Main Power Supply System of SuperKEKB

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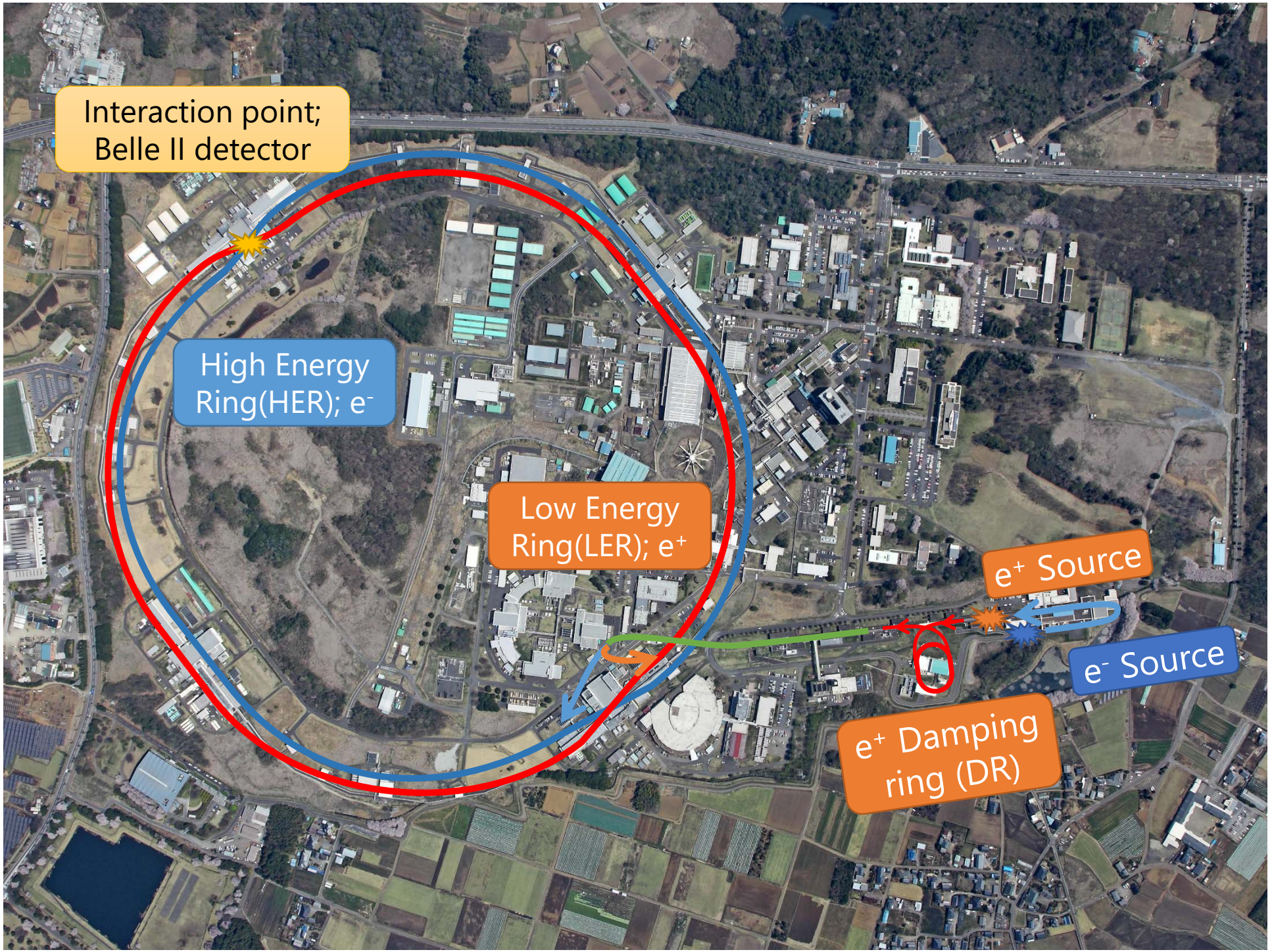
KEK

2018/9/25 6th POCPA Workshop


Interaction point;
Belle II detector
High Energy
Ring(HER); e⁻
Low Energy
Ring(LER); e⁺
e⁺ Source
e⁻ Source
e⁺ Damping
ring (DR)

Machine Parameters

2017/September/1	LER	HER	unit	
E	4.000	7.007	GeV	
I	3.6	2.6	A	
Number of bunches	2,500			
Bunch Current	1.44	1.04	mA	
Circumference	3,016.315		m	
$\varepsilon_x/\varepsilon_y$	3.2(1.9)/8.64(2.8)	4.6(4.4)/12.9(1.5)	nm/pm	():zero current
Coupling	0.27	0.28		includes beam-beam
β_x^*/β_y^*	32/0.27	25/0.30	mm	
Crossing angle	83		mrad	
α_p	3.20×10^{-4}	4.55×10^{-4}		
σ_δ	$7.92(7.53)\times10^{-4}$	$6.37(6.30)\times10^{-4}$		
V_c	9.4	15.0	MV	
σ_z	6(4.7)	5(4.9)	mm	
ν_s	-0.0245	-0.0280		
ν_x/ν_y	44.53/46.57	45.53/43.57		
U_0	1.76	2.43	MeV	
$\tau_{x,y}/\tau_s$	45.7/22.8	58.0/29.0	msec	
ξ_x/ξ_y	0.0028/0.0881	0.0012/0.0807		
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$	

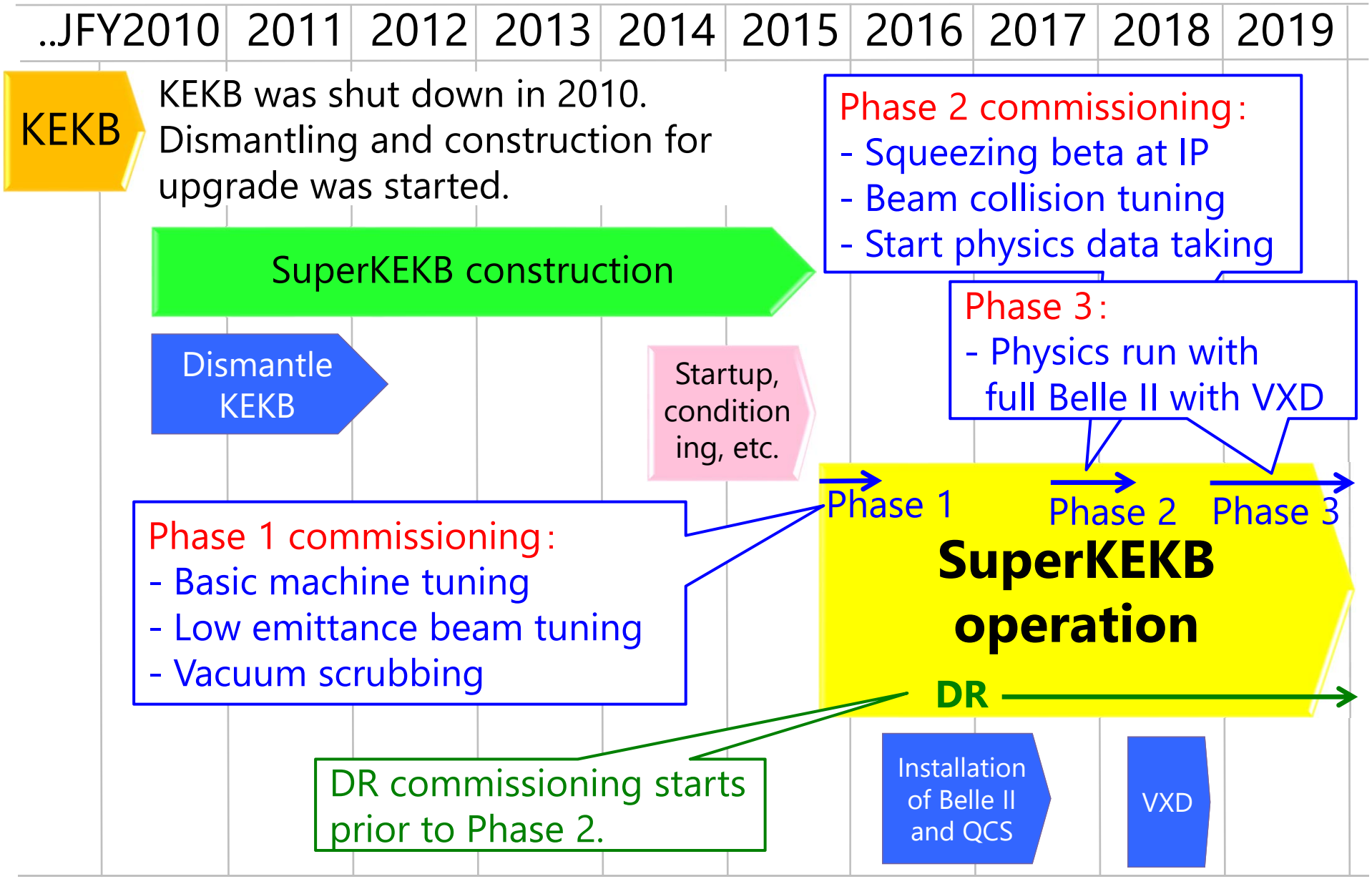
Beam current is
Two times larger than KEKB

