DUAL ONE-TURN COILS FOR TLS EXTRACTION KICKER MAGNET

K.L. Tsai*, C.S. Fann, S.Y. Hsu, Y.S. Cheng, C.Y. Wu, K.H. Hu, Y.C. Liu#,
K.T. Hsu, K.K. Lin, C.T. Chen, NSRRC, Hsinchu, Taiwan

Abstract

The test results of a dual one-turn coils configuration for Taiwan Light Source (TLS) booster extraction kicker is presented in this report. The achieved capability of the test unit demonstrates that the rise-time of the kicker current pulse has been improved for beam extraction optimization. This improved performance is mainly accomplished by reducing the load inductance effectively with a dual one-turn coils configuration. The measured result of rise-time variation versus the corresponding load inductance change is briefly discussed.

INTRODUCTION

A kicker system is usually equipped in a synchrotron radiation accelerator for injecting and/or extracting the electron beam [1, 2]. For the purpose of achieving fast beam accumulation in the storage ring, maximizing the available filling bunches in the booster is usually expected. In order to optimize this capability in the booster, the current pulse characteristics of a fast fall-time for injection kicker and a fast rise-time for extraction kicker are required.

Pulse forming network (PFN) kicker power supplies are equipped in the TLS booster to perform fast injection and fast extraction of the electron beam [3]. The rise-time and fall-time of these PFN kickers are about 50~100 ns depending upon the load inductance of the kicker magnets. With the revolution time of 240 ns in the booster, the available bunch train becomes around 140 ns. This available bunch train was decreased to about 80 ns when the one-turn kicker magnet coil was modified into two-turn coil for higher field operation. This modification was taken place ten years ago when the booster energy was upgraded from 1.3 GeV to 1.5 GeV. An option of two-turn kicker magnet coil was chosen for easy adoption without involving PFN enforcement and system interface adjustment [4]. Since the booster was capable of providing adequate beam current for storage ring injection, the influence of the shortened available bunch train on routine operation was insignificant. However, as the operation of a flexible filling pattern is requested in the future, restoring the capability of providing maximum available bunch train is needed.

In this report, the test result of a dual one-turn coils configuration for the booster extraction kicker power supply is presented. It demonstrates that the recently tested coils configuration has improved the rise-time of extraction kicker effectively. This improved performance is mainly accomplished by reducing the corresponding load inductances with respect to the PFN power supplies.

*tsai.kl@nsrrc.org.tw
#ESS Department, NTHU

EXPERIMENT

Both configurations of the original two-turn coil and the modified dual one-turn coils for the TLS booster extraction kicker magnet are illustrated in Fig. 1(a) and Fig. 1(b), respectively. As indicated in Fig. 1(a), the magnet current travels a two-turn loop resulting in higher field strength for 1.5 GeV while using the same PFN kicker power supply. On the other hand, Fig. 1(b) shows that both upper and lower magnet coils are independently powered by two separate PFN kicker power supplies. The assembling ferrite blocks of magnet in the figures were made transparent for visualization purpose.

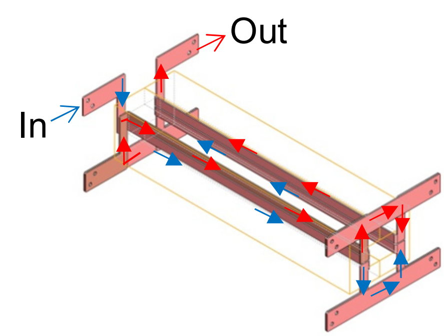

Figure 1(a): The existing two-turn coil configuration; blue arrow: first current loop; red arrow: second current loop. The measured load inductance is 3.8 μH.

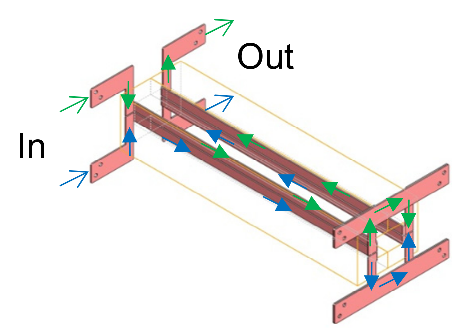

Figure 1(b): The modified dual one-turn coils configuration; green arrow: upper coil current loop; blue arrow: lower coil current loop. The measured load inductance for each coil is 1 μH. Both coils are powered simultaneously with independent PFN power supplies.

A bench module of the PFN kicker power supply was constructed for this improvement study by making use of the existing spare components. The measured corresponding load inductances for both magnet-coil configurations are listed in Table 1. The individual powered dual one-turn coils configuration gives much smaller load inductance to the PFN power supply in comparison with the two-turn coil configuration.

