ANSOFT CORPORATION PRESENTS:

CONVERGE

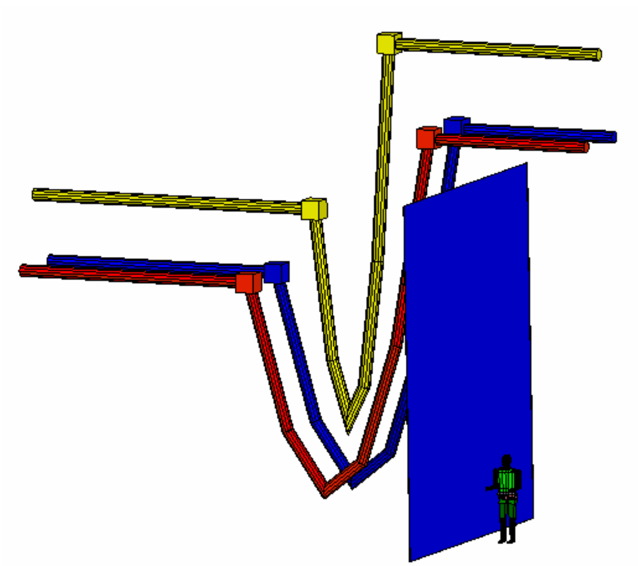
AN APPLICATIONS WORKSHOP FOR HIGH-PERFORMANCE DESIGN

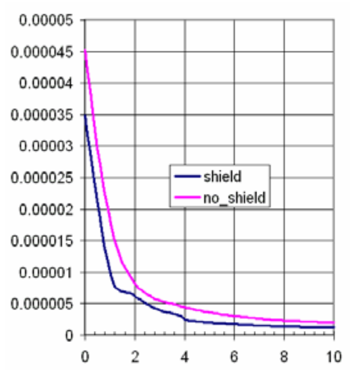
Industrial EMC/EMI Applications

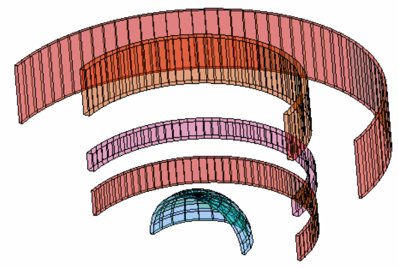
Bogdan C. Ionescu, PhD

Industrial EMC/EMI Applications :

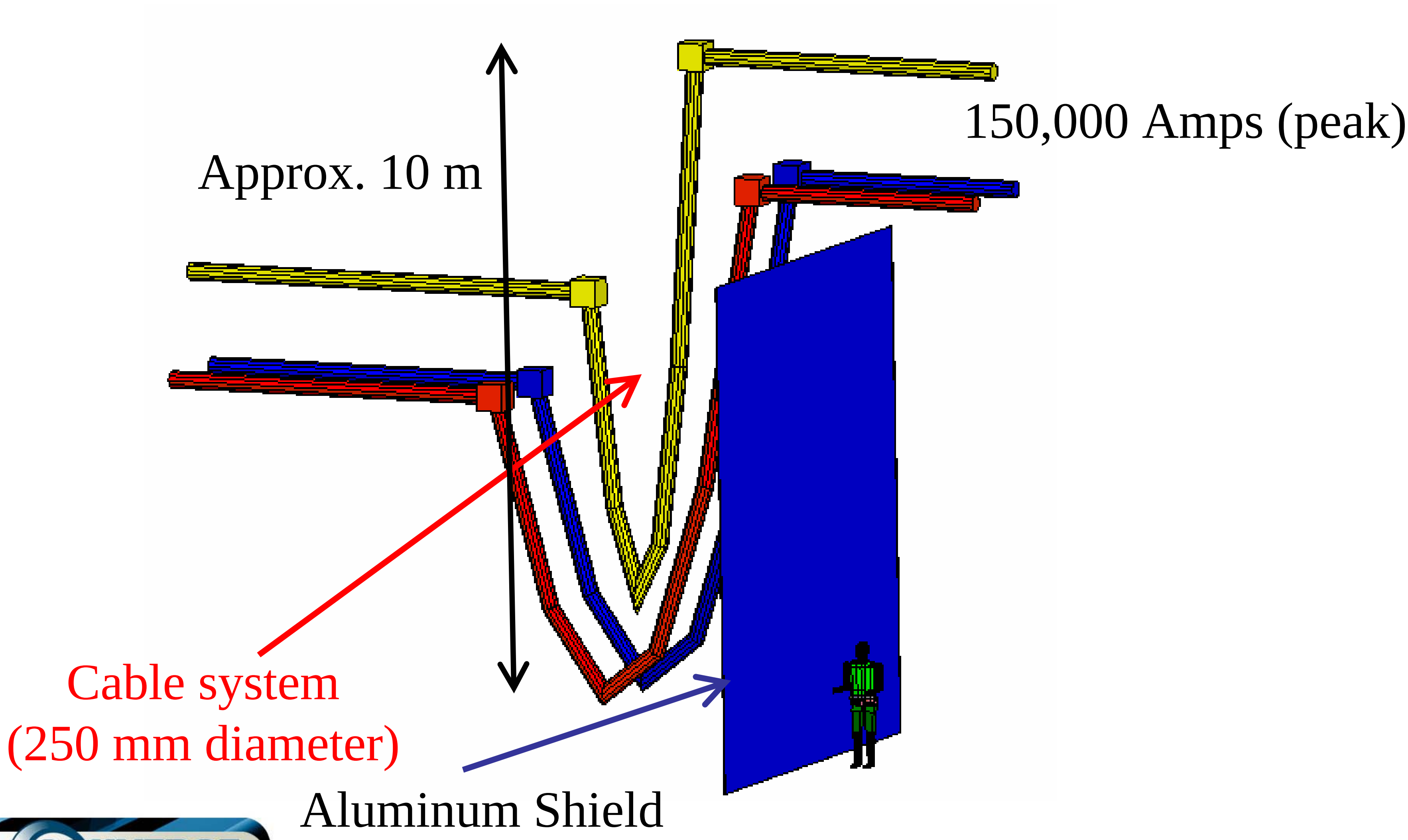
Shielding of large industrial enclosures



