A.5: Upgraded power supplies for TL-2 dipole magnets and Indus-1 quadrupole magnets

Existing power supplies for dipole magnets in transport line - 2 (TL-2) (300 A, 60 V/ 80 V ± 100 ppm stability, one no. each) and quadrupole magnets in Indus-1 storage ring (300 A, 120 V ± 400 ppm stability, two nos.) are based on 6-pulse controlled rectifier and are being continuously used for over two decades. These are being upgraded with new power supplies with improved performance using a full-bridge zero-voltage-switching (FBZVS) converter.

Magnet power supplies frequently need to be operated from very low to the rated output current. Therefore conventional FBZVS converters are not suitable for this application as they suffer from non-ZVS operation at low output current level. The authors have reported a FBZVS converter with ZVS over entire conversion range in IEEE Trans. Power Electron., vol. 23, no. 4, pp 1743-1750, July 2008 and its earlier version was tested [RRCAT Newsletter, vol. 25, Issue 2, page 11, 2012] as a magnet power supply. The topology, with certain enhancements, has been used to develop the present power supplies.

A simplified circuit diagram of the power converter is shown in Fig.A.5.1. Three phase ac mains is rectified and filtered to get the intermediate dc-link voltage for the dc-dc converter. Switches S_1-S_4, dc blocking capacitor C_{dc}, inductor L_s, transformer T_r, center-tap rectifier D_{r1}, D_{r2} and the output L-C filter constitute the conventional FBZVS converter operating at 25 kHz. An auxiliary inductor L_{aux} connected from the primary center-tap to the mid-point of dc-link splitting capacitors C_1-C_2 forms the auxiliary circuit that maintains ZVS operation over the entire conversion range. The circuit portion shown inside the dashed lines is designed to provide 300 A, 60 V. To increase the output voltage, two such stages are connected in input-parallel (across points A and B) and output series (at the output dc terminals). Components of the preceding stages is adequately rated to facilitate this arrangement.

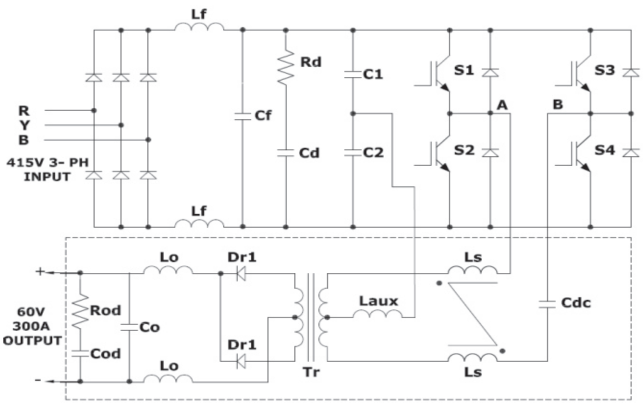

Fig. A.5.1: Circuit diagram of the power converter.

Fig. A.5.2: A photograph of the power supply installed in Indus-1 magnet power supply hall.

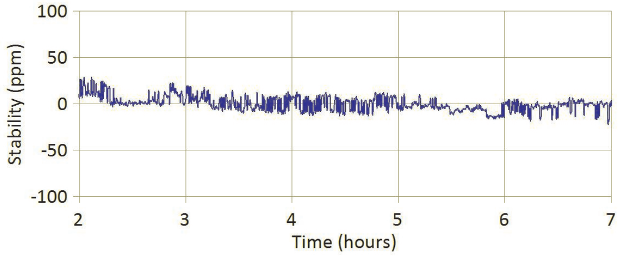

Fig. A.5.3: Output current stability of power supply

Thus, the modules of 300 A, 60 V have been standardized to cater the varied output voltage requirement in these power supplies, thereby reducing the development time, converter types and facilitating easy management of spares. Properly designed component assembly layout and provision of bypass diodes facilitate easy connection or removal of the stages.

The power supply is housed in 0.8 m×1 m×32 U cabinet. An on-board oven is used to maintain temperature of the important electronic components and circuit portion within ± 0.2 °C. The required stability has been achieved with a Zeranin shunt, avoiding the use of (DC current transformer) DCCT. The development of all the power supplies has been completed and one power supply for the main winding of the focusing quadrupole magnets in Indus-1 (PS-4, QF-MW) has been installed, commissioned and is working satisfactorily. Fig.A.5.2 shows a photograph of the power supply installed in Indus-1 magnet power supply hall. A rate limiter circuit for the current set reference and an over-voltage clamp circuit in the feedback loop circuit has been incorporated in the power supply for immunity against large-signal variation in the set values. Fig.A.5.3 shows the stability of the output current measured independently using a 300 A DCCT, which is well within ± 50 ppm. The measured full-load conversion efficiency is about 90%.

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