COMSOL CONFERENCE 2015 PUNE

Electromagnetic & Electrostatic study in High Voltage Switchyard

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Introduction

- Constant exposure of humans even to low frequency electromagnetic radiation may be hazardous.
- Exposure limits have been specified for electrical and magnetic fields at the power supply frequencies.
- Our objective is to check whether the limits specified are exceeded in a 765 kV, 2000 MW switchyard

Rest of the Talk

- Review of Existing work
- Main contribution
- Our approach
- Simulation Resuts & Verification
- Conclusions

Review

- Several studies have been made on the electromagnetic fields in substations of Very High Voltages
- Due to the complexity of the geometric structure of the electric lines and equipment, most of the studies have resorted to simulation tools to determine electromagnetic field inside the substation

Review (contd)

- Finite element analysis is one of the popular tools used for determining the electromagnetic radiation levels in the areas concerned
- Also, many of the studies assume symmetry of the structure along one dimension to reduce the problem to a two dimensional study

Review (contd)

- In the project reported in the paper, an attempt is made to simulate the three dimensional structure of the field distribution
- We make simplifying assumptions on the basis of tower structures, auxiliary equipment etc.

Main Contribution

- Provide a workable finite element analysis based 3D simulation of the electrical and the magnetic field distributions in a switchyard of 765 kV.
- Simulation results of the electromagnetic field are verified against selected field measurements
- Provide a simple solution to keep the radiation levels within the regulatory limits

Approach Used

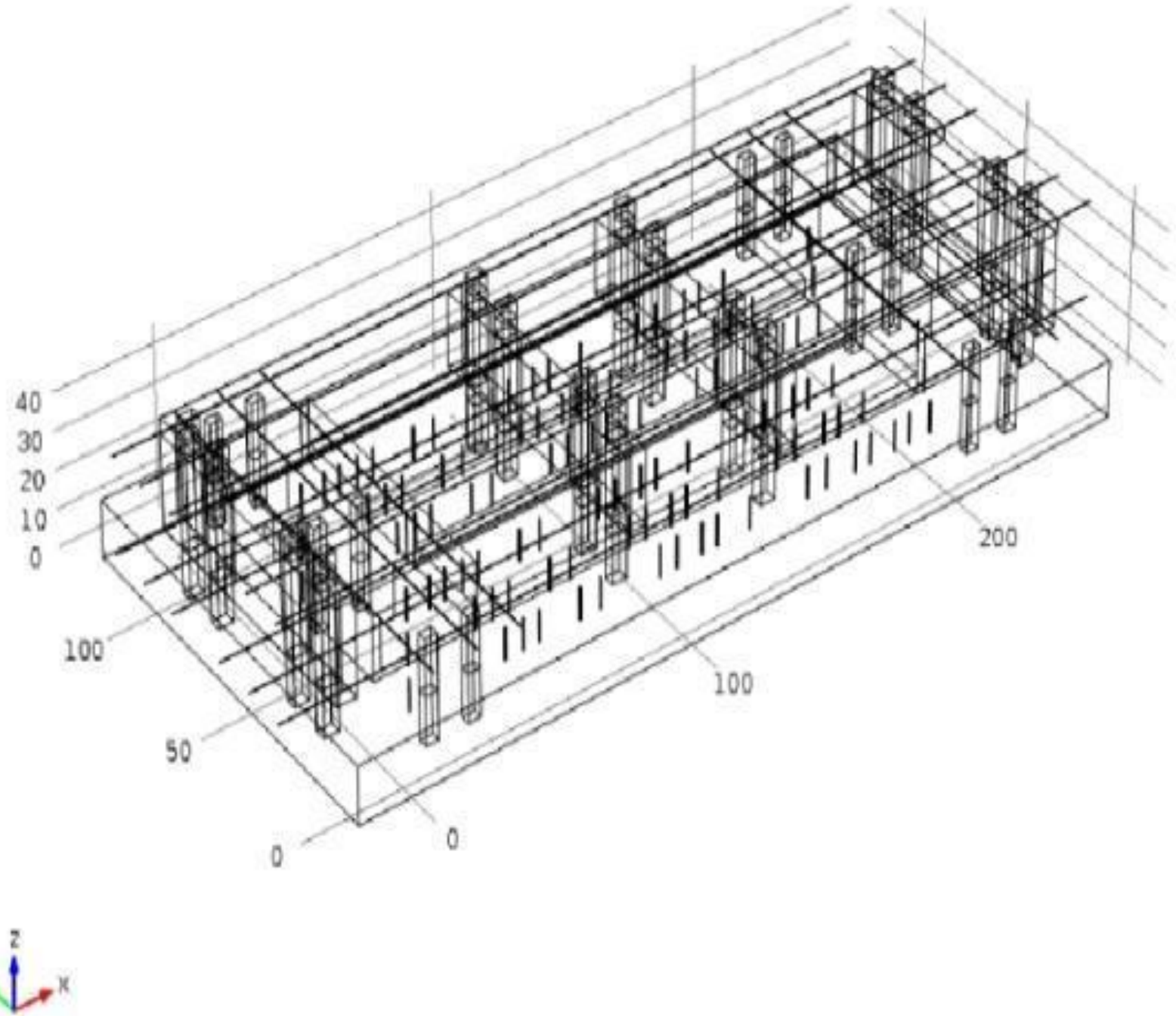
- Due to the complexity of the geometry of the switchyard layout, a practical approach to the solution of the problem is to carry out finite element modelling (FEM) analysis
- COMSOL (Basic pack plus AC/DC module) is chosen
- Due to low frequency of operation, electric and magnetic fields can be treated separately without losing accuracy

