

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

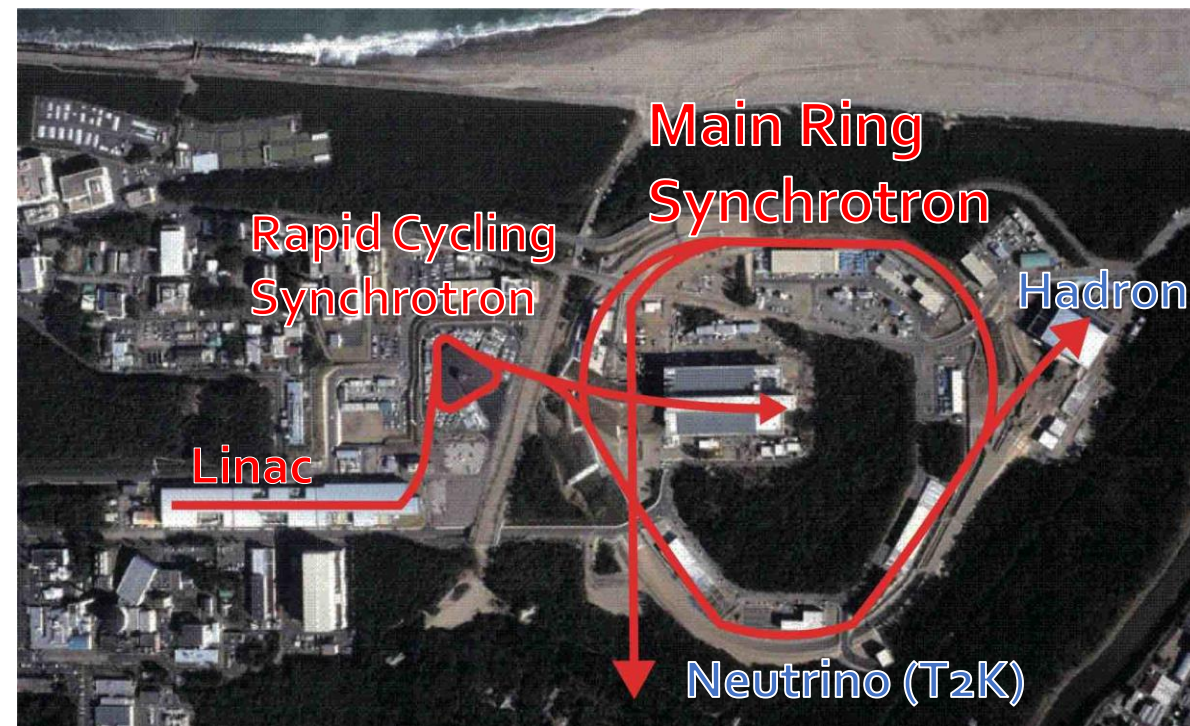
Status

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

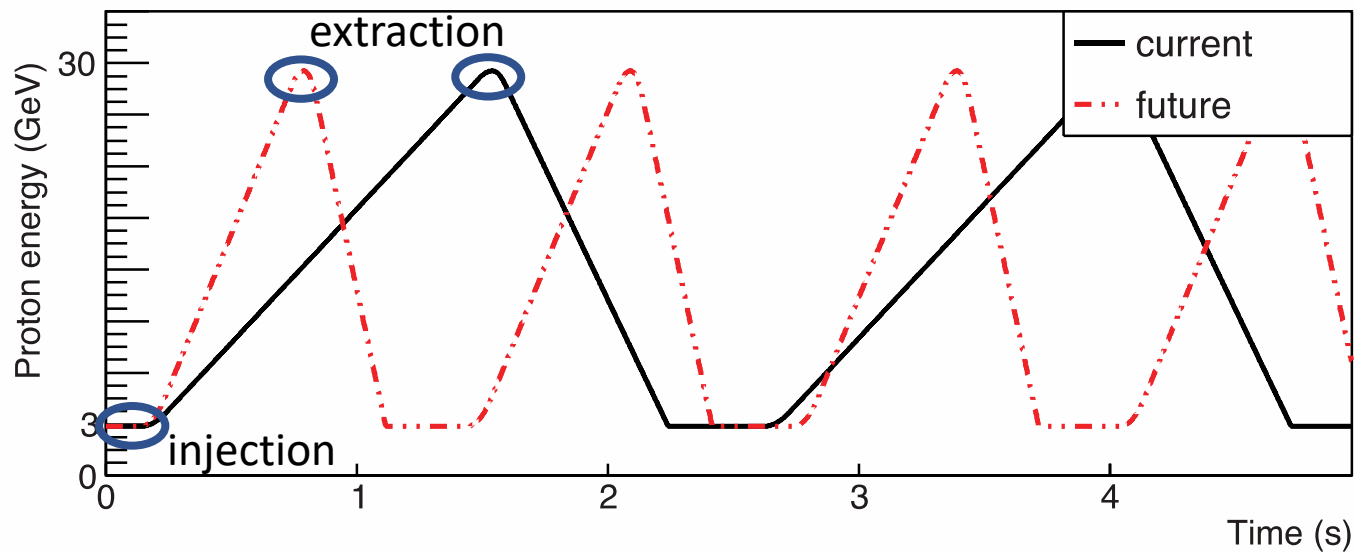
Injection/ Extraction Energy	3 GeV/ 30 GeV
Operation mode	Fast(neu) / Slow(had)
Beam power	500 kW(neu)/ 50 kW(had)

