AURORA: Learning Superconductivity Through Apps

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***Abstract*—The growing interest in modeling superconductors has led to the development of increasingly effective numerical methods and software. Alongside this interest, the question of how to teach and to explain the operation of superconductors to students has arisen. EPFL and KIT have created a series of web applications based on COMSOL Multiphysics that are accessible through an open access web server called AURORA. This project allows users to dynamically change the parameters of the apps and observe their influence on the results, creating a vivid learning experience. The project is particularly directed to students. If, as Richard Feynman used to say "the questions of the students are often the source of new research," why not stimulate students to ask questions on superconductivity?**

***Keywords*—App, teaching, web application, COMSOL, superconductivity, AURORA, open access**

I. Introduction and Learning Approach

In confronting the growing necessity of innovative teaching methods, it is necessary to consider students' audience and today's educational system. Modern education is partially online, which *open new paths* for the learning process.

In Roman mythology, *Aurora* was a goddess who flew across the sky at dawn, opening the path to the Sun and a new day[1] [1]. Similarly, the server AURORA aims at opening the path to a new generation of brilliant students and 'initiate' them by le**A**rning s**U**pe**R**c**O**nductivity th**R**ough **A**pps. The possibility of using apps for educational purposes allows demonstrating complex phenomena with a user-friendly interface. It also leverages a straightforward and visual teaching method to raise interest in students and convey the importance that superconductivity has on the world.

II. Application Examples

In this contribution, we present three apps currently available on the AURORA server [2].

A. Time-Dependent Ginzburg-Landau Equation for Type-I and Type-II Superconductors

Superconductors have the property of excluding magnetic fields up to a certain strength. When the field exceeds this strength, the field penetrates the material. This process is modeled by a set of equations, proposed by Ginzburg V. and Landau L. in 1950 [3]. The app helps visualize the magnetic field penetration in type-I and type-II superconductors (in the latter case, in the form of quantized current vortices). It is possible to modify parameters such as the applied magnetic field, the radius of the sample and the Ginzburg–Landau parameter k, which determines whether a superconductor is type-I ($0 < k < 1/\sqrt{2}$) or type-II ($k > 1/\sqrt{2}$).

B. Critical State Model

This applications simulates the electromagnetic response of an infinitely long superconducting wire of elliptical cross-section to a sinusoidal external field applied in transverse direction (perpendicular to the wire's length). The app is based on A. M. Campbell's implementation [4] of Bean's critical state model [5], [6]. Users can change the magnitude of the applied field and the aspect ratio of the wire and calculate the resulting magnetization cycle.

C. Resistive Superconducting Fault Current Limiters

In a power-system the fault currents occurring during a short-circuit can exceed the nominal current by more than ten times. Superconducting fault current limiters (SFCL) can limit the fault current and protect the power system without interruptions. With this app users can investigate the electric and thermal response of a resistive SFCL under AC fault conditions using a 1-D thermal model coupled with circuit. It is possible to evaluate figures of merit such as the limited current, the prospective current and the maximum temperature reached within the tape during the fault and modify the superconducting properties and the geometric parameters of the device.

[1] "Aurora now had left her saffron bed, and beams of early light the heav'ns o'erspread" Aeneid Book IV, Verses 585-586.

References

[1] Virgil *Aeneid, Book IV Verses 585* URL https://www.thelatinlibrary.com/vergil/aen4.shtml

