A.3: 1000 A/10 V power converter for testing of superconducting magnets

A superconducting wavelength shifter, with on-axis peak magnetic field of 5 T, is presently being developed for Indus-2 synchrotron radiation source. The winding of the superconducting coil will be assembled in an iron pole, and the whole assembly will be tested inside a liquid helium (LHe) cryostat to determine the threshold value of the excitation current for which quench is initiated in the coil. The objective is to test the mechanical rigidity of the coil windings. For a good quality winding, the quench current should be very close to the short sample critical current of the superconductor and it is typically higher by 15-20% of the operating current as per the load line. For this activity, a low-voltage high-current magnet power converter with 1000 A/10 V output rating and output current stability of ±500 ppm has been developed at RRCAT. The power converter can also be used, within its specified maximum output ratings, for testing and qualification of other magnetic elements.

The power converter is based on 'interleaved series-input, parallel-output (ISIPO) forward converter' topology. Each of the two high-frequency transformers in the ISIPO forward converter are futher sub-divided into two transformers connected in series-input parallel-output configuration, each followed by independent high-frequency rectifier and inductor. This arrangement results in four 250 A stages operating in naturally-current-shared mode to deliver a total of 1000 A at the output, which in turn greatly facilitates the design and fabrication of high-frequency magnetic components (transformers and inductors) and thermal management by distributing the power losses in the high-frequency rectifier diodes. Semiconductor switches in the forward converter operates at 20 kHz in phase-staggered manner. This configuration, along with the phase-staggered operation results in the small-sized output filter, which also helps in improved transient response. Common output filter capacitor of low value is used for all the stages facilitating low energy storage in the output. A precision shunt, mounted with force-air-cooled arrangement, is used for sensing the output current. Mechanical assembly has been planned to facilitate the testing as well as its maintenance.

The challenges invloved include selection and design of a low-voltage high-current switch-mode power converter topology with distributed thermal management to take care of losses due to high output current, besides satisfying the functional and performance requirements. Customized water-cooled heat-sinks are designed for power semiconductors and high-frequency transformers for thermal management of power losses. The power converter has been tested to the rated specifications. Figure A.3.1 show photographs of the developed power converter. Figure A.3.2 shows experimental waveforms demonstrating phase-staggered operation and frequency doubling at the output. In Figure A.3.2, y-axis for Ch-1(yellow) and Ch-3 (pink) shows waveform of rectified voltage of two stages with scale of 50 V/div while y-axis for Ch-2 (blue) shows output voltage with scale of 5 V/div. The x-axis has the scale of 25 µs/div. The power conversion efficiency of nearly 86% has been measured, as shown in Figure A.3.3, along with input power factor of 0.95 at full load.

(a) (b)

Fig. A.3.1: Photographs of developed power converter: (a) front view and (b) rear view.

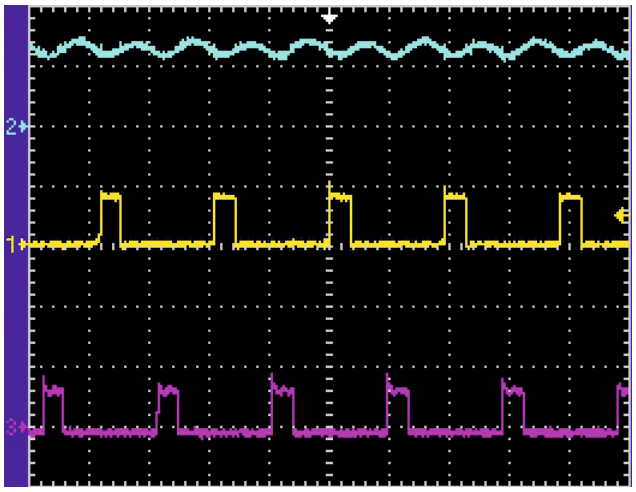

Fig. A.3.2: Ch-1 (yellow)and Ch-3 (pink): rectified voltage waveforms of two stages; Ch-2 (blue): output voltage.

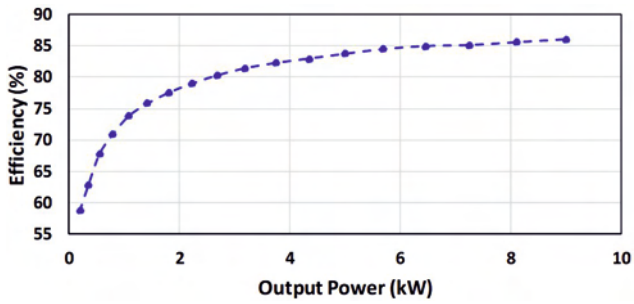

Fig. A.3.3: Measured efficiency of power converter.

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