×

Beam size at collision point is
20 times smaller than KEKB

Luminosity is
40 times higher than KEKB.

SuperKEKB master schedule



List of Magnet power supplies

- Newly fabricated or old power supplies for Main Ring

Output power	Newly fabricated PS	Reused PS (#overhauled)	
0.95 MW	2	0	Main dipoles
0.4-1 MW	9	0	Wigglers
0.1-0.5 MW	0	18#	Main quadrupoles
2-105 kW	92	335#	Bend./Quad./Sext.
0.3-2.4 kW	209+29	1493+α	Steering magnets/ corrector coils
Total	312+29	1846+α	2158+α

- Newly fabricated power supplies for final-focus superconducting magnets system(QCS)

2kA, 15V	8	0	QCS Main quads.
<500 A, 20 V	3	0	QCS Solenoids
±70A, ±10V	43+2	0	QCS correction coils

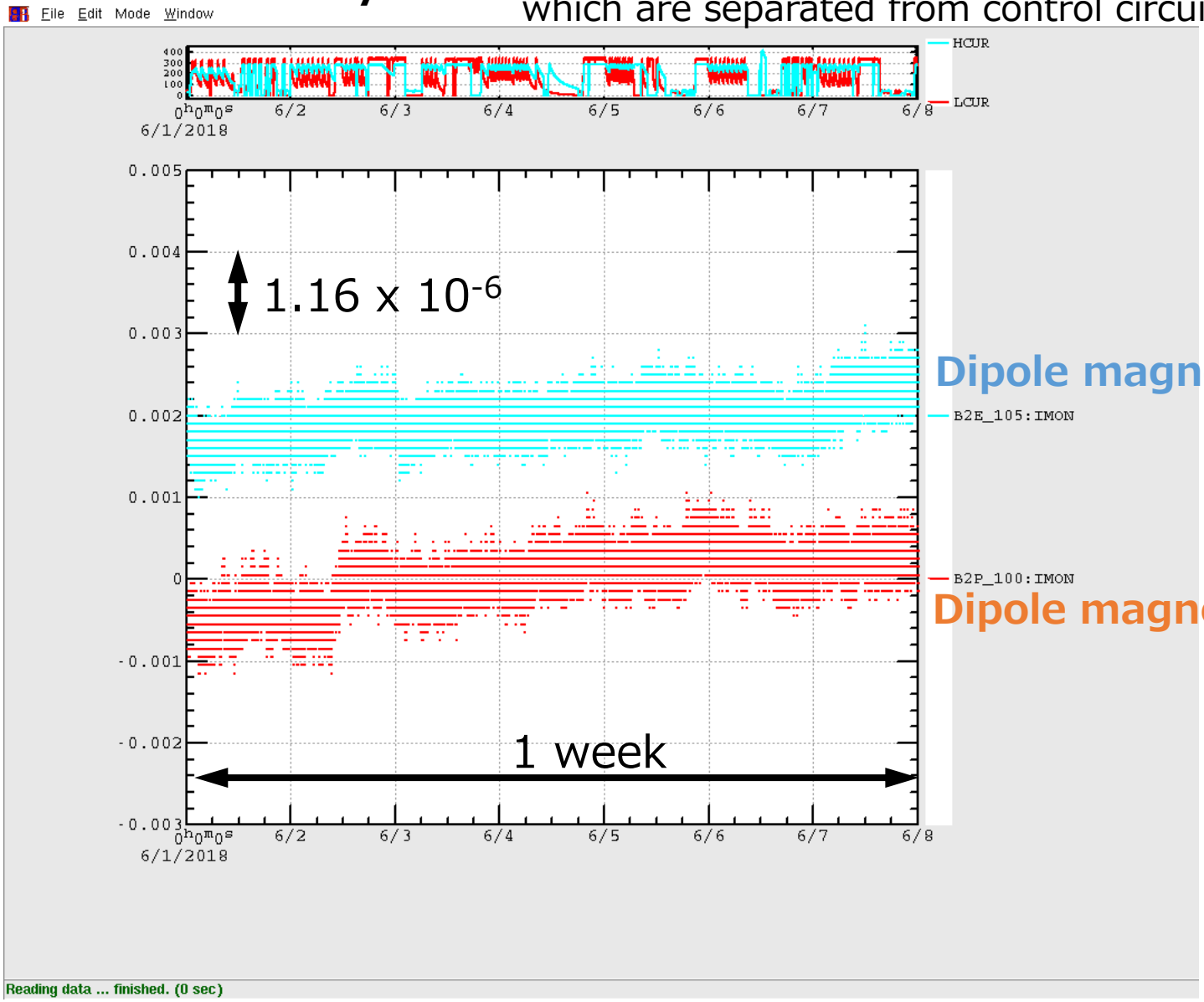
Large class PS (Main Dipoles, Wigglers)

	Rated current (A)	Max. Voltage (V)
Main Dipoles	860, 840	1100
Wigglers	800 ~ 1400	350 ~ 750

Large class PS (Main Dipoles, Wigglers)

Output current stability

These are measured with high precision DCCTs, which are separated from control circuit of the PSs.



