POWER SUPPLY SYSTEM FOR KLYSTRON IN J-PARC LINAC

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Abstract

This paper describes the present status, technical specifications, operating experience, and upgrade plan for the power supply systems (PS systems) for the klystrons in the J-PARC (Japan Proton Accelerator Research Complex) linac. The PS systems include both the high voltage DC power supplies (DCPSs), which drives one or four modulating-anode klystrons each, and the anode-modulators, one per klystron. Currently, the energy output of the J-PARC linac is 181 MeV, which includes the energy necessary to run twenty 324 MHz klystrons. In 2012, the linac will add twenty-five 972 MHz klystrons and upgrade the energy output to 400 MeV.

INTRODUCTION

Since the first beam commissioning of the J-PARC (Japan Proton Accelerator Research Complex) linac [1] in November 2006 [2], all components of the linac have been operated continuously during the beam commissioning runs. If the rate of linac operation is to increase, the components must be highly reliable.

Klystrons [1]-[4] are the high-power (more than 100 kW) rf source of the linac. These klystrons have an rf output power of 3 MW, a cathode voltage of 110 kV, and a beam duty-factor of 3.5 % (700 μs × 50 pps), and they use modulating-anode-type electron guns.

The power supply systems (PS systems) [1]-[3],[5][6] for the klystrons in the J-PARC linac are based on the power supply for the JHP (Japanese Hadron Project) linac [7] built at KEK Tsukuba Campus in 1989.

SYSTEM CONFIGURATION AND TECHNICAL SPECIFICATIONS

In the upgraded J-PARC 400 MeV linac, twelve 324 MHz klystrons (TOSHIBA, E3740A) and twenty-five 972 MHz klystrons (TOSHIBA, E3766) will be used as RF sources. The 324 MHz klystron will feed the RF power to RFQ, DTLs, and SDTLs (separated-type drift tube linacs); the 972 MHz klystrons will feed to bunchers, ACSs (annular coupled structure linacs) and debunchers.

Figure 1 shows the configuration of the PS system in the 400 MeV linac [8].

Each DC power supply (DCPS) drives one or four klystrons, applying DC power to the cathodes of the klystrons; each anode-modulator drives one klystron, applying pulse power to its modulating-anode. Twelve DCPSs (DCPS1-12) and 45 anode-modulators (M1-45) will be included in the 400 MeV linac.

Table 1 lists the technical specifications of the DCPSs. The type-A DCPSs (DCPS2-5), which are currently in operation as components of the 181 MeV linac, will comprise the low energy part of the 400 MeV linac. The type-B DCPSs (DCPS7-12), which are under construction now, will be in high energy part of 400 MeV linac. The high energy DCPSs (type-B, power output 748 kW) will have larger capacitor banks (28.8 μF rather than 25.5 μF) as they will need to apply power to the klystrons than the low energy DCPSs. DCPS12 will drive one klystron of the 400 MeV linac, which will be used as test stands.