We plan to achieve more than 750 kW with fast extraction until 2022

Strategy for high power beam

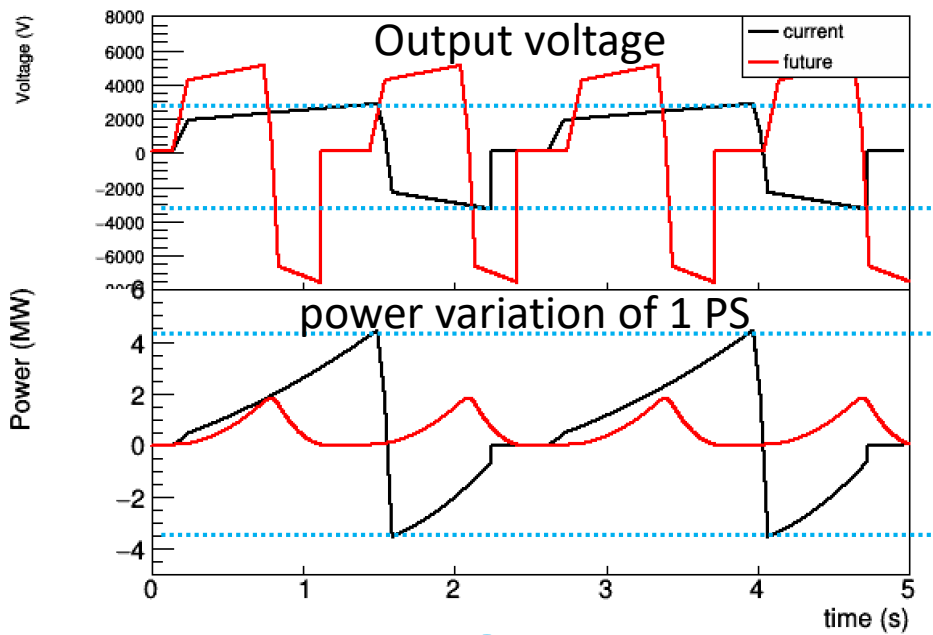
$$\text{Beam power} \propto \frac{\# \text{ of proton} \times \text{proton energy}}{\text{Repetition cycle}}$$

Repetition cycle ↓ = Beam power ↑



	Repetition cycle (s)	beam power (kW)
current	2.48	500
future	1.3	>750

Requirements for the power supplies



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

We develop new power supply.

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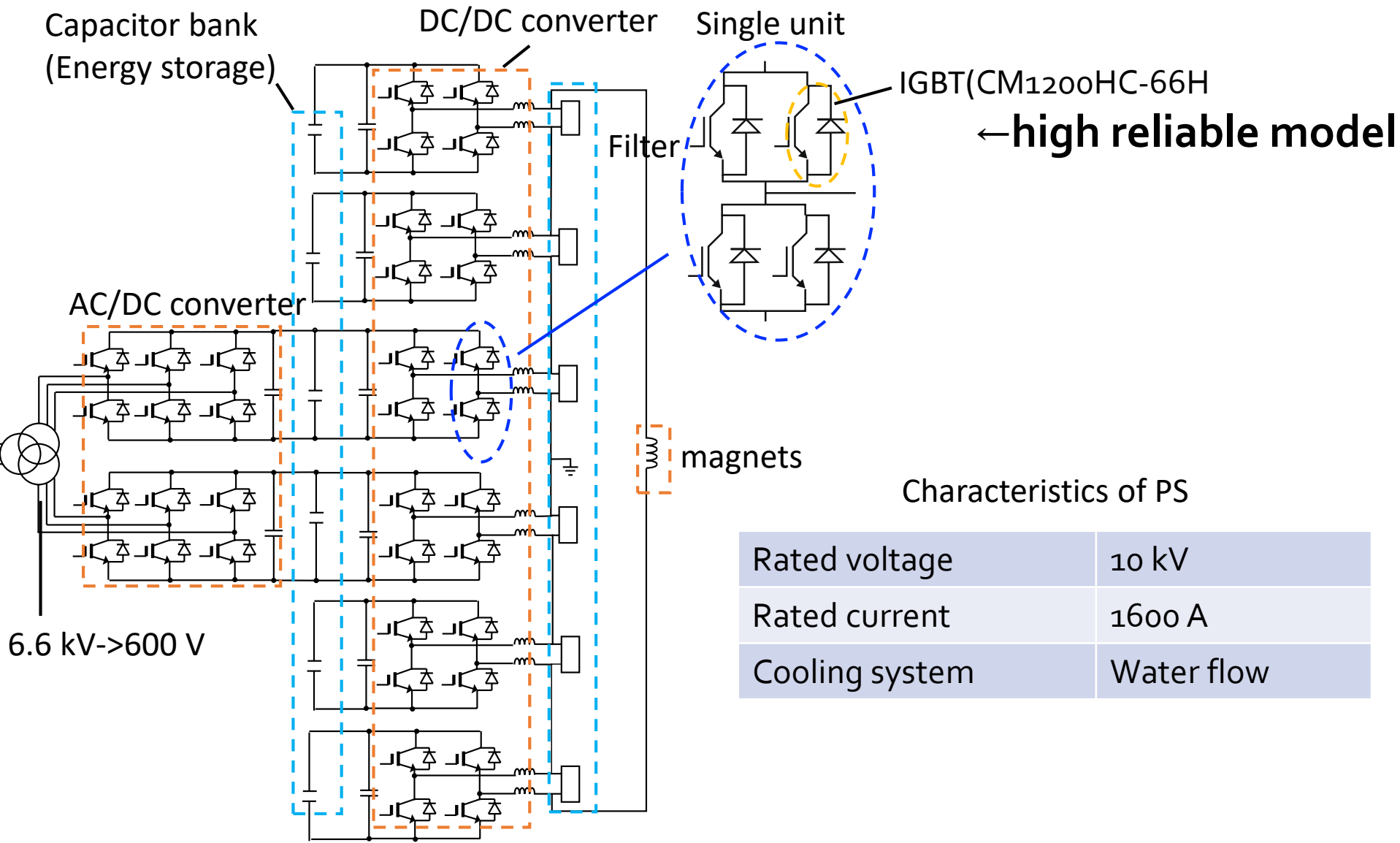
Schematic view

