THE UPGRADING OF THE TLS INJECTOR BUMPER AND SEPTUM POWER SUPPLIES FOR TOP-UP OPERATION

C.S. Fann*, K.B. Liu, S.Y. Hsu, K.T. Hsu, Y.C. Liu, J.Y. Hwang, K.K. Lin
NSRRC, Hsin-Chu, Taiwan

Abstract

Due to the inevitable requirement of routine top-up mode operation at TLS (Taiwan Light Source), the reliability of all components in TLS injector has been re-evaluated in the past several months. Among all possible subsystems to be reinforced, the bumper and septum power supplies revealed urgent need to be upgraded while being operated continuously in the user shifts. In this report, the modification of the charging mechanism of the pulsed power supplies is described. The modular feature of the newly-built units provides fast replacement capability in case of components failure. The unified specifications for all components have greatly reduced the effort in preparing spare parts. The test results of these units are presented in this report.

INTRODUCTION

The TLS injector was commissioned in 1993 operated at 1.3 GeV [1]. Later, it was upgraded to 1.5 GeV in 2000 in order to perform full energy injection into the storage ring. In this upgrade project, the major changes in system components are listed as follow.

- magnet power supplies of dipole and quadrupoles
- dipole and quadrupole transformers in the associated White-circuits [2]
- extraction septum and kicker magnets [3]
- a new set of control system [4]

The evaluation of extraction bumpers and septum power supplies (PS) indicated that they were usable owing to the available safety margin of the original design. Therefore, these units kept fulfilling their function needs for both at 1.3 GeV and 1.5 GeV.

The overall performance of these extraction units was quite satisfactory in the past years except that the power supplies tripped occasionally in about once a week. It indicated that malfunction of the charging power supplies was the major cause. When it occurred, the refilling process was postponed for about 15 minutes for system restoring; either hardwires or control interface resetting.

This interruption of refilling was not a matter of concern because the TLS users noticed only an insignificant delay within the grace period of refilling process, which took place every 8 hours with an average of 2 minutes duration in the decay mode operation.

Yet, the situation was not the same while the TLS was operated in top-up mode started in October, 2005. The top-up operation kept 300 mA at storage ring. The beam current refilling was performed every 1 minute with 2 seconds duration. The estimated duty cycle of the injector pulsed power supplies was increased for a factor of 10. The occurrence of power supply trip became about every other day. Whenever the bumper power supply trip occurred, the previously mentioned 15 minutes restoring time would terminate the top-up process leading to a 5 mA beam current dip in the storage ring. This was quite significant in comparison with a constant beam current of 300 mA with variation of ±1 mA in the top-up operation. Moreover, the corresponding photon intensity change of this amount of 2% in the beamline was not acceptable in terms of spectrum normalization for most of the users. Consequently, this power supply trip should be dealt with in order not to interrupt a smooth top-up operation.

The construction of the newly-built extraction bumper and septum power supplies was completed last October. They were installed into the booster during the maintenance shutdown period in last December. These units have been well tested and equipped with large operation margins. The test results of these units are summarized and presented in this report.

MODIFICATIONS OF POWER SUPPLY UNITS

The evaluation of bumper and septum power supplies concludes that the following issues need to be dealt with for a smooth top-up operation.

- charging capability shall be upgraded
- unification of the specifications for construction and spare components consideration
- control interface shall be enhanced for the purpose of noise resistance
- change resonant charging into command charging

The original circuit of bumper and septum power supplies utilize resonant charging technique in order to reduce the power consumption of the associated DC-PS, as shown in Fig. 1. Alternatively, the newly-built units rely on the capability of command charging PS to fulfil the need, as shown in Fig. 2.

A major change on the circuitry of the new units is that the logical control is replaced by relay interlock. This makes the control interface turn into robust to the noisy electronics environment. The system debugging becomes straight forward and is beneficial to the top-up operation.

* csfann@nsrrc.org.tw

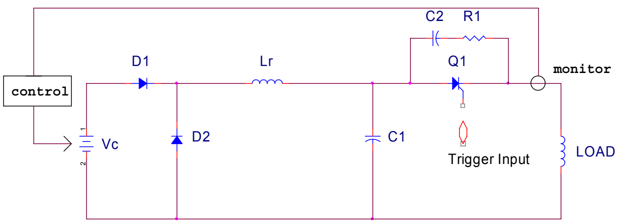

Figure 1: The large inductor Lr acts for resonant charging to multiple the voltages at capacitor C1. The load monitor provides feedback information for precision control of the magnet current.

