EMI NOISE SUPPRESSION IN THE KLYSTRON PULSE POWER SUPPLY FOR XFEL/SPring-8

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Abstract

Klystron modulator power supply of XFEL/SPring-8 is required low electro-magnetic interference (EMI), in order to realize a high stable beam by a feedback loops of high-precision beam monitors. We suppressed the EM noise of the modulator by the enclosure of the steel tank, eliminating a DC core bias circuit, and inserting pair noise filters into heater power lines. To estimate the effect of the noise filter, we measured the conducting noise on the heater power line. The amplitude of the noise was suppressed to less than 10 V peak-to-peak. In the prior operation test, we confirmed that the modulator noise hardly affects the low-level rf devices.

INTRODUCTION

In XFEL/SPring-8 project, we need a high stability of an electron beam in order to get a stable X-ray Free Electron Laser (XFEL) light. The stability is realized by an accurate feedback from beam monitors to the rf sources. Therefore, the monitors should be operated in the low noise environment.

The EM noise radiated from the modulator power supply is a problem for a long time [1]. When the modulator is triggered the PFN capacitor, the large EM noise is emitted and interferes surrounding electrical instruments [2]. The noise suppression of the modulator is one of the most important issues for the stable FEL light source.

We have developed a low-noise modulator power supply which is used for a 50 MW C-band klystron (TOSHIBA E37202). The typical specification is written in Table 1 [3]. The characteristic features of this modulator are all-in-one type and compact; it is contained a PFN unit, a thyratron, a pulse transformer, and other components in a thick steel tank filled with insulation oil. The dimension of modulator is L1.7 m × W1 m × H1.1 m.

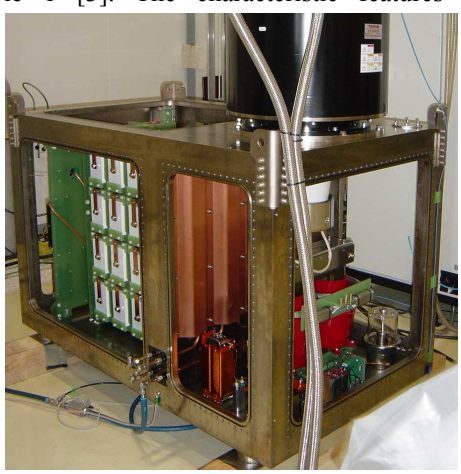

Figure 1: The inside view of the all-in-one modulator power supply. The size is L1.7m W1m H1m.

Table1. Specification of the modulator power supply.

PFN capacitance	29.3nF×16serise
PFN charging voltage	50 kV max.
Thyratron	e2v CX1836
Primary voltage and current of pulse transformer	23kV, 5kA
Secondary voltage and current	-350kV, 310A
Klystron peak output power	110MW
Pulse width (at 70% peak)	4.2 μs
Maximum repetition	60 pulse/sec.

In this report, we explain the EM noise prevention of the modulator power supply, and report the effects.

EM NOISE FORM KLYSTRON-MODULATOR POWER SUPPLY

When the thyratron is triggered, the anode voltage droops 50 kV max, and the large current pulse flows from PFN capacitor to the pulse transformer and the klystron. At that moment, the EM noise is generated by two mechanisms.

One mechanism is the thyratron switching. When the thyratron is triggered, the plasma is created in the thyratron, and the plasma oscillation radiates the EM noise. The frequency range of the noise is about 10 – 100 MHz. The amplitude of the thyratron noise is large which causes the problem at the control devices, frequently.

The other noise is the inductive field by the loop-current from PFN to klystron. The frequency of this noise depends on the rise time of the PFN discharge. In our case, the frequency is about 1 MHz.

These noises transmit by two ways, travelling in the space and conducting on the wires. Therefore, the key points of the suppression of EM noise are the shielding the travelling noise, and the filtering the conducting noise.

NOISE REDUCTION DESIGN FOR NEW MODULATOR

Completely Enclosed Metallic Shield

The modulator tank is monocoque structure, which frame itself supports the load of the tank and the klystron. Because the inner support is not necessary, the structure can take the large internal space. As the result, the high power components can be housed within the tank. By this all-in-one system, the pulse current loop is confined to the

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tank. In addition, the loop dimension can be minimized, and the inductive filed noise is suppressed.

The aperture area of the frame is closed by stainless-steel panels to seal the insulation oil. Therefore, these noise sources are completely enclosed by thick metallic plates, and then the radiated noise cannot leak to outside.