Dipole magnet of HER

Dipole magnet of LER

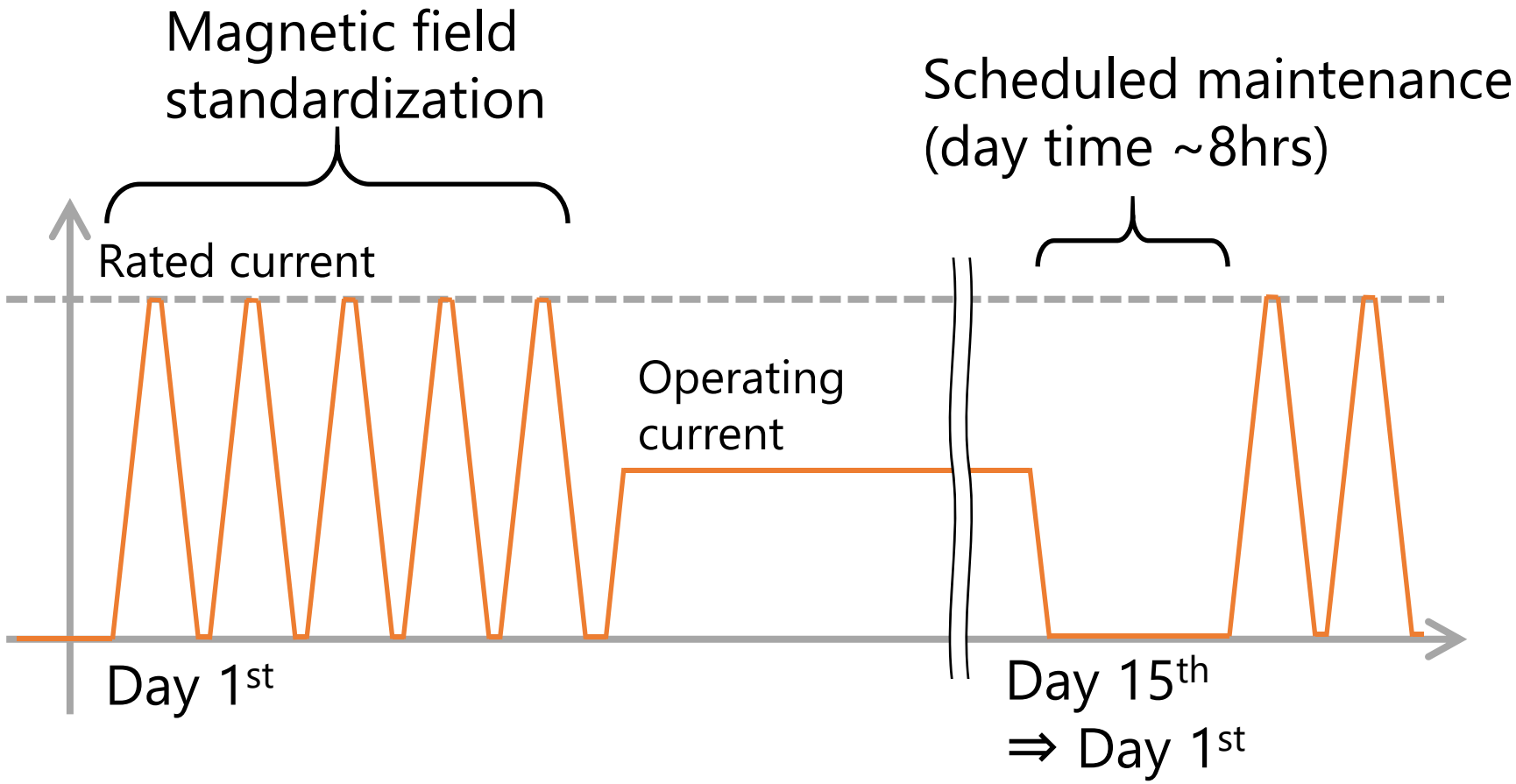
Medium class PS (Bend./Quad./Sext.)

	Rated current (A)	Max. Voltage (V)	Stability (Idiff/Irated)
Bend./Quad./ Sext.	200 ~ 1250	10 ~ 120	< 2 x 10^{-5} / day

Small class PS (Steerings, auxiliary coils)

	Rated current (A)	Max. Voltage (V)	Stability (Idiff/Irated)
Steerings, etc.	±5, ±10	±50 ~ ±100	< 1 x 10^{-4} / day

Typical operation cycle of the power supplies



Magnetic field standardization: the output current is increased to the rated current of each power supplies and then decreased to 0 A. After this cycle, which is repeated several times, the output current is set at the desired value determined by the machine optics. This cycle cancel out a relict magnetic field and assure us of repeatability of the magnetic field.

Scheduled maintenance: Scheduled maintenance runs every two weeks.

PS Control system

1. Remote control

   Setting output current, ON/OFF control, and reading various status of PS

   PSICM mounted in each Power Supply.

   (PSICM = Power Supply Interface Controller Module)

   Connected to the IOC through ARCNET.

   ARCNET = Attached Resource Computer NETwork

2. Current monitor

   Digital Voltmeter(KEITHLEY 2002 or 2001) with scanner(KEITHLEY 7001).

   Connected to the IOC through GPIB or Ethernet.

3. Interlock system to protect Magnets and Power supplies

   Standalone PLC system.

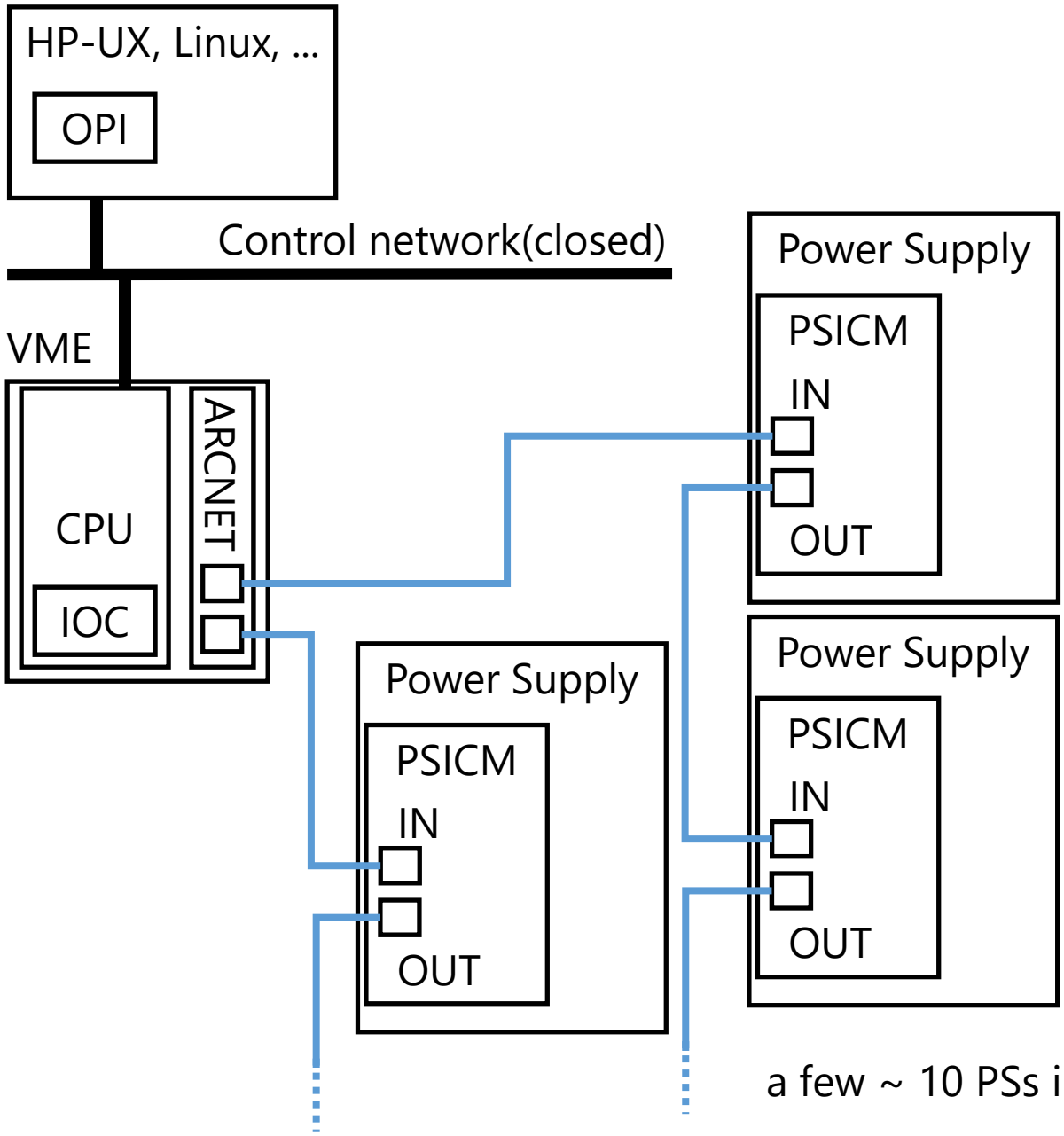
   The IOC is embedded in the PLC module(F3RP61).

