Magnetic Modelling
11/06/2013

So having had a look through my slides from last week I've pretty much achieved none of what I set out to achieve but I have made quite a bit of progress with a new sub model.

What have I not achieved… (We can all make huge ppt presentations like this!)

- Need to complete autogen images for model 90 set
- Need to run comparison of model 90 with model 60 to check for mesh convergence
- Need to run quad sub-model – Tried for 2 days to get this to work (I'll come back to this…)
- CM talk – Made progress but not complete. Note talk time has been reduced to 20 mins so I will only have room for a couple of slides from Melissa. Will circulate on Thursday after I have visited Vector Fields with Mike.

I'm having a lot of trouble getting the quad sub model to work – but like the last set of troubles the problem is not revealing itself until we get beyond the meshing, in this case when we get to the "create model database" part of the model creation process. This is the final part of the process before the model is solved.

Symptoms:

- Modeller quits unexpectedly.
- Modeller throws an unhelpful error.

There are no errors in the model at the meshing/volume meshing stage so we are in difficult territory again. By running a series of tests on my quad sub-model I thought that I had found the part of the code that was causing the problem but the waters are being muddied as I'm starting to gather some evidence that OPERA 16 **may** have a subtle issue of its own. (bold to pre-empt any libel in case I'm wrong). I'll come back to this shortly.

First a whinge (although I know I'm complaining at the wrong people!) One of the illuminating errors that I have from the modeller reads:

N3DSF_Tet: negative Jacobian determinant
Command file processing aborted.

And after enquiring about this the reply I received from VF:

"Creating the database, additional checks are performed. I can not remember seeing this message in the Modeller, but sometimes we got this message in the old Pre-Processor when there was a problem with the mesh (twisted inside-out elements). Regrettably there are no indicators available to help you identifying the troublesome cells. The only way forward is to figure out what is different between the model "Quad_Sub_Model_10.op3" and previous models."

My interpretation:

So basically our software is giving you an error that we don't really understand and so you're on your own.

I can tell you what has changed in the model: Most of the mesh so it's not helpful. That's what we've just spent the last few weeks revising the hall model for. (The quad sub-model is based on the hall model) There is no small change between this and the previous quad sub-model to compare with…so really I'm stuck.

But now lets get to my other concern:

Often in Opera 16 a model seems to fail for no reason (it crashes at the modeller stage or it falls over at the solver stage) and then you re-run the exact same model and it seems to work…

As you can imagine this took me a while to find because rerunning a model that has failed without changing anything is not the first thing you would think of doing.

Evidence: Look at these two snippets from logs (Exactly the same model – no changes to the code– but this is a sub-station model!) I must point out the log on the right hasn't finished solving yet but I noticed exactly the same pattern the other day in another log file - but I haven't had chance to dig that one out and I may have overwrote it (duh)

```
Total number of field calculations: 0
Average number of field calculations per edge: 0.0
Calculating edge integral coil fields  complete 00:00

External fields with drive label (None)
SSORCG iterations: 598, relative change=9.62986223444
Error in nodal potential jump calculation: 2.9973E-09
Calculating nodal potential jump       complete 00:00

External fields with drive label (None)
Calculating face integrals of Nodal WH.n over 71624 f
  Coil field integrals computed over 7162 faces
  Coil field integrals computed over 14324 faces
  Coil field integrals computed over 21486 faces
  Coil field integrals computed over 28648 faces
  Coil field integrals computed over 35810 faces
  Coil field integrals computed over 42972 faces
  Coil field integrals computed over 50134 faces
  Coil field integrals computed over 57296 faces
  Coil field integrals computed over 64458 faces
  Coil field integrals computed over 71620 faces
Total number of field calculations: 0
Average number of field calculations per face: 0.0
Calculating face integral coil fields  complete 00:00
Evaluating coil field calculations     complete 00:01
Residual tolerance for nonlinear convergence: 1.0E-08
Initial residual: NaN

Nonlinear iteration 1                  started at 23
Simple nonlinear update
```

```
Total number of field calculations: 0
Average number of field calculations per edge: 0.0
Calculating edge integral coil fields  complete 00:00

External fields with drive label (None)
SSORCG iterations: 598, relative change=9.62986223444(
Error in nodal potential jump calculation: 2.9973E-09
Calculating nodal potential jump       complete 00:00

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  Coil field integrals computed over 7162 faces
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  Coil field integrals computed over 42972 faces
  Coil field integrals computed over 50134 faces
  Coil field integrals computed over 57296 faces
  Coil field integrals computed over 64458 faces
  Coil field integrals computed over 71620 faces
Total number of field calculations: 0
Average number of field calculations per face: 0.0
Calculating face integral coil fields  complete 00:00
Evaluating coil field calculations     complete 00:00
Residual tolerance for nonlinear convergence: 1.0E-08
Initial residual: 0.3956594

Nonlinear iteration 1                  started at 11
Simple nonlinear update
```

