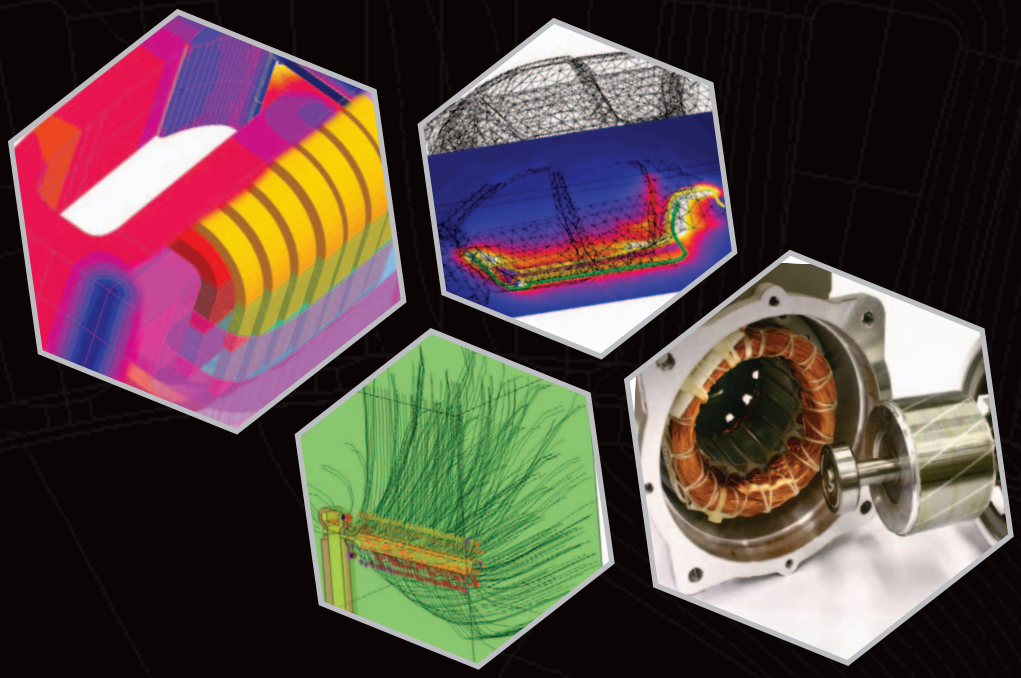
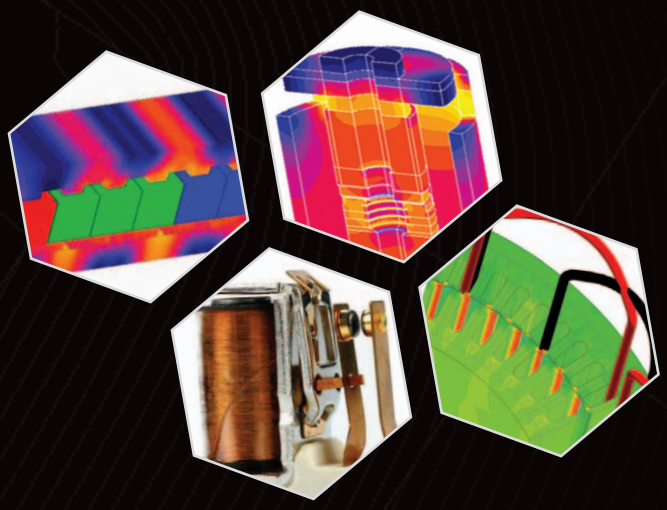
POLYCAE solutions

Flux by CEDRAT

ELECTROMAGNETIC DEVICES ANALYSIS



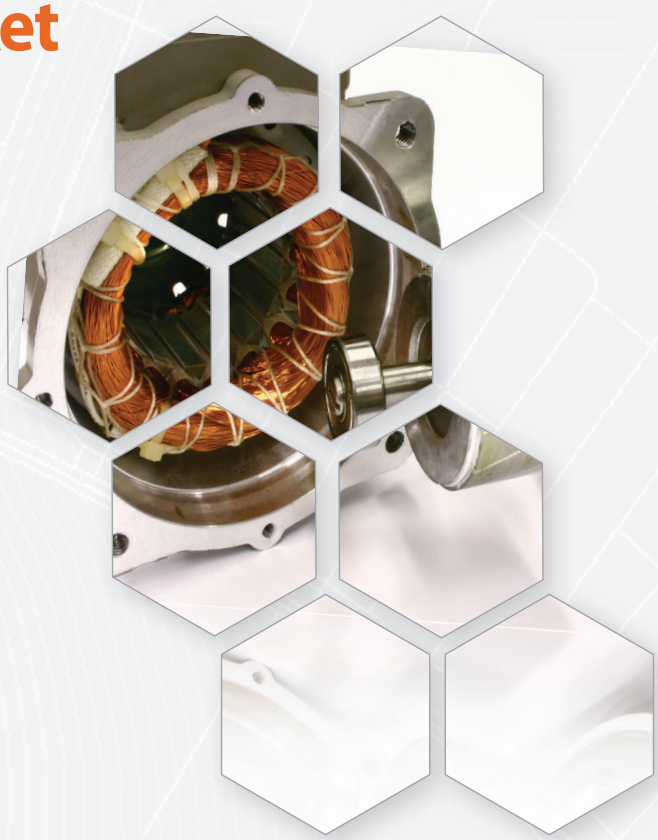
Optimize your product performance



Reduce your development cost

CEDRAT
design solutions for electrical engineering

Reduce your design cost
Reduce your time to market



For more than 30 years, Flux simulation software has been used worldwide in leading industries and university labs. It has become **a reference for the high accuracy** it delivers. Whatever the electric device or equipment you are designing, it captures the complexity of electromagnetic and thermal phenomena to predict the behaviour of your products with precision.

