RESONANT FREQUENCY CONTROL WITH RCCS FOR THE KOMAC PROTON LINAC

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Abstract

The Resonance control cooling system (RCCS) has been operated for cooling the drift tubes (DT) and controlling the resonant frequency of the drift tube linac (DTL) at the Korea Multi-purpose Accelerator Complex (KOMAC). The RCCS can maintain the cooling water temperature within ±0.1°C by controlling 3-way valve opening. The RCCS has two types of control mode, the constant cooling water temperature control mode and the resonant frequency control mode. In the case of the resonant frequency control, the error frequency is measured in the low-level RF (LLRF) control system and the RCCS compensates the error frequency by controlling the cooling water temperature of DT with PID algorithm. In this paper, the operation results of the resonant frequency control with the RCCS as well as some modification of the LLRF system are presented.

INTRODUCTION

There are 11 sets of RCCSs in the KOMAC for cooling proton linac (4 sets of RCCSs for 20 MeV DTL, the other 7 sets for 100 MeV DTL) [1]. Figure 1 is a picture of RCCS. Each RCCS consists of a cooling skid (pump, surge tank, pipes, 3-way valve, etc.) and control system. To accelerate the proton beam, 350 MHz radio-frequency (RF) is applied in DTL tank. So it is important to maintain the resonant frequency of DTL tank with 350 MHz during operation, and the RCCS can maintain the temperature of the cooling water within ±0.1°C [2, 3]. LLRF control system measures the error frequency of DTL tank [3, 4]. The RCCS controller can calculate set point temperature of cooling water for making the error frequency to 0 Hz. The DTL tank's sensitivity, which is defined the error frequency per 1°C, should be known to calculate set point temperature. The sensitivity can measure by changing temperature because the error frequency is changed when cooling water temperature is changed [5].

The RCCS controller controls 3-way valve opening with PID algorithm after calculating set point temperature by using LLRF system. Figure 2 is the block diagram of the resonant frequency control mode in RCCS. LLRF system calculates the error frequency of DTL tank and transfer to the RCCS controller. Then the RCCS controller calculates the set point temperature which can make the error frequency 0 kHz. After calculating the set point temperature, the RCCS controller sends the current to 3-way valve control unit. 3-way valve is sent the current from 4 mA to 20 mA, so 3-way valve is controlled (form 0% to 100% opening). By doing this, the cooling water temperature is controlled. It makes the error frequency changed. After changing temperature, the LLRF control system measures the error frequency again, and the RCCS controller calculates set point temperature again [1, 5]. Before the RCCS is operated with the resonant frequency control mode, the sensitivity is calculated by changing the temperature in the temperature control mode.

Figure 1: A picture of RCCS.

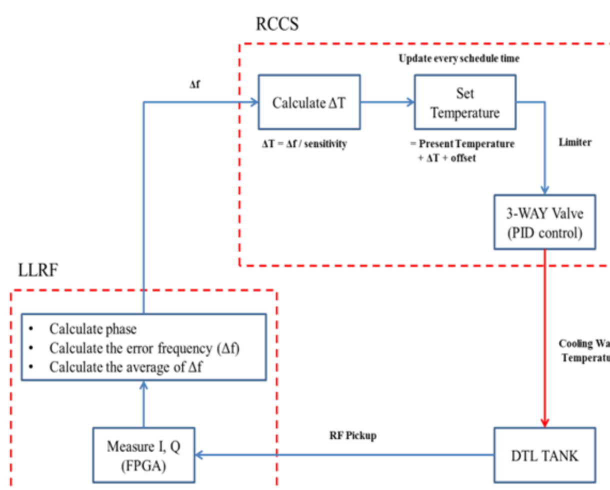

Figure 2: Block diagram of the resonant frequency control mode.

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ISBN 978-3-95450-147-2

EXPERIMENTS AND DISCUSSION

Calculate Sensitivity

Experiments were performed with one of RCCSs (using RCCS105) and the RF repetition 1 Hz. To calculate the sensitivity, temperature was changed from 37.7 °C to 37.2 °C and the error frequency was changed around from 0 kHz to 2 kHz. So the sensitivity of RCCS105 was -4 kHz/°C.

Resonant Frequency Control Test

After the sensitivity was measured, RCCS105 was operated with the resonant frequency control mode. The repeat time that the RCCS controller calculated set point temperature was 2 seconds. The temperature was controlled with the PID value (P gain was 25, I gain was 150, D gain was 25). P gain was changed from 25 to 50 in the middle of test.

Test Results

When RCCS105 were operated with resonant frequency control mode, some variables were measured such as temperature, RF status (amplitude, phase, RF power, error frequency). As shown in Fig. 3, the temperature was changed periodically around 1 and half minute. In Fig. 4 through 6, other variables were changed because of the temperature change. Table 1 is the summary of variables measured while the RCCS105 were operated with the resonant frequency control mode. The error frequency was changed from −1.68 kHz to 1.95 kHz. The phase was increased around 151° when the RF was turned on, after resonant frequency control the phase was changed from 37.43° to 56.46°. The amplitude was maximum value when the error frequency was 0 kHz. Both forward and reverse power was measured fluctuations like the temperature. They also had maximum value when the error frequency was 0 kHz.

