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Troubleshooting of Modulator DC power supply at KOMAC

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1. Introduction

KOMAC (KOrea Multi-purpose Accelerator Complex) has four HVCMs (High Voltage Converter Modulator) which are the power source of nine klystrons. Four HVCMs are already operated since 2013 for operating the 100 MeV linear proton accelerator at KOMAC. This HVCM system includes the 12-pulse rectifier (ac-dc), capacitors bank (dc-link, Pos, Neg) and converter modulator (dc-dc). Especially, the 12-pulse rectifier system receives the power from the utility and converts 3,300 ac voltage to 2,200 dc voltage for supplying the dc power to the capacitors bank. This rectifier system used twelve thyristors for the rectification and applied RC snubber networks to protect the semiconductor switches (thyristors).

In November 2015, to increase the output beam power of the 100 MeV proton Linac, four HVCMs operating duty also increased to 3 % (1.5 ms, 20 Hz). However, in this process, 2nd modulator had troubles related to the switch plate and the dc power supply. So, in this paper, the process of solving problems to operate the 2nd converter modulator will be introduced. Also, the PSpice simulation result about the 12-pulse rectifier will be compared with the measurement result.

2. Troubles of 2nd HVCM

To increase the beam power of 100 MeV proton Linac, four HVCMs operating duty was increased to 3 %. At this time, the 2nd HVCM output voltage and current were 95.2 kV, 48.4 Amp each. As a result, the average output power of the 2nd HVCM was 138.230 kW.

However, when the 2nd HVCM attained the 3 % duty, the contact side of 20 kHz switch plate was damaged by electrical arcing as shown in the Fig. 1.

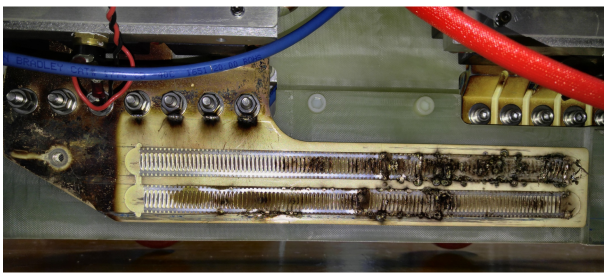

Fig. 1. Damaged contact side of the switch plate

The predictable reason of this electrical arcing at the contact side may be the loose assembling. Nevertheless, we cannot assure the exact reason of this electrical arcing.

Another trouble of 2nd HVCM was the dc power supply's output voltage leakage. Although the modulator was not triggered and dc power supply was not fired, the dc power supply's output voltage increased at 1 V/sec. At first, we anticipated that the MOVs (Metal Oxide Varistor) were broken by electrical arcing. However, when the MOVs, thyristors, diodes were exchanged with new ones, the dc output voltage still increased at 1 V/sec.

3. Troubleshooting of 2nd HVCM

To troubleshoot the dc power supply, we measured the voltage of each thyristor using differential probe without thyristor firing. Also, we repeated the same test eliminating the snubber network of blocking diode. The measurement result is shown in the Fig. 2. As shown in the Fig. 2, the voltages of the thyristors connected to the delta connection were changed every measurement.

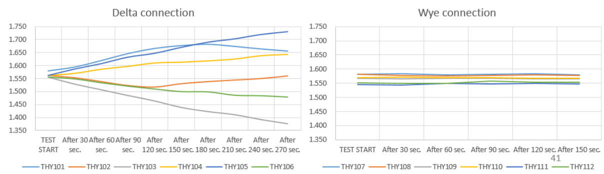

Fig. 2. The measured voltage values of each thyristor

To understand this phenomenon, the PSpice simulation was implemented about the 12-pulse rectifier. [1] The simulation results were shown that the change of the RC snubber network values will affect the voltage value of the thyristors. In our dc power supply case, the snubber network connected to the delta connection might cause the problems except for the wye connection.

With this view point, we find the faulty wiring of the thyristor snubber network connected to the delta connection in our dc power supply. The imbalance of one phase caused the voltage increasing phenomenon at zero voltage setting.

4. PSpice simulation of the dc power supply

At first, we assumed that the snubber network makes the problems. So, we simulated the dc power supply with changing the snubber values. As a result, we found that imbalanced snubber values can make the abnormal phenomenon at zero voltage setting. The PSpice simulation assumed that MOVs was ruled out and thyristor firing signals were disabled. Also, the load of the dc power supply was capacitive loads (112 mF each). The simulation schematic was shown Fig. 3. As shown in the Fig. 3, the input voltage is 3,300 ac voltage from the utility.

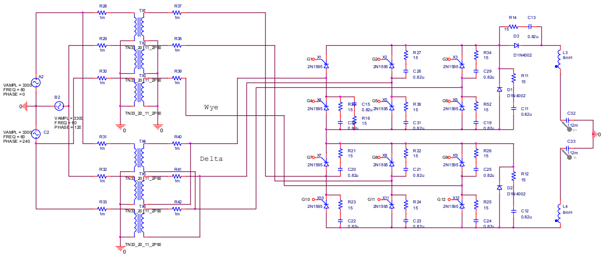

Fig. 3. PSpice schematic of the dc power supply

In the Fig. 3, the one thyristor snubber network was not connected. Instead, that snubber network parallel connected to the other thyristor. This faulty wiring was observed in our dc power supply.

The simulation result was shown in the Fig. 4.

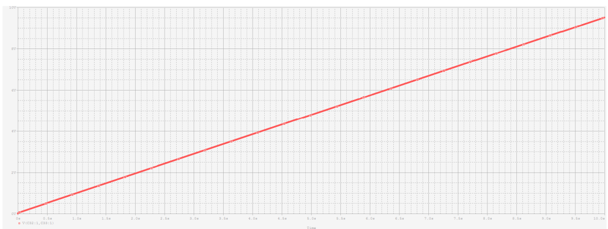

Fig. 4. PSpice simulation result (X: time, Y: voltage)

In the Fig. 4, x-axis is time and y-axis is dc output voltage of the dc power supply. The dc output voltage increases linearly and the increasing rate is 0.951 V/sec. This increasing rate is similar to that of our dc power supply at zero voltage setting.

5. Summary

Since the 2nd modulator dc power supply has troubled, the troubleshooting process conducted by the staves of KOMAC. It takes 3 months to solve the problems because it is not easy to find the faulty wiring. Nevertheless, our staves found the faulty point with a hope to operate the modulator system and the PSpice simulation helps to solve the problems. Using PSpice which is tool for simulating the circuit, the dc power supply abnormal phenomenon was simulated exactly. After corrected the faulty wiring, the modulator dc power supply operated normally.

These troubleshooting process and PSpice simulation results also can apply to the kinds of silicon controlled rectifier systems when the snubber network was degraded. [2]

ACKNOWLEDGMENT

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