Both of these logs are from exactly the same model and the code hasn't been touched– The model on the LHS crashed last night with some horrible errors (which didn't get logged) The model on the right is currently running – touch wood it will solve. This code has previously solved – you will be seeing the results in a minute. The only difference between the solved code and the version that gave the above logs is a tiny meshing tweak.

I'm wondering if my Quad model errors are due to a similar problem…

I will continue to collect evidence on this. VF state that no one else has had problems.

I have had to leave the Quad sub model issue for now to move onto the sub-station. I will return to the Quad sub model when I get another Opera Licence as it is too time consuming to keep letting the model run to fail. I want to try the quad sub model on OPERA 15R2 to see how it fairs on the old version of OPERA

I have started to build a simplified model of the substation.

Not sure if this is the right approach but I need to start somewhere….

Use the old rack generator code to generate 3 boxes which have a 2mm skin.

Superimpose an external field onto the boundary conditions (At the moment I have assumed Bz of 5 gauss but this needs checking)

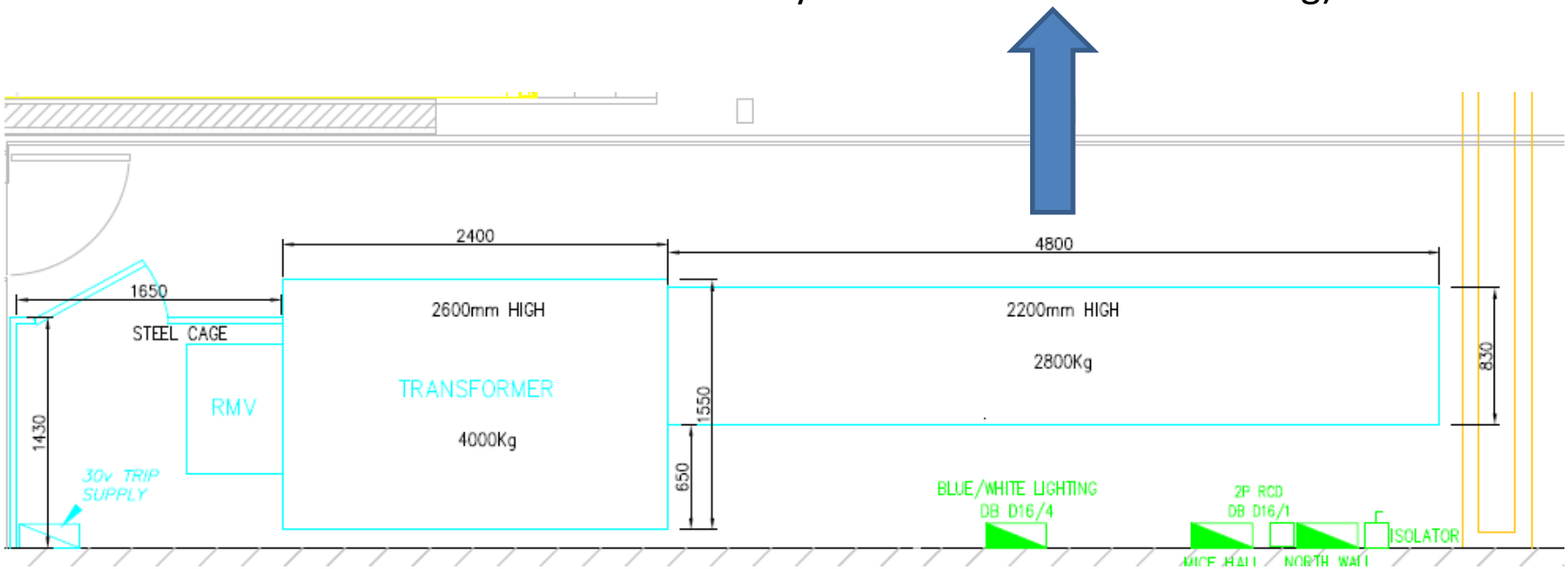
High meshing resolution – This small model has more elements than the hall model! (Roughly meshing resolution is 10 times higher than I can achieve in hall model.)