Status

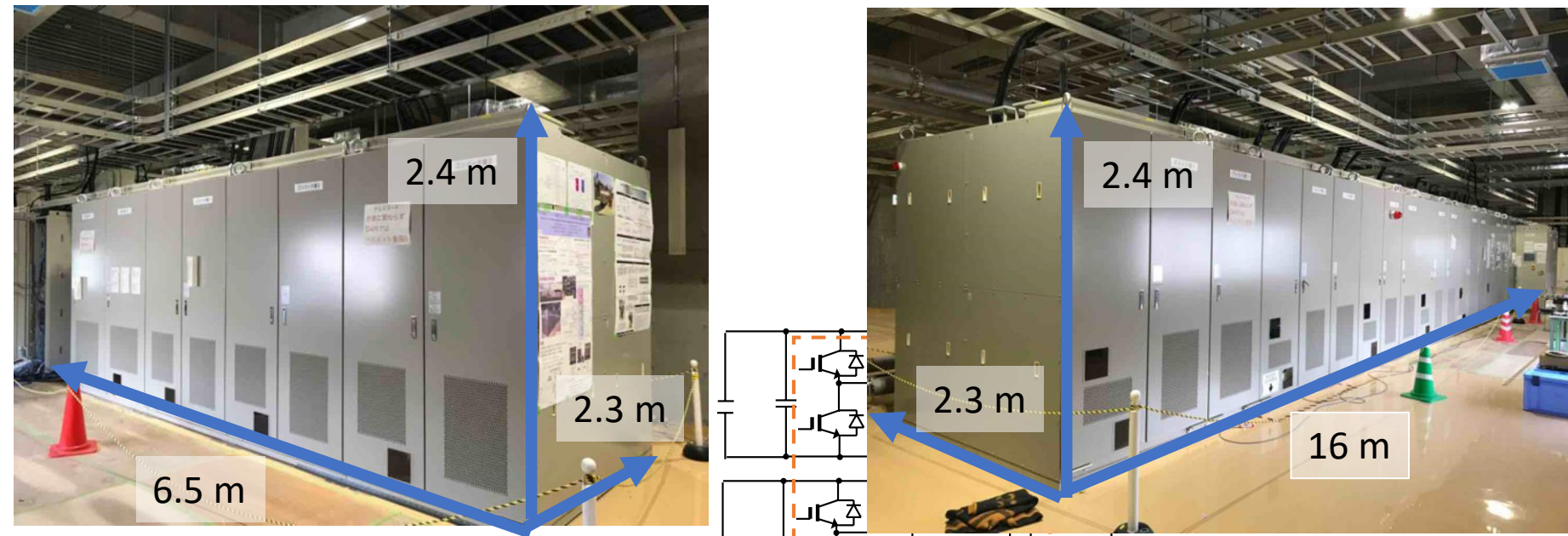
operation of 1st PS for Q magnet

commissioning of 1st PS for B magnet

Schematic view

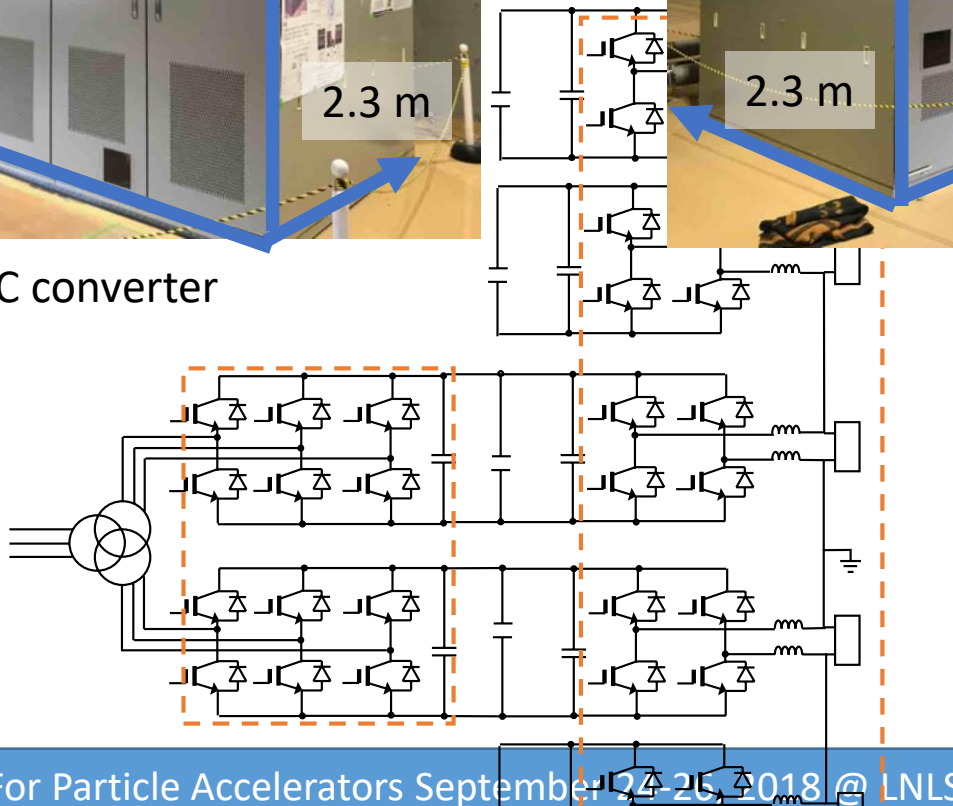


Schematic view



AC/DC converter

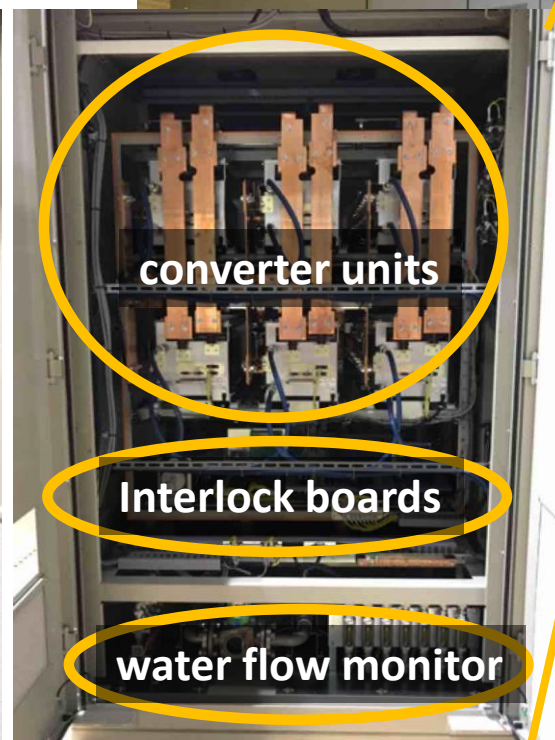
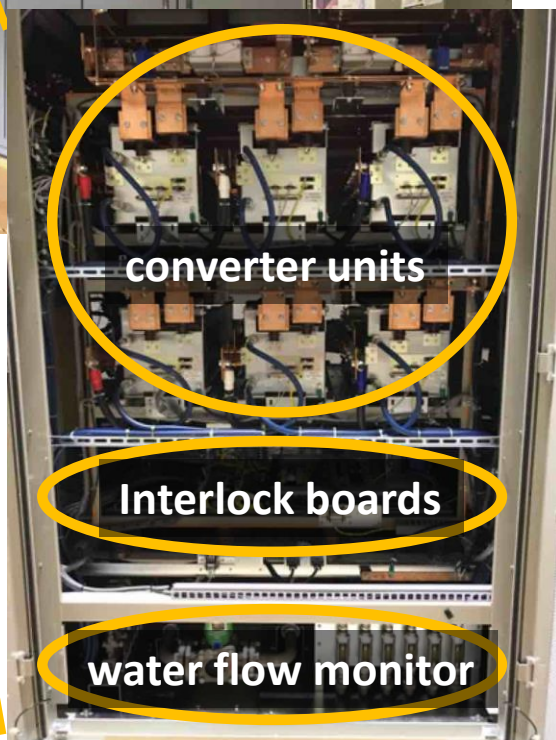
DC/DC converter & Filter



