

Development of new power supplies for J-PARC MR upgrade

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J-PARC Main Ring (MR)



Circumference	1568 m
Injection Energy	3 GeV
Extraction Energy	30 GeV
Repetition Rate	0.4 Hz
RF Frequency	1.67-1.72 MHz
Number of bunches	8
Synchrotron tune	0.0025-0.0001
Betatron tune	22.4, 20.75

Proton beam is provided by 2 different extraction modes

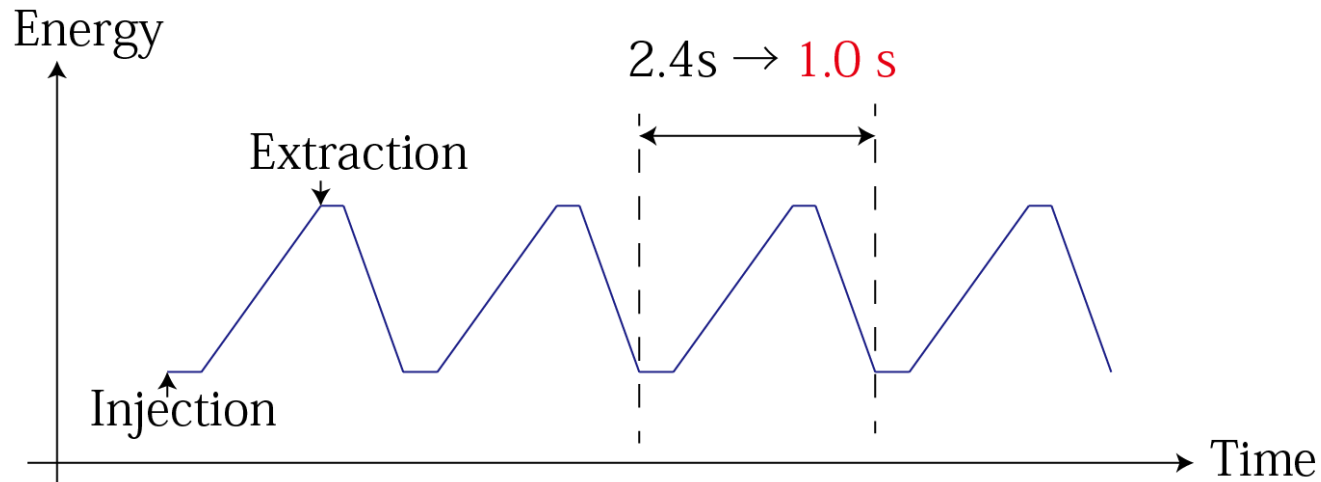
Fast Extraction : Long baseline neutrino oscillation experiment (T2K)

Slow Extraction : Hadron and Nuclear physics experiments

The current intensity is up to 250 kW (Fast Extraction)

Upgrade toward 750 kW Operation

Increasing Repetition Rate from 0.4 Hz to 1 Hz

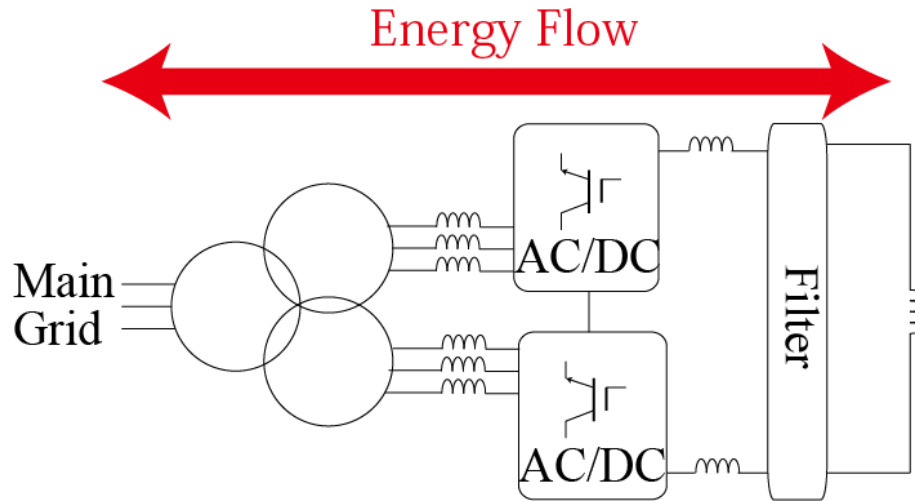


Requirement for new Power Supply

	Current PS	New PS
Output Voltage	3 kV	6 kV
Output Current	1560 A	1560 A
Output Power	5 MW	10 MW
Rep. Period	2.5 s	1.0 s

