BNL Quarterly Report on Superconducting Magnetic Energy Storage Prepared for ARPA-E Through CRADA No. BNL-C-11-01 with ABB Inc.

Q10 Progress Report and Status of Milestones

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Advanced Quench Protection and Energy Extraction Systems

Significant progress has been made on completion of the advanced quench detection electronics. The software and hardware are being developed and tested with a series of HTS coils. The number of input channels for detecting a quench signal has more than doubled over what was previously used. We are now in the process of testing and evaluating high voltage isolators with +/-500mv input and +/- 10V output with isolation in range of 2KV to 3KV. Apart from precision, we are looking at long term zero input offset stability. We have evaluated isolators from Knick USA (Morgan Hill, CA), and are awaiting the delivery of two other isolators for evaluation from another manufacturer, Verivolt of Berkeley, CA.

Other major activities during this period were: (a) expanding and testing the quench detection system, (b) assembling and testing the second energy extraction and power supply system, (c) preparing for a two-section energy extraction test and (d) preparing for the integration of various modules with a master controller.

Fig. 1 shows the LabView display of the expanded quench detection system and new hardware modules.

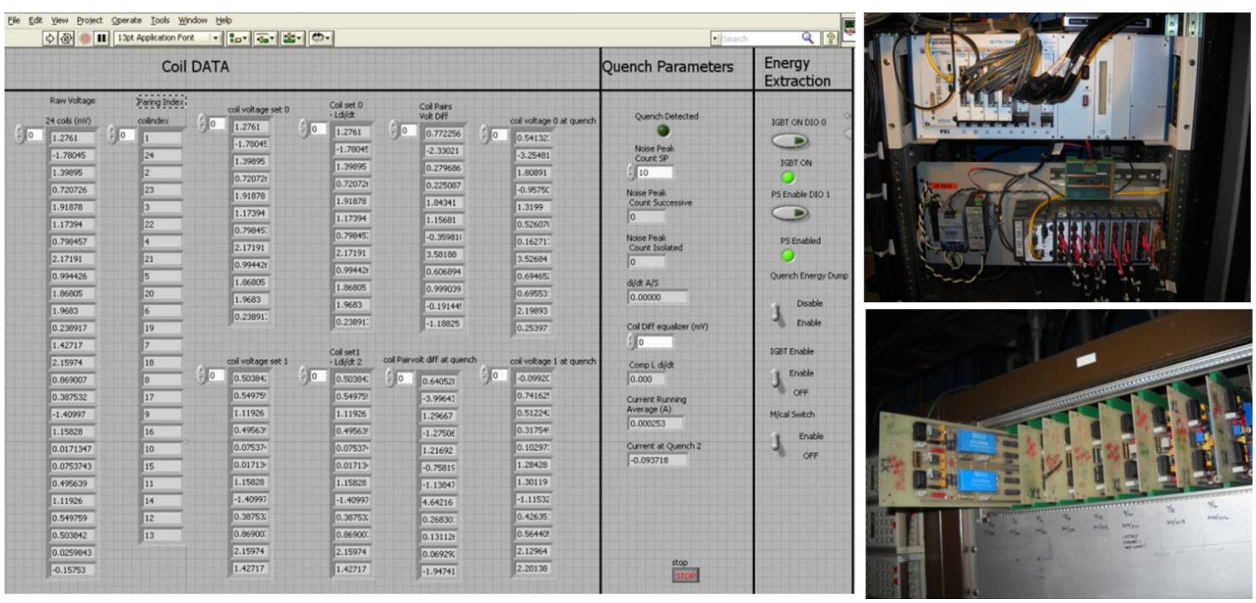


Fig 1: Expanded quench detection system with display from LabView on left, 26 channel quench detector on top-right and isolation modules on bottom-right.

BNL has accomplished the following on the Quench Detection (QD) and Quench Protection (QP) system:

- expanded and tested the quench detection system
- assembled and tested the second energy extraction and power supply system
- prepared for a two-section energy extraction test and
- prepared for the integration of various modules with a master controller. We continued work on the QD and QP system including an evaluation of the individual components to withstand high voltage in the quench detection and protection system.

