CONDUCTIVE EMI REDUCTION TO KICKER MAGNET POWER SUPPLY IN NSRRC*

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Abstract

The purpose of this paper is to estimate and reduce the conductive Electromagnetic Interference (EMI) from kicker magnet power supply in TLS. A Line Impedance Stabilization Network (LISN) system was conducted to measure the EMI spectrum of kicker power supply. The EMI noise exceeded FCC standards in some frequency range especially during kicker firing. Reducing EMI level by using different EMI filters were applied. Double pi filter was more efficient than single pi filter. After using filter, the conducted EMI could diminish lower than FCC class B. The experimental results will provide useful information to future TPS pulsed magnet design.

INTRODUCTION

Due to increase the synchrotron stability, the conducted and radiated EMI of power supplies should be carefully noticed [1]. The LISN system is very important for conducted EMI measurement and evaluation [2]. It may affect the stability of the power line and cause error signal to other subsystems in the synchrotron. According to the operation experiences in TLS, the pulsed power systems, AC/DC power transformers, frequency convertors or RF system could be the possible sources induced error messages. Therefore, established EMI test system and eliminated conducted noise before operation should be necessary [3]. Based on the experience of experiment, the user made and home designed systems could produce higher EMI noise than commercial equipment.

CONDUCTED EMI STANDARDS

According to FCC Part 15/VDE 0871 standards, conducted EMI in the frequency range from 9 kHz to 30 MHz should be tested. Class A is suit for industrial product and lower EMI level - Class B is for residential product. In order to reduce interference between subsystems, the residential standard - Class B is the goal for the power supplies in NSRRC, especially subsystems located in tunnel.

First, the noise level for quadurpole, corrector magnet and pulsed magnet DC HV power supplies were tested. The EMI of these commercial power supplies were all complied FCC Class B standard. Besides, several vacuum pumps, eg. dry pump, turbo pump and ionized pump were also measured. The IP with high voltage output (7 kV) was exceeded FCC Class A standard. The EMI fileter or off-line UPS could effectively reduce conducted EMI to FCC Class B.

*Work supported by NSRRC
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KICKER EMI TEST

First, the kicker magnets in TLS were tested in core area. The HV DC power supplies and their control system were located in core area; while the kicker magnets and pulsers were placed in tunnel. Because conducted EMI could affect the other systems by electric network, the tested point was set to the downstream of the power break. Fig. 1 showed conducted EMI of K4 magnet under standby. The red and green lines indicated the FCC Class A (60 dBμV) via Class B (48 dBμV) from 1.6 MHz to 30 MHz. The power was switch off and correspond EMI was also lower than residential product level.

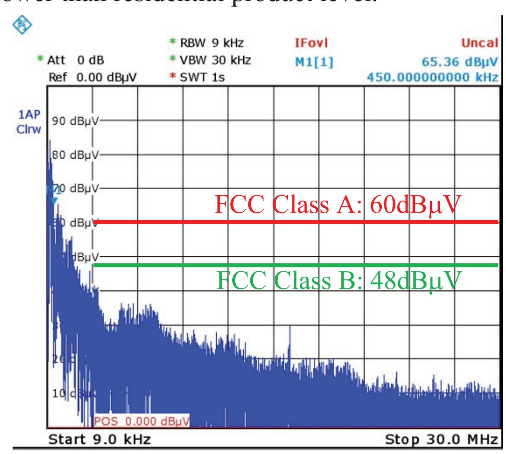

Figure 1: HV off (standby).

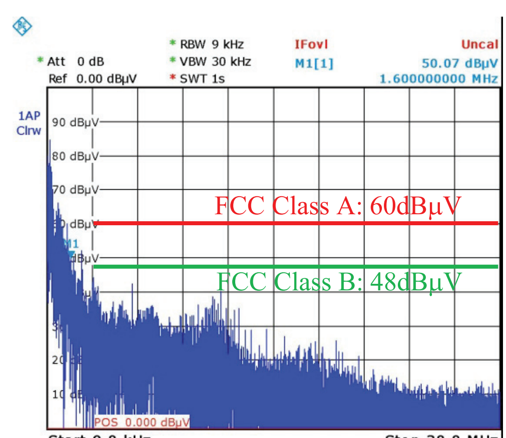

Figure 2: 3 kV power on.

Secondly, the K4 was switch on 3 kV. The DC power supply was charged on and the experimental result showed the conducted EMI were still under FCC Class B

ISBN 978-3-95450-115-1

(see Fig. 2), although the noise level is slightly higher than HV off status. Next, the EMI was tested during K4 firing. There was apparently exceeded Class A and B in MHz range shown in Fig. 3. The measurement was made from K1 to K4, the experimental results showed the conducted EMI of K2 and K4 were exceeded FCC Class A in some frequency range.

