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

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Thyristor converters are very promising as a large current power conditioning system for superconducting magnets. Using variable series capacitors such as a gate-commuted series capacitor (GCSC), the thyristor converters can control the DC voltage of the superconducting magnets with a resulting leading power factor seen from the grid. Combined with a pure traditional thyristor converter, the combined converter can control both the power factor and the DC voltage.

In this work, using a series compensated diode rectifier and a pure thyristor converter, the author demonstrated the active and reactive power control capability of the combined converter system including the circulating current control mode (back-to-back). Figs. 1 and 2 show an experiment circuit and a photograph of the combined converter system, respectively.

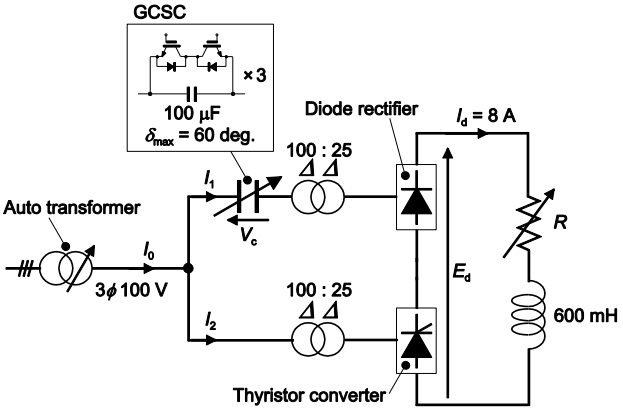

Fig. 1. Experimental circuit of the combined converter system using variable series capacitors.

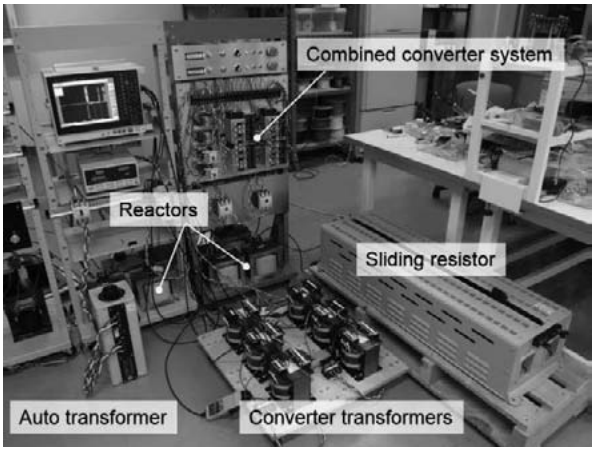

Fig. 2. Photograph of the experimental converter system.

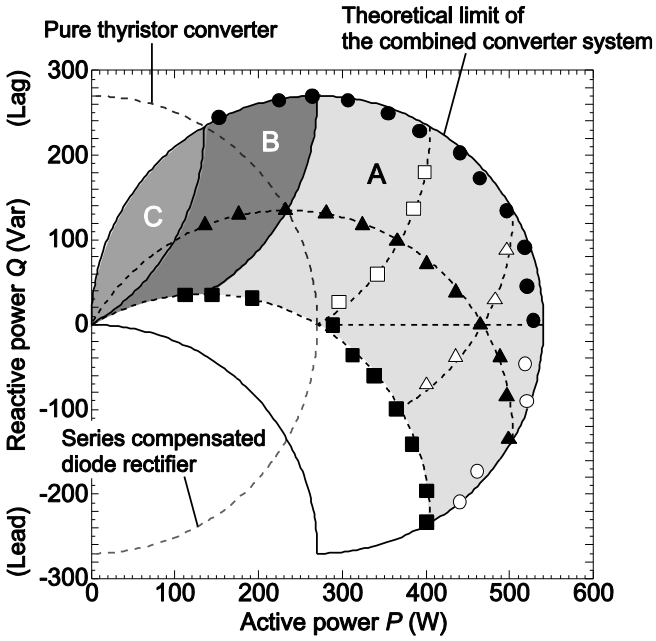

Fig. 3. Active and reactive power control capability of the combined converter system.

Using the firing angle α of the pure thyristor converter and the current leading angle δ of the series compensated diode rectifier, the active power P and the reactive power Q are expressed as

$$P = \left(3\sqrt{2}/\pi\right)VI_{\mathrm{d}}(\cos\alpha + \cos\delta), \quad (1)$$

$$Q = \left(3\sqrt{2}/\pi\right)VI_{\mathrm{d}}(\sin\alpha - \sin\delta), \quad (2)$$

note that the leading reactive power is defined as negative value. V and I_{d} are the line voltage and the DC current, respectively.

Fig. 3 shows the active and reactive power control capability of the combined converter system using variable series capacitors. The dots indicate the experimental results. The solid lines show the theoretical limits of the operation area of the experimental combined converter system. Since the series capacitor of the GCSC is designed that the maximum current leading angle becomes 60 degrees, the ideal operation area of the converter system is expressed as the darker hatches A, B and C. Although the areas B and C show the circulating current control mode, the commutation errors of the thyristor converter occurred in the area C.

From the results in Fig. 3, using variable series capacitors, the combined converter system enables the unity power factor control, and can also control both the lagging and leading reactive power. Even when the diode rectifier is operated with a leading power factor by the effect of the series compensation, the circulating current operation is achieved and the combined converter system can control both active and reactive power.

The papers of the research outcomes:
1) Nomura, S. et al.: EPE'13 ECCE Europe (2013) 729.
2) Saito, D. et al.: EPE'13 ECCE Europe (2013) 753.
3) Matsumoto, I. et al.: EPE'13 ECCE Europe (2013) 805.