The face of the tank is plated with electroless nickel. This coating not only prevents the rust but also takes a good conductivity for the adopters connecting to the frame ground.

Pair Noise Filter

The EM noise can also transmit to the outside of the tank by conducting the metallic lines connecting to external cables: the heater power lines, the thyratron trigger lines, and the monitor signal lines. Especially, the heater lines of the thyratron must conducts the thyratron noise because it directly connects to the thyratron cathode.

To reduce the conducting noises on the heater lines, it is effective to insert noise filters into the lines. The noise filter is required to seal the tank filled with the insulation oil, and to pass the electrical heater power at 60 Hz.

We have developed the low-pass noise filters satisfying the above requirements. The figure 2 shows the view and the equivalent circuit of the pair noise filter. The filter has a pair line for the ac power, line A and B. The common mode noise is blocked by the common-mode choke inductor, and the capacitors connecting to the frame ground. The differential-mode noise is blocked by the capacitors connecting between the power lines. To sealing the tank, the filter is moulded by epoxy, and equips an O-ring on the contact surface with the tank. This filter is made by RISHO KOGYO Co., Ltd.

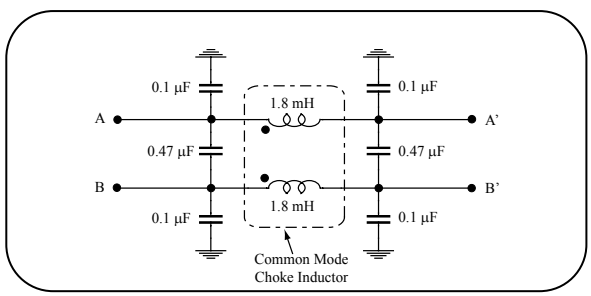

Figure 2: View of the pair noise filter and the equivalent circuit.

The pair noise filters have been inserted into the three heater lines: thyratron cathode heater, thyratron reservoir heater, and klystron cathode heater.

Removal Bias Choke Circuit

Conventional transformer had a DC bias circuit in order to avoid the magnetic flux saturation of the transformer core by supplying the DC current to the core. This circuit is designed to cut the high frequency pulse by a LC low-pass filter. But the pulse noise practically leaks to the outside [4]. Moreover, the current returns to the DC supply through the various ground lines, and generates the inductive field.

In the pulse transformer of the modulator, the core of transformer is made of the high-silicon steel which has low magnetostriction properties [5]. As the result, the core has a large air gap and avoids the flux saturation. We eliminate the DC bias circuit.

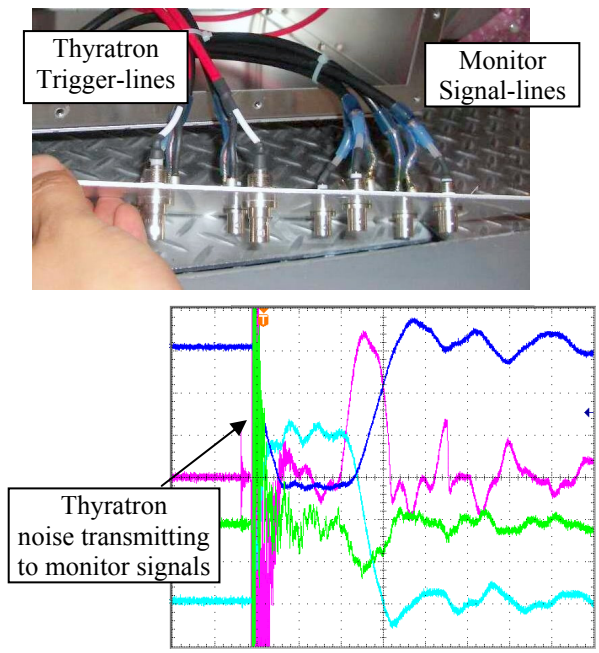

Figure 3: Top figure is the inside of connector panel in the bad case. The bottom figure is the waveforms of the thyratron noise transmitting the monitor signal.

Assembly of Connector

When the receptacle adopters had been used for the panel connection of the thyratron trigger lines, the thyratron noise conducting the trigger lines transmitted to the other monitor signal lines, as shown figure 3. The coupling was caused at the end of cable where the centre core and the shield of the co-axial cable were divided.

To prevent the noise coupling, we used the jack to jack co-axial panel adapters. As the result, the thyratron noise disappeared from the monitor signals.

