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IMPLEMENTATION OF USING IGBT SWITCH BASED PULSER FOR TPS BOOSTER EXTRACTION KICKER

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Abstract

A pair of thyratron-switch based pulse-forming-network (PFN) pulser has been operating successfully in the past 5 years for Taiwan Photon Source (TPS) booster extraction kickers. In order to improve the flattop of drive-current pulse and to extend possible electron bunch train adjusting knob required, an IGBT-switch based pulser has been designed, fabricated, and installed onto the TPS booster for its characteristics verification. In this report, the overall technical considerations for the pulser upgrade is described and its beam commissioning results is given for illustrative purpose.

INTRODUCTION

The Taiwan Photon Source (TPS) has been serving user at top-up mode operation in the past 5 years. A routine operation pattern is developed in terms of injection bunch train control regarding bucket address assignment for the sequential arranged injection cycles. Presently, the top-up injection stored electron beam between 450-405 mA and the injection cycle takes place in every 4 minutes. The bunch train filling pattern is developed empirically and is a compromising result among machine status, beam stability, lifetime, and user demand as well. In 2018, a previously compromised thyratron switch PFN pulser for booster injection was upgraded to an IGBT switched pulser [1, 2]. The injection bunch train from the linac was able to extend from 0.2 micro-second to 1 micro-second. Yet, the booster extraction kicker pulser did not replace to similar upgraded version due to proper IGBT module was not available at that time. Consequently the booster extraction bunch train does not make the best use of the long bunch train that the injection kicker pulser can provide. In this report, we summarize the test result of a newly built IGBT pulser which overcomes the technical challenge of using two IGBT module in parallel to improve the pulser performance.

LAYOUT OF THE PULSED INJECTION ELEMENTS AT THE TPS

The location of all TPS pulser is displayed in Fig. 1. There are two pulser units of the booster extraction kickers. The booster injection kicker pulser was upgraded using an IGBT switch in 2018. This report provides the latest beam test result of the booster extraction kicker IGBT switch pulsers. Due to the recent profound progress of the solid-state components, an evaluation of migrating the storage ring thyratron based half_sine pulser toward a quasi-solid-state pulser is under studying.

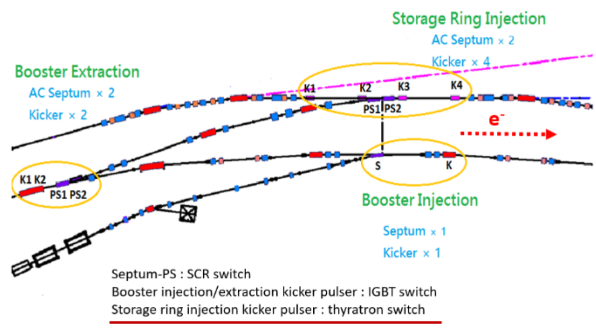

Figure 1: The layout and location of all pulsed power supplies for TPS.

THE BOOSTER EXTRACTION KICKER PULSER

One of the major technical challenges encountered is that a fast rise-time requirement of the kicker pulse. It requires to execute booster beam extraction while making use of the "fall-time gap" at the bunch train given by the injection kicker characteristics. Figure 2 shows the drive current signal of the past thyratron based pulsers. The fast switch-on feature of the thyratron is certainly fulfill the rise time required for booster beam extraction character. Yet the flatness requirement better than +/- 1% of the drive current pulse is usually a circuitry challenge. In addition, its routinely operating under high voltage (HV) environment of 25 kV increase the maintenance checkup loading.

