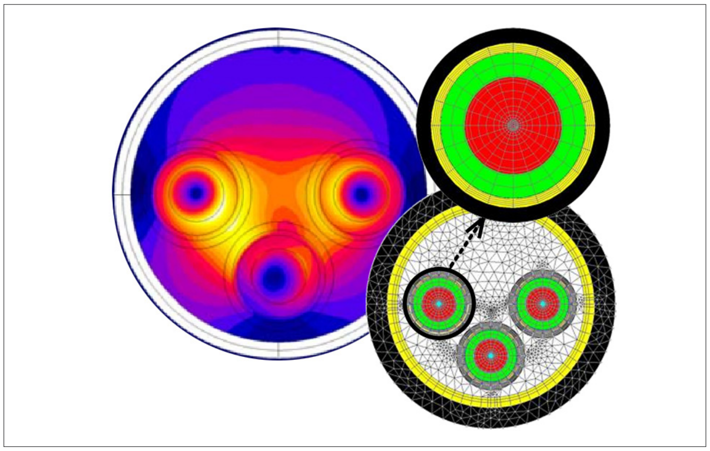
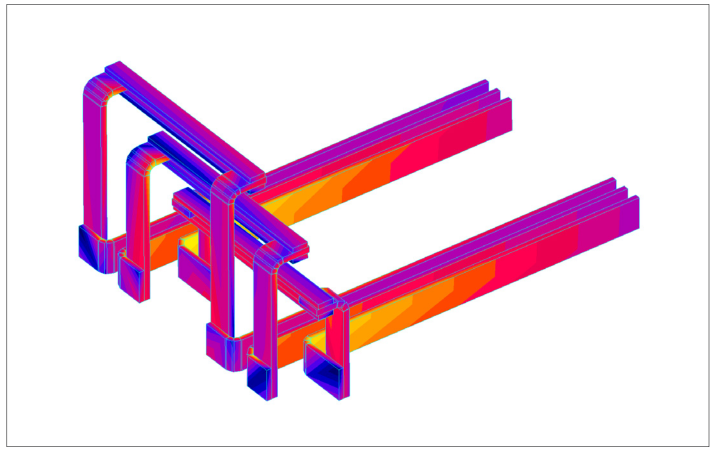
Power Cables and Busbars



Magnetic flux density shown in a cross section of a three-phase cable with mixed meshing



Laplace forces on conductors of a power bar system generated by high current flowing

Powerful Tools for Analysis and Design

Power cables, power bars and busbars are used to distribute and transmit electrical energy through the grid. Their design must comply with several electromagnetic and thermal constraints to guarantee high performance, safety and efficiency. Altair offers the innovative Flux™ software to answer these challenges:

- **Flux 2D and 3D** lets you analyze electromagnetic and thermal behavior of cables in different applications and configurations including static, harmonic and transient states.
- **Flux PEEC** lets you analyze R, L and C parasitic parameters and losses of power bars and busbars, with the capability to co-simulate with Flux 3D thermal solver to take into account effects of temperature.

Cable Simulations

The design of power cable bundles involves several physical domains and constraints that can be all analyzed by Flux in an accurate and efficient way thanks to a suite of specialized models.

By providing **both 2D and 3D electromagnetic and thermal** Finite Element computations, Flux lets you study cable behaviors in **static, harmonic and transient states.** Moreover, the circuit-coupling context embedded inside the Finite Element environment makes it possible to supply the sources and loads that are plugged into to the cable to capture the cable's exact working conditions.

Coupling between magnetic or electric analysis with thermal computations is available in one software environment along with optimization tools that leverage multi-parametric solver and external DoE tools like HyperStudy.®

Advanced Multiphysics Capabilities

Efficient meshing tools combined with specific advanced formulations decrease the number of nodes required, decrease computation time, and produce excellent results on various physical quantities.