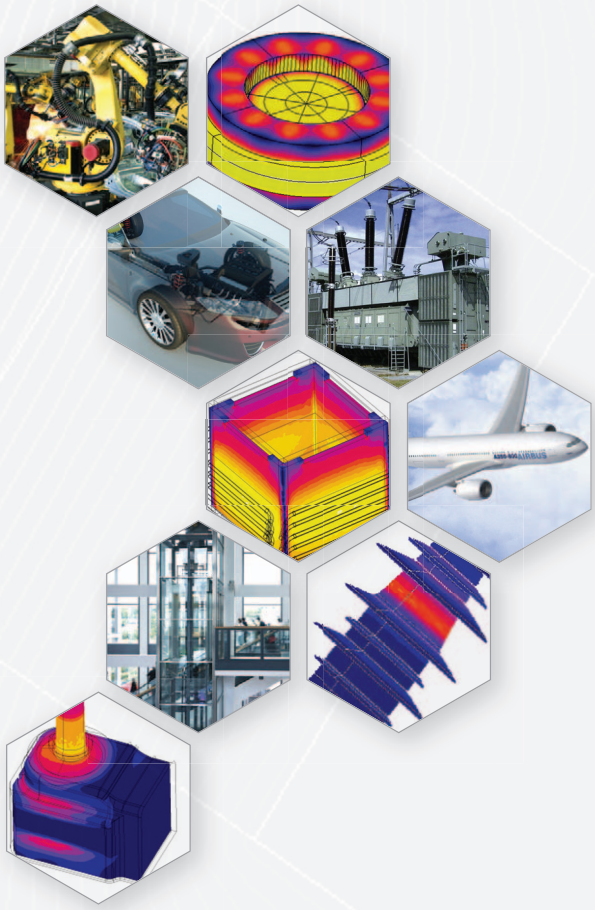
With its **continuously improving technology**, Flux is a **versatile, efficient and user-friendly tool** that will help you to generate optimized and high-performance products, in less time and with fewer prototypes. Together with a **highly qualified support network** and a strong community of users, CEDRAT provides you with its **recognized expertise in electrical engineering**.

In a greener and more electric world, you can rely on Flux to assist you in designing energy efficient devices, bringing more innovation and more value to your customers.

Serving the major industries, Flux is the right tool for the analysis, design and optimization of your application. Featuring **embedded multi-parametric analysis** capabilities, it deals with different simulation domains and is well suited for **multiphysics couplings**.

Simulation domains

- Magnetics
- Electric
- Thermal
- Multiphysics



Applications

- Rotating machines
- Linear actuators, solenoids
- Transformers & inductances
- Induction heating processes
- Sensors
- High voltage equipments
- Cables, electric connections
- Electromagnetic compatibility

>> More info: www.cedrat.com\home\applications

Industries

- Automotive and transport
- Energy management
- Aerospace and defense
- Industry equipment
- Building and residential
- Academics

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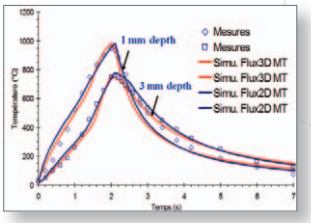
Flux® keys benefits

Open and intuitive, Flux **can be easily included in your design workflow** to deliver **reliable analysis results**. With the most advanced numerical methods available, it deals with the most complex modeling situations.

Its **multi-parametric capabilities** allow an efficient search of the design space for optimal performance of your device. **Customization, automation** and connection to CAD tools are available for maximum productivity.

Accurate

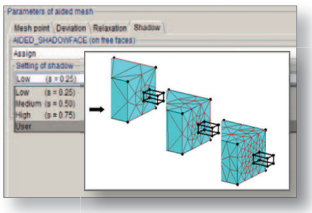


Through the years, Flux has proven its ability **to get close to measurements** and to reproduce with **great accuracy complex phenomena**.

Flux generates results you can trust and will let you concentrate on innovation. It is based on **the most advanced numerical methods** and **specific well-adapted modeling techniques**, providing precise results in a very efficient way.

Flux solvers are constantly improved to bring the best **solving speed**, allowing for the evaluation of thousands of design configurations.

Flexible



Because each simulation is unique, Flux can be easily **adapted to your specific needs**. Different options are available to fine tune the models and the solvers, to bring **accurate results in the most efficient way**. The software behavior can also be **customized** depending on the user preferences.

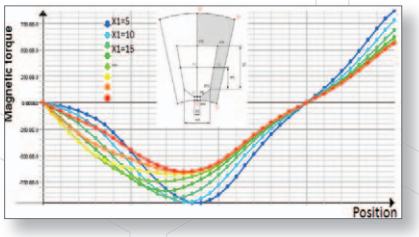
With its **embedded scripting tools** and the ability to write **macros**, Flux allows to **capture simulation processes** and to **automate** them, speeding-up the everyday use of the software.

You can easily drive Flux from any software, enabling high productivity, and giving a possible access to non-specialists to Flux accuracy.

Parametric simulation

Using a parameter to define a geometric dimension or a physical characteristic is **natural in Flux**, it is one of the fundamentals of the tool. Linking several parameters together through equations is also very easy.

You can then **explore in a very intuitive way the influence of any parameter**, visualizing the results through multidimensional curves and animations of color shades or arrows.



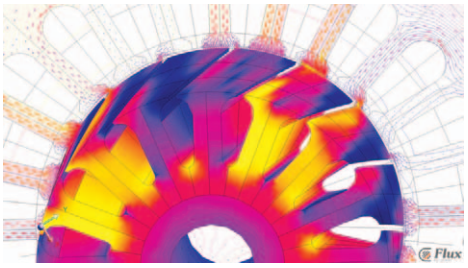
Flux also takes advantage of the **distribution of the calculations** over different processors or computers, allowing for the evaluation of numerous design configurations with an optimized computational time.