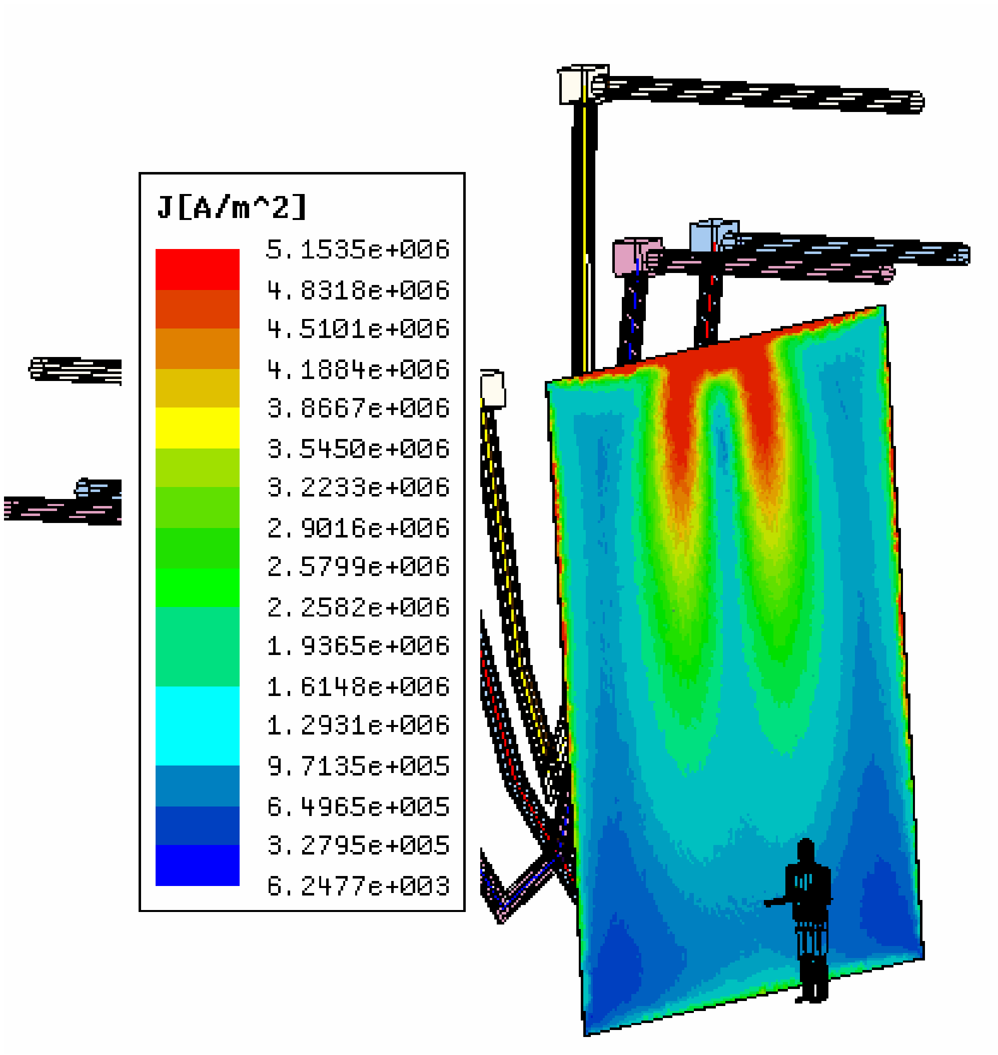


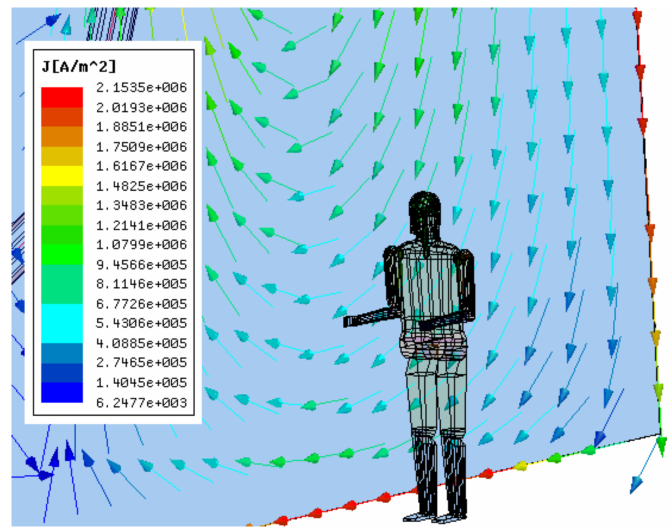


Modeling of shields for electric smelting operations



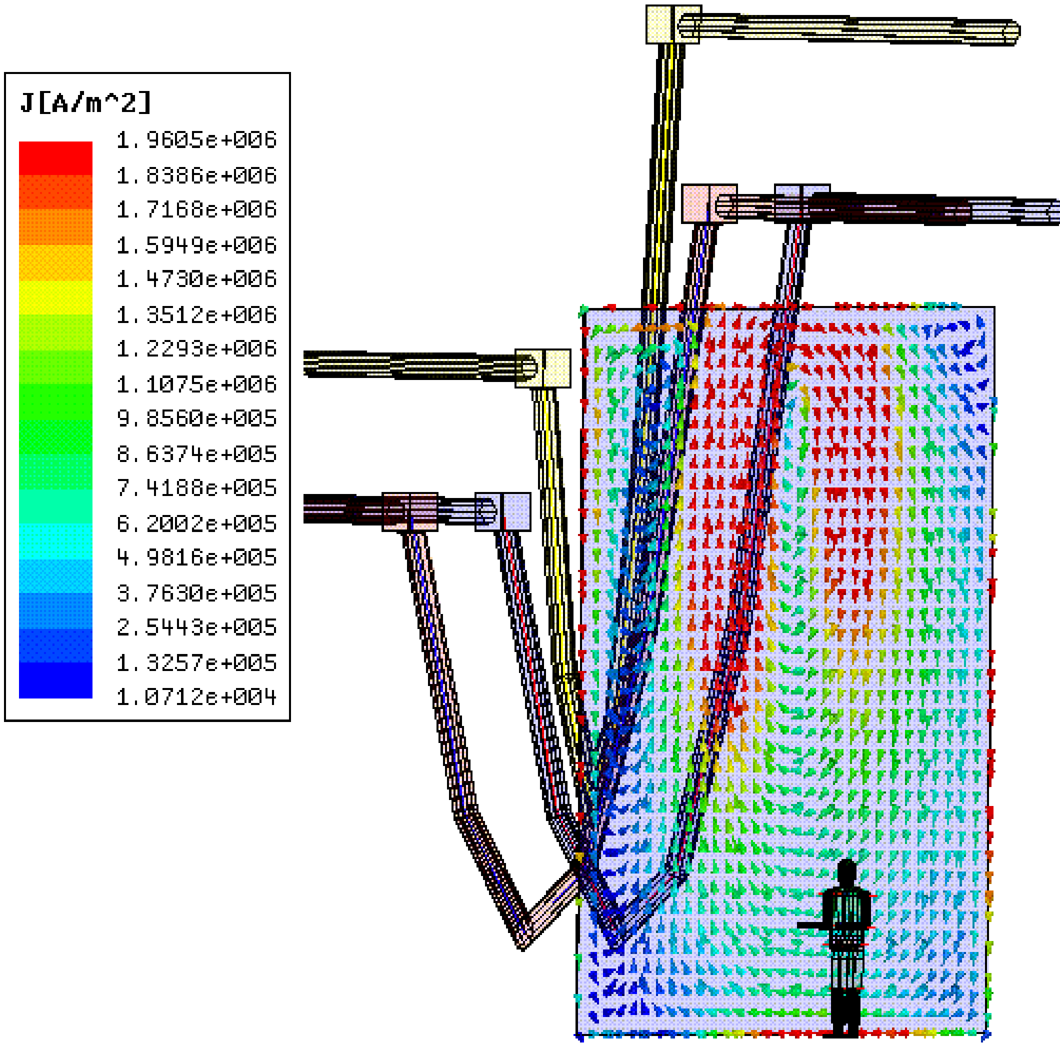
Induced currents in the shield

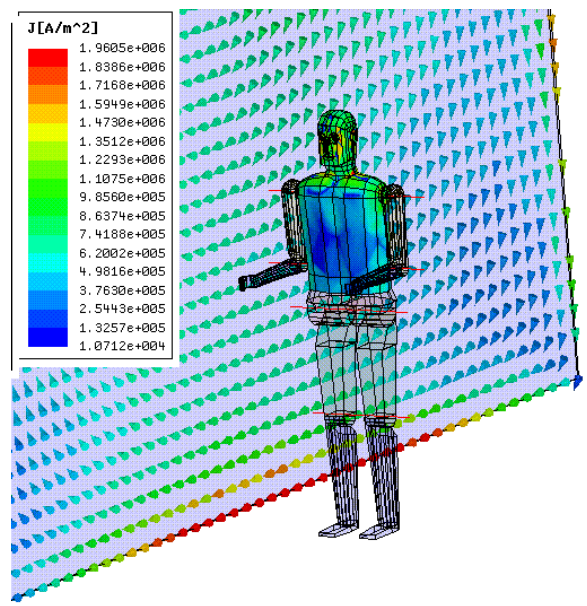




Detail of current flow

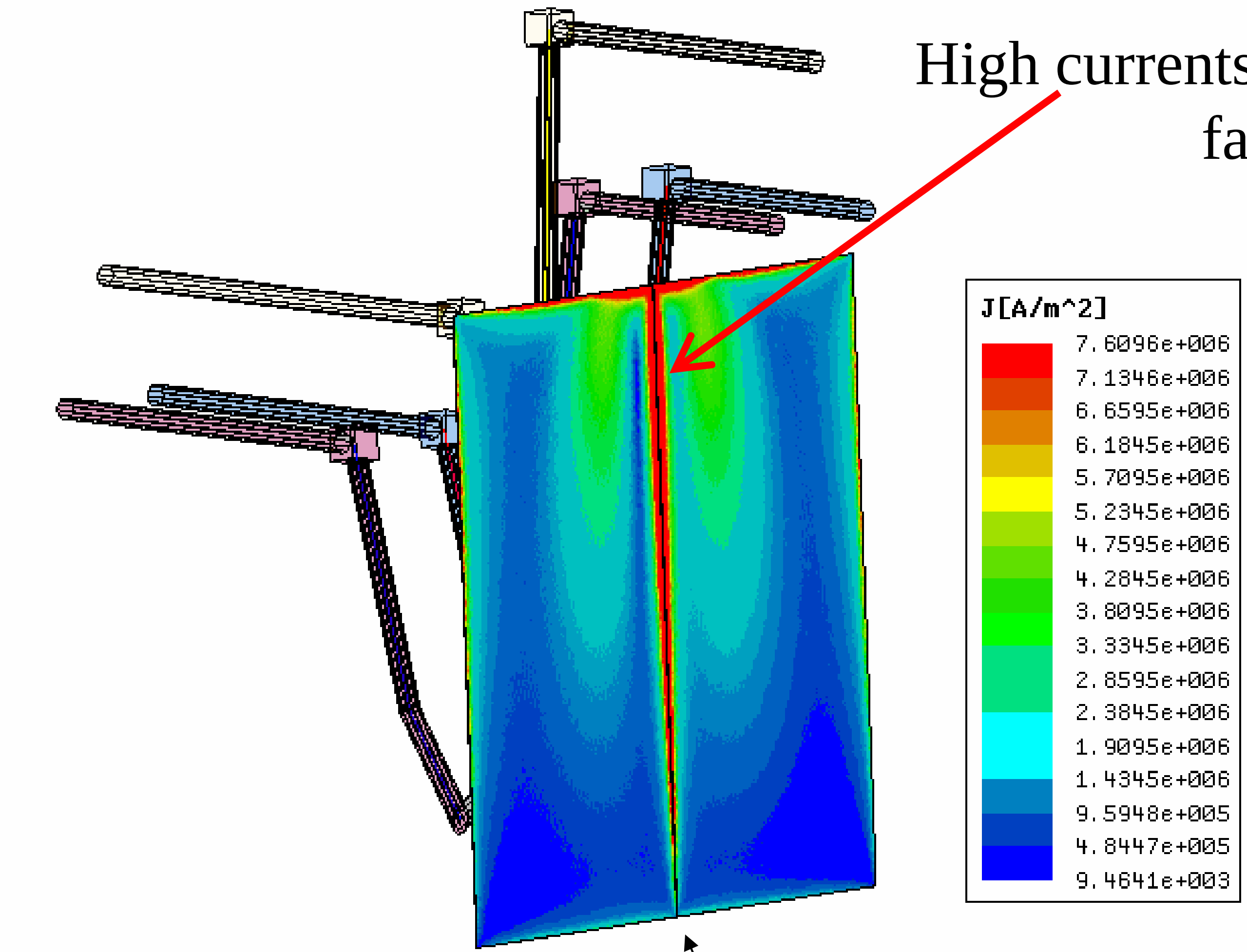
Induced currents - animation





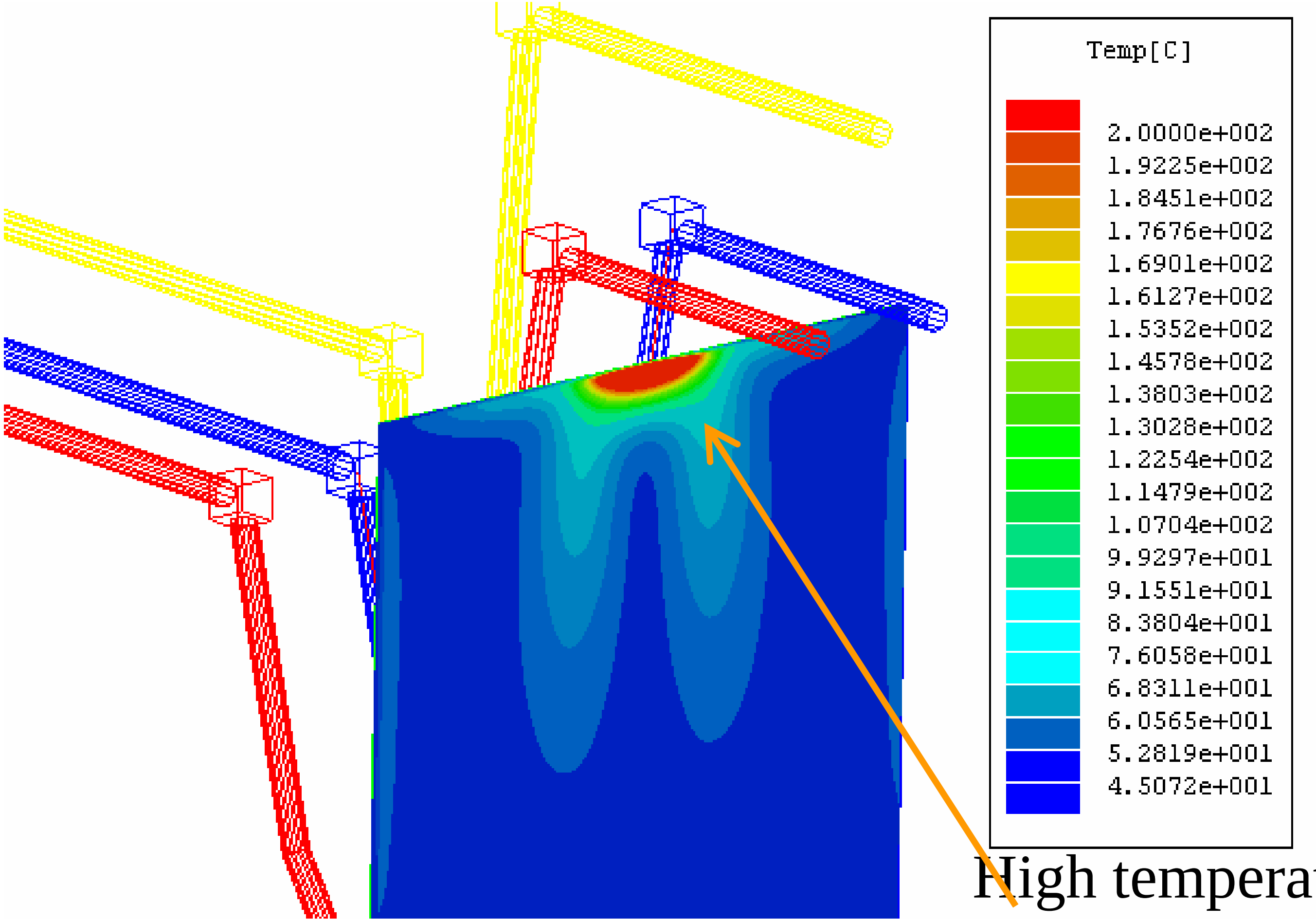
Modeling of imperfect contact between aluminum sheets

High currents flowing along the fault line



Imperfect contact between two vertical aluminum sheets

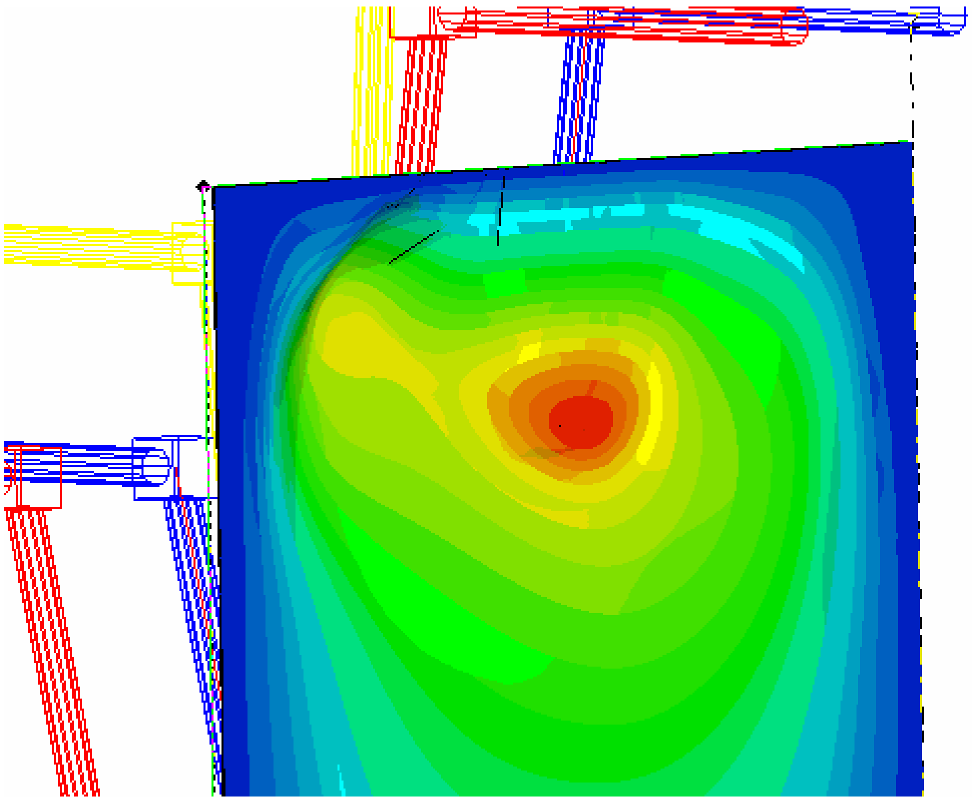
Thermal consequences of shield induced currents



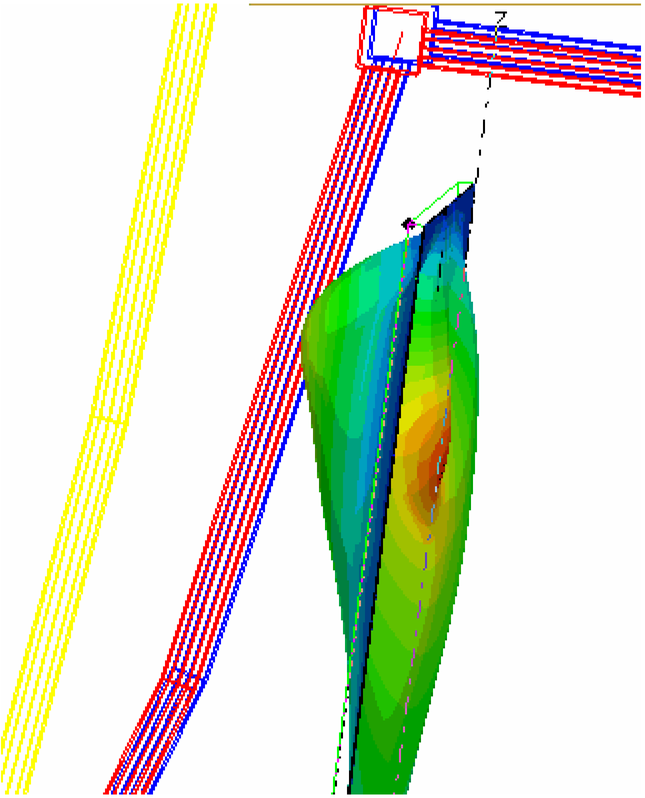
High temperatures (over 200 C) in regions of high current densities

Deformation due to high temperatures (magnified plots)

Structural constraints (zero displacement BCs) placed around the shield

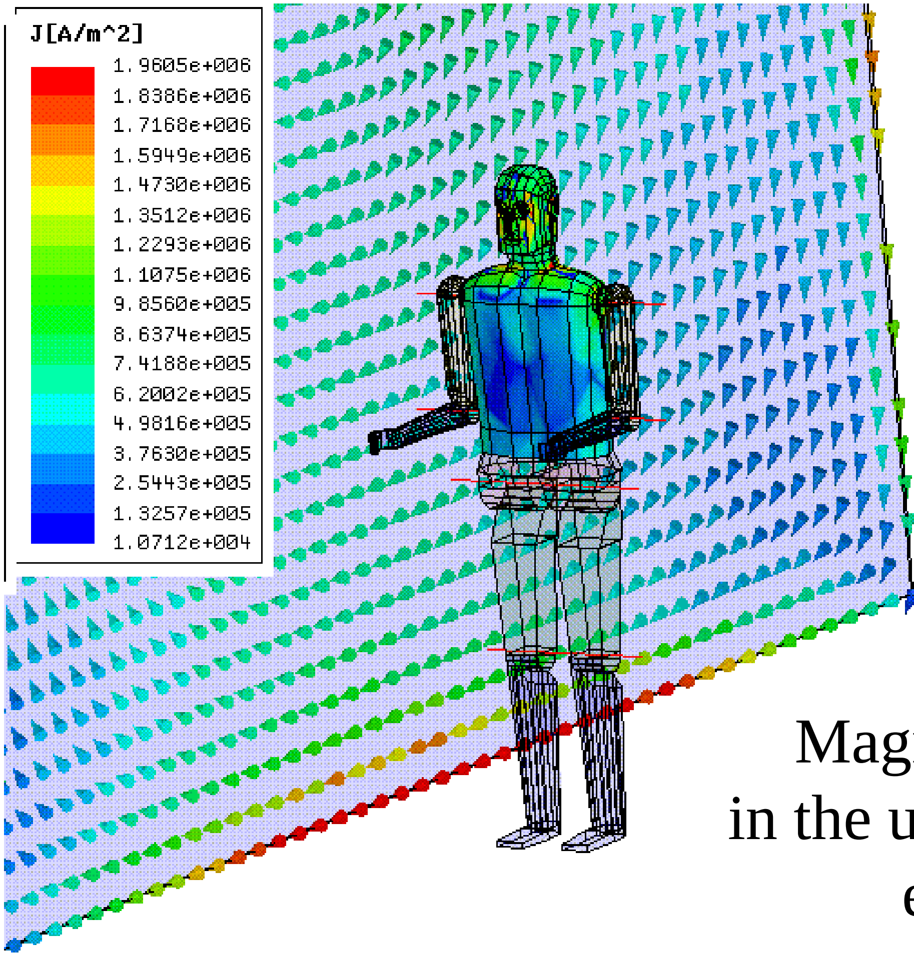


Front view



Side view

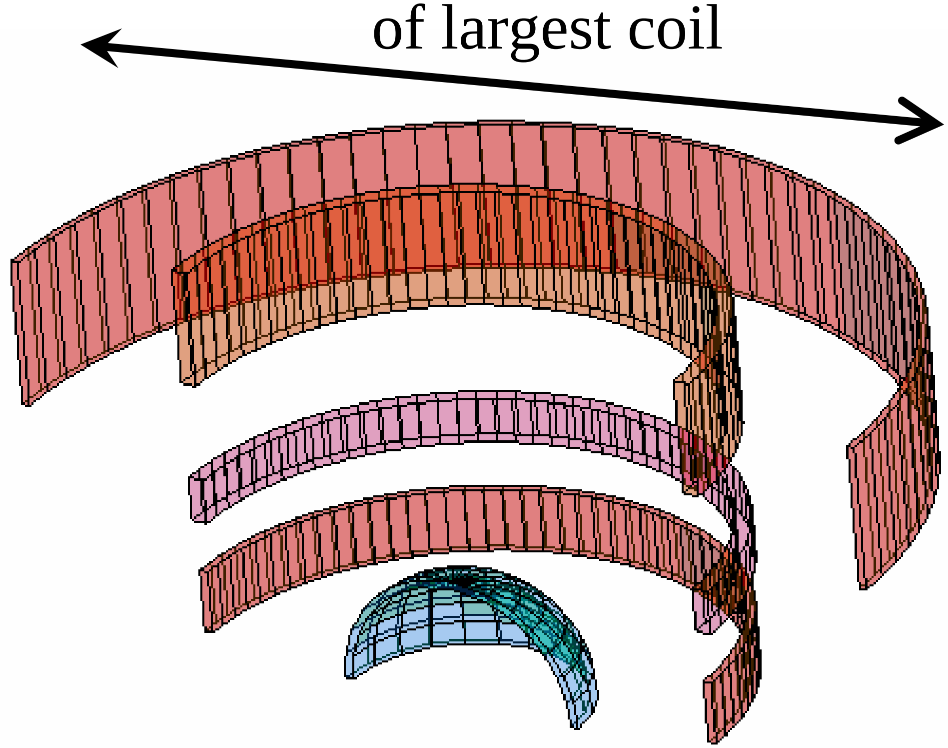
Biological effects evaluation



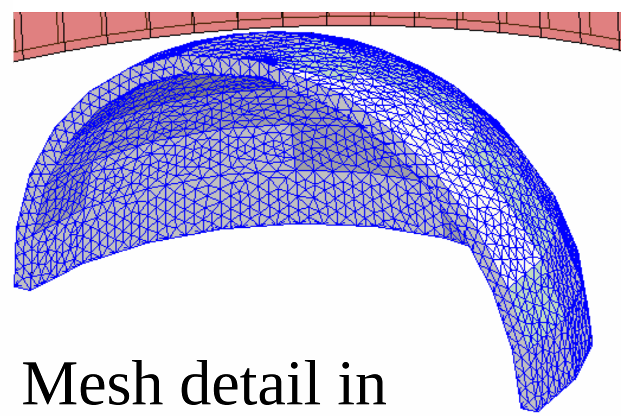
Magnetic field distribution in the upper body (5 mT) due to eddy currents and proximity to the shield

