Magnetic Modelling Update
20/08/2013

Sub Station

P J Smith

Hall Model 113 includes 5300 KG of steel in a shell approximation of the substation in order to get a feel for whether the addition of this steel would affect the local field distribution. – Next few slides

Prior to this I had been running some sub models of the sub station with an external field of 5 Gauss. The 5 Gauss was a deliberate over-estimation based upon the 1-2 Gauss observed in model 91.

The sub models were based upon a series of racks with a rack skin thickness of 2mm, This gives a complete sub-station mass of approximately 1000kg. This 'missing' mass is significantly short of the 5300kg but as I was primarily interested in what happens to the field around 'holes' placed in the steel skin of these racks and so this additional mass is missing from these models.

The missing mass could be added as a lump in the centre of each rack but is this a realistic distribution? Would we gain anything? It could be done but I'm not sure I have the time now to do this and rerun the simulations.

To aid the fine meshing in the model the Transformer section is undersized. Realistically modelling this the geometry of the substation and keeping the many layers across the 2mm of steel would be challenging…

A list of substation models/submodels that have been run.

Sub_Station_02_Model_17
Model Element Type: Quadratic. Surface Element Type: Quadratic.
This is the same as model 13 except that this is a quadratic solve.

Sub_Station_02_Model_16
Model Element Type: Quadratic. Surface Element Type: Quadratic.
This is the same as model 13 except that the field runs East to West (+z).
Note this is a quadratic solve.

Taken a couple of 'window' plots from these files.

Sub_Station_02_Model_15
Model Element Type: Quadratic. Surface Element Type: Quadratic.
This is the same as model 14 except that the field runs East to West (+z).
Note this is a quadratic solve.

Sub_Station_02_Model_14
Model Element Type: Quadratic. Surface Element Type: Quadratic.
This has a large cutout in each rack. Note this is a quadratic solve.

Mostly used these files for today's results

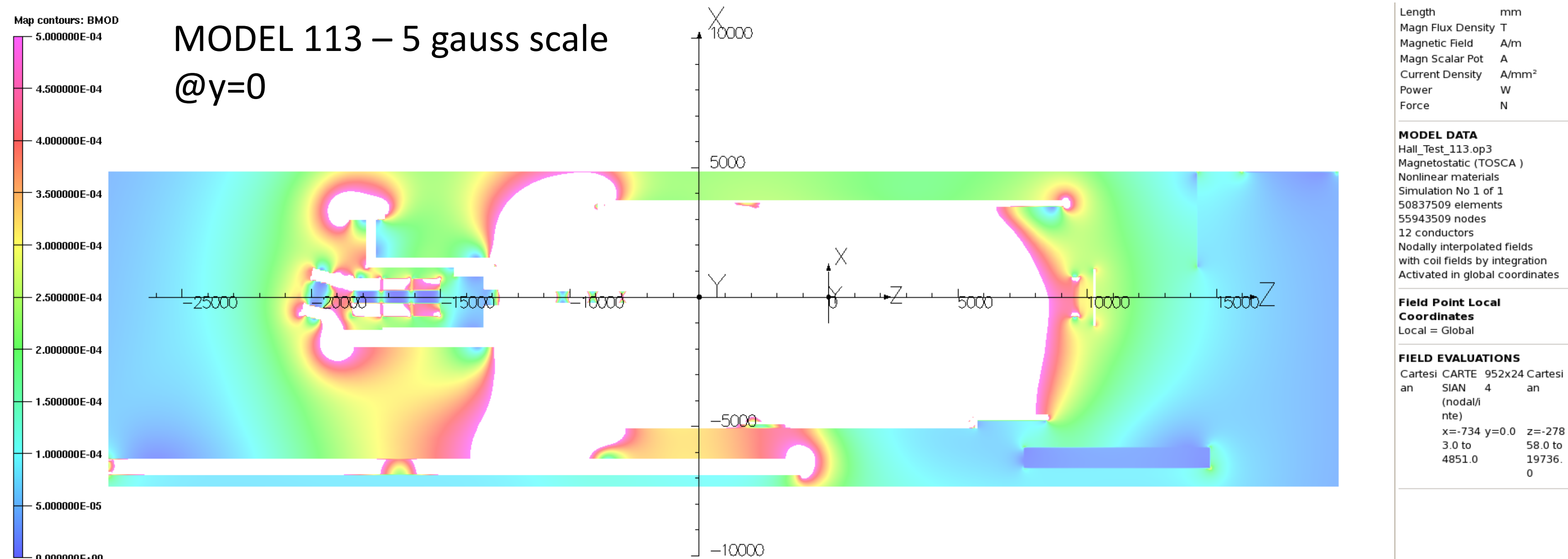
Sub_Station_02_Model_13
Model Element Type: Linear. Surface Element Type: Curved.
This has 4 small cutouts in each rack. Note this is linear solve.

Sub_Station_02_Model_12
Model Element Type: Linear. Surface Element Type: Curved.
DO NOT USE THIS SOLUTION AS ALTHOUGH THIS MODEL SOLVED IT HAD MESHING ERRORS

model_113
Model Element Type = Linear. Surface Element Type = Quadratic.
Magnet Configuration: Step IV Solenoid Mode - 240MeV/c - No return yoke.
This model includes an approximate outline of the substation
with iron mass represented in the outer skin -5300kg.

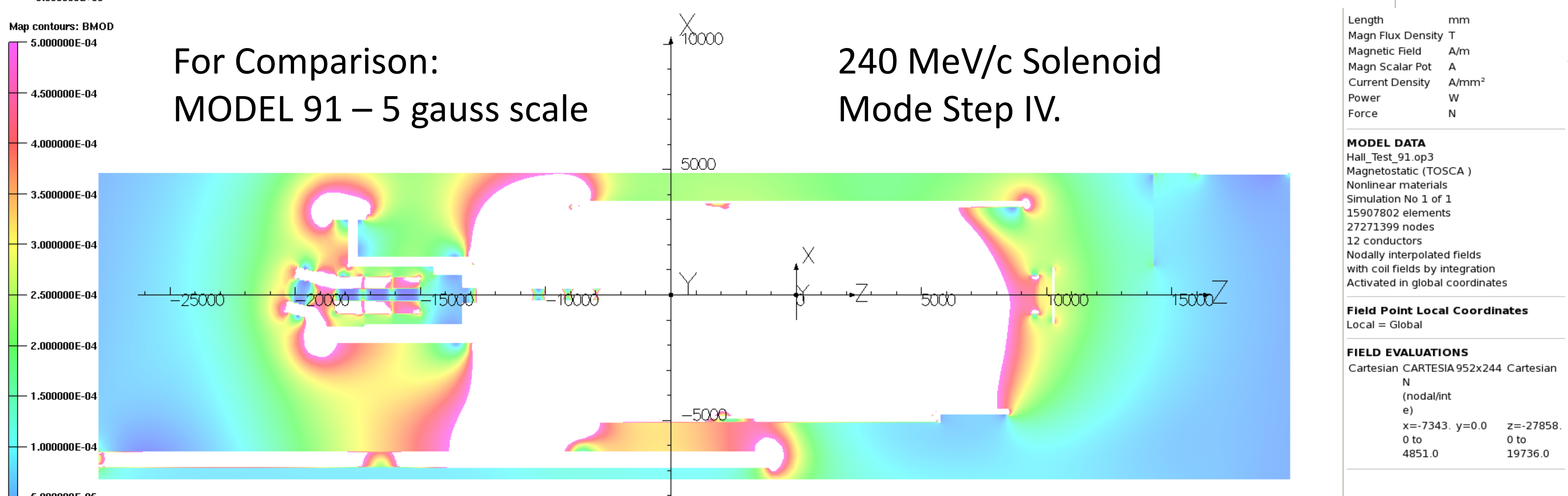
The Hall model file that includes the mass of the substation