Table 1: The measured inductance of different types coil configurations for the extraction kicker magnet

Type	Inductance (μH)
Two-turn coils	3.8
Dual one-turn coils (upper)	1.0
Dual one-turn coils (lower)	1.0

A photo of the modified dual one-turn coils configuration for the kicker magnet is shown in Fig. 2. The black insulators give fixture of 2 mm gap separation between the upper and lower coils. The coil separation is operational up to the testing limit of 30 kV charging voltage at the PFN power supplies.

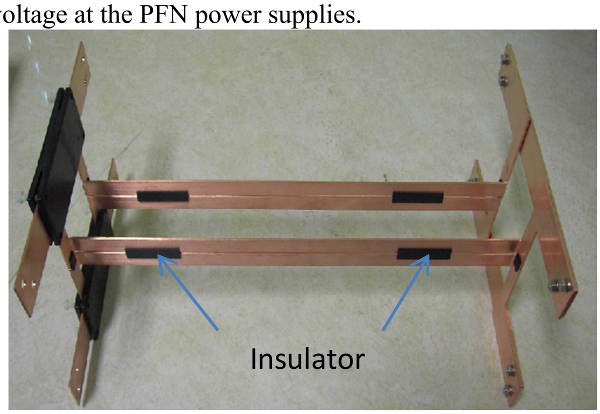

Figure 2: Photo of the dual one-turn coils configuration.

The functional block diagram of the PFN kicker power supplies for the dual one-turn coils test unit is shown in Fig. 3. The controller manages two independent PFN power supplies. Each PFN cable is energized by HVPS of Glassman ER30P10. When two CX1159 thyratron tubes are triggered simultaneously, the two sets of PFN cable are discharged through the kicker magnet of dual one-turn coils. During the experiment, an adjustable delay knob has been applied to optimize the observed waveform of total current signal. The current waveform of the kicker magnet is recorded with a current transformer (Pearson-101) and TDS3054 scope.

RESULTS AND DISCUSSION

Typical measurement result of the PFN kicker power supply, using existing two-turn coil configuration, is shown in Fig. 4. The rise-time and the current pulse duration are 200 ns and 320 ns, respectively. The available bunch train in the booster is about 80 ns. Similar measurement result for using the modified dual one-turn coils configuration is given in Fig. 5.

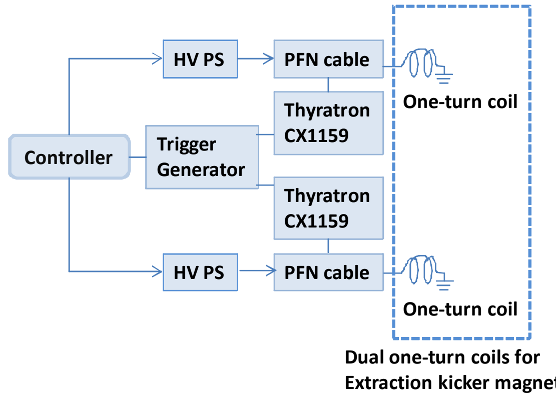

Figure 3: Functional block diagram of the PFN kicker power supplies for the dual one-turn coils configuration.

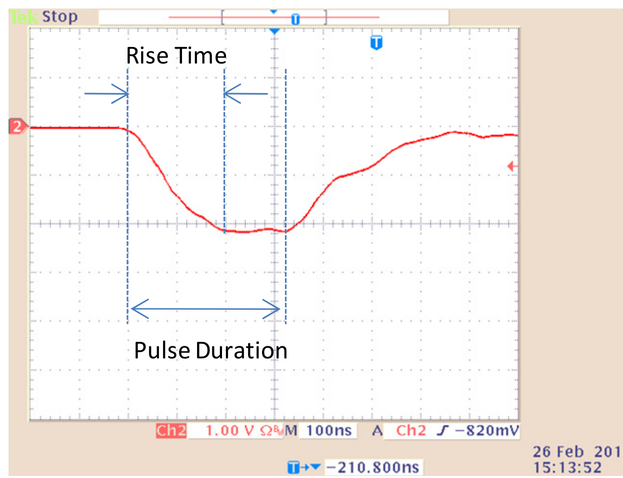

Figure 4: Typical PFN current waveform in two-turn coils configuration. Current monitor: Pearson-101; sensitivity: 0.01 volt/Amp.