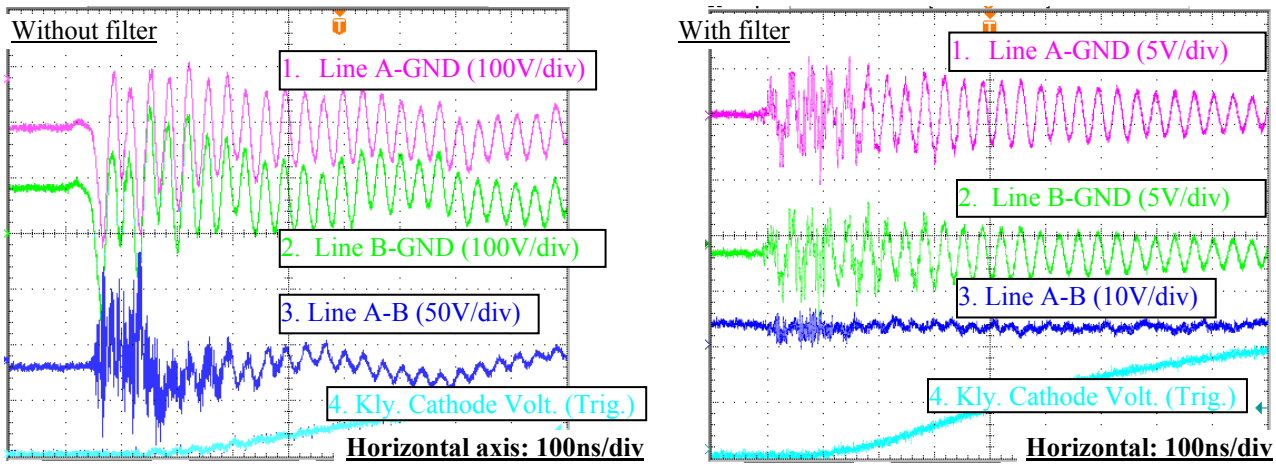

Figure 4: The noise waveforms of the thyratron cathode heater line at the moment of the thyratron trigger. Left figure shows the waveforms without the pair noise filter, and the right figure shows with the pair filter. In these figures, the wave 1 (red) and the wave 2 (green) shows the voltage between the line A and ground, and that between line B and ground. The wave 3 (blue) shows the voltage between line A and B. The wave 4 (clear blue) shows the klystron applied voltage, which is used as the trigger of the data acquisition.

MEASURING EMI

Conducting Thyratron Noise

We measured the effect of the twist pair noise filter for the conducting noise on the thyratron cathode heater line. Figure 4 shows the typical waveforms of the thyratron cathode heater voltage at the moment of the thyratron trigger. The wave 1 and 2 are the voltage between the heater line A and ground, and that between the line B and ground, respectively. These waves represent the mixing of the common-mode and the differential-mode noise. That is, the same pattern of the two waves indicates the common-mode noise components, and the different pattern indicates the differential components. The wave 3 represents the voltage between the line A and the line B, which indicates the differential-mode noise.

These heater voltage waves spike just before the rising edge of the klystron cathode voltage which is indicated as wave 4. It means these noises are generated around the thyratron. These waveforms indicate as below. Without the noise filter, the common-mode components of the conducting thyratron noise have mainly about 300 V peak-to-peak at 30 MHz, and the differential-mode components is about 150 V peak-to-peak. By inserting the noise filter, the noise amplitude is decreased to about 10 V peak-to-peak for common mode, and to about 7 V peak-to-peak at differential mode. We confirmed the filter decreased the common and differential mode noises.

Prior Operation Test

The modulators have been installed since July 2009. In February 2010, the prior operation test of the modulator and controller devices has been hold. In order to investigate the influence of the noise of modulator, we measured the noise level of the low-level rf system in the case of in operation and non-operation of modulator. As the result, there was no difference between these operational statuses.

SUMMARY

For XFEL/Spring-8 project, we developed the low noise modulator power supply; the noise sources are confined the completely enclosed metallic tank, the pair noise filters are inserted into the heater line, the DC core bias circuit is eliminated, and the coupling noise between the cables is suppressed. We measured the conducting noise on the thyratron cathode heater, and confirmed the noise filter decreased the noise to sufficiently small. In the prior operation test, we investigated the influence to the other devices, and confirmed that the interference was negligibly small.

ACNOKLEGEMENT

We thanks to Nichicon Corporation for the cooperating to the noise measuring and the improving the modulator. We also thanks to RISHO Corporation for the development of the pair noise filter.

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