

Collaborative writing with Overleaf at TE-MPE-PE

Michał Maciejewski
on behalf of TE-MPE-PE

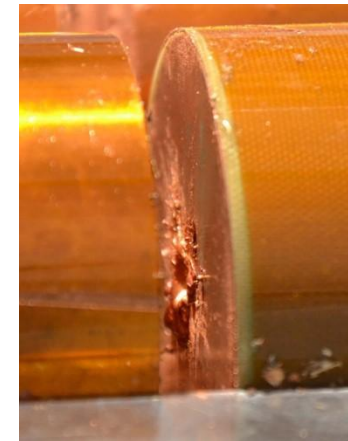
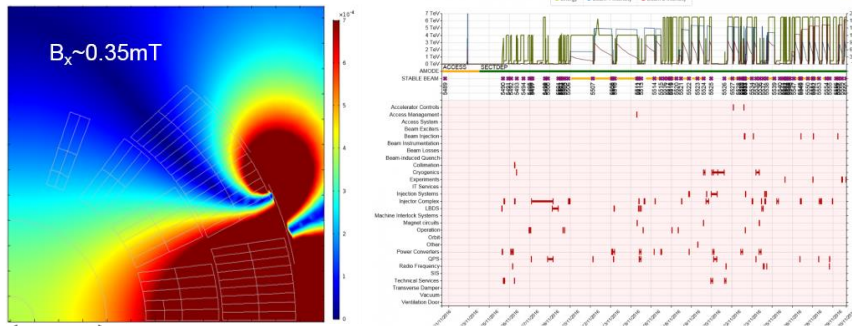


CERN TE-MPE-PE - “Technology” department, “Machine Protection and Electrical Integrity” group, “Performance and evaluation” section

Courtesy: Arjan Verweij, Section Leader

R&D, studies, simulations, experiments and data analysis aiming to further enhance the operational performance of the LHC and to optimize performance of future accelerators

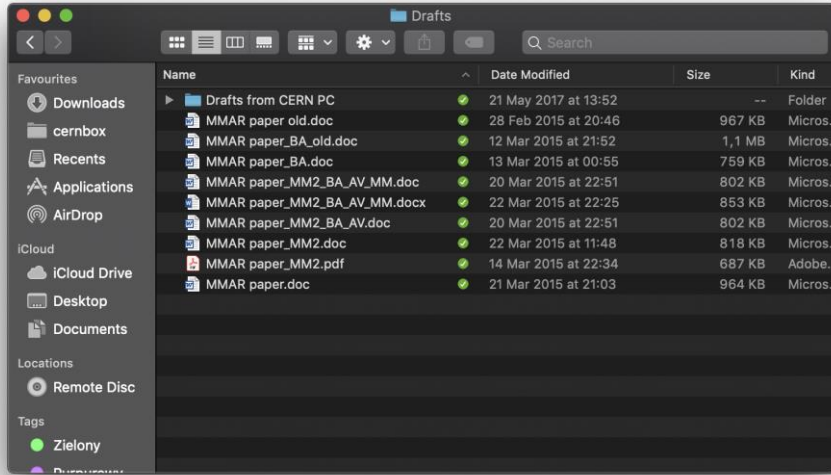
- Protection of superconducting magnets and circuits
- Development of STEAM
- Damage studies and impact of beams on machine equipment
- Reliability and availability studies of CERN’s accelerator complex



Our main product are the LHC performance evaluation studies carried out in a highly collaborative setting.



From e-mail collaboration...



Automated Object-Oriented Quench Simulation Framework

Michał Maciejewski, Emmanuele Ravaoli, Bernhard Auchmann, Arjan Verweij, Andrzej Bartoszewicz

Abstract—The paper describes a flexible, extensible, and user-friendly framework to model electro-thermal transients occurring in superconducting magnets. Simulations are a fundamental tool for assessing the performance of a magnet and its protection system against the effects of a quench. The application has a scalable and modular architecture based on object-oriented programming paradigm, which opens an easy way for future extensions. Models are composed of thousands of lumped-element blocks automatically created in MATLAB/Simulink. Additionally, it is possible to run sets of simulations with varying parameters and model structure. Due to its flexibility, the framework has been used to simulate various protection and magnet configurations. The experimental results were in a very good agreement with simulations.

