HIGH-POWER SWITCH WITH SI-THYRISTOR FOR THE POWER SUPPLY OF VERY HIGH REPLETION RATE PULSED QUADRUPOLE MAGNET *

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Abstract

A solid-state switch with Static Induction Thyristor (SIThy) is tested as high-power and high-repetition switch for KEKB pulsed magnet power supply. The pulsed quadrupole magnet installed in KEKB [1] positron ring uses the 24 FETs as the switching devices. We replaced these FETs to SIThy for the test. The result of 100kHz switching with SIThy is presented.

INTRODUCTION

Static Induction Thyristor (SIThy) is used for many applications in the accelerator field, such as high power switch of RF modulator [2], the energy discharger switch for pulsed magnet [3][4] and for induction synchrotron [5]. In KEKB, SIThy had been used in the Low Energy Ring (LER). One of the thyratron used in the power supply of the injection kicker magnet was replaced to SIThys, and successfully operated. [3]

SIThy can treat relatively large current and high voltage operation. In this paper, the result of smaller packaged SIThy application is presented.

KEKB PULSED QUADRUPOLE MAGNET

The photoelectron generated in the KEKB positron ring gives the focusing force to the positron beam. For the abort kicker setup time, “500 nsec beam abort gap”, where no beam can be filled is reserved [7] Just after the abort gap, the density of electron cloud is lower, therefore the focusing force is weaker and betatron tune becomes lower at the head of train. In order to cancel this tune shift, the pulsed quadrupole magnet was designed and constructed. [8] The pulsed quadrupole magnet gives focusing force to the beam during the first 700nsec of train head out of 10μsec revolution period.

Table 1 : Parameters of Pulsed Magnet

The field gradient (T/m)	0.075
Ferrite core length (mm)	250
Coil inductance (μH)	5-6
Peak current (A)	100
Output current waveform	Half Sinusoid
Pulse width (μsec)	1.5
Repetition Rate (kHz)	100

The pulsed quadrupole magnet is the conventional ferrite core magnet. The ceramic vacuum chamber is inserted with a thin Ti conducting layer coated on the inner wall of ceramic [6]. Dimension of the pulsed magnet and its characteristics are given in Table 1. The repetition rate of 100kHz with 1.5 μsec of half sinusoid pulse has been achieved. The maximum peak current is 100A with the field gradient 0.075 T/m. Figure 2 shows the schematic circuit diagram of the pulsed quadrupole magnet power supply. The power supply is composed from three parts. The dc-charging power supply and control interface are implemented in the klystron gallery, where we can access during accelerator operation.

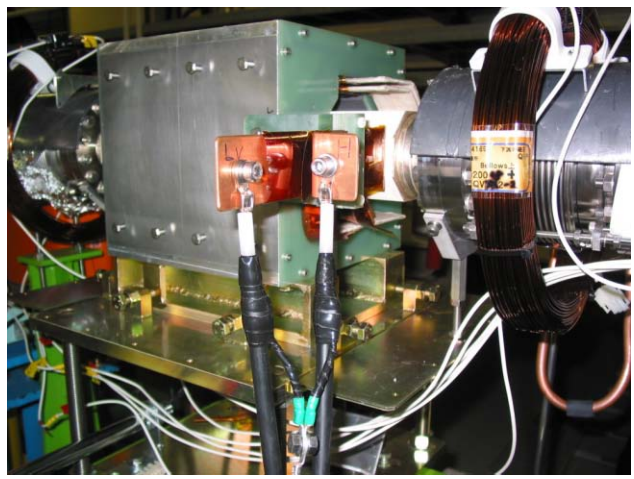

Figure 1 : The pulsed quadrupole magnet in the KEKB positron ring.

The main capacitor and switching device are placed in the sub-tunnel, which are 40m from dc-charger and 7m from the quadrupole magnet. The matching impedance is placed under the magnet to adjust the output current waveform. It prevents from having an undershoot in the sinusoid wave. The pulsed magnet changes the vertical tune of 0.005 and horizontal tune of 0.001.

