

HIGH-POWER SWITCH WITH SI-THYRISTORS FOR THE POWER SUPPLY OF THE KEKB INJECTION KICKER MAGNET

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Abstract

A solid-state switch with SI-thyristors is implemented as the high power switch for the KEKB injection kicker magnet power supply. [1] One of the thyratrons is replaced to the SI-thyristor. The switch has been successfully operated at 20kV voltage, 1.3kA peak current and 2 μ sec pulse width under 50 Hz repetition rate. It has been used for the KEKB operation since the last summer without any problems.

1 INTRODUCTION

As the next stage of the B-factory experiment, a luminosity upgrade of the KEKB collider [2] is considered. The B-factory operating at a luminosity of 10^{35} /cm/s (Super KEKB) is the kind of the mixture of storage ring and the linear collider. [3] Because of short lifetime of the stored beam, the continuous injection during the experiment might be necessary, or at least frequent beam injection is inevitable. In this sense, the accelerator is close to the linear collider.

In the Super KEKB or the linear collider, their kicker may have to be fired all the time and the kicker magnets are pulsed order of 10^9 /year. Under these situations, the use of the solid-state switch in the pulsed magnet must be considered seriously. Recently R&D using SI-thyristor started in the accelerator field, such as high power switch for klystron pulse modulators [4], the energy discharger switch for the pulsed magnets. [5] We started to use SI-thyristors under the normal operation of working accelerator and to see if the solid-state switch works stably.

2 KEKB INJECTION KICKER MAGNET

The KEKB, an asymmetric electron-positron collider consists of a 3.5 GeV positron storage ring (LER) and an 8.0 GeV electron storage ring (HER). [6] The KEKB injection kickers have to meet many requirements under KEKB operation. 6 kicker magnets are implemented in each ring. Three kicker magnets are incorporated into one group and are equipped at the upper and lower stream of the injection point respectively. The betatron phase advanced between two groups of magnets is 180 degree. As shown in Figure 1, the current shape of kicker magnet is half sin with 2 μ sec pulse width. The pulsers operate at repetition rate of between 1 and 50 Hz as dictated by the operational mode of KEKB. The KEKB beam repetition

rate varies dynamically to protect Belle detector and certain components from damage by the beam.

Table 1: Parameters of the kicker magnet

Number of kicker magnets	6
Ferrite core length (mm)	225
Ferrite core gap (mm)	90
Length of ceramic	420
Ti coating thickness (μ m)	6
Peak magnetic field (Gauss)	500
Peak current (A)	2000
Peak voltage (kV)	35
Time jitter (nsec)	2-3
Repetition rate (Hz)	50
Rise time (μ sec)	1
Fall time (μ sec)	1
Current shape	Half sine
Peak current stability (%)	< 0.1
Pulse shape distortion (%) - Kicker dependence	< 1.5
Pulse shape distortion (%) - Pulse height dependence	< 1.5

The KEKB injection kicker magnet is the conventional window-frame ferrite core kicker magnet. The ceramic vacuum chambers are inserted between the ferrite and beam, with a thin Ti-Mn conducting layer deposited on the inner wall of ceramic. [7] Dimension of the kicker magnet is written on Table 1. The maximum voltage and current levels are 35kV and 2000A with the magnetic field level 500 gauss. This parameter was chosen for the stable operation of the thyratrons in the air. The number of kicker magnets is determined by this condition. The deuterium filled ceramic thyratrons is chosen as the energy discharge switch. The power supplies are composed of three parts. The main part of the power supply, control part and a dc-charging power supply, is implemented in the klystron gallery where is accessible during an accelerator operation. The thyratrons housing are placed at the sub-tunnel where is approximately 40 m from the main part of the power supply and 7m from kicker magnet. And matching impedance is placed under the kicker magnets to adjust the output current pulse shape. The radiation at the matching box and the thyratrons unit are measured with an alanine dosimeter. In

the high-energy ring injection area, dose rate is between 40 and 220 Gy/hour and around 40 Gy/hour in LER. [8] The diffraction angle at usual operation is 0.7-1.1mrad in HER and 1-1.5mrad in LER respectively. The thyristors are operated 16-20kV in HER and 10-16kV in LER, which is the half of the maximum allowed voltage.