MODEL 113 – 5 gauss scale @y=0



For Comparison:
MODEL 91 – 5 gauss scale

240 MeV/c Solenoid
Mode Step IV.

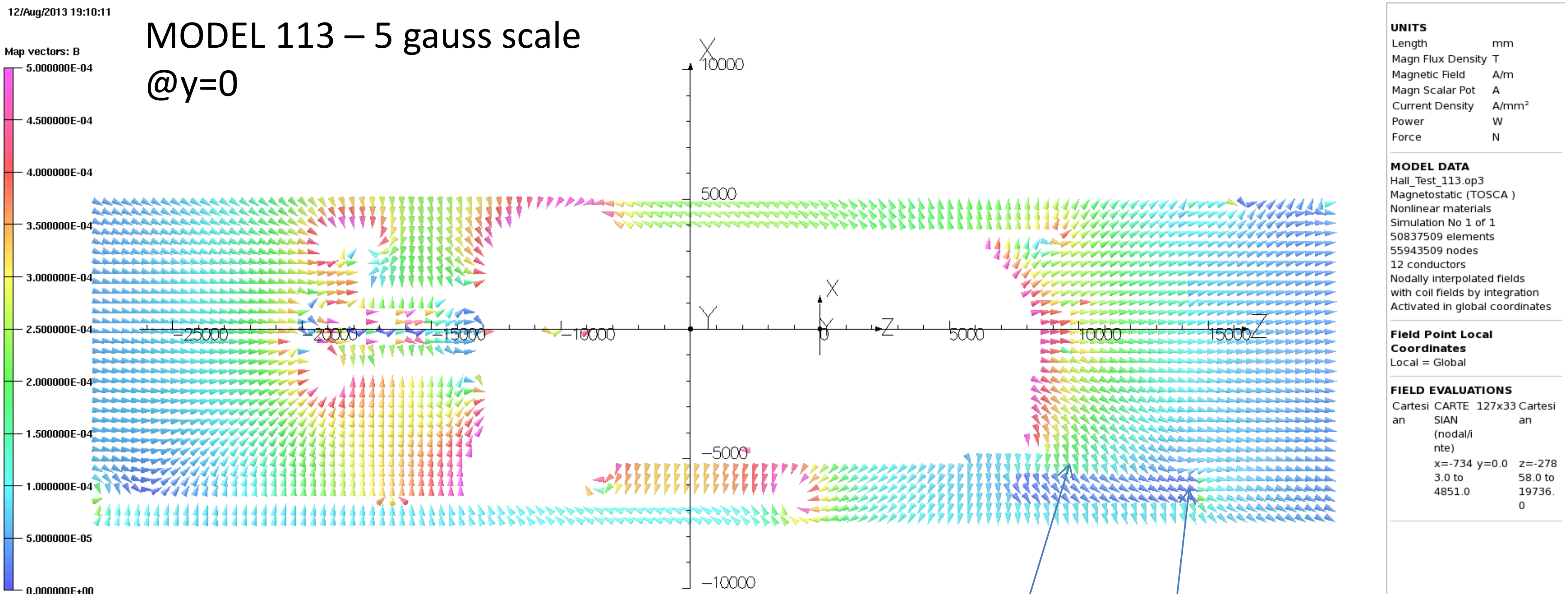


5.000000E-05
0.000000E+00
Integral = 1.894551E+07

As the sub-models assume the substation sits in an external field of 5 gauss we can see that this is probably an overestimate.

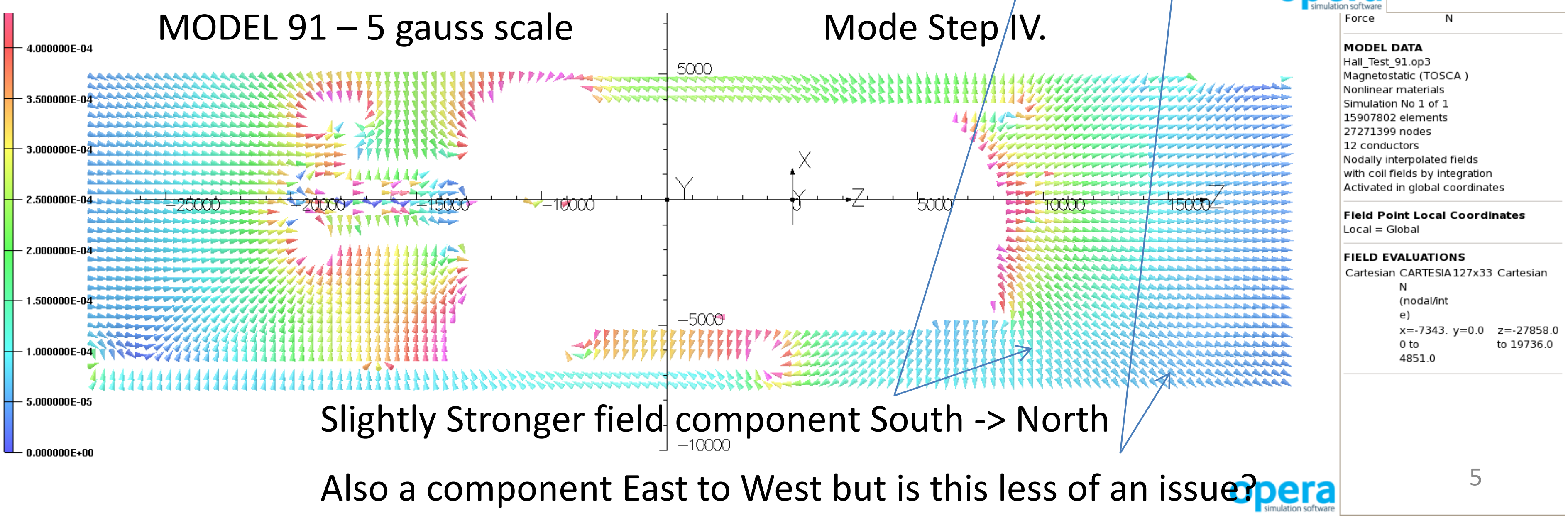
opera simulation software

MODEL 113 – 5 gauss scale
@y=0



For Comparison:
MODEL 91 – 5 gauss scale

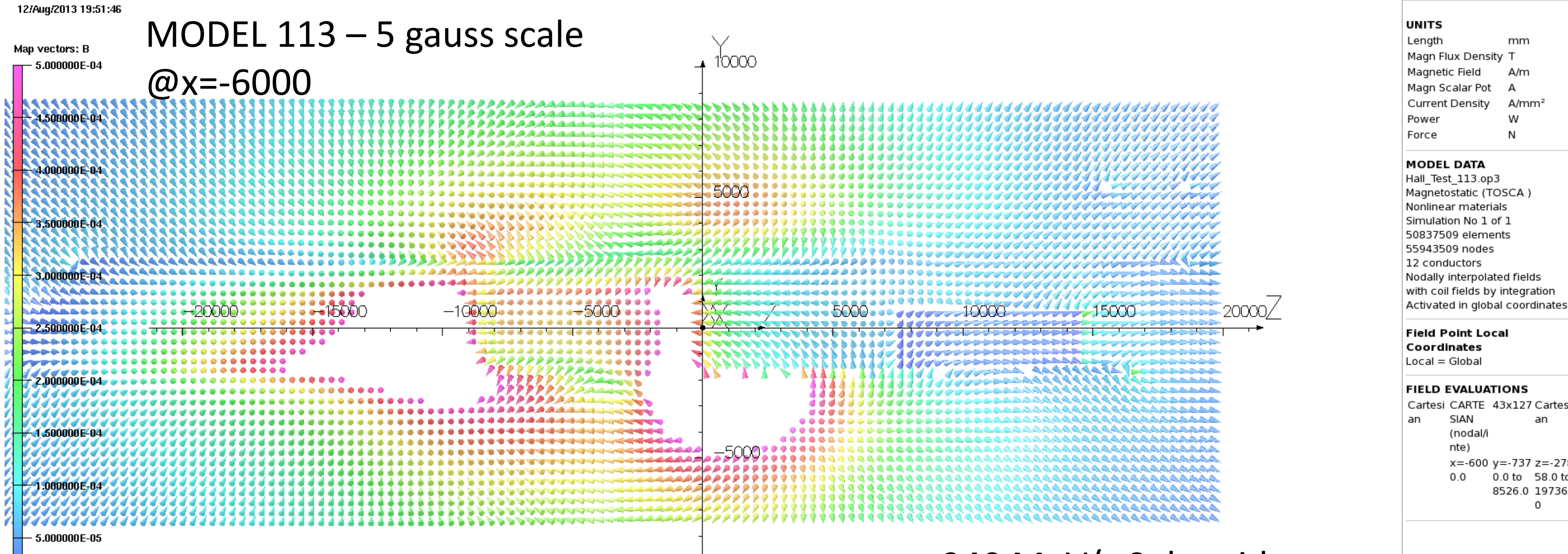
240 MeV/c Solenoid
Mode Step IV.



Slightly Stronger field component South -> North

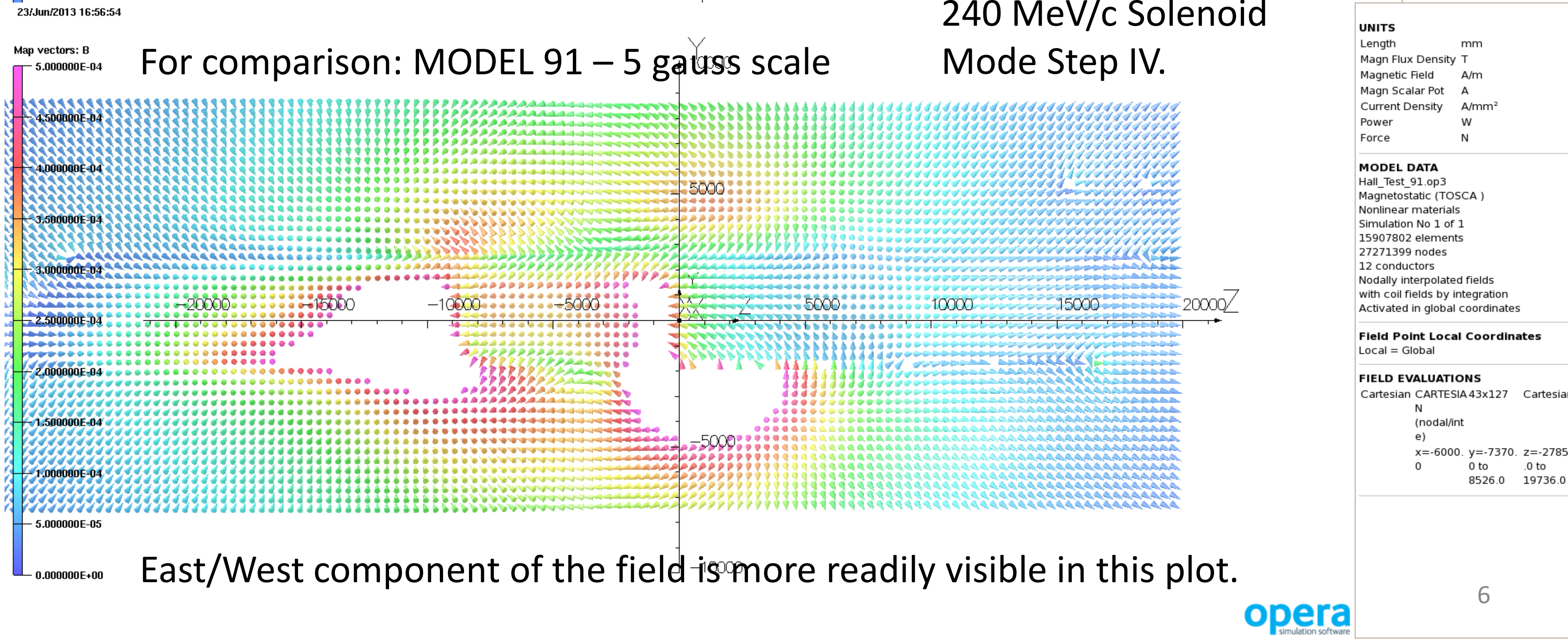
Also a component East to West but is this less of an issue?

