Status of Q6 Milestones & Progress Report at BNL Magnet Division

Ramesh Gupta, Piyush Joshi, S. Lakshmi Lalitha and P. Wanderer
(For Superconducting Magnet Division)

Summary

Status of Q6 Milestones

Task 5A: 1st coil built and tested to reach field > 10 T

Single pancake coils (12 required + 2 spare) fabricated. Double pancake coils (6 required) assembled with internal splice and tested at 77 K. Basic component of the advanced quench protection circuitry have been demonstrated to withstand over 1 kV. Preparations are well under way for 10+ T test at 4 K.

Task 9A: Verification of support structure and mechanical robustness

Structural analysis completed with stress, strain and deflections within tolerable limit.

GO/NO GO Decision/Review items: Successful test of first coil demo demonstrating field strength > 10T

This task is progressing well, however, with about a month delay. This is a major task that requires significant resources with delay partly associated with cash flow issues that slowed the construction. Internal loan at BNL has now resolved this issue and construction has accelerated. Demonstration of 10+ T coil is expected by the end of April (onsite review date: May 11, 2012).

Please see more details under the progress report section in the following pages.

Progress Report

Design, Construction and Test of Scaled SMES Coil for Q6

Quarter six has a major milestone that requires the demonstration of SMES coil producing over 10 T. The Q6 sub-scale coil will consist of 12 pancake coils made for inner layer of the 2.5 MJ SMES coil due at the end of the project. The final design consist of 28 pancake coils for inner layer (including 12 used in Q6 milestone test) and 28 for outer layer. Magnetic model of the coil for Q6 milestone is shown in Fig. 1 which shows field contour in 2-d model and parallel and perpendicular components of the field on the surface of the coil in 3-d model. It has an inductance of ~0.5 Henry and a stored energy of ~100 KJ at 650 A. The computed maximum field on the axis is ~10.6 T. The performance of the superconducting coil is determined by the maximum field on the coil (also referred to as peak field). The computed peak field is ~10.7 T. However, in HTS, the critical current also depends on the field angle in addition to the magnitude of the field with much smaller values for the same field in a direction perpendicular to the wide face of the conductor than to the parallel. The computed maximum perpendicular field in this model is ~4.6 T.

All SMES coil parts have been fabricated. The results of Q6 test are expected to be available by the end of April (about one month delay in schedule).

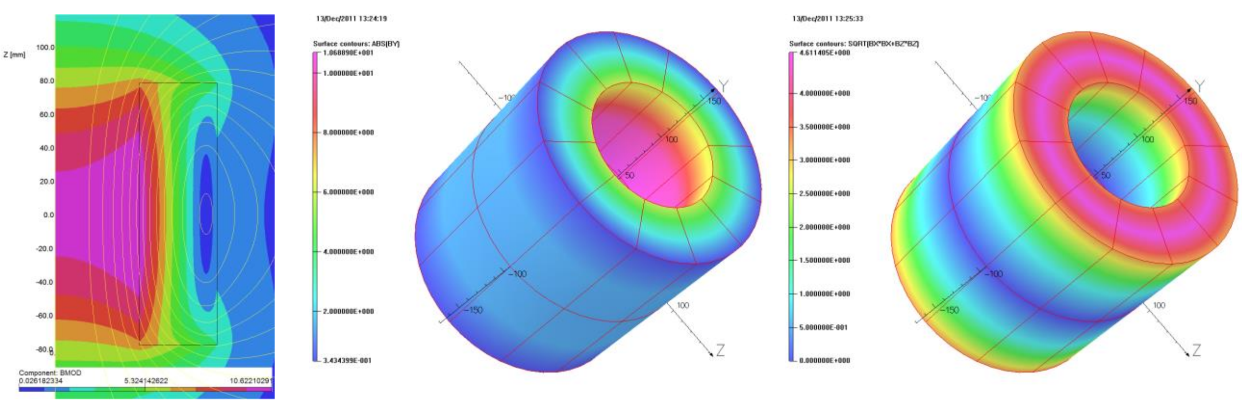

Fig. 1: 2-d axi-symmetric and 3-d magnetic model of the SMES coil to be tested in Q6. Parallel (maximum 10.7 T at SMES coil design current) and perpendicular (maximum 4.6 T at SMES coil design current) components of the field are shown on the surface of the 3-d model.