Energy Storage

Current Power Supply



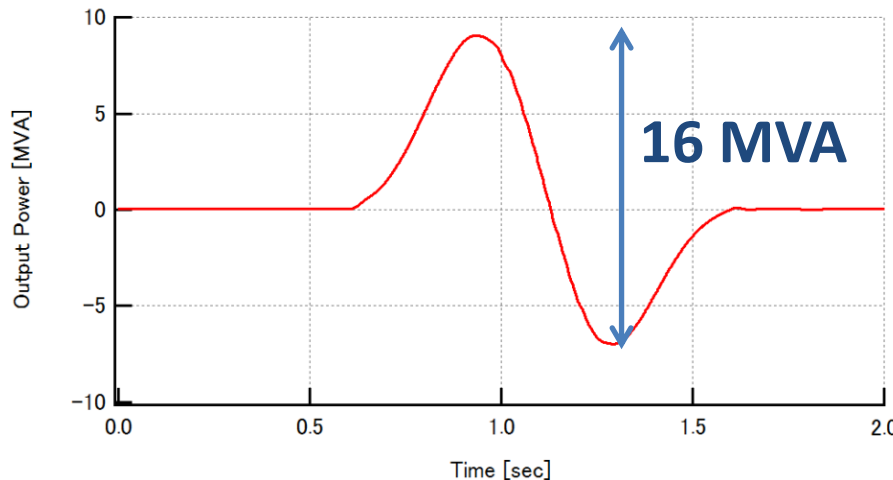
- Only one converter between load and main (current-type converter)
- No Energy Storage



Output Power = Power at main

Output Power Variation @ 1 Hz Operation

Output Power of the PS for **one** Bending magnet family



for all Bending Families

Output Power Variation
= 96 MVA

not allowed at main !!



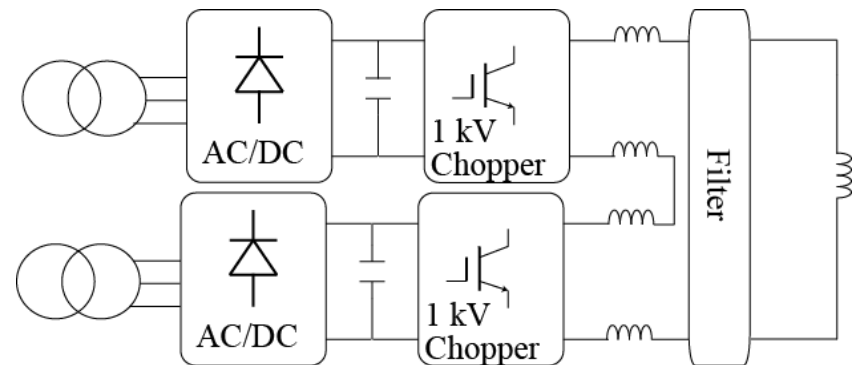
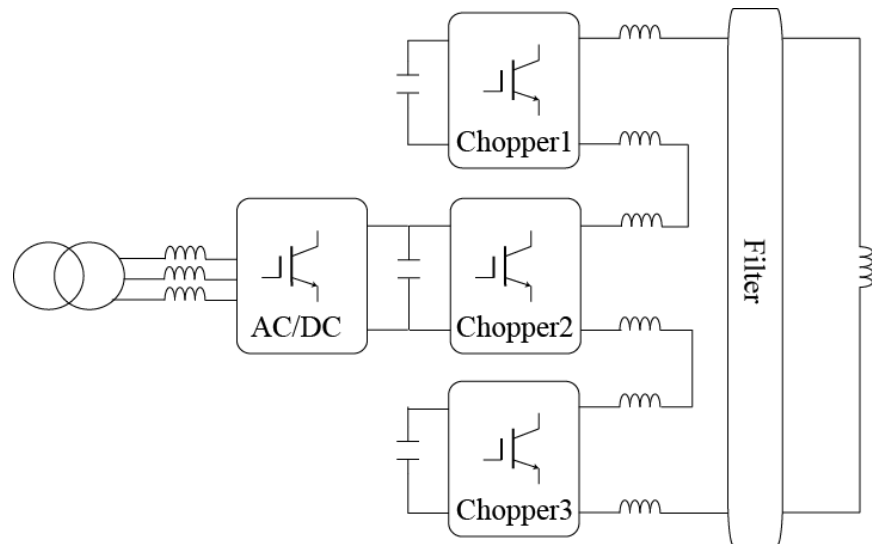
Need Energy Storage