Shielding of MRI devices

1.8 m diameter
of largest coil

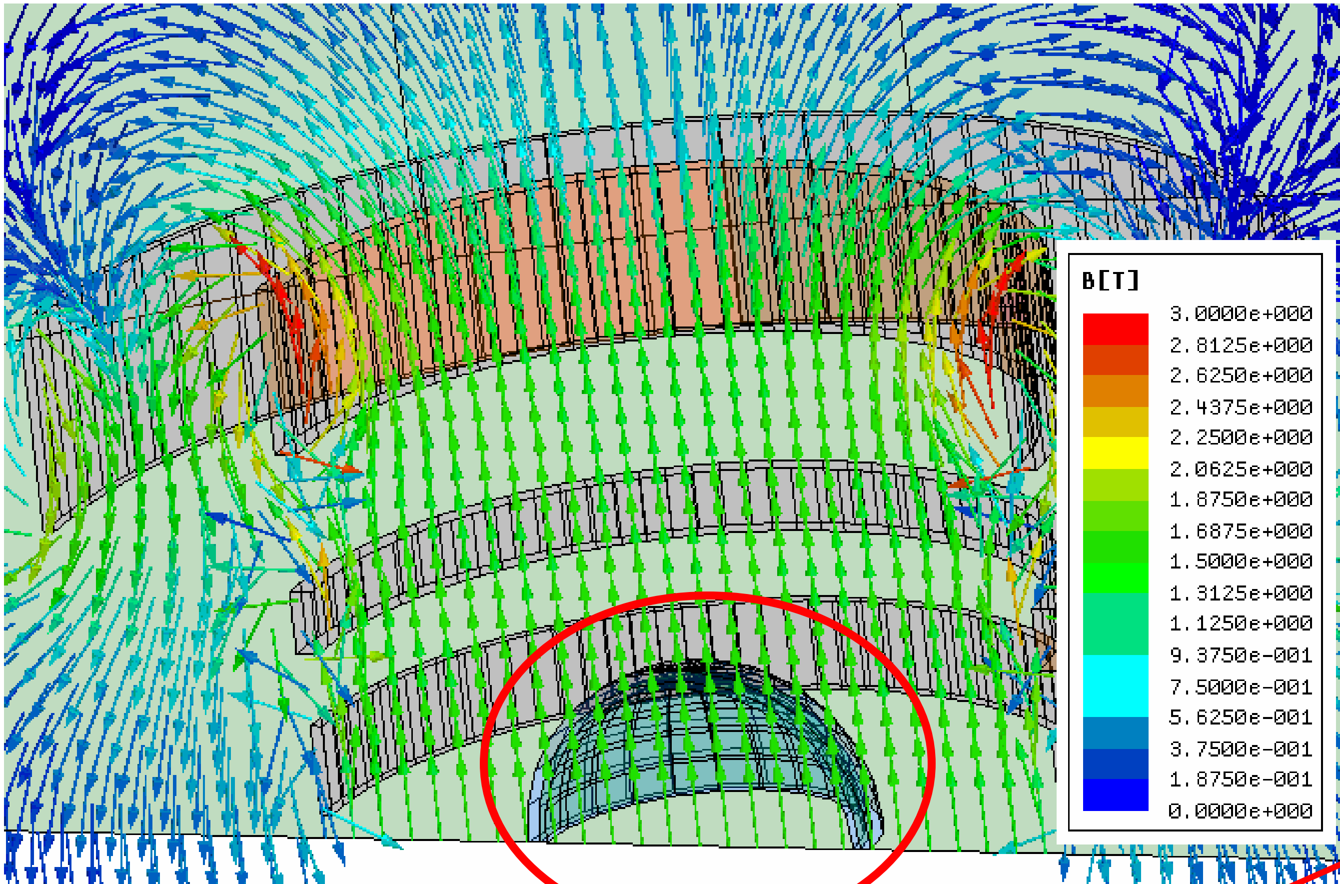


High field coil system
of the MRI device



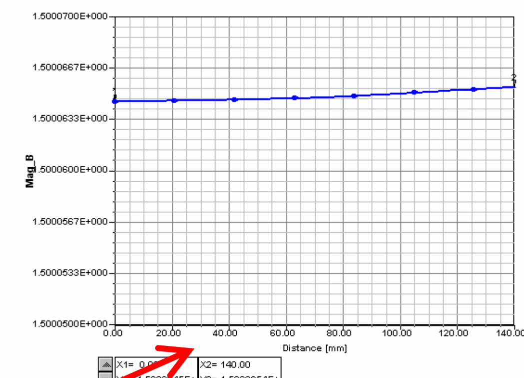
Mesh detail in
high field uniformity
region
(over 2 Million tets)