Keywords—object-oriented modeling, quench simulations, superconducting magnets, MATLAB/Simulink

I. INTRODUCTION

The energy stored in the windings pack of a superconducting magnet is typically sufficient to melt kilos of material. Thus, a quench can cause irreparable damage in the magnet. For that reason, quench protection methods are used to keep the temperature in the magnet at a safe level. Quench protection systems consist of parallel diodes, resistors, and energy extraction systems [1] as well as quench heaters [2] and the Coupling Loss-Induced Quench (CLIQ) system [3–5]. The former dissipate energy outside of the coil whereas the latter heat up the magnet in order to increase its internal resistance and dissipate energy over a larger volume.

In order to obtain a safe operation of the superconducting magnets, quench protection systems must be thoroughly analysed by means of computer simulations. Firstly, it is needed in order to properly design robust electrical circuits with superconducting magnets. Secondly, simulation is vitally important in assessing the performance of existing superconducting circuits. Thirdly, during design of new quench protection methods, the model provides more information as compared to analytical expressions.

A convenient simulation environment is required to simulate complex electro-thermal transients accurately and in a relatively limited time. Traditional superconducting circuits can operate either standalone or as a part of the chain. However, the simulations of superconducting magnets pose considerable challenges. The presence of multi-domain problems, time-varying physical properties, highly non-linear behaviours, very different time and spatial scales require developing a sophisticated simulation environment. Thus, the modeller has to carefully select the model resolution and resulting representation [1].

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Finite-element modelling (FEM) is an advanced and powerful computing method for solving sets of differential equations on the basis of a domain discretization into a finite number of elements. The FEM simulation software allows building one-dimensional (1-D), two-dimensional (2-D) and three-dimensional (3-D) quench models [6, 7]. ROXIE [8] is applied to design and optimize superconducting accelerator magnets [9]. Moreover, 3-D models offer a good accuracy and are applied whenever longitudinal propagation in the magnet has a significant impact on its behaviour. However, in order to obtain a good prediction of propagation velocities, a fine spatial resolution is required. The high complexity of the model and the large scale of the magnets often make the FEM application inefficient due to extremely long simulation time.

Lumped-element modelling (LEM) provides a deep understanding of the physics representing the model behaviour. It requires deriving equations that describe the entire, complex problem and enables to quickly draw conclusions how the circuit performs what are the most important parameters; how it can be adjusted in order to obtain better results. Furthermore, this requires finding convenient ways to reproduce complex behaviours with a limited number of differential-algebraic equations (DAEs). As a result, the simulations are carried out faster because of the smaller quench propagation analysis.

To sum up, a full 3-D FEM model of the superconducting magnet is not the only accurate solution. In some cases, even a simple lumped inductor can be a reasonable superconducting magnet approximation. As presented in [10] a good agreement between measurements and simulation for a chain of superconducting magnets was achieved by simple lumped-element network. Another example is QP3 developed in FORTRAN at CERN and used to simulate quench propagation [9].

Nevertheless, existing simulation environments, both commercial and custom, were not able to provide the desired flexibility. Therefore, the Quench Simulation Framework (QSF) has been developed employing advanced MATLAB/Simulink and programming techniques. Since the FEM methods in their standard form are not feasible to apply in all cases, in the paper an alternative 2-D lumped-element modelling approach has been employed. This implementation employs an object-oriented modelling approach in both implementations and software development.

II. LUMPED ELEMENT SUPERCONDUCTING MAGNETS MODELLING

A two-dimensional lumped-element model is very efficient in terms of time required to solve the problem and it provides an acceptable accuracy for a wide range of problems including quench protection mechanisms such as passive by-pass devices, energy extraction, and CLIQ. The adopted model consists of thermal, electrical and magnetic subsystems coupled together and solved simultaneously.