Basic Design of new power supply

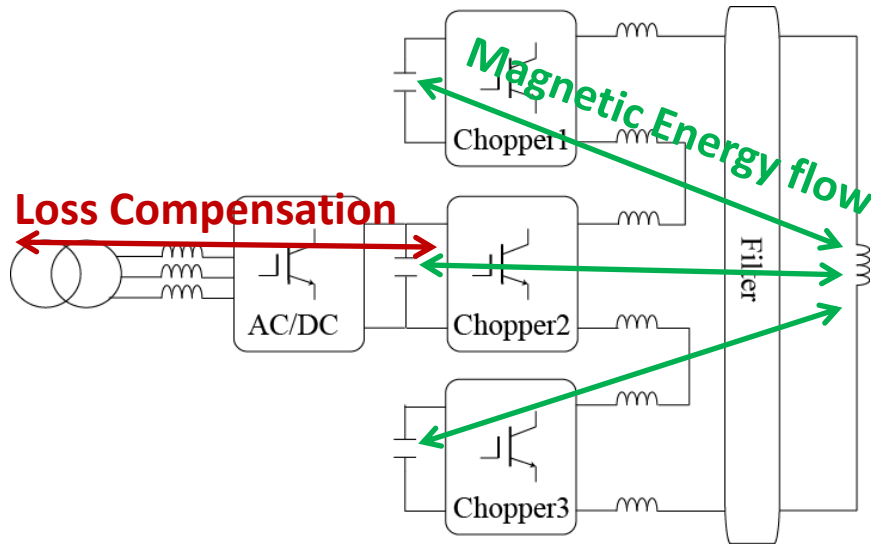
Design Concept for 1 Hz Operation

- Large capacitive energy storage to reduce power variation at main grid
- Choppers in series for higher output voltage (shorter ramp up time)
- Low noise digital feedback system for precise current control

PS For Large Magnets (B and Large Q) PS For Small Magnets (Small Q and Sext.)

