New Power Supply For Bending Magnets In J-PARC Main Ring

J-PARC Main Ring Magnet & PS Group
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Introduction

J-PARC & Main Ring
Strategy for high power beam
Requirement of the PS for high power beam

New power supply
Schematic view
Status
Operation of 1st PS for Q magnet
Commissioning of 1st PS for B magnet
Introduction J-PARC and Main Ring

J-PARC : Japan Proton Accelerator Research Complex

- **MR feature**
  - **Injection/Extraction Energy**: 3 GeV/30 GeV
  - **Operation mode**: Fast(neu) / Slow(had)
  - **Beam power**: 500 kW(neu)/50 kW(had)

We plan to achieve more than 750 kW with fast extraction until 2022
Strategy for high power beam

Beam power $\propto \frac{\text{# of proton} \times \text{proton energy}}{\text{Repetition cycle}}$

Repetition cycle ↓ = Beam power ↑

<table>
<thead>
<tr>
<th>Repetition cycle (s)</th>
<th>beam power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>current 2.48</td>
<td>500</td>
</tr>
<tr>
<td>future 1.3</td>
<td>&gt;750</td>
</tr>
</tbody>
</table>
Requirements for the power supplies

We develop new power supply.

Output voltage

Limitation of the current PS system.

\[ V = L \frac{dI}{dt} + RI \]

replace power supply

\[ P = VI = L \frac{dI}{dt}I + RI^2 \]

return to energy storage

twice

remove

We develop new power supply.
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Schematic view

Capacitor bank (Energy storage)

AC/DC converter

DC/DC converter

Filter

magnets

Single unit

IGBT(CM1200HC-66H)

high reliable model

Characteristics of PS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>10 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>1600 A</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Water flow</td>
</tr>
</tbody>
</table>
Schematic view

AC/DC converter

DC/DC converter & Filter
Schematic view

AC/DC converter

DC/DC converter & Filter

Converter units

Interlock boards

Water flow monitor
Monitor & control boards are full digitized, and optically connected.
Schematic view

Capacitor bank (2bank/1container)

Characteristics of 1 bank

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance</td>
<td>480 mF</td>
</tr>
<tr>
<td># of capacitor</td>
<td>96</td>
</tr>
<tr>
<td># of fuse</td>
<td>24</td>
</tr>
</tbody>
</table>

Isolated from the ground
Summary of the design

6 high-reliable converter is connected in series
-> High output voltage

Capacitor bank
-> Low power variation

Full digitized boards & optical connection
-> Low noise
Introduction

J-PARC & Main Ring

Strategy for high power beam

Requirement of the PS for high power beam

New power supply

Schematic view

Status

operation of 1st PS for Q magnet

commissioning of 1st PS for B magnet
1st PS for QM

Used in the beam operation from Oct. 2016. 1/6 of BM PS, no C-Bank.

AC/DC converter  DC/DC converter  Filter

FFT of current ripple

The noise is reduced by one order at less than 200 Hz. \( \rightarrow \) Becomes negligible to the beam operation.
1st PS for QM, failure 1

Voltage monitor was broken within 2-4 week.

Rated voltage of the DCCT was not enough. → Replace the DCCT.

<table>
<thead>
<tr>
<th></th>
<th>Condition of endurance test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old DCCT</td>
<td>4.2 kV, 50 Hz, 1 min</td>
</tr>
<tr>
<td>New DCCT</td>
<td>9 kV, 50 Hz, 1 min</td>
</tr>
</tbody>
</table>

DCCT

Rated voltage of the DCCT was not enough. → Replace the DCCT.
1st PS for QM, failure 2

- Output oscillated in the regeneration control and interlock worked.
  - In the holiday morning or high repetition operation test.
  - Add the reactor of 20 μH and tune feedback parameters.
  - The over current/voltage has not occurred after the improvements.

There have been no other failures.
Connection & operation test of all Interlock systems were done. Charging & dis-charging tests for all components were done.

<table>
<thead>
<tr>
<th>Component</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC/DC converter</td>
<td>full</td>
</tr>
<tr>
<td>CBank</td>
<td>half</td>
</tr>
<tr>
<td>DC/DC converter</td>
<td>full</td>
</tr>
<tr>
<td>load</td>
<td>dummy(0.05H, 1/35 of magnets)</td>
</tr>
</tbody>
</table>
1st PS for BM

We successfully carried out continuous running for 8 hours. Next step: Continuous running with full C-Bank and bending magnets.

Work of the connections are on going. We will start commissioning from next Nov.

I_{out}, V_{P-G}, V_{G-N}: **Half** of the rated value.
Summary

• Achieve more than 750 kW by shortening the repetition cycle. → We need the new power supply to satisfy the requirement of the output voltage and the power variation.

• We developed the power supplies with high output, low power variation, and low noise.

• 1st new PS for QM has been well working.

• The commissioning of the 1st PS for BM is on going.
  • The commissioning with full components will start next Nov.

• All PS will be available until 2022.
Appendix
Input voltage pattern to DC/DC converter not connected to AC/DC converter.
Reference pattern

AC/DC converter

DC/DC converter not connected AC/DC converter

Iref pattern for DC/DC converter connected AC/DC converter