Table 2 : Characteristics of SIThy

Non-Repetitive peak Off state Voltage	<3600V
Repetitive Peak Off state Voltage	<3600V
On state current: (R.M.S)	<30A
Peak one cycle surge On state current	<300A
Controllable On state current	<70A
Forward Peak gate current	80A
Turn On time	0.7μsec
Turn Off time	1.0μsec
Repetitive Peak Off state current	10mA
Peak On state voltage	8V

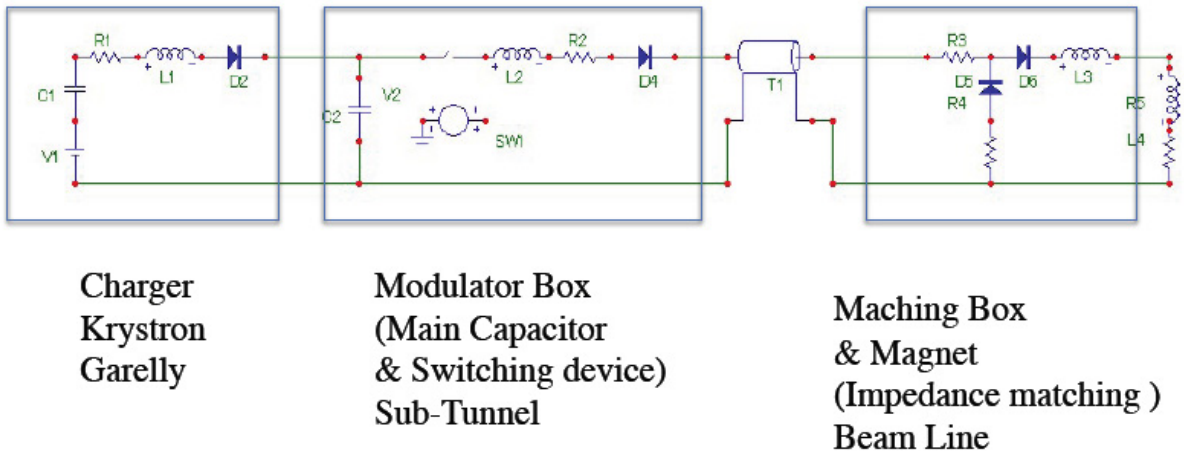

Figure 2 : The schematic circuit diagram of the pulsed quadrupole magnet power supply.

SITHY

Static Induction Thyristor (SIThy) was invented by Dr. Nishizawa in 1975. SIThy has superior characteristics for high voltage and high current application. (1) A low "ON" state voltage drop (2) high speed switching and low loss characteristic (3) the high blocking voltage (4) high current rise rate [9]. Table 2 shows the characteristics of the SIThy used in the pulsed quadrupole magnet power supply. For the replacement of FET switch, small size SIThy N403-1 is used.

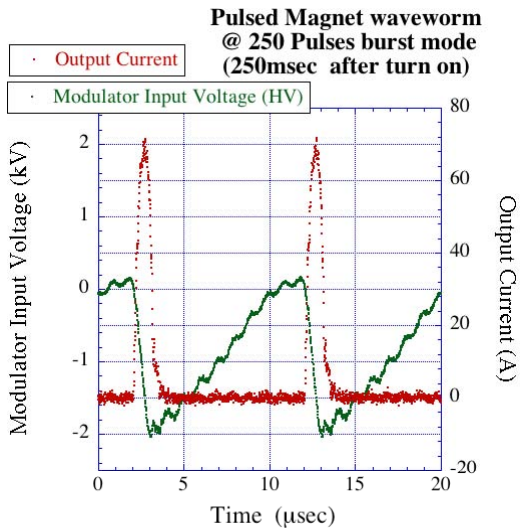

Figure 3 : The output current and supply voltage waveform.

SITHY IN THE PULSED PUADRUPOLE MAGNET POWER SUPPLY

In the LER pulsed magnet power supply, 24 FET's, 3 parallels and 8 series, are used as switching devices to drive the 100 A 1.5μsec pulse in 100kHz. In order to get the stronger magnetic field, we have to increase the current, therefore have to increase the number of FETs. To increase the current twice, the number of FET have to be increased 4 times as many as current system. It is very important to use the switching device that can treat bigger current and higher voltage, to keep the reasonable number of switching devices and keep the reasonable reliability of the whole system.

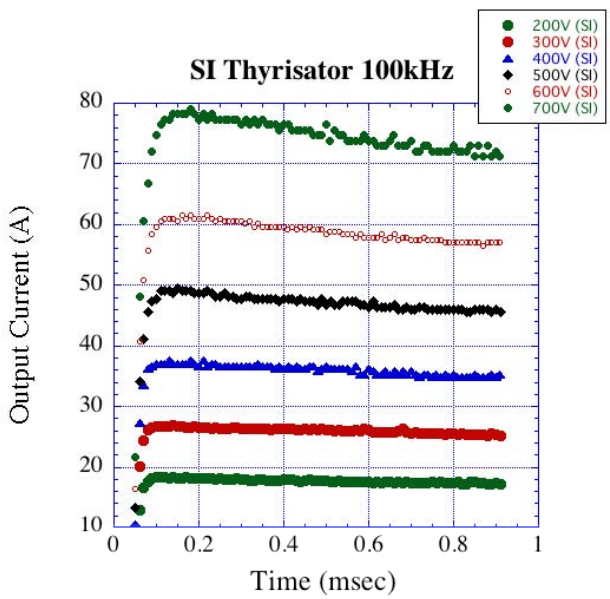

Figure 4 : The pulse height of the output current. SIThy circuit is operated in 100kHz.