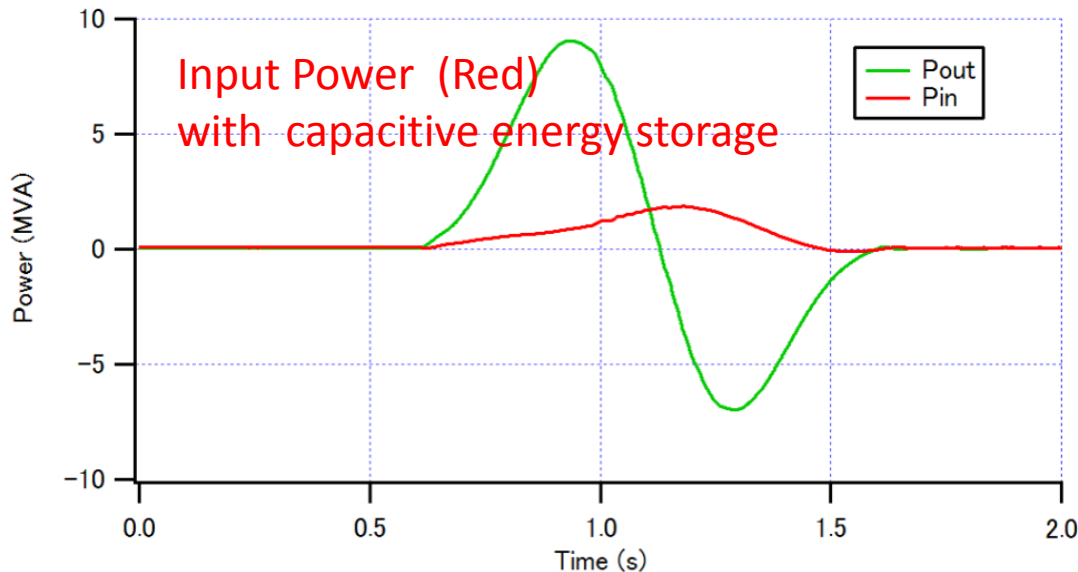


Effect of Capacitive Energy Storage



- All magnetic energy (~ 10 MJ for 1 bending family) is provided from the capacitor energy storage
- Only loss is compensated from the main

Simulation for one bending magnet family

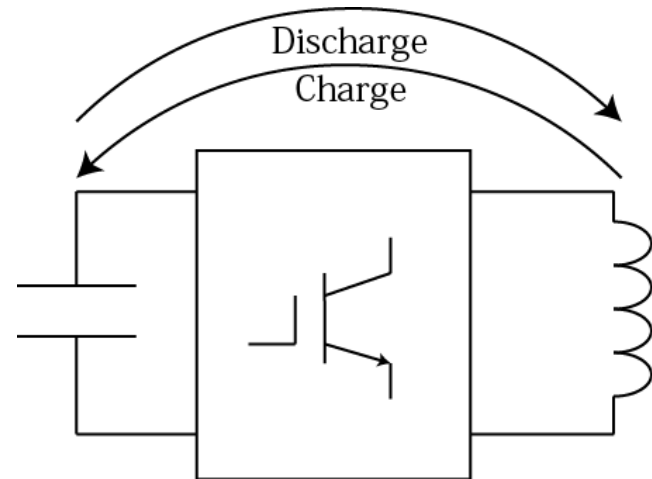
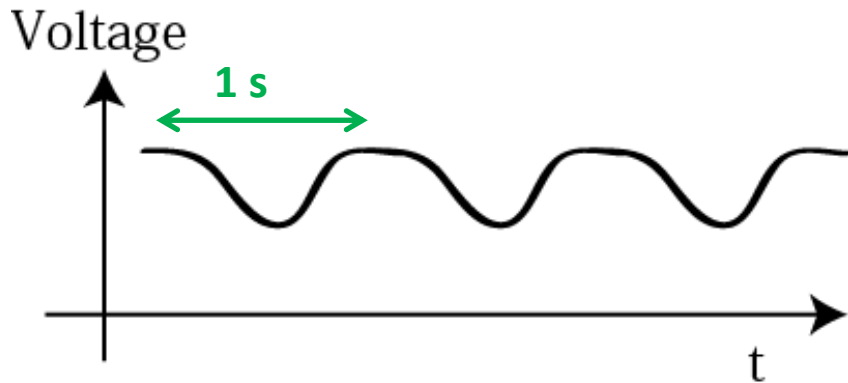


Input Power can be reduce by 70 %

Capacitive Energy Storage

The capacitor should

have longer than 10 years lifetime ($\sim 10^8$ charge-discharge cycles)
not be shorted internally (for safety)