Interoperable

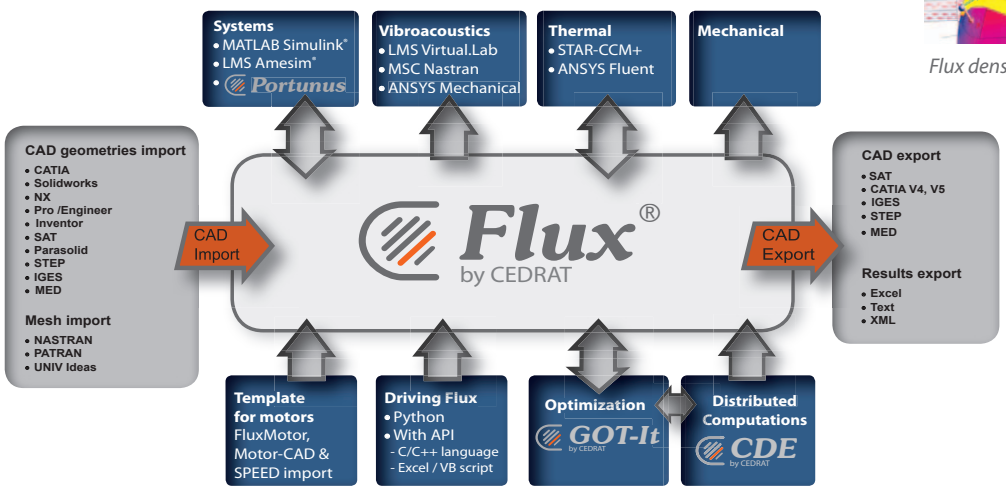
Because the **design workflow** of a product requires different tools, the communication of Flux with external software has been made easy and efficient.

The connection with **all the major CAD tools** includes automatic **healing** and geometry **defeaturing**. Flux can be coupled to the best available 3D analysis software to **consider multiphysics** and get the **most realistic representation** of phenomena.

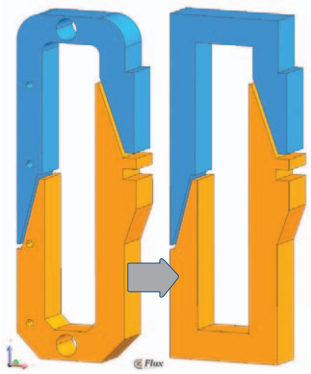
Considering a device as a component of a larger system, or designing its control strategy is also possible by **linking Flux to system level simulation** tools. Different levels of interaction can be used, ranging from reduced model extraction to full co-simulation.



Flux density in an induction machine with Skew rotor.



A virtual modeling process in 5 steps

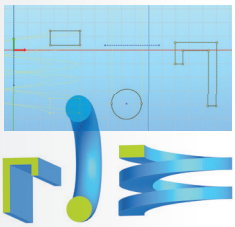


Defeaturing and simplifications of CAD geometries.

STEP 1

High performance geometric description

- An easy **sketcher** of 2D geometry including parametric capabilities
- **Embedded 3D modeler** with **fully parametrized** modeling constructs
- **Advanced CAD import** & export
- **Defeaturing** & **simplification** capabilities
- A dedicated environment **for electric rotating machines design in 2D&3D**
- **Skew modeling** capabilities avoiding long 3D analysis thanks to 2,5D models.



2D Sketcher and extrusions of geometries.

STEP 2

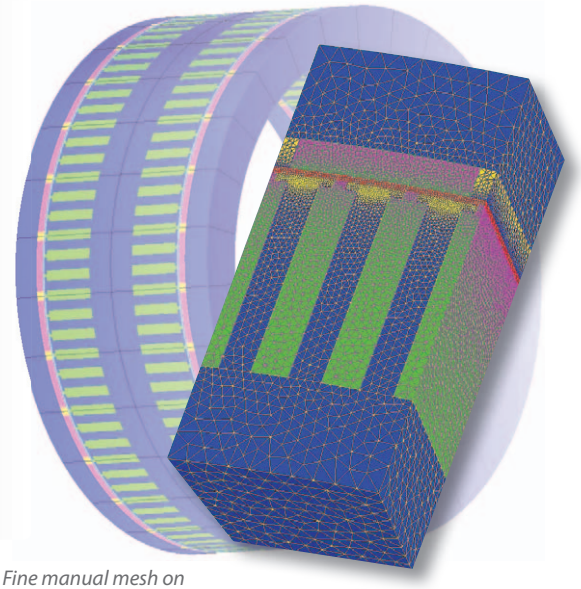
An easy and flexible mesh generator

The Flux® mesh generator provides different mesh types and meshing technologies that can be mixed in both 2D and 3D situations:

- Triangular / tetrahedral elements obtained by Delaunay type or advancing front method algorithms
- Quadrilateral / hexahedral elements generated through either mapped or extrusive meshing

It offers powerful features that help the user to **quickly get a precise mesh:**

- **Smart automatic mesh** generation based on geometry
- **Fine manual control** of mesh size and distribution
- Linked mesh between identical geometric entities
- **Auto-adaptive mesh** refinement during solving in 2D & 3D.



Fine manual mesh on a rotating machine.

STEP 3

Advanced physical properties for high performance calculations

A full range of physical models to simulate the low frequency behavior of electromagnetic devices.