Geometry Model

- To make the problem tractable, physical modelling of the switchyard is simplified without compromising on the accuracy of simulation
- Four parallel bays of transmission lines are reduced to single bay and a gap between two parallel bays
- Transmission towers along the transmission lines are modelled as two metallic pillars at ground potential at appropriate locations
- Circuit breakers, isolators and other equipment below the transmission lines are modelled as metallic grounded objects positioned on the ground at appropriate locations and to the given height

Geometry model (contd)

- In order to avoid the minute gaps when the drop lines meet the transmission lines, conductors are modelled as rectangular blocks so that the drop lines sit on each other without any gap on the joined surfaces.
- The cross-section of the transmission and drop lines are approximated to be 0.04m square. The effect of such approximations on the results is nil due to the distances involved from transmission lines to ground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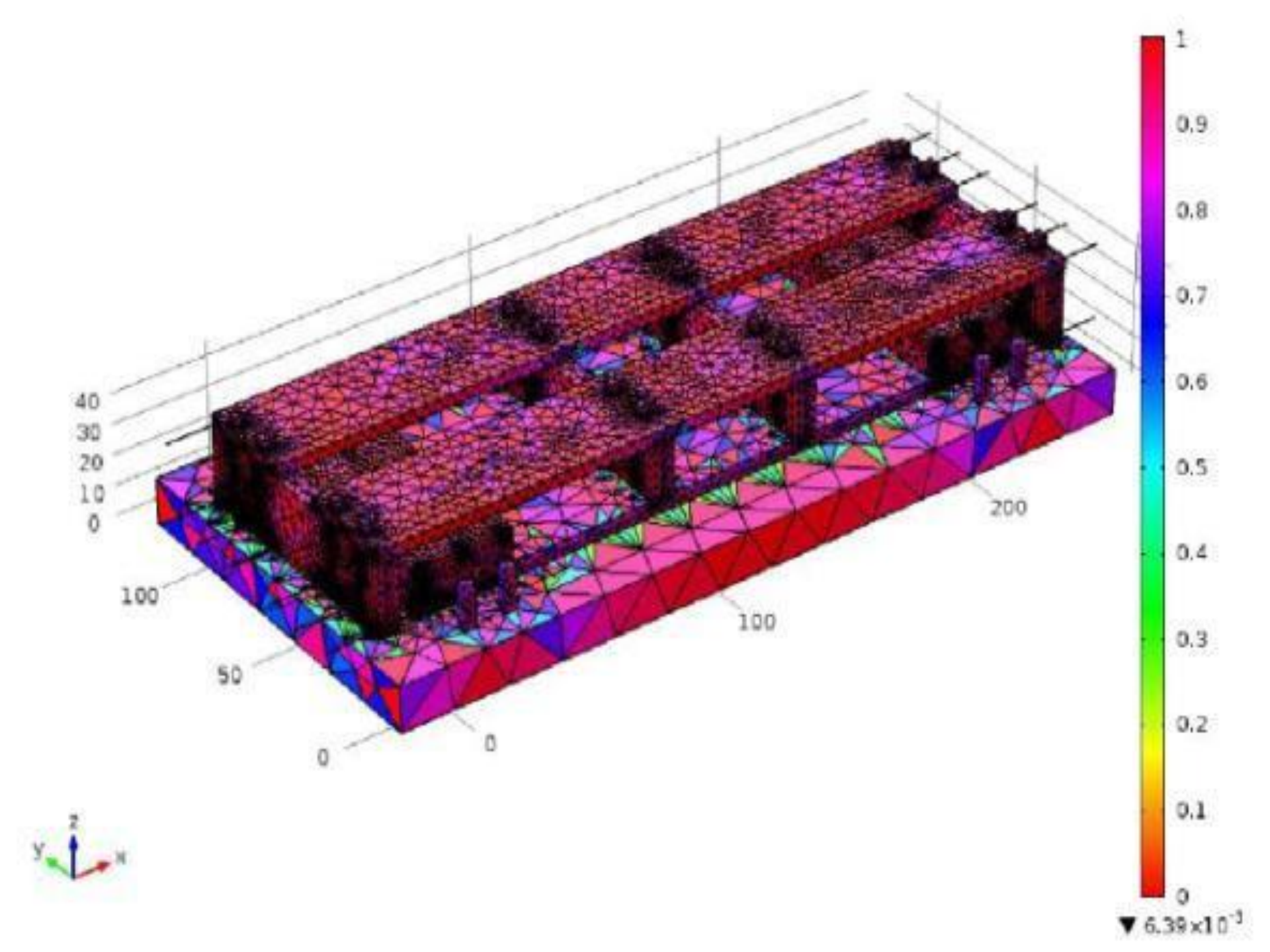
Meshing

- In view of the large diversity in the length of conductors, cross section of conductors, as well as the height of the transmission lines and towers, it was found necessary to house various geometrical spaces into virtual boxes which, while not being part of the geometry, help in building an efficient meshed geometry

Meshing (contd)

- Typical number of meshes encountered in our solution ranged from 3 million to 5 - 6 million.

- The following shows the meshed form of Fig 1 useful for finite element analysis of EM field distribution.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0.3
0.2
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▼ 6.39×10⁻³