Field uniformity

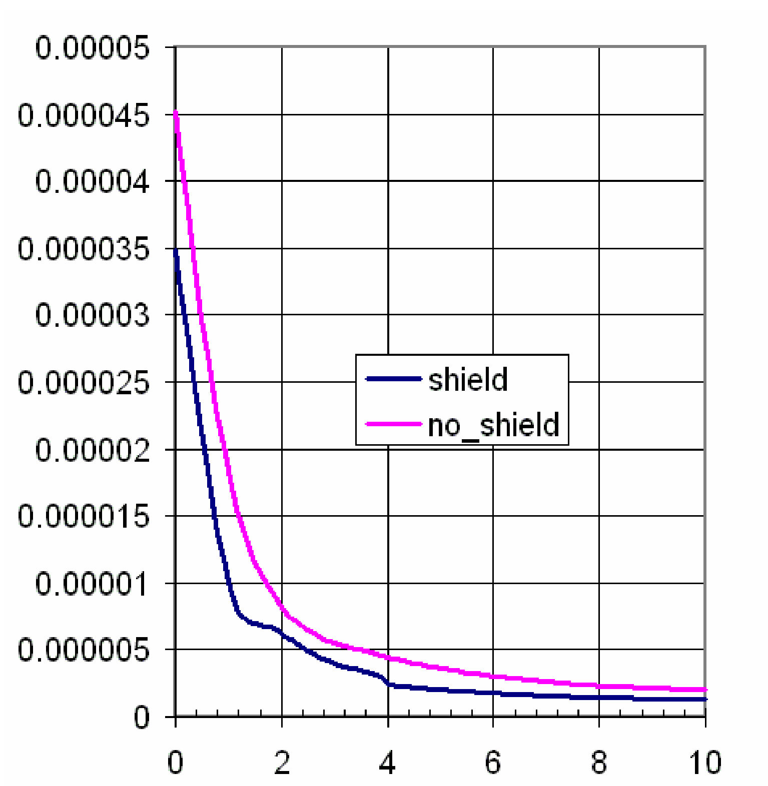


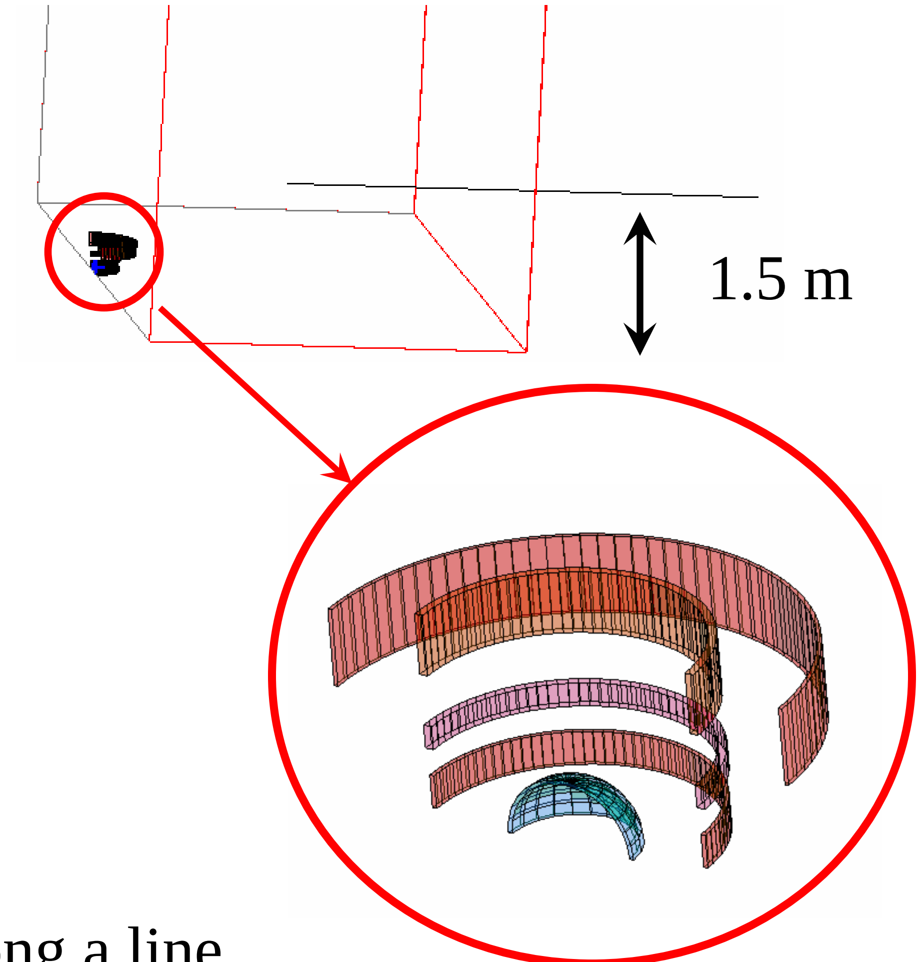
Region of high field uniformity

Field values are between 1.5000645 and 1.5000654 for 140 mm distance



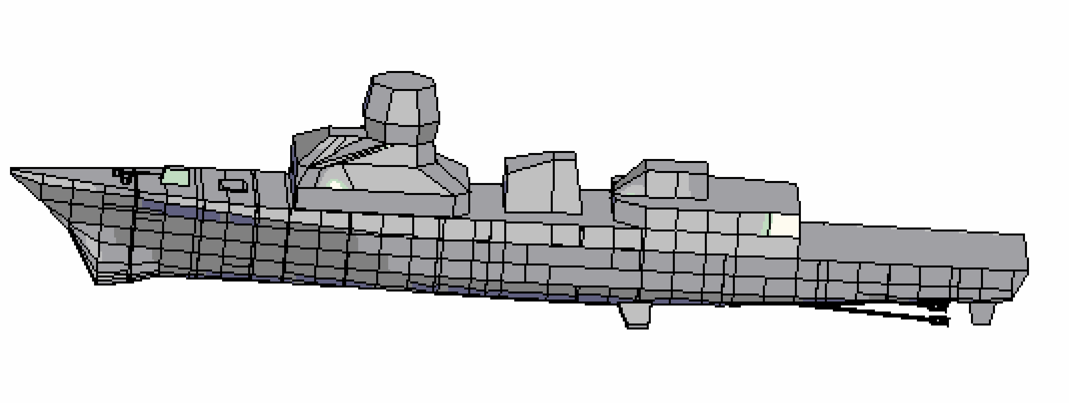
Shield effect



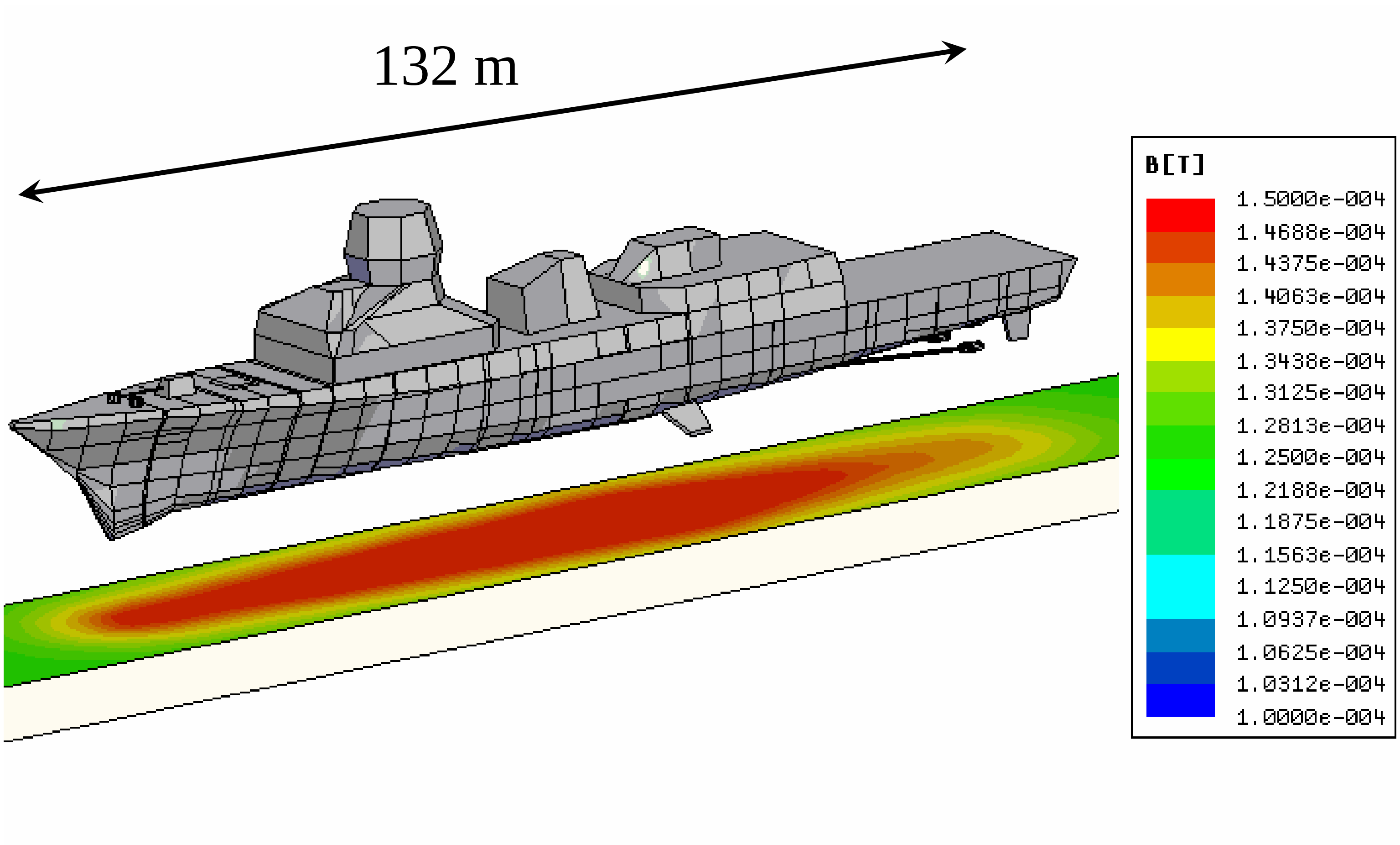


Field magnitude along a line
1.5 m above symmetry plane

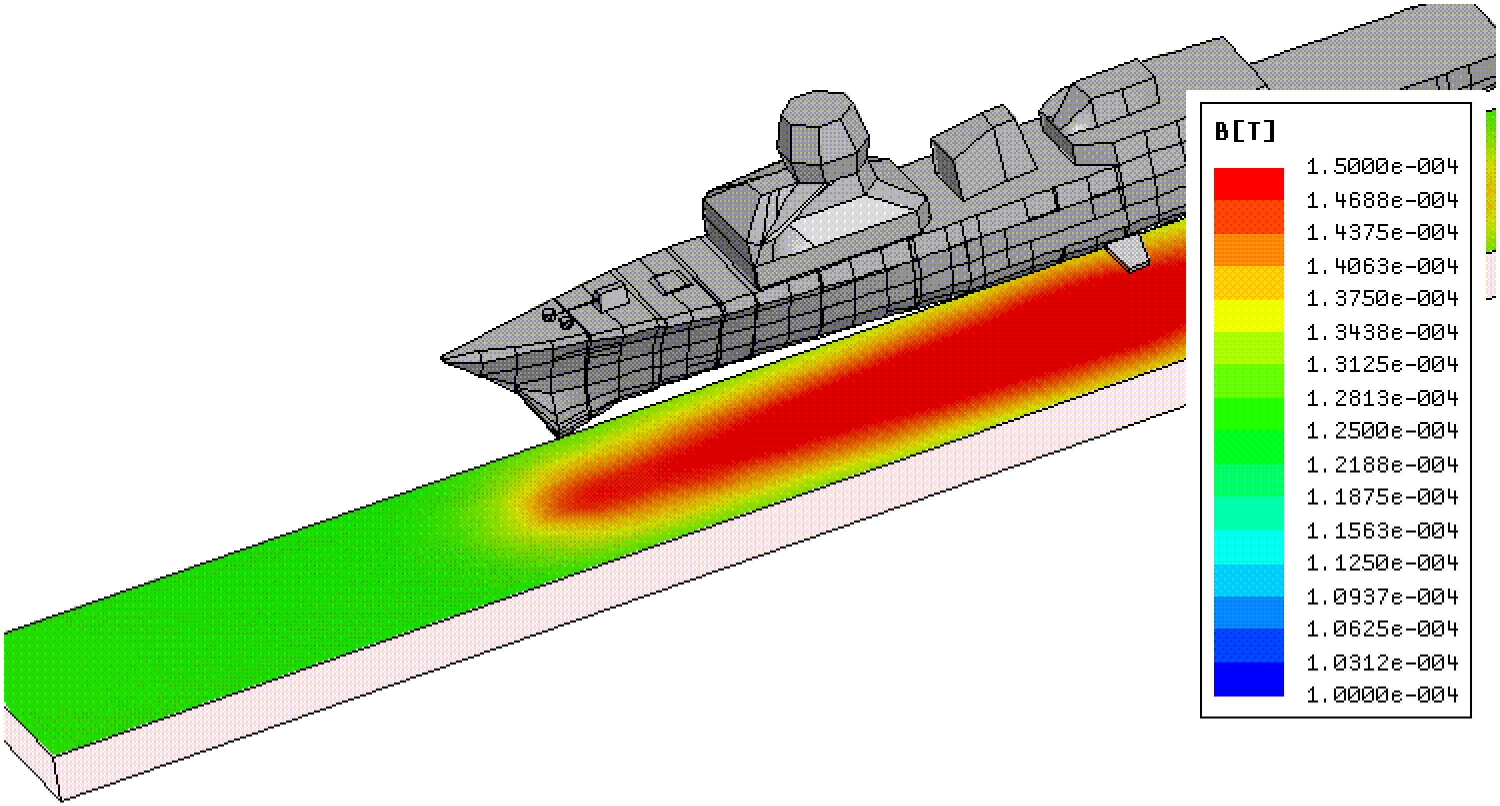
Industrial EMC/EMI Applications :
Electromagnetic signature of a ship



Signature of a large ship in external magnetic field

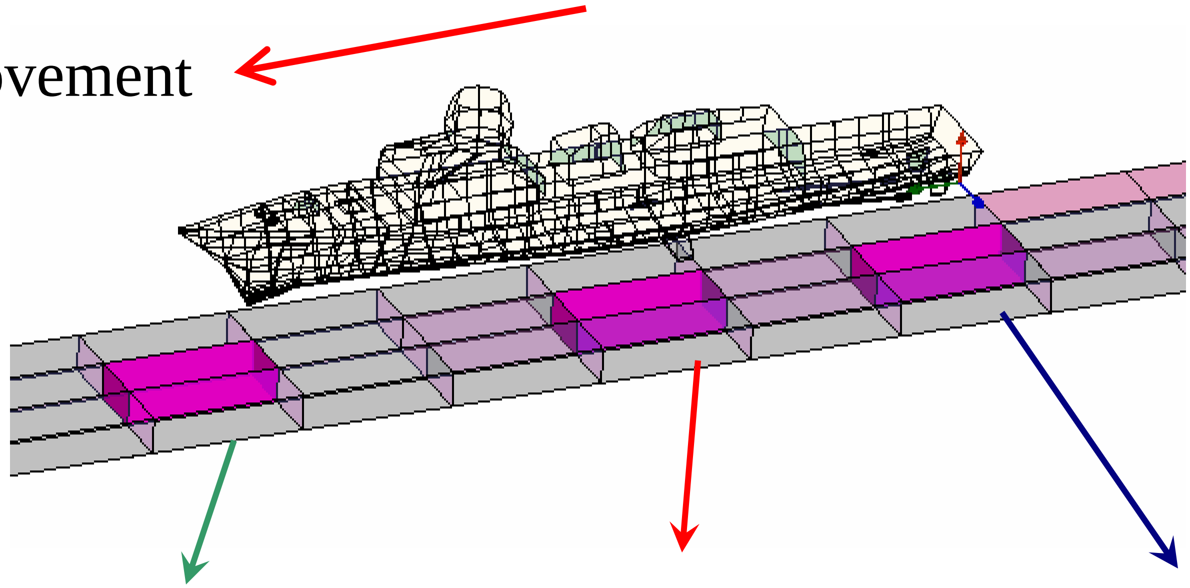


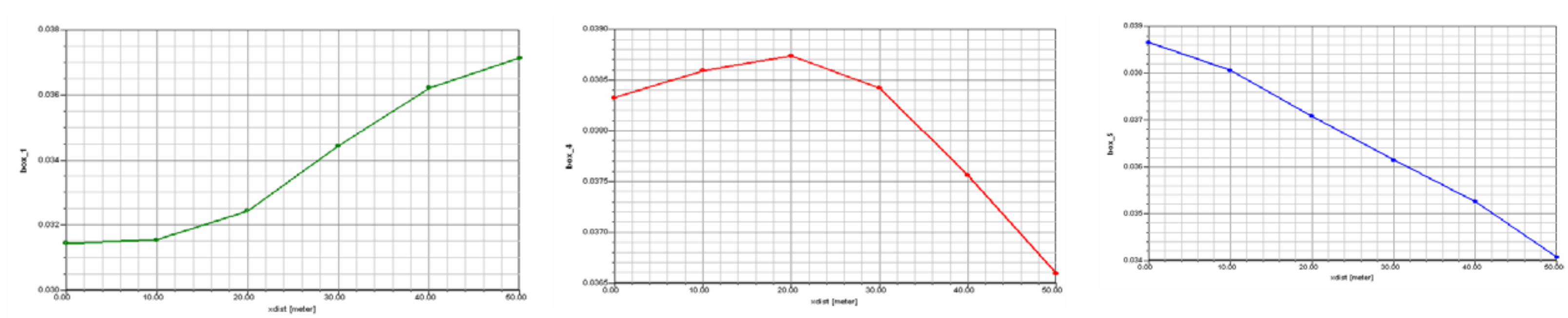
Animation of a parametric analysis results



Flux variation vs distance measured at different locations

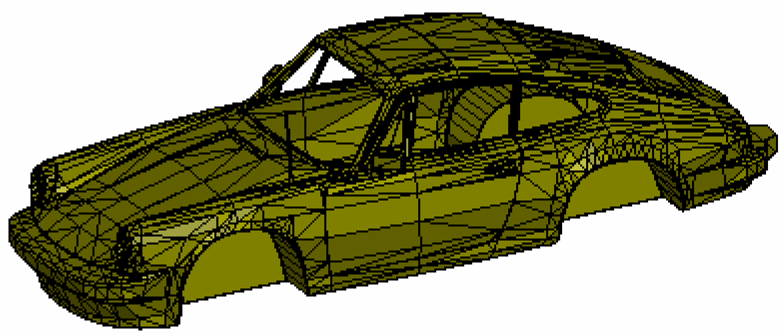
Ship movement





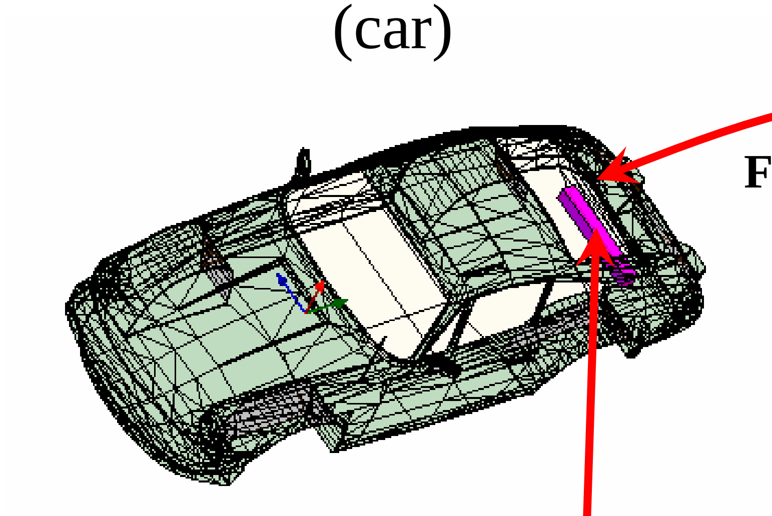
Industrial EMC/EMI Applications :

Electromagnetic radiation of ignition system



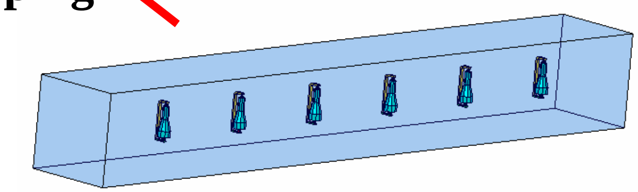
Principle of the Maxwell – HFSS link

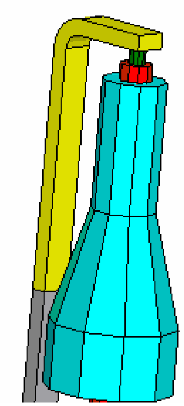
HFSS model
(car)



Maxwell model
(spark plugs)