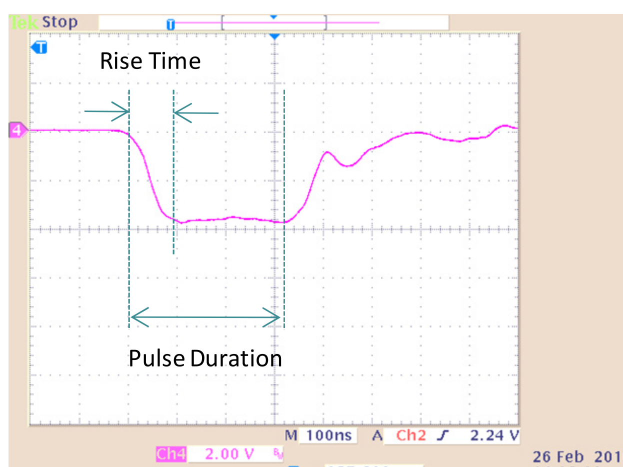

Figure 5: Typical PFN current waveform in dual one-turn coils configuration. Current monitor: Pearson-101; sensitivity: 0.01 volt/Amp.

The observed rise-time and the current pulse duration have been changed to 90 ns and 320 ns, respectively. The available bunch train in the booster becomes around 150 ns. It demonstrates that the rise-time of the extraction kicker current pulse has been improved significantly. It provides longer bunch train and hence tuning flexibility for future requested filling pattern manipulation [5].

Since the measurement results indicate that the load inductance of the PFN power supply has significant influence on the kicker magnet performance, it is worthwhile to explore how an appropriate load inductance would be chosen according to the practical needs. In order to carry out the measurement in a systematic manner, various inductive loads have been arranged as testing kicker magnet to investigate the response of current pulse rise-time as a function of load inductance. The results are shown in Fig. 6. The rise-time increases linearly with the applying load inductance.

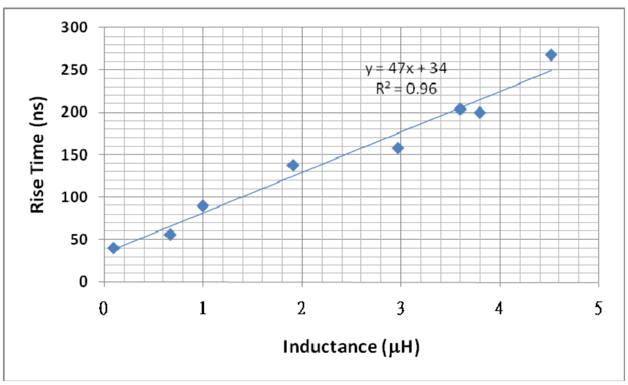

Figure 6: The kicker current rise-time vs. load inductance.

Since the kicker current rise-time (t_r) is well determined by the load inductance (L_m) and the system characteristic impedance (Z), as follow: [6]

$$t_r = L_m / Z\,, \qquad (1)$$

the fitted line, shown in Fig. 6, gives an estimated characteristic impedance 21.3 Ω for the modified PFN-kicker configuration. On the other hand, consider an ideal kicker magnet system with insignificant inductance, one would expect that the corresponding offset value appeared in Fig. 6 vanish. In practical case, it is equivalent to have a shorted circuit at the PFN power supply output terminals. It was realized that the fitted offset 34 ns of the testing PFN system was resulted from the 5 meters feed-line to the kicker magnet, i.e.

[$t_r = L_m$ (0.14 μH/m * 5 m) / Z (21.3 Ω) = 33 ns].

SUMMARY

The test unit of a dual one-turn coils configuration for the TLS booster extraction kicker system has been constructed and tested in this work in order to reduce the rise-time of the kicker current pulses. The kicker magnet inductance has been effectively reduced from 3.8 μH for the original two-turn coil configuration to 1 μH for the modified version. The test results shown that the rise-time is improved to 90 ns instead of 200 ns in comparison with the previously installed two-turn coil kicker magnet. The relation of current pulse rise-time and load inductance has been explored and the results, both the response and offset, agree well with the calculated estimation.

REFERENCES

[1] L.J. Lindgren, A. Sandell, and M. Eriksson, "Fast Kicker Magnet System", Nucl. Instr. and Meth. 214, p. 175 (1983).

[2] E. Nakamura, "Fast-rise High-field Kicker Magnet Operating in Saturation", Nucl. Instr. and Meth. A 612, p. 50 (2009).

[3] J. Modeer, "1.3 GeV Electron Synchrotron", PAC-1993, p.2034.

[4] J.P. Chiou, J.S. Chen, C.S. Fann, C.H. Ho, S.Y. Hsu, C.S. Hwang, K.K. Lin, J.T. Sheu, T.S. Ueng, "The Upgrade of SRRC Booster Extraction System", PAC-1999, p.1450.

[5] K. L. Tsai, et. al. "Performance of a PFN kicker power supply for TPS Project", these proceedings.

[6] Alexander Wu Chao and Maury Tigner, Handbook of Accelerator Physics and Engineering (World Scientific, Singapore and London, 1998), p460-p466.