Dry-type film Capacitor

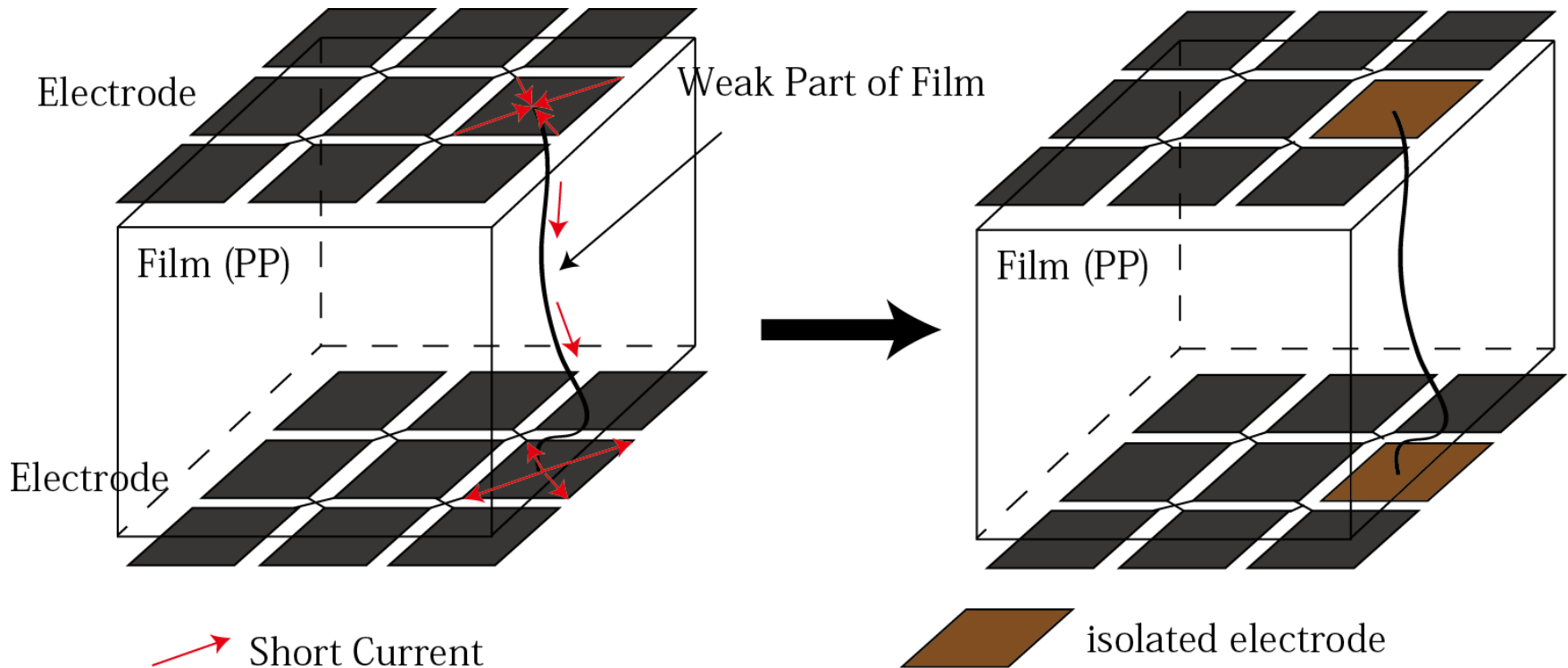


- Long lifetime
- No internal short by self-healing structure
- smaller and cheaper by recent technology progress

