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Preliminary operation of the upgraded Ohmic Heating system on the QUEST spherical tokamak

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Introduction

Effective current start-up methods have been established in spherical tokamak research. Compared to non-inductive methods, ohmic heating (OH) is classical and fundamental but still quite effective in heating and starting up plasma current in tokamaks. The loop voltage can be reduced with assist by Electron Cyclotron Heating (ECH).

To heat plasma further and achieve high electron temperature by electron Bernstein wave, an important step is to exceed the cut-off density depending on EC frequency. Over-dense plasma, of which electron density exceeds its cut-off density, was hard to be achieved by the OH system with single flux swing in the QUEST spherical tokamak. Hence, an upgrade OH system through double flux swing assisted by 28 GHz EC heating is applied to obtain higher plasma current and generate over-dense-plasma.

OH system

As shown in Fig. 1, the upgraded OH system can be equivalent to a transformer circuit. Two power supplies, the Positive Supply (PS) and the Negative Supply (NS), are connected to the Central Solenoid (CS) coil through two Insulated Gate Bipolar Transistor (IGBT) stacks, where a positive circuit (red lines) and a negative circuit (blue lines) are formed. The CS on the primary side is mimicked as a resistance R_{CS} and an inductance L_{CS}.

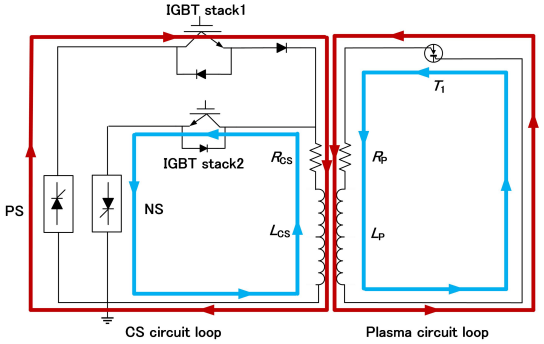

Fig. 1 OH power supply system

Plasma is assumed as the secondary side with R_P and L_P. The IGBT stacks as the switches changing the polarity of the current are installed between the power supplies and the CS. A diode is added on the PS side to avoid the current flow from NS. Using this circuit, the plasma current is produced with double flux swing.

The system is mainly controlled by Field Programmable Gate Array (FPGA) which handles the IGBT switching and ensures the safety of the upgrade OH system.

Experiment

The OH experiment was conducted with PS current I_{PS} = 3 kA and NS current $I_{NS} = -6$ kA. The waveforms of I_P and I_{CS} are shown in Fig. 2.

The PS power supply was turned on from 1.45 s to 2.35 s and NS power supply was working during 2.45 s to 4.00 s. The plasma current rose up at 2.34 s by I_{CS} ramp-down from 3 kA, and it reached 62 kA. By the NS current swing, the I_P is around 120 kA at around 2.7 s when the Ics reached -6 kA.

Summary

The upgrade OH system which performs double flux swing of the CS coil can achieve I_P over 100 kA. IGBTs are controlled by FPGA which protects the OH system in safe operation.

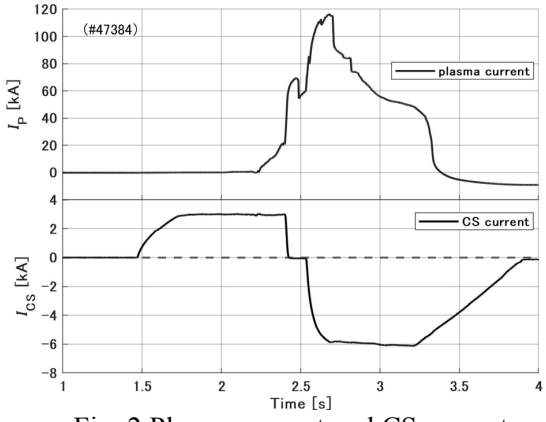

Fig. 2 Plasma current and CS current