IS 3 T PEAK, 3T/S RAMP, A DREAM ?

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Abstract

Experience with AC superconducting magnets for accelerators has still to be gained. So far, few experiments were carried out typically in pulsed mode (one or few ramps). The design and manufacture of an AC dipole providing 3 T in the aperture ramped at 3 T/s ramp shall take into account many aspects resulting in a balanced compromise between the different contributions of magnet losses, temperature/field margin, lifetime under the cyclic operation in a radioactive environment. This note recalls some aspects to be considered for designing and manufacturing such a dipole, pointing out the still open issues which need R&D.

I. 3 T PEAK, 3 T/S RAMP

The successful manufacture of such dipole strongly depends on the availability of a suitable wire.

In an AC superconducting magnet using Rutherford cables the sum of the thermal losses produced during operation and the beam losses have to be kept below 10-20 W/m to allow operating in the superconducting state.

With the use of internally cooled cables, this limit can be raised above 50 W/m [1]. However, internally cooled cables make magnet manufacture (interface with connections and interconnections) and operation more difficult and less reliable than with Rutherford cables.

In this aspect, where possible, internally cooled cables should be considered only when beam or magnet losses become unacceptable for a safe operation.

The range 3 T peak, 3T/s ramp can certainly be achieved with Rutherford cables provided beam losses are kept well below 10 W/m (possibly with adequate shielding) and some R&D is pursued for wires and for cable treatment and manufacture.

The main conductor losses can be roughly summarized as:

- hysteresis losses
- matrix losses
- losses due to interstrand currents

While for such field rates we need a resistive matrix (CuMn or CuNi), the requirement for filament size and cable treatment (resistive coating on the strands or resistive core in the cable to limit interstrand currents) depends on the specific magnet design.

As an example, the losses due to interstrand coupling currents strongly depend on the cable width (to the cube for a given strand diameter). Similarly, the peak field in the coil and the coil volume affects the hysteresis losses so that, below a certain filament diameter, for a given design, the interest to further reduce the filament diameter weakens.

In summary, designing the proper pulsed dipole shall be an iterative operation involving many competences including cryogenics and beam physics, because trimming certain parameters (including machine requirements) may open new opportunities for a simpler and more efficient design.

II. THE GSI001 MODEL

A superconducting dipole achieving 4 T peak and 4 T/s (for a limited number of pulses) has already been built and tested [2-3]. The design is based on the RHIC dipole magnet with a cable modified to produce lower losses and the copper wedges in the coil cross section replaced by G11 wedges. With respect to the RHIC conductor, the filament twist pitch was reduced from 13 mm to 4 mm and the wire was stabrite coated. Furthermore, to reduce interstrand coupling losses, 2 stainless steel sheets (core) to decouple the two layers of strands.

While providing a good quench performance for up to 4 T/s ramp rates, such model showed issues which have to be solved for use in an accelerator going from field quality to losses when cycled in AC mode (about 80 J/cycle for 3 T/s, 3T peak, corresponding to 20 W/m for a 4 seconds cycle) and, last but not least, long term stability under the cyclic operation could not be demonstrated.

III. CONCLUSION

3 T peak, 3 T/s ramp in AC mode with periods of 4 seconds seem in reach of present or near future technology once a number of issues would have been solved :

- industrial manufacture of strands with resistive matrix and filament diameter smaller than 3 microns
- superconducting stability of cables with high interstrand resistance (coated or core) and long term mechanical stability
- field quality : wire, magnet design and magnetic measurements

Finally, in addition to R&D on the above items, an integrated design trimmed considering beam losses, cryogenics and beam physics is the base for success.

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