As part of that work we divided the coil into several parts. Each coil itself will be divided in two parts as shown in Fig. 2. This reduces the inductance and hence the maximum voltage generated. This requires the use of multiple power supplies. We are upgrading our existing power supplies and control systems so that they can accommodate high current and high voltages.

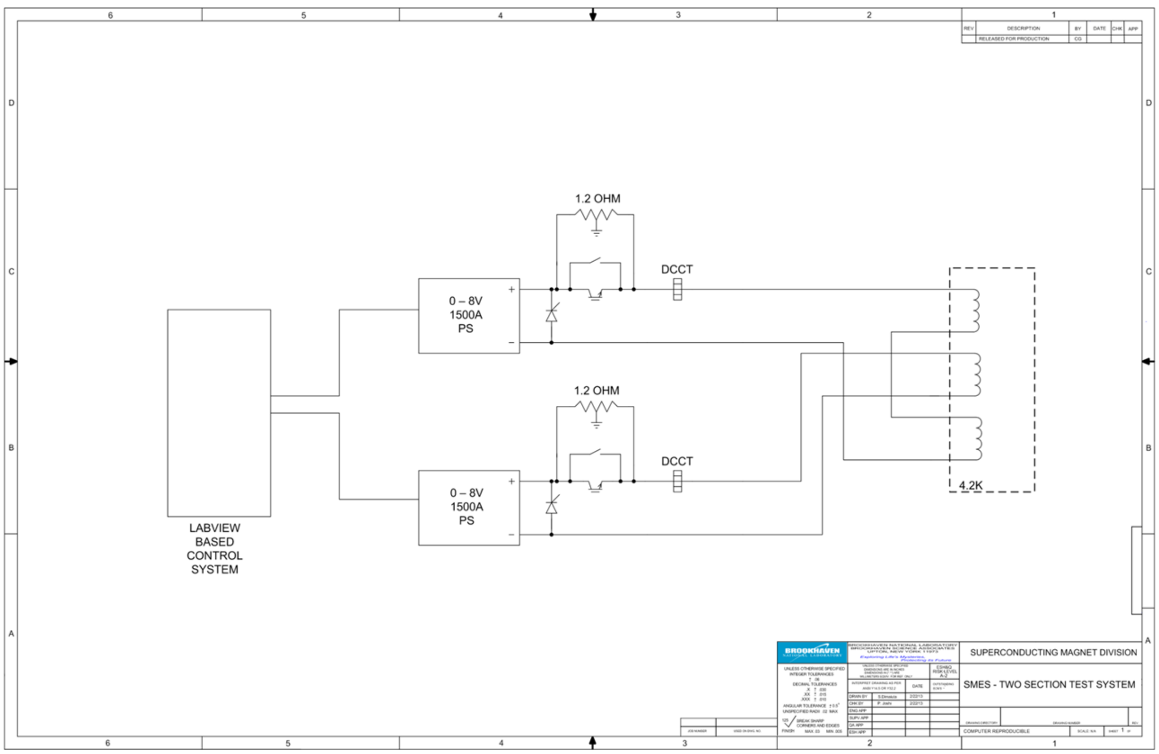


Fig 2: Quench protection circuit when inner or outer coils are divided in two sections.

System Integration

We have designed the overall control system for SMES and tentatively identified responsibility for various software and hardware modules as follows:

1. Master Computer (SMD)
2. Converter, interface and monitoring (ABB)
3. SMES coil and cryostat interface (SMD)
4. Quench detection and energy extraction (SMD)
5. Superconducting switch, ON/OFF logic and RF interface (CMPMSD)
6. Transient data logger (SMD)
7. Continuous data logger (SMD)

Fig. 3 shows a schematic view of the arrangement of the above seven modules.

