CALYPSO: Circuit Analyzer Problem Solver for NI-HTS Coils and HTS cables

CALYPSO is a circuit-based solver from the University of Bologna for no-insulation HTS coils (used when reliability and operational stability are critical), that resolves magnetization currents inside each tape and inter-turn currents, via a non-linear lumped circuit model. The model can also be applied to the computation of losses in HTS conductors based on twisted-stacked or other configurations. Originating from fusion needs, it captures charging delays, current bypass and loss levels consistent with representative NI-HTS cases. For industry it reduces cryogenic testing and design cycles, improves stability and protection settings, and applies beyond fusion to accelerator magnets, MRI and NMR magnets, and HTS power devices; collaboration options include simulation on customer data, parameter identification, joint R&D, training, model transfer and licensing.

Description of the technology

CALYPSO is a circuit-based solver developed at the University of Bologna to analyze no-insulation, high-temperature superconducting (HTS) coils in conditions where current can flow not only along the turns but also across adjacent turns through a finite contact resistance. In simple, professional terms, it builds an electrical twin of a layer-wound or pancake-wound HTS coil, discretizes each turn, assigns to each turn element its longitudinal resistance and inductance, connects adjacent turns with measured or estimated surface contact resistances, applies the intended current or field waveform, and then computes, step by step in time, how current redistributes, how much power is dissipated, and how long the coil needs to reach the operating point. This is necessary because NI-HTS coils are attractive for fusion, accelerator, and high-field magnets to their ability to bypass local hot spots, but the same transverse conduction changes charging time, field quality, and losses in ways that simplified or steady-state models do not capture.

In detailed investigations carried out with CALYPSO on representative case studies, the code was validated versus analytical and numerical results obtained for straight tapes, NI-HTS coils and twisted –stacked HTS conductors.

The know-how behind CALYPSO comes from long-standing work at the University of Bologna on circuit models for HTS systems, on the representation of magnetization and screening currents in REBCO tapes, and on the identification of turn-to-turn conductance from experimental data retrieved at the superconductivity laboratory of RSE (Ricerca sul Sistema Energetico, Milan, Italy). This experience is important because the quality of the prediction depends directly on realistic contact-resistance values, on a correct description of the number of turns and pancakes, and on driving the model with the same waveform that will be used in the experiment or in operation.

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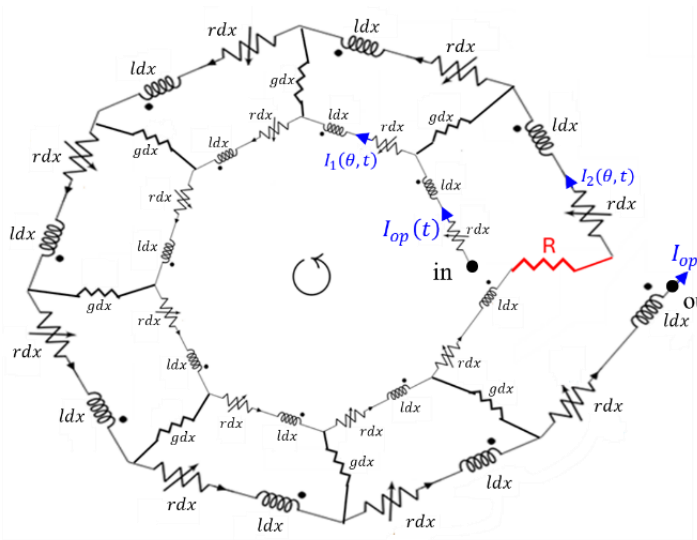
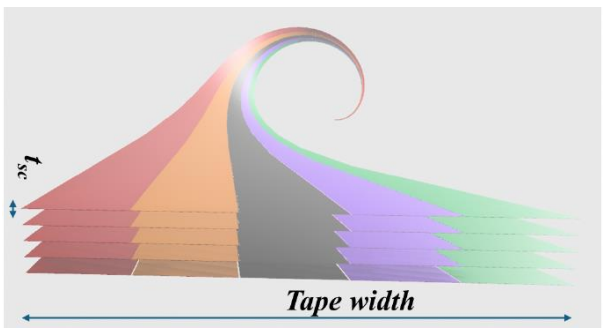
Description of the technology

For a prospective technology receiver, CALYPSO is useful because it delivers quantitative outputs that can be compared with measurements, such as peak power, total energy over a defined time window, current in each turn, and voltages across selected turns. It makes explicit how sensitive charging delay and losses are to contact resistance, which is a parameter that can be controlled during manufacturing by surface treatment or winding procedures. It also shows that, for a given target field, even a small coil with very low interturn resistance may require several hundred seconds to charge and may dissipate a few joules per minute in steady conditions, which is an operational limit to consider. The University of Bologna can support adopters with model setup, parameter identification, validation against coil tests, training, and, when agreed, transfer or licensing of the code.



NI-HTS coil CALYPSO model (2 turns)



Twisted stacked cable geometry in CALYPSO

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Innovation and advantages of the offer

Compared with lumped circuit tools that omit explicit turn-to-turn paths and finite-element models, CALYPSO uses a full interturn network with physics-based models for magnetization and screening currents, capturing charging delay, current bypass, and local heating under realistic waveforms. Adoption requires standard inputs such as winding geometry, contact resistances, and the drive waveform, together with basic magnet design expertise; the University of Bologna team can provide setup, parameter identification, training, and code transfer.

Non-fusion Applications

Potential domains include superconducting accelerator magnets and test facilities, medical particle-therapy gantries using HTS (REBCO) coils, MRI and NMR magnets and HTS power devices. In all these areas, predicting charging dynamics, screening-current effects, and inter-turn bypass directly supports safety margins, stability, and cryogenic load planning.

EUROfusion Heritage

CALYPSO was developed for fusion because twisted – stacked conductors for fusion coils must withstand long pulses, high dI/dt, and disturbances without quenching. Within EUROfusion the team created a modeling workflow that unifies inter-tape conduction and screening currents in one circuit framework and uses measured contact resistances and tape properties to deliver time-domain predictions. EUROfusion investments included multi-year researcher time, access to design and test data, computing resources, and validation against tape measurements and benchmark cases; the result is a reusable code base, verified data sets, and trained personnel ready for end-to-end studies.

Visit our website to learn how fusion can help your business
www.tech-transfer.eurofusion.eu

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