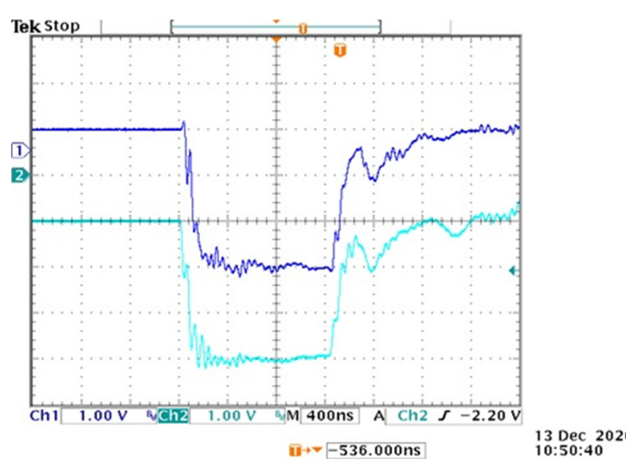

Figure 2: The thyratron switch PFN dirve current pulses.

While surveying the available IGBT modules, no suitable units are found to meet all the general requirements as the extraction kicker pulser. However, one could manage to combine two units and optimizing the

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performance as a whole. This conceptual layout of the circuitry is given in Fig. 3.

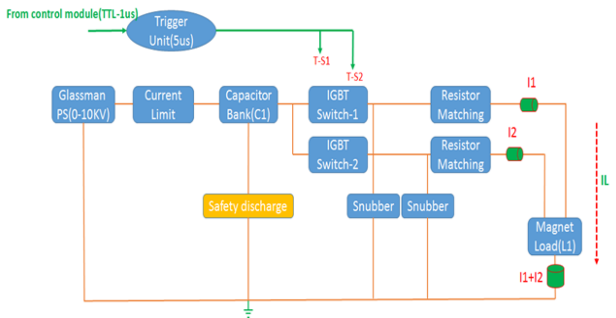

Figure 3: The circuitry layout of the IGBT pulser.

The Two selected IGBT modules are connected in parallel for the needs. They drain the stored charge from the same capacitor bank while receiving the trigger signal from the extraction sequential control. Technical considerations are taken and deal with in the above circuitry arrangement. For examples:

The capacitor should be adequate enough so that draining from two IGBT switches will not affect the flatness of the drive current. However, selecting high capacity implies that precautious of safety is considered to provide safety discharge of the units.

During the process of switching on/off, the observed electrical noise is frequently large enough to damage the switching unit itself. Therefore, a noise damping snubber is developed to overcome the tough handling feature.

As shown in the figure, applying a matching resistor is needed of adequate tuning of the drive current rise-time.

Figure 4 shows the photo of pulser assembling. The drive current pulse shape of the IGBT unit is displayed in Fig. 5. The flatness of the drive current is remarkably improved to better than 0.1%. After satisfy required specification and long-term testing criterion, two units of the IGBT pulser are fabricated along with the spare units. They are tested with the same technical standards and endurance examination as well.

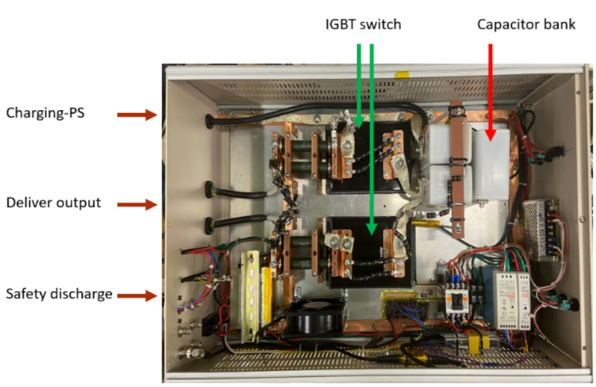

Figure 4: The detailed layout of the IGBT pulser.