Multiphysics

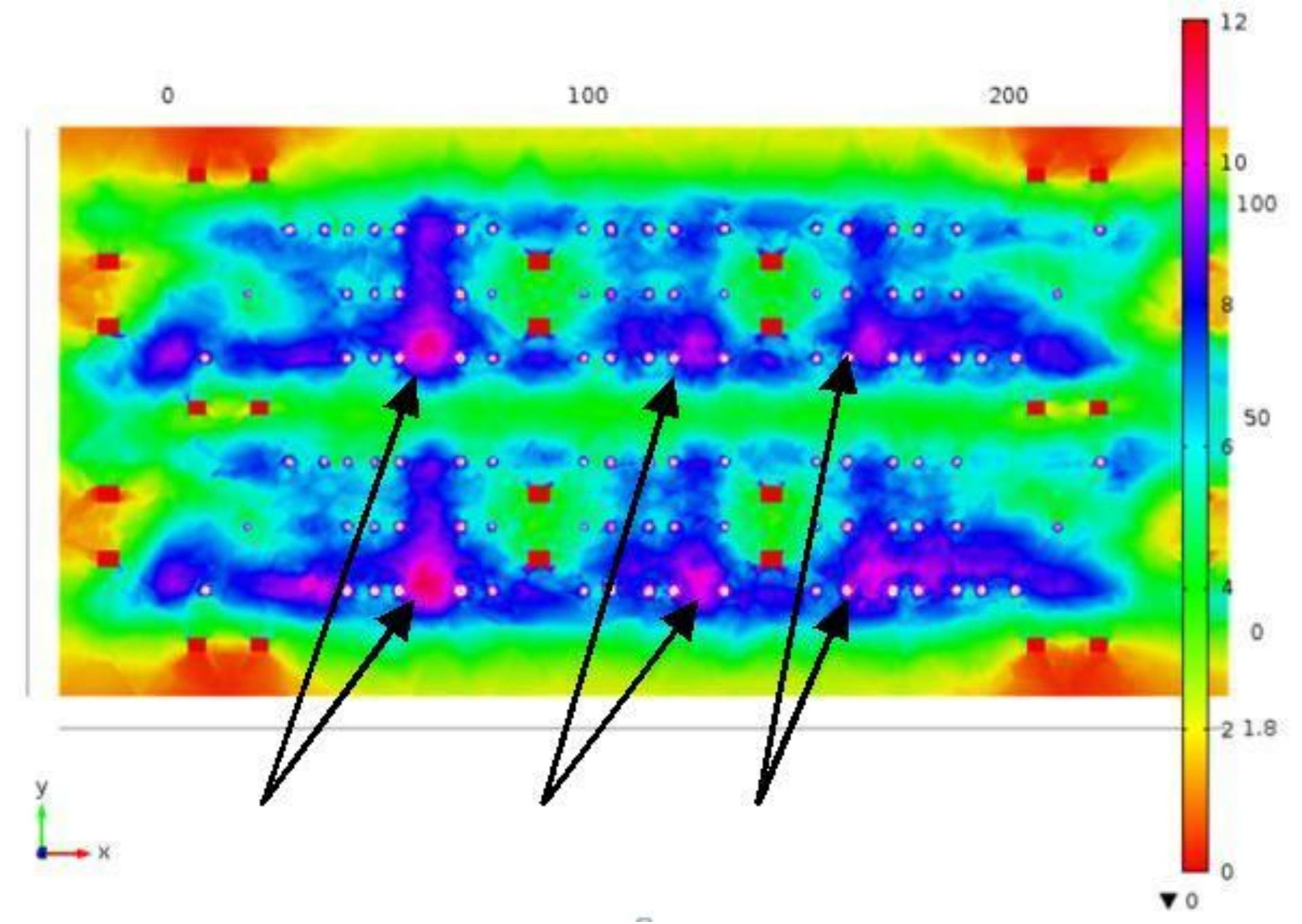
- For the study , the coupling of electric circuit with electric current physics is used for the study of electric field.
- In the case of magnetic field, coupling of magnetic field and electric circuit physics is used

Solvers

- We used many linear iterative solvers to arrive at the EM field solution. The number of degrees of freedom involved in the solution varies depending on the number of meshes involved and whether an electrical field or a magnetic field study is considered
- Generally the number of degrees of freedom ranged from about 4 million to 9 million in numbers.

Solvers (contd)