Fourteen coils (including two spares) have been fabricated. Twelve are shown in Fig. 2. Four of them have been spliced in two double pancakes with a diagonal splice at the coil inner radius.

Fig. 3 shows a double pancake coil in fixture ready for 77 K test in liquid nitrogen. So far 12 pancake coils (6 double pancakes) have been tested. As such this satisfies the requirement of Q6 milestone, however, we will assemling last two pancake coils in double pancake structure and testing it at 77 K to determine which of the 6 double pancake should be chosen for the test.

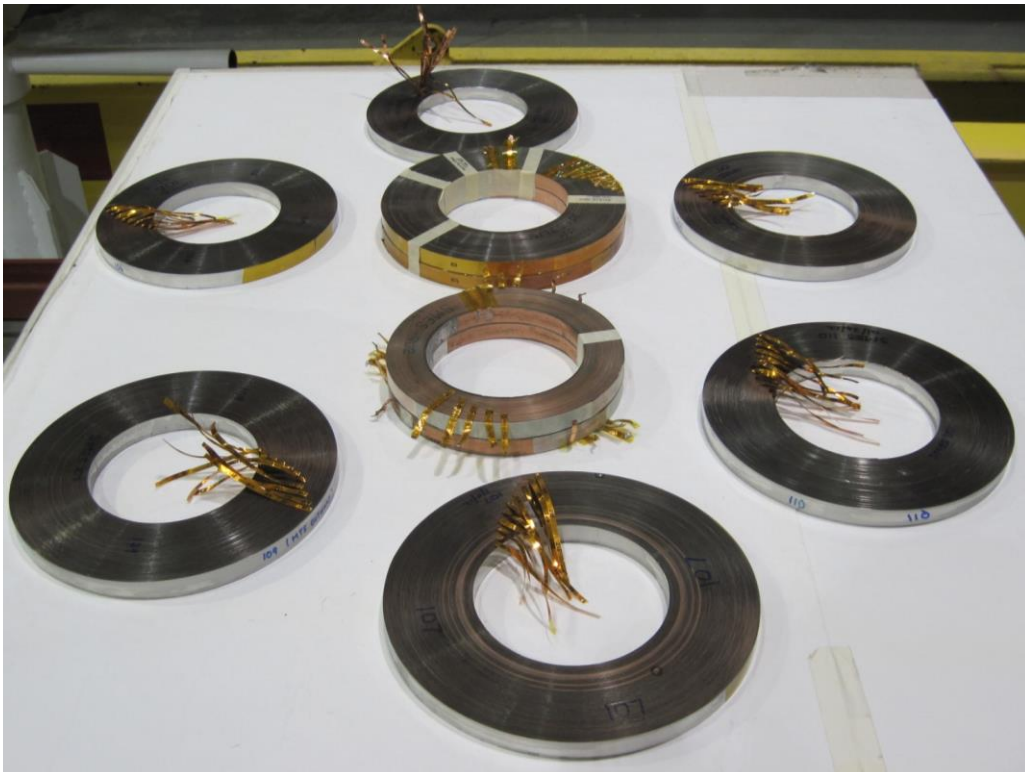

Fig. 2: Twelve pancake coils constructed for SMES project. Four of them (at middle) have been used in two double pancake assemblies with a diagonal splice at coil inner radius.