MODEL 113 – 5 gauss scale @x=-6000

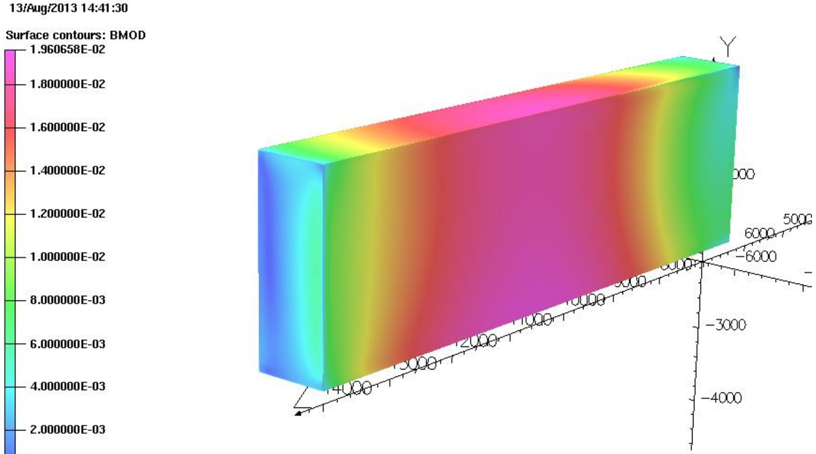


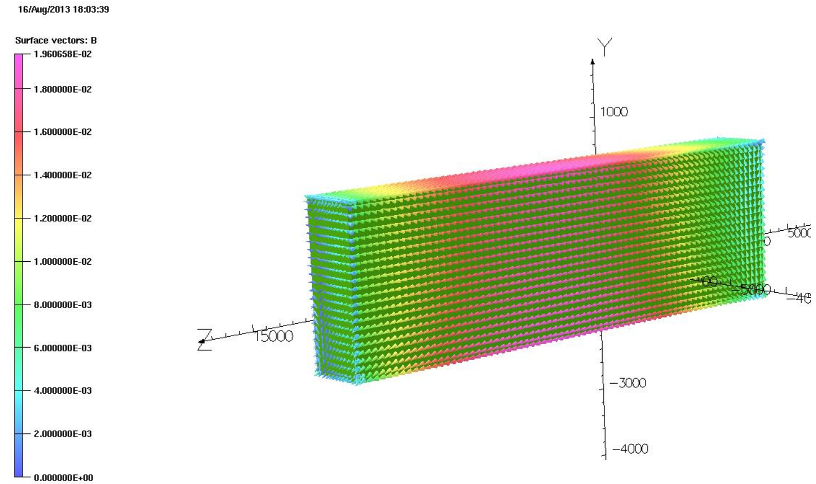
240 MeV/c Solenoid Mode Step IV.

For comparison: MODEL 91 – 5 gauss scale

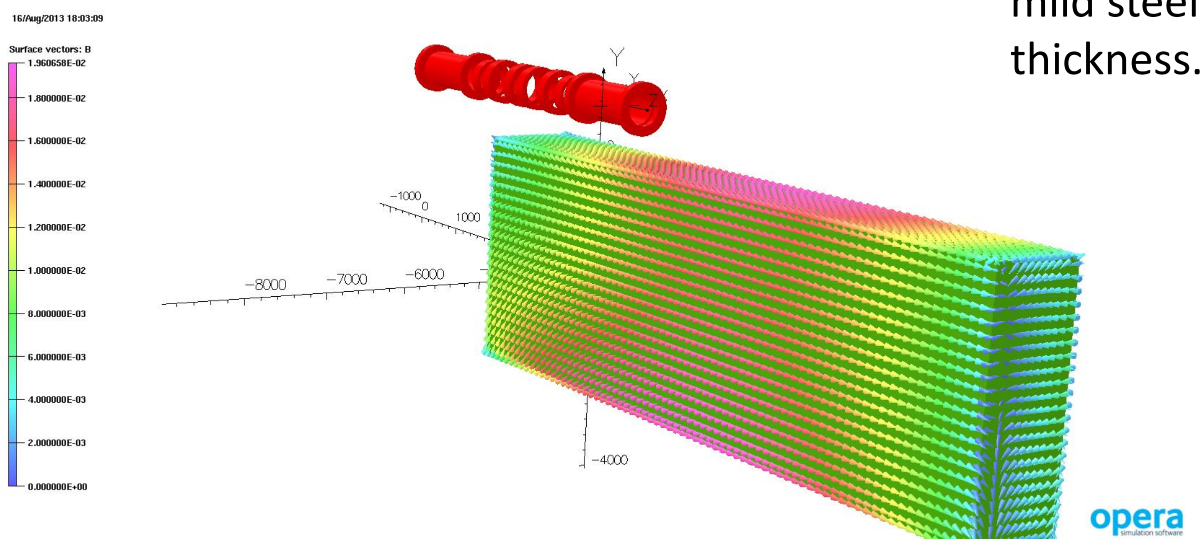


East/West component of the field is more readily visible in this plot.





This is a single block of mild steel ~14mm wall thickness.



From Hall Model 113 – Bmod of Steel and Vector Plots

Sub Station Sub Model Plots…

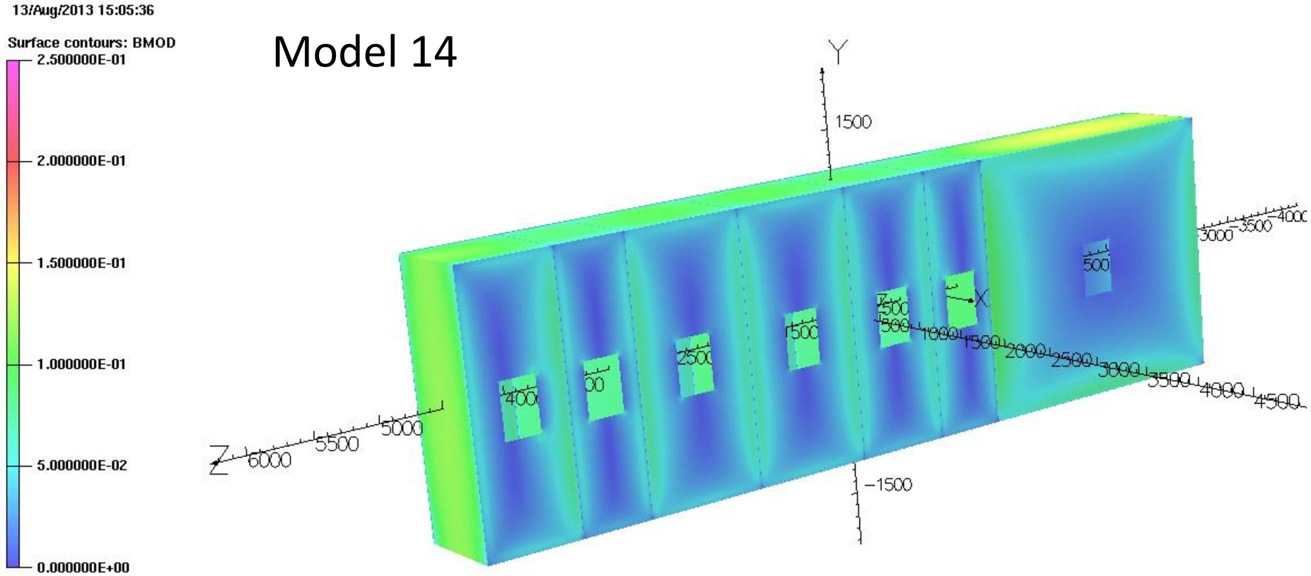
I’m just going to initially look at model 14, this has a single large window in each rack, with a field from +x. Each window is 450mm x 300mm.

