Comparison of the Calculation of the Magnetic Field and the Metal Pad Current Density from Different Models for a 330 kA Cell

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Abstract

This paper compares the magnetic field and the metal pad current density obtained using different mathematical models for a 330 kA cell.

First, an MHD-Valdis model is built using the busbar and potshell geometry defined in the SAMI magnetic model. The SAMI magnetic model [1] is based on ANSYS finite element method while MHD-Valdis magnetic model is based on the boundary element method. The magnetic field results and the CPU time requirement are compared.

Second, GeniSim's parametric CurDen electric model and GeniSim's parametric full cell slice thermo-electric (TE) models are adjusted to represent the 330 kA cell and the metal pad current density results obtained by the SAMI full cell slice model [1]. They are compared with the MHD-Valdis model and GeniSim's parametric models. For the two full cell slice thermos-electric (TE) models, it is only possible to compare the y direction horizontal current density (Jy) while for the CurDen and the MHD-Valdis models, both the horizontal current density in both x (Jx) and y directions are calculated. It was already demonstrated that both Jx and Jy are detrimental to the cell stability, hence Jx needs to be minimized too [2].

Finally, a non-linear transient cell stability analysis is performed using the MHD-VALDIS model, the only model available to perform such a cell stability analysis.

Keywords: Magnetic field, Horizontal current density, Aluminium cell, MHD stability, Mathematical models.

1. Introduction

The present work is a follow up of the work presented in SAMI's TMS 2024 paper [1]. In that paper, the modeling work performed to retrofit a 330 kA cell into a 350 kA cell is presented. Figure 1 of [1] is presenting the busbar layout as implemented in SAMI's ANSYS based magnetic model. This type of ANSYS based magnetic model was first presented in [2]. Figure 1 presents that very first ANSYS based magnetic model mesh, it is showing part of the model that Figure 1 of [1] is now showing, the 3D potshell elements and the 3D space elements inside and outside the cell. Since ANSYS is solving the magnetic field using the finite element method, it is required to mesh the space inside the cell which consists of the liquid zone where we want to know the magnetic field value but also the lining, crust, etc. and the air outside the cell where we do not necessarily want to know the magnetic field but that we need to calculate as well. Solving the magnetic field this way requires between 1 to 1.5 hours of CPU time.