They are controlled with EPICS

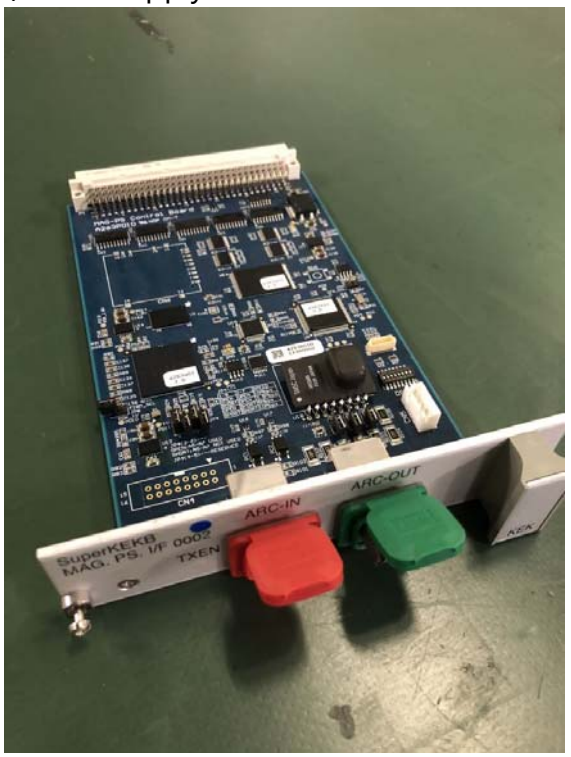
(Experimental Physics and Industrial Control System).

KEKBlog system are logging channels of the EPICS records.

Remote control (ARCNET)

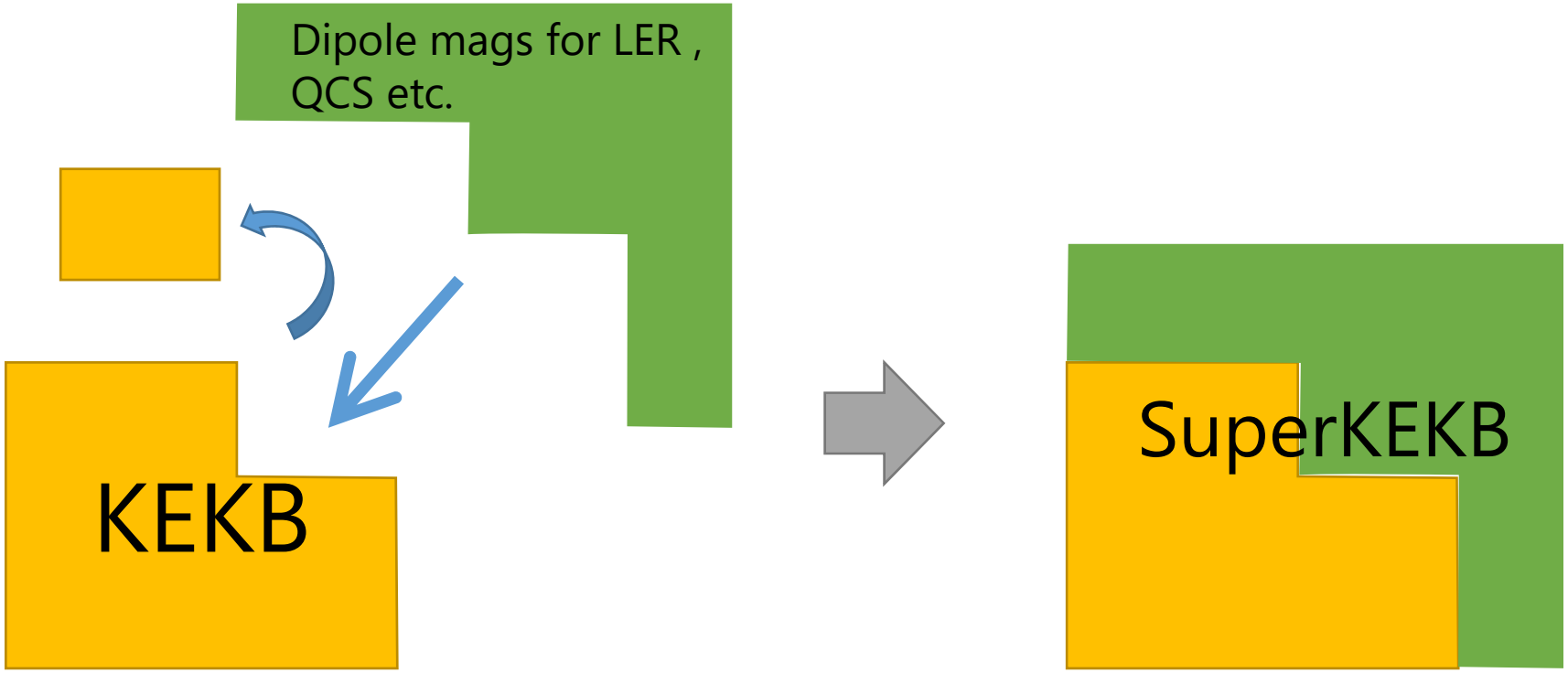


PSICM
(Power Supply Interface Controller Module)



SuperKEKB succeed KEKB

Some devices running in KEKB were replaced new ones.
New components for SuperKEKB are added on legacies from KEKB.



Some troubles occurred on the connection.

Trouble summary

in Phase 1 (2016.2.8 ~ 2016.6.28) / in Phase 2 (2018.3.19 ~ 2018.7.17)

Magnet power supply system works well except for following failures.