Magnetic:
- Static, steady state AC magnetic, transient

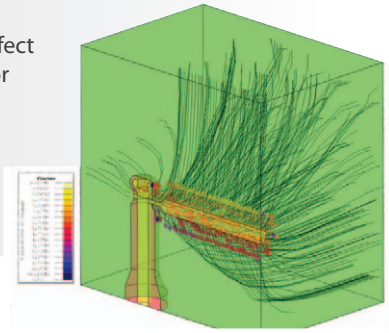
Electric:
- Electrostatic, conduction, steady-state AC electric

Thermal:
- Steady state AC thermal, transient

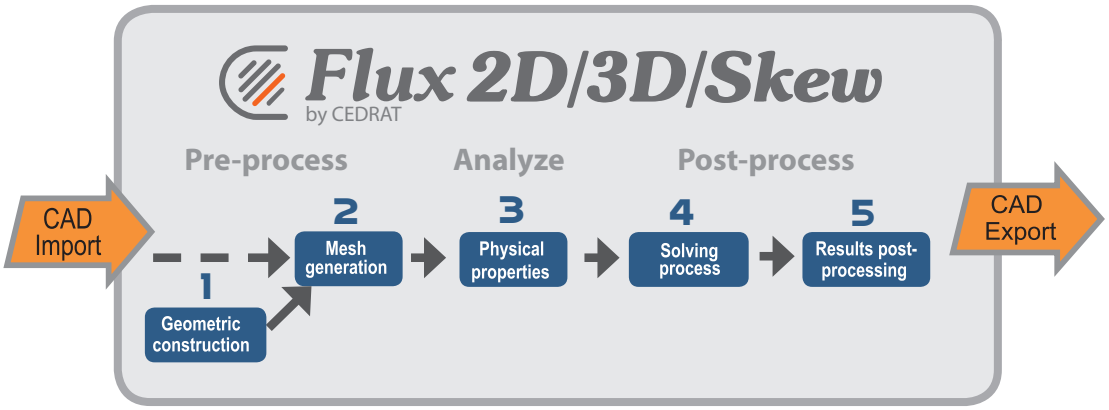
Thermal couplings:
- Electro-thermal, magneto-thermal

Electric circuits and rigid body motion:
- Strong coupling with electric circuit equations
- Translation, rotational and pivotal motion.

Advanced modeling techniques for accurate and fast results:
- Infinite box for open boundary problems
- Non meshed coils
- Thin regions represented by surface models (no need to mesh the thickness)
- Fast evaluation of geometry skewing effect
- Non-linear anisotropic material behavior
- Hysteresis modeling
- Skin and proximity losses in windings



Electric field lines on a conductor.

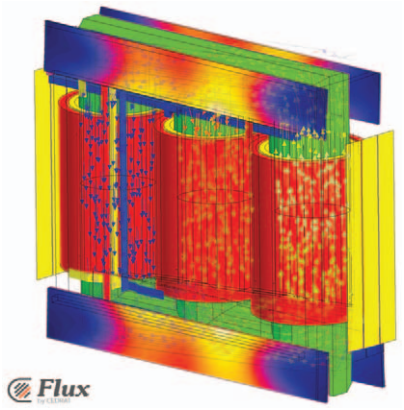


STEP 4

Solving process: A fast and robust solver

Fully parametric solver allowing geometrical or physical parameter sweeps

- Several **iterative** or **direct linear solvers** with **multiprocessing** (parallel computing)
- **Robust** non-linear solvers.
- **Distributed parametric studies** across several cores or machines.
- **Auto-adaptive mesh** and time-step



Results of a short-circuit test on a power transformer.

STEP 5

Results post-processing: Show your results and convince

A **complete and versatile** postprocessor enabling one to analyze the results from multi-parametric solving

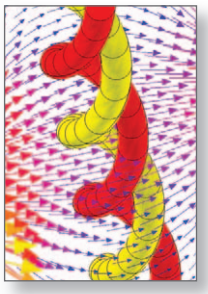
An extensive range of results

Flux® gives access to various quantities such as:

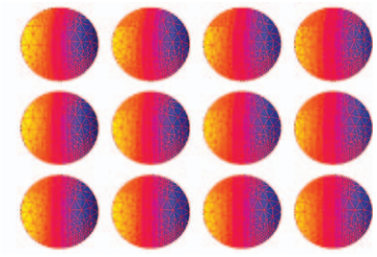
- Potential, flux density, temperature, electric and magnetic fields
- Global quantities: magnetic flux, inductances, stored energy
- Iron losses (Bertotti, LS Model), Joule losses in conductors
- Quantities on electrical components: current, voltage, power, inductance
- Mechanical quantities: position, velocity, force, torque, speed
- Skin effect visualisation
- User defined quantities

Presented in different ways

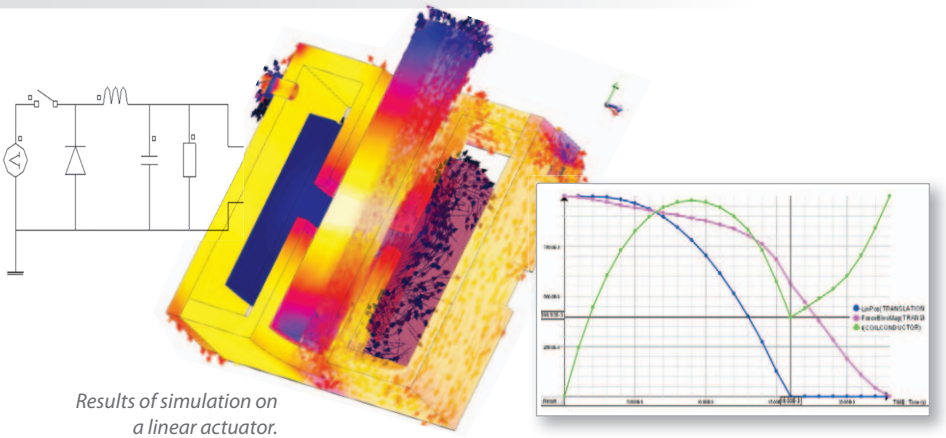
- Colour shaded maps and isovalues plots
- Vector plots
- 2D and 3D curves as a function of varying parameters on a path, a grid, probe, …
- Spectral analysis
- Cutting planes
- Look up tables towards system simulation tools
- Extensive export capabilities (Excel, text, …)
- AVI animations, png drawings



Simulating twisted conductors.



Current density in windings.



Results of simulation on a linear actuator.