- **Magnetic states** (flux, current density, losses and Laplace/Lorentz forces) are shown in all bundled parts. This feature helps you track the nominal power that can be carried by the cable and analyze couplings between wires, as well as skin and proximity effects.
- **Electric fields** in insulating parts ensure that voltages do not exceed dielectric breakdown conditions. These fields also help you analyze induced lightning currents, polarity changes, and parasitic capacitance values.
- **Thermal quantities** check cable temperature variations and study their influence on material characteristics and magnetic or electric performances.

The Flux embedded graphical post-processor provides easy access to data on various supports in a wide variety of formats, animations, and raw tables.

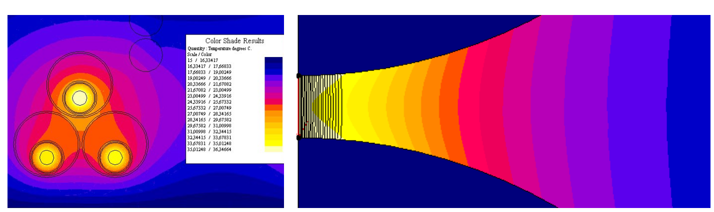
Typical Flux Computations for Cables

Steady State AC Magnetic coupled to Transient Thermal

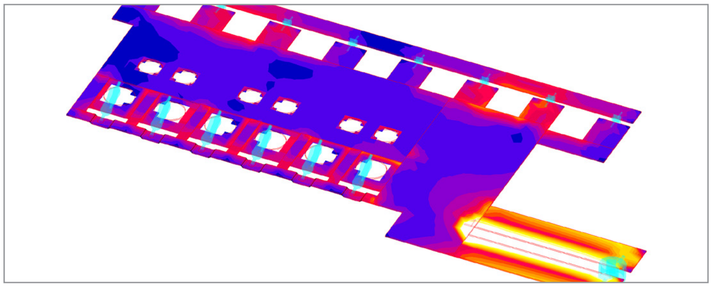
The steady state AC Magnetic application (available in both 2D and 3D modules) lets you compute the generated Joule losses that naturally become the input of a transient thermal simulation, the results of which indicate the temperature distribution inside the cable. Furthermore, the accuracy of computations can be easily improved with the use of temperature-dependent models for cable conductivities and permeabilities, which run a magneto-thermal simulation loop that quickly converges on the correct working conditions of the cable.

Electrostatic

The Flux electrostatic feature lets you study the electric field distribution between wires, and provides the highest voltage values before a gas breakdown and its possible paths in order to design insulation characteristics of the cable.



Temperature map in a three-phase cable obtained by a 2D magneto-thermal analysis (left) and possible dielectric breakdown paths (black lines) between two wires (dark blue areas) computed by an electrostatic application (right)



Current distribution in a laminated busbar with temperature effects taken into account

Power Bar and Busbar Analysis

Parasitic behaviors (resistive, inductive and capacitive) of conductors, skin and proximity effects have great influence on power bar and busbar performances as they can generate extra-losses, mutual couplings, switching overvoltages and unbalanced current sharing. Thanks to the innovative and efficient PEEC (Partial Element Equivalent Circuit) methodology, Flux is very well-suited to guide engineers with these types of designs that can involve long and/or flat geometries that are difficult to model with Finite Elements.

The intrinsic ability of the Flux PEEC steady state AC solver to model the studied devices as an equivalent circuit makes it easy to directly supply and load the conductors with frequency-dependent active or passive electric components, and produce results with the current distribution, Joule losses, and Laplace/Lorentz forces that identify the most critical areas from a thermal or structural point of view. The radiated magnetic field can also be produced for reviewing magnetic exposure limits in the surroundings.