- Solution time varied from a few hours to more than 24 or 48 hours in many cases.
- Many times the iteration was stopped when the solution reached an error of the order of 10^{-2}.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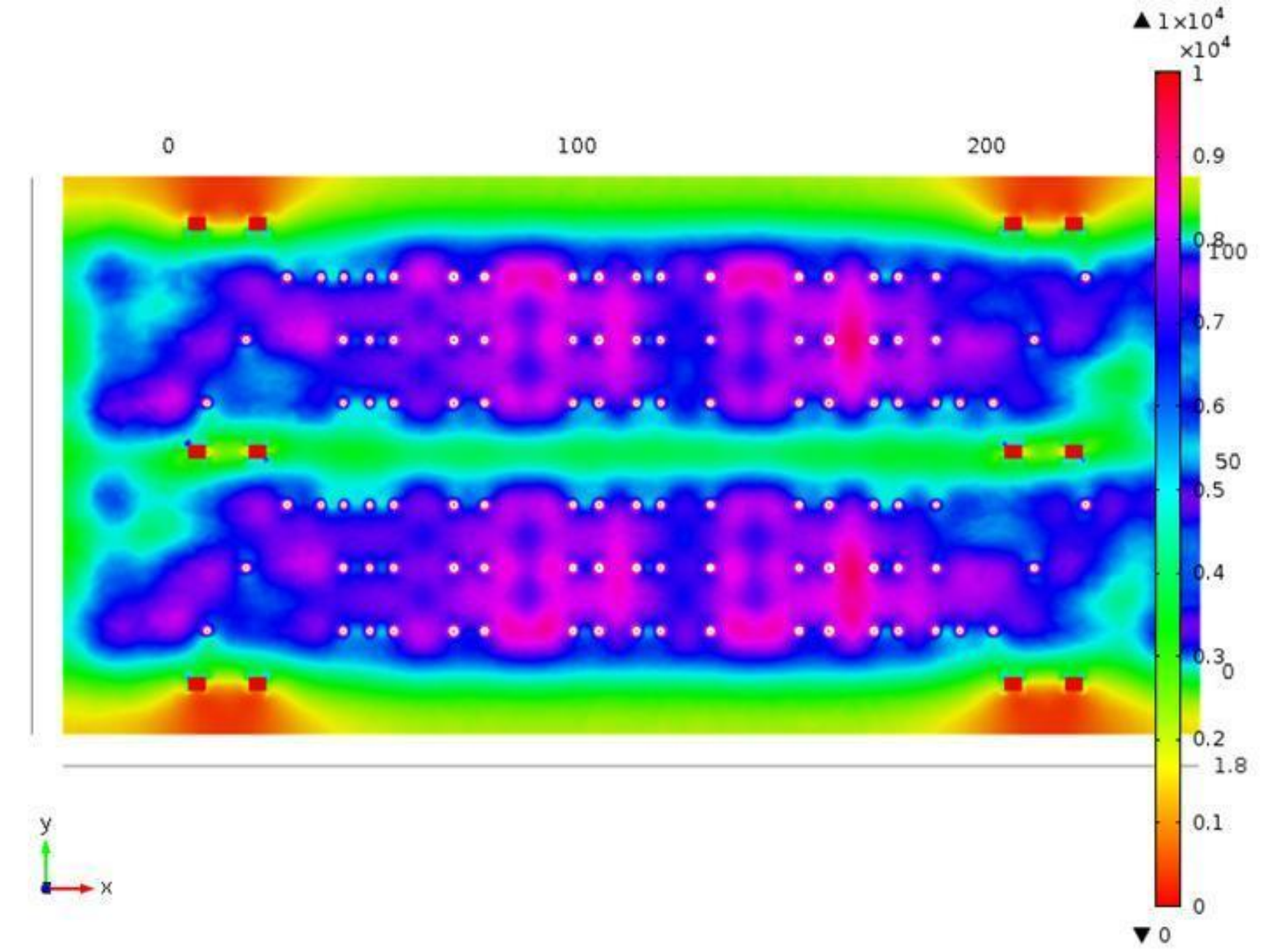
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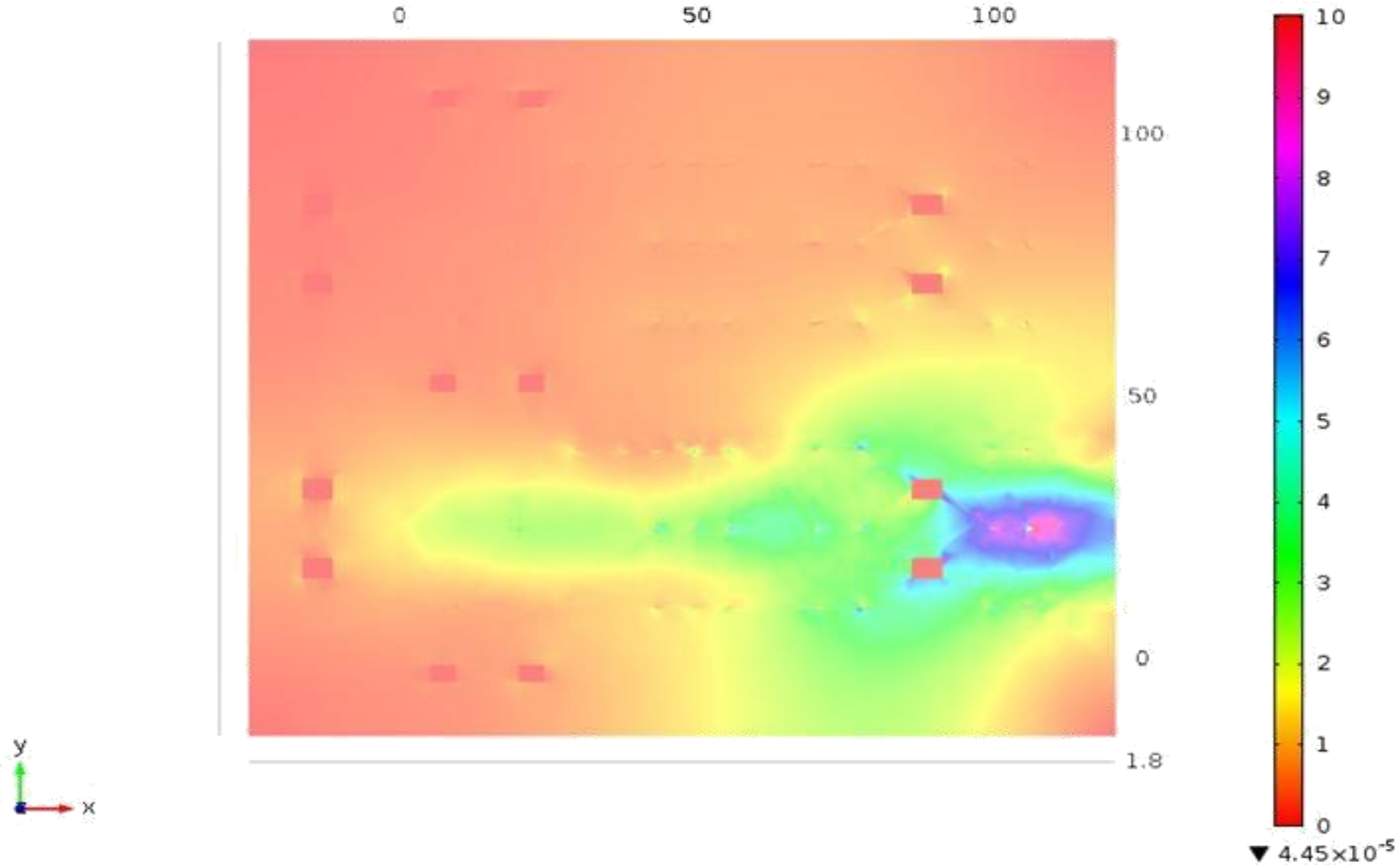
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▼ 4.45×10-5