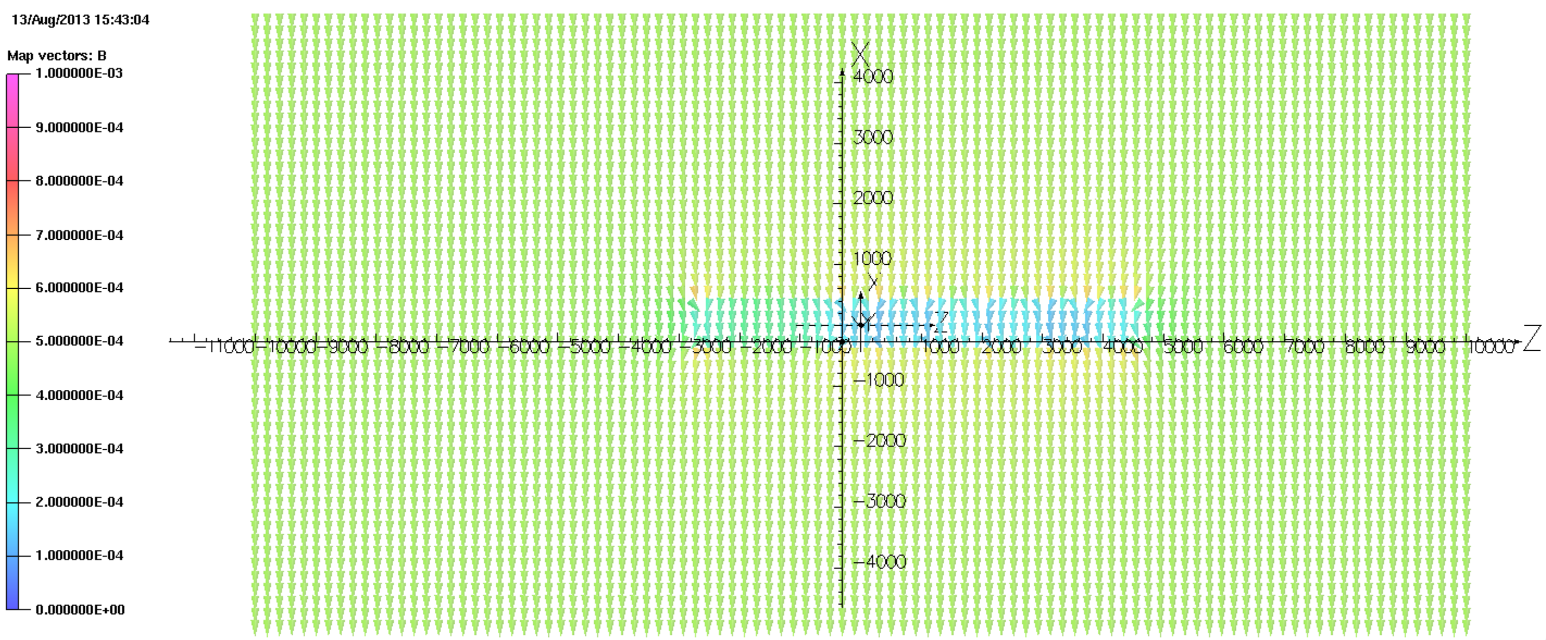
I’m then going to compare this with the results from model 15 (Single Large Window in each rack) with field from –z.

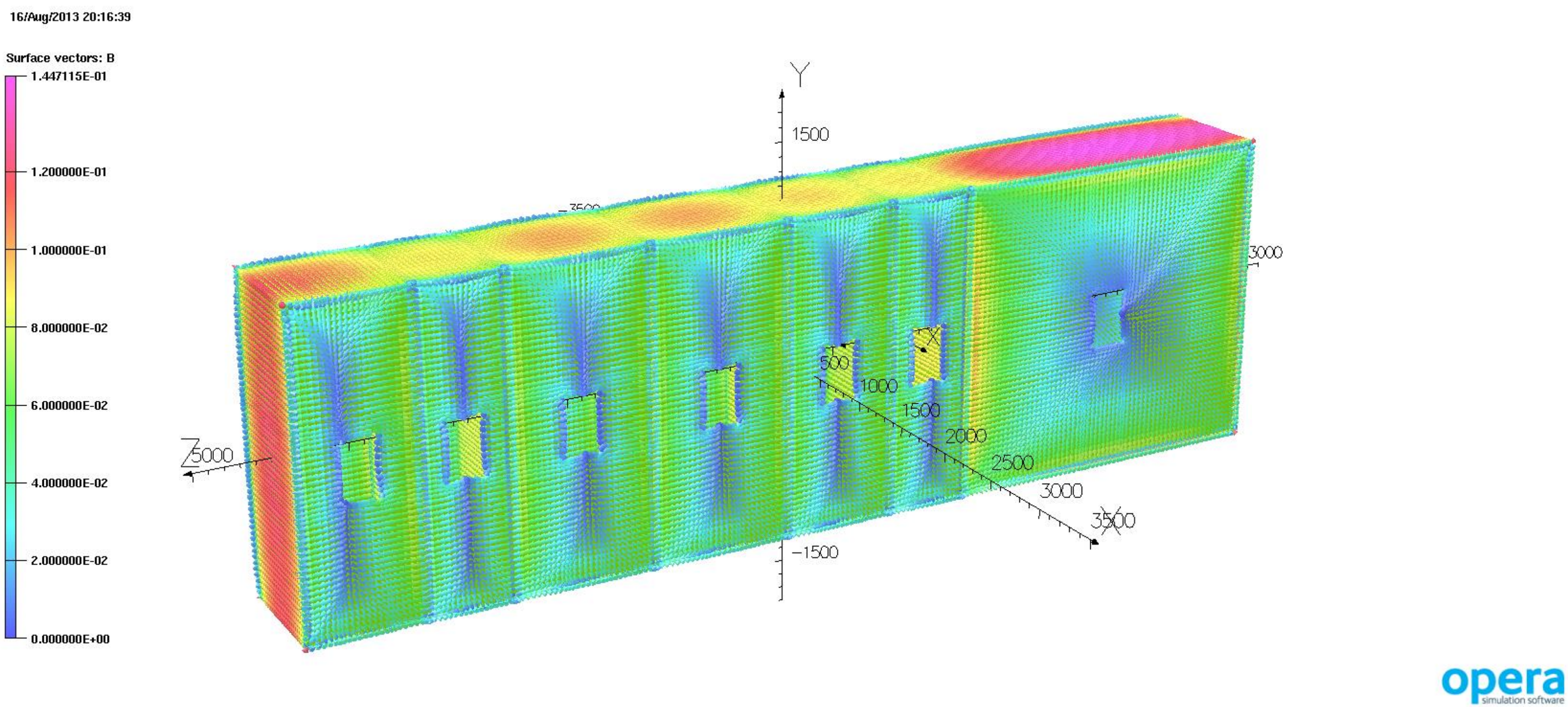
Finally I’ll show a couple of comparison plots from the models with 4 smaller windows in each rack. Each Window is 100mm x 100 mm with 150mm width centres, 200mm height centres.

Model 14

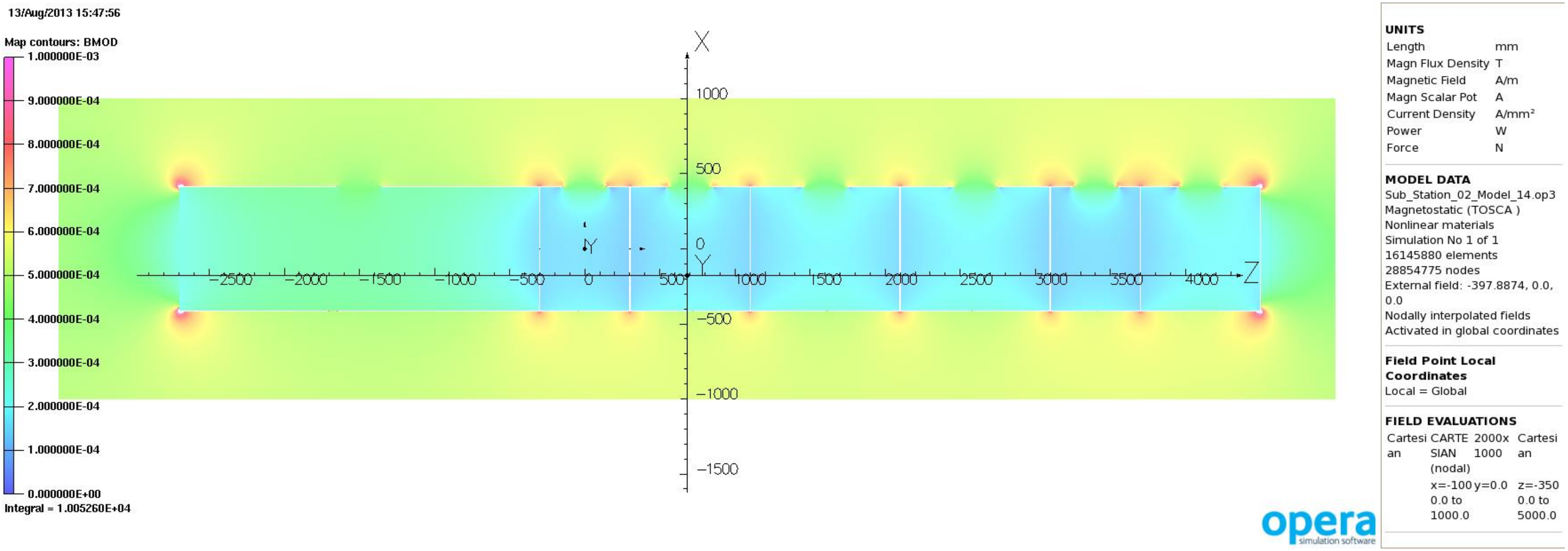
Transformer section is smaller in model than in reality