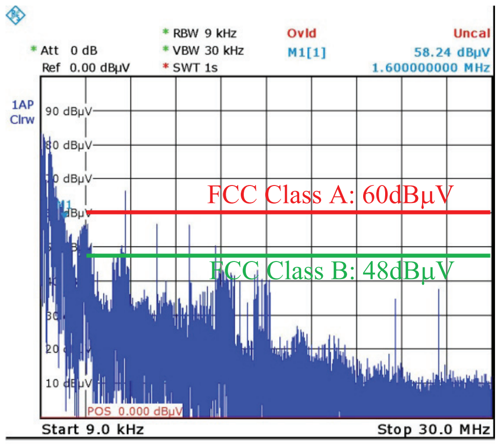

Figure 3: Kicker firing under 3 kV.

3-PHASE SYSTEM LINE FILTER

The EMI filters were used to reduce conducted EMI because of K2 and K4 exceed FCC Class A standard. The choice of EMI filter was based on voltage and current capacity. The 3-phase 250 V/25 Ampere line filters were chosen (see Fig. 4). The 1-π and 2-π filters were tested the effect of EMI reduction.

The insertion loss of 1-π filter (HUA-9010-2510) was showed in Fig. 5a. The effective frequency range is from 100 kHz to 10 MHz, and the insertion loss was over 40 dB in 500 ~600 kHz. Figure 5b showed the insertion loss of 2-π filter (HUA-9010-L325). The effective frequency range is wider than 1-π filter, especially in higher frequency (over MHz range). And the insertion loss of 2-π filter almost reaches to 80 dB, double than 1-π filter. The EMI reduction for these 2 filters was predicted that the 2-π filter should more effective than 1-π filter.

Figure 4: 3-Phase line filter (1-π vs. 2-π).

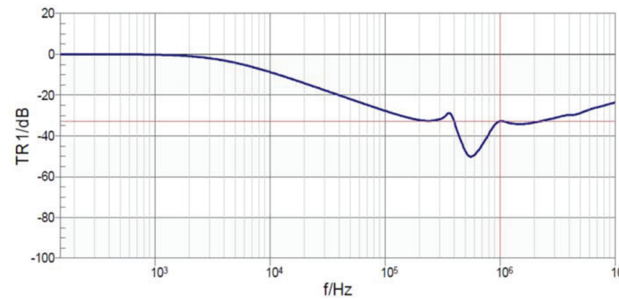

Figure 5a: Insertion loss of HUA-9010-2510 (1-π filter).

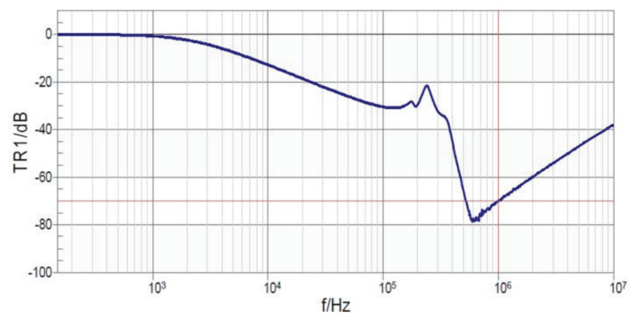

Figure 5b: Insertion loss of HUA-9010-L325 (2-π filter).

EMI FILTER IMPLEMENTATION

EMI reduction Experimental Setup

Figure 6 showed the experimental setup of LISN test with EMI filter. The EMI filter was added between LISN and HV power supply. The 1-π and 2-π filters were measured the effectiveness.

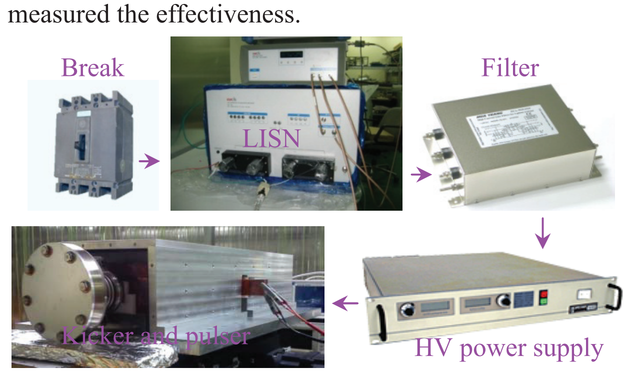

Figure 6: Experimental setup with EMI filter.

EMI Reduction - K2 Magnet

According to the conducted EMI test mentioned in above section, conducted EMI of K2 magnet was exceeded Class B level. Although the EMI level increased again while kicker firing, the main noise occurred when control system on and cooling water switch on. This EMI noise was not from pulsed power system, but from other assistant subsystems during system standby. Thus the 1-π filter is good enough to reduce K2 EMI level to FCC Class B standard (see Fig. 7).