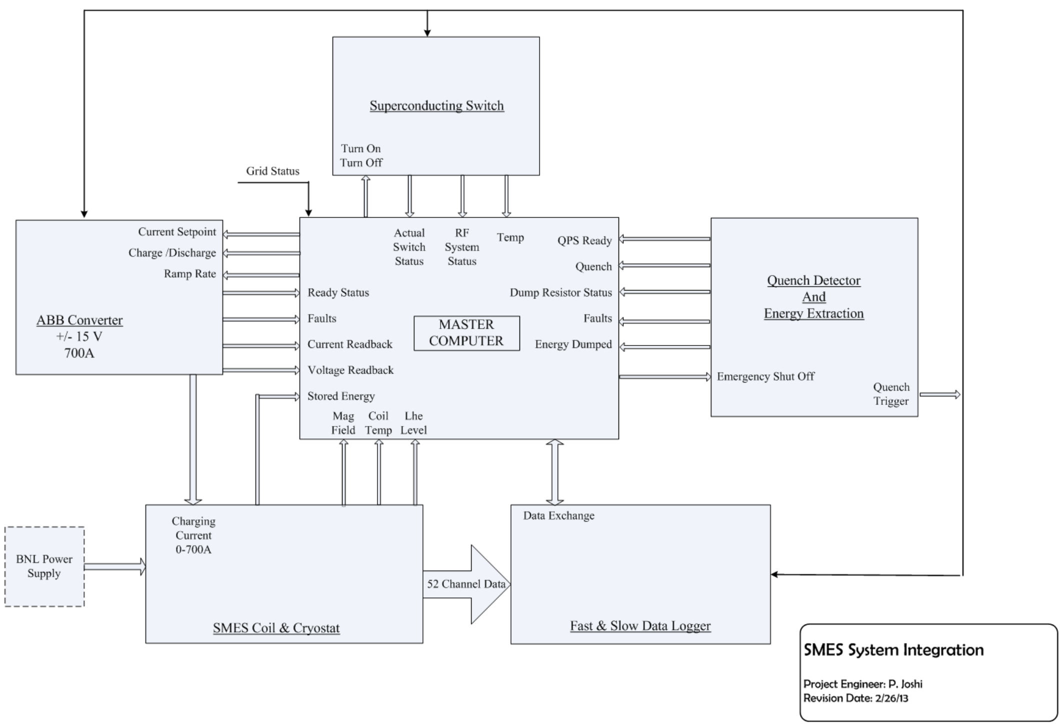


Fig 3: Proposed Integrated system for SMES

Engineering Design of the 1.7 MJ Support Structure

After having received the DOE ARPA-E decision that the device will be a 1.7 MJ SMES coil, we have continued working on the detailed engineering design for portions were different between the 1.7 and 2.5 MJ revisions. The design work has been prioritized so that all parts needed for the magnet can be ordered as soon as possible.

Fabrication of Fixture for Testing the Outer Double Pancake Coils

We completed the construction of the fixture for testing the larger outer double pancakes at 77 K. This test fixture is significantly larger and heavier than the inner double pancake coil test fixture. In addition, four test leads are incorporated, instead of two, making this fixture more advanced than the one used to test the inner coils. This design allows testing of both pancakes, of the double pancake arrangement, individually to their full potential even if they have significantly different critical currents. The new test fixture has been now been used to test all double outer pancakes (two double pancakes) at 77 K. Fig. 4 (top-left) shows an outer double pancake coil. Fig. 4 (lower left) shows the assembly during preparation for test in a horizontal position and Fig. 4 (right) shows it in the final stage in vertical position ready for 77 K QA test. There is a significant amount of instrumentation with a large number of voltage taps installed within the coil to measure and assure that there is no local defect in the conductor, splice or winding.