Only just started to get the model to work but it solves in about 4-5 hours in a single iteration.

A few slides to show where I am and what I have got but I wouldn't yet classify these as results…

Steel skin is assumed to be 2mm thick. –Modelled as mild steel.

I've moved this section forward 70mm in my model to get alignment with transformer (Makes my life a lot easier with meshing)

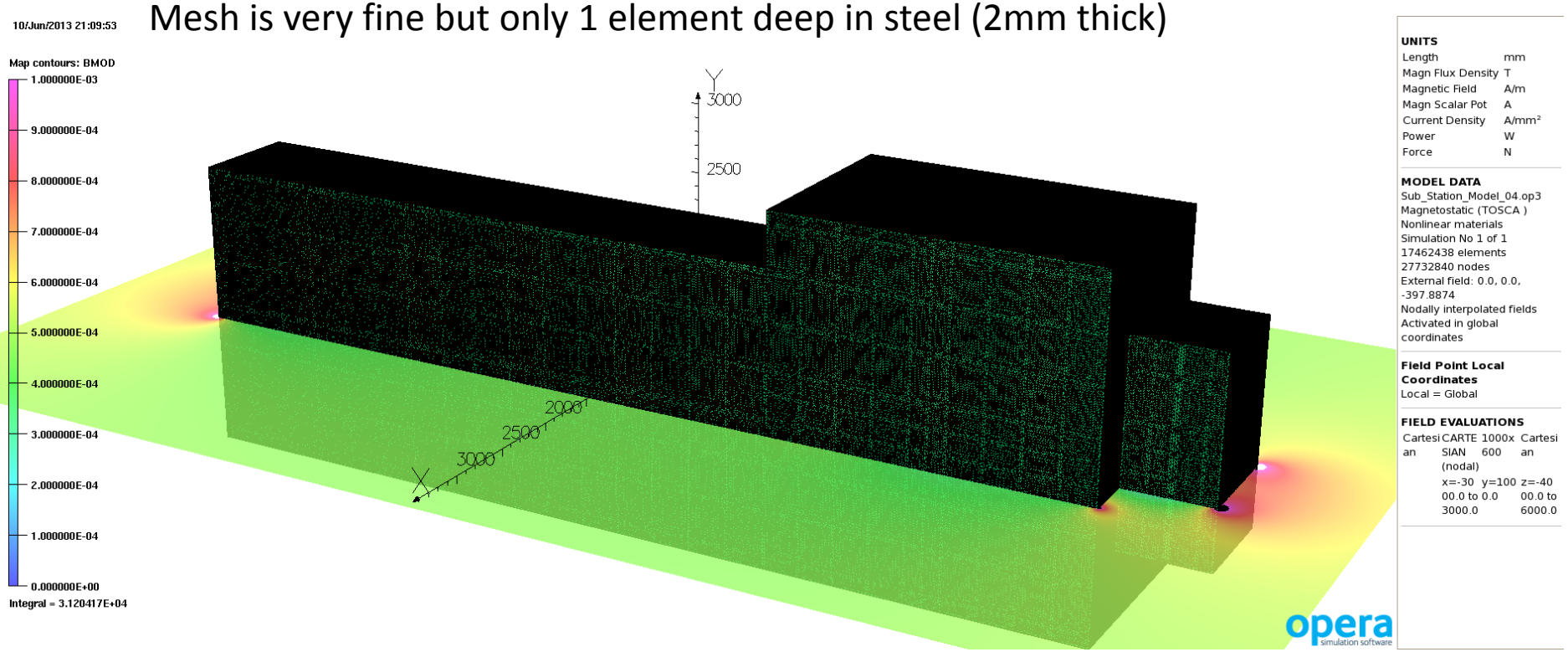


