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M2Po2B-02: Numerical study of the clamping system and mechanical stress amplitudes in powerline busbars of SIS100 synchrotron fast ramped superconducting magnets

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The mechanical stress in the superconducting magnets due to clamping forces and Lorentz forces have been investigated by many researchers. The main issue is a critical current and quench induced by a magnetic field and mechanical strains in the busbars. Unfortunately, much less attention was paid to the mechanical stress and stability of the busbars that power the magnets. The self-induced magnetic field in the powerline busbars is much weaker than in the magnets, so the critical current is higher and not problematic. However, the Lorentz forces are still significant if the busbars are routed close to each other. If the magnet is powered by an AC current, pulsation of the Lorentz forces can be a cause of fatigue damage of the busbars.
In the paper, the powerline busbars of the SIS100 synchrotron magnets are analyzed. The SIS100 synchrotron is part of the FAIR project, realized in Darmstadt, Germany. The fast ramping magnets used in SIS100, are based on NbTi Nuclotron-type superconducting busbars. Four pairs of powerline busbars are routed in the common vacuum envelope with the process pipes providing cooling to the magnets. Due to high demand for magnet control quality, the electromagnetic cross-talk between busbar pairs must be minimized. For this reason, the busbars in each pair are clamped close to each other, while the distance between pairs is equal to 200 mm. The clamping of the busbars in a single pair effectively cancels an external electromagnetic field, minimizing the crosstalk between the busbar pairs.
The special G10 busbar clamps are spaced along the busbar pair at a distance of 45 mm. This design was tested and is used in around 2000 m of the powerline busbars of the SIS100 synchrotron. However, the problem was revealed in the interconnection areas:

- between powerline busbar sections;
- between powerline busbars and magnets
- between magnets.

Due to the design of the busbar interconnection (soldering), the distances between busbars in the single pairs are different from the standard busbar section (distance of 9 mm) and equal to 25 mm or 50 mm. In the interconnection areas during pulsed powering tests, a significant movement of the busbar was observed, which can cause mechanical fatigue damage to the busbar and powerline failure. The question was: How should the busbars in the various interconnection areas be clamped to achieve fatigue life similar to or longer than the standard powerline section clamped with a spacing of 45 mm?
The numerical study was carried out to optimize the minimum clamp spacing in the interconnection areas. A detailed Nuclotron cable was prepared that contained 23 NbTi superconducting wires around a central cooling pipe made of CuNi. All contacts between wires, between wires and cooling pipe, and between busbars and clamps are included in the model. Three busbar clamp designs were tested:
- with standard with 9 mm distance between busbars, used in powerline section
- with 25 mm distance used near the soldering area
- with a distance of 50 mm used in the soldering area
Each design was tested in a representative section of the clamped busbar pair, with four subsequent clamps included to minimize the influence of the boundary conditions.
After the initial clamping force, the dynamic simulation of the busbars loaded by a few cycles of Lorentz forces was carried out, up to stabilization of the busbar pulsating stresses. Simulations were repeated for various spacings between clamps along busbars in order to find the spacing at which the mechanical stress amplitudes

in interconnection areas are equal to stress amplitudes in the standard powerline section.
The areas of the busbars were identified, allowing for an improved clamp design. The maximum stress on the busbar was detected not in the clamp, but in the area next to the clamp.
As a result of all numerical simulations, the dependencies between busbar distance in pair, clamp spacing, and mechanical stress amplitudes were presented and discussed.

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