Of the four outputs of DCPS1, three (DTL1-3) have

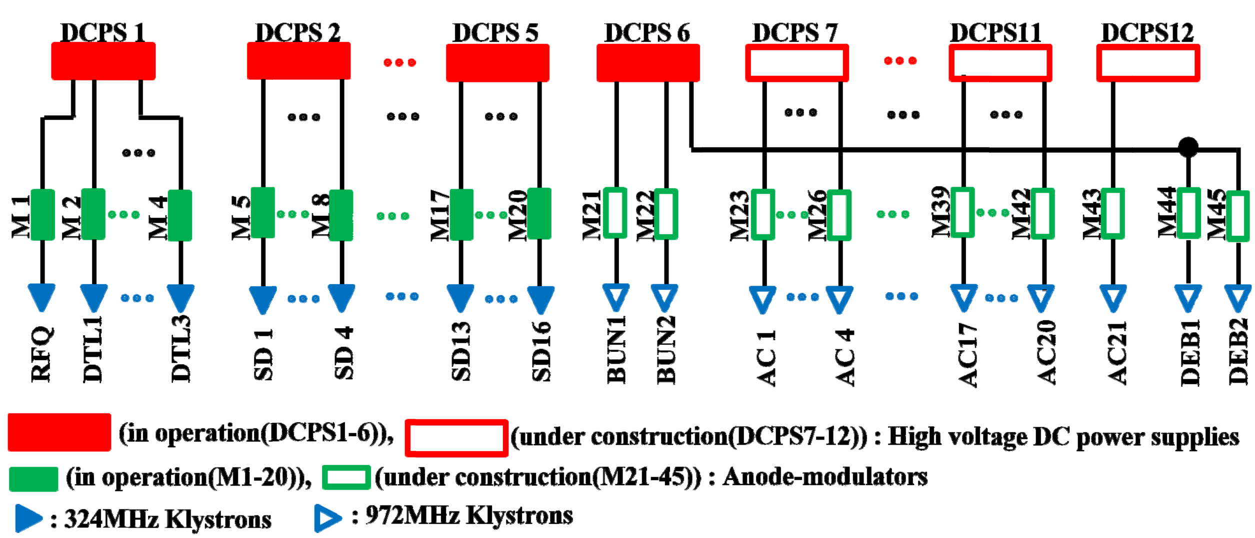

Figure 1: Configuration of power supply system for klystrons in J-PARC 400MeV linac.

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Table 1: Specifications of DCPSs

	Type-A	Type-B
DCPSs	DCPS2-5	DCPS7-12
Number of klystrons	4	
Cathode voltage (kV)	110	
Average of current (A)	6.3	6.8
Power (kW)	693	748
Pulse current (A)	180	200
Pulse width (μs)	700	
Repetition rate (pps)	50	
Duty-factor (%)	3.5	
Voltage sag (%)	5	
Capacitor bank (μF)	25.5	28.8

a 110 kV maximum and one (RFQ) has an 80 kV maximum. DCPS6 has four outputs with 80 kV maximums,

Figure 2 shows the schematic diagram of an anode-modulator (M1-20). In order to shield the anode-modulator from extraneous electromagnetic inputs, almost all of the components are installed in an oil tank, with outer dimensions of 1230 mm × 1020 mm × 1505 mm. The pulse-on-signals, which widths are from 100 μs to 800 μs, are received in the drive unit through an optical cable and cause the FET switch to be closed. When the switch closes, the cathode voltage is divided between resistors of 93 kΩ and 17 kΩ, a potential difference occurs between the cathode and the modulating-anode, and the klystron beam current flows.

In order to adjust the specifications of the new klystrons and to apply the larger power needed, the new anode-modulators (M21-45), will have the 17 kΩ (7 kΩ, 29.2 kΩ changeable) resistor changed to 12.47 kΩ (7.2 kΩ, 3.1 kΩ changeable) resistor. This change is necessary to adjust the specifications of the klystrons and to apply larger power to them.

Figure 3 shows the photos of the components.

PRESENT STATUS AND OPERATING EXPERIENCE

Before the beam commissioning of the J-PARC 181 MeV linac in November 2006, the PS system had operated for conditioning of the klystrons and the accelerating cavities [6]. The total operation time (high-voltage-ON time) of the PS system is more than 14900 h. The total operating time of the J-PARC accelerator during the last three runs (Run32-34, from April to June 2010) was 1908.1 h. Since the failure time due to the breakdown of the PS system was less than 9.0 h, the failure rate of the PS system is less than 0.47 %.

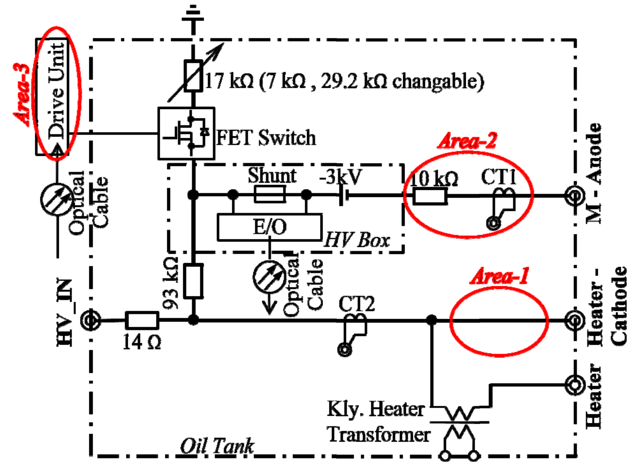
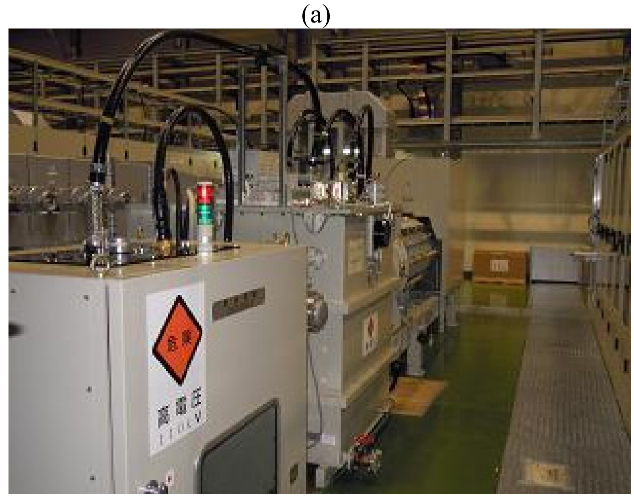


Figure 2: Schematic diagram of anode-modulator (M1-20).