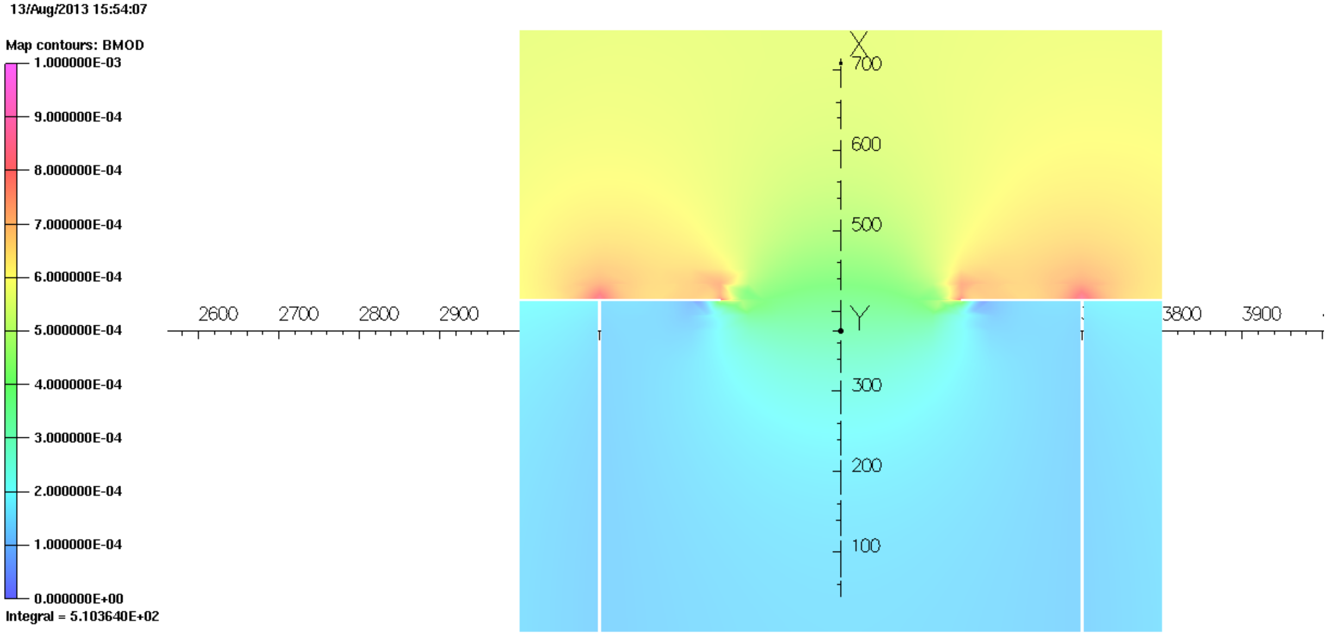




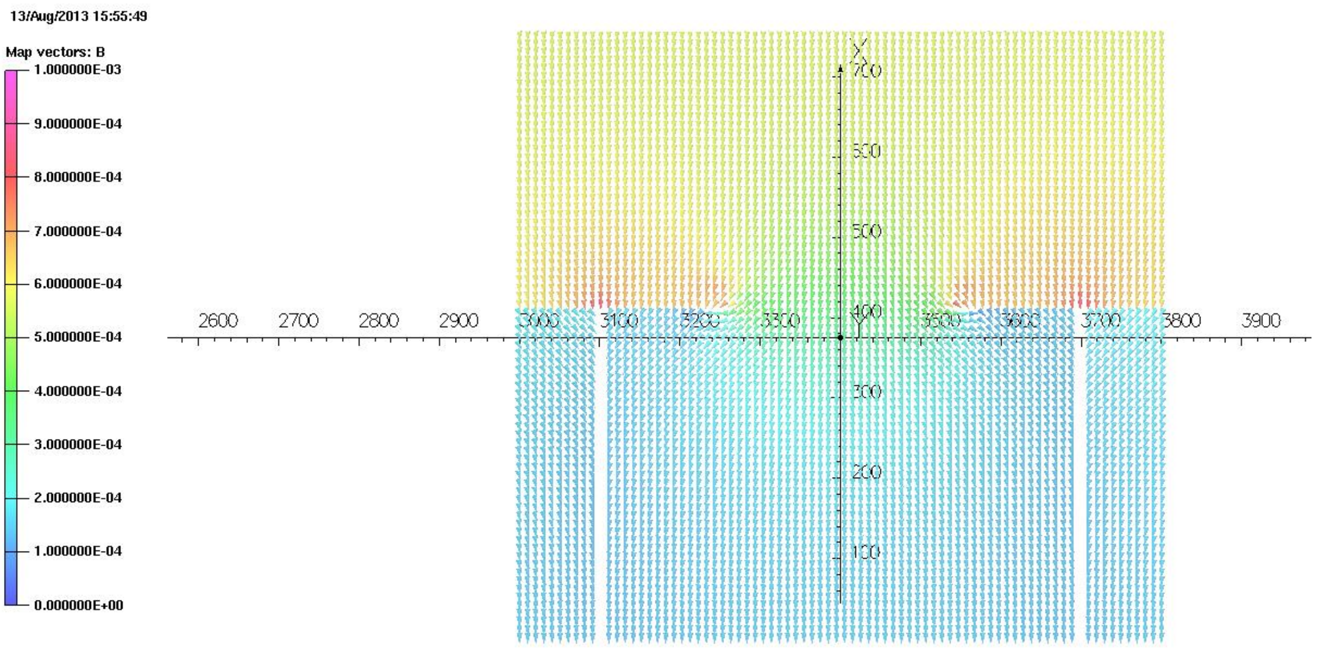
The flux sees the substation as a low reluctance path and uses the steel as a shortcut. The West End of the substation looks similar to the plot shown for hall model 113 but the in the east end the flow is in the opposite direction. This difference is just due to the source being to the east of the substation in the hall model, whereas there is general field from +X in the substation model.



13/Aug/2013 15:47:56
Map contours: BMOD
1.000000E-03
9.000000E-04
8.000000E-04
7.000000E-04
6.000000E-04
5.000000E-04
4.000000E-04
3.000000E-04
2.000000E-04
1.000000E-04
0.000000E+00
Integral = 1.005260E+04
X
1000
500
0
−500
−1000
−1500
Y
Z
−2500 −2000 −1500 −1000 −500 0 500 1000 1500 2000 2500 3000 3500 4000
opera
simulation software
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_02_Model_14.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 1 of 1
16145880 elements
28854775 nodes
External field: -397.8874, 0.0, 0.0
Nodally interpolated fields
Activated in global coordinates
Field Point Local Coordinates
Local = Global
FIELD EVALUATIONS
Cartesian CARTESIAN (nodal) 2000x 1000 Cartesian
x=-1000.0 to 1000.0 y=0.0 z=-3500.0 to 5000.0

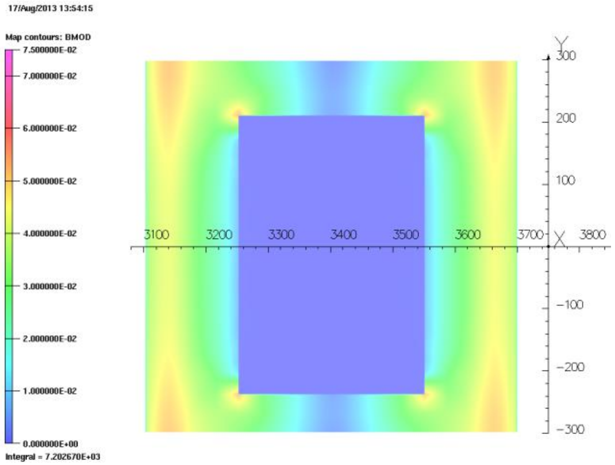


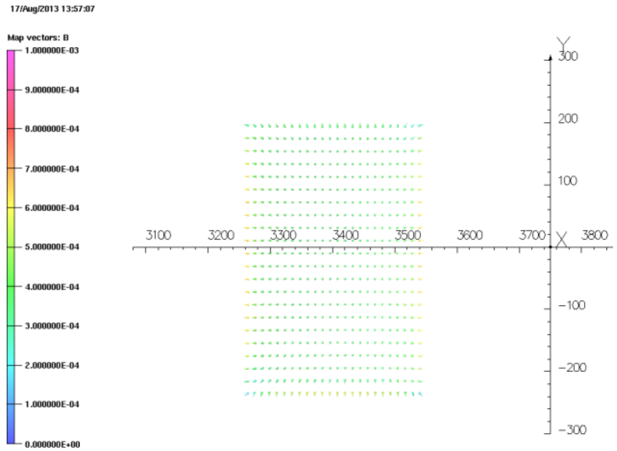
13/Aug/2013 15:54:07
Map contours: BMOD
1.000000E-03
9.000000E-04
8.000000E-04
7.000000E-04
6.000000E-04
5.000000E-04
4.000000E-04
3.000000E-04
2.000000E-04
1.000000E-04
0.000000E+00
Integral = 5.103640E+02
X
Y
700
600
500
300
200
100
2600
2700
2800
2900
3800
3900

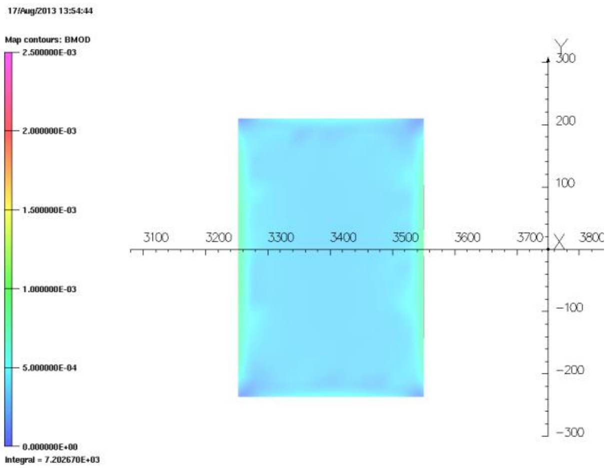


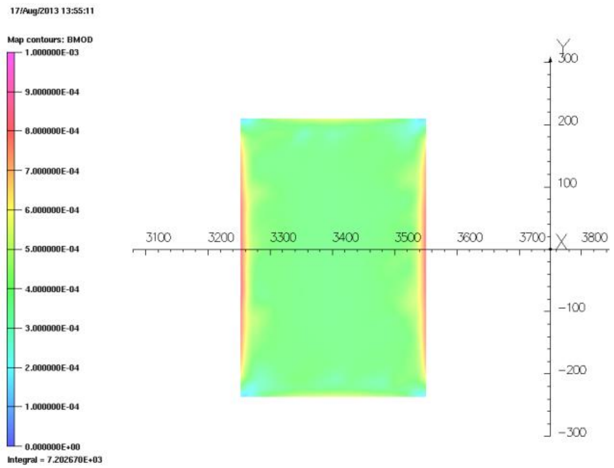
13/Aug/2013 15:55:49
Map vectors: B
1.000000E-03
9.000000E-04
8.000000E-04
7.000000E-04
6.000000E-04
5.000000E-04
4.000000E-04
3.000000E-04
2.000000E-04
1.000000E-04
0.000000E+00
2600
2700
2800
2900
3800
3900