Go multiphysics!

In order to have **realistic and complete simulations** of electrical devices, the need for multiphysics is quite important. Nowadays, this becomes necessary because of **system integration**. The availability of computing power & new numerical techniques make it more and more affordable and allows to go towards 3D high fidelity models. Coupling two Flux models with different physics or coupling Flux with an external software is a **reliable solution for multiphysics.**

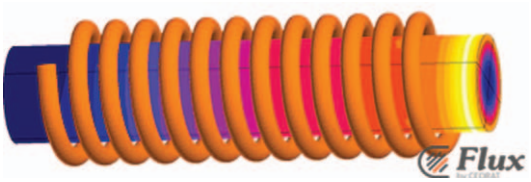
Flux provides fully cabled solutions do set up co-simulations and exports with specialized tools focusing mainly on magneto-thermal & magneto-vibro-acoustics analysis.

Magneto Thermal analysis

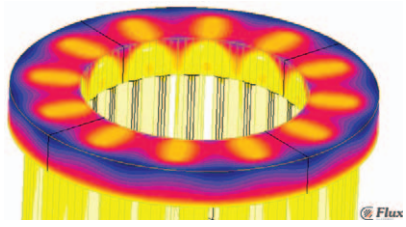
Flux features a **strong coupling** between magnetic and thermal computation, both for 2D and 3D simulations:

- Magnetic and electric material properties (linear or non linear) may **depend on temperature variations**
- **Dedicated application** (steady state AC magnetic coupled with transient thermal) for magneto-thermal couplings gives **great performances** for **heat treatments** and for **any heating inside electromagnetic devices** (rotating machines, transformers, actuators…)
- All couplings between any magnetic application and any thermal application is now available and easy to set up!
- Couple Flux with **CFD simulation tools** like **CD-Adapco STAR-CCM+** or **Ansys Fluent** to take into account the fluids dynamic and enhance the accuracy of the thermal analysis.

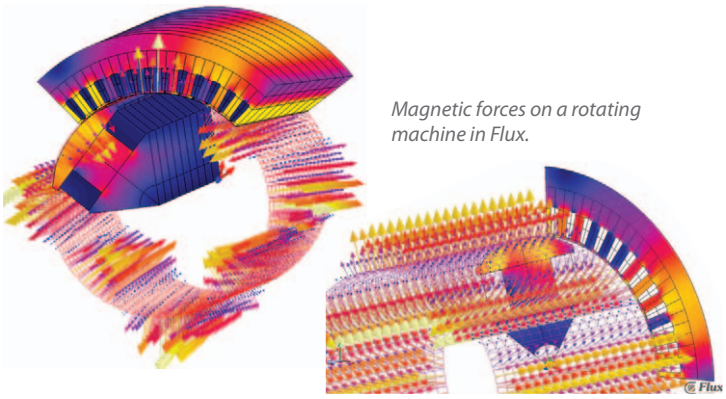
Efficient and accurate design is possible with Flux thanks to all the available thermal couplings!



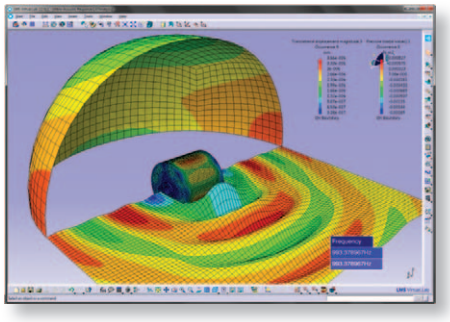
Flux induction heating application.



End winding temperatures in Flux 3D



Magnetic forces on a rotating machine in Flux.



LMS Virtual.Lab acoustic analysis.

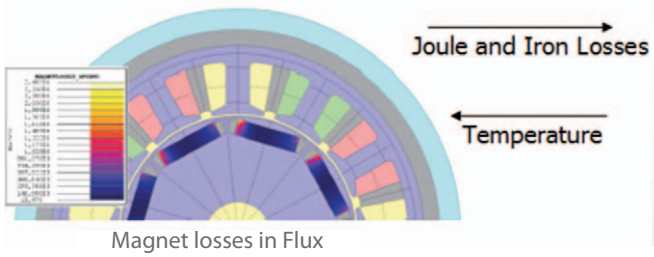
Vibroacoustics coupling to reduce noise and vibration

From a **simple** and **quick** magnetic forces export to **a mechanical software**, Flux allows to set up a vibro-acoustic study. This export is available in a new context for mechanical analysis.
Compute the magnetic pressures on the borders between magnetic regions and air or vacuum regions and then communicate with **LMS Virtual.Lab**, **MSC Nastran** or **ANSYS Mechanical.**
This method can be used for **rotating machine vibrations** but also for any other electromagnetic device. The vibro-acoustic coupling is available for transient applications in Flux 2D, 3D and Skew.
Benefit from magnetic simulations to complete the mechanical analysis and **reduce noise and vibrations** in your system!

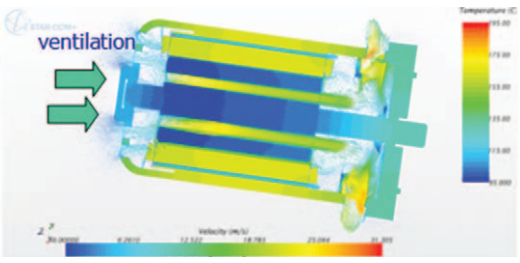
Co-simulation is ready

In addition to thermal or vibro-acoustic couplings, Flux benefits from a dedicated context to set up **multiphysics couplings**. Thanks to the ability to export any quantity, it is possible to communicate between Flux and other software.

So **any coupling** with Flux is possible to set up!



Magnet losses in Flux



with ducts

Flux coupled to Star-CCM+.

