Simulation of the Modulator for Driving a Klystron in KOMAC

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1. Introduction

For operating a 100 MeV proton accelerator in KOMAC (Korea Multi-purpose Accelerator Complex), the modulator has been used as a pulse power supply to drive two or three klystrons. In KOMAC, 4 modulators drive 9 klystrons, 9 klystrons supply the RF power to the DTL tank. The specifications of the modulator which drives two klystrons are shown in Table 1.

Table 1. Specifications [1]

Peak Power	5.8 MW
Pulse width	1.5 ms
Max. Repetition	60 Hz
Duty	9%
Input voltage to SCR	3.3 kV_{ac}
Max. output voltage from SCR	2.2 kV_{dc}
Max. output voltage	105 kV_{dc}
Max. output current	50 A_{dc}

KOMAC has a plan to develop a modulator which drives one klystron. This modulator's output voltage and current are 105 kV_{dc}, 25 A_{dc} respectively.

In order to develop a modulator which drives one klystron, the simulation of the modulator should be implemented.

In this paper, the analysis of the modulator which drives two klystrons was implemented first to compare with the current operation data. And then, the simulation of the modulator which drives one klystron implemented using same topology by changing parameters.

2. Analysis

In this section, the analysis of the modulator which drives two klystrons was implemented. The simplified diagram of the modulator is shown in Fig. 1. [2]

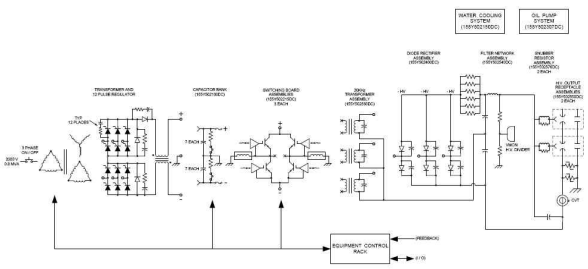

Fig. 1. Block diagram of modulator

In Fig. 1, IGBTs attached to the switching board assemblies operate at 20 kHz and transfer the 3-phase voltage to the first side of transformers. This voltage is square wave source with 90% fixed duty.

The simplified circuit diagram seen from the second side of the transformers is shown in Fig. 2.[3] The leakage inductance of the transformers (L_a, L_b, L_c) and resonating capacitors (C_a, C_b, C_c) constitute a LC resonant circuit.

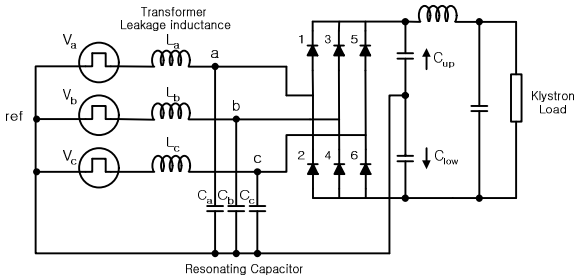

Fig. 2. Simplified circuit diagram seen from second side of the high voltage transformer

Although these transformers have the 17.94 turn ratio, amplified voltage measured at second side of each transformer is more than 47.7 times due to LC resonant circuit.

3. Simulation

3.1 Modulator with the current operation parameters

The operation data of the modulator which drives two klystrons is shown in Table 2.

Table 2. Operation data of M02

M02 SCR voltage[kV]	Output voltage[kV]	Output current[A]
1.85	88.653	45.204

In order to compare with the operation data, klystron load value (1.961 kΩ) was determined as shown in Fig. 3 which is PSpice schematic of Fig. 2.

The simulation parameter values in Fig. 3 are shown in Table 3.

Table 3. Parameter values

L_r	4.464 mH
C_r	1.8 nF
R_{load}	1.961 kΩ
Source voltage at 2nd side of TR	1.85 kV x 17.94 (turn ratio) = 33.189 kV

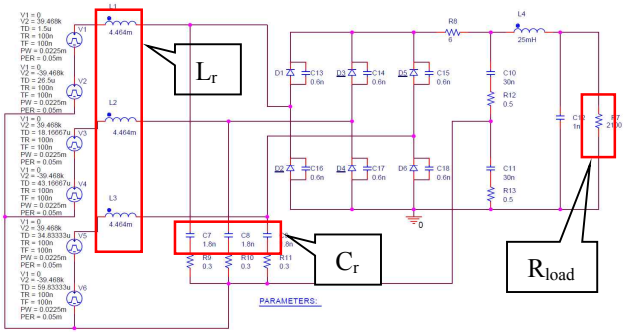

Fig. 3. PSpice schematic of Fig. 2

The simulation result of the circuit in Fig. 3 is shown in Fig. 4-1 and Fig. 4-2.