Since SIThy can operate at high voltage of 3kV and large current of 70A, it is possible to reduce the number of switching device and its incidental facilities.

SIThy was tested as a candidate of new switching device. The characteristics were compared to that of FET's. The same magnet, dc-charger and matching impedance were used. Only the modulator box, which contains switching FETs and a main capacitor, are replaced for the test of this device. The 4 SIThys, 2 parallels 2 series, are used as the switching device.

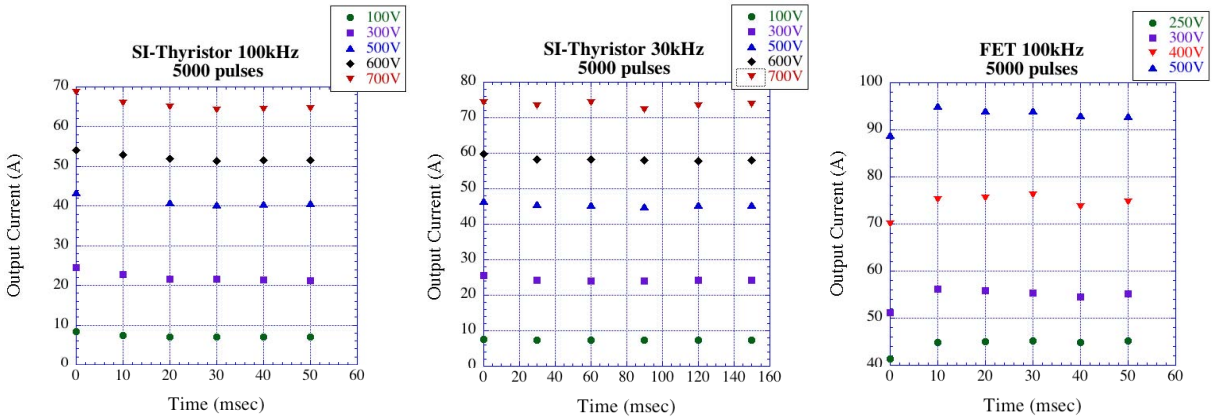

Figure 5 : The pulse height of output current as function of the time of SIThy and FET switch under 100kHz and 30kHz operation

First, the SIThy was tested in the burst mode. Figure 3 shows the waveform of the output current and the supply voltage at the input of modulator box. Around 80A operation, the output current decreases slightly within the first 1msec. (Figure 4)

To see the behaviour of the switching device for longer period, 5000 pulses burst mode operation has been done under the repetition rate of 100kHz and 30kHz.

In the 100kHz operation output current drop slightly at the first a few hundred pulses. After that period, the output current becomes stable. In the 30 kHz operations, this drop was not seen even 70A operation. Continuous pulsing has successfully been done up to 35 A in 100kHz and 45 A in 30kHz.

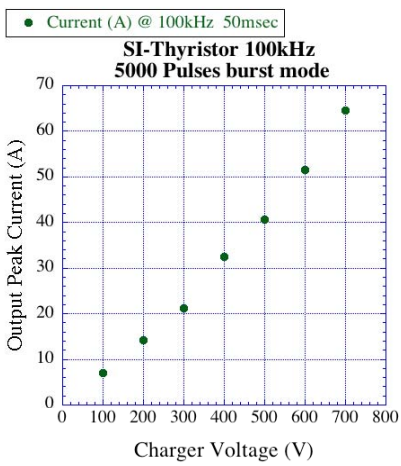

Figure 6 : Supply voltage and output current of the pulsed quadrupole magnet.

SUMMARY

The new switching device are tested with KEKB LER pulsed magnet system. The 4 SIThys were used as switching device. The SIThy can drive 70 A in the 100 kHz and 75A in 30 kHz 5000 pulse burst mode. In the continuous mode, the switching devices were tested up to 100 kHz 35A and 30kHz 45A. SIThy is a strong candidate of the high-power and high-repetition switch.

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