RMU Transformer Controls

Note Current Mass in Model:

Controls & RMU = 258kg (skin) + 43Kg(skin) = 301kg (~ 0.11 actual Mass)
Transformer = 220Kg (skin) + 3780kg(centre) = 4000kg

Mesh is very fine but only 1 element deep in steel (2mm thick)

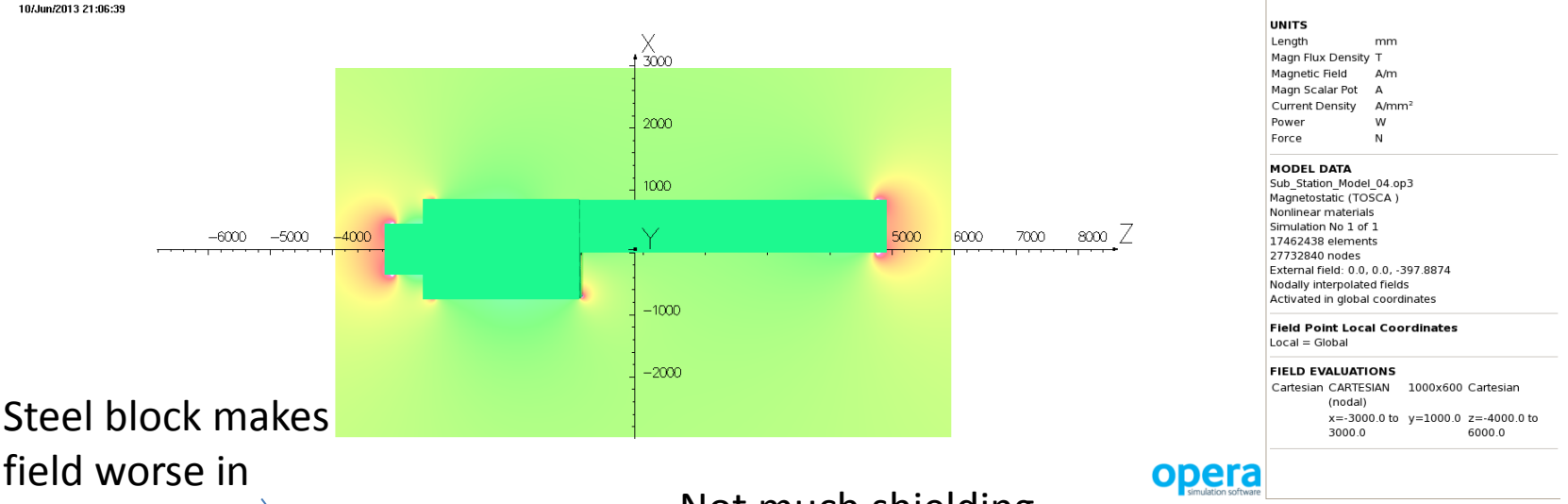


Note Current Volumes in Model:

Controls & RMU Steel Volume in Skin = 0.0323 m3 + 0.0055 m3 = 0.0378 m3
Total Internal Volume ~ 8.76 m3 + 0.8m3 = 9.56 m3
Fraction = 252

