High Power Test for Klystron Stability

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1. Introduction

A 100-MeV proton linac of the Korea multi-purpose accelerator complex (KOMAC) has been operated for beam service to users from July in 2013. The KOMAC accelerator facility has a 100-MeV proton linac, five beam lines for 20-MeV beam utilization, and another five beam lines for 100-MeV beam utilization [1]. The 100-MeV linac consists of a 50-keV proton injector based on a microwave ion source, a 3-MeV RFQ with a four-vane structure, and a 100-MeV DTL [2-3]. Nine sets of 1MW klystrons have been operated for the 100-MeV proton linac. The klystron filament heating time was approximately 5700 hours in 2014. During the high power operation of the klystron, unstable RF waveforms appeared at the klystron output, and we have checked and performed cavity frequency adjustments, magnet and heater current, reflection from a circulator, klystron test without a circulator, and the frequency spectrum measurement. The problems may be from harmonic power stay between the klystron and the circulator. A harmonic filter of waveguide type is designed to eliminate the harmonic power

2. Klystron

The specifications of the klystron for 100-MeV proton linac are summarized in the followings.

- Klystron : TH2089K (Thales)
- Operating frequency : 350 MHz
- Beam voltage (max) : 107 kV
- Beam current (max) : 26 A
- Mod. Anode voltage (max) : 71 kV
- Heater voltage (max) : 30 V
- Heater current (max) : 30 A
- Peak RF power (min) : 1.6 MW
- Gain (min) : 41 dB
- Efficiency (min) : 58 %
- Ion pump current (max) : 10 uA
- Electromagnet current (max) 12 A
- Electromagnet voltage (max) : 300 V

Figure 1 shows klystrons installed at the gallery for the 100-MeV proton linac. Nine sets of 1MW klystrons have been operated for the 100-MeV proton linac. There are four high voltage converter modulators for the klystrons.

RF operation time was 2863.4 hours for beam service and accelerator study, and the klystron filament heating time was 5700 hours in 2014.

Figure 1: HPRF installation

3. High Power Test

Nine sets of the klystrons have been operated for the 100-MeV proton linac. During the high power operation, some klystrons have unstable RF waveforms at a specific power level. Figure 2 shows the unstable RF waveform at the klystron for a DTL105. We have performed a cavity frequency adjustment to solve it, and we checked a reflection from a circulator as shown in Figure 3. We also measured a frequency spectrum at the unstable RF waveform as shown in Figure 4. We performed klystron high power test without a circulator to know if the unstable RF is caused by the klystron or not. The test results show that the klystron output signal is not normal.

The problems may be from harmonic power stay between the klystron and the circulator. During the test, a reflected power to the klystron was different due to a 350 MHz band pass filter. The reflected power level was over 300 kW without a BPF, but the reflected power level was ~50 kW.

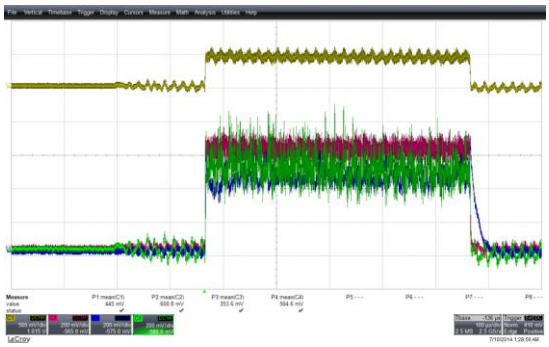

Figure 2: Unstable RF waveform at klystron operation (Yellow: klystron drive, Red: klystron output, Blue: circulator output, Green: reflection to klystron)

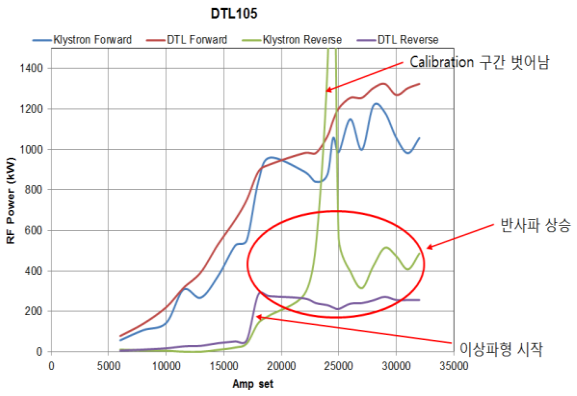

Figure 3: Reflection measurement of klystron

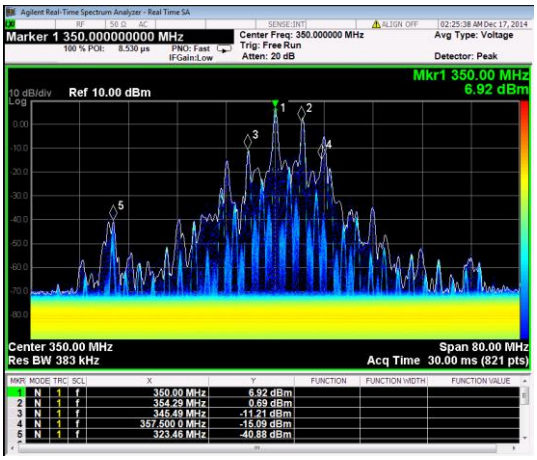

Figure 4: Frequency spectrum at klystron output

4. Harmonic Filter Design

The unstable RF may be from harmonic power stay between the klystron and the circulator. To eliminate the harmonic power, a harmonic filter of waveguide type is designed as shown in Figure 5.

It has 6 antennas protruding into the narrow wall of the waveguide are terminated in a few hundreds Watts, 50 Ohm, air cooled loads.

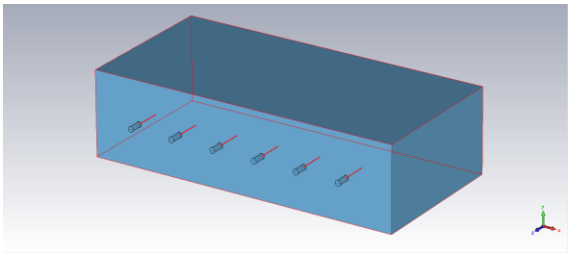

Figure 5: Harmonic filter modeling

Since the fundamental frequency is carried in the TE10 mode with the electronic fields orthogonal to the broad wall, the antennas are inserted through the narrow wall of the waveguide to couple out harmonic power in the TE11 and TM11 modes. [4] If the antenna is too thick, it can couple a significant amount of power at the fundamental frequency. An optimal length and thickness for the antennas were chosen. [5] The diameter of all antennas is 2 mm, and the length is 98.5 mm.

5. Conclusions

Nine sets of the klystrons have been operated for the KOMAC 100-MeV proton linac. Some klystrons have unstable RF waveforms at specific power level. We have checked and tested the cavity frequency adjustment, reflection from a circulator, high power test without a circulator, and frequency spectrum at the unstable RF. The unstable RF may be from harmonic power stay between the klystron and the circulator. To eliminate the harmonic power, a harmonic filter of waveguide type is designed. We have discussed the problem with Thales (manufacturer) to solve them.

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