§6. Voltage Enhancement of the DC Power Supplies of LHD Superconducting Coils

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The fundamental operation of the LHD is performed under the DC magnetic field, but in some situations such as start up of excitation, dynamic control of magnetic field will be required. With similar reason, the LHD operation requires dynamic control of magnetic field. For this purpose, the output voltages of power supplies are enhanced using additional pulse power supplies.

Figure 1 shows the circuit diagram of the IV power supply. The steady state power supply shows the current power supply and the pulse power supply means the additional one. As shown in figure, these two power supplies are connected in series and the both output voltages are induced to the coil. Because of the limitation of the operating current and time of the pulse power supply, two bypass switches are connected as shown. In the figure DS5 is a large current but slow operation switch and DS6 is medium current but quick operation switch. For the high magnetic field operation, which requires the higher current than 6.2kA, the DS5 is closed and the coil is excited by the steady state power supply only.

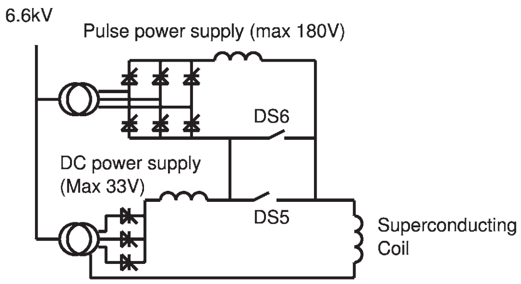

Fig. 1: Circuit diagram of the power supply for IVcoil.

At the low field operation, DS5 is opened and the pulse operation can be performed. When the high voltage is required in the plasma experiments, DS6 is turned off quickly then the pulse power supply is inserted in series and the coil current flows through the pulse power supply. The time delay to insert the pulse power supply is less than 1 s and is enough short for the plasma experiment.

The insertion sequence of the pulse power supply is shown in Figure 2. The sequence runs as follows;

a Before the pulse operation, the DS 6 is close and the pulse power supply generate negative voltage.

b When the signal to start of pulse operation is triggered, the pulse power supply generate the positive voltage, then I_c to pulse power supply from DS 6 and the current flowing DS 6 I_{sw} decrease to zero.

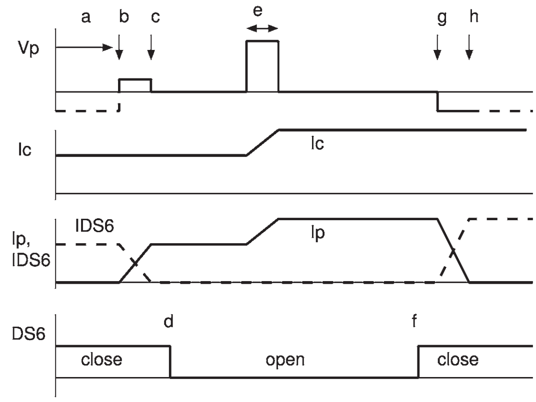

Fig. 2: Sequence of connection and disconnection of the pulse power supply.

[c] At this time, a reverse voltage for the series diode D is induced and D cut off.

d When I_{sw} becomes zero, DS 6 turned off and the pulse power supply output voltage is controlled to zero immediate.

Figure 3 show a sample of waveforms when the coil currents are swept using pulse power supplies.

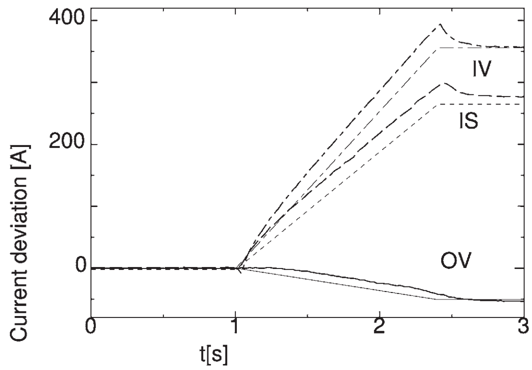

Fig. 3: Current change when the dynamic current control is performed.

In the figures, the thin lines mean the coil current references and the thick lines are actual coil currents, and there are offset between the reference and actual current for IV and IS coils when currents ramp up. The offset is about 40 A and it causes the overshoot at the end of ramp up. These current offsets are caused by the reaction of the induced current flowing in the plasma or strictures such as coil can or supporting shell of the LHD.

With the test results, it is confirmed that the dynamic connection sequence for the pulse power supply works as designed and the seamless current control has enough performance. The new power system is now works as powerful equipment for the dynamic plasma experiments.