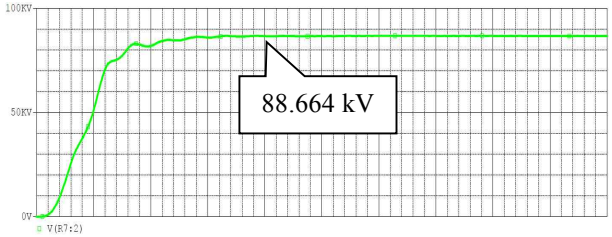

Fig. 4-1. Output voltage of the modulator with the current operation parameters

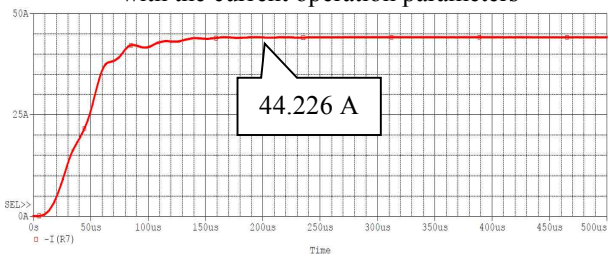

Fig. 4-2. Output current of the modulator with the current operation parameters

According to the result of the simulation, the error between the simulation output and the operation date is below 2.2%.

3.2 Modulator planned to develop

For supplying 105 kV_{dc}, 25 A_{dc} to a klystron, some parameters in Fig. 3 was changed. Capacitance of resonating capacitors (C_r) modified from 1.8nF to 0.6nF. And resistance of load resistor (R_{load}) changed to 4.2 kΩ.

After applying the changed parameter values, the result of the simulation is shown in Fig. 5-1 and Fig. 5-2.

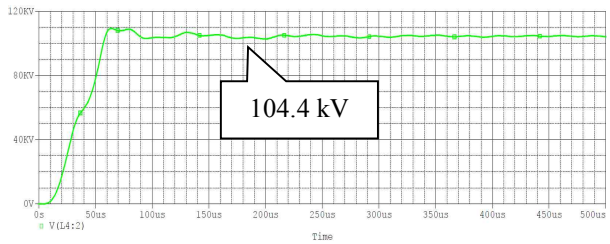

Fig 5-1. Output voltage of the modulator planned to develop

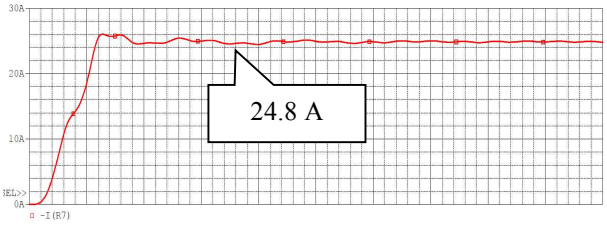

Fig 5-2. Output current of the modulator planned to develop

These output shows that the result of the simulation satisfy the driving condition of a klystron.

4. Summary

Using PSpice which is useful circuit analysis tool, the simulation of the modulator under the operation was implemented with the allowable error. Also, by using this tool, result of the simulation confirms that LC resonant circuit topology is effective model to develop the modulator driving one klystron in KOMAC.

In the future, the stress test of the devices which were included in the modulator will be executed. This analysis will optimize the parameter value of each device for developing the modulator which drives one klystron.

ACKNOWLEDGMENT

This work has been supported through KOMAC (Korea of Multi-purpose Accelerator Complex) operation fund of KAERI by MSIP (Ministry of Science, ICT and Future Planning)

REFERENCES

[1] D. I. Kim, H. J. Kwon, H. S. Kim, Y. G. Song, Y. S. Cho, Arc Energy Limiting Mechanism of the High Voltage Converter Modulator, Transactions of Korean Nuclear Society Autumn Meeting, October 2009

[2], [3] W. Reass, D. Baca, R. Gribble, D. E. Anderson, J. Przybyla, R. Richardson, J. Clare, High-Frequency Multimegawatt Polyphase Resonant Power Conditioning, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 33, NO. 4, Page 1211&1215, August 2005