PERFORMANCE OF A PFN KICKER POWER SUPPLY FOR TPS PROJECT

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Abstract

A test unit of a pulse-forming-network (PFN) kicker power supply has been designed and fabricated for Taiwan Photon Source (TPS) beam injection/extraction of the booster ring. In order to fulfill the requirements, the performance of the designed unit has been bench tested and the results are examined for evaluation purpose. The pulse-to-pulse stability and the flattop specifications are specified according to the beam injection/extraction requirements. Effort has been made to enhance the rise/fall time of the delivered pulse current. The engineering evaluation and its possible application for beam diagnostics purpose are briefly discussed.

INTRODUCTION

The TPS under construction consists of a 150 MeV electron linac [1], a 3 GeV full energy injection booster, and a 3 GeV storage ring [2-3]. There are two types of booster design for recently commissioned synchrotron light sources: 1) compact booster: ASP, Diamond, Soleil, SSRF [4-7]; 2) concentric booster: SLS, ALBA, TPS [8-10]. The TPS booster and storage ring are located in the same tunnel and the circumferences are 496.8 m and 518.4 m, respectively. With this booster circumference, it is possible to perform injection with long bunch train (up to 1 μs) for fast beam accumulation in the storage ring. Also, the requirements on the corresponding rise-time and fall-time of the injection/extraction kicker pulse field are relatively relaxed.

In this study, test units for the PFN injection/extraction kicker power supply have been built to examine their performance. The results show that it fulfills the pulser requirements on all specifications. The system configuration and the test results are briefly described in this report.

PERFORMANCE REQUIREMENT

The specifications used to evaluate the performance of PFN kicker test unit are listed in Table 1. The proposed injection/extraction scheme demands a 1 μs flattop for both injection and extraction kickers [2, 10]. The kicker pulses have either fast rise-time or fall-time needs for the extraction and injection processes. The stability requirements of both pulse-to-pulse and flatness for the test unit are ±0.1% and ±1%, respectively.

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Table 1: Specifications of the PFN kicker power supply

Parameter	Booster Injection Kicker	Booster Extraction Kicker
Pulse shape	Flat top	Flat top
Nominal current (A); [Max.]*	270; [500]	380; [580]
Rise time, 5%-95% (ns)	···	<400
Fall time, 95%-5% (ns)	<400	···
Flat top (μs)	1	1
Pulse to pulse stability (%)	±0.1	±0.1
Flatness (%)	±1	±1

*: maximum requirement ···: not critical
The load inductance of kicker magnet is specified to be 1.9 μH.
Operation repetition rate: 1 ~ 5 Hz, adjustable.

SYSTEM CONFIGURATION

The functional block diagram of the PFN test unit is shown in Fig. 1.

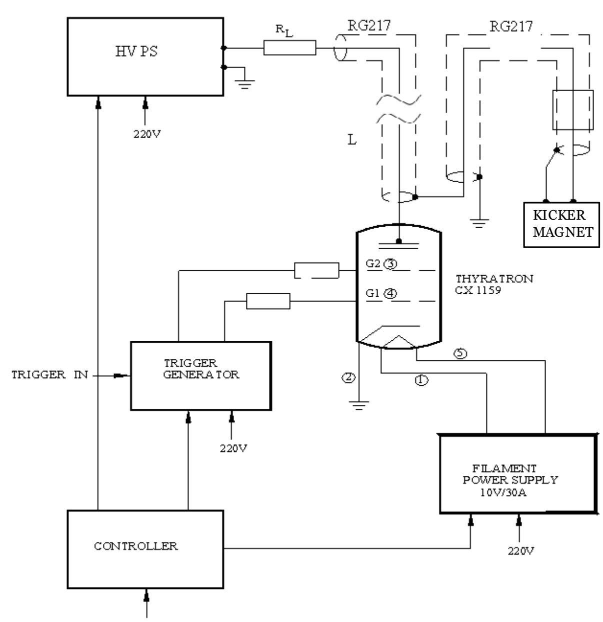

Figure 1: Functional block diagram of the PFN pulser.

