A 25 kA, 0,5 kW THERMALLY SWITCHED SUPERCONDUCTING RECTIFIER
H.H.J. Ten Kate, J. Knoben, H. Steffens, L.J.M. Van de Klundert

To cite this version:

H.H.J. Ten Kate, J. Knoben, H. Steffens, L.J.M. Van de Klundert. A 25 kA, 0,5 kW THERMALLY SWITCHED SUPERCONDUCTING RECTIFIER. Journal de Physique Colloques, 1984, 45 (C1), pp.C1-659-C1-662. <10.1051/jphyscol:19841133>. <jpa-00223604>

HAL Id: jpa-00223604
https://hal.archives-ouvertes.fr/jpa-00223604
Submitted on 1 Jan 1984

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
A 25 kA, 0.5 kW THERMALLY SWITCHED SUPERCONDUCTING RECTIFIER

H.H.J. ten Kate, J. Knoben, H.A. Steffens and L.J.M. van de Klundert

Twente University of Technology, Department of Applied Physics, P.O.B. 217, 7500 AE Enschede, The Netherlands

Résumé - Le succès de l'expérience d'un redresseur supraconducteur à 25 kA est rapporté. Ce redresseur est une composante très importante d'un système électrique et cryogénique complet pour charger des bobines à courants très intenses.

Abstract - The successful test of a 25 kA superconducting rectifier is reported. This rectifier is an important component of a complete cryogenic power system to energise high current superconducting magnets.

INTRODUCTION

The introduction of high currents by current leads to a cryogenic region in order to energise a superconducting magnet causes considerable losses of about 2W/kA /1/. These losses are avoided if the conversion of the electric power to low voltage and high current is moved from roomtemperature to the temperature of liquid helium. The thermally switched superconducting rectifier-fluxpump has the best prospects to be applied as a highly efficient cryogenic power converter to energise s.c. magnets. Since 1979 we study all aspects of fluxpumps /2,3/ and have a research and development program to investigate the feasibility of superconducting rectifiers for several applications. Therefore, a number of four s.c. rectifiers for currents between 50 A and 9 kA have been built and tested /4,5/. The present activities concern a 25 kA, 0.5 kW thermally switched full wave superconducting rectifier, which is a prototype for a future 25 kA, 1.5 kW rectifier system /6/.

THE 25 kA CRYOGENIC POWER SYSTEM

The cryogenic power system (Fig. 1) can be divided into the rectifier itself (transformer M and two switches S₁ and S₂), its power input, a protective system (protection switch S₉ and a dumpresistor R₉) as the intermediate circuit between the rectifier and the load-magnet /8/, and the control and protection electronics. The necessary operation of the protective system has been described elsewhere /9/. The maximum current and the average power that the s.c. rectifier can supply is determined by the frequency of operation (0.05-0.1 Hz), the magnetudes of the inductances

* These investigations in the program of the Foundation for Fundamental Research on Matter (FOM) have been supported (in part) by the Foundation for Technical Research (STW), future technical science branch/division of the Netherlands Organisation for the Advancement of pure research (ZWO).
Fig. 1 - Circuit of a s.c. magnet with its cryogenic power supply consisting of the input, control and protection units, the s.c. rectifier and a protective circuit.

(The fluxpump, load) in the circuit and the amplitude of the primary current. These design data for this rectifier are explained in /6/. With an amplitude of the primary current of 25 A flowing through a primary inductance of 10.5 H with a repetition rate of 0.1 Hz, the rectifier can easily charge a 25 kA magnet with a power of 500 W. The several components of the powersystem have been connected to each other with removable soldered joints in order to allow for future experiments with a more extended rectifier system /7/.

The complete fluxpump and its load-magnet are shown in Figure 2. In this apparatus space has been reserved for two extra rectifiers (two transformers and four switches). The three rectifiers together will have an average power of 1.5 kW or 5.4 MJ/hr at 25 kA.

THE 25 kA RECTIFIER

The circuit formed by the secondary of the transformer and both thermally controlled s.c. rectifier switches S1 and S2 have been tested. As both switches are closed, the maximum current in the secondary circuit has been measured to be 26.4 kA. The secondary current alternates then between zero and its peak value with a current rate of about 15 kA/s and a cycle frequency of 0.1 Hz. The same value was found during a separate test of the shortcircuited transformer /7/. The maximum current is still limited by the conductor in the secondary of the transformer. The d.c. critical current of this 24 strand Cu/NbTi Rutherford cable /7/ is 26 kA at 3T. This value is nearly approximated by the testresult at 0.1 Hz since the peak field at the windings of the transformer is 0.1 T/kA. The maximum current of the 720 strand braided CuNi/NbTi switch-conductor will be about 55 kA at 2T.

THE COMPLETE FLUXPUMP AND LOAD

The s.c. rectifier cannot be connected directly to a load-magnet. The rectifier switches will be damaged when a quench occurs and the coil energy is dumped totally in these rectifier switches. A protective circuit being for example a protection switch and a dump resistor, has to ensure a quick decrease of the current in the open switches and a safe dissipation of the energy in the resistor located outside the helium bath. The thermally activated protection switch has to open very fast by a high heating power. The entire protective system should operate very reliable before the energy content of the load-coil is brought to its maximum. At the moment the protective system for this 25 kA rectifier is studied. For this reason the current in the load coil cannot exceed 10 kA. In spite of this a typical load curve is shown in Fig. 3. The current in the load-coil increases or decreases step by step depending on the phase relation between the state of the rectifier.
switches and the primary current. The current rate or the power of the rectifier can be manipulated by the amplitude of the primary current or the frequency. The first run in Fig. 3 shows an increase of the current in the load magnet ($L_L = 250 \times 10^{-6} \text{ H}$) from zero to 8.2 kA within 80 seconds. The average power is then 105 W at 8.2 kA. The d.c. resistance of the circuit during the persistent mode when the input

---

**Fig. 2 - Photograph of the 25 kA flux pump and its load.**
Fig. 3 - Typical shape of the current $I_L$ in the s.c. magnet. The magnet can be charged and discharged.

is turned off, is measured to be $2.5 \, \text{mQ}$ at $10 \, \text{kA}$. This resistance is caused by the six soldered joints between the high current conductors in the secondary circuit.

FINAL REMARKS

There is evidence that the results mentioned above are preliminary results. The described fluxpump can be brought to full power when the protective system has been approved. Moreover, a lot of details about the experimental behaviour have to be studied in order to present a complete picture of the feasibility of high current superconducting rectifiers. Though, the successful test of the $25 \, \text{kA}$ rectifier inspires confidence in the application of s.c. rectifiers to energise s.c. magnets.

REFERENCES