Field mapping

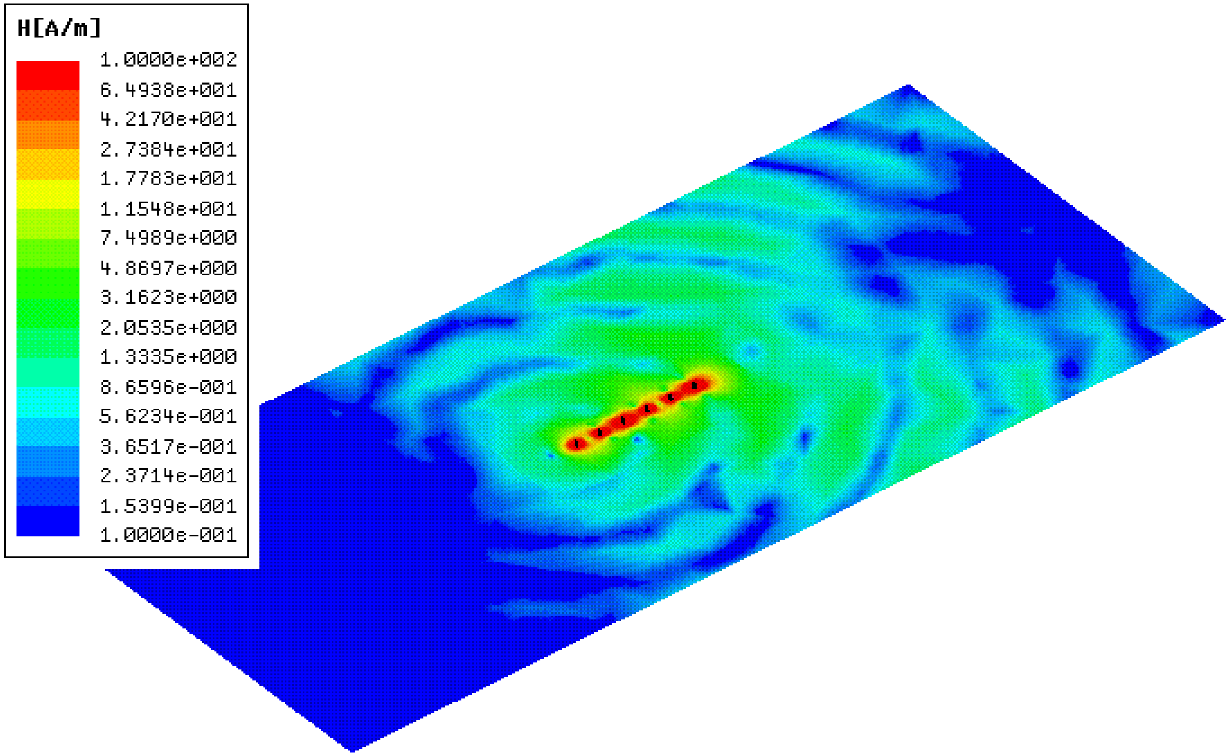




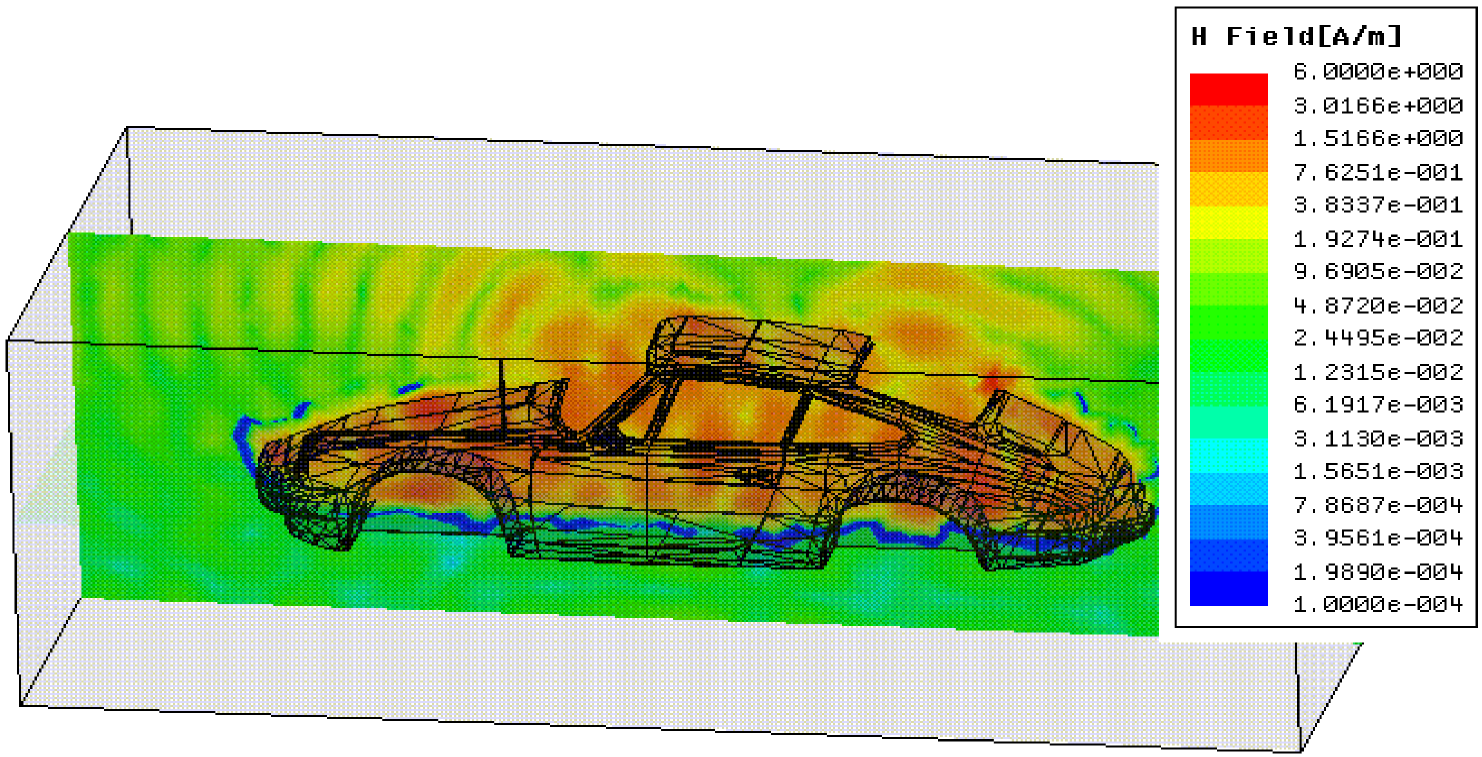
Spark plug
detail

Target box
for field mapping

Source field in Maxwell model

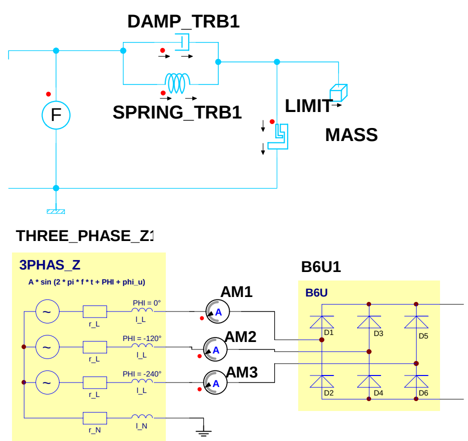


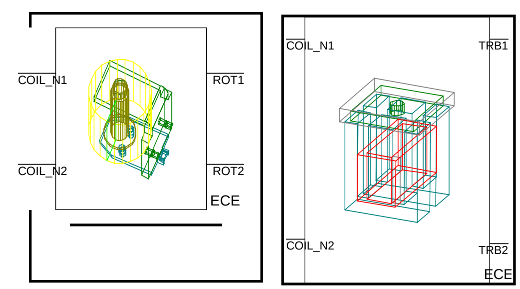
Radiation in HFSS model (source is in the Maxwell model)



Industrial EMC/EMI Applications :

Conducted interference
(source impedance coupling effects)



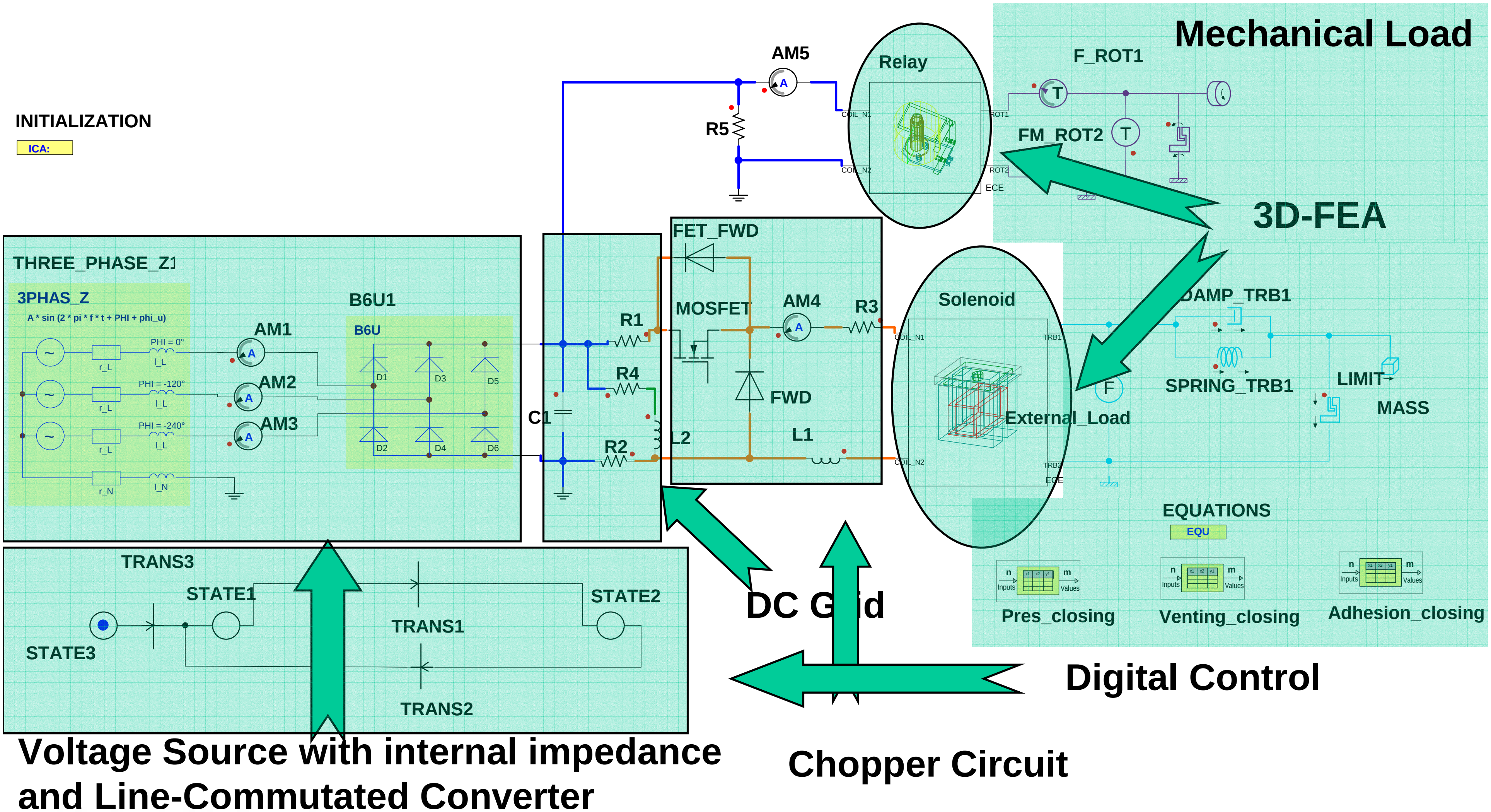


Case Study – Integrated Sub-System Design

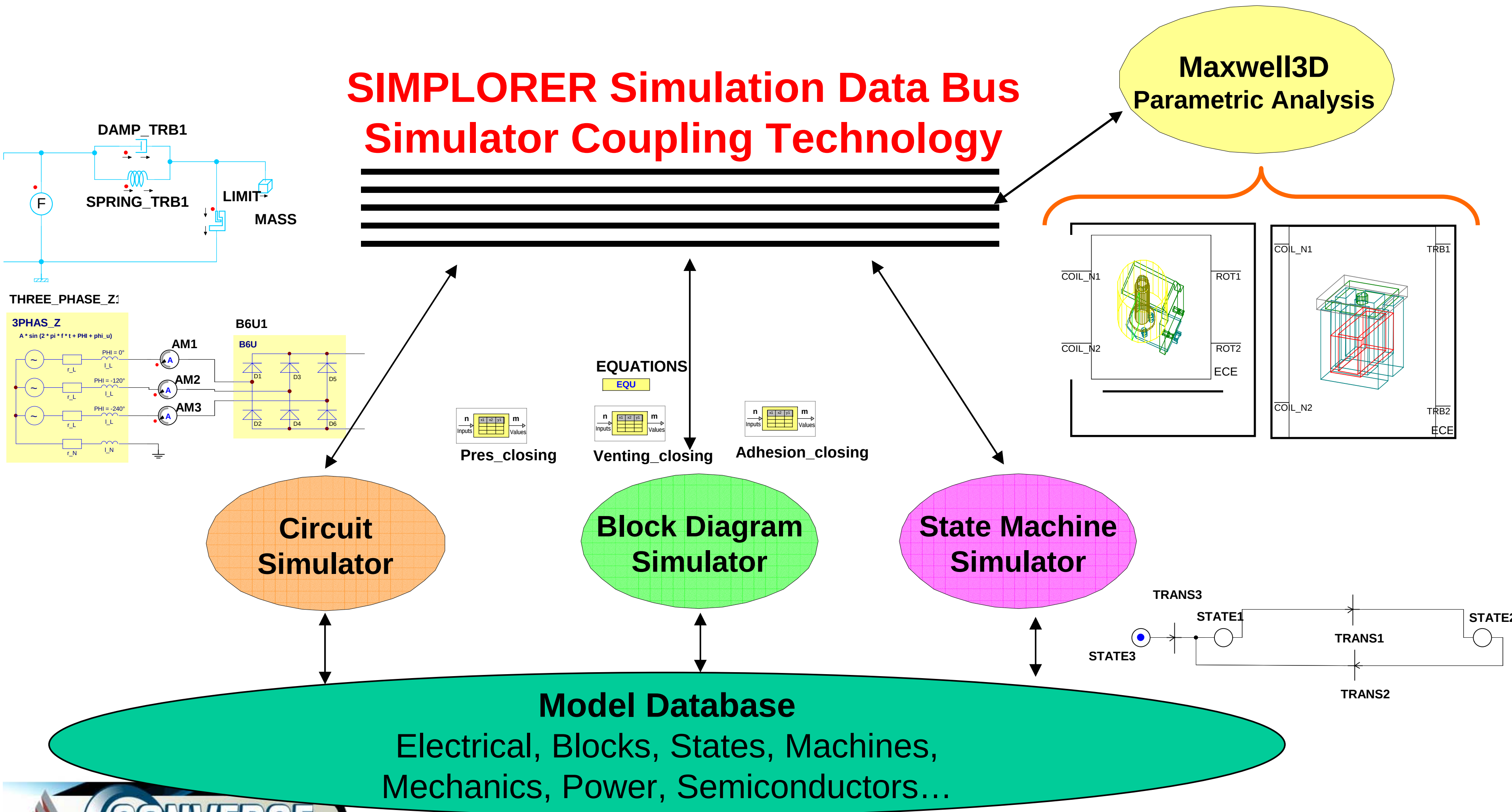
Fuel Injection Solenoid and Electromagnetic Relay

- **EMC issue**
  - Due to the internal impedance of the power source and the nonlinear characteristics of the individual components in the system, the electromagnetic relay will encounter a chattering time-response behaviour upon closing/opening the solenoid valve
- **Consequences**
  - As an immediate consequence of these instabilities, the contact resistance of the relay armature will increase by increasing the amount of dissipated power with increasing the probability of melting the relay parts
  - Power quality depreciation due to high level of harmonics induced in the circuit

Case Study – Integrated Sub-System Design



Case Study – Integrated Sub-System Design



Case Study – Integrated Sub-System Design

Solenoid Base Operation

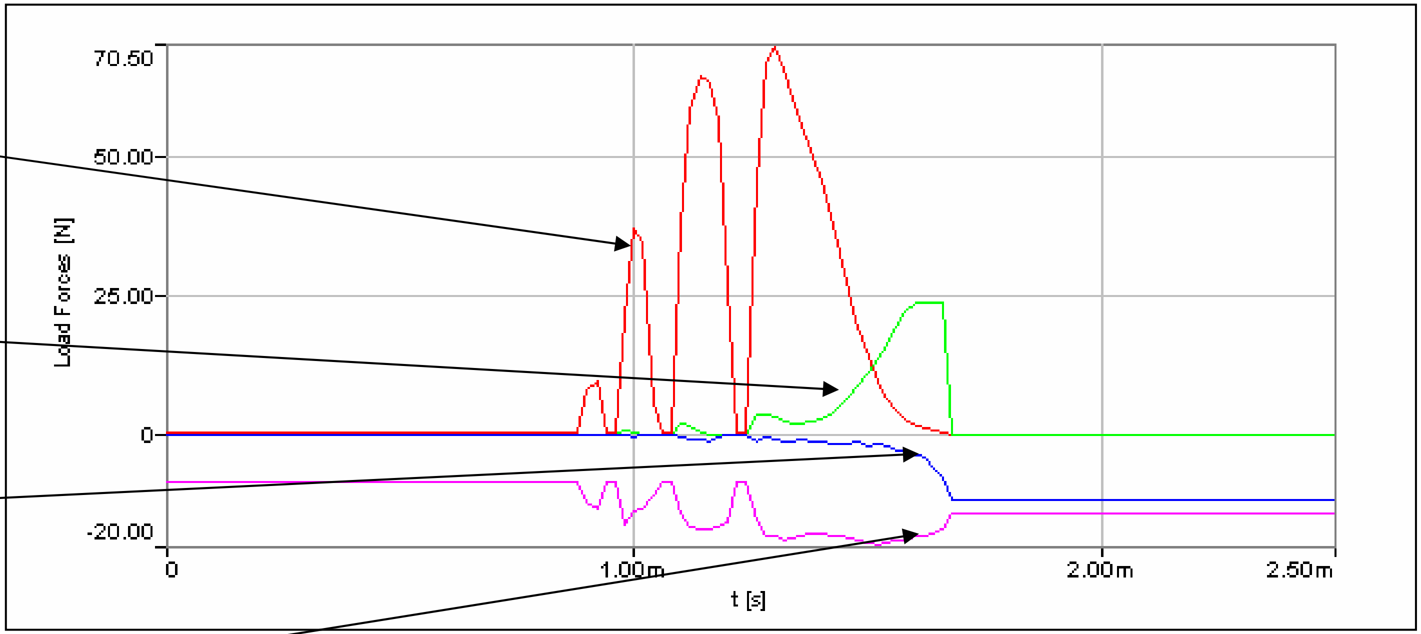
External Load Configuration

Adhesion Load
F(Position)