Used for many applications such as shinkansen , hybrid car and so on

Self-Healing Structure

Internal Structure of Film Capacitor

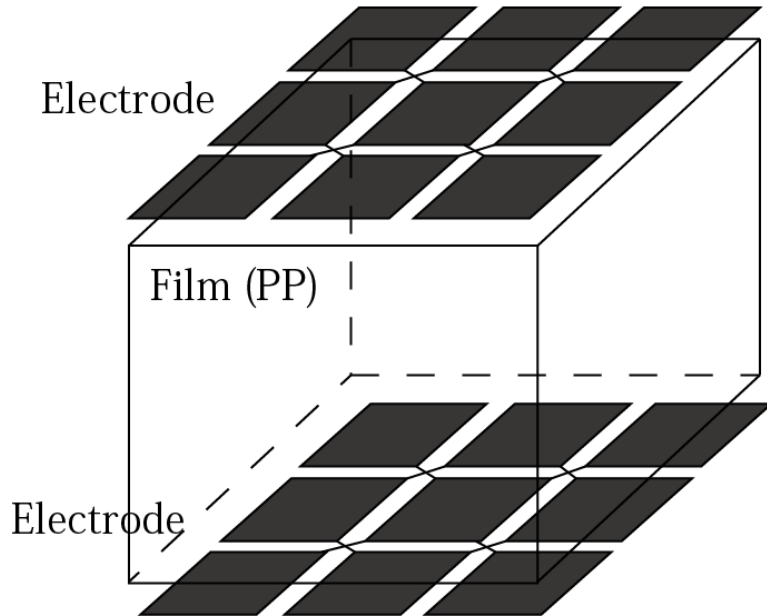


More pixels = Safer

- Many small pixel capacitors connect with each other
- A pixel capacitor with weak part is isolated by over current
- As a result, the capacitance decreases by 1/10000
- **The lifetime is defined as the time until capacitance decreases by 5 %**

AC or DC ?

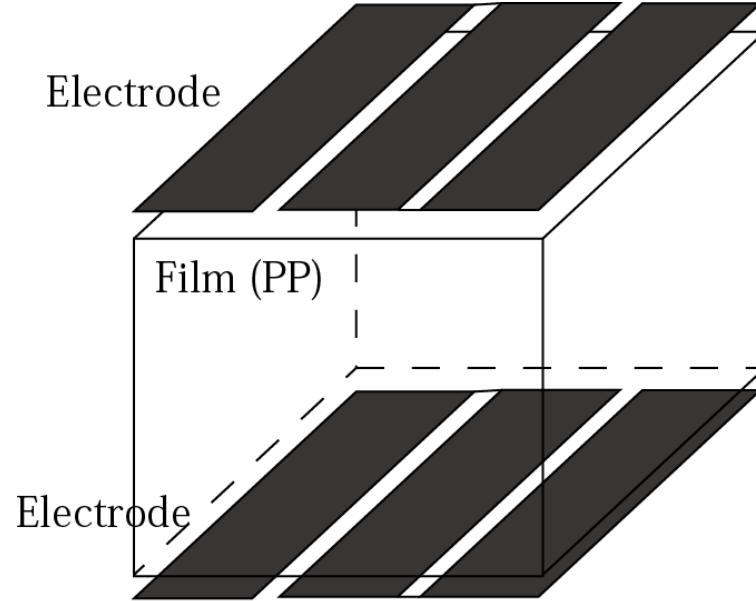
For DC voltage



- Many (small) pixels
- Higher voltage (200 V/ μm)



For AC voltage (50/60 Hz)



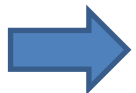
- fewer (Large) pixels to reduce discharge at the surroundings of pixels due to voltage change
- Lower voltage (<100 V/ μm)



