In the world of electromagnetic and electromechanical design, state-of-the-art Finite Element simulation is critical to the virtual testing of new concepts and optimization of existing designs. This enables a reduction in the number of costly prototypes and offers the engineer an insight into the behavior of the magnetic field which complements, rather than competes with, test and measurement. CST EM STUDIO® (CST EMS) is a specialist tool for the static and low frequency simulation, design and analysis of electromagnetic devices. Applications covered include electrical machines, electromechanical components, sensors, power electronic components, power engineering and industrial equipment.

Low frequency problems inherently require many physical models and simulation techniques for handling non-linear material properties, permanent magnetic, eddy currents, power loss calculation, open boundaries and so on. Sometimes, simple approaches to complex problems can be successfully applied such as the use of electrostatic solutions to aid in the estimation of a breakdown risk in high voltage equipment.

Full-wave solutions, whereby the full range of Maxwell’s equations are solved, are required for applications such as proximity sensors where inductive and capacitive effects require modeling. On the other hand, efficient solutions may be obtained when displacement currents can be safely neglected. In this case, electro- and magneto-quasi-static solvers offer rapid and memory-efficient solutions. Transient phenomena may also arise in, for example, non-destructive testing sensors and can be successfully simulated with transient eddy current solvers.

A key factor in the effective use of simulation in electromagnetic design is the efficiency with which such a tool may be used in a commercial/industrial environment. Effective simulation tools therefore need to offer a balance between user-friendliness and flexibility. To facilitate this, CST EM STUDIO supports:

- Complex model creation and import
- Fast and efficient multi-grid solvers
- Mesh adaption for reliable results
- Advanced techniques such as open boundaries and surface impedance approximation
- Automatic and flexible post-processing
Power Engineering

CST EM STUDIO can be successfully applied to the simulation of devices and components in the energy sector. A common requirement is the estimation of dielectric breakdown in equipment such as switchgear and transformers. Critical to this process is the efficiency import and modification of complex CAD models, application of special curved and higher order elements, and especially important, the fast and easy extraction of fieldlines data.

Electromagnetic Sensors

Sensors are used in systems such as encoders, input devices and non-destructive eddy current testing devices to detect numerous phenomena, including proximity, touch, posititon, fuel level, weather conditions and hidden materials flaws. Electromagnetic field simulation may be applied to devices where hall-effect transducers are involved or where coils are in use e.g. eddy current probes. In the former, permanent magnets are commonly found. The numerical requirements for sensor simulation may vary from straightforward electrostatic solutions of touch screen devices where capacitive effects are involved to full-wave time-harmonic solutions of proximity sensors in which both inductive and capacitive effects need to be accounted for.

Typical parameters important in, for example, proximity sensor design, include complex impedance, Q-factor and the Q-sensitivity as a function of frequency and sensor/target position. These may be automatically extracted from full-wave simulation results.

Losses and forces in bus bar systems may also be calculated and exported for thermal and structural mechanics simulation in CST MPHYSICS® STUDIO (CST MPS) or third party tools. Surface impedance aids in the accurate and efficient modeling of skin effect.

One application of the full-wave time-harmonic solver is to visualize the electromagnetic field generated by the Helmholtz coils in a newly designed measurement system of a gradiometer sensor at 1 MHz. Simulation with CST EMS can reveal the presence of high electric fields which render accurate measurement impossible. This effect can only be seen in simulation which was then successfully applied to the development of a broken cage shielding arrangement.
**Electromechanical Components**

Actuators, solenoids and circuit breakers can all be simulated with CST EMS. An important requirement for such applications is the need to accurately calculate the electromagnetic forces such mechanical devices may consist of coils, solid bus bar conductors and/or permanent magnets. With the powerful integrated parameterisation and post-processing modules in CST EMS, the force characteristics can be extracted from the simulation.

Equivalent circuits can be extracted for use in CST DESIGN STUDIO™ (CST DS) or external system level circuit simulators. For this purpose, non-linear inductances, energy and co-energy and flux linkages are automatically provided.

**Circuit co-simulation**

CST DS set-up of a multi-domain simulation of a solenoid system coupling the electric, magnetic and mechanical domains for dynamic studies.

**Power Electronics**

With increasing demands on the performance of power electronic components, optimal thermal characteristics is a critical requirement. The CST MPS thermal solver can import winding and core losses obtained from CST EM STUDIO simulations. This coupled EM-Thermal approach has been used to determine the temperature rise in a power choke in a solar inverter system.

Loss distribution in a power choke operating at 18.8KHz
Courtesy of Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM.¹

¹ As part of SOLar project funded by the Federal Ministry of Education and Research under grant agreement no 16N10943
CST EM STUDIO – Features

- Powerful, intuitive and easy-to-use user interface
- CAD import, automatic healing, structure modification (Pro/E, CATIA, STEP, DXF)
- Robust automatic meshing with manual mesh control
- State-of-the-art multi-grid solver technology
  - Statics
  - Time-Harmonic Quasi-/Full Wave-Solvers
  - Transient Magnetoquasistatic
- Direct and iterative solvers
- Higher order elements for increased accuracy
- Curved elements
- Infinite elements for open boundary modeling in Electrostatic solvers
- Surface Impedance for modeling skin effect in time-harmonic magnetoquasistatic solutions
- 2D Cartesian and axisymmetric Magnetostatic Solver
- Non-linear DC current flow solver
- Automatic adaptive mesh refinement
- Fully integrated optimization and parameterization modules
- Global and local optimization methods - Trust Region, Nelder-Mead Simplex, Genetic, Particle Swarm
- Automatic calculation of force, torque, inductance, capacitance, flux linkage and induced coil voltages
- Potential and charge definition
- Voltage sources, stranded coils, current paths
- Permanent magnets, nonlinear materials
- Automatic Post-Processing Template system for manipulation of simulation data
- Integrated field line visualization and data export
- Power loss and force density export to CST MPS for thermal and structural mechanics simulation

Electrostatic field results used for the breakdown estimation and analysis in a 24 kV gas insulated ring main unit load break switch

The Pro/E CAD model shown was provided with the permission and courtesy of ABB, Baden-Dätwill, Switzerland