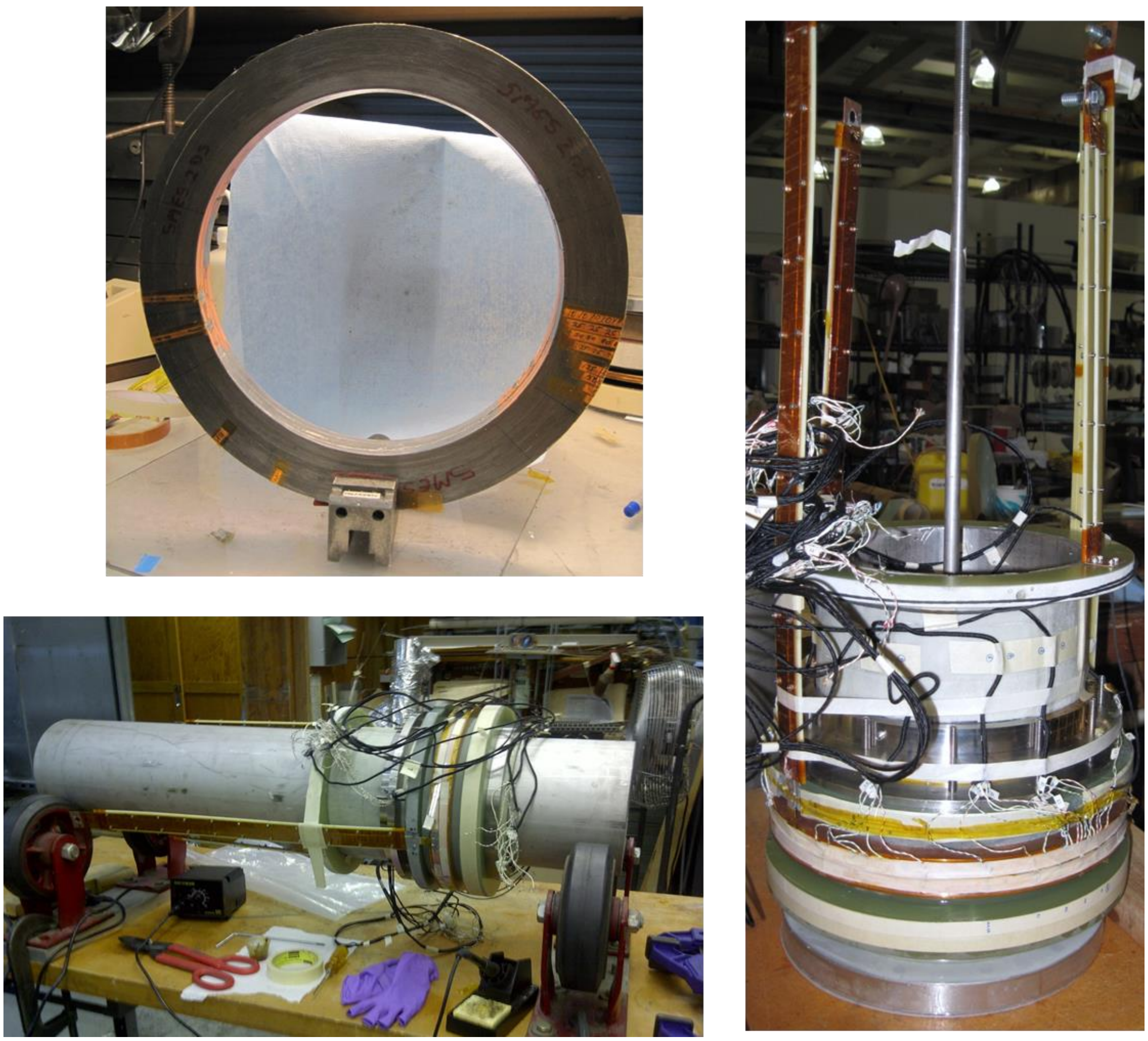


Fig. 4: Construction of fixture for testing outer double pancake coils at 77 K. Outer double pancake coils (upper left), during preparation for test in horizontal position (lower left) and ready for 77 K test (right) in vertical position.

Fabrication and Testing of Pancake Coils for Outer Layers

The 1.7 MJ design consists of 28 single pancakes (14 double pancakes) in the inner layer and 16 single pancakes (8 double pancakes) in the outer layer. We have completed fabricating all 28 single pancake coils (last one fabricated this quarter) for inner and 7 single pancake coils for outer (five of them fabricated this quarter). These are important Quality Assurance (QA) tests before the coils are integrated in the SMES system.

Fig. 5 and Fig. 6 show selected tests of double pancake coils. In Fig. 5, we show the case when the double pancake coil passes the QA test. On left side of the Fig. 5, we show the case when both single pancake coils are powered individually and on right side when they are powered together. One can see that the two pancakes have significantly different critical currents. The new fixture with four leads allowed us to test a double pancake coil and splices separately and together and determine their individual critical currents despite having a significantly different value for each single pancake.