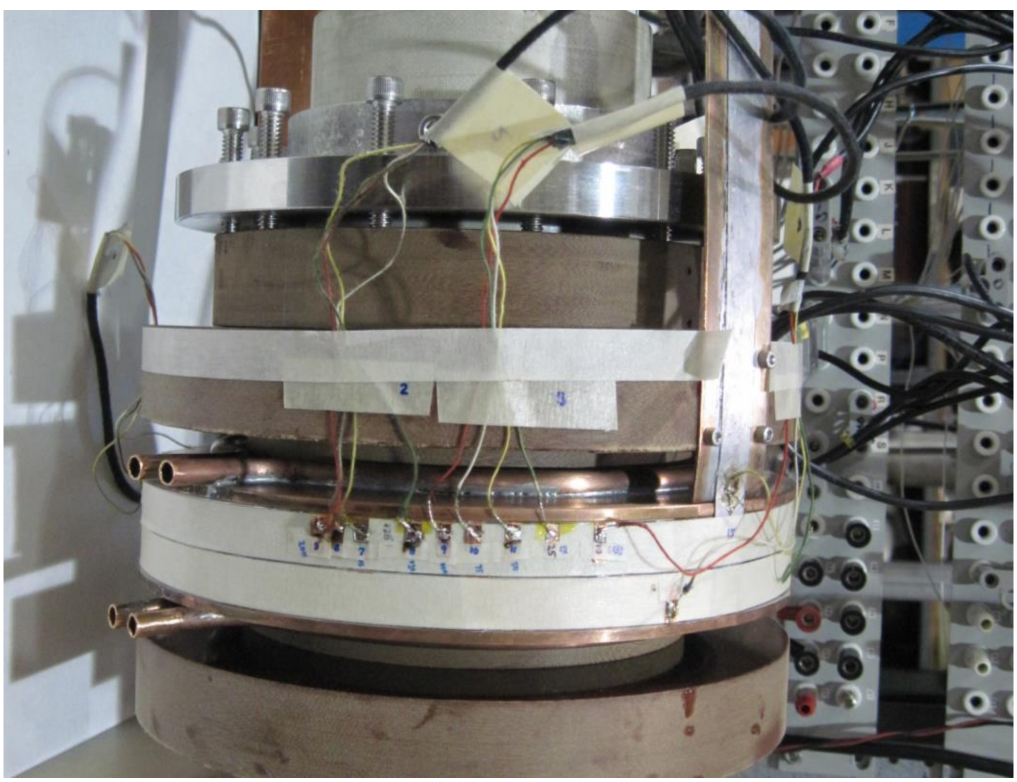

Fig. 3: A double pancake coil in a fixture ready for 77 K test in liquid nitrogen.

Measured critical current of the twelve pancake coils at 77 K is shown in Fig. 4. The main purpose of the 77 K measurement is to serve the role of Quality Assurance (QA). Even though there is a significant variation in the measured critical current of various coils, there appears to be no outstanding defect. This variation may partly be because of the improvement of wire critical current over time and partly because of variation in scaling between the self-field critical current of wire outside the coil and in-field critical current of wire in the coil. A detailed analysis of voltage distribution (not shown here) of various turns within the coil, however, shows a region of concern (not necessarily a defect) in one coil.

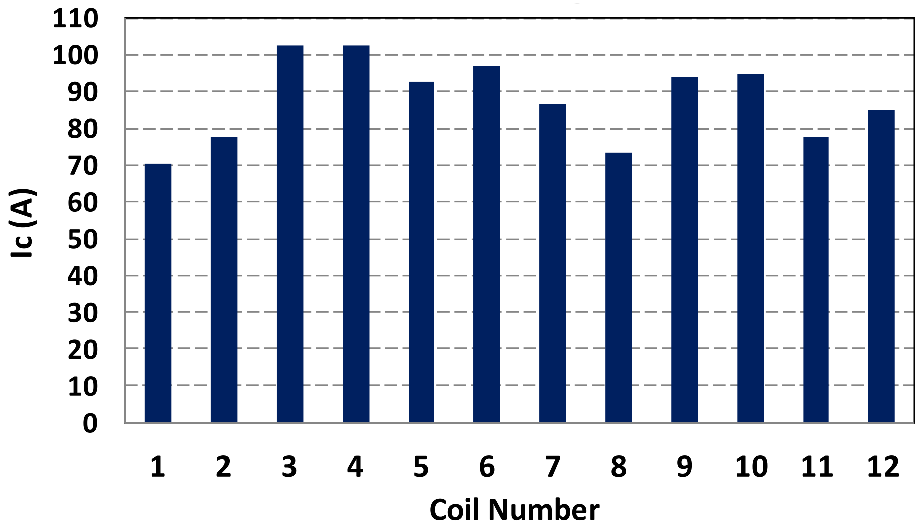

Fig. 4: Measured critical current of double pancake coil in a fixture ready for 77 K test in liquid nitrogen.