Viscous Load
F(Speed)

Press Load
F(Position)

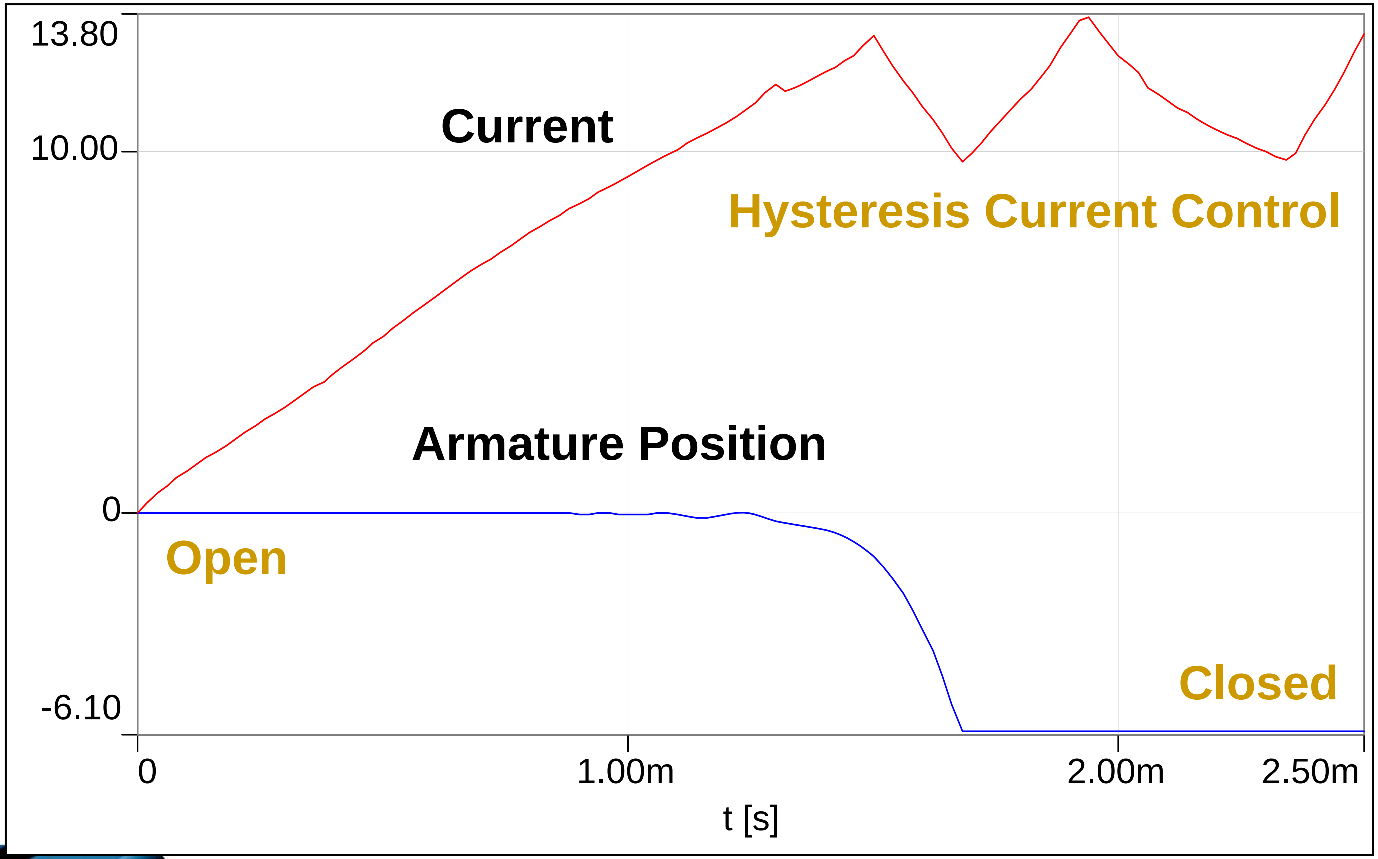
Venting Load
F(Position)



Case Study – Integrated Sub-System Design

Solenoid Base Operation

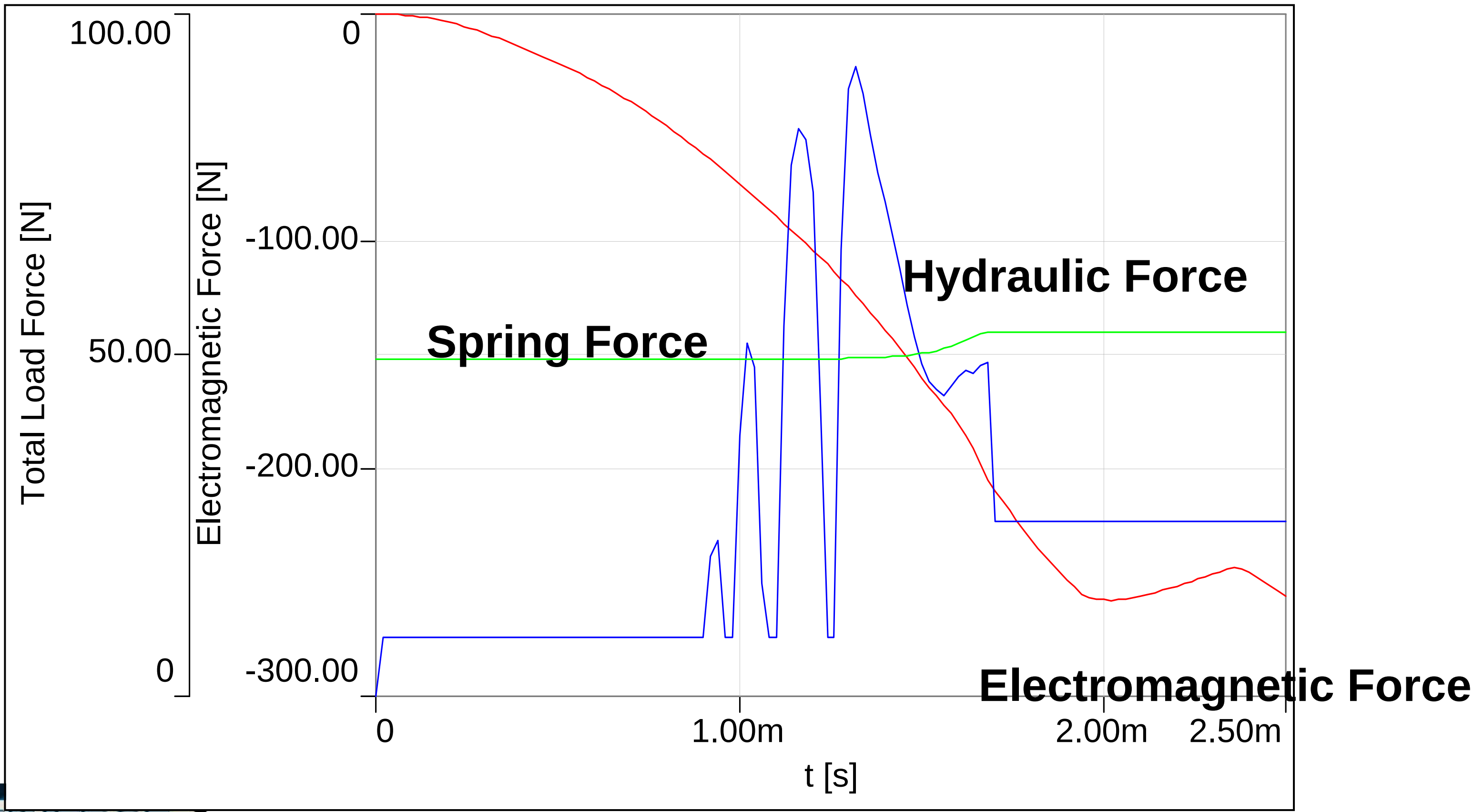
Current and Position Characteristics



Case Study – Integrated Sub-System Design

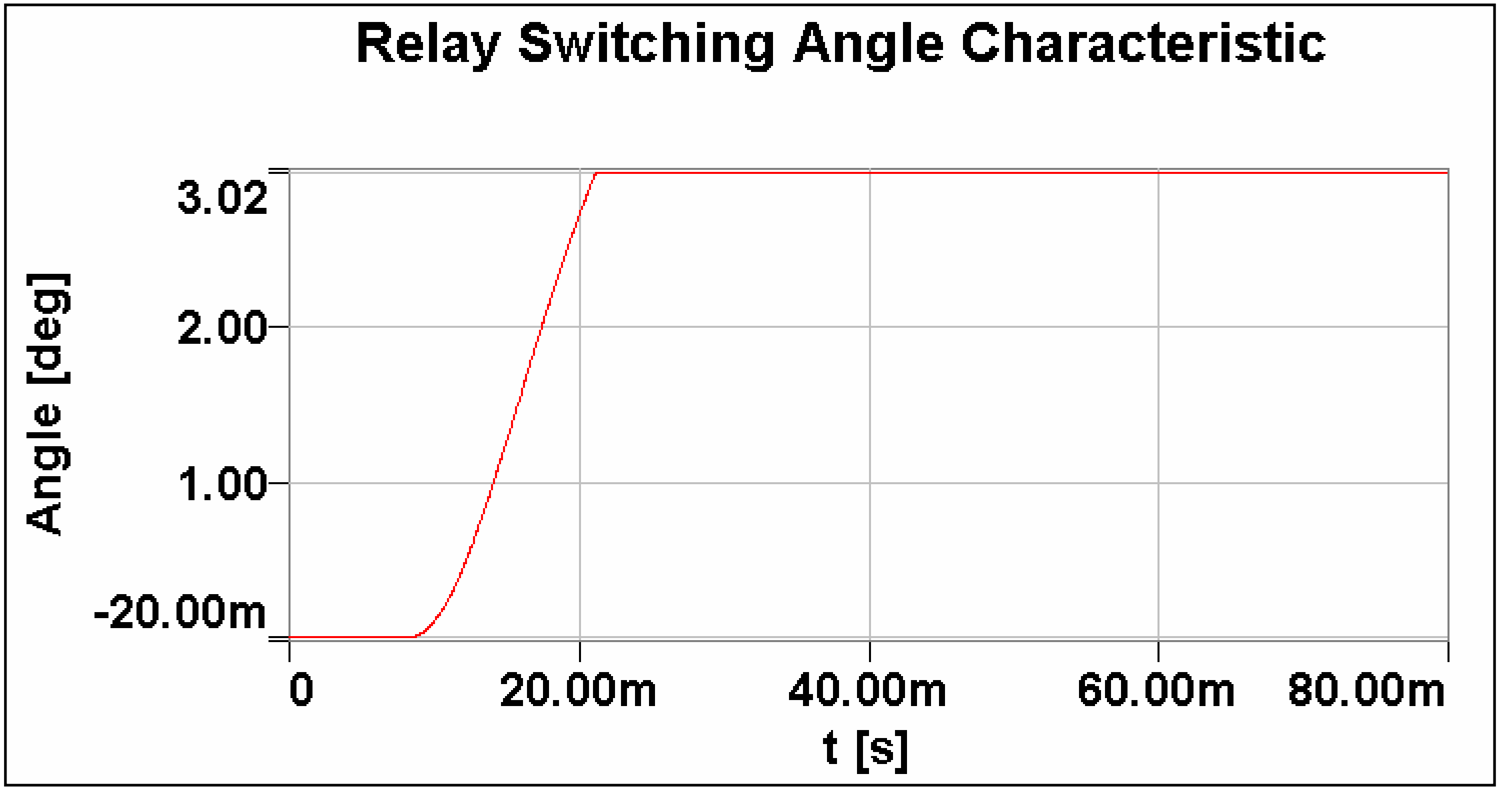
Solenoid Base Operation

Force Characteristic



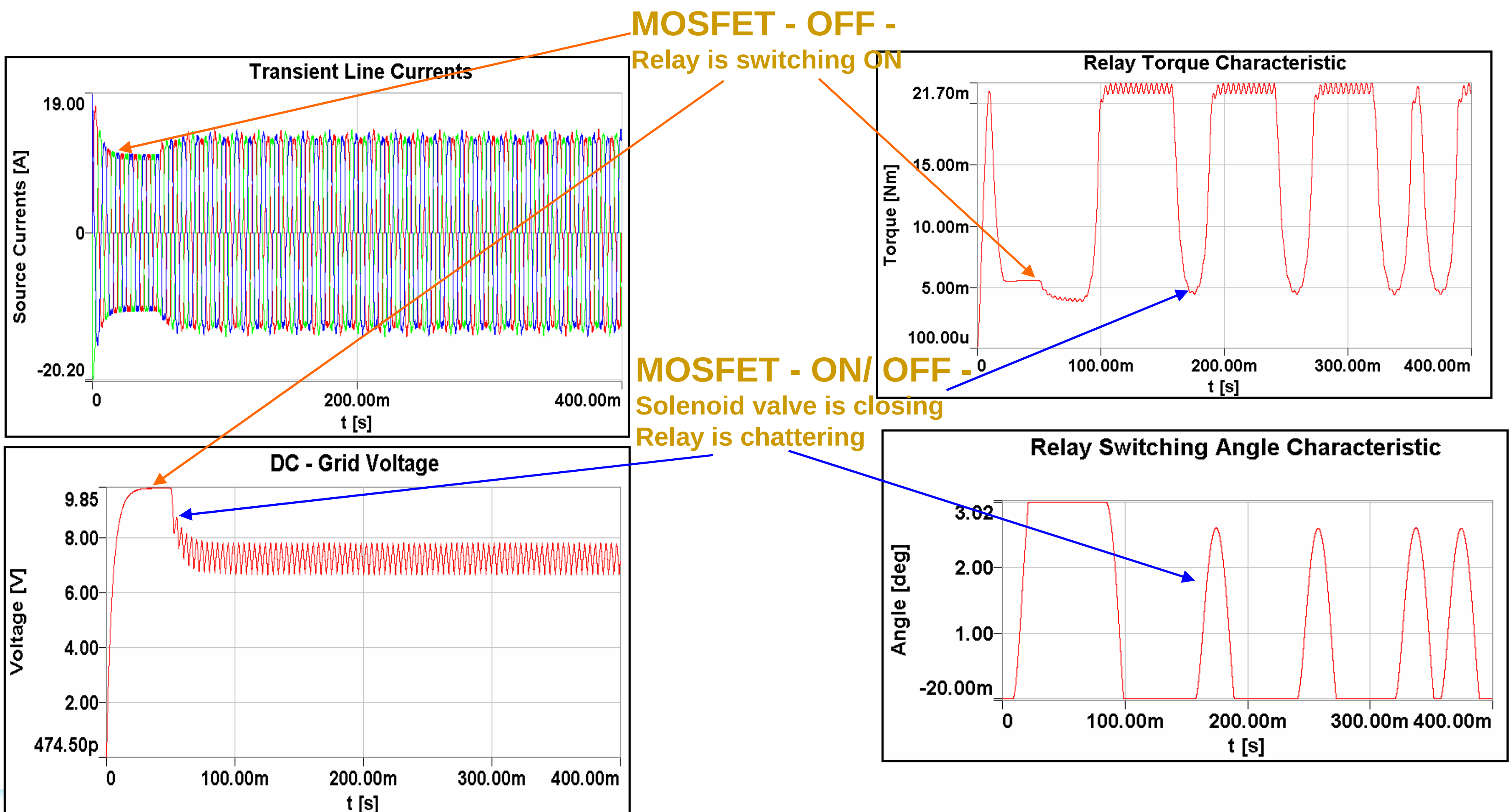
Case Study – Integrated Sub-System Design