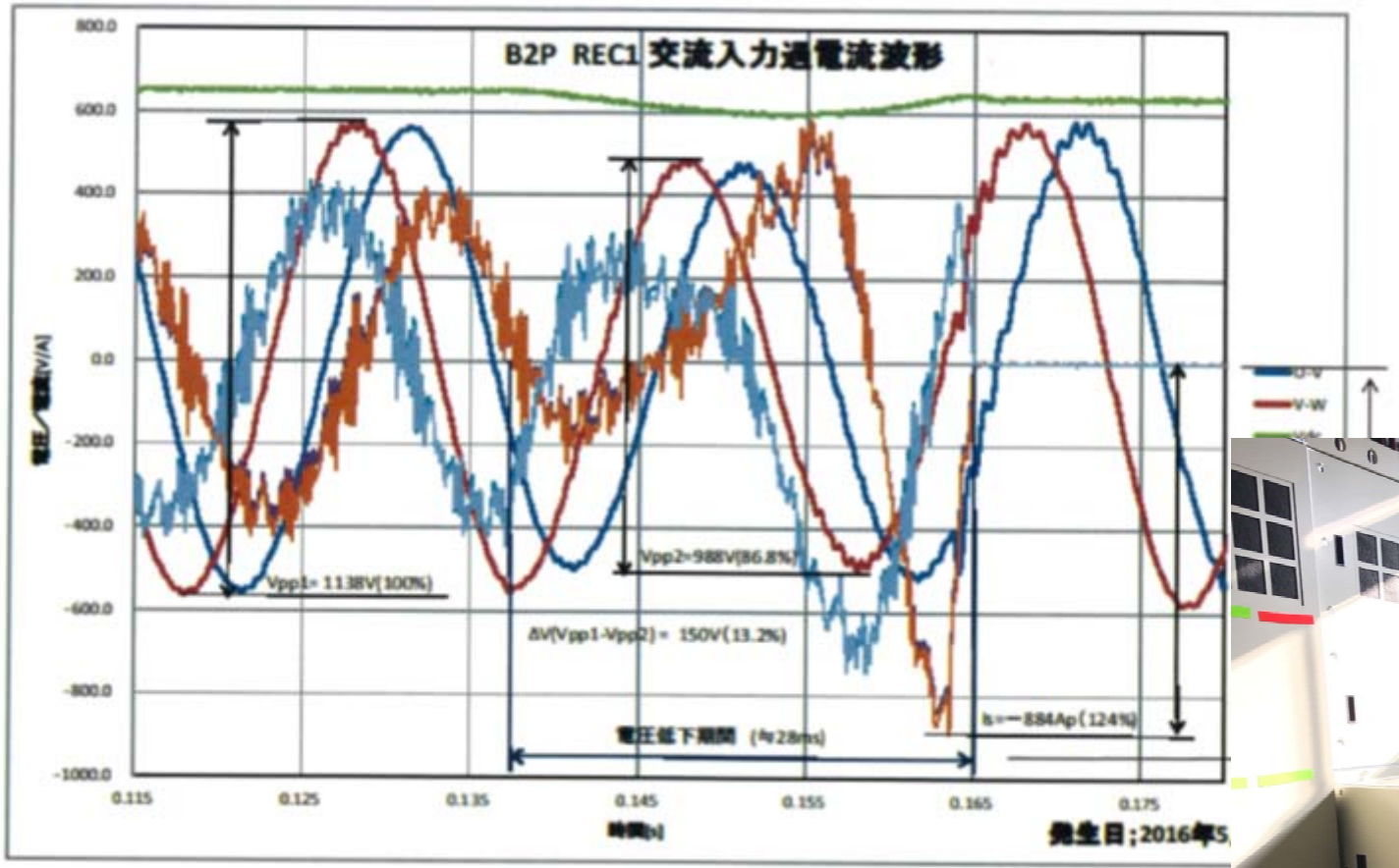
Failures in Large class PS	# of event	comment
AC input over current	13 / 0	AC distortion (RF system crowbar or/and VAR system# works)
AC input Stop, CB Fault	6 / 0	Earthquake, Malfunctions.

Failures in Medium class PS	# of event	comment
Thermostat	7 / 14	Thermal control equipment trouble. Poor air conditioning.
Over current (IGBT modules)	6 / 1	Modules were replaced. Repaired.
Cable GND fault	1 / 0	The fault cable was disconnected.
Tracking error	1	Fault in the polarity inversion circuit. Repaired.

Failures in small class PS	# of event	comment
DC-DC board failure etc.	10 / 2	Power supplies themselves were replaced.

#) Compensation system for a reactive power in the AC power distribution facility. AC line phase-advancing capacitor equipment was automatically controlled. However, unexpected operation occurred in early stage of Phase 1. Since capacitors has been manually operated, failures doesn't occur.

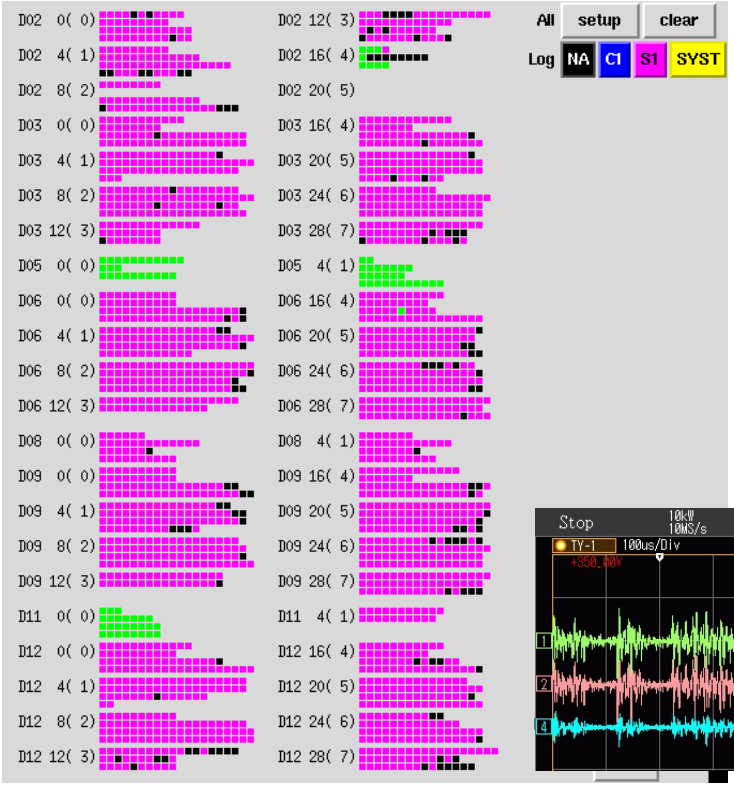
AC input failure



Insert additional AC inductors(ACL).
Then the peak height of the inrush current is reduced.
Main dipole magnet PSs are treated with the ACL.
The others are postponed due to a budget.

Signal noise from switching PSs

Synchronization trigger status



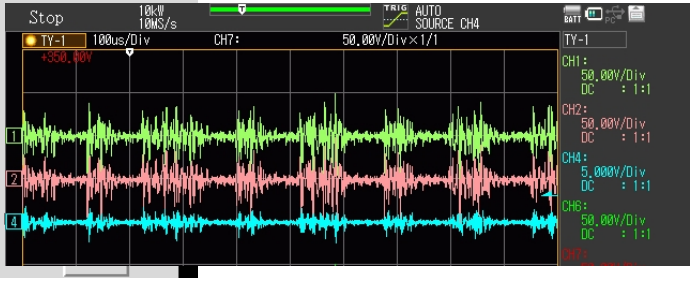
Ready

Running

N/A

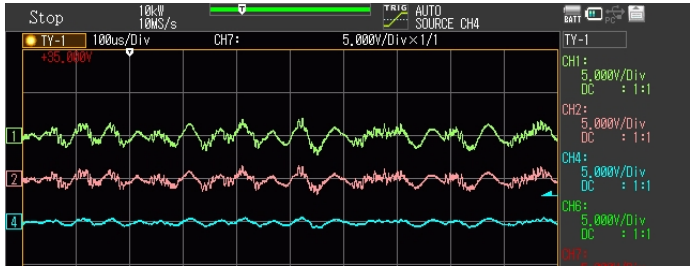
Synchronization trigger :
When optics parameters are changed, all PSs have to drive synchronously to avoid beam loss.