The PFN cable "L" is energized by a high voltage power supply (HVPS). After triggering the thyratron (CX1159), the PFN cable is discharged through the delay cable. And the kicker magnet is terminated with matching resistors. The current waveform of the kicker magnet is measured by using Pearson current monitor (model-101) and TDS3054 scope.

A photo of the bench tested PFN kicker pulser is shown in Fig. 2. The PFN cable length has been tested with various needs at 30 m, 100 m, 125 m, and 150 m, respectively.

Figure 2: Photo of the PFN pulser test unit.

MEASUREMENT RESULTS

The measurement results of the pulser test units are presented and discussed in this section.

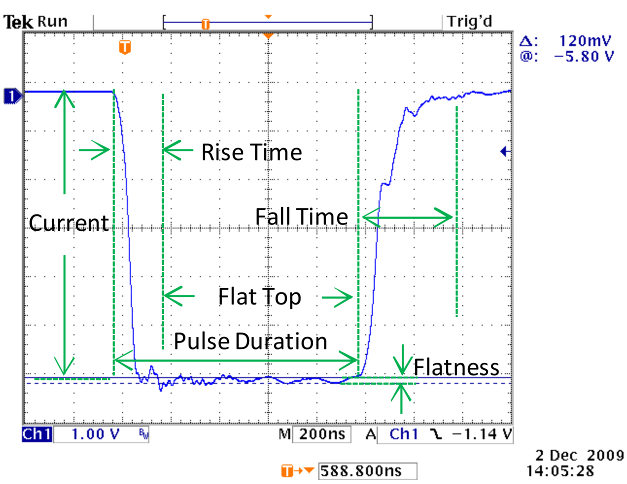

Figure 3: A typical PFN waveform delivered by the test unit.

A typical 100 m PFN waveform delivered by the test unit is shown in Fig. 3. The major evaluated parameters such as operation current, rise-time, fall-time, flattop and flatness are indicated along with the waveform for illustration purpose.

The PFN pulse duration is determined by the unit-length inductance, the unit-length capacitance and the PFN cable length as: [11, 12]

$$T_0 = 2\sqrt{L'C'}\, l_c , \qquad (1)$$

where T_0 is the pulse duration, L' is the unit-length inductance, C' is the unit-length capacitance, and l_c is the PFN cable length. The measured L' and C' are 0.135 μH/m and 0.2 nF/m, respectively. The calculated pulse duration, T_0, is given as: T_0 = 10.4 ns/m * l_c . Consider a 100 m PFN pulser, as given in Fig. 3, the pulse duration is 1000 ns and the flattop is about 800 ns. In order to determine the appropriate cable length for specified pulse duration need, the PFN pulse duration has been tested at various cable length and the measured results are shown in Fig. 4.

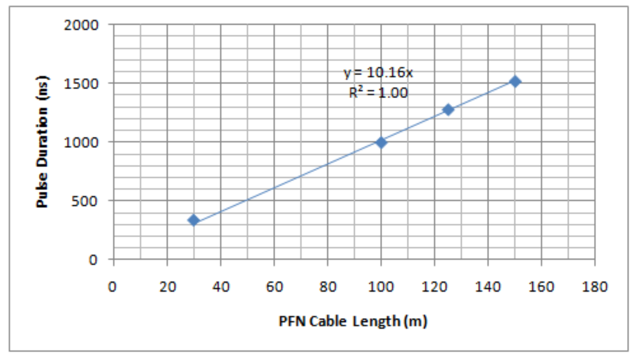

Figure 4: Pulse duration as a function of the PFN coaxial cable length.

The fitted slope in the figure gives a value of 10.2 ns/m. It is about the same value as the previously calculated one. For a 1 μs flattop requested PFN pulse, a cable length of 125 m is chosen.