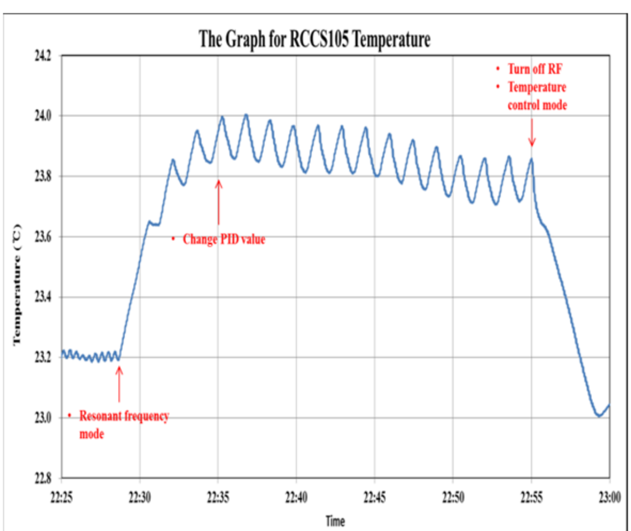

Figure 3: The graph for RCCS105 temperature.

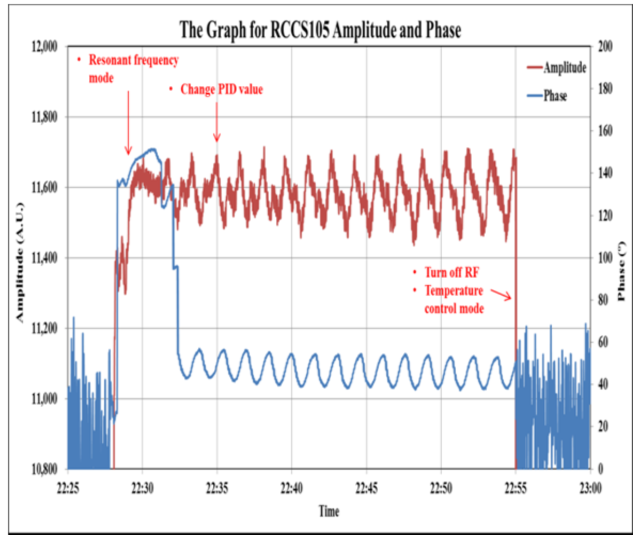

Figure 4: The graph for RCCS105 amplitude and phase.

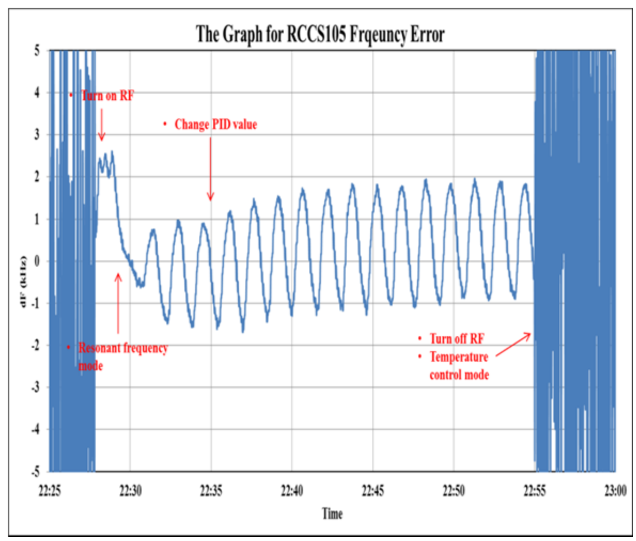

Figure 5: The graph for RCCS105 error frequency.

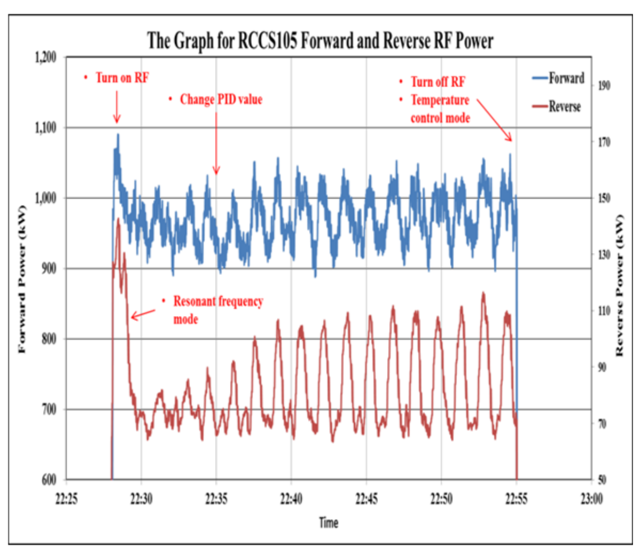

Figure 6: The graph for RCCS105 RF power.

Table 1: Summary of Variables

Variables	MIN	MAX	AVG	STEDV
Temp (°C)	23.71	24.00	23.90	0.07
Amplitude (A.U.)	11436	11714	11580	0.51 %
Phase (°)	37.43	56.46	46.50	5.55
Error Frequency (kHz)	-1.68	1.95	0.30	1.02
Forward Power (kW)	888.19	1056.46	970.80	36.00
Reverse Power (kW)	63.63	116.44	82.50	14.53

CONCLUSION

In conclusion, RCCS105 was operated in the resonant frequency control mode. The set point temperature was calculated and the error frequency was transferred to 0 kHz at which the amplitude reached its maximum value. Because of the PID characteristic, the temperature was fluctuated periodically. It made other variables fluctuated. Thus, the PID control value should be adjusted to control with less fluctuation. The LLRF system needs some modification. When the phase was around ±180º, the LLRF system calculated the wrong error frequency. It can make the fluctuation of temperature when RCCS is operated with resonant frequency control mode. In the future, the characteristic test of PID control will proceed along with the modification of LLRF system for measuring error frequency.

ACKNOWLEDGEMENT

This work is supported by the Ministry of Science, ICT & Future Planning of the government of Korea.

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ISBN 978-3-95450-147-2