

§14. Feasibility Study on Series Compensated Thyristor Converters for Superconducting Magnets

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Thyristor converters are used as power conditioning systems for superconducting magnets. However, thyristor converters control the magnet voltage with a lagging power factor on the ac side, and require reactive power compensation. The objective of this work is to discuss the series compensation of thyristor converters using variable series capacitors and minimize the reactive power compensation need. The series capacitor can control the magnet voltage through a unity power factor thyristor converter with a resulting leading power factor seen from the grid. Therefore, as shown in Fig. 1, combined with the conventional thyristor converter, this system enables both leading and lagging reactive power control, and also the active power control of the superconducting magnets¹⁾. This feature leads to a potential reduction in reactive power compensation need of 50 percent of the conventional thyristor converter system. The required capacitance C with a leading phase angle δ is calculated by

$$C = \frac{3\sqrt{2}I_d}{\pi\omega V \sin \delta}, \quad (1)$$

where I_d and V are direct current and line voltage, respectively.

As a first step of this work, leading power factor control of a three phase diode rectifier was examined in order to investigate the concept of series compensated thyristor converters. In the experiments, 136 mH of reactors and 0~300 Ω of variable resistors were connected in series as a direct current load. The line voltage and the direct current was selected to 100 V and 2 A, respectively. Fig. 2-(a) shows the detailed experimental waveforms when a passive series capacitor was connected to the ac side of the diode rectifier²⁾. The capacitance of the series capacitor is 120 μ F. In this case, 44.6 V of the capacitor voltage with a trapezoidal waveform is

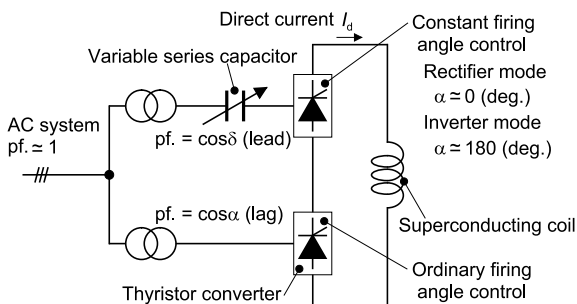


Fig. 1: Series compensation of thyristor converters with a variable series capacitor.

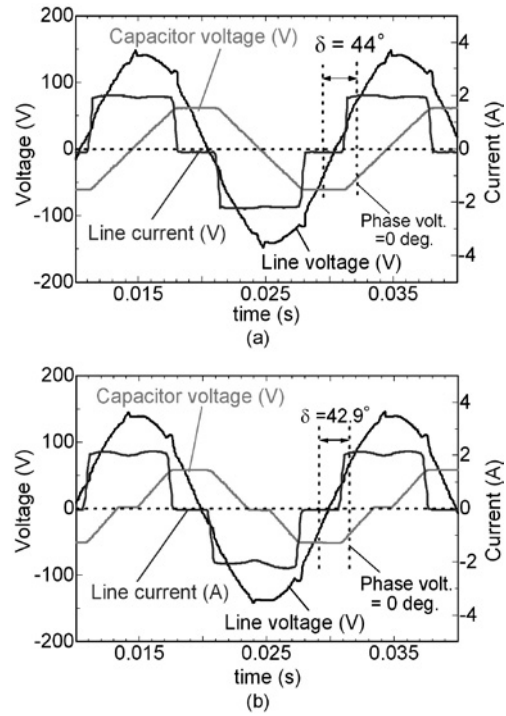


Fig. 2: Leading power factor control of the three phase diode bridge using passive series capacitors (a) and a gate-commutated series capacitor (GCSC) (b).

applied between the ac source and the diode bridge. By this effect, the line current is operating with 44 degree of the leading phase angle. On the other hand, Fig. 2-(b) shows the leading power factor control using a gate-commutated series capacitor (GCSC)³⁾. The GCSC is one of the variable series capacitor configuration using power electronics devices. The variable capacitor voltage with a discontinuous trapezoidal waveform is 41.3 V. By the effect of the GCSC voltage, the line current is operating with 42.9 degree of the leading phase angle. These experimental results could confirm the leading current control capability of there phase diode rectifier by selecting an optimal series capacitance. In this work, the direct voltage and the active power control capabilities using variable series capacitors were also verified.

- 1) S. Nomura, J. A. Wiik, R. Shimada, "Series compensation of thyristor converters for superconducting magnets", in Proc. The 2010 International Power Electronics Conference, (2010) pp.1534-1540.
- 2) K. Nishihara, S. Nomura, "Leading power factor control of three-phase diode rectifiers using series capacitors", The 2012 annual meeting of IEEJ, 4-064 (in Japanese).
- 3) I. Matsumoto, S. Nomura, "Leading power factor control of three-phase bridge diode converters using gate-commutated series capacitor", The 2012 annual meeting of IEEJ, 4-065 (in Japanese).