Trigger input signal



P-Body (**50V**/div)
N-Body (**50V**/div)
P-N (5V/div)
100μs/div

Filters : normal 0.1μF, common 0.1μF



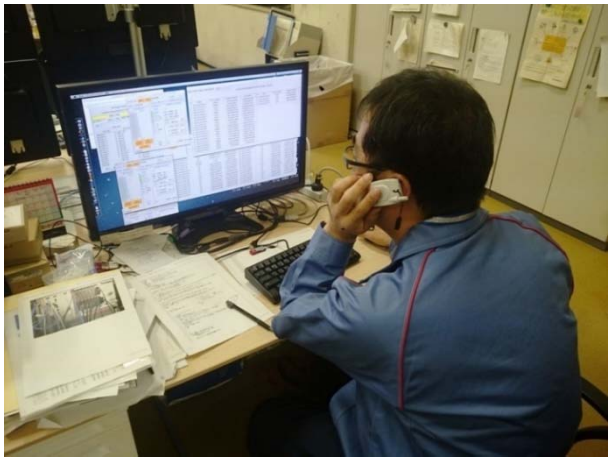
P-Body (**5V**/div)
N-Body (**5V**/div)
P-N (5V/div)
100μs/div

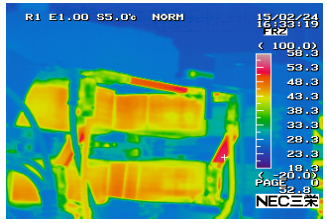
Summary

- SuperKEKB is an e^--e^+ collider, which succeed KEKB.
- Operation of the SuperKEKB have started from 2015, and Phase2 have finished now.
- Some of the large class PSs and ~100 number of the medium class PSs are newly fabricated.
- The most number of the PSs (mainly small class PSs) are running with/without overhauls.
- Some troubles have occurred between the legacies of KEKB and the new power supplies for SuperKEKB.

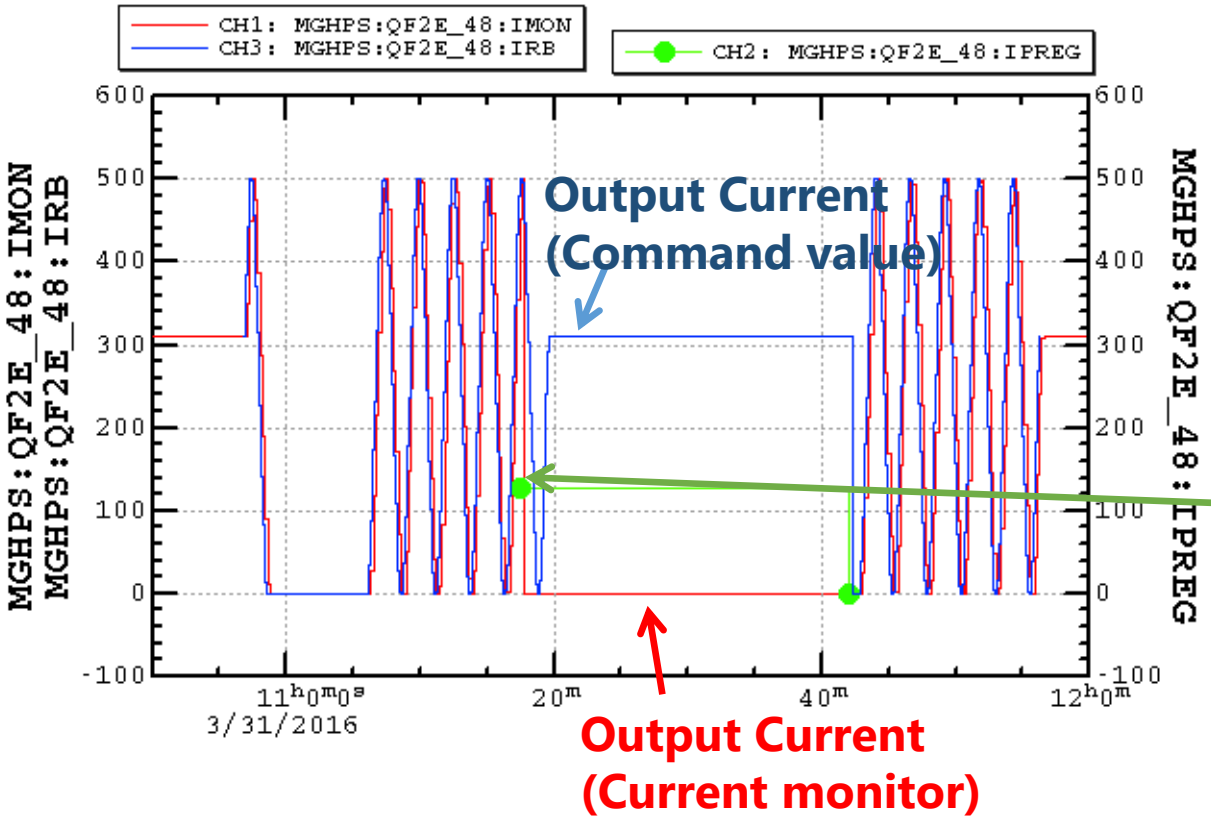
Start up: system check and full power load test

Full-scale start-up tasks such as network test, interlock system test, full power load test, cable connection check to avoid abnormal heating, polarity check, magnet standardization test and so on were completed before February 8(2016) beam injection to the MR.





KEKBlog viewer

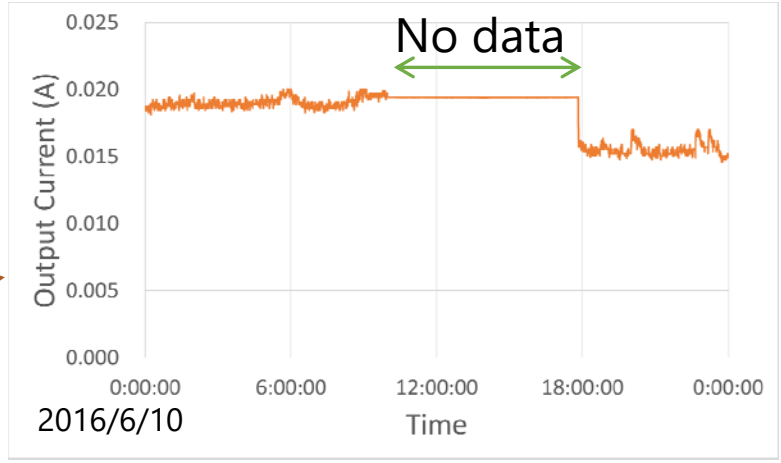


KEKBlog indicates 4W(who, when, what, where).
We have to investigate remains(why, how).