3 SI THYRISTOR

Static Induction Thyristor (SI-thyristor) was invented by Dr. Nishizawa in 1975. SI-thyristor has superior characteristics for high voltage and high current applications.

- (1) A low "ON state voltage drop" characteristics.
- (2) The high speed switching and low loss characteristic.
- (3) The high blocking voltage.
- (4) High current rise rate.
- (5) High current characteristics.

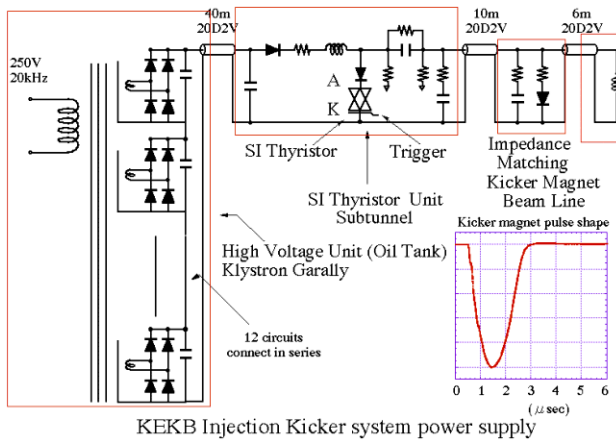


Figure 1: The schematic drawing of the modified kicker system.

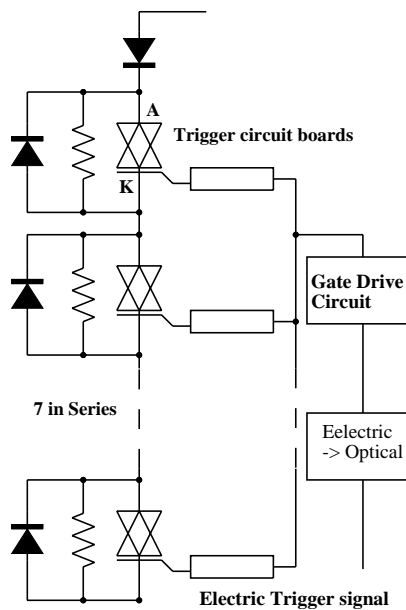


Figure 2: The simplified circuit diagram of the stacked SI-thyristor switches.

For the replacement of a thyatron in our kicker power supply, the reverse conducting static induction thyristor RS1600PA40T1 (NGK Insulators. Ltd) is chosen. Repetitive peak off-state voltage is 4kV. Maximum rating of R.M.S. on-state current is 600A. Peak off current is typically 20mA. Peak forward voltage drop is 2V at 600A. [11]

4 SI-THYRISTOR IN THE KICKER MAGNET POWER SUPPLY

The switch has been assembled for the KEKB LER kicker magnet power supply. Seven SI-thyristors are stacked in series.

Figure 1 is the schematic drawing of the modified kicker system. We replaced a thyatron to a SI-thyristor switch and modified trigger circuit to suit for the new switching device at the SI-thyristor unit.

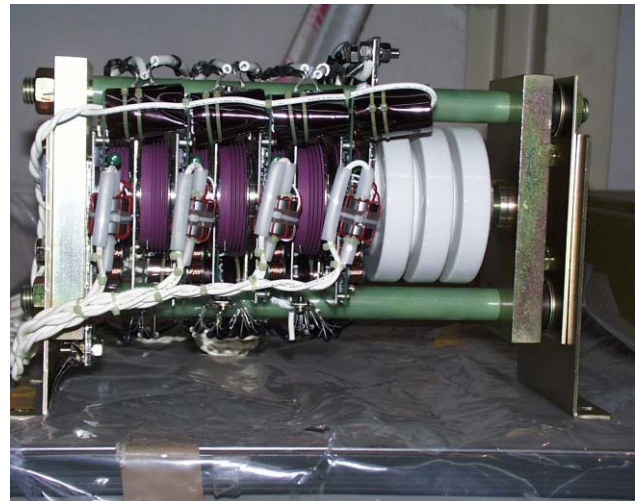


Figure 3: 7 series of stacked SI-thyristors.

