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Optimization of piezo operation for superconducting TESLA cavities

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Superconducting cavities with high Q-factor require precise tuning to match the RF frequency, ensuring stable electromagnetic fields and minimizing RF power consumption. At the XFEL accelerator, TESLA cavities are tuned using slow tuners (step motors) for coarse adjustments and fast tuners (piezoelectric actuators) for fine-tuning and compensating disturbances such as Lorentz Force Detuning (LFD) and microphonics.
*Critical to this system, Piezo actuators require high-voltage (up to 100V) and high-current (up to 1A) driving signals for effective LFD compensation. However, they are vulnerable to overvoltage, overcurrent, and overheating**, and their protection is crucial since replacing damaged piezo in fully assembled modules is unfeasible. Additionally, piezo induced vibrations can affect the machine's stability.
Optimizing piezo excitation—by reducing voltage, current, and current slope while ensuring effective LFD compensation—improves both reliability and machine stability. This paper explores the optimization of piezo excitation at XFEL, detailing methods and results applicable to other facilities with superconducting cavities.

Footnotes

*M.Grecki et al. "Piezo control for XFEL." Proc. LLRF Workshop, Barcelona, Spain, Oct. 2017, arXiv:1803.09042 (2018).**Z.He et al. "A reliability model for piezoelectric actuators," Proc. Int. Power Eng. Conf, Singapore, 2005, pp. 939-944 Vol. 2, doi: 10.1109/IPEC.2005.207043.

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