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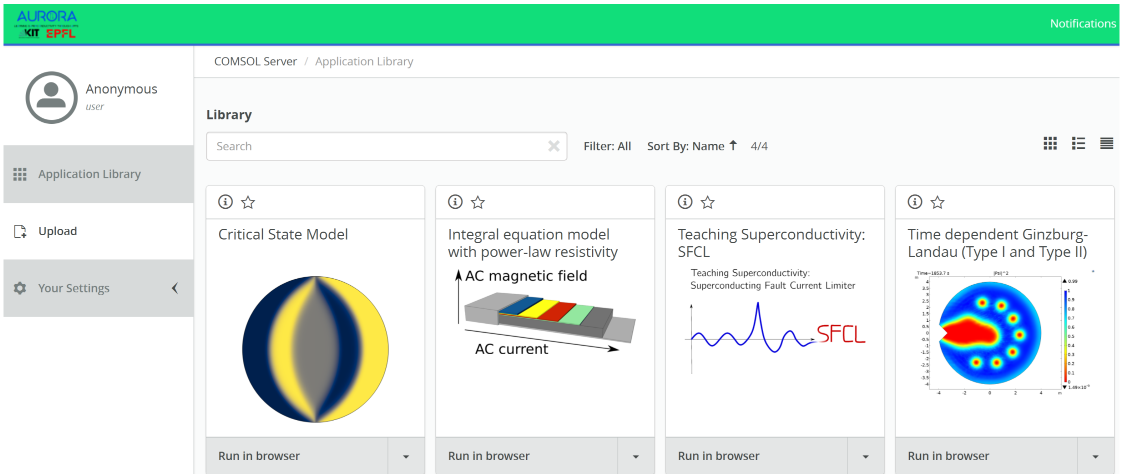
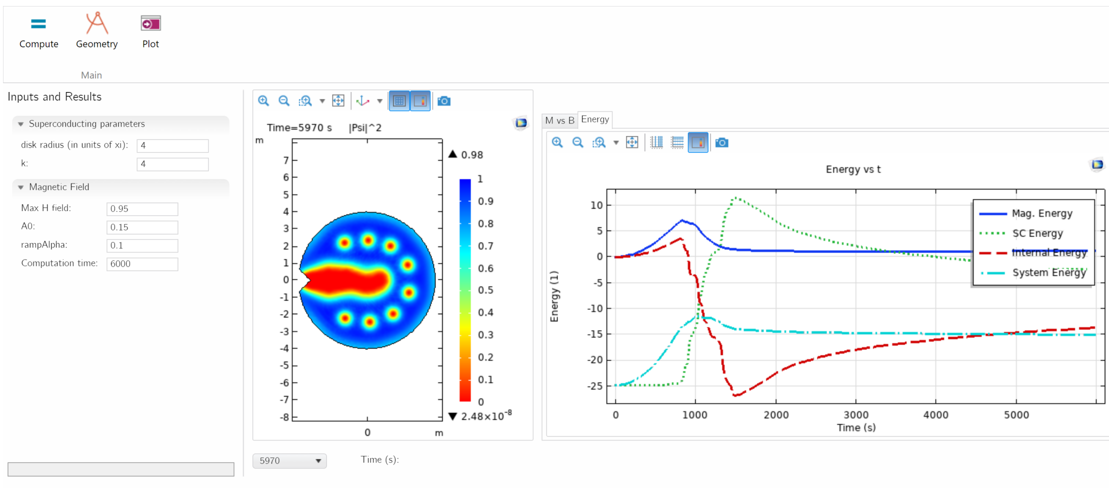
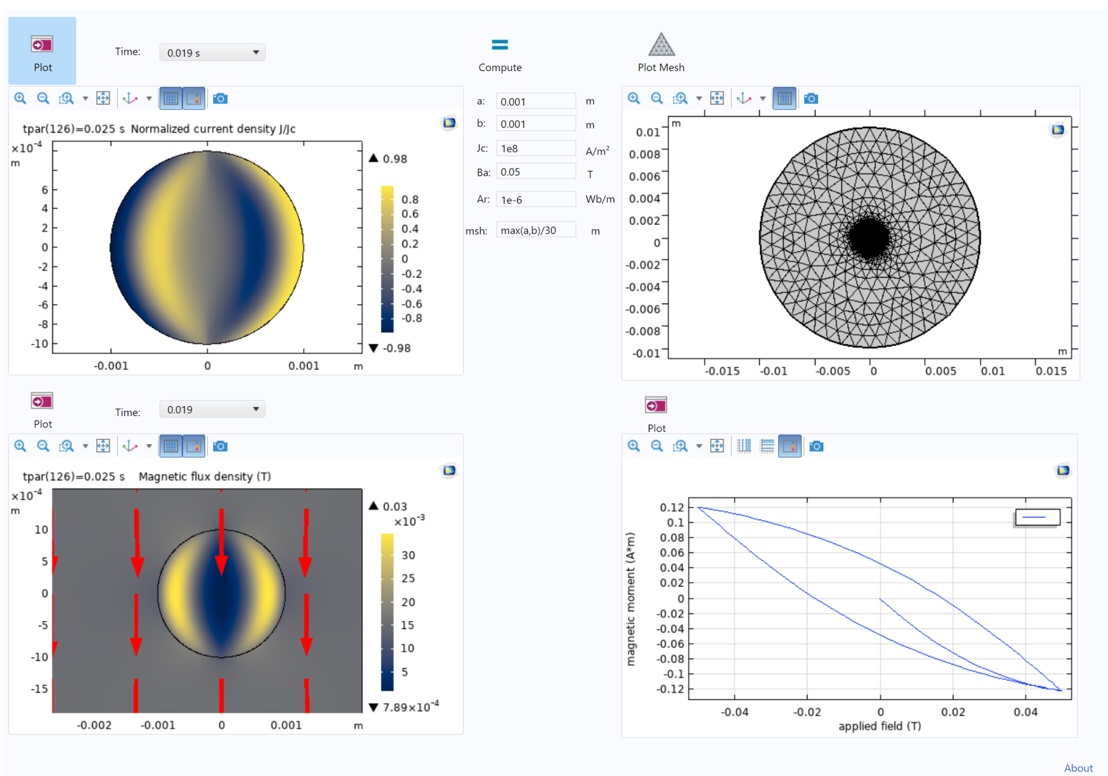


(a) AURORA server appearance.



(b) Time-Dependent Ginzburg-Landau Model App.



(c) Critical State Model App.

Fig. 1: The website is open access and does not require a VPN (https://aurora.epfl.ch/app-lib).