Advanced system integration

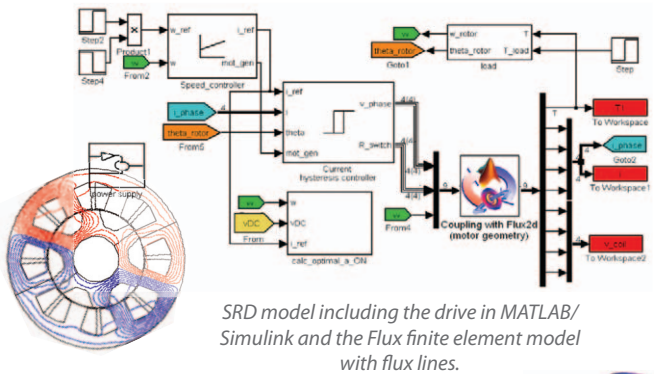
Tools and methods for system simulation

Different levels of system coupling are available according to the application:

- **Export of tables**: From a parametric solved project, generate tables **easily** towards a system simulation software and benefit from an accurate model of your device. This method is the **fastest way to integrate your device in a complex system**
- **Co-simulation**: Take the most of Flux **accuracy** with finite elements solution directly integrated in a system environment to set up **drive and control** of the device with the greatest model possible. Co-simulation enables to consider any type of electromagnetic device in several system simulation tools, depending on your specific need. The coupling takes into account phenomenon as: **saturation**, **Eddy currents**, motion, thermal effect, control loops and system interaction.

Flux-MATLAB® Simulink for drive & control

Flux to Simulink technology, the most advanced tool for system design, provides data exchanges capabilities for transient electromagnetic computations with a direct link to the finite element model. Co-simulation works for both 2D and 3D solvers of Flux and there is virtually **no limitation with the parameters** that can be shared between both software. Benefits are unlimited and range from the study of **load impact** to the design of **complex drives** such as PWM and vector control, motor drive or non linear drag force.
Allowing Flux and Simulink simulator talking together removes simulation or modeling bolts and open **unlimited design possibilities** with Flux and Matlab.



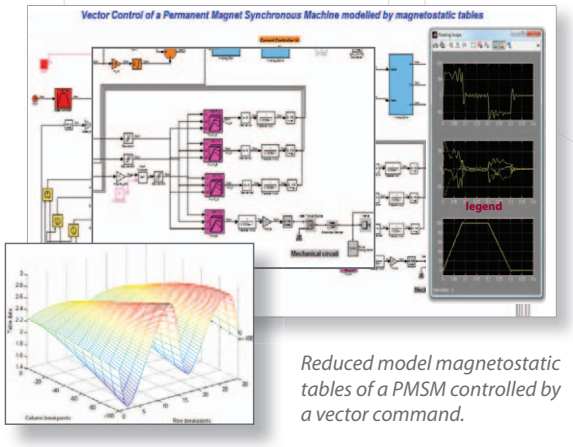
SRD model including the drive in MATLAB/ Simulink and the Flux finite element model with flux lines.

Flux-Portunus for mechatronic systems

Co-simulation between Flux (transient magnetic application) and Portunus system simulation software in 2D & 3D offers the possibility to analyze the interaction of a device with a complete mechatronic system, considering into control loops, motion, electric circuit coupling, saturation… Taking into account the effects of the system load or improving its drive now becomes easier thanks to the **Flux-Portunus** co-simulation. **Reducing the simulation time** considering the needed accuracy, or the nature of the system is made possible thanks to direct access to several co-simulation algorithms that can be parameterized.

Using CEDRAT products, Flux and Portunus, provides benefits:

- **Very flexible modeling**
- Analysis in time, frequency and DC domain
- **Fast and robust solver** using variable step sizes
- Powerful interfaces for data import and export, simulator couplings and automation

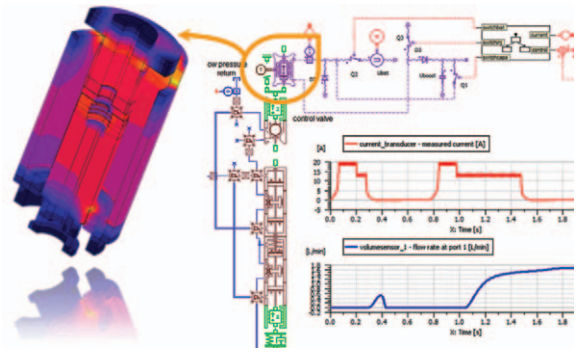


Reduced model magnetostatic tables of a PMSM controlled by a vector command.

Flux-LMS Imagine.Lab Amesim for complex mechanical loads

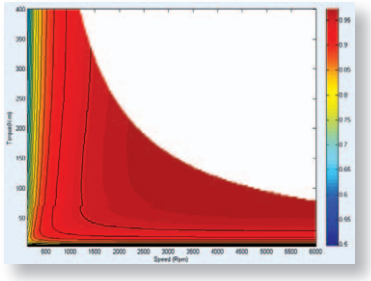
Considering high impact of eddy current on injectors' dynamic and high interaction between fluids and magnetic systems, there is a strong need to make global system simulation in these systems. **Flux-Amesim** co-simulation proposes a state of the art simulation solution for these issues by combining the **handling of complex mechanical load** and **Eddy current accurate simulation.**

A dedicated export interface for motors, sensors and actuators makes possible an **easy co-simulation**: LMS Vitual.Lab Amesim can drive Flux with time step adaptation for **fast and accurate solving**.



Co-simulation of an injector with LMS Amesim and Flux3D.

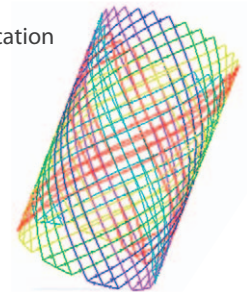
New functionnalities thanks to Flux macros



Efficiency maps for motors.

