PHYSICAL MODEL OF SUPERCONDUCTING FAULT CURRENT LIMITER- DESIGN AND TEST

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Abstract - **The high temperature superconducting fault current limiter has been studied worldwide and are classified into a resistive, inductive and hybrid type. The fault current limiter of an inductive type seems to be most prospective due to the simple design of the secondary winding which has the form of a ceramic tube (based on Y or Bi) and for the escape of current leads at cryogenic temperature. Design and results of preliminary test of the physical model for such limiter have been presented in the paper.**

Keywords: *high temperature superconductors (HTSC), superconducting fault current limiter, superconducting screen, cryostat, data acquisition*

1. INTRODUCTION

Superconducting fault current limiters are one of the most promising devices for transmission and distribution of electrical energy due to low nominal losses, rapid reaction times to fault current and automatic response without external trigger mechanism [1,2].

This paper describes the physical models of an inductive-type screened iron core limiter (LSC) that has been performed and investigated in the INCDIE ICPE-CA. The models differ from each other on primary windings, superconducting tube heights and the type of magnetic circuit-open or closed.

2. INDUCTIVE LSC OPERATION

LSC can be modeled as a transformer: a primary Cu winding is inserted in the circuit and it is coupled (via magnetic circuit) with shorted secondary winding with the shape of an YBCO tube. The impedance of LSC in a steady state is nearly zero, since the zero impedance of the secondary winding is reflected to the primary. In case of a fault, the large current in the circuit induces a large current in the secondary and the winding loses its superconductivity. The impedance in the secondary is reflected into the circuit and limits the fault.

It has been performed two models of LSC which differ on the height of the tube: 100 mm (LSC-100) respectively 120 mm (LSC-120). Primary Cu winding has tappings on each layer for an easy magnetic field control. The magnetic core (silicon steel plate, 0.27 mm thickness) was manufactured by mould technology. The parameters of the models are shown in Table 1.

Superconducting screen	Hallow cylinder: ID 54 mm*OD 60 mm*100 mm
	Ring: ID 54 mm*OD 60 mm*H 20 mm
	Material: $Y_1Ba_2Cu_3O_x$ sintered, oxygenated, surface impregnated
	Critical current density (intragrain): 800-1000 A/mm^2
	Critical temperature: ~90 K
	Specific heat: ~0.2 W/g*K
	Heat conductivity: ~6 W/m*K
Primary winding	Diameter of Cu conductor: 0.9 mm
	Inner diameter of winding: 110 mm
	Number of layers: 5
	Thickness of winding: 5 mm
	Number of turns on layer: 95 for LSC-100; 117 for LSC-120
	Height of winding: 90 for LSC-100; 110 for LSC-120
Magnetic circuit	Silicon steel plates: 0.27 thickness
	Epoxy resin mould pressing limb
	Diameter of a limb: 25 mm
	Height of a limb: 130 mm
Cryostat	Sticlostratitex elements
	Joints by hot soldering with adhesive: HY805 resin, TETA reinforcement, cryostat unit powder 80 % and EPOXON activator

Table 1: The parameters of the models

Physical models are presented in photo 1-3.

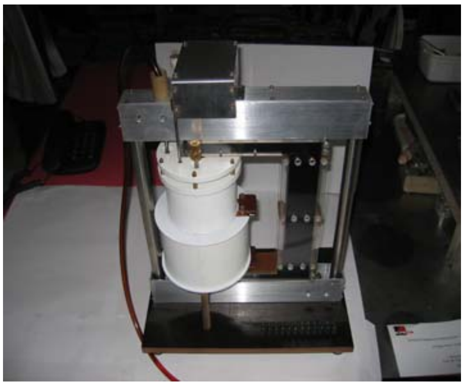

Photo 1

Photo 2

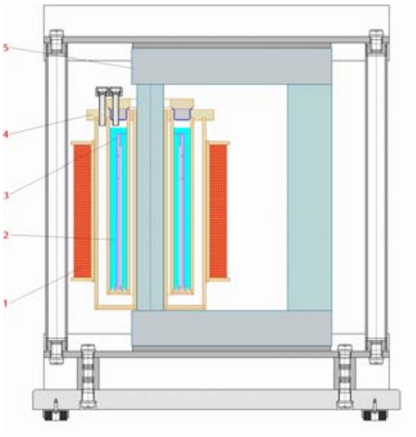

Photo 3

Legend: 1. Primary winding
2. Fluid nitrogen
3. Superconducting screen
4. Magnetic circuit
5. Cryostat

