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Anomaly Detection with Artificial Intelligence: Identification of pre-cursors of interturn shorts in the LHC's superconducting dipole magnets

Background

The Large Hadron Collider (LHC) at CERN is the world's largest and most powerful particle accelerator – and perhaps the largest machine ever built by humankind. Inside the accelerator with a circumference of 27 km, two high-energy particle beams of protons or ions travel counter clockwise at close to the speed of light before they are made to collide. With this principle collision energies reach above 13 TeV which is even extended with the actual High-Luminosity LHC project.

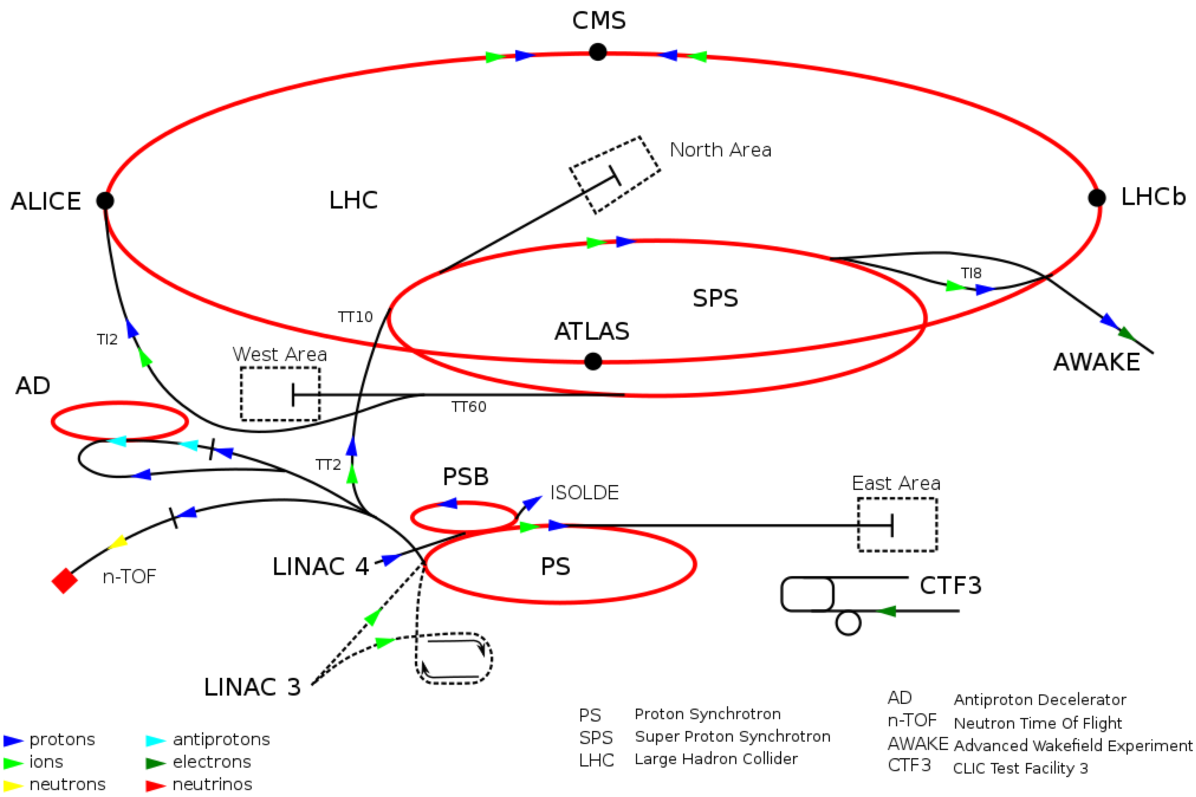

Figure 1 Particle accelerator cascade from injection to collision in the LHC

To avoid damage to accelerator components, a sophisticated Machine Protection and Electrical Integrity System is implemented and evolved continuously.

The LHC consists of more than 1200 superconducting main dipole magnets, which are subdivided into 8 sectors. The task of these magnets is to keep the particle beam on a circular path of 27 km circumference. Therefore, the correct functioning of these magnets is critical for the operation of the LHC. A single dipole magnet has a length of 15 m and its replacement requires several months, due to the need of warming up and re-cooling down the affected circuit. Therefore, it is important to identify precursors of critical issues in these circuits in advance. Such issues can be inter-turn shorts in the solenoid or shorts to ground to the implementation. Mitigation measures are taken before the operation of magnets in LHC, to limit the risk of causing damage to the circuit. A proven method is “quenching” the dipole magnet under controlled conditions – whereas a quench denotes the loss of superconductivity within the magnet.

