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Enhanced quench detection at the EuXFEL through a machine learning-powered approach

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The European X-Ray Free-Electron Laser is the largest particle accelerator for X-ray laser generation worldwide. The facility utilizes hundreds of superconducting radio-frequency cavities (SRFCs) for the acceleration of electron bunches to very high energies, reaching up to 17.5 GeV. This enables the generation of extremely intense laser flashes for an important number of users every year. However, the accelerator's smooth operation can be disrupted by various anomalous events, with quenches being particularly severe, as they result in the loss of superconductivity and down-times that can last for several hours. Hence, quench detection plays a vital role in ensuring the safe and optimal operation of the accelerator.
In this context, we undertake an analysis of signals that reflect the behavior of the SRFCs using a two-stage approach. The initial stage involves employing analytical redundancy, specifically the parity space method, to process the data and generate a residual. By evaluating this residual using the generalized likelihood ratio, we can identify faulty behaviors. In the subsequent stage, we focus on distinguishing quenching events from other anomalies. For this purpose, we employ a semi-supervised machine learning model based on the k-medoids algorithm, which explores various similarity measures such as lock-step and elastic measures. Evaluation results obtained during the second half of 2022, in comparison to the currently deployed quench detection server, demonstrate the effectiveness of our approach.

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