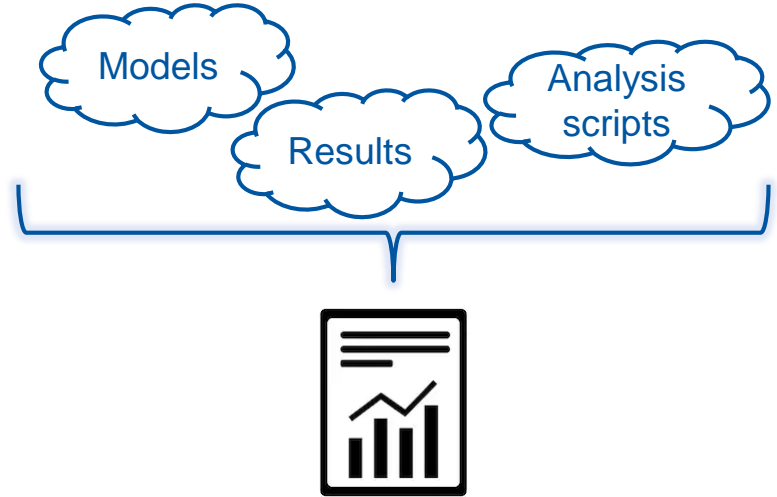
- BernhardAuchmann... Around since the 60ies
- BernhardAuchmann... for
- BernhardAuchmann... solving boundary-value problems
- BernhardAuchmann... The ROXIE quench simulation is a
- BernhardAuchmann... Moreover w.r.t. what?
- BernhardAuchmann... Deleted: it
- BernhardAuchmann... Long simulation times are not
- BernhardAuchmann... Why deeper than FEM?
- BernhardAuchmann... No?
- BernhardAuchmann... How is that linked to LEM? You have
- BernhardAuchmann... The energy is stored in the
- BernhardAuchmann... Which material, Copper.
- BernhardAuchmann... damage – singular noun
- BernhardAuchmann... To avoid this
- BernhardAuchmann... Measures, not methods
- BernhardAuchmann... Not correct.
- BernhardAuchmann... Deleted: methods
- BernhardAuchmann... Deleted:
- BernhardAuchmann... To what problem?
- BernhardAuchmann... The statement as such is trivial.
- BernhardAuchmann... 'Former' and 'later' categories not w
- BernhardAuchmann... ensure
- BernhardAuchmann... Why does FORTRAN matter? An
- BernhardAuchmann... robustness not well defined.
- BernhardAuchmann... study
- BernhardAuchmann... efficient
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- BernhardAuchmann... Deleted: Model
- BernhardAuchmann... Moreover
- BernhardAuchmann... At this point in the paper it cannot be
- BernhardAuchmann... Deleted: T., o dimensional
- BernhardAuchmann... What is the magnetic subsystem?



Where does it came from?

A typical modelling work includes

- ✓ creation of model,
- ✓ running some simulations
- ✓ post-processing results
- ✓ summarizing results
(paper, report, presentation)



Often times the link between the plots, schematics and report is broken.

With the use of **tikzpicture**, part of these data can be integrated into a notebook.

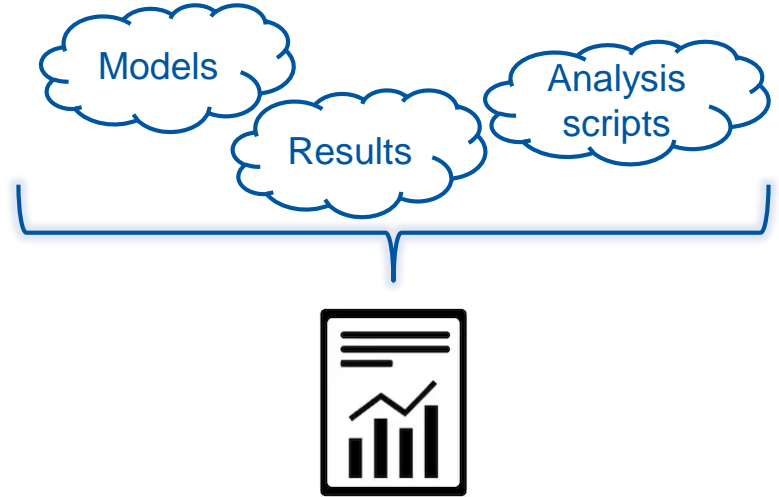
This way a document becomes a repository of data queried to provide relevant information.