Test results of first four coils are shown in more detail in Fig. 5 where the voltages across the individual pancakes (SMES101 thru SMES104) and double pancakes (DPC1001 and DPC1002) are plotted as a function of current.

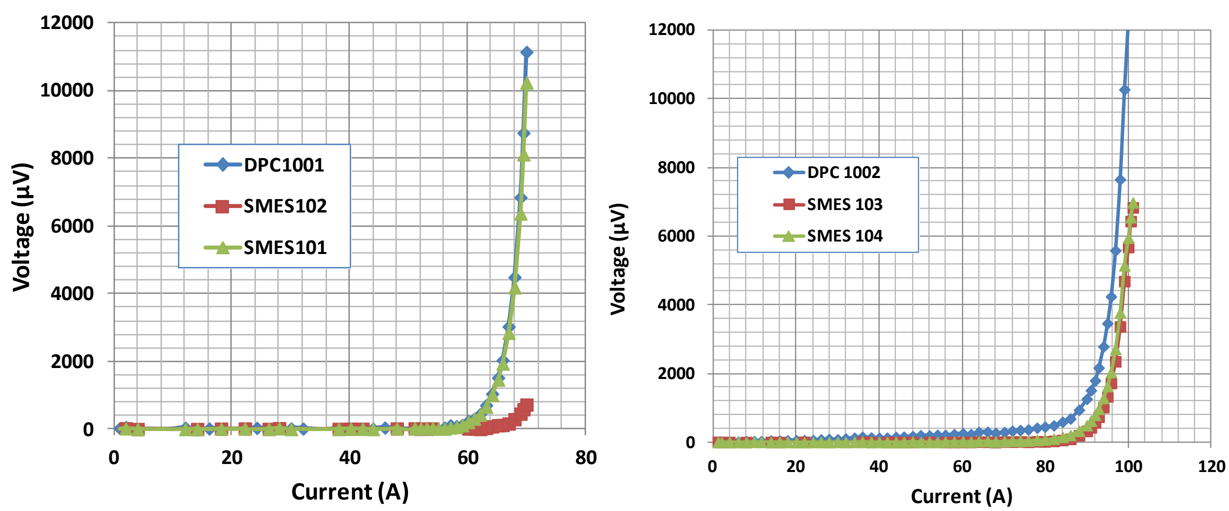

Fig. 5: Voltage across the individual pancakes (SMES101 thru SMES104) and double pancakes (DPC1001 and DPC1002) as a function of current in first four pancakes tested in liquid nitrogen.

Mechanical Structure Analysis

Mechanical structural analysis was completed in previous quarters. The structure was designed such that the deflections remain below 200 micron. In addition stress and strain within coil was also examined and remain within the guideline provided by vendor.

Quench Protection System for Large SMES

An advanced Quench Protection System (QPS), developed partially for other projects, is being adapted for Q6 test. 14 channel QPS system is schematically shown in Fig. 6 with picture of hardware and software screen shown in Fig. 7. The system can monitor 14 coil voltages and 16 joint voltages with its 32 channel transient data recorder.

The following are the challenges in multi-channel quench protection system for large SMES:

- Protection of electronic against High Ldi/dt voltage as the number of coil pairs and inductance increase.
- Data logger with Channel to Channel and Channel to ground isolation of at least 2 kV.
- Current interrupter IGBT switch becomes complex assembly of series and parallel devices.
- Bigger dump resistor develops higher voltage across IGBT and QPS electronics. This is a limiting factor in determining rate of energy extraction.
- Synchronization of two or more backplanes.
- Keep track of genuine simultaneous sampling for A/D converters.

Progress is well underway to meet above challenges in the quench protection system that is being developed for Q6 milestone of the SMES project.