Model 14 Window Plots

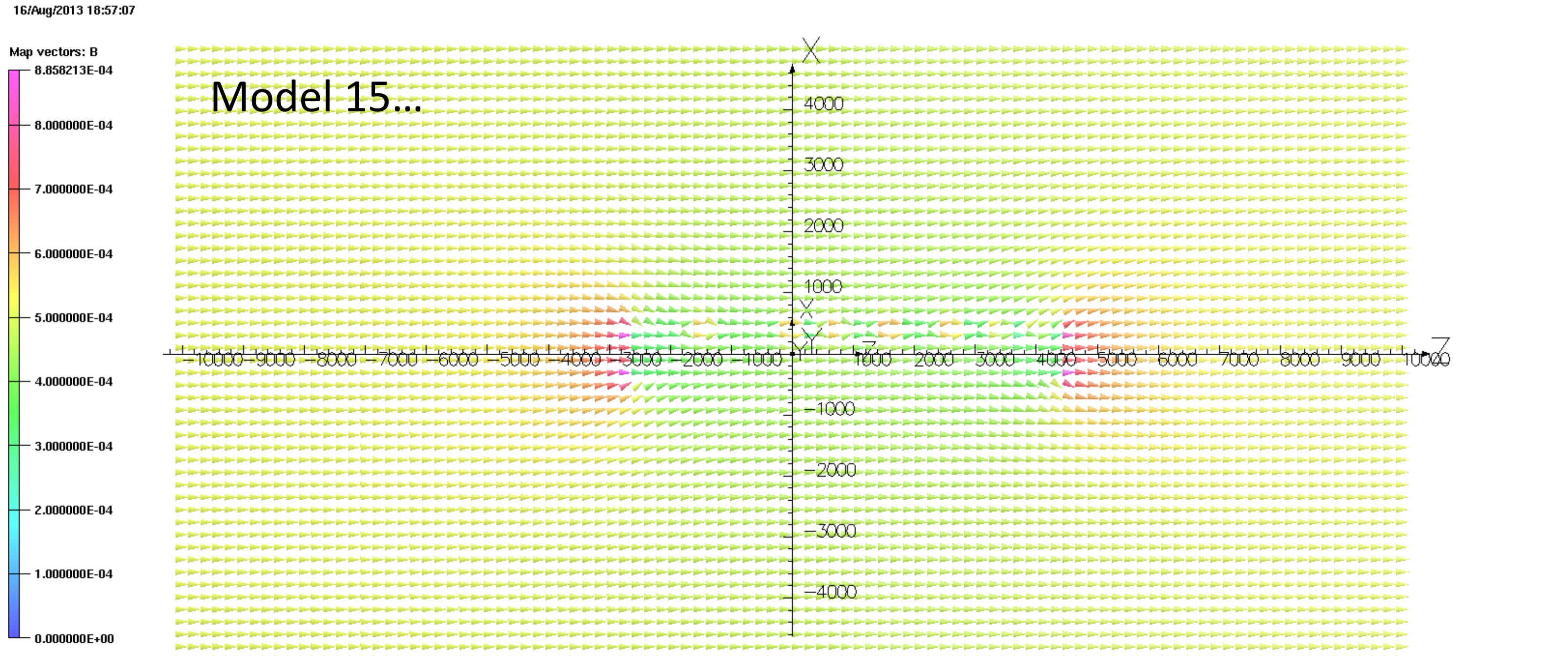








Model 15...



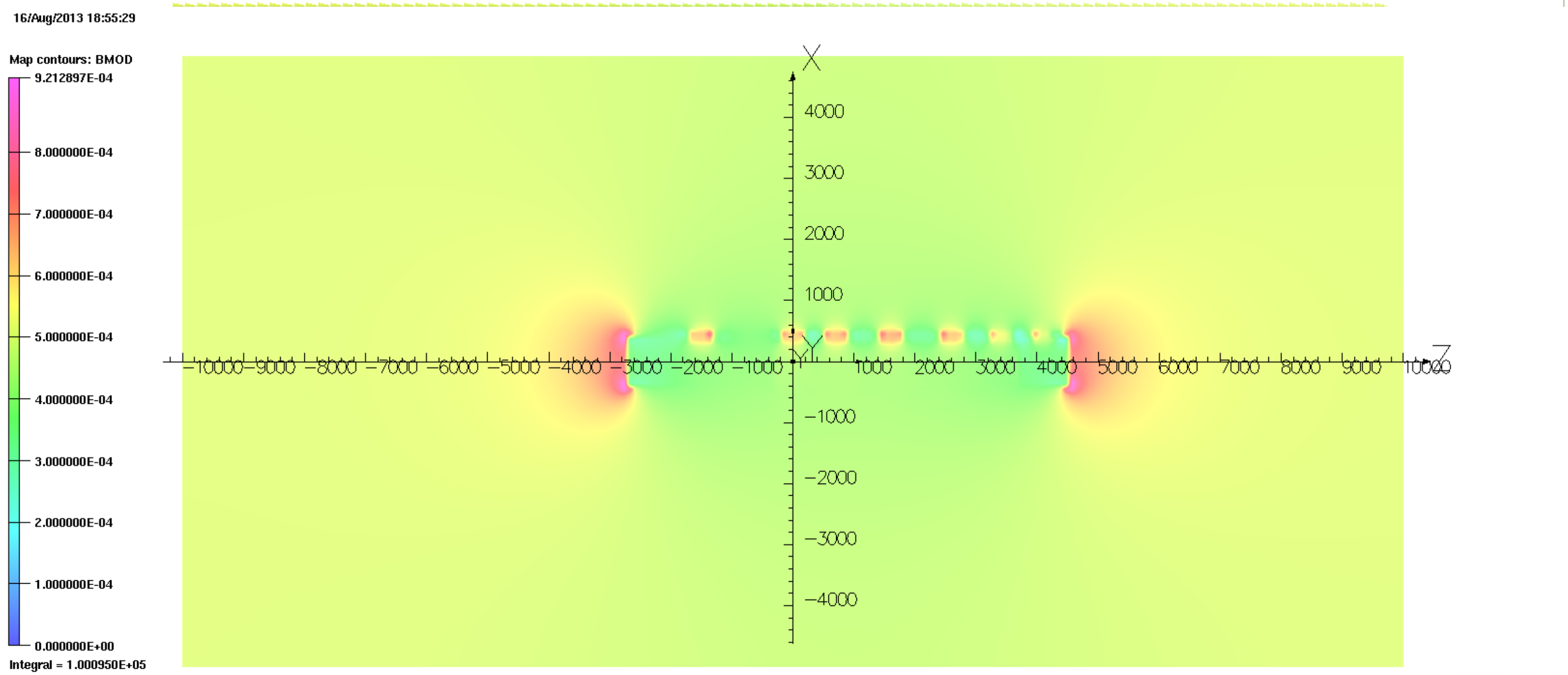
UNITS

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_02_Model_15.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 1 of 1
16145880 elements
28854775 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) 100x50 Cartesian
x=-5000. 0 to 5000.0 y=0.0 z=-10000. 0 to 10000.0



UNITS

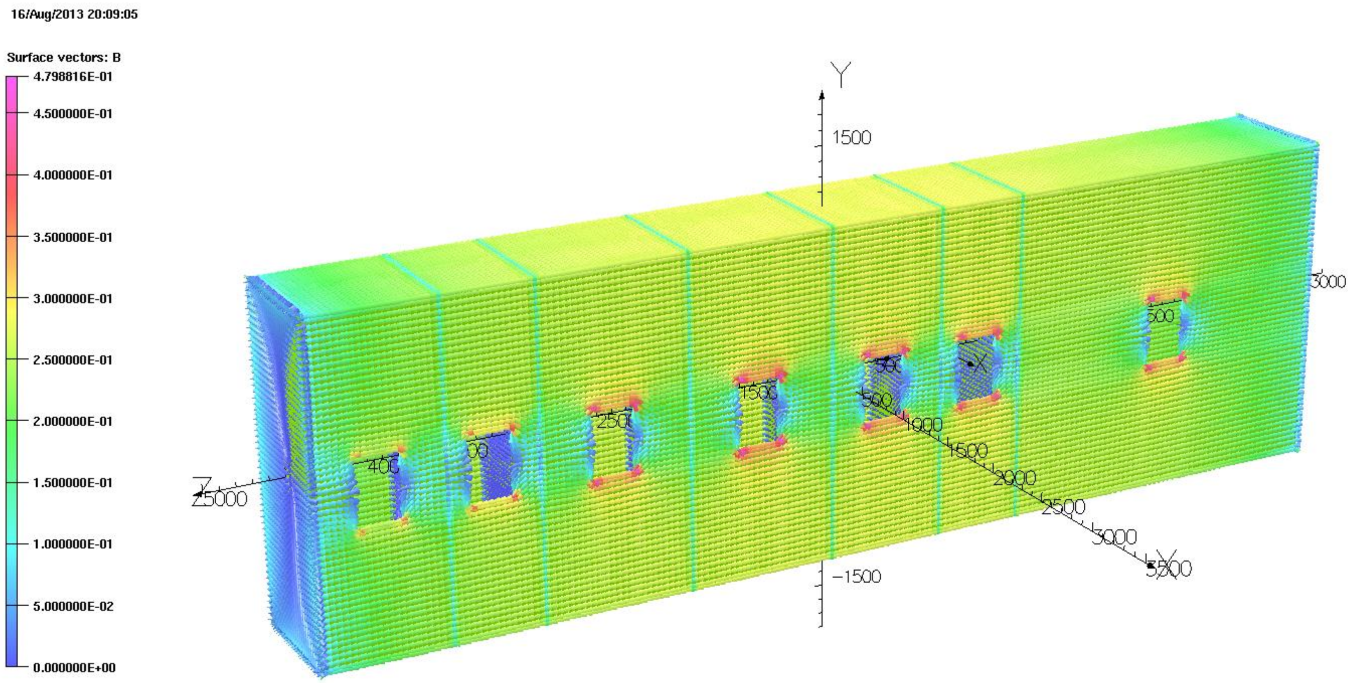
Length	mm
Magn Flux Density	T
Magnetic Field	A/m
Magn Scalar Pot	A
Current Density	A/mm²
Power	W
Force	N