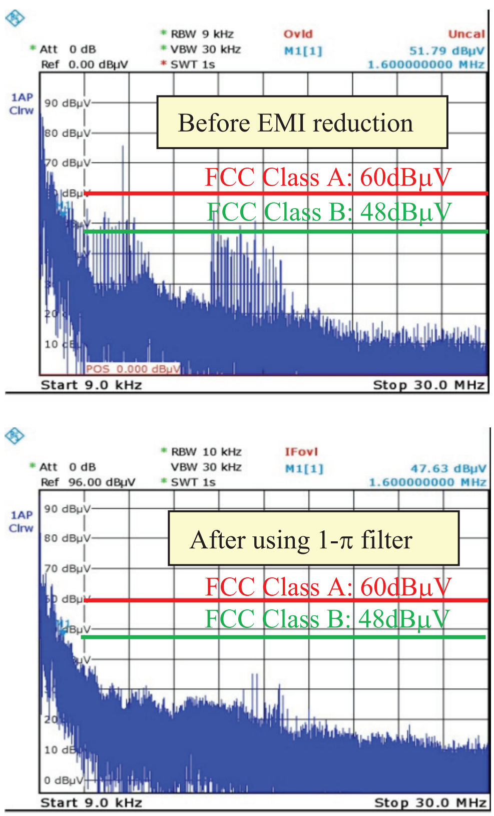

Figure 7: K2 EMI reduction by 1-π filter (standby).

EMI reduction – K4 magnet

Not similar to K2 magnet, the conducted EMI of K4 magnet was increased during HV power on and kicker firing in 3 kV (see Fig. 1 ~3). The noise level increase in ~11 MHz range while HV power on and EMI noise increase more in wide frequency (1.6 ~ 30 MHz) range even exceeded Class A level during kicker firing. After adding 1-π filter, the noise level decrease to Class B. But the results showed the insertion loss was not enough, there was still some noise remained during K4 firing. In order to get better result, the 2-π filter was added and the experimental result was showed in Fig. 8. The EMI noise diminished in wide frequency range, especially ~11 MHz and reached to FCC Class B standard.

CONCLUSIONS

The LISN system was build up and the conducted EMI were tested in this paper. The noise level for the kicker systems in TLS was under evaluated. Reducing EMI level by using different EMI filters were applied. The capacity and type of the EMI filters were very important specifications. 2-π filter was more efficient than 1-π filter, but it is more expensive. After adding filter, the conducted EMI could diminish lower than FCC Class B. The experimental results provided useful information for TPS design of different subsystems. In the future, the conducted EMI must be reduced and eliminated and EMI prevention schemes will be implemented.

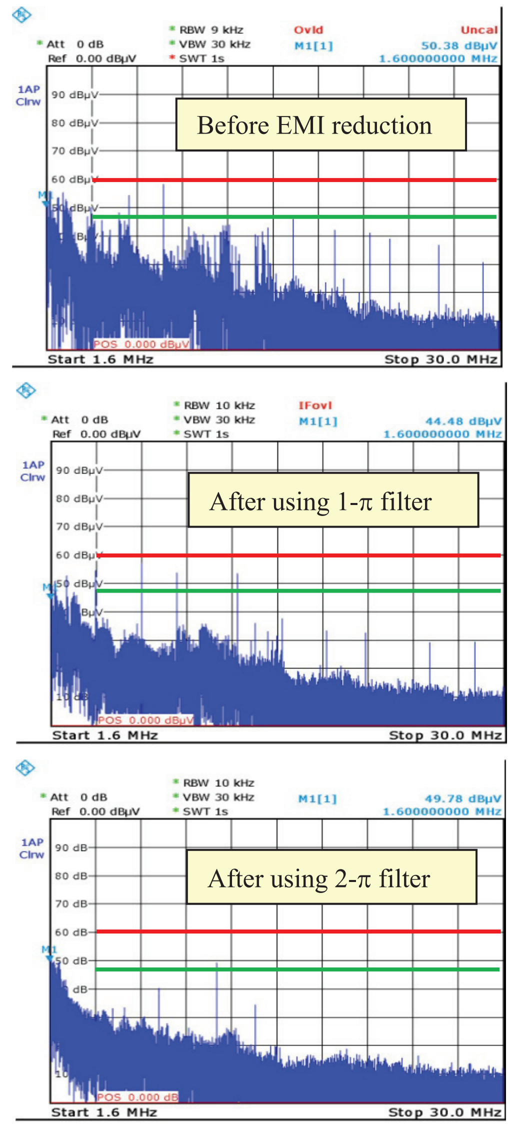

Figure 8: K4 EMI reduction by 1-π & 2-π filter (3 kV firing).

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[3] Y.-H. Liu et al., "Conduction EMI Test of Magnet Power Supply in NSRRC" *2010 International Particle Accelerator Conference (IPAC2010)*, Kyoto, Japan.

ISBN 978-3-95450-115-1