§8. Study on Testing Methods for Joints of Large-Scale Cable-in-Conduit Conductors

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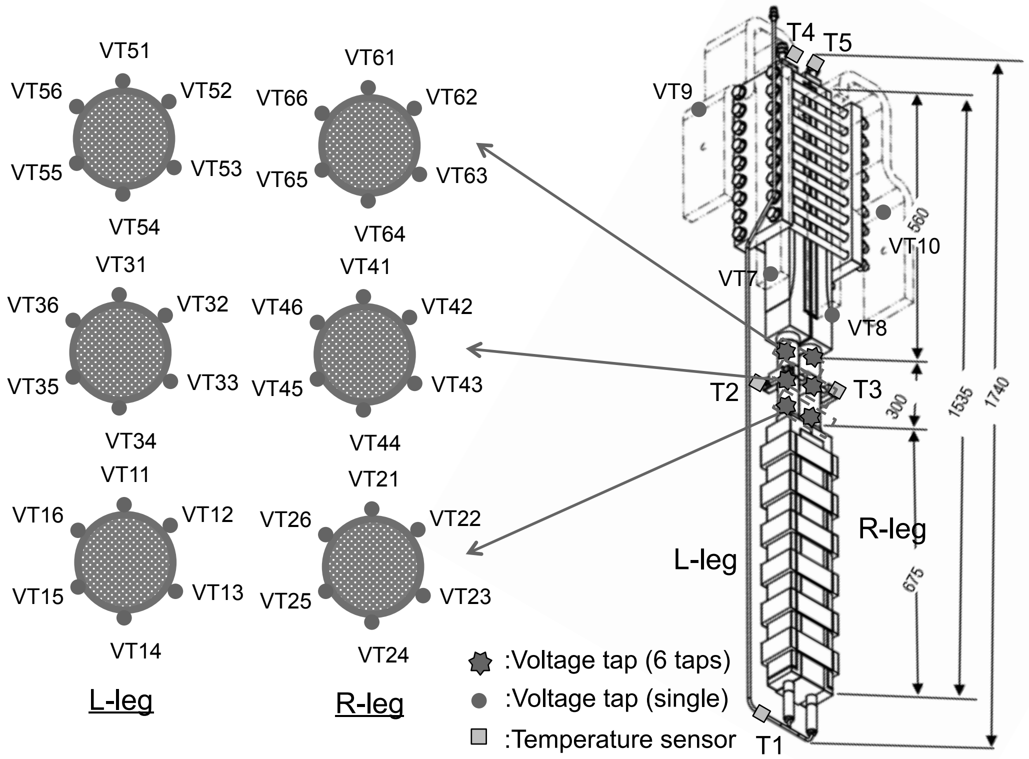
Large superconducting magnets are indispensable for magnetic confinement fusion. In order to suppress the voltage at quick discharge for the magnet protection, high current conductors are needed. A cable-in-conduit (CIC) conductor, which comprises a multi-strand cable of superconducting wires within a tube-like conduit, is suitable for them. For example, the 70 kA class CIC conductor is adopted for Toroidal Field (TF) coils of ITER. A joint resistance of superconducting conductors must be sufficient low to assure its cryogenic stability higher than the other parts. In the case of the ITER-TF conductors, the allowable joint resistance is 3 nΩ. The electrical voltage at the joint part is not uniform in a cross-section of CIC conductors because of the current transfer between the strands.[1] Therefore, researches are necessary for measurement of the joint resistance of CIC conductors with sufficient accuracy. The purpose of this study is to improve the measurement accuracy of joint resistance of a large CIC conductor.

Based on the design study in the last year, testing methods and testing jigs for the ITER-TF joint samples are determined. The set up of the joint sample is shown in Fig. 1. Two straight CIC conductors are jointed at the lower end, which is set at the center of the 9 T split coil. The upper ends are jointed to copper busbars that are connected to the current leads. The sample is inserted in a stainless steel case that prevents the sample from being immersed with liquid helium in order to change the sample temperature. The joint sample is cooled with pressurized helium that is supplied at the bottom. The temperature of the joint sample is controlled with tape heaters that are attached on the inlet cooling pipe inside the sample case. The 9 T split coil is charged up to the certain current, and the current of the joint sample is increased to the nominal current with holding currents for 3 minutes at 15, 30, 45, 60, and 68.1 kA. The other testing conditions are as follows:

Helium flow rate in the sample:	1-3 g/s
Sample inlet pressure:	0.3-0.5 MPa
Inlet temperature:	4.4 K, 6 K
Ramp rate of sample currents:	+150 A/s (ramp up)
	-600 A/s (ramp down)
External field at the center:	0, ±2.4, ±3.7, ±4.8 T

Outputs of the voltage taps and the temperature sensors are collected at intervals of 10 ms through the low pass filter of 10 Hz to a data acquisition system of Agilent VT1413C. The averaged voltages in last 30 s in each current holding period are utilized for the evaluation of the joint resistance. Since the averaged voltage of each pair of taps is proportional to the sample current with more than 99% certainty, the joint resistance can be estimated from the incline of the fitting line with sufficient accuracy for the measurement of the joint resistance less than 3 nΩ.

1) Koizumi, N., Matsui, K., and Okuno, K.: Cryogenics 50 (2010) 129–138.



Pair	+ tap	- tap
#1	VT11	VT21
#2	VT12	VT26
#3	VT13	VT25
#4	VT14	VT24
#5	VT15	VT23
#6	VT16	VT22
#7	VT31	VT41
#8	VT32	VT46
#9	VT33	VT45
#10	VT34	VT44
#11	VT35	VT43
#12	VT36	VT42
#13	VT51	VT61
#14	VT52	VT66
#15	VT53	VT65
#16	VT54	VT64
#17	VT55	VT63
#18	VT56	VT62
#19	VT7	VT9
#20	VT8	VT10

Fig. 1 Joint sample and position of voltage taps and temperature sensors.