3. CRYOGENIC MAINTENANCE

Superconductivity is regarded widely as low temperature phenomena and as such requires the use of cryogenic technology to achieve 77 K and to maintain 77-87 K YBCO temperature. This is based on the liquid nitrogen injection from Dewar vessel to the cryostat pool. Cooling system include an injection top head coupled with an air compressor, a flexible double pipe for nitrogen transmission and return, sensor for YBCO temperature measurement (PT-100) and security elements for an overpressure.

4. DATA ACQUISITION

The system consists of a PC and an ADC-16-Keithley plate with 18 different inputs for 0-5 V supply voltage. The software for data processing allows a permanent display (in real time) of the LSC current and terminal voltage and the YBCO temperature.

5. PRELIMINARY TEST OF PHYSICAL MODEL LSC-100

Figure 1 shows the experimental system used in the investigation.

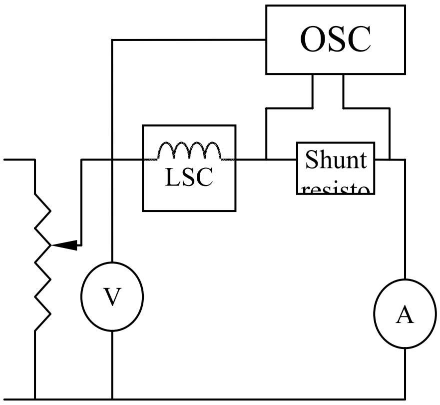

Figure 1: Experimental system

The results are given in table 2.

Data acquisition shows an approximate critical value of ampere-turns θ_c=113 At, which leads to the critical current density $J_c=10^6$ A/m^2. Must be noticed that a V-I characteristic will accurately indicate the critical value of ampere turns and therefore the critical current density.

To distinguish the transition to the resistive state has been realized another simple experiment. A primary Cu winding (50 turns) is coupled via magnetic circuit, with the secondary YBCO ring (54*60*20 mm) and the whole assembly is immersed into a liquid nitrogen pool. Consequently of a good magnetic coupling, the transition is clearly: the primary current is lowered from 5 A to 2 A when the YBCO ring reached 77 K. It results a critical current density $J_c=5\cdot10^6$ A/m^2.

Primary winding: 475 t Normal conductivity tube			Primary winding: 475 t Superconductivity tube		
U	I	Z	U	I	Z
V	A	Ω	V	A	Ω
5	0.024	208	5	0.067	74.63
10	0.05	200	10	0.111	90.1
15	0.071	211	15	0.14	107.4
20	0.097	206	20	0.17	117.65
25	0.126	198	25	0.21	119
30	0.161	186	30	0.24	125
35	0.2	175	35	0.29	120.69
40	0.247	162	-	-	-
45	0.31	145	45	0.38	118.4
50	0.382	131	50	0.45	111.11
60	0.518	116	60	0.58	103.45
-	-	-	65	0.74	87.84
70	1.052	67	70	1.05	66.66
-	-	-	75	1.53	49.02
80	2.042	39	80	2.1	38.1
-	-	-	85	2.61	32.57
90	3.4	26	90	3.46	26.01
100	4.58	22	100	4.45	22.02

Table 2: Results of experiments

6. CONCLUSIONS

The goal of the preliminary test of LSC was to verify the design and the manufacturing technology for the cryostat and the cooling system.

Most validity of conception was the joints of sticlostratitex elements by brazing hot soldering with adhesive crystal unit powder and EPOXON activator. The injection top unit coupled with a compressor also is viable solution for the physical model of LSC.

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