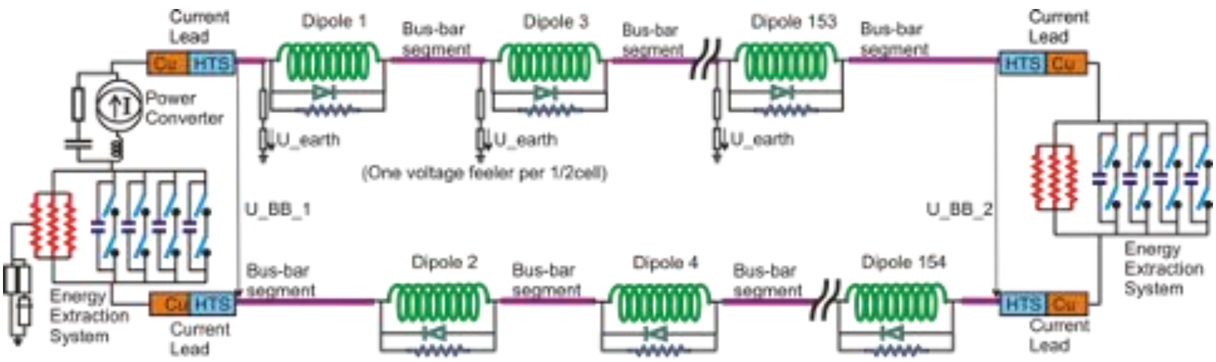

Figure 2 Overview of a circuit of superconducting dipole magnets and protective equipment in a sector of LHC

Topic

The LHC has just come out of a long shutdown period and nearly finished an intense training campaign of the superconducting magnet circuits, with several hundred quenches in the main dipole circuit. The successful candidate will retrieve the recorded data from the dipole training quenches, clean them, sort them and prepare datasets, which can be used for training and testing of different machine learning algorithms. The results of the training of the different algorithms should then be compared to previous work and the differences discussed.

A possible precursor for magnet quenches could be so-called “wiggles” – i.e. anomalies in the current measured – in adjacent magnets (see Fig. 3). These wiggle patterns should be analyzed in the framework of this master’s thesis.

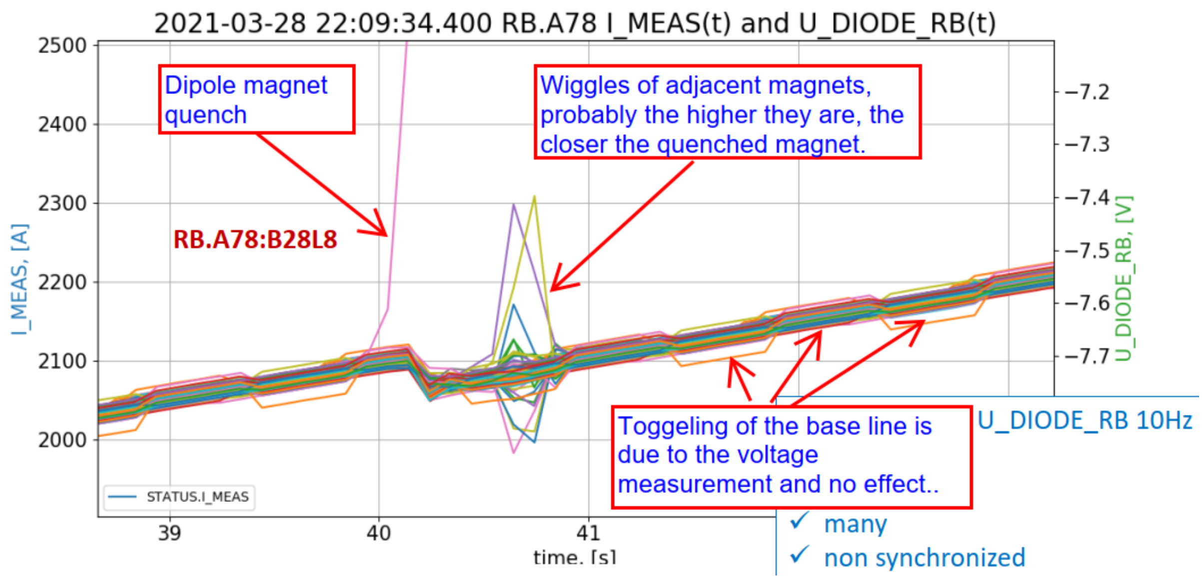

Figure 3 Quench of a dipole magnet with associated wiggles as possible precursors of subsequent quenches in adjacent magnets

Prerequisites

- Basic concepts in machine learning and artificial intelligence
- Good Programming skills in Python with standard libraries numpy, matplotlib and pandas, supplemented by keras and tensorflow or similar libraries
- Basic knowledge of data logging architectures (databases, time series data, data exchange between systems and data preprocessing, communication over networks, etc.)
- Knowledge of distributed computing with PySpark is an advantage
- Interest in working in a heterogeneous team of scientists, with a lot of freedom to bring in own ideas
- English language skills to discuss your work with colleagues who cannot communicate confidently in German

The thesis is supervised in cooperation with Dr. Christoph Wiesner and Dr. Daniel Wollmann from the section Controls and Beam Studies for Protection at CERN Geneva, Switzerland.

Contact

Prof. Dr. Andreas Müller
Room 03.06
Building D14
Schöfferstraße 8b
64295 Darmstadt
+49 6151 1638448
andreas.mueller@h-da.de