5. STEAM Frontend Notebooks

- *Models as repositories of data*

A typical modelling work includes

- ✓ creation of model,
- ✓ running some simulations
- ✓ post-processing results
- ✓ summarizing results (paper, report, presentation)

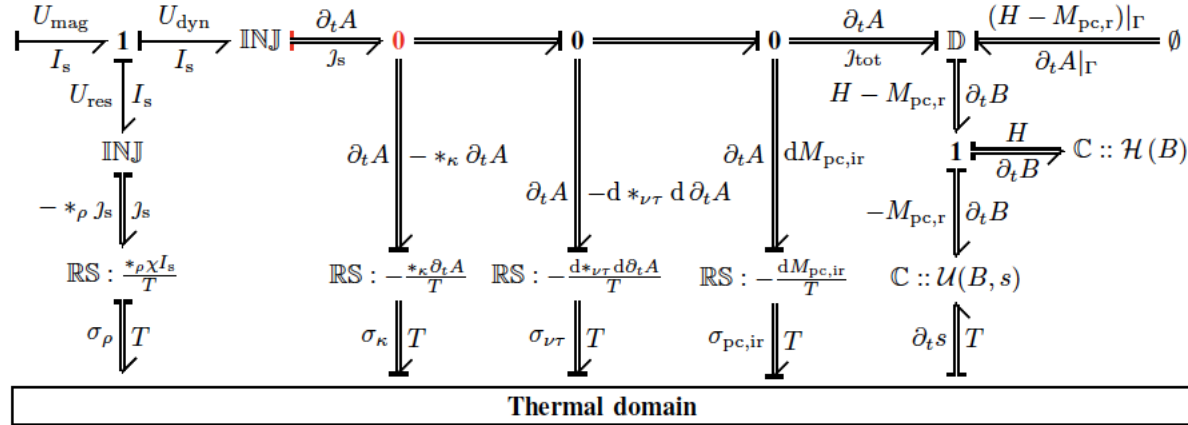
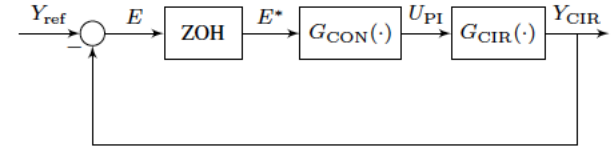
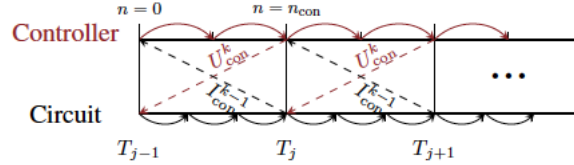
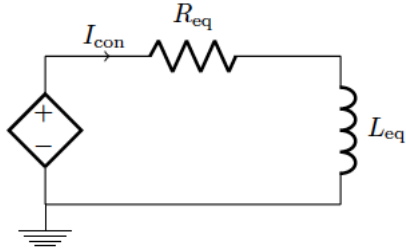