(a)



(b)

Figure 3: Photos of components. (a) DC power supply. (b) (From left to right) DISCON switch, anode-modulator, 324 MHz klystron. The control cabinets are at the right end.

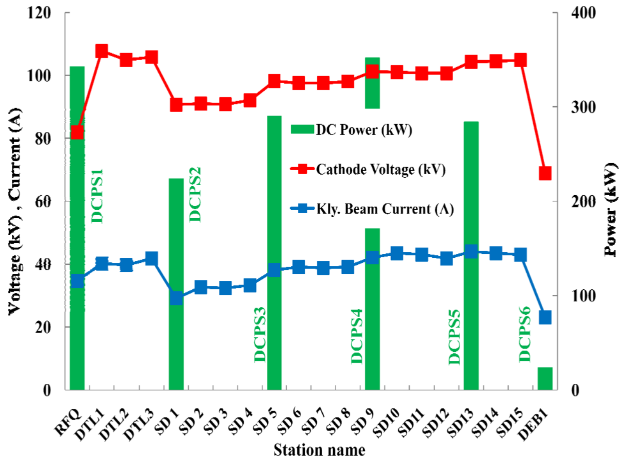


Figure 4: The Sample data of 181 MeV linac, operating on June 28, 2010. DCPS5 drives three klystrons (SD13-15), and DCPS6 drives one 324MHz klystron (DEB1).

Figure 4 shows the cathode voltages, the klystron-beam currents, and the DC powers for a run on June 28, 2010. In the 181 MeV linac, DCPS5 drives three klystrons (SDTL13-15 and M17-19), and DCPS6 drives one 324 MHz klystron (DEB1, M20). The repetition is 25 pps, and the total output power of the PS system is 1.52 MW.

In past operation, we experienced breakdowns in the anode-modulators because of various reasons; Figure5 shows one case. The breakdown point was Area-1 in Figure 2. The copper bar was covered by a thin polyethylene pipe and could discharge traces between the polyethylene surface and the inner surface of the oil tank of the anode-modulator, resulting in frequent breakdowns during operation.

Breakdown also occurred in Area-2; the circuit connected to the 10 kΩ resistor and passed through the CT1 (current transformer, Stangenes 3.5 - 0.1 Model or Pearson 3025 Model) needed more distance to insulate it

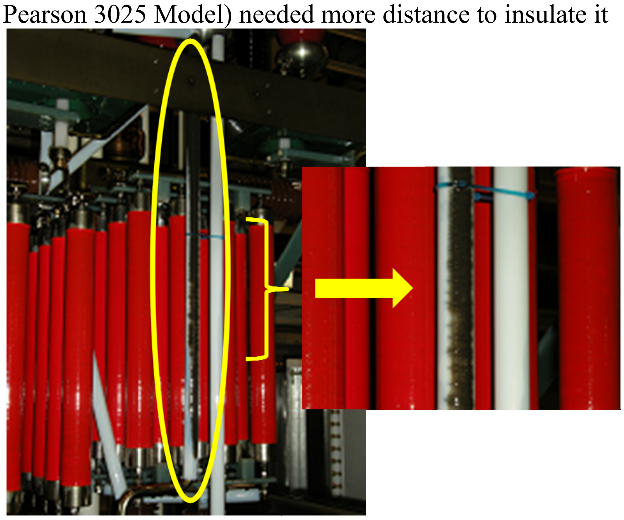


Figure5: Discharge traces in anode-modulator oil tank (in Area-1 of Figure 2).

from the other components in the oil tank. As a consequence, frequent discharge waves were observed on oscilloscopes during operation and discharges traces were observed when the oil tank was opened.

In addition to these two issues, all the anode modulators showed corrosion by ozone in the drive units (Area-3).

To remedy these anode-modulator-related problems, we thoroughly reviewed the arrangement of components with a focus on saving, or increasing, the insulation distance [8]. In the drive units, we made holes through the unit boxes for ventilation and changed the type of some components.

UPGRADE PLAN

All components of the PS system for the upgrade plan have been manufactured and positioned in the J-PARC linac building. Since the 181 MeV linac is operated almost every day except during a three-month summer shutdown, the high-power test of the PS system will begin in October 2011, after the wiring and piping work. The operation of the new klystrons will begin in November 2012.

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