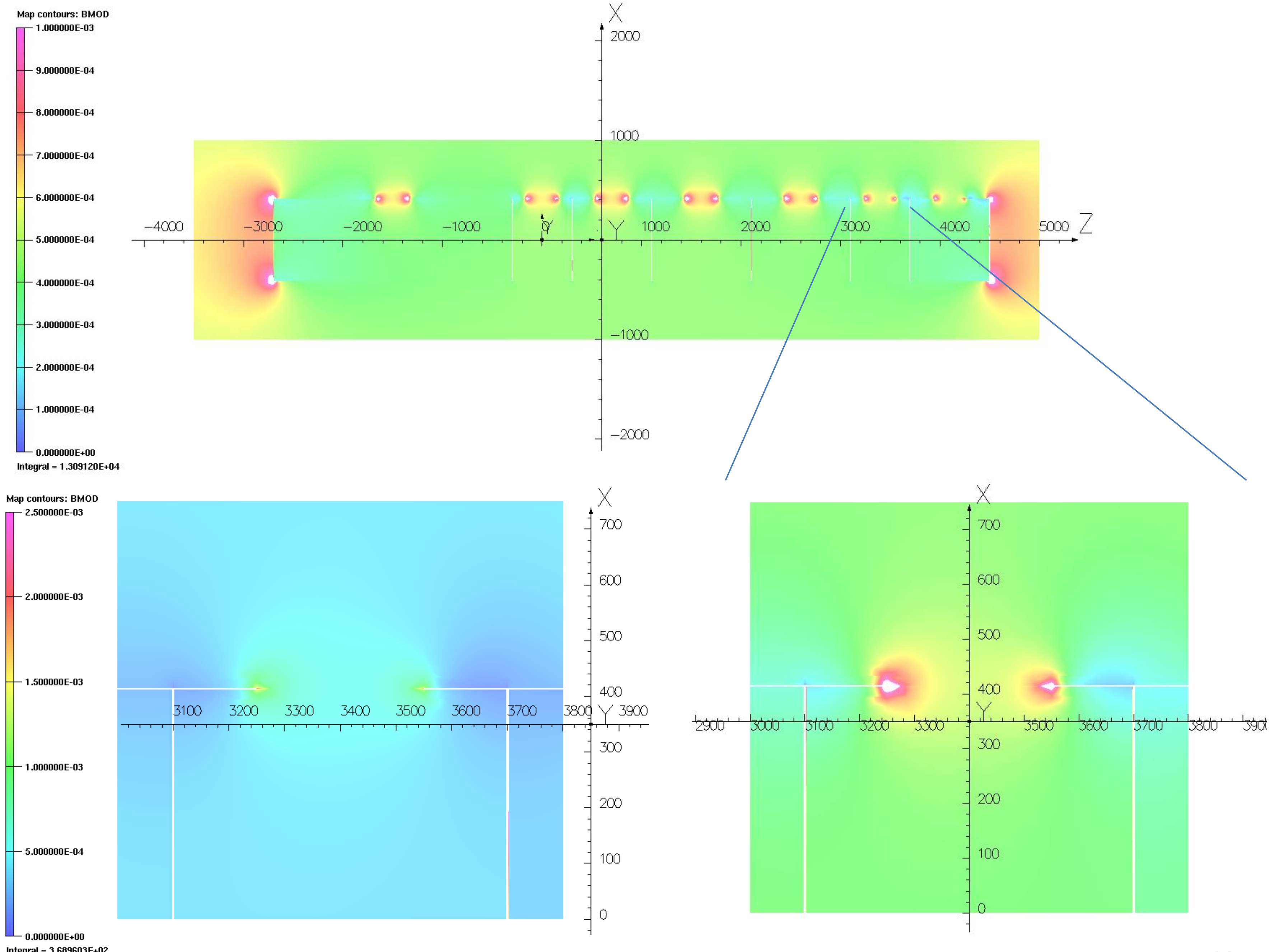
MODEL DATA
Sub_Station_02_Model_15.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 1 of 1
16145880 elements
28854775 nodes
External field: 0.0, 0.0, 397.8874
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates
Local = Global

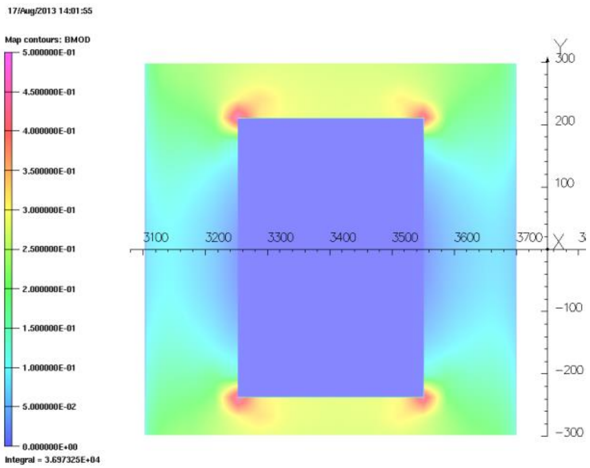
FIELD EVALUATIONS
Cartesian CARTESIAN (nodal) 200x100 Cartesian
x=-5000. 0 to 5000.0 y=0.0 z=-10000 .0 to 10000.0

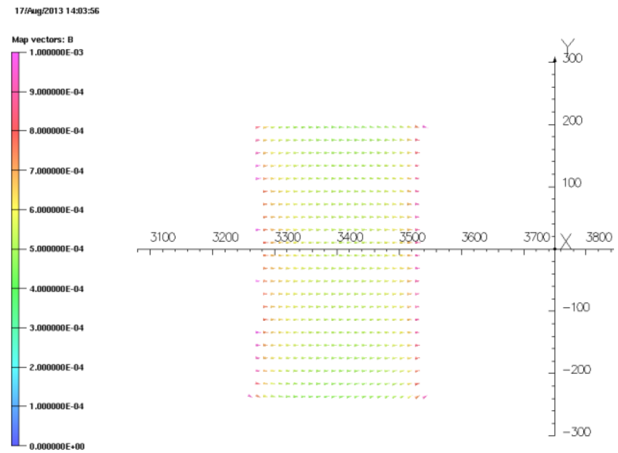
Model 15

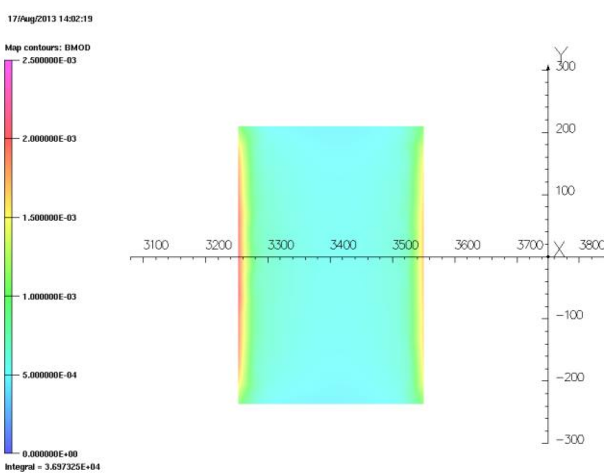

16/Aug/2013 20:09:05
Surface vectors: B
4.798816E-01
4.500000E-01
4.000000E-01
3.500000E-01
3.000000E-01
2.500000E-01
2.000000E-01
1.500000E-01
1.000000E-01
5.000000E-02
0.000000E+00
Y
1500
-1500
Z
X
1000
1500
2000
2500
3000
3000

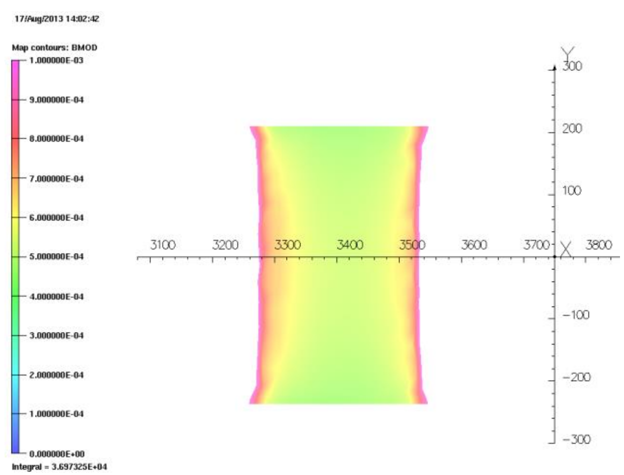

Map contours: BMOD
1.000000E-03
9.000000E-04
8.000000E-04
7.000000E-04
6.000000E-04
5.000000E-04
4.000000E-04
3.000000E-04
2.000000E-04
1.000000E-04
0.000000E+00
Integral = 1.309120E+04
Map contours: BMOD
2.500000E-03
2.000000E-03
1.500000E-03
1.000000E-03
5.000000E-04
0.000000E+00
Integral = 3.689603E+02
X
Y
Z