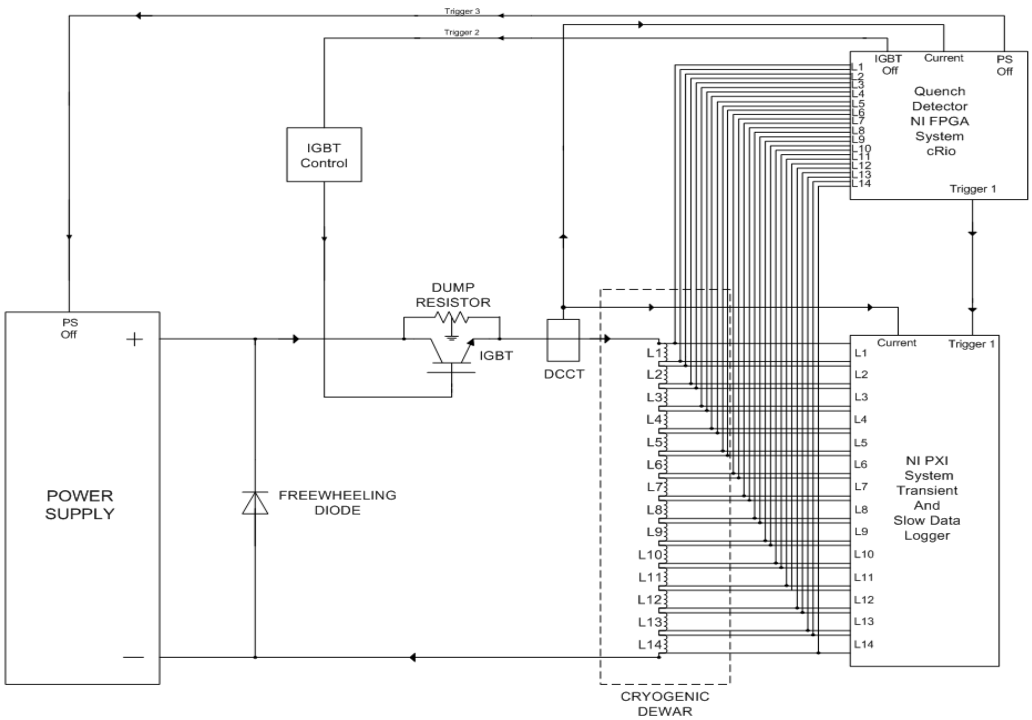

Fig. 6: Schematic of the 14 channel Quench Protection System (QPS).

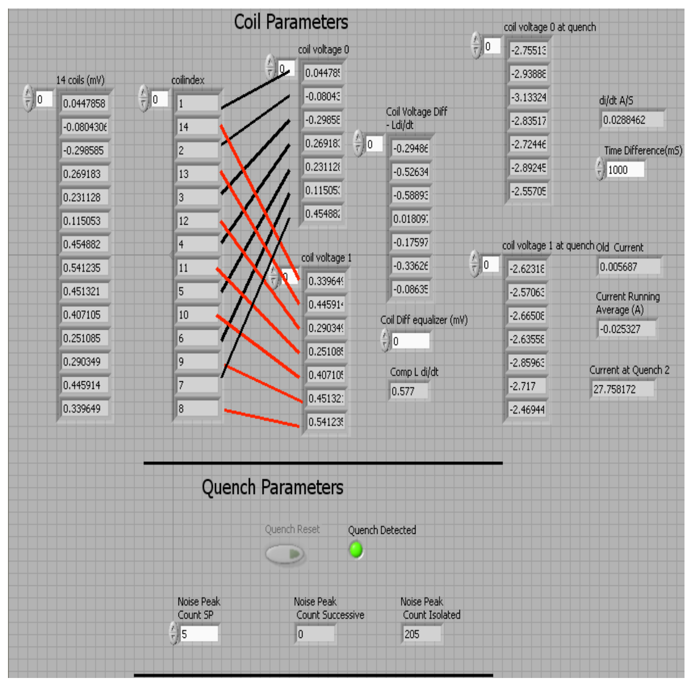

Fig. 7: Hardware (left) and screenshot of Labview software (right) for the quench protection system of SMES.