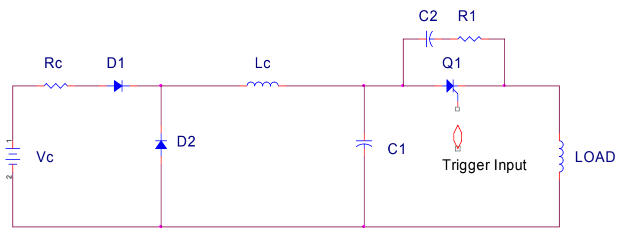

Figure 2: The charging voltage at C1 is determined by Vc of the command charging PS. Resistor Rc and a small inductor Lc are added for practical reasons.

UNIFICATION OF THE POWER SUPPLY SPECIFICATIONS

The charging power supply of the original units is divided into three categories for various power rating, i.e. injection septum (1 unit), extraction septum (1 unit), and bumpers (3 units). The associated power parameters are listed in table 1, as follow [5].

Table 1: Settings of the extraction elements

item	I-sep	E-sep	B-1	B-2	B-3
current (A)	1450	5800	183	165	183
width (ms)	0.5	0.5	2	2	2

* I-sep: injection septum; E: extraction; B: bumper.

Although the charging power supply requires relatively small rating for the bumper, yet the variety for 3 categories results in 3 units of spare unit with different ratings. Moreover, the charging inductors built into the original resonant charging circuit were not the same for different categories. This implies that the components required for the newly built extraction units will have various specifications unless they are unified for uniformity consideration. Consequently, it is worthwhile to re-scale the component specifications of these extraction elements so that the newly-built units are equipped with components of the same rating, including the spare units.

This technical modification resulted in slight “over-rating” of the charging power supply for bumpers. However, the benefit gained from the unified specifications is enormous. The specifications include DC-charging-PS, SCR, trigger unit, recovery circuit diode, and resistor. Besides, the unified specifications have great advantage in modularizing the pulsed power supply systems. This modular feature of the newly-built units provides fast replacement capability in case of components failure. Also, the unified specifications for all components have greatly reduced the effort in preparing spare parts.

TEST RESULTS

All units have been tested at 120% of their nominal settings continuously for over 8 hours with overall stability better than 1%. This estimated 1% variation is limited by the capability of monitoring tools. As a matter of fact, these units are equipped with capability of achieving 0.01% per hour stability after warming up for 1/2 hours [6]. Typical example of the pulsed current signals of theses units is shown in Fig. 3. Detailed information concerning system design and construction has been described in reference [5].

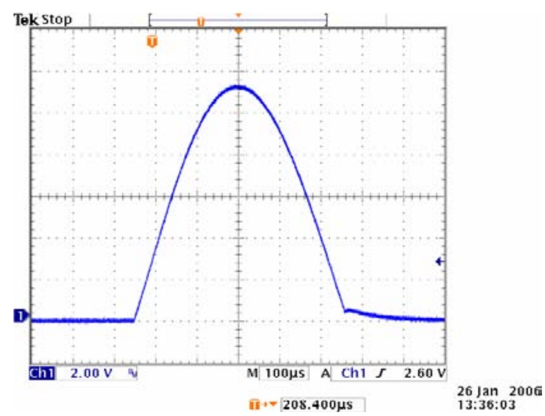

Figure 3: Example of the pulsed current signal of extraction septum. (pulse width : 500 µs; pulse height : 1000 A / 2 V)

The observed deformed tail of half-sine pulse in the above figure actually depended upon the model of current transformer (CT) used in the measurement. Different model of CT reads the same value of peak current with slightly different tailing shape deviated from the ideal half-sine pulse. Estimating the pulse stability was limited by the display resolution of the oscilloscope. One has to make use of the offset capability for accurate monitoring purpose.

DISCUSSIONS

The design working point of TLS booster lattice was: ν_x = 4.40, ν_y = 2.43 [7]. However, a practical solution was allocated in the commissioning phase to compromise the tune drift during ramping, as shown in Fig. 4 [8].

An appropriate operation point may be shifted due to the need of practical purpose in routine operation. In fact, it has been operated at various working points in different stages, such as the tune maneuver in the 1.3 to 1.5 GeV upgrade project [9].

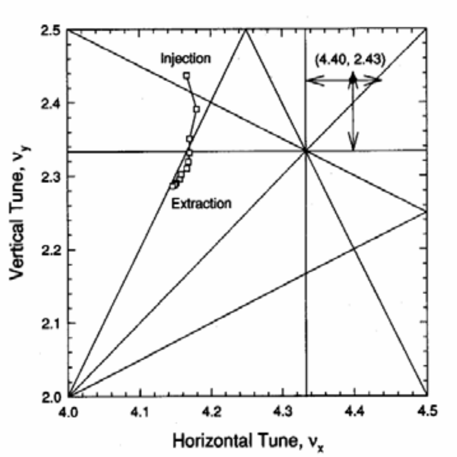

Figure 4: Tune diagram of the booster. The designd tunes ($\nu_x = 4.40$, $\nu_y = 2.43$) and corresponding tuning ranges for 50 MeV, DC mode operation are shown in the upper-right corner. Tune drift in ramping operation is also indicated.