Bigger



Our application (Not 50/60 Hz but only 1 Hz) is the middle of DC and AC

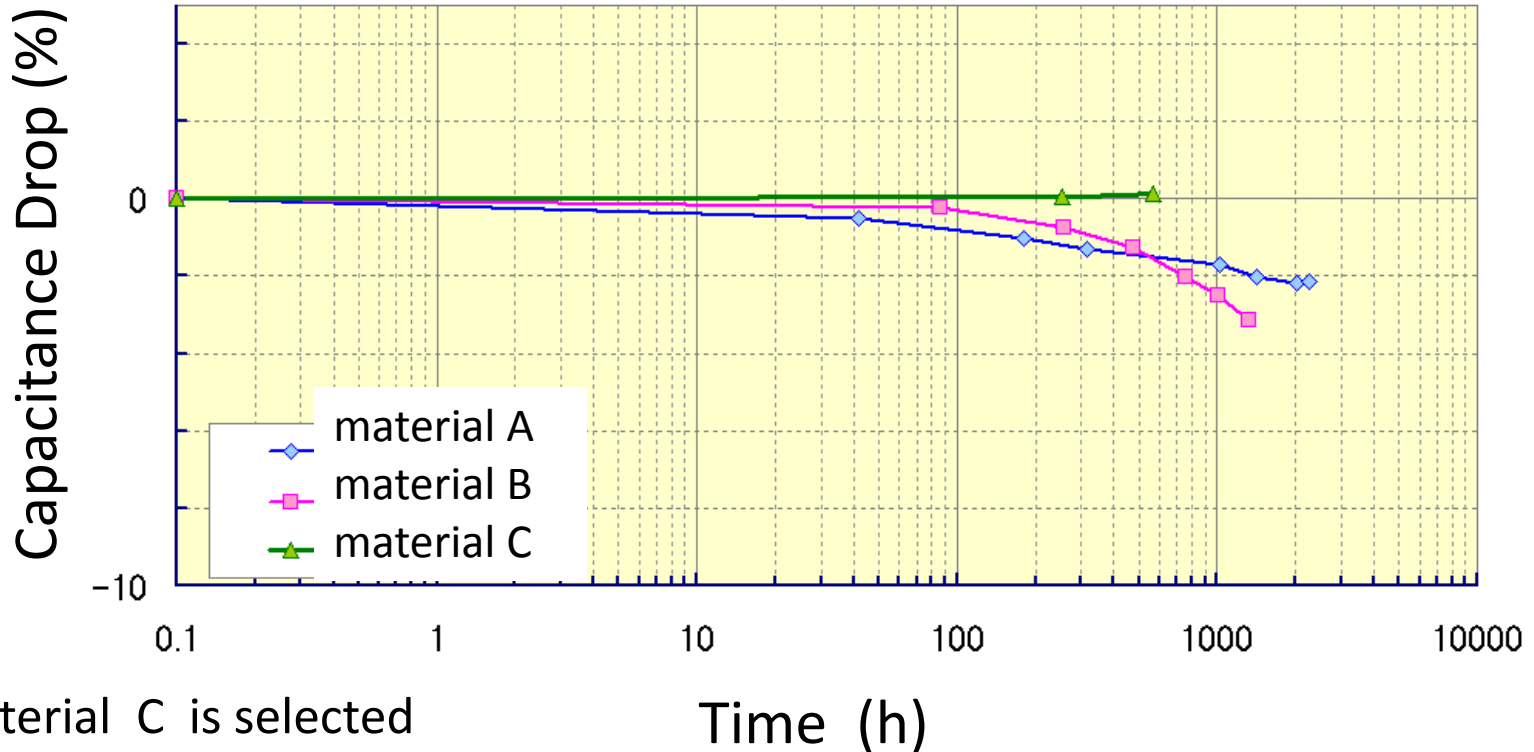


DC Capacitor- based development !!

Lifetime test with DC capacitor

Difference of the electrode material

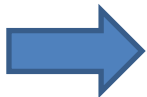
60 Hz (accelerating test by factor 60)



Material C is selected

Time (h)

Extrapolated lifetime (5 % capacitance drop) = 4.5×10^8 pulses



Capacitor design was fixed !!