Schematic view

AC/DC converter

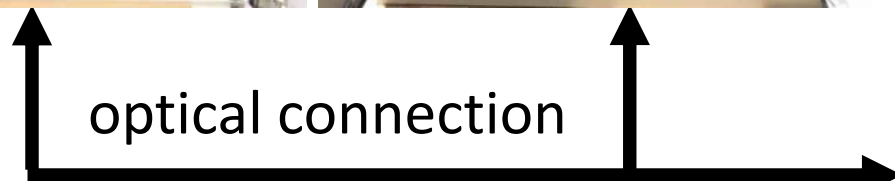
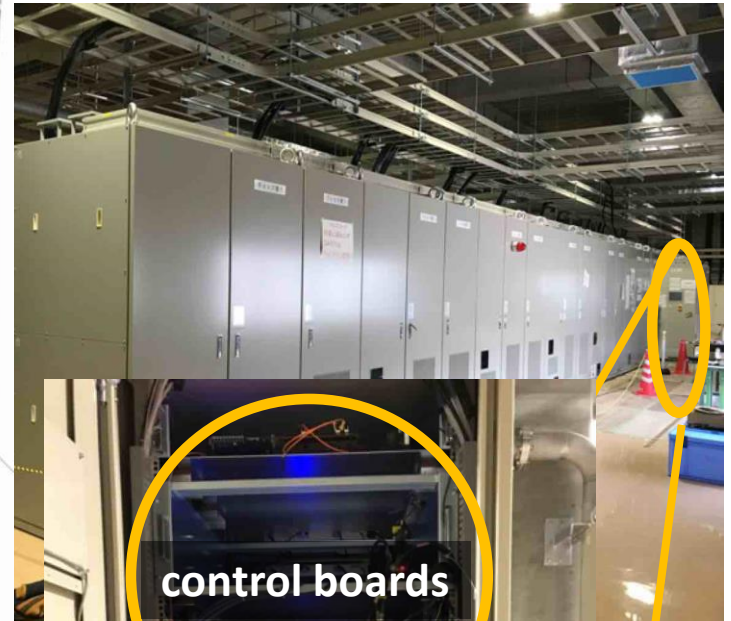
DC/DC converter & Filter



Schematic view

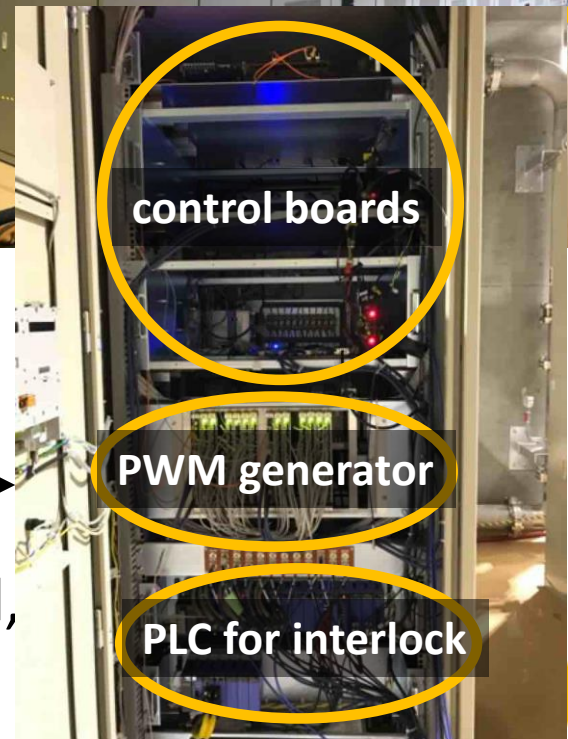


DC/DC converter & Filter



optical connection

Monitor & control boards are full digitized,
and optically connected.



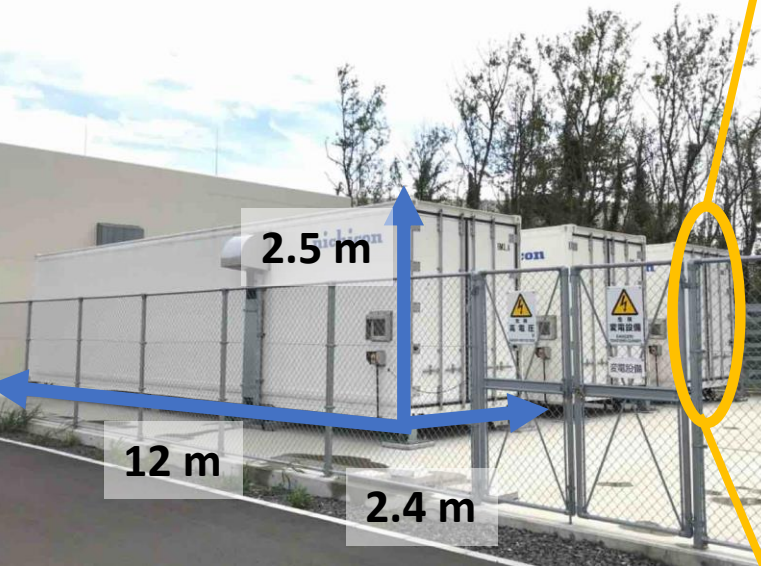
control boards

PWM generator

PLC for interlock

Schematic view

Capacitor bank
(2bank/1container)