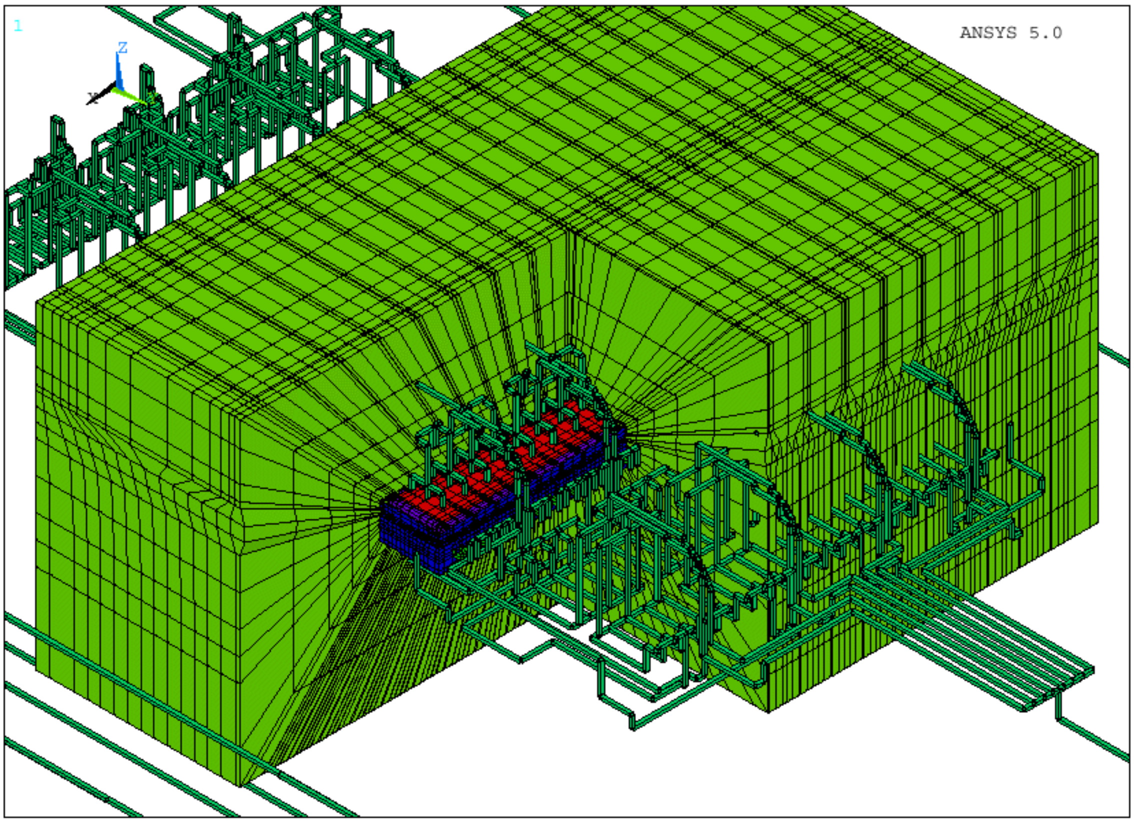

Figure 1. Finite element mesh of the very first ANSYS based magnetic model, reproduced from Figure 6 in [2].

2. MHD-VALDIS Magnetic Model of the Retrofitted 330 kA Cell Operated at 350 kA

It is possible to solve the magnetic field much more quickly using the boundary element formulation instead; which only requires meshing the conductors in 1D and the ferro-magnetic materials (potshell) in 3D as it is done in the software MHD-Valdis.

To solve the magnetic field using MHD-Valdis, it is first required to solve the busbar network thermo-electric problem. The source currents used to solve the magnetic field are coming from the solution of that first problem. In order to do so, the 3D busbar network must be represented as a simplified 1D busbar network that is entered in an input file called BUSNET. Figure 2 presents the 1D busbar layout of the retrofitted 330 kA cell, the colors are representing the obtained currents that will be used to compute the magnetic field. That thermo-electric solution is obtained in few seconds of CPU time.

The next calculation step is to compute the magnetization of the potshell ferro-magnetic material. It is a very non-linear behavior, so solving it requires many iterations. Hence solving that potshell magnetization requires between 30 minutes to 1 hour CPU time depending on the potshell mesh refinement. This must be done from scratch once, but it is possible to save the magnetization results in a file and use these results file after that in order to save this CPU time subsequently. Figure 3 presents the potshell magnetic field, notice that the same simplified potshell geometry that was used in the ANSYS model has been used in MHD-Valdis model.

investigate for any cause of discrepancies. Many causes of discrepancies could exist: the details of the representation of the busbar network using 1D line elements, the details of the setup of the convection and radiation boundary conditions on the busbar, selection of the B-H curve for the calculation of the potshell magnetization, etc.

The 4 sets of results for the transversal horizontal component of the metal pad current density field (Jy) presented here and the Jy field presented in Figure 4 of [1] are also very comparable, so again it was decided not to investigate for any cause of discrepancies. Many causes of discrepancies could exist: the setup of the ledge profile and ledge toe, the setup on the contact resistance between the cast iron and the cathode carbon block, the setup of the temperature dependent materials electrical resistivity, the setup of the convection and radiation boundary conditions in the thermo-electric models or the choice of user defined temperatures in the electric models, etc.

Considering that the set of results produced by SAMI and the set of results produced by GeniSim have been obtained totally independently, without consultation and they are in very good agreement, this is a very good sign of model results reliability.

On the design side, according to the Figure 5 and Figure 7, we can see that the Jx is smaller than Jy, so it should have less influence on the cell stability. Hence, further reduction on Jy can be investigated using models that only compute Jy, but eventually when Jx and Jy get to same magnitude, then it will become important to use models that compute both, such as CurDen or MHD-Valdis.

The final conclusion is that this model comparison demonstrates that the MHD-Valdis code for electric, magnetic and CFD calculations is quite reliable and efficient.

10. References

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