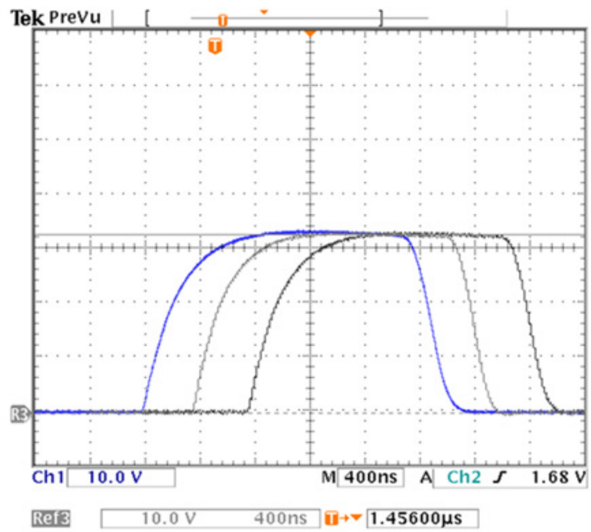

Figure 5: The drive current pulse shape of the IGBT pulser.

Using IGBT module for switching on/off in this respect also benefit the spatial occupation reduction as a whole. As shown in Fig. 6, the thyratron switch unit occupies 2 units of 19 inches rack with 2 m height, one rack for 120 m PFN cable winding and the other one for thyratron tube assembling. Yet, for the IGBT switch unit, only a 19 inches box with 20 cm height is used. There are two sets of extraction kicker pulser driving two independent extraction kicker magnet. Altogether, there are 4 units of 19 inches rack of 2 m height occupying the storage ring tunnel at the straight section removed. Also, removing the racks can prepare the possible use of the straight section for future insertion devices installation as well.

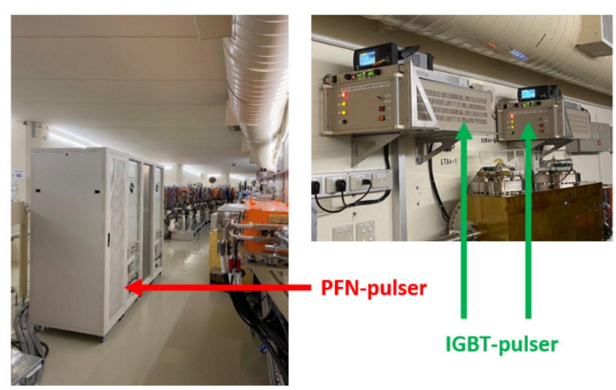

Figure 6: Comparison of the spatial occupation of the PFN pulser and the IGBT pulser.

COMMISSIONING WITH ELECTRON BEAM

The booster extraction kicker IGBT pulsers were installed to replace the PFN thyratron pulser in February during a scheduled long shutdown of the TPS. The pulser commissioned with beam were put to work immediately after the TPS starting up. Figure 7 shows the beam position

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monitor (BPM) signals of the electron bunch train observed at the booster injection and extraction moments together with the associated IGBT kicker pulses. the length of the bunch train is extendable, with tuning knob, up to 1 micro-second as expected.

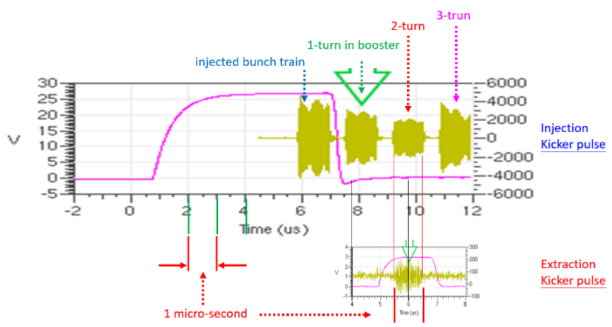

Figure 7: The booser BPM signals for both injected bunch train and the extraction bunch train together with the associated IGBT injection/extraction pulsers.

SUMMARY

We summarize the technical development and test result of a pulsed power supply for TPS booster extraction kicker using IGBT switch. The benefit for storage ring routine operation by installing this test unit is briefly outlined. Specific technical challenges is resolving systematically with satisfactory outcome. The pulser performance demonstrated in the IGBT pulser shows that it fits properly to the requirement of providing an optimized bunch-train tuning knob. The performance feature, in combination of using IGBT injection and extraction kicker pulsers, also provides the best tuning capability of arranging single bunch (SB) and multi-bunch (MB) filling pattern in hybrid mode operation.

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