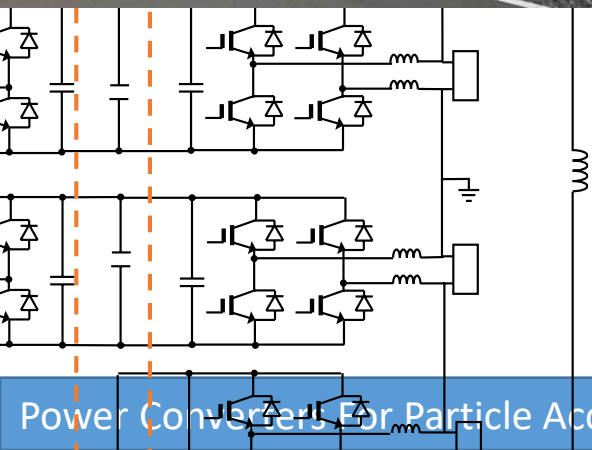
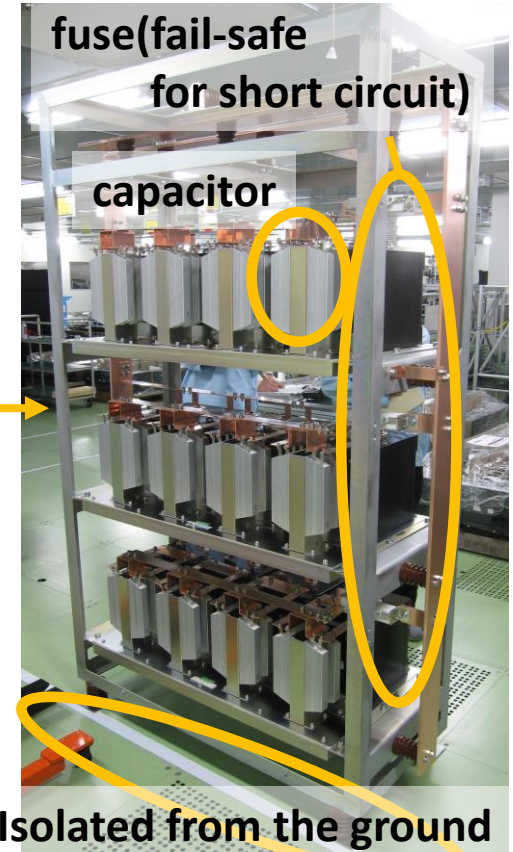


front view



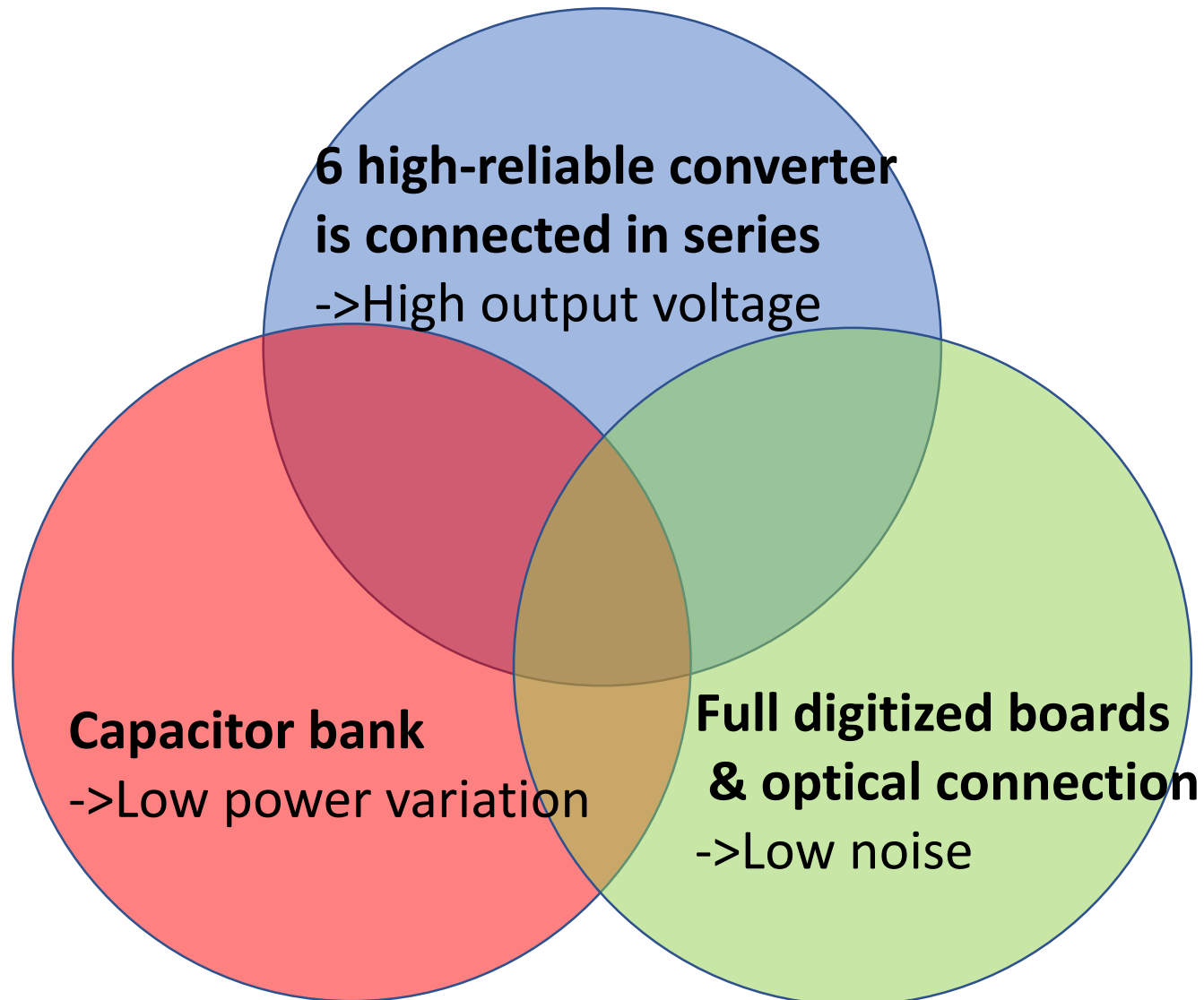
characteristics of 1 bank

capacitor module
fuse(fail-safe
for short circuit)



capacitance	480 mF
# of capacitor	96
# of fuse	24

Summary of the design



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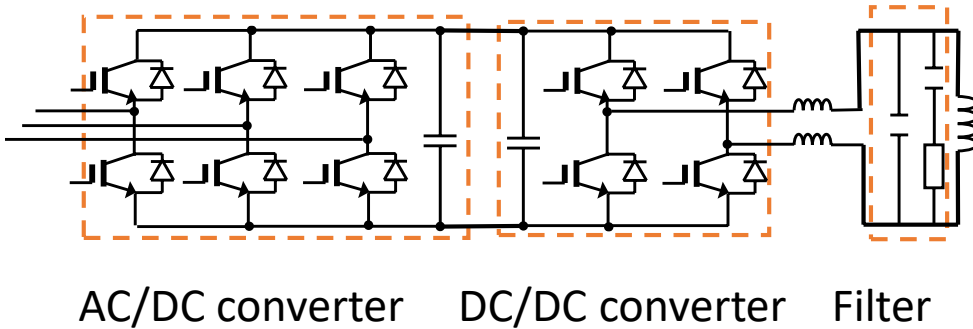
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operation of 1st PS for Q magnet