Model 15 Window Plots

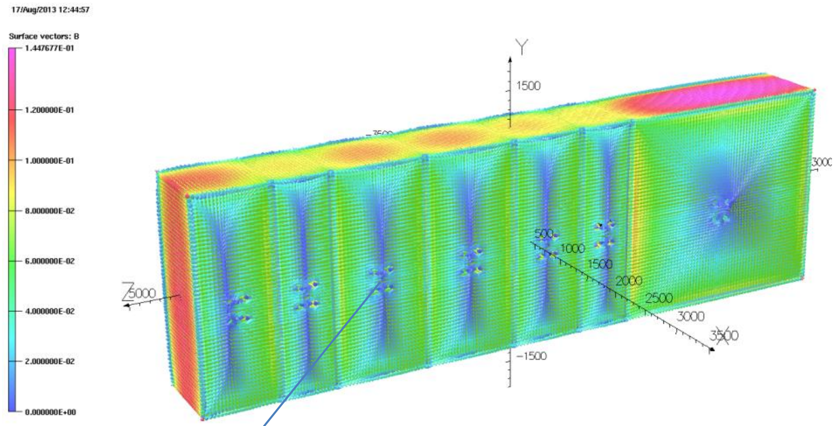




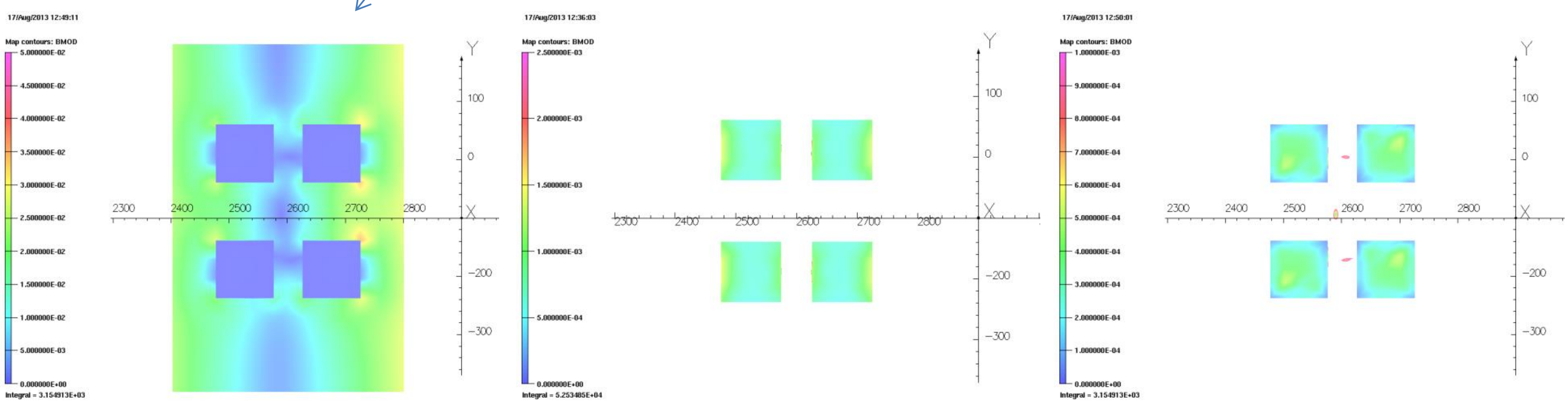




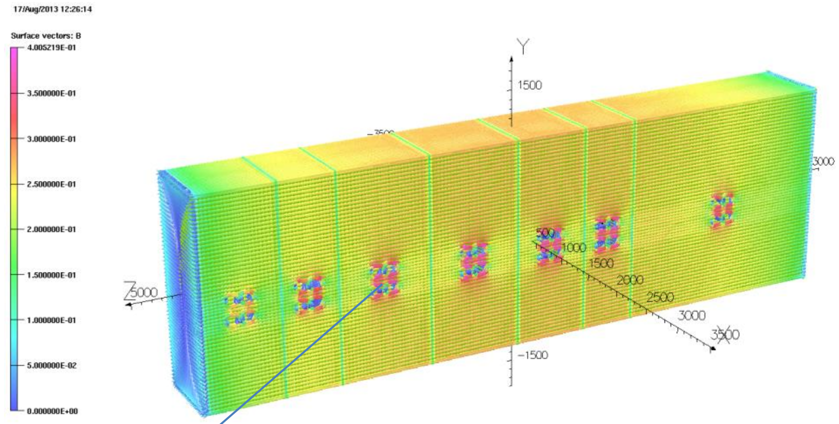
Model 17



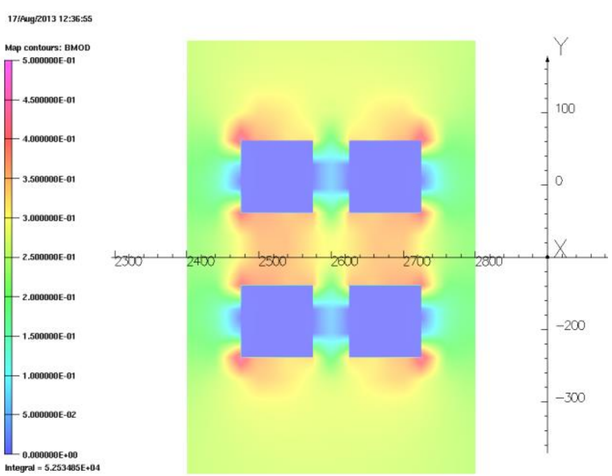
Field perpendicular to sub-station
(South to North)

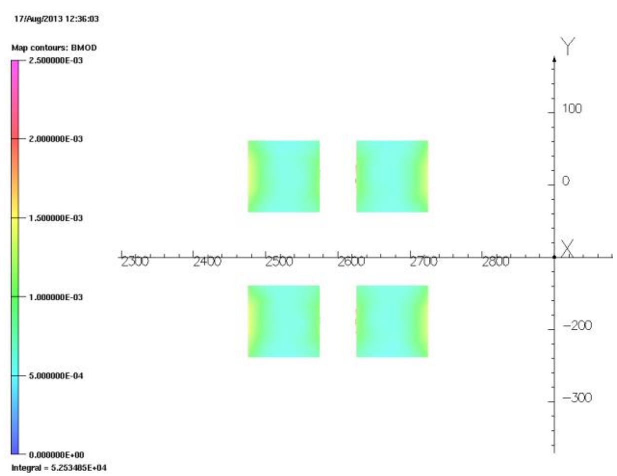


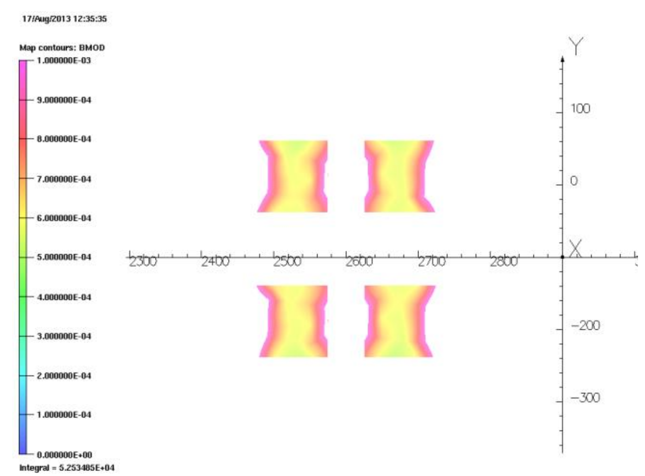
Model 16



Field parallel to sub-station (East to West)







Conclusions

The Hall model indicates that the substation will see a maximum air field of 2 Gauss, but generally it is much below this. The field looks to have components in both South -> North and East -> West. It looks like the South->North dominates.

All sub models have been run with an external field of 5 Gauss -but these results should scale linearly for comparison with model 113 as they are no where near saturation in the steel.

The direction of the external field clearly has an effect upon the magnetisation of the substation skin. (But the magnetisation of the real substation may be less as the model assumes unbroken magnetic conductivity.) Also note that there is only ~1000kg of iron represented in substation sub models.

The amount of magnetisation in the air gap in the steel wall appears to be dependent upon the direction of the external field. External field South -> North is better than East -> West.

For South -> North external field the central part of any window is seeing the magnitude of approx ~external field. Intrusion of higher field into the window seems minimal.

For East -> West external field the centre of the window is seeing slightly higher field than external field and there is significantly more intrusion of the field into the window.

There is the question of how significant the missing iron in the sub-models will affect the result. If it the iron is lumped in the centre of the rack from previous models I wouldn’t have thought that the effect would be too significant. Recall model 113 does contain the full mass of iron.

Other news

My contribution for the review documentation has been converted to latex, it is not complete but I think that it is a good start. I have already circulated what I have done for comment. It will be apparent that there are clearly a number of holes in the both the documentation and our knowledge wrt the baseline solution and I'm concerned that we won't have time to address all of these before the review.

I will try and re-run some of the simulations for the shield walls whilst on A/L providing they are not too troublesome. The results from these simulations bother me but I'd like to tidy them up a bit before they are presented in the review documentation which means running some more models with a few more tweaks. This may interfere with Craig getting access to the machine for a few days…