Conclusions(contd)

- The electromagnetic field study of the switchyard extending over a length of about 250 m, breadth of about 200m and height of about 40 m is not an easy problem
- Finite element analysis of the electromagnetic field is a practical solution.
- Due to the large variation between the cross-sectional dimensions of the conductor and length of the conductor, the meshed elements are large in number running into several millions.
- Also, to keep the number of meshed elements at an affordable range, it was necessary to simplify the modelling of towers as well as the insulation supports involved.

Conclusions (contd)

- Given the complexity of the problem as above, we need to take advantage of the symmetry of the switchyard geometry to reduce the problem complexity
- In the case of magnetic field , especially , we had to take advantage of left and right symmetry of even a single bay to make the problem tractable in terms of complexity

Conclusions (contd)

- In terms of results, it is found that the magnetic field in the switchyard is far below the level at which it is considered harmful to human operators in the switchyard.
- On the other hand the electric field could be at levels near or above the regulatory levels allowed for continuous exposure of humans.
- It is then possible to mitigate the electric field effect by suspending grounded thin conductors at a height of, say, 8 m above ground at the critical regions

Conclusions (contd)

- The EM field simulation results were also compared with field measurements made at selected points on the ground .It is generally found that the measurements tend to support the field values obtained through simulation.

Thank you