Electromagnetic Relay Base Operation



Case Study – Integrated Sub-System Design

Sub-System Operation – Relay Chattering

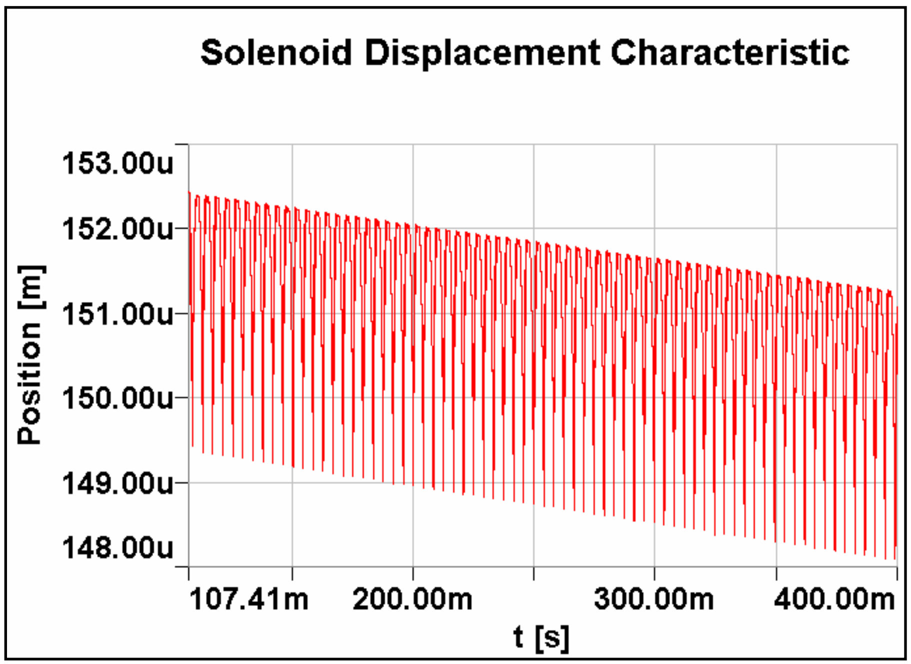


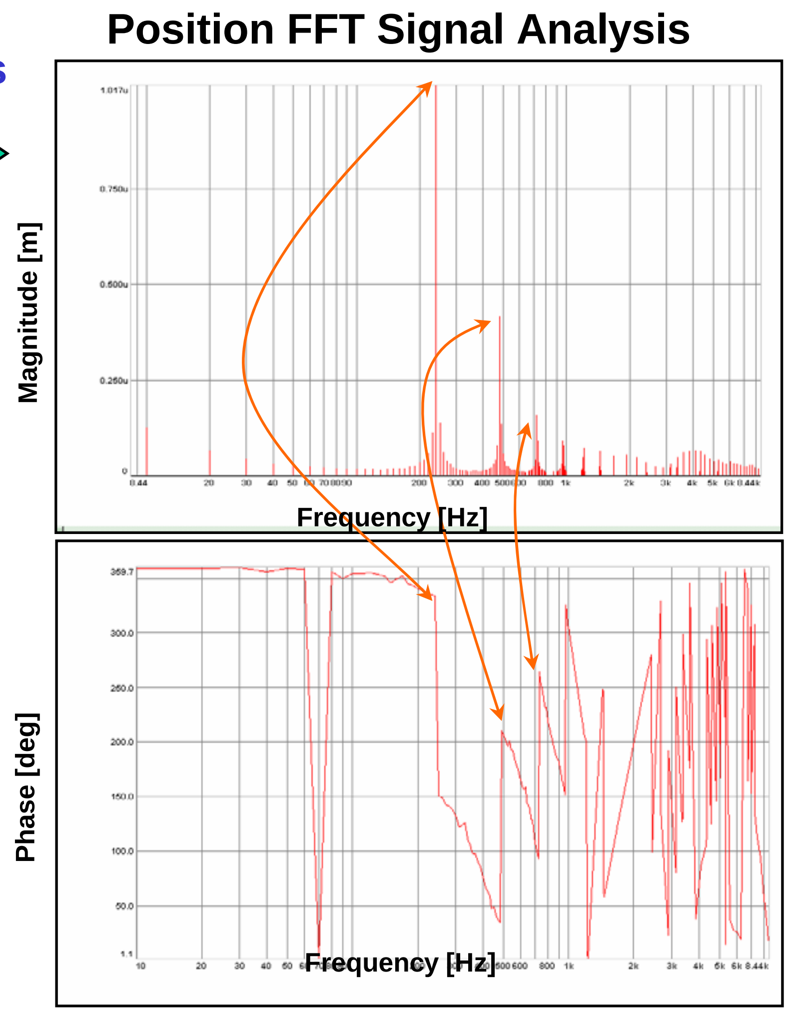
Case Study – Integrated Sub-System Design

Sub-System Operation – Solenoid Vibration

Mechanical vibrations

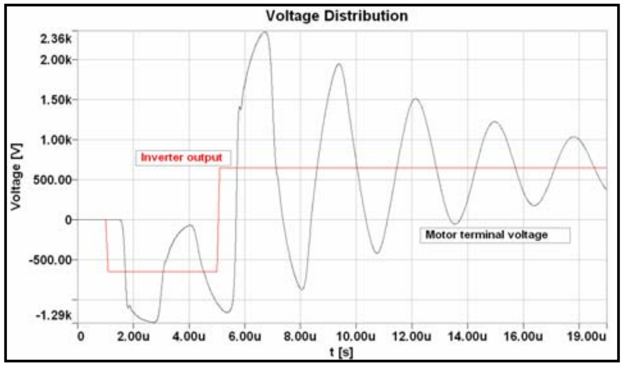
Audible noises

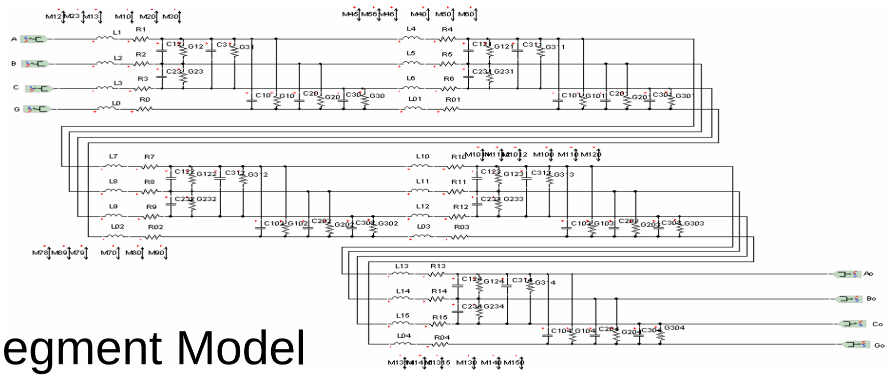




Industrial EMC/EMI Applications :

Over-voltages in windings due to cable – motor impedance mismatch





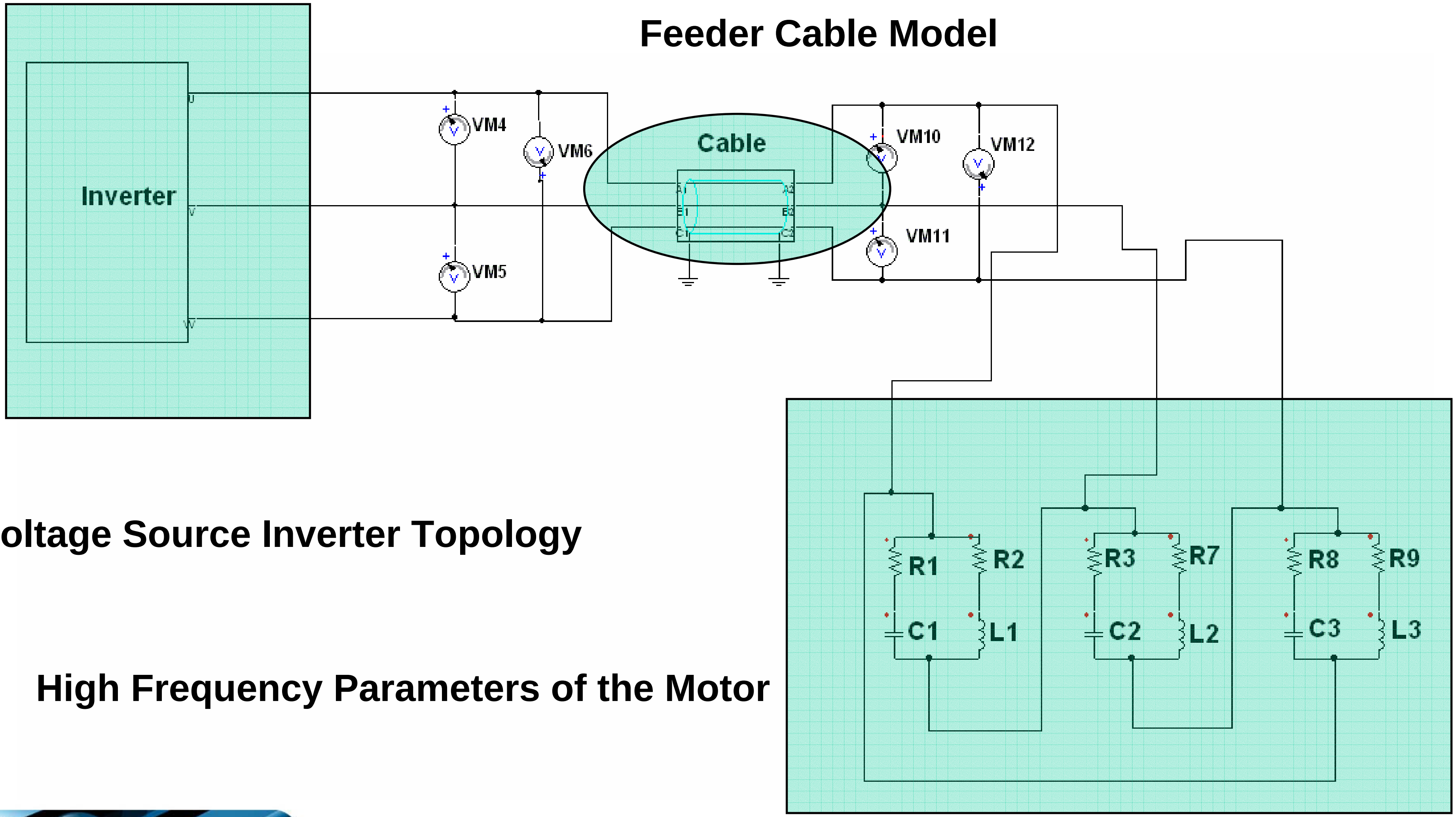
5 Segment Model

Case Study – Inverter Fed Induction Motor Design

- **EMI Definition**
  - Electromagnetic emissions from a device or system that interfere with the normal operation of another device or system
- **EMI Description**
  - When the motor is fed by an inverter power supply, there will be non-sinusoidal voltages and currents in the motor windings and hence additional losses
  - Typical problems associated with voltage source inverter fed motors are non-linear distribution of voltage among the turns and the windings of the stator, bearing currents, excessive heating, etc
  - Introducing feeder cable may cause voltage doubling at the motor terminals because of the voltage reflections (due to the mismatch between the characteristic impedances of the cable and the motor) and result in very high stress on the insulation

Case Study – Inverter Fed Induction Motor Design

Feeder Cable Model



Voltage Source Inverter Topology

High Frequency Parameters of the Motor

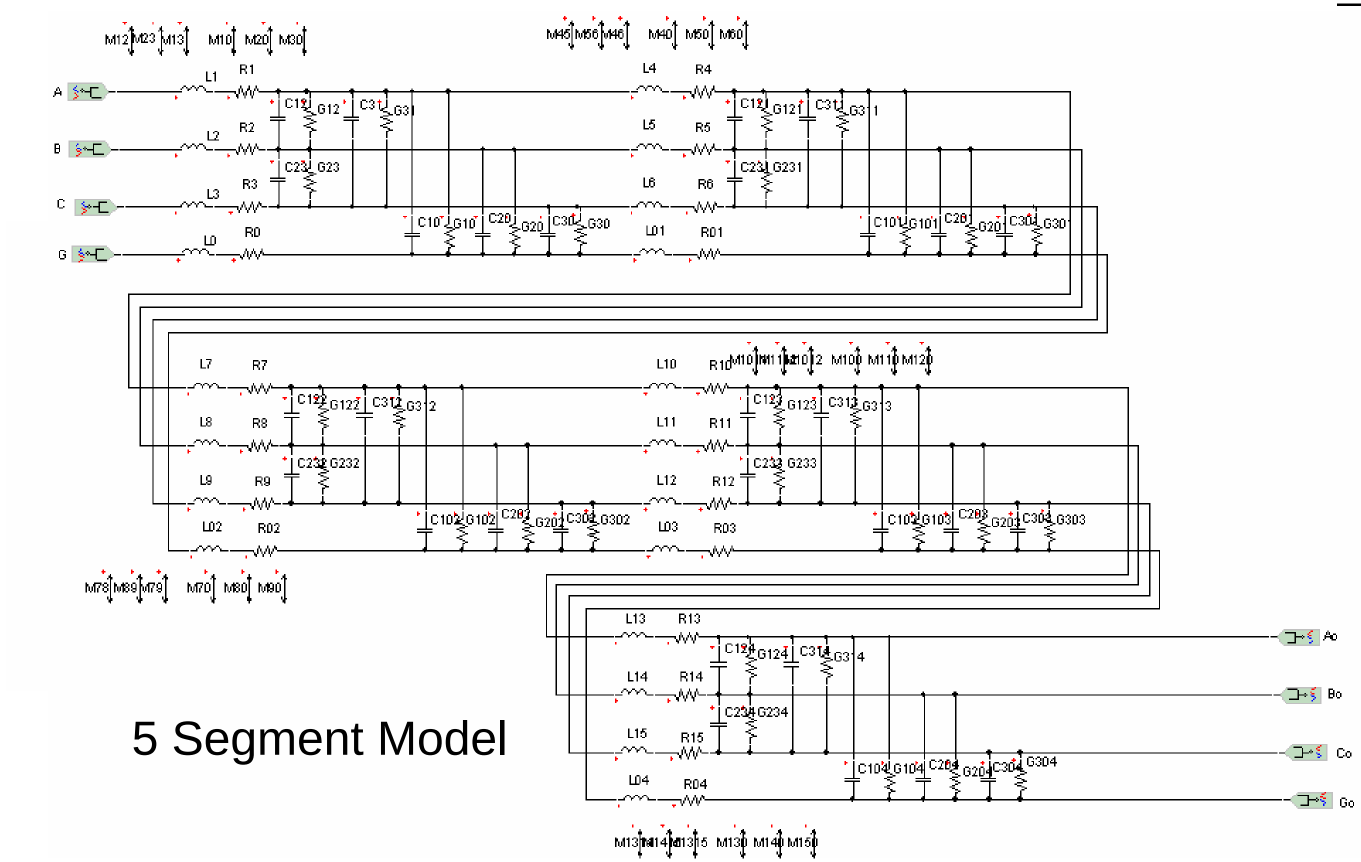
Case Study – Inverter Fed Induction Motor Design