Macros make it possible to add new functionalities to Flux, automating tasks, making Flux easier to use. Macros allow sets of commands to be executed using PyFlux command language, after questioning the user.
Flux is delivered with around 150 ready-defined macros. **You will find new macros on the CEDRAT gate (https://gate.cedrat.com).**

What is a macro?



Faulhaber coil in 3D.

- A new button available in your Flux application
- Python file easy to create yourself
- Automation of some tasks
- Creating new functionalities

Advantages

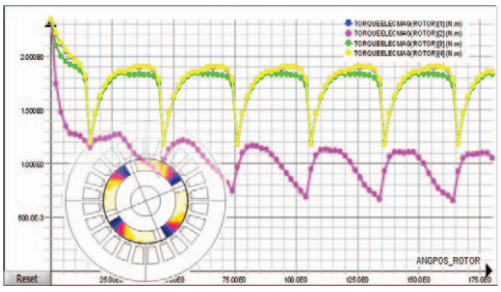
- Interface automatically managed
- Possibility to:
  - use dialog box
  - select already existing Flux entities (points, lines, regions, …)
  - select files (by opening a windows explorer)
  - use jython libraries (http://www.jython.org)
  - reach internally **all** Flux entities

Benefits

- Save time by automating tasks (creating geometry, post-processing, …)
- Be more efficient by adding new functionalities
- Be more accurate by introducing new model such as demagnetization

Some macros for geometry and mesh

- ***MeshSkinEffectFaceRegion/VolumeRegion:*** allow selecting number of layers in the skin depth for face region/volume region
- ***ModifyCoordinateSystemForPoints:*** modification of coordinate system in order to switch from cartesian coordinate system to cylindrical coordinate system for easy parametrization of radius (after importing geometry)
- ***AddParameterToPointsCoordinate:*** possibility to add a parameter on X, Y or Z coordinate to a list of selected points (after importing files for instance)
- ***Create2DProjectsFrom3DProjects:*** create a 2D project from a cut plane in 3D



Magnetization field value effect on the permanents magnets demagnetization.

Some macros for physics

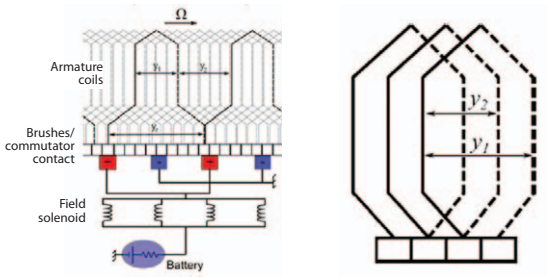
- ***CreateMotorWindingWithSolidConductor:*** create winding with all turns, creating automatically the geometry, the regions for all turns, the electric circuit, and the link between regions and circuit component
- ***Circuit_Collector:*** create automatically the circuit for DCM motor with collectors
- ***CreateFaulhaberCoil3D:*** create winding of Faulhaber coil
- ***CoilAroundTorus:*** create a coil around a torus with or without airgap

Some macros for solving

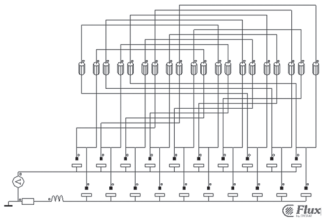
- ***RunDemagnetization2D/3D:*** taking into account of demagnetization during the solving process in 2D/3D
- ***ComputeCapacitanceMatrix2D/3D:*** compute matrix of capacitance (for 2D/3D electric application)
- ***ComputeInductance:*** compute matrix of inductance
- ***ControlSupplyToMatchAGivenResults:*** possibility to regulate a quantity in order to follow a specific order in a defined range (ex: find out the current supply in order to have a constant torque)
- ***RunEfficiencyMap/WithLdLqData:*** compute efficiency map for motors (2D, Skew and 3D)/starting from equivalent circuit (using Park method)

Some macros for post-processing

- ***CreatePathFromLineRegion:*** create a path following the shape of a line region
- ***ExportFieldsFaceRegion/VolumeRegion:*** export a quantity for all steps of a solving scenario
- ***BertottiIronLossesVsSlip:*** compute and display iron losses in AC for IM motor
- ***CreateSensorFor2D/3DMotorSlotForce:*** create sensors in order to compute force on teeth of stator slot for 2D/3D motors
- ***ExportAreaAverageValue:*** export for each element the area and the average value of a specific quantity



Winding configuration collector.



Optimize your design with GOT-It

What is optimization?

When designing a device using numerical tools, optimization software is often required to efficiently search the design space and find the optimal solution.

Boost your simulation tools capabilities

Boost your Flux capabilities using GOT-It, **powerful and reliable optimizer**, even without being an expert in optimization methods. Well adapted to drive FEM models, GOT-It goes beyond simple parametric studies, allowing obtaining significant gains in your designs.

A powerful and reliable tool

Thanks to the CEDRAT server technology described on the adjacent picture, Flux can be easily coupled to GOT-It. Thus, FEM calculations are **driven by GOT-It on an automatic way**.
The input parameters (corresponding to Flux I/O and geometric parameters) and the output functions (corresponding to Flux sensors and I/O parameters (formula)) are automatically exchanged via server. GOT-It pilots the Flux parameters values and return the results (performances) computed by Flux.