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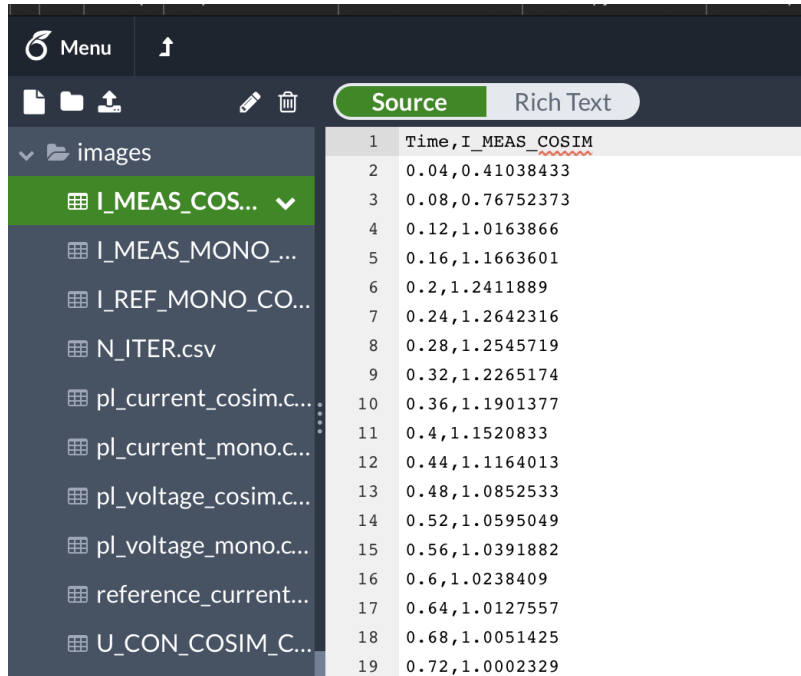
With the use of **tikzpicture**, part of this process can be integrated into a document.

This way document becomes a repository of data queried to provide relevant information.

Integration of schematics in papers

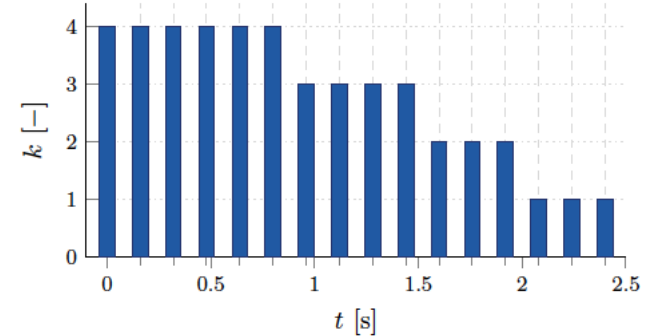
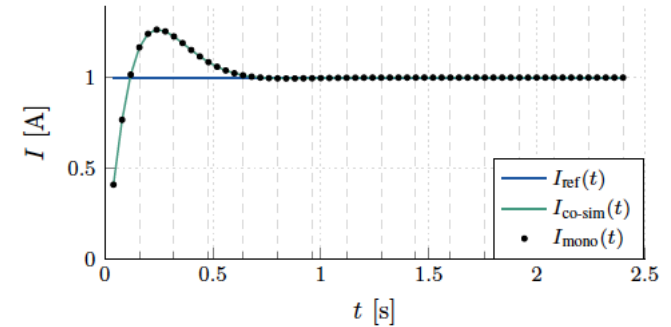


Integration of data in papers



The screenshot shows a file explorer interface with a list of files on the left and a table of data on the right. The table has two columns: 'Time, I_MEAS_COSIM' and numerical values. The data points are as follows:

Time, I_MEAS_COSIM	Value
0.04	0.41038433
0.08	0.76752373
0.12	1.0163866
0.16	1.1663601
0.2	1.2411889
0.24	1.2642316
0.28	1.2545719
0.32	1.2265174
0.36	1.1901377
0.4	1.1520833
0.44	1.1164013
0.48	1.0852533
0.52	1.0595049
0.56	1.0391882
0.6	1.0238409
0.64	1.0127557
0.68	1.0051425
0.72	1.0002329



Wishlist

1. Shared bibliography
2. Mode for view only (without code)
3. Transfer of rights between users
4. Linking documents to an e-group
5. Our templates in the main gallery