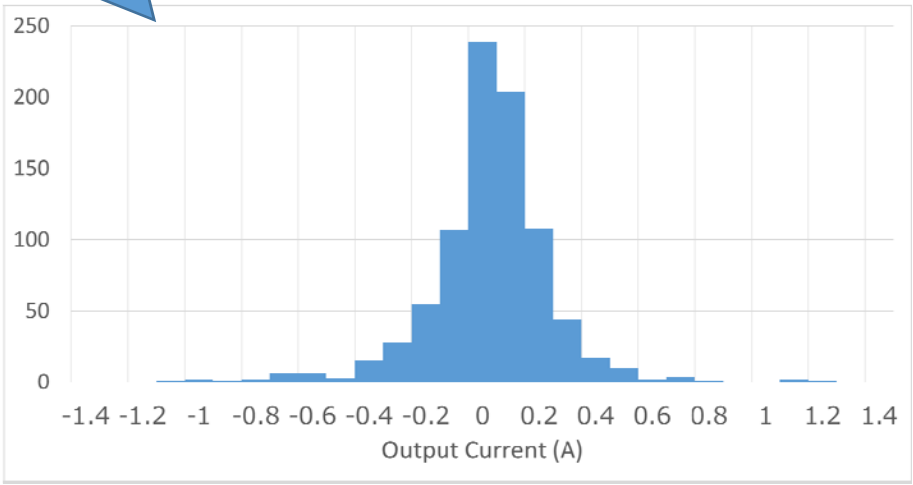
bit	Interlock
0	Output OC
1	Output OV
2	Thyristor Fuse
3	Case Temperature
4	Semicon. Failure
5	GND Fault
6	Emergency
7	External
8	DCCT Fault
9	-
10	Water Flow
11	-
12	-
13	Thermostat
14	Tracking
15	Fan