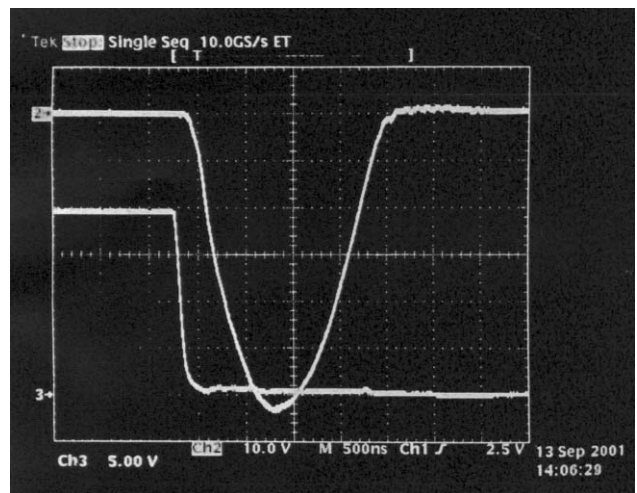


Figure 4: Anode voltage (7 series) and the output current. 500nsec/div, 5kV/div (Anode Voltage), 200A/div (output current)

Figure 2 shows the simplified circuit diagram of the stacked SI-thyristor switch. Several diodes are connected

in parallel to protect from emergent large reflected current. The trigger signal is sent to SI-thyristor unit in electric signal. Then the trigger signal is converted into the optical signal and sent to the gate driver. The gate driver distributes the trigger signal to the gate of 7 SI-thyristors.

Figure 3 is the picture of 7 series SI-thyristor stack. The diameter of SI-thyristor is 92mm ϕ and thickness is 26mm.

Figure 4 shows output current and the voltage difference between anode-cathode (Va-k) of SI-thyristor. Switching time is about 100nsec.

The time jitter and the longer term effect of time drift of switching device have to be careful for the kicker operation. Time jitter of Va-k falling time against the output of SI gate driver is measured. Figure 5 shows time jitter of Va-k. It is less than 5n sec. And no long term time drift is observed.

Required rise rate of on-state current (dI/dt) is about 2kA/ μ sec in our application. The critical rate of rise of on-state current of this SI-thyristor is 150kA/ μ sec. Since that value is much bigger than our requirement, there is no difference in the output pulse shape between SI-thyristor and thyratrons circuit.

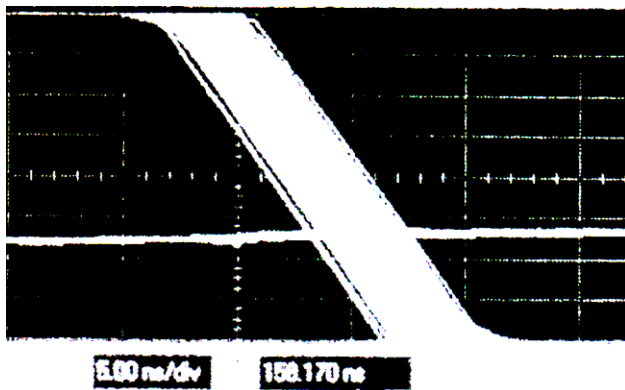


Figure 5: Time jitter of Va-k falling time against the output of SI gate driver is measured.

5 SUMMARY

One of the power supplies of the KEKB injection kicker magnet is modified to use the solid-state switch instead of thyratrons tube. The system was designed to have 20kV hold-off voltage, 1.3kA peak current with 2 μ sec pulse width in the 50 Hz repetition rate. A 20 kV solid-state switch consists of 7 SI-thyristors stacked in series. It has been used on the actual KEKB operation. SI-thyristor can be used for pulsed magnet discharger. We started to use this SI-thyristor switch in the last September. Normally LER kicker magnet is pulsed about 3 hours a day and applied voltage is about 10kV. So far we do not have any troubles, so that we conclude that SI-thyristor is usable for the conventional window-frame ferrite core kicker magnet.

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