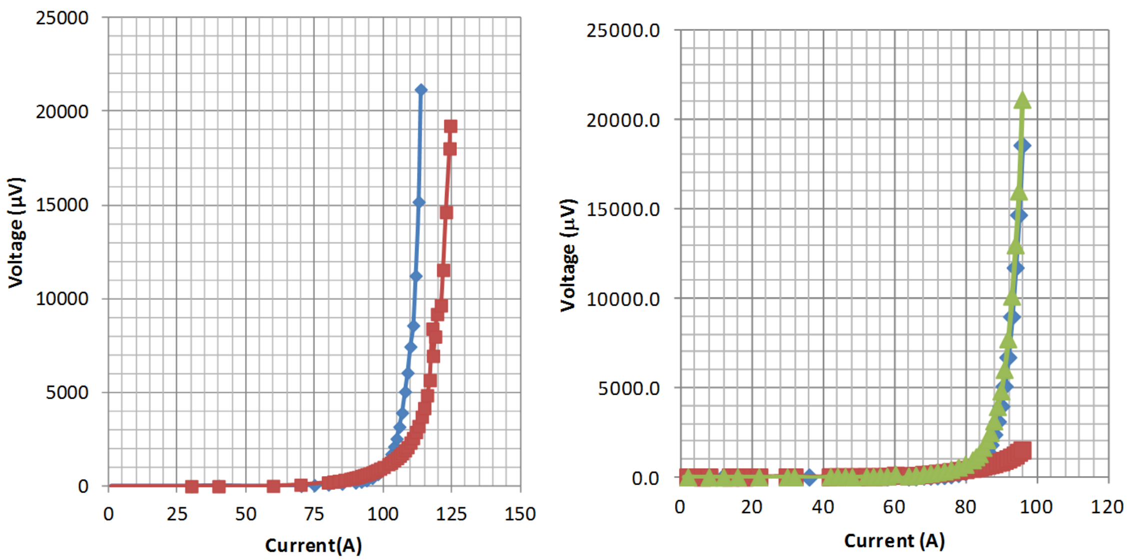


Fig. 5: The new test fixture allows the testing of the individual single pancake coils (in the double pancake structure) separately, if needed. This is the case when the two single pancakes have significantly different performance (as above). Figure on the left shows the test performance when the two coils are powered separately and figure on the right when they are powered together.

In Fig. 6, we show the case when the double pancake coil was not able to pass the QA test. One can see an early onset of resistive voltage in the single pancake coil SMES 205 which is primarily responsible for the total voltage in the double pancake coil assembly DPC2003 which also contains SMES 206. In Fig. 7, we show the case when both single pancake coils are powered individually with a number of voltage-taps monitoring voltage in small sections of the coil. Fig. 7 (left) shows the measurement in good coil and Fig. 7 (right) shows the measurement in defective coil. Incorporation of a large number of voltage-taps allows us to identify the section of the conductor with poor performance and send the feedback to conductor manufacturer (SuperPower) to evaluate if there was something unusual during the construction. Only two single pancakes out of 44 that are needed for a 1.7 MJ device, did not pass the QA test. Both will be replaced by new coils for which SuperPower has agreed to provide extra conductor.