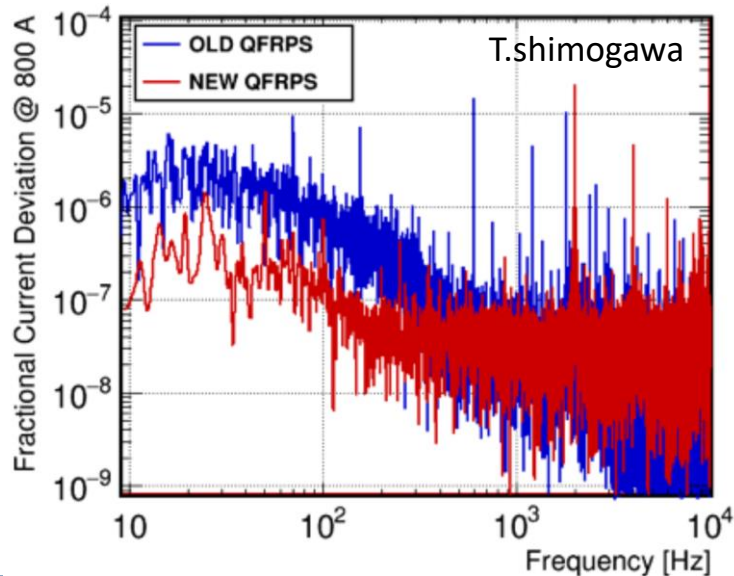
commissioning of 1st PS for B magnet

1st PS for QM

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



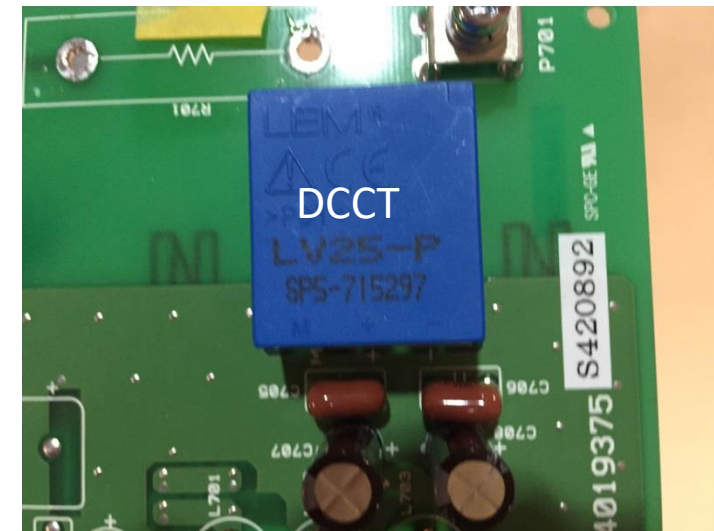
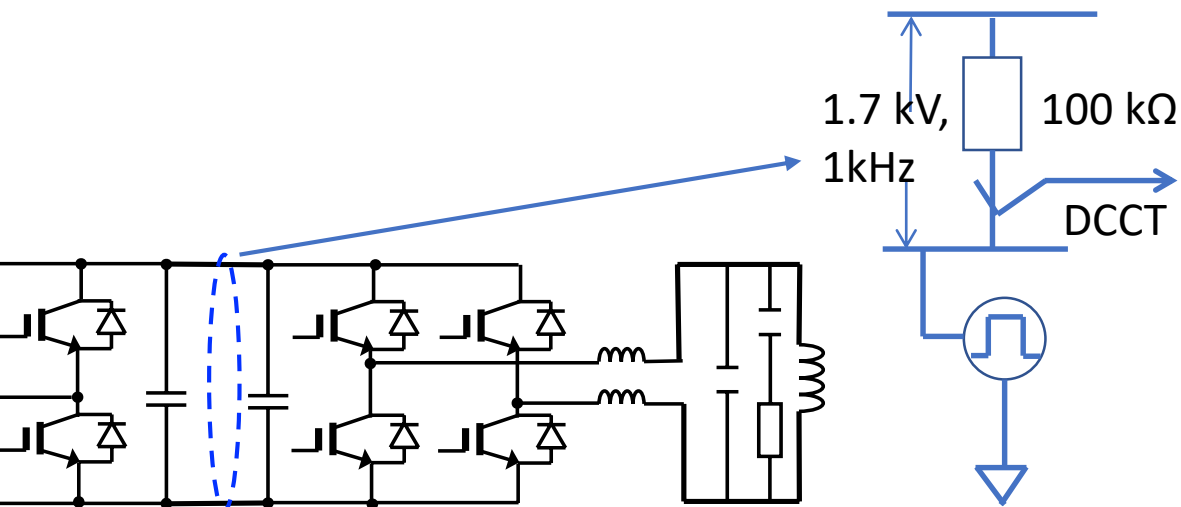
FFT of current ripple



The noise is reduced by one order at less than 200 Hz.
→ **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.