Advanced Multiphysics capabilities

As multiphysics constraints (mechanical and thermal) have to be considered jointly in electromagnetic behavior during the design of power bar and busbar structures, Flux PEEC features two important capabilities:

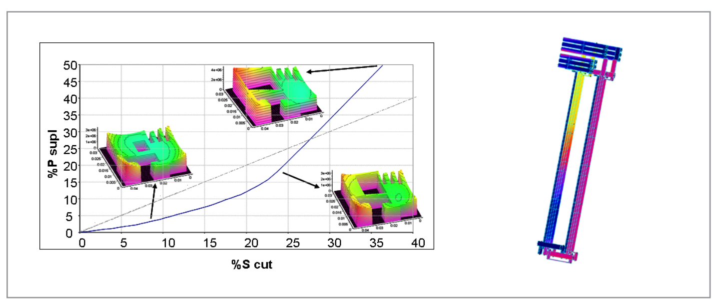
- **Export of Laplace/Lorentz force values** for structural simulations that can be critical due to high currents flowing inside conductors in short-circuit conditions.
- **Thermal co-simulation with Flux 3D** to include temperature dependencies of material properties and to study the steady-state temperature distribution reached by conductors.

On the other hand, the design of busbars also requires the computation of parasitic impedances of the cabling. The PEEC methodology is the best-suited technique for extracting quantities such as loop inductances, capacitive couplings and resonance frequencies of the system. Equivalent models can be easily generated and then included into functional SPICE-like time-domain analysis to keep under control any switching overvoltages or unbalanced current sharing that may dramatically reduce the lifespan of the semiconductor components connected to busbars.

The great advantage of the PEEC method is that only the conductor volumes need to be meshed, not the surrounding space. Combined with a Fast Multipole Method accelerated solver, the PEEC method performs fast and accurate multi-parametric computations, even with large and complex geometries. Coupled with HyperStudy, it also enables advanced optimization/DoE studies.

Flux Capabilities

- **Advanced CAD import**
- **2D sketcher and 3D modeler** to create geometry from scratch, **defeature and heal** CAD imported objects with the aim of removing defaults, define symmetries and periodicities, and prepare meshing procedures.
- Ability to **switch from 2D to 3D environments** and vice versa, with extrusions and cutting planes, respectively.
- **Robust mesh generator** automatically adapts to the geometry, physical properties, and studied frequency range.
- **Advanced Finite Elements physical formulations** like surface impedance account for the skin effect inside solid conductors and eddy currents on thin regions like armor shells.
- State-of-the-art **PEEC computations accurately account for skin, proximity and capacitive effects** even for flat and long meshing elements, and thereby reduce simulation time.
- **Embedded circuit solver** enabling to integrate external electrical components (even non-linear in case of transient computations) in the same simulation environment .
- Computation of **Joule losses and Laplace/Lorentz forces** on all conductor points in order to export to thermal (AcuSolve®) or mechanical solvers and perform multiphysics analysis.
- 2D and 3D geometries can **perform magneto-thermal co-simulations** for taking into account effects of temperature changes due to current flowing.
- PEEC – Finite Elements **magneto-thermal co-simulation** to deal with flat and long conductors (busbars in particular) in an efficient and accurate way.
- **Extended post-processing capabilities** to perform spectral analysis of any transient quantity and plot 2D/3D curves.
- **Synthesis of RLC equivalent macro-models** in the most advanced standard formats (SPICE, Modelica, VHDL-AMS…) and for the most common circuit solvers (SABER, Portunus, Activate…).
- **Full multi-parametric analysis** (geometry, physical properties and electric components) with possible connections to HPC systems (PBS) to dramatically reduce computation time.
- **Coupling with optimization/DoE tools** (HyperStudy) to increase the performances of the designed system. For example, minimizing the cost of the cabling (raw material) or the generated losses, while respecting imposed constraints like maximum current, maximum electric field in the insulation, wire diameter, and more.
- **Automation capabilities** using macros and Python command files.



Optimization of a bar section shape to minimize extra-losses generated by skin and proximity effects (left) and current distribution mismatching due to unbalanced conditions simulated by Flux PEEC (right)