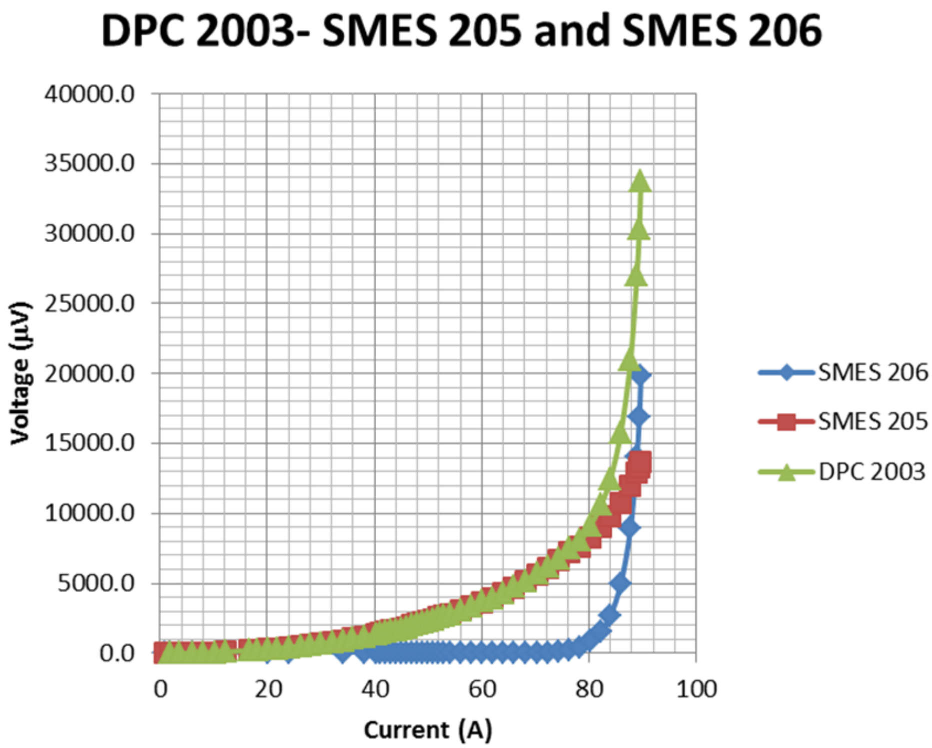
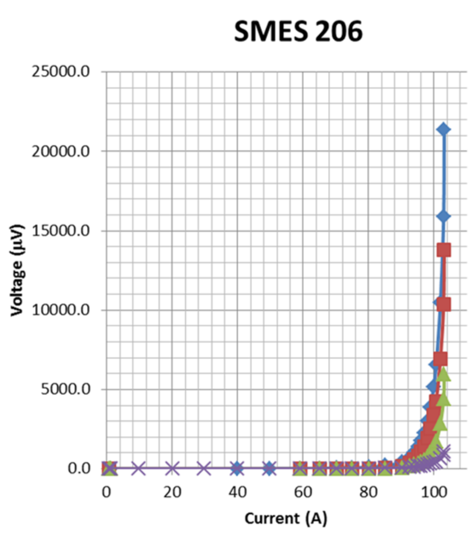


Fig. 6: One single pancake coil (SMES 206) of the double pancake coil (OPC 2003) showed an early onset of resistive voltage during the QA test at 77K. This coil will not be used in the entire 1.7 MJ SMES coil assembly which will be tested at 4K which produces significantly high stress and strain. SMES 205 is acceptable.



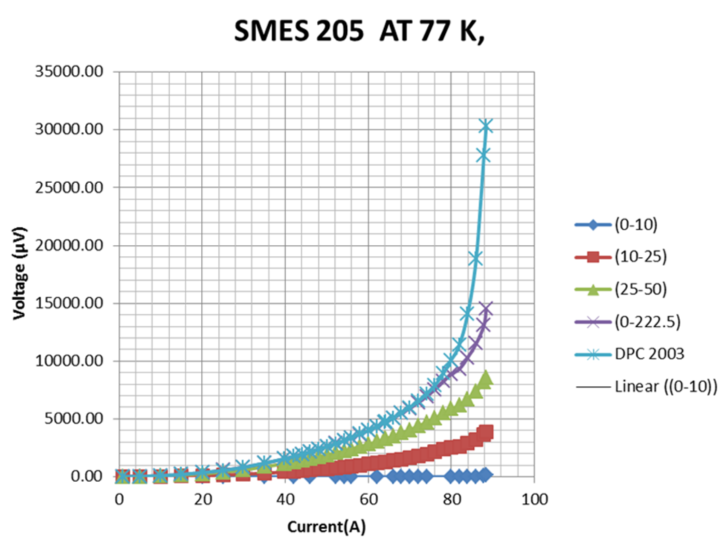


Fig. 7: Performance during the test of individual coils (only one single pancake powered at a time). Good coil is shown on the left. Number of voltage taps help localize the bad region(s) in the coil (see early onset of resistive voltage on right)