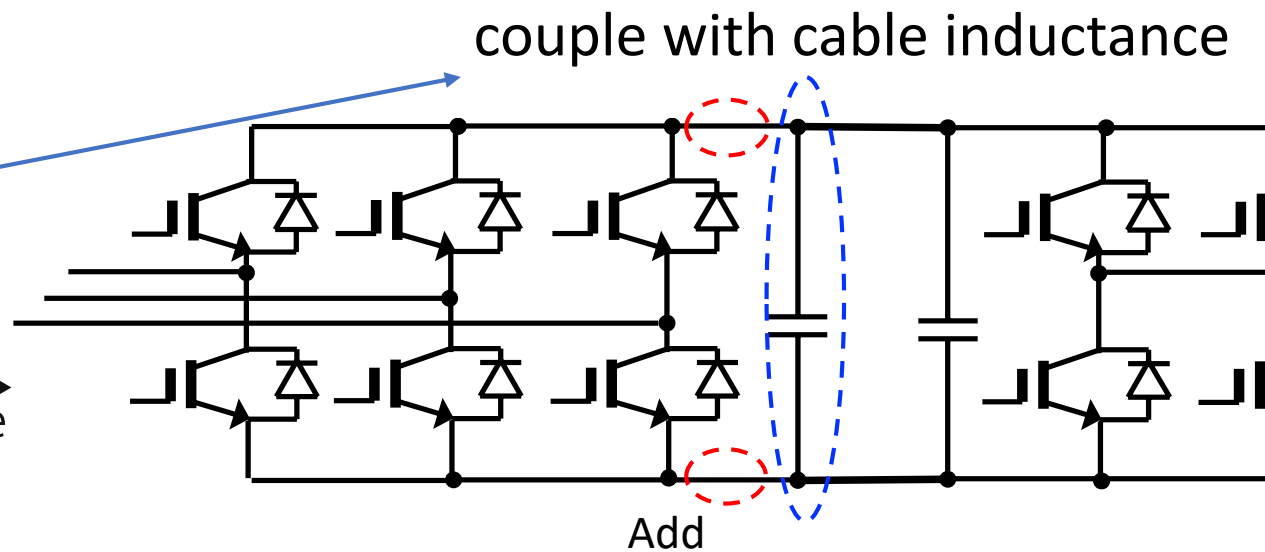
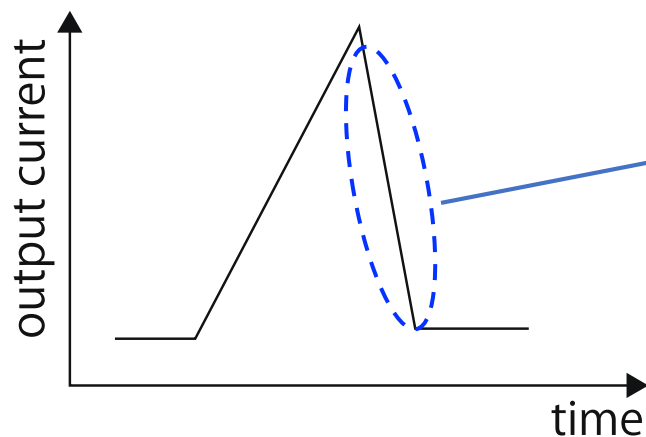
→ Replace the DCCT.

	Condition of endurance test
Old DCCT	4.2 kV, 50 Hz, 1 min
New DCCT	9 kV, 50 Hz, 1 min

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 $20\ \mu\text{H}$ and tune feedback parameters.
 - The over current/voltage has not occurred after the improvements.

current cycle of PS



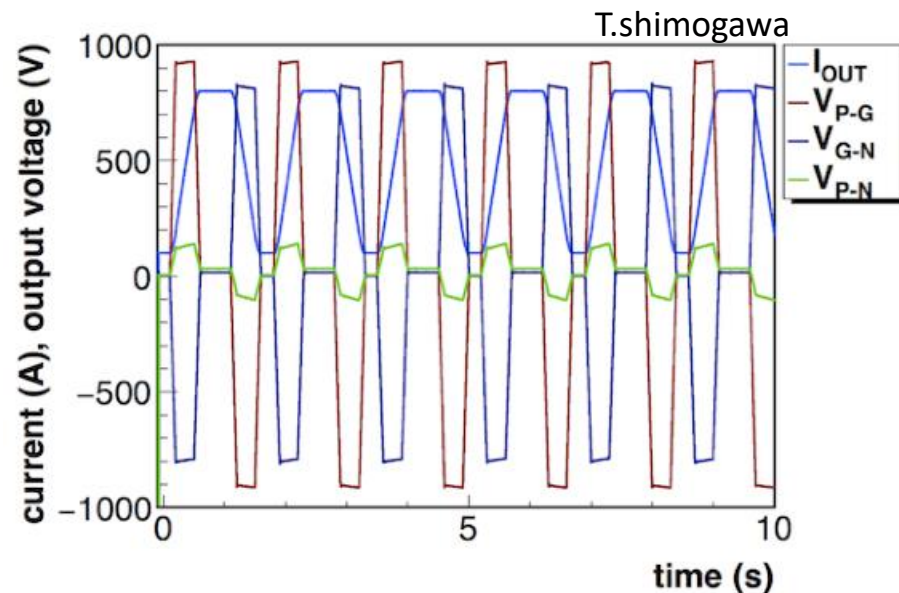
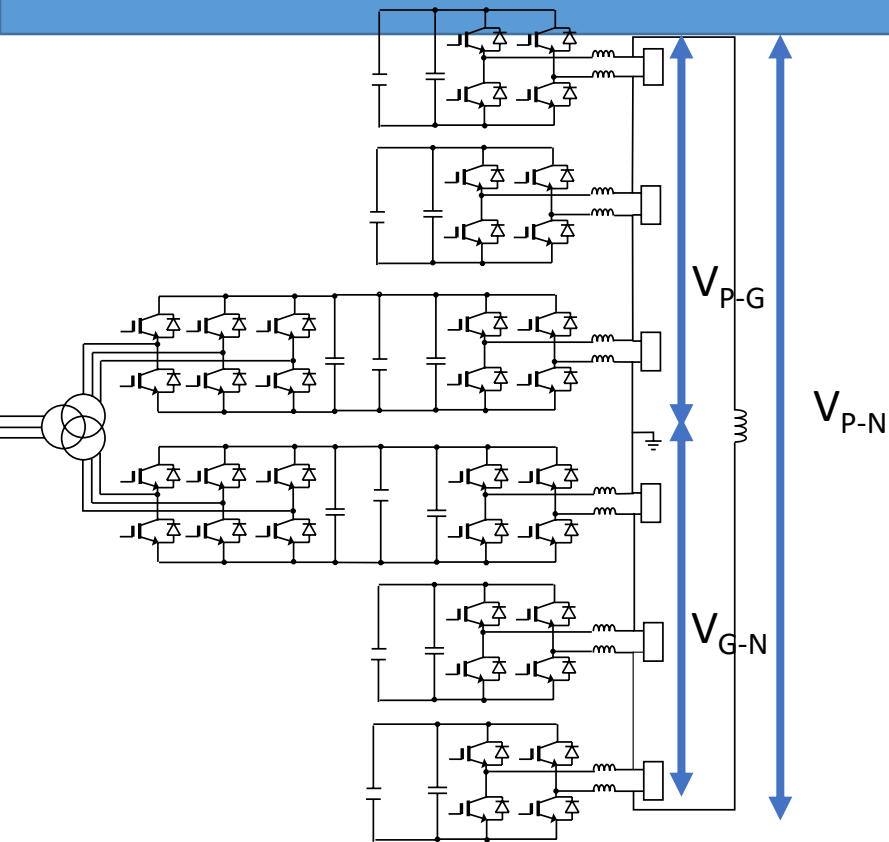
There have been no other failures.