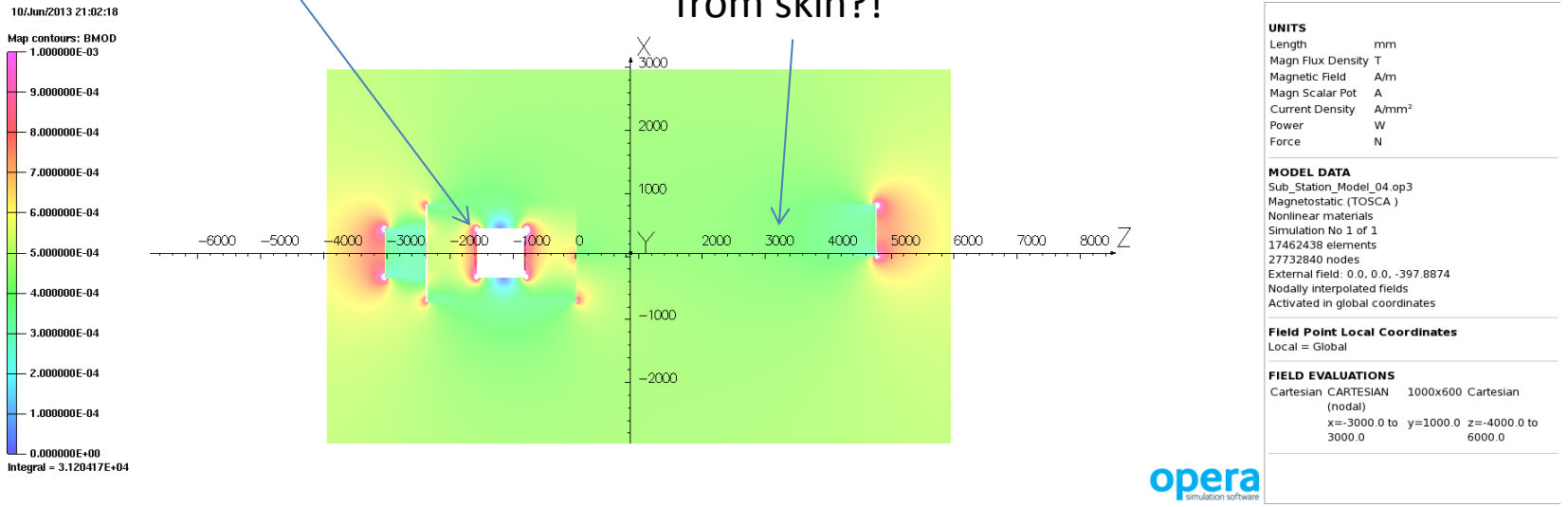
Transformer Steel Volume in Skin = 0.028 m3
Total Internal Volume = 9.67 m3
Fraction = 345

