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Upgrade of High Voltage Power Supply and Integrated Control System for efficient EC System in KSTAR

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Currently, ECH (Electron Cyclotron Heating) system for KSTAR (Korea Superconducting Tokamak Advanced Research) is composed of two dual-frequency gyrotrons, each generating 950kW of RF power at 140 GHz and 800kW of RF power at 105 GHz. EC system will be installed up to 6 gyrotrons by 2022. Currently, the electron gun of gyrotron installed in KSTAR is diode type, and two high voltage power supplies (HVPS) are required to operate this type of gyrotron. The HVPS is one of the important system that affects the quality of the RF beam. A control system is required to precisely inject the RF beam into the plasma. In addition, the control system is an important system to protect the gyrotron and the HVPSs. Electron cyclotron heating (ECH) is used as one of the most important auxiliary heating method for plasma heating in modern fusion research. In addition to plasma heating, EC system is used for plasma current drive and control of plasma instabilities such as NTM (Neoclassical Tearing Modes). Recently, multi-frequency gyrotrons are demanded for efficient plasma control. Dual-frequency gyrotron can increase the heating region in the plasma and can be operated for various heating scenario [1]. As these reasons, currently, EC systems for KSTAR are used two dual-frequency gyrotrons, operating at 105/140 GHz with a pulse length of 300s [2]. 105/140 dual-frequency gyrotron was used at KSTAR tokamak for plasma heating and current drive experiments during 2017-2018 years. In order to increase the efficiency, single-stage depressed collector is applied and their efficiency is about 45%. The gyrotron design parameters are summarized in Table 1.

Table 1. Operation parameters of gyrotron

	'EC2' gyrotron	
	105 GHz	***140 GHz***
Output mode	TE17,6	TE22,8
Contents of TEM00 mode (%)	>97	>97
RF output power (kW)	800	950
Pulse duration (s)	300	300
Efficiency at full power (%)	> 45	> 45
Beam Voltage (kV) / Current (A)	45 / 32	44 / 39
Body Voltage (kV) / Current (mA)	23 / 20	24 / 20
Heater power (W)	1030	1040 - 1080
Main magnet (T)	4.1	5.46

In order to operate KSTAR's gyrotron efficiently, an improved PSM type power supply and a control system capable of real time control are being developed. The waveform of the RF power to be injected in the different plasma scenarios has an influence on the HV power supply requirements. In order to stabilize plasma MHD instabilities, the EC H&CD RF power requires modulation at frequencies of up to ~5 kHz. The power system currently in use can not be modulated during a pulse. Recently, HVPS based on PSM technology is widely used in EC system. The storing energy of the PSM type power supply is much lower than other power supply. It is very important factor to gyrotron protection. The protection time and energy are less than 10us and 10J. Output voltage stability and ripple are less than 1% (<1%) and +/-200V (<200V). The output voltage is adjustable in 0.1kV increments. The HV switch should stop the high voltage fast, ensuring the limited arc energy inside the gyrotron tube. Fig 1 shows the HVPS scheme of new EC system. The power supply for the new EC system is focused on improving the performance of the power supply while simplifying its function. A new concept of control system has been developed to handle some of the functions of the new HVPS. In addition, this control system can control the output of the gyrotron in real time. The newly developed power supply and control system is easy for the user to access when the load changes or the equipment to be controlled changes. The new control system can adjust the power change or pulse length within same pulse. In addition, when a fault occurs due to noise, the power supply is retried to generate RF.

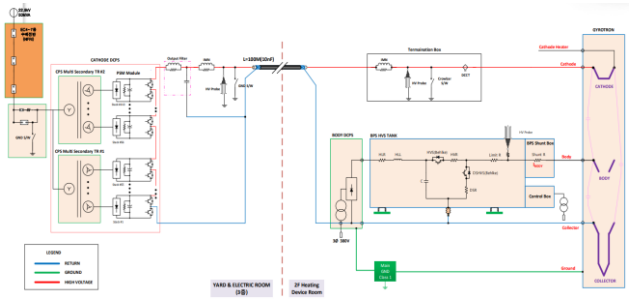

Fig. 1 Single line diagram of the PSM HVPS for 'EC4' gyrotron

In this paper, we will show you the details and test results of the new power supply and integrated control system applied for an efficient EC system.