Single capacitor : 2mF 2.5 kV 20-30 kg

Next Step

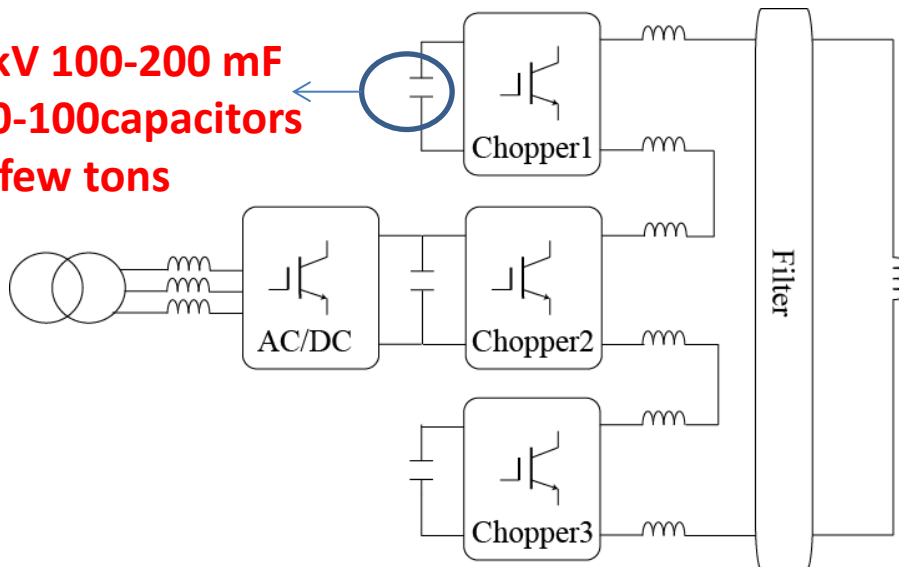
Things to do for Capacitor bank design

- number of capacitors in one unit bank ?
- type of containers
- selection of fuse
- type of tests (short test with fuse ?)

We are currently working on those issue

Ex. PS Bending families (Most of capacitors are there)

2kV 100-200 mF
50-100capacitors
a few tons



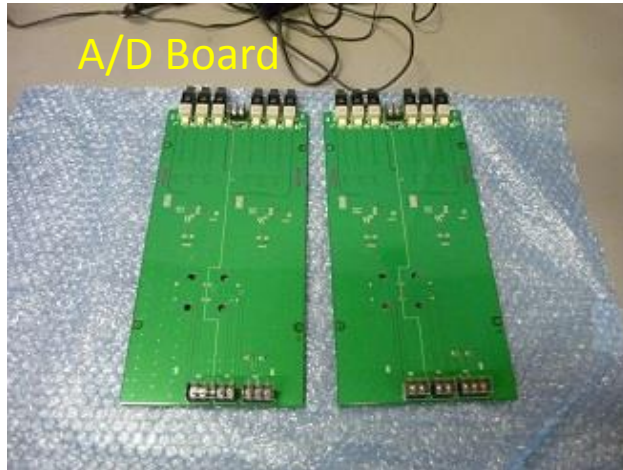
× 12 (# bending families)

Summary

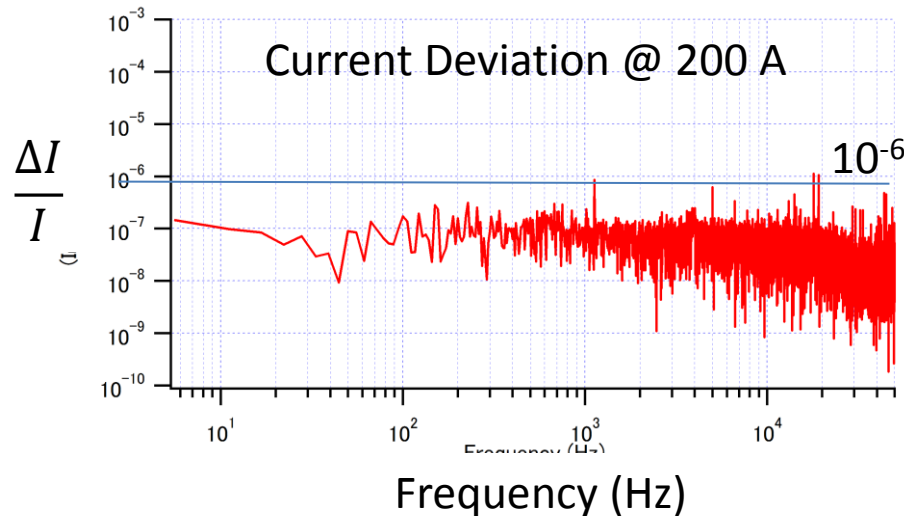
- Upgrade for 750 kW is planned in J-PARC MR by increasing the repetition rate from 0.4 Hz to 1.0 Hz
- Power supplies with energy storage is needed for the 1 Hz operation due to reduce the power variation at main grid
- Capacitive energy storage is the 1st candidate
- Capacitor development have been completed
- Designing of the capacitor bank is the next step

Other R&Ds - Low Noise Digital Feedback System-

- 24 bit A/D board and DSP board was developed in KEK



Test of the developed system using the PS for Sextupole



The output current can be controlled at **ppm** level

The result will be published