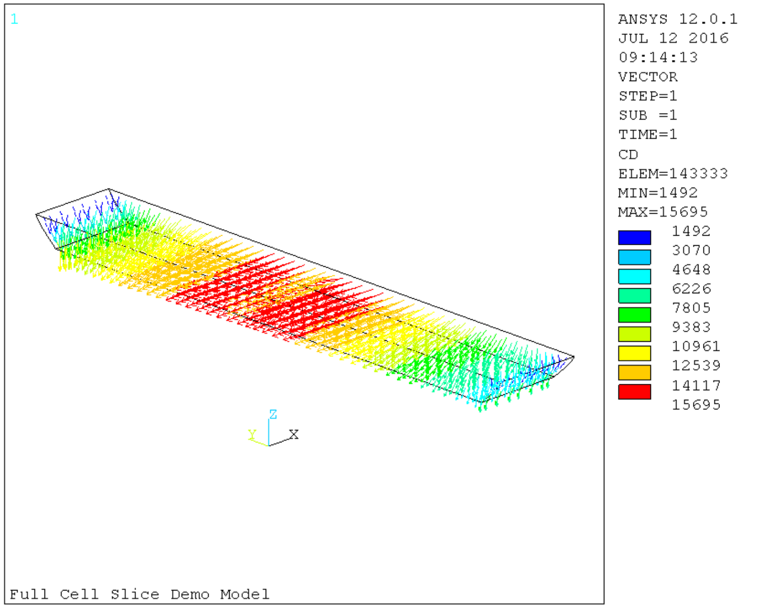
- As for the cell energy consumption of that 500 kA cell design with that new cathode design using copper collector bars extracting 100 % of its current on the downstream side and using ECC busbar configuration is predicted to operate at 12 kWh/kg while operating at the same 3.5 cm ACD reported in [1].

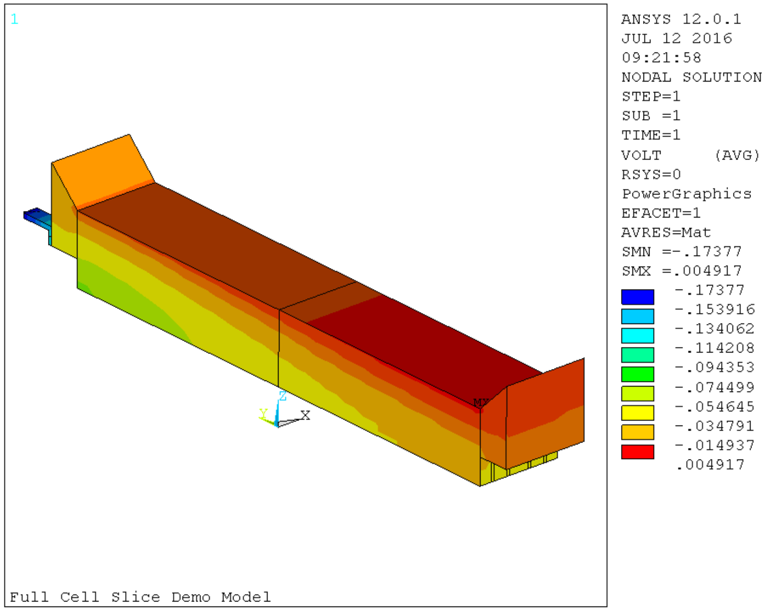
- A revised calculation was done using 3.2 cm of ACD instead of 3.5 cm as since 2011, indications are that ACD has been reduced further in low energy consumption cell prototypes. At an ACD of 3.2 cm, the predicted cell energy consumption is calculated to decrease to 11.7 kWh/kg Al.

Ref: [1] M. Dupuis and V. Bojarevics, Retrofit of a 500 kA cell design into a 600 kA cell design, ALUMINIUM 87(1/2), 2011, 52-55.

Conclusions

- The results presented demonstrated that the usage of copper collector bars with similar sizes as standard steel collector bars can be used to extract 100 % of the cell current on the cell downstream size without generating excessive horizontal current in the metal pad or generating excessive cathode voltage drop.





Conclusions

- A 500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using a revised alternating anode risers RCC busbar configuration is predicted to be MHD stable and to run at 12.4 kWh/kg while operating at 3.5 cm ACD and 0.8 A/cm2 of anode current density.

- From previous work, it can be extrapolated that a 740 kA or a 1500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using the same type of revised alternating anode risers RCC busbar configuration would work equally well at the same level of power efficiency.

- A 500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using a revised ECC busbar configuration is predicted to be MHD stable and to run at 12 kWh/kg while operating at 3.5 cm ACD or 11.7 kWh/kg while operating at 3.2 cm ACD and 0.8 A/cm2 of anode current density.