Not sure I understand all of the results from preliminary model…

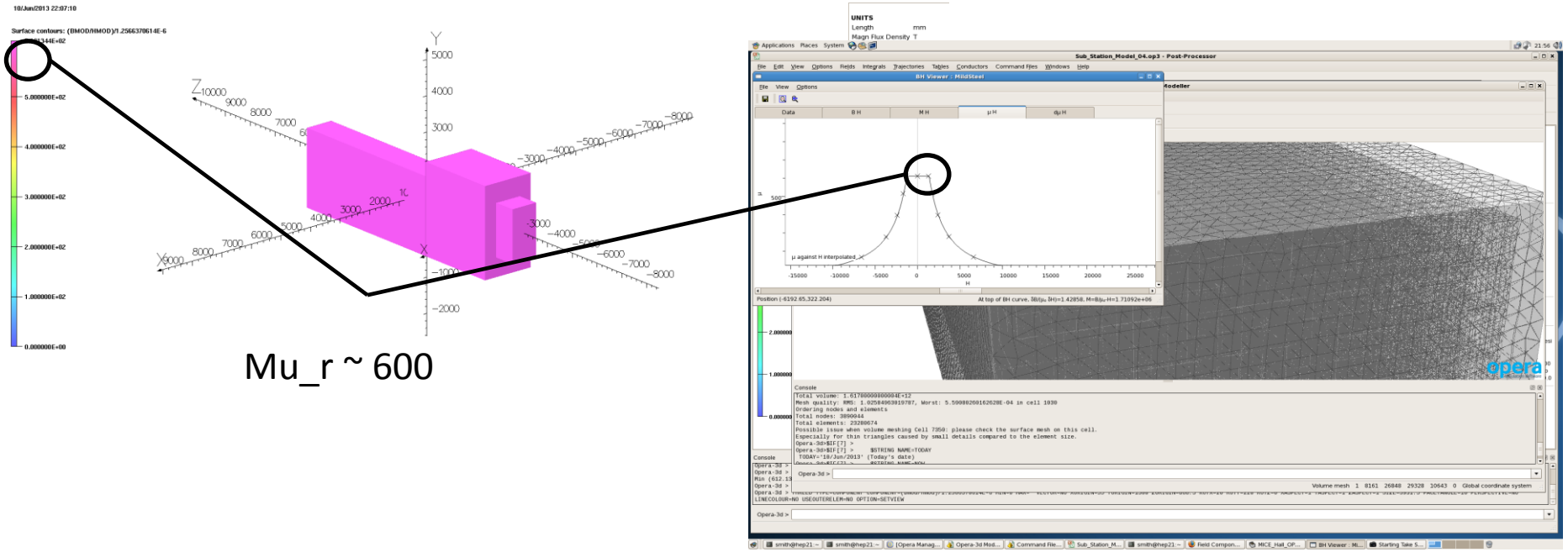


Steel block makes field worse in transformer

Not much shielding from skin?!



Plot of Bmod 10 gauss scale



Acting like a bar magnet (ok this I get)
The 2mm skin does not seem to be shielding the inside of the substation at all.

This is interesting. The mu_r is operating at about 600. However the volume of the substation/volume of steel is running at ~200-300. Of course flux travels into steel from outside of substation as well so perhaps this would indicate that there is just not enough steel in the skin to shield the inside of the sub-station?

Thoughts from anyone? Note that a lot of the steel mass is missing from the controls section of the model…. (We only have 300kg out of 2800kg but this doesn't change the skin depth, just structural components inside the substation)

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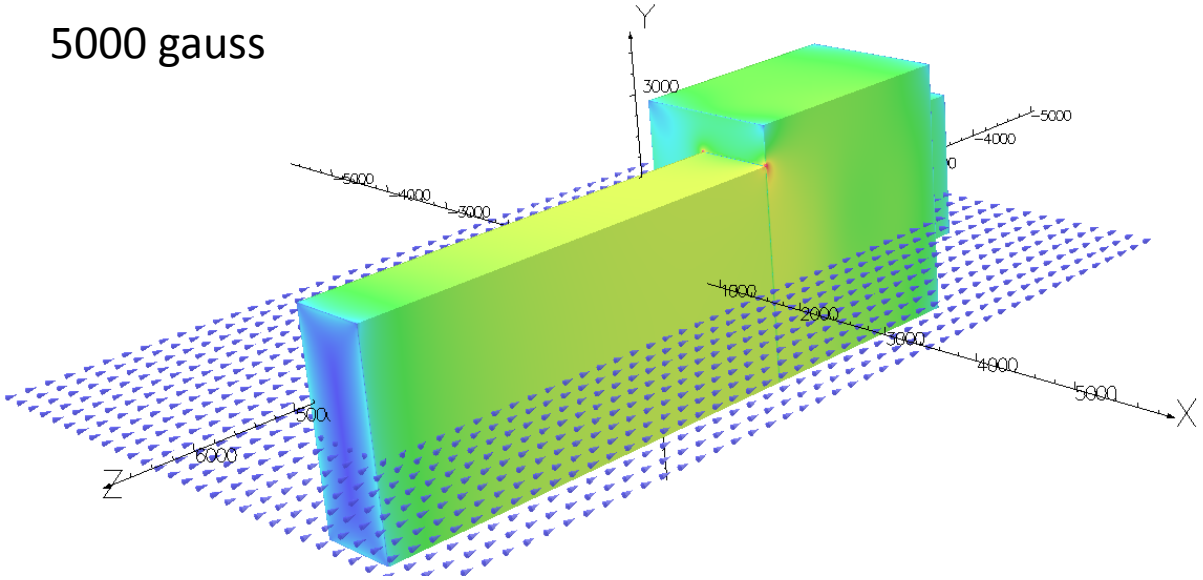
Map vectors: B