Current configure

Component	Connection
AC/DC converter	full
CBank	half
DC/DC converter	full
load	dummy(0.05H, 1/35 of magnets)

Connection & operation test of all Interlock systems were done.
Charging & dis-charging tests for all components were done.

1st PS for BM



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

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.

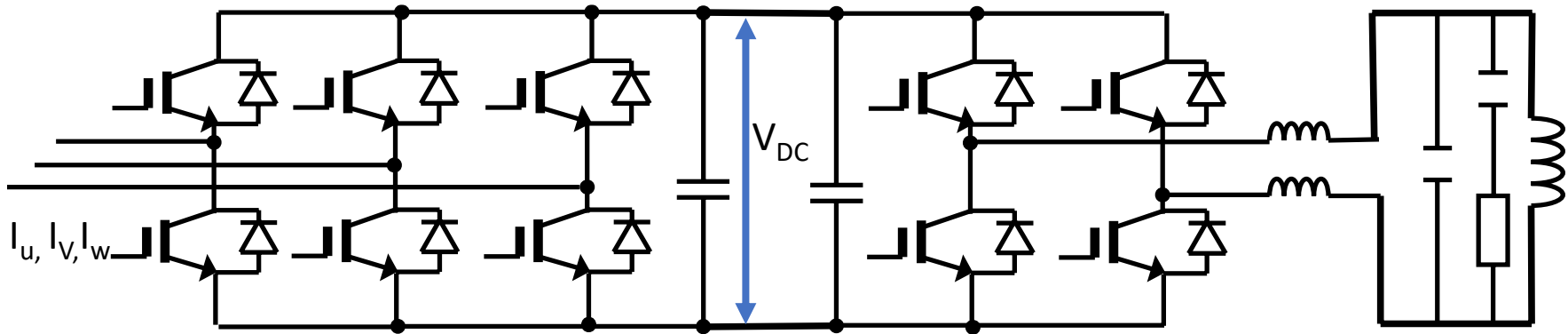
We will start commissioning from next Nov.

Summary

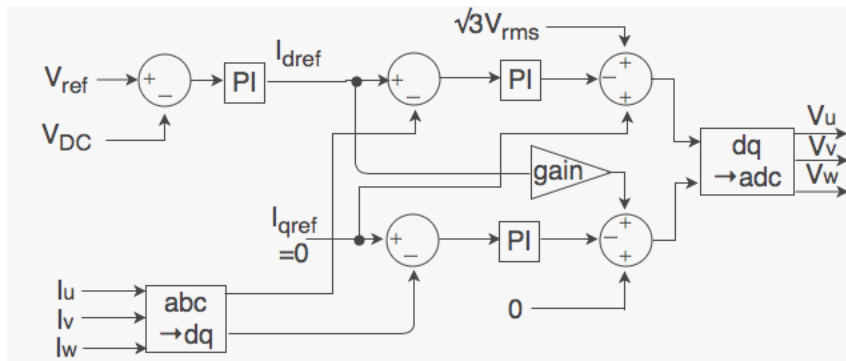
- Achieve more than 750 kW by shortening the repetition cycle.
→ We need the new power supply to satisfy the requirement of the output voltage and the power variation.
- We developed the power supplies with high output, low power variation, and low noise.
- 1st new PS for QM has been well working.
- 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

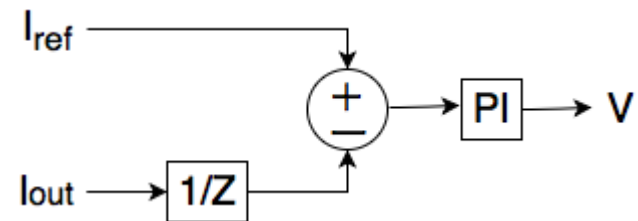
Control of converters



control of AC/DC converter



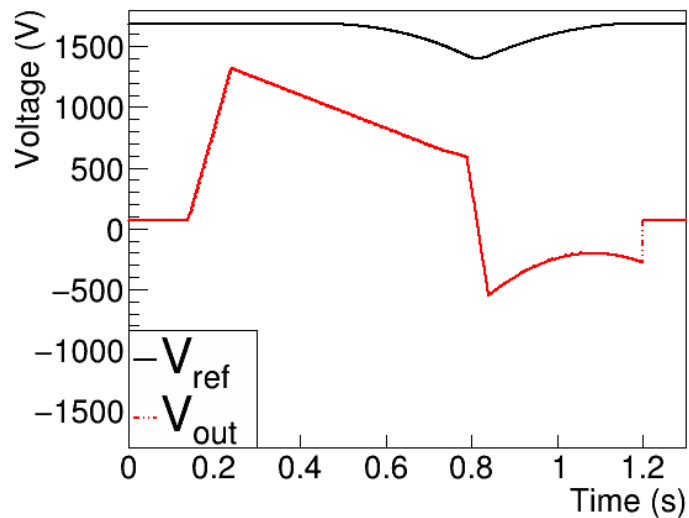
control of DC/DC converter connected to AC/DC converter



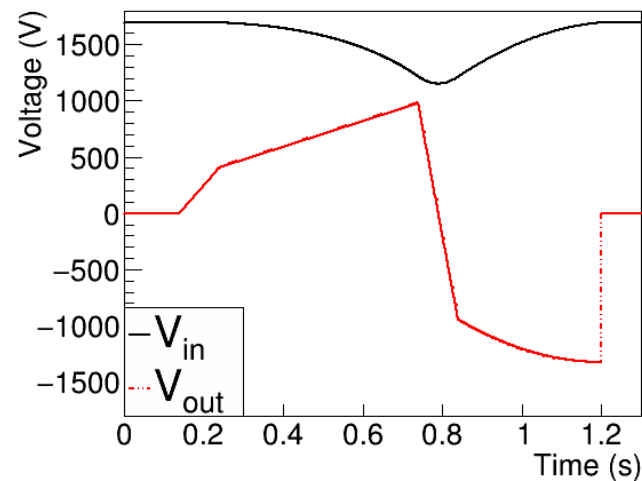
Input voltage pattern to DC/DC converter not connected to AC/DC converter.

Reference pattern

AC/DC converter



DC/DC converter not connected AC/DC converter



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

