Improvement of the switch plate with a modulator at KOMAC

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1. Introduction

KOMAC (Korea Multi-purpose Accelerator Complex) has been operating four modulators since 2013 to run the 100 MeV linear proton accelerator at the facility. The modulator is composed of three main parts: an SCR unit that rectifies 3-phase 3300V power, an HVCM that outputs the pulsed high voltage through switching modules and transformer, and a controller that drives various monitoring and control functions.

The modulator operates in the following manner: 3-phase, 3300-Vac power is rectified by the SCR unit, which utilizes a transformer and 12-pulse thyristor to generate 2.1kV. The HVCM filters the voltage through a capacitor bank and then feeds it into an inverter IGBT switching module to convert it back into 3-phase at a frequency of 20 kHz, using 3 pairs of full-bridge modules. The output voltage is then transformed into a high-voltage using a transformer and capacitor (for charging and ripple filtering). Finally, the high voltage being supplied to a klystron.

Figure 1. Overview of the modulator at KOMAC

Table 1. Specifications [1]

Peak power	5.6 MW
Pulse width	1.5 ms
Max. Repetition	60 Hz
Duty	9%
Max. output voltage	105 kV
Max. output current	50 A

In March 2022, we experienced an IGBT failure at the 4th modulator caused by a short circuit between the 2kV line and ground of the Rogowski coil. The cause and solution of the troubles that occurred in that time will be described.

2. Troubles of the switch plate with a modulator

We have confirmed that the insulation of the cable for the Rogowski coil, which is used for monitoring IGBT signals, has been damaged. This happened because the cable insulation was stripped off during the tightening of assembly bolts, causing it to stick to the high-voltage switching plate during assembly. This cable is responsible for feeding the interlock and monitoring signal for the controller through an integrator. We have discovered that the high voltage carried by the signal cable can cause abnormal operation of the controller.

Figure 2 The IGBT blast (left) short between the high voltage line and Rogowski coil(right)

3. Improvements of the switch plate with a modulator

3.1 IGBT driver board relocation

When an IGBT blast occurs with the switch plate, the driver board that is stacked on the IGBT cooling plate can also be damaged. To resolve this issue, it is necessary to physically separate and protect the IGBTs and IGBT driver boards. As shown in Figure 3 below, the driver board was separated from the IGBT and reassembled.

By relocating the drivers away from the IGBT plate, it is anticipated that less damage will be caused and also recovery time will be reduced.

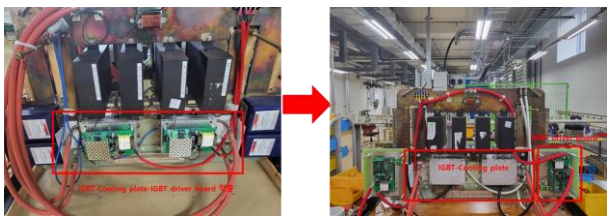

Figure 3 IGBT driver relocation

After completing the task above, the IGBT driver test

has been completed. It was confirmed that the driving voltage between the gate and emitter of the IGBT was ±15Vdc for the IGBT driver outputs.

Figure 4 shows the original and upgrade IGBT driver gate signals. Table 2 presents the rising and falling times for each phase. The time delta values of both the original and upgraded signals are less than 0.04us. It is acceptable range of the IGBT gate rising and falling time. [2]

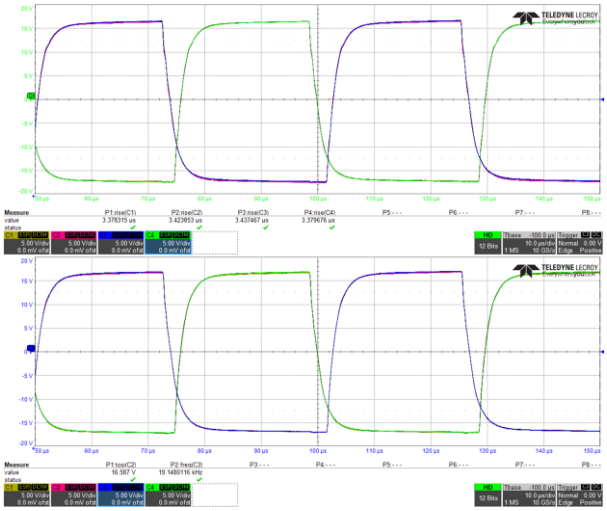

Figure 4. IGBT gate signal between the original (up) and the upgrade (down)

Table 2. Rising and falling time in gate

	Original		Upgrade	
Phase	**rising[us]**	**Falling[us]**	**rising[us]**	**Falling[us]**
A-	3.42	3.74	3.48	3.81
A+	3.39	3.7	3.47	3.85
ΔT_A	**0.03**	**0.04**	**0.01**	**0.04**
An-	3.41	3.75	3.48	3.82
An+	3.42	3.72	3.52	3.83
ΔT_{An}	**0.01**	**0.03**	**0.04**	**0.01**

3.2 Switching plate jig lift

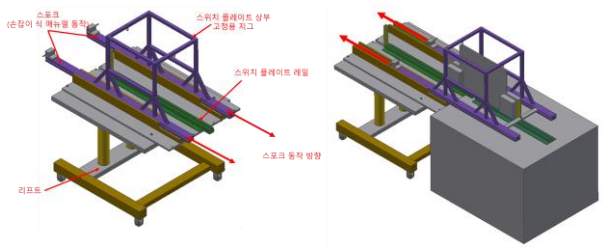

Figure 5. Modeling the switch plate transfer jig lift

The need to complete the task in a short amount of time also contributed to human errors. To reduce worker fatigue and enable more efficient maintenance, we designed a jig lift for transporting the switch plate. The switch plate transfer jig lift will allow one worker to perform a task that previously required three or more workers. Additionally, equipment handling and worker safety can be ensured.

4. Future work

We will test an improved switch plate on an independent modulator test bench. The following tests will be conducted on the test bench: mapping of the electromagnetic waves or induced magnetic fields caused by IGBT relocation, and test of alternative products for IGBT discontinuation currently in use. And when conducting the experiment, the switch plate transfer jig lift will be applied.

ACKNOWLEDGMENT

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REFERENCES

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[2] Testing single phase IGBT H-bridge switch plates for the high voltage converter modulator at the Spallation Neutron Source, Vladimir V. Peplov; David E. Anderson; Dennis J. Solley2014 IEEE International Power Modulator and High Voltage Conference (IPMHVC) INSPEC Accession Number: 15503045