The test result of a 125 m cable PFN unit is shown in Fig. 5. The peak-to-peak jitter is less than 2 ns. Its performance satisfies the requirements listed in Table 1. The influence of the magnet inductance on the rise-time and fall-time of the PFN pulse was further explored and the results are shown in Fig. 6. It implies that the achievable performance of this PFN pulser can be well estimated in case the load inductance would need to be adjusted.

Measurement results of the test unit, operating at the maximum requirement of 580 A, is shown in Fig. 3. This achieved maximum current is about 40% higher than the nominal value. It is expected that the maximum current capability will provide the flexibility in manipulating the injection practice during commissioning.

The ±0.1% pulse-to-pulse stability requirement of the PFN pulses is accomplished by using a HVPS with stability 0.05% (Glassman ER30P10). The analysis of the measured amplitude distribution for a typical 30 consecutive pulses is shown in Fig. 7. The estimated standard deviation of the peak field is about ±0.1%. However, since the baseline fluctuation is also close to the same number, the quantitative analysis of the achieved stability of ±0.1% is limited by the instruments used in the measurement.

This PFN kicker system can also be applied in the storage ring for specific beam diagnostics purpose. For example, it can be used as a transverse beam orbit perturbation source capable of providing equal driving strength for all electrons within the selected bunch train under study. In that case, minor hardware modifications may be required according to the practical needs, e.g.

1) the length of the PFN cable (for proper pulse length);

2) reducing the load inductance (for fast rise-time and fall-time) [13].

SUMMARY

The test unit of a PFN kicker pulser has been constructed and bench tested in this work. The measurement results show that this test unit can fulfill the required performance specifications. The rise-time, fall-time, flattop, flatness and delivered current amplitude are given as 200 ns, 400 ns, 1 µs, ±1% and 580 A, respectively. The PFN cable length of 125 m can provide the flattop requirement of 1 µs. The pulse-to-pulse stability within ±0.1% is also achieved by using a high stability HVPS.

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Figure 5: Operation current with the PFN cable length of 125 m and 5(b): Jitter (p-p) of a typical PFN waveform delivered by the test unit.

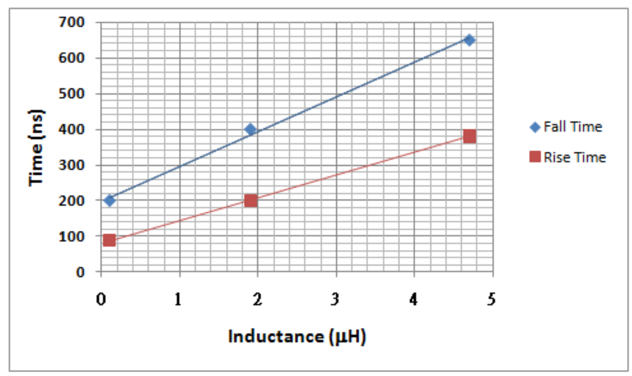

Figure 6: The rise-time and fall-time variation vs. system load inductance.

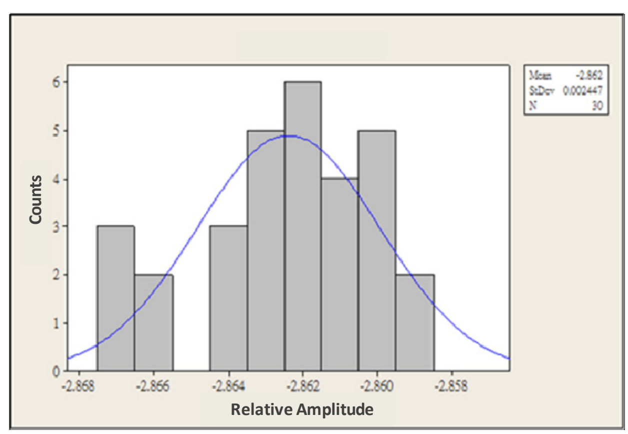

Figure 7: The amplitude distribution for 30 consecutive pulses.