- **Design methodology**
  - **Inverter Topology**
    - To feed the motor, a voltage source PWM IGBT inverter configuration is used. The train of wave-fronts has very sharp rise-times and fall-times
  - **Feeder Cable Model**
    - Maxwell FEA engine is used to estimate the distributed parameters of the cable
  - **Electrical Motor Model**
    - The high frequency equivalent model is obtained for a set of measurements of a 100 hp motor

Case Study – Inverter Fed Induction Motor Design

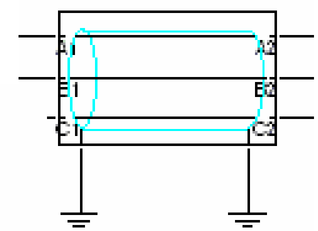
Feeder Cable Model

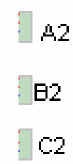
Using hierarchical structure within SIMPLORER environment



5 Segment Model

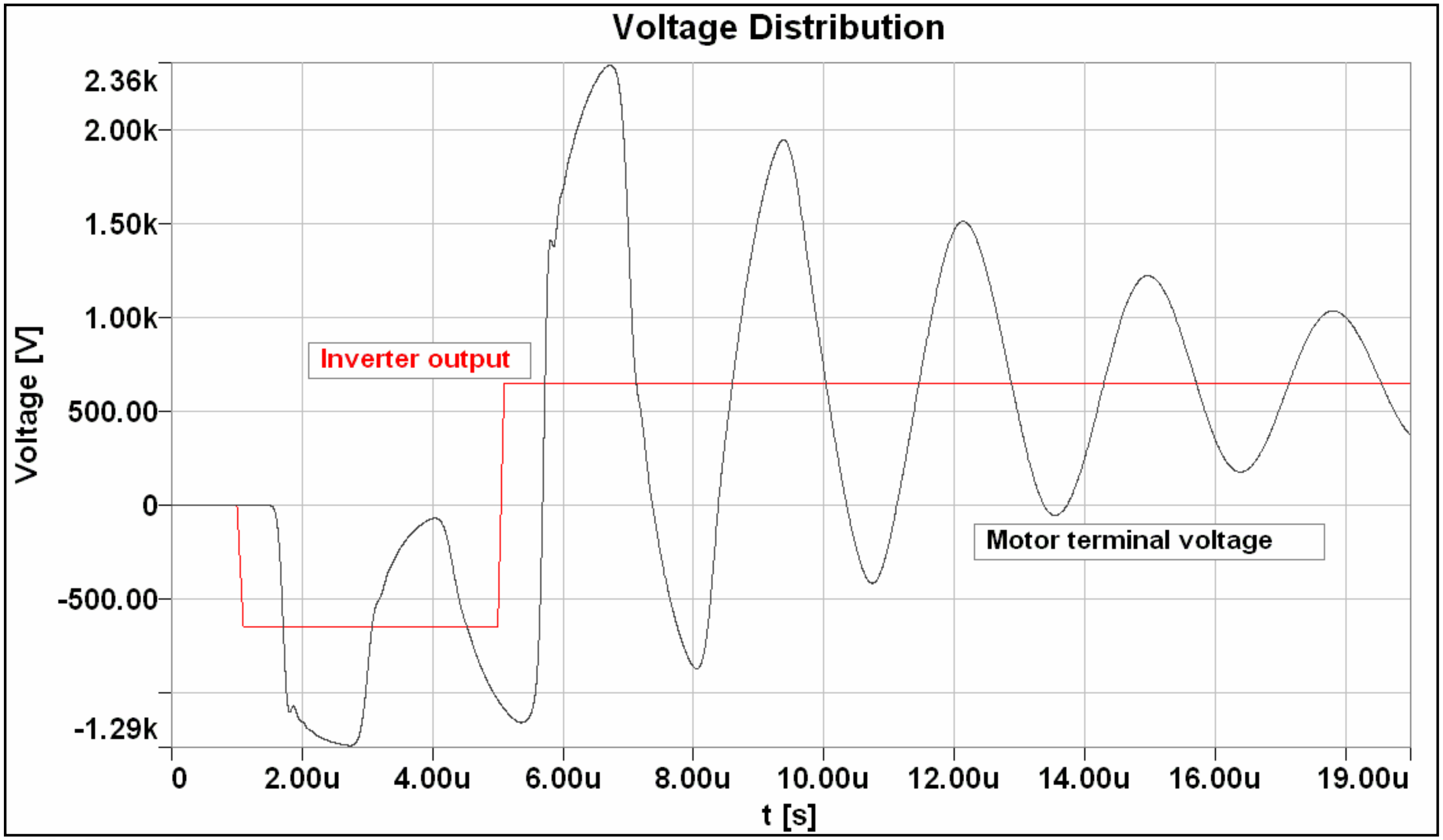
Cable



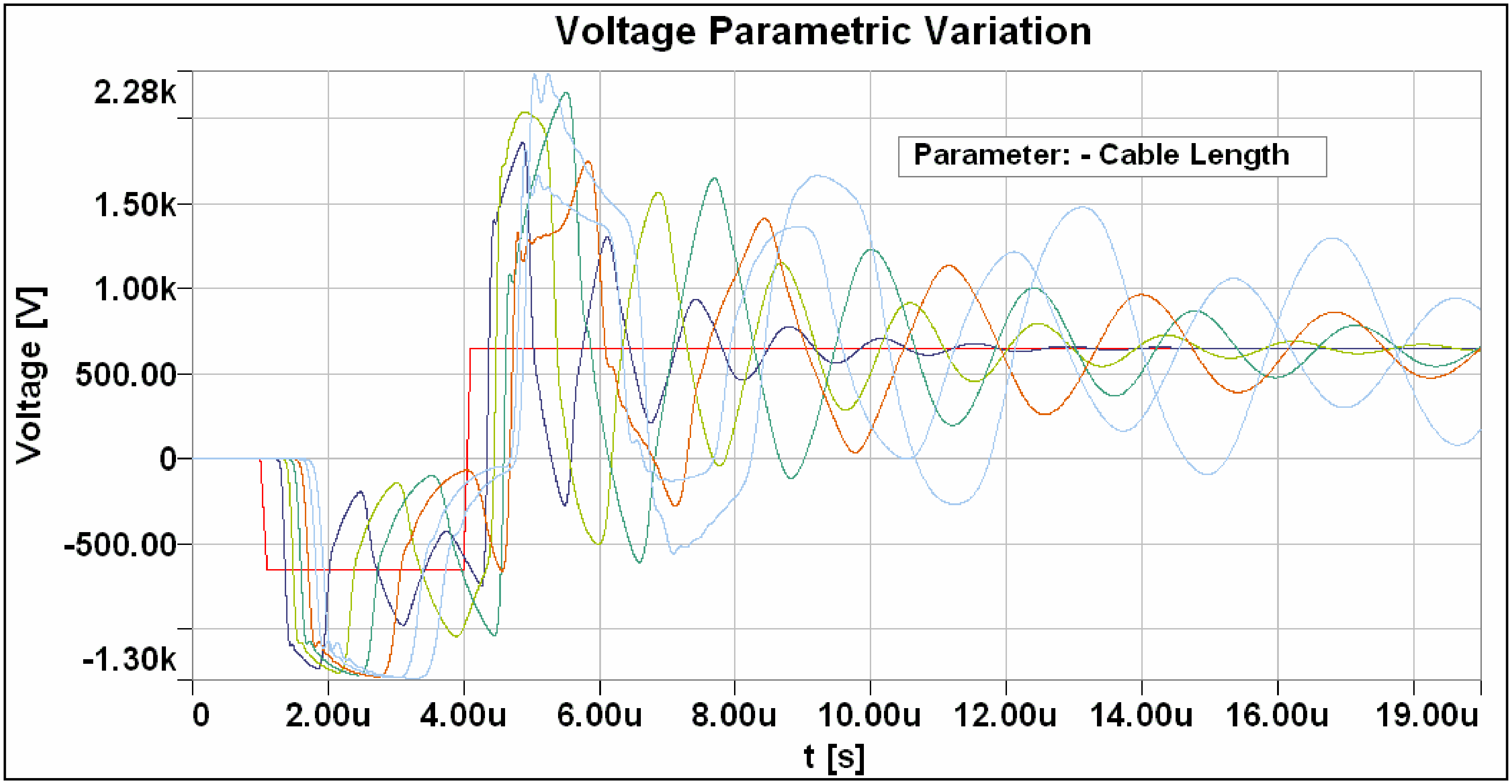


Case Study – Inverter Fed Induction Motor Design

Simulated inverter output voltage and motor terminal voltage with 35m long cable

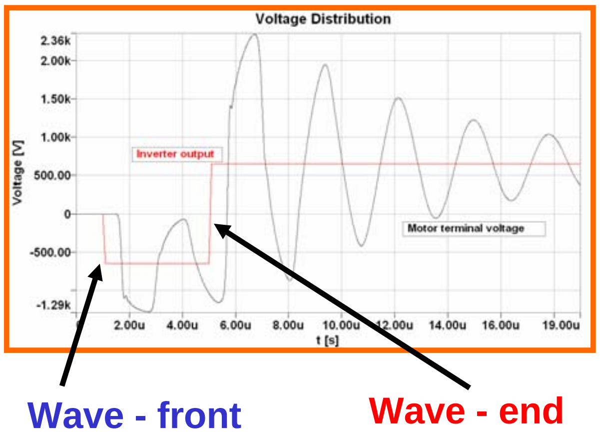


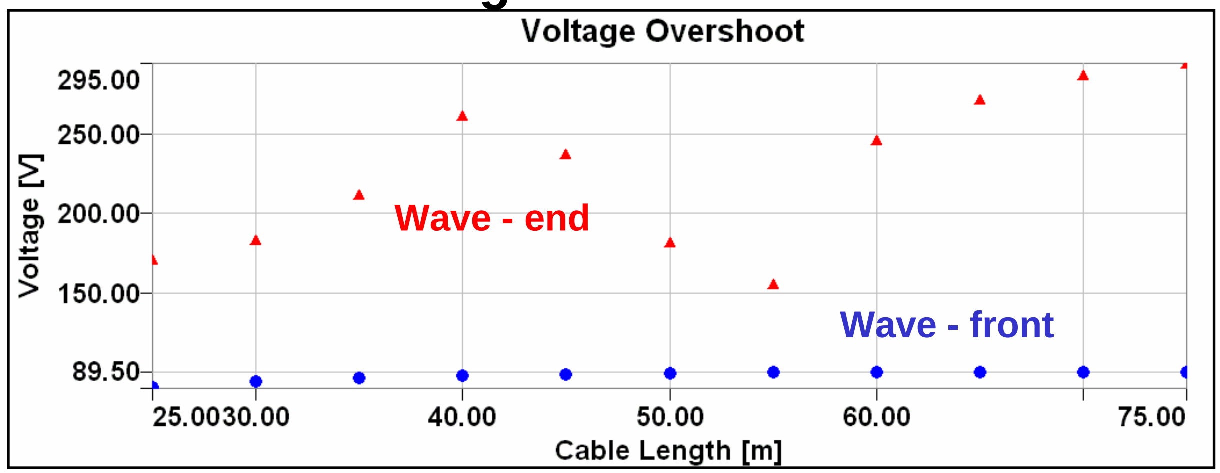
Case Study – Inverter Fed Induction Motor Design

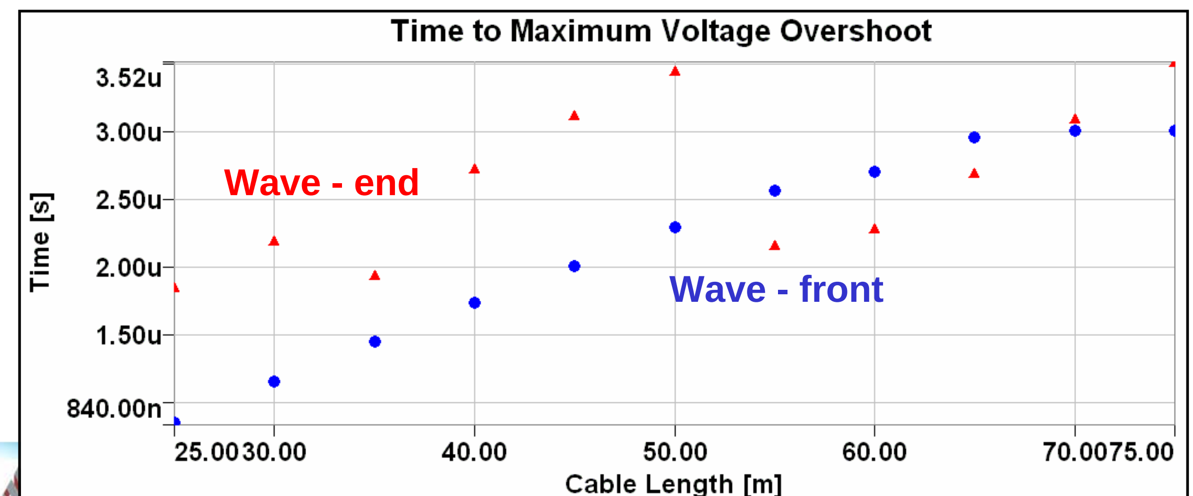


Case Study – Inverter Fed Induction Motor Design

Motor terminal voltage overshoot characteristics variation with the cable length







Case Study – Inverter Fed Induction Motor Design

Sensitivity Analysis @ -60% Fall Time and Rise Time

Parameter	Performance Measure	Nominal Value	Abs	RelDev
Inverter.FallTime Nominal Value: 100.00n Varied Value: 40.00n	CTRL_TR1.OVERSHOOT	219.05	219.48	1.97m
	CTRL_TR.TPEAK	1.47u	1.45u	-11.10m
	CTRL_TR.OVERSHOOT	95.66	95.99	3.46m
	CTRL_TR1.TPEAK	2.03u	1.98u	-23.01m
Inverter.RiseTime Nominal Value: 100.00n Varied Value: 40.00n	CTRL_TR1.OVERSHOOT	219.05	218.88	-737.48u
	CTRL_TR.TPEAK	1.47u	1.41u	-41.20m
	CTRL_TR.OVERSHOOT	95.66	95.66	-7.87n
	CTRL_TR1.TPEAK	2.03u	1.98u	-24.21m

Sensitivity Analysis @ +60% Fall Time and Rise Time

Parameter	Performance Measure	Nominal Value	Abs	RelDev
Inverter.FallTime Nominal Value: 100.00n Varied Value: 160.00n	CTRL_TR1.TPEAK	2.03u	2.03u	-504.71u
	CTRL_TR1.OVERSHOOT	219.05	219.24	879.93u
	CTRL_TR.TPEAK	1.47u	1.47u	3.27m
	CTRL_TR.OVERSHOOT	95.66	95.27	-4.00m
Inverter.RiseTime Nominal Value: 100.00n Varied Value: 160.00n	CTRL_TR1.TPEAK	2.03u	2.09u	28.28m
	CTRL_TR1.OVERSHOOT	219.05	220.34	5.91m
	CTRL_TR.TPEAK	1.47u	1.52u	38.30m
	CTRL_TR.OVERSHOOT	95.66	95.66	-3.50n

Conclusion

- Large spectrum of industrial applications in many areas
- Involves Maxwell, SIMPLORER, ePhysics, etc
- Covers:
  - Electromagnetic field applications (Maxwell)
  - Coupled Maxwell – SIMPLORER applications
  - System level simulations containing Maxwell models
  - Multi – physics effects accounted for (ePhysics)