The magnet strength of extraction bumpers listed in table 1 indicates that the ratio of the bumper strengths, B1: B2: B3, is 1: 0.9: 1 instead of 3: 4: 3 in comparison with the case of $\nu_x = 4.40$ discussed previously [10]. Since the bumpers 1, 2, 3 are located at longitudinally consecutive sections 8, 9, 10, as shown in Fig. 5, the phase advance between B1→B2 and B2→B3 is identical. Therefore, the phase-space evolution of the local orbit bump, B1-B2-B3, can be retrieved accordingly, as depicted in Fig. 6.

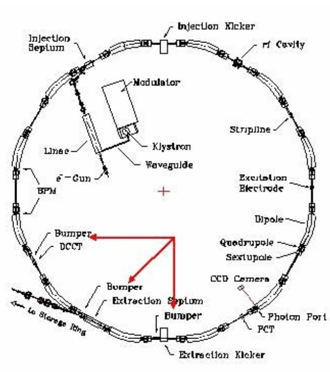

Figure 5: Layout of TLS injector. The bumpers are located at sections 8, 9, 10.

The retrieved phase advance of 117° per cell in the booster ring implies that the horizontal tune at extraction moment is 3.90. Comparing the estimated tune of $\nu_x = 3.90$ at extraction with the stop band information provided in Fig. 4, it is found that this operation point is acceptable to the stop band of $\nu_x = 4.00 \pm 0.06$ [11]. Optimization of beam extraction at $\nu_x = 3.90$ deserves further study after commissioning of these newly-constructed bumper and septum power supplies.

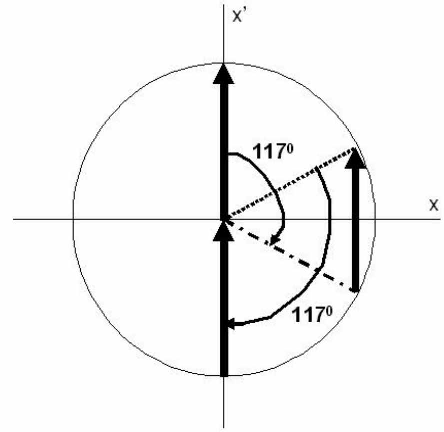

Figure 6: Phase space evolution of the electron beam at extraction moment in TLS booster ring.

REFERENCES

[1] K.K. Lin, K.T. Hsu, T.S. Ueng. "Measurement on the SRRC 1.3GeV electron booster synchrotron operation parameters and the ramping behavior", PAC1993, p. 2031-2033.

[2] C.S. Chen, C.J. Wang, J. Chen, K.H. Hu, S.H. Lee, T.S. Ueng, K.T. Hsu, K.K. Lin. "Performance of the new White circuit in upgraded 1.5GeV booster synchrotron", EPAC2000, p. 1829-1831.

[3] J.P. Chiou, J.S. Chen, C.S. Fann, C.H. Ho, K.T. Hsu, S.Y. Hsu, C.S. Hwang. "The upgrade of SRRC booster extraction system", PAC99, (TUA159).

[4] a. C.S. Chen, J. Chen, J.S. Chen, K.T. Hsu, K.K. Lin, C.J. Wang. "Control integration for the injector in SRRC", EPAC98, p. 1658-1660.
b. C.S. Chen, C.J. Wang, J. Chen, J.S. Chen, S.H. Lee, K.H. Hu, K.T. Hsu, K.K. Lin. "Performance of the rejuvenated injector control system in SRRC", PAC99, p. 682-684.

[5] C.S. Fann, K.B. Liu, S.Y. Hsu, K.K. Lin. "Construction and measurement of a new set of bumper and septum power supply of TLS booster" (in Chinese), NSRRC-PS-06-01, January 2006.

[6] "Instruction manual – LH series, PS/LH001R5.0-21, Glassman High Voltage Inc. 2005.

[7] "Conceptual design report of the SRRC injector", 9-IJ-25-001/88, Scanditronix AB, 1988.

[8] K.K. Lin, K.T. Hsu, T.S. Ueng, J.P. Chiou, J.I. Hwang, Y.C. Liu, J. Modeer. "Performance of SRRC 1.3GeV electron booster synchrotron", NIM-A 361(1995)1-12.

[9] K.T. Hsu, J. Chen, T.S. Ueng, K.K. Lin "Tune measurement of SRRC booster during ramping", EPAC2000, p. 645-647.

[10] Y.C. Liu, C.S. Fann, K.B. Liu, S.Y. Hsu, K.T. Hsu, K.K. Lin, "Feasibility study of modifying beam extraction scheme of TLS booster", NSRRC/PS/05/01, March 2005.

[11] H. Wiedemann, "Particle Accelerator Physics", p. 243, Springer-Verlag, 1993.