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BRIS for KSTAR superconducting coil

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Abstract: The Blip Resistor Insertion System (BRIS) is developed for Korea Superconducting Tokamak Advanced Research project. The BRIS, which consists of turn on/off switch and blip resistor, is employed to provide fast magnetic coil current swing to PF coils for the plasma initiation and reduce the PF coil driving voltage for the improvement of grid power requirements. The switch must have the characteristics of high dc current cutoff, long lifetime and reliability. BRIS turns off and on maximum 25 kA dc current during 100 ms and generates high dI/dt for plasma initiation.

1. INTRODUCTION

Start-up of Tokamak may be broken into three distinct phases. They are: 1) Charge phase. The PF coils are charged to their pre-blip values of current at constant voltages with coil resistance assumed to be constant. 2) Blip phase. The loop (open) voltage in the vacuum chamber rises as rapidly as possible to breakdown and initiates plasma. The PF coil currents are driven down very quickly to produce a large electric field within the torus. The loop voltage reaches a certain value at which the plasma breaks down and during the next few milliseconds the avalanche phase is in progress. 3) Current rise phase. The plasma has initiated and the coil currents change to drive the plasma current at a reasonable ramp rate. The BRIS, which consists of turn on/off switch and blip resistor, is employed to provide fast magnetic coil current swing to PF coils for the plasma initiation and reduce the PF coil driving voltage for the improvement of grid power requirements.

2. BRIS

Required specifications of BRIS switch is as follows; On-state current and maximum controllable turn-off/on current are 25 kA (PF1,2,3,4) and 20 kA (PF5,6), maximum dI/dt is high and maximum off-state voltage is 3 kV (PF1,2,3,4) and 6 kV (PF5,6). Also, for getting fast dI/dt of coil current blip resistor is inserted during the off-state of switch. The blip resistor could consume the coil energy for short time duration and have small leakage inductance for small overvoltage. When initiating the charging of PF coil at time t = 0, (1) the coil current is generated from thyristor rectifier converter and simultaneously the turn-on signal is sent to the BRIS. (2) After charging and checking the coil, Blip switch is turned off and the coil current is transferred to the blip resistor. The coil current thereupon decays with a fixed time constant Lcoil/Rblip. During about 100 ms, this is the maximum operation time of BRIS, blip switch keeps the off-state. (3) When blip finished, blip switch turns on and the power supply system controls the coil current and builds up the plasma current. Considering the specification of critical rate of riseof on-state current of power semiconductor device, we choose the IGCT as a blip switch. And also it has large current handling capability and simple gate driver.

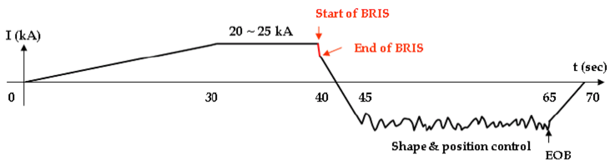

Fig. 1. Conceptual PF coil operation scenario for plasma generation and control

3. PROTOTYPE BRIS

At the superconductor test facility the 4 kA BRIS tested with BKG superconducting coil of 150 mH, using the 12 pulse thyristor, quench protection circuit and safety connection system same as in the Fig. 2. The BKG superconducting coil is the both prototypical of CS coils and suitable as a facility for testing full-scale conductors to high field and high current. One of the sample scenarios is conducted within the limitation of test facility power.

When the IGCT turns on, 4 kA coil load current is commutated from blip resistor to IGCT and turn-on dI/dt of IGCT, which determined by the stray inductance of blip resistor and circuit, is higher than the critical rate of rise time of IGCT. Therefore, turn-on snubber inductor was used for limiting the dI/dt of

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IGCT turn-on current. Resistor and diode, series connected, were used for dissipating the turn-on snubber inductor energy during the IGCT turn-off phase. PF superconducting coil requires positive and negative current and also thyristor converter can do 4 quadrant operations. Because blip of superconducting coil occurred always at positive current operation, diode was used as reverse current conducting switch.

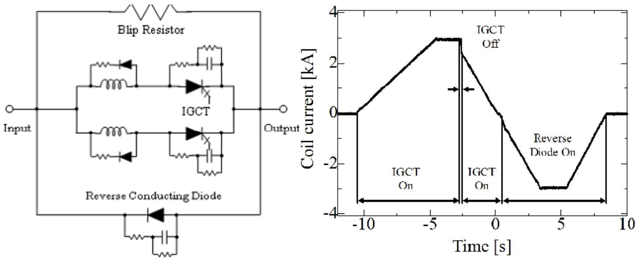

Fig. 2. Schematic diagram of 4 kA prototype BRIS and test result(coil current)

From Fig. 3, we get the coil current dI/dt ≈ 27 kA/s and BRIS voltage about 2.6 kV. The required dI/dt of KSTAR system is about 17 kA/s and the results satisfy it. When the BRIS starts, namely IGCT turns off, the voltage spike is shown. It results from the stray inductance of blip resistor and busbar connection between blip resistor and IGCT. If this spike exceeds the voltage rating of IGCT and insulation level of superconducting coil, we will add the RC snubbers for blip resistor reducing it. This result will be used to design and fabricate the 25 kA BRIS system of KSTAR superconducting coil.

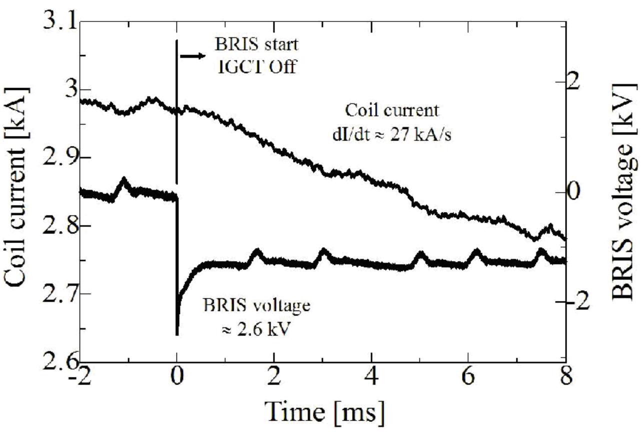

Fig. 3. BRIS test result when BRIS starts(coil current and voltage)

4. Conclusion

The 4 kA prototype BRIS, especially IGCT module and blip resistor was tested successfully and the 25 kA BRIS for KSTAR was designed and tested up to 15 kA. Up to 15 kA the current sharing of each IGCT is well balanced, but the overvoltage of IGCT turn-off due to the stray inductance of blip resistor is high when considering the 25 kA operation of BRIS. The snubber of blip resistor will be added and tested at 15 kA for reducing the overvoltage and spikes. The performance and reliability test of blip switch and blip resistor is continued.

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