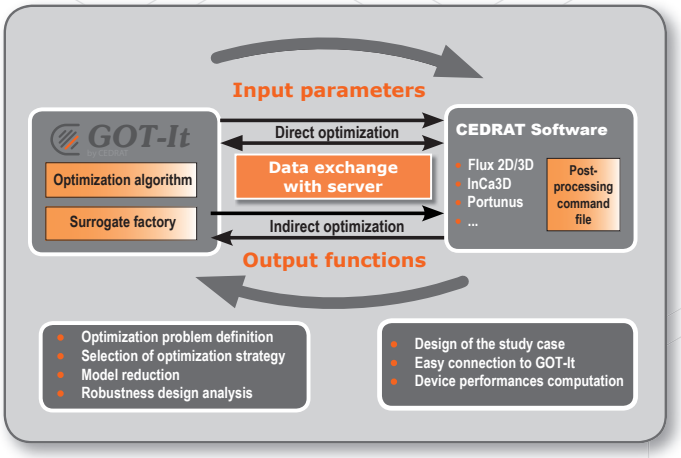
The challenge of computing time reduction

An efficient optimization tool is a software which **reduces the computation time** to the minimum to **get the optimal design of a device**.
Furthermore the tools for model reduction, GOT-It is also equipped by **HPC capabilities** by means of distributed computing. Thanks to the **CEDRAT Distribution Engine** (CDE) associated to Flux and GOT-It it is now possible to take benefit of all available computation resources. For instance, the computations required for an optimization are automatically distributed and launched on all the available cores on a single machine or on a cluster, the gain depends on the number of cores used.

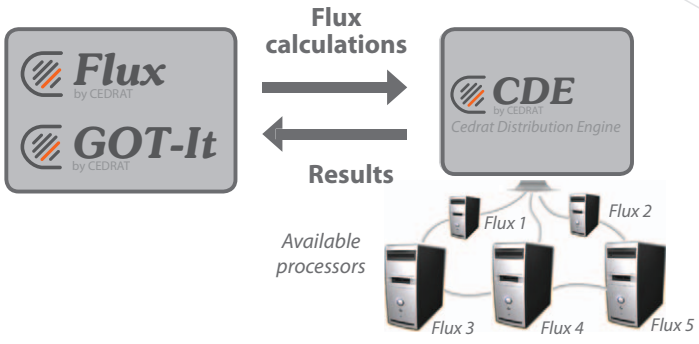
A wide range of applications
- Minimize the electrical losses of a motor
- Optimize the time response of a system
- Minimize the torque ripples and the losses

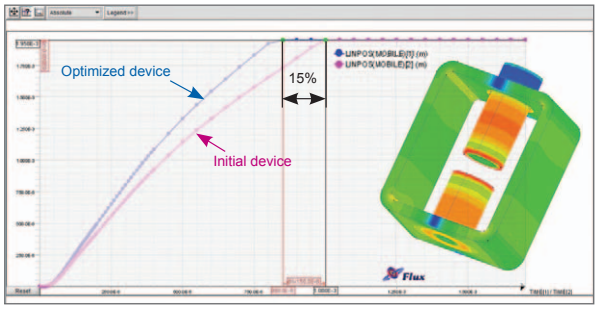
Main features

- Continuous or discrete parameters
- Single or multi objective functions, problems with or without constraints
- Design of experiments & surrogate functions (polynomial, RBF, kriging, Space Mapping, …)
- Analytical and numerical functions (or combinations)
- Direct or indirect optimization with response surfaces methods
- Deterministic algorithms (CG, BFGS, …) or stochastic (GA, Niching, PSO, …)
- Post-processing (curves, surfaces, 2D & 3D Pareto frontiers, sensitivity and robustness analysis)

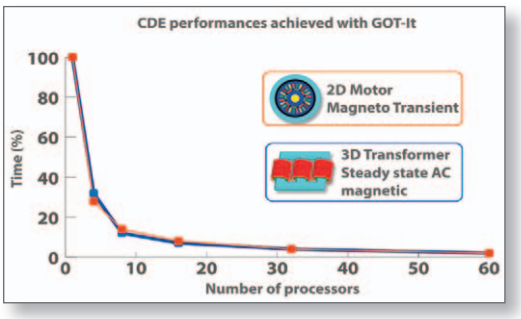


CEDRAT coupling technology.





15% gain on response time - Actuator response time optimization



Performances evaluated using Flux 2D/3D parametric computations driven by GOT-It.

CEDRAT, 30 years of experience in Electrical Engineering

4 modeling and simulation tools, 11 international partners, 30 years of experience and more than 50 engineers, developers and consultants.
With its expertise in the field of Electrical Engineering, CEDRAT and its multidisciplinary team of engineers offers innovative solutions and top of the line tools geared towards the specific needs of each industry.
Strong of its tied connections with industries and research institutes, including a close collaboration with G2Elab, CEDRAT focuses on today and tomorrow's goals of energy efficiency, cost reduction and smart features.

Not just tools!

Long term experience in both software development and consulting work make CEDRAT and its distribution network a valuable partner to support and train you when using our software. Training and support competencies:

- Use of the programs
- Numerical methods
- Adapted methodology
- Application / Device specific
- Limits of the models' validity
- Customer's models resolution

Consulting services

Lack of competence? Temporary overloaded department? Missing software know-how? Improvement on methodology needed? CEDRAT provides consulting and computation services.
A team of experienced design engineers is available to create, design or optimize innovative solutions. If you are interested in contracting our consulting services, please contact us or visit our website.

Quality assurance

Flux® is controlled and developed under Quality Assurance procedures. It ensures a constant validation of the capabilities and the results of the software.

Documentation

Over 3500 pages are availabe in 30 manuals and a variety of tutorials for key applications. A full HTML on-line help will support you in your daily job to go straight to the necessary information.
Technical papers are also available to assist you to explore creative ideas for innovation.

References

ABB, Alstom, Auxilec, BMW, Bombardier, Borg Warner, Bosch, CEA, CNES, European Space Agency, Faulhaber Motoren, Gauss Magneti, Globe Motors, Goodrich, Grundfos, Hager Electric, Isliker Magnete, ISL, ITT FLYGT, Kollmorgen, Legrand, Leroy Somer, LG electronics, Lokheed Martin, Magneti Marelli, PSA, Renault, Robert Bosch, Schneider Electric, SEW Eurodrive, Siemens Automotive, Snecma, Sulzer, Thales, TRW, Valeo, Visteon, Walker Magnetics, Wolf, Zodiac as well as many university labs and teaching institutes...

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