5.000000E-01
4.500000E-01
4.000000E-01
3.500000E-01
3.000000E-01
2.500000E-01
2.000000E-01
1.500000E-01
1.000000E-01
5.000000E-02
0.000000E+00

5000 gauss



UNITS

Length	mm
Magn Flux Density	T
Magnetic Field	A/m
Magn Scalar Pot	A
Current Density	A/mm²
Power	W
Force	N

MODEL DATA

Sub_Station_Model_04.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 1 of 1
17462438 elements
27732840 nodes
External field: 0.0, 0.0, -397.8874
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates

Local = Global

FIELD EVALUATIONS

Cartesian	CARTESIAN (nodal)	45x30	Cartesian
	x=-3000.0 to 3000.0	y=1000.0	z=-3000.0 to 6000.0

opera simulation software

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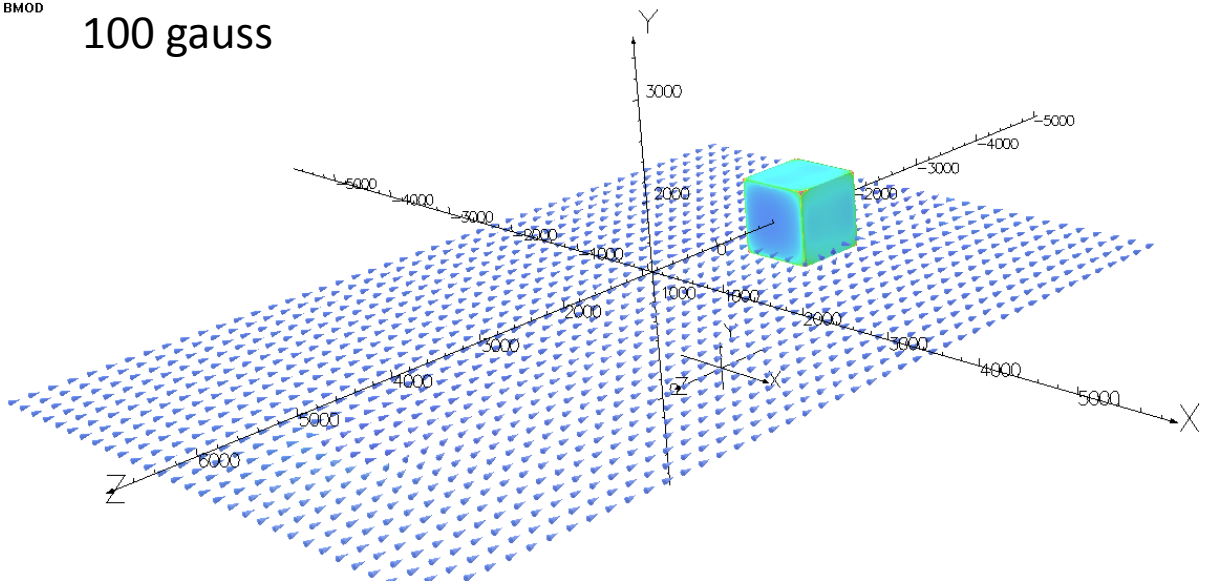
Surface contours: BMOD

1.000000E-02
9.000000E-03
8.000000E-03
7.000000E-03
6.000000E-03
5.000000E-03
4.000000E-03
3.000000E-03
2.000000E-03
1.000000E-03
0.000000E+00

100 gauss



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opera simulation software

Field in skin of substation – Note: Different scales on plots.

Plans:

Get a better estimate of external field on the substation

Make some holes in the substation to see what happens to the field around those holes

To consider what to do with the missing steel mass on the controls section…