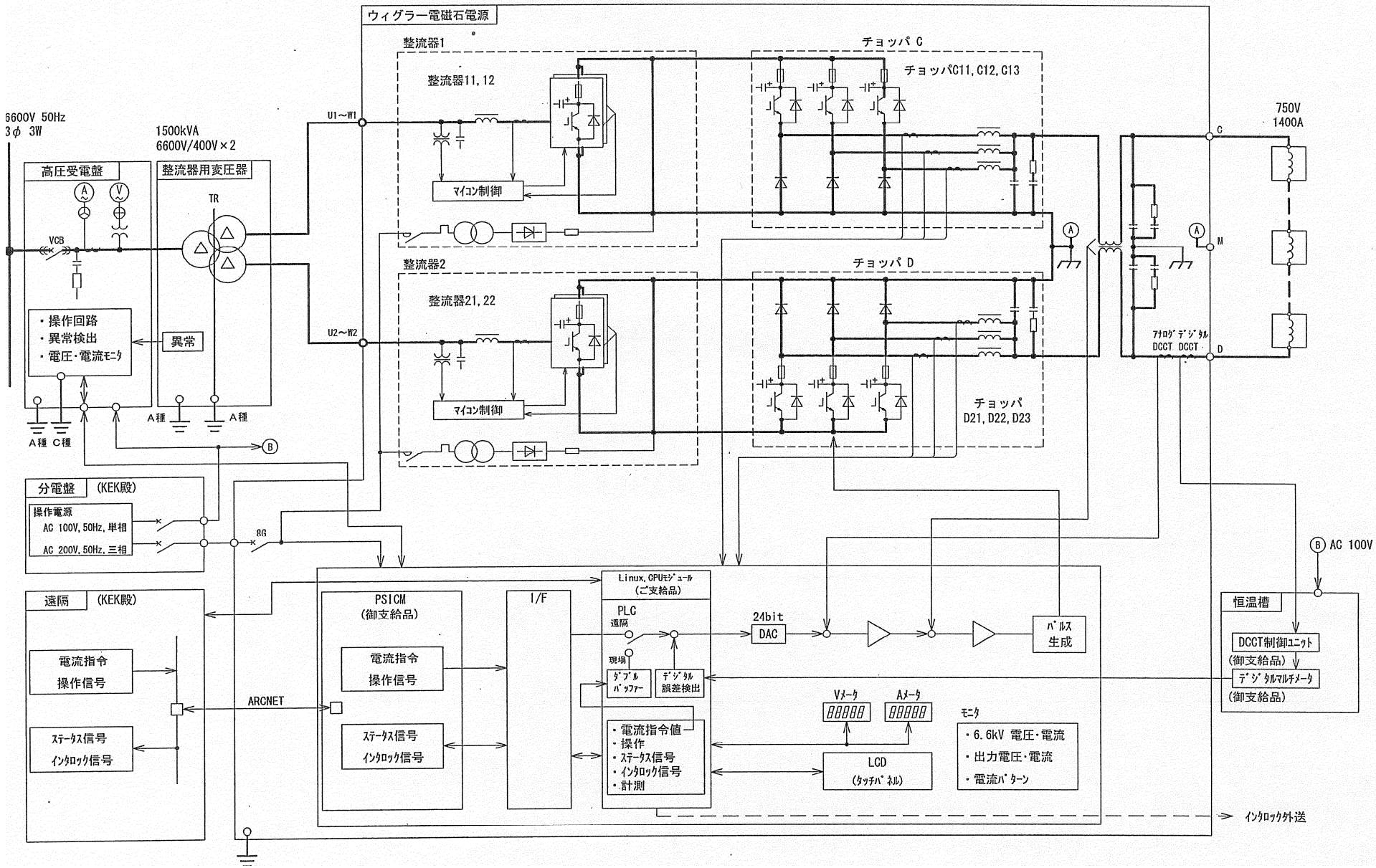
Archived data

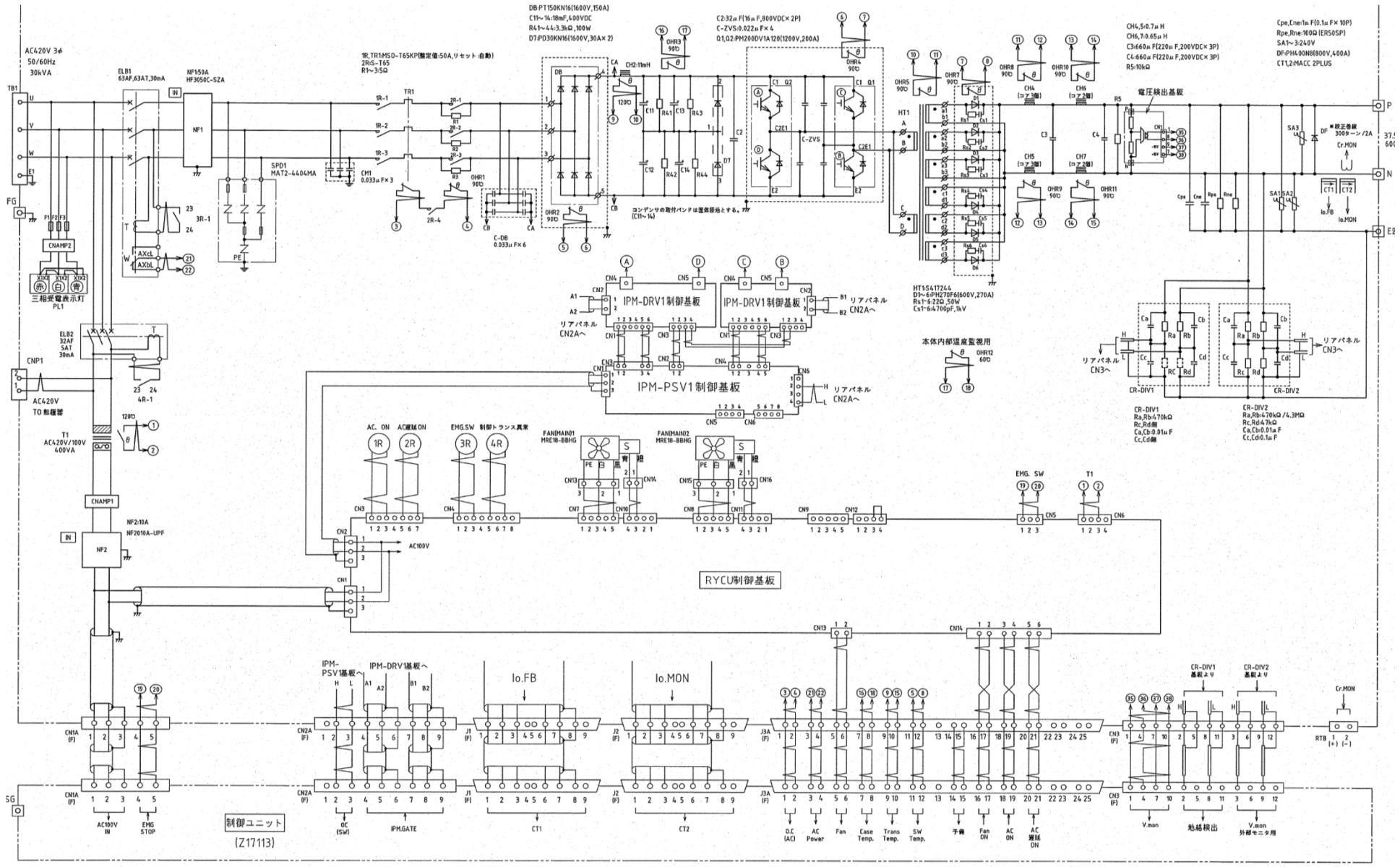
Time	record name	value
06/10/2016 00:00:36.48	MGLPS:ZVQD1P_1:IMON	1.843338e-02
06/10/2016 00:00:49.85	MGLPS:ZVQD1P_1:IMON	1.876372e-02
06/10/2016 00:01:26.15	MGLPS:ZVQD1P_1:IMON	1.875872e-02
06/10/2016 00:01:39.35	MGLPS:ZVQD1P_1:IMON	1.843839e-02
06/10/2016 00:01:55.85	MGLPS:ZVQD1P_1:IMON	1.843338e-02
06/10/2016 00:02:18.95	MGLPS:ZVQD1P_1:IMON	1.844840e-02
06/10/2016 00:02:45.35	MGLPS:ZVQD1P_1:IMON	1.844339e-02
06/10/2016 00:03:11.75	MGLPS:ZVQD1P_1:IMON	1.843338e-02
06/10/2016 00:03:38.15	MGLPS:ZVQD1P_1:IMON	1.843839e-02
06/10/2016 00:04:04.55	MGLPS:ZVQD1P_1:IMON	1.844339e-02
06/10/2016 00:04:30.95	MGLPS:ZVQD1P_1:IMON	1.844840e-02
06/10/2016 00:04:44.15	MGLPS:ZVQD1P_1:IMON	1.844339e-02
06/10/2016 00:04:57.35	MGLPS:ZVQD1P_1:IMON	1.843839e-02
06/10/2016 00:05:10.55	MGLPS:ZVQD1P_1:IMON	1.843338e-02
06/10/2016 00:05:23.75	MGLPS:ZVQD1P_1:IMON	1.844840e-02
...		



Histogram of output current of steering magnet PSs




ウィグラー電磁石電源
整流器1
整流器11, 12
マイコン制御
チョッパ C
チョッパC11, C12, C13
整流器2
整流器21, 22
マイコン制御
チョッパ D
チョッパ
D21, D22, D23
6600V 50Hz
3φ 3W
1500kVA
6600V/400V×2
高圧受電盤
整流器用変圧器
TR
VCB
U1～W1
U2～W2
・操作回路
・異常検出
・電圧・電流モニタ
異常
A種
A種
A種 C種
750V
1400A
C
M
D
アナログ DCCT
デジタル DCCT
分電盤 (KEK殿)
操作電源
AC 100V, 50Hz, 単相
AC 200V, 50Hz, 三相
BG
B
AC 100V
遠隔 (KEK殿)
電流指令
操作信号
ステータス信号
インタロック信号
ARCNET
PSICM
(御支給品)
電流指令
操作信号
ステータス信号
インタロック信号
I/F
Linux, CPUモジュール
(ご支給品)
PLC
遠隔
現場
ダブル
バッファー
デジタル
誤差検出
24bit
DAC
パルス
生成
・電流指令値
・操作
・ステータス信号
・インタロック信号
・計測
Vメータ
Aメータ
LCD
(タッチパネル)
モニタ
・6.6kV 電圧・電流
・出力電圧・電流
・電流パターン
恒温槽
DCCT制御ユニット
(御支給品)
デジタルマルチメータ
(御支給品)
インタロック外送


AC420V 3φ
50/60Hz
30kVA
TB1
ELB1
63AF,63AT,30mA
NF150A
HF3050C-SZA
NF1
SPD1
MAT2-4404MA
CM1
0.033μF×3
1R,TR1M50-T65KP(指定値:50A,リセット 自動)
2R:5-T65
R1~3:5Ω
TR1
1R-1
1R-2
1R-3
2R-1
2R-2
2R-3
2R-4
3R-1
R1
R2
R3
OHR1
90℃
C-DB
0.033μF×6
DB:PT150KN16(1600V,150A)
C11~14:18mF,400VDC
R41~44:3.3kΩ,100W
D7:PD30KN16(1600V,30A×2)
CH2:1mH
OHR3
90℃
OHR4
90℃
C2:32μF(16μF,800VDC× 2P)
C-ZVS:0.022μF×4
Q1,Q2:PM200DV1A120(1200V,200A)
C-ZVS
OHR5
90℃
OHR7
90℃
OHR8
90℃
OHR10
90℃
CH4,5:0.7μH
CH6,7:0.65μH
C3:660μF(220μF,200VDC× 3P)
C4:660μF(220μF,200VDC× 3P)
R5:10kΩ
CH4
(コア3個)
CH6
(コア3個)
CH5
(コア3個)
CH7
(コア3個)
OHR9
90℃
OHR11
90℃
電圧検出基板
Cpe,Cne:1μF(0.1μF× 10P)
Rpe,Rne:100Ω (ERS0SP)
SA1~3:240V
DF-PHL400N8(800V,400A)
CT1,2:MACC 2PLUS
HT1
HT1:5417244
D1~6:PHZ70F6(600V,270A)
Rs1~6:22Ω,50W
Cs1~6:4700pF,1kV
SA3
DF
※設定巻線
300ターン/2A
Cr.MON
CT1
CT2
Io.FB
Io.MON
SA1
SA2
P
N
E2
IPM-DRV1制御基板
IPM-DRV1制御基板
リアパネル
CN2Aへ
IPM-PSV1制御基板
リアパネル
CN2Aへ
本体内部温度監視用
OHR12
60℃
CR-DIV1
Ra,Rb:470kΩ
Rc,Rd:無
Ca,Cb:0.01μF
Cc,Cd:無
CR-DIV2
Ra,Rb:470kΩ /4.3MΩ
Rc,Rd:47kΩ
Ca,Cb:0.01μF
Cc,Cd:0.1μF
リアパネル
CN3へ
CR-DIV1
CR-DIV2
三相受電表示灯
PL1
CNAMP2
CNP1
ELB2
32AF
5AT
30mA
AC420V
TO 制御電源
T1
AC420V/100V
400V
120℃
CNAMP1
NF2:10A
NF2010A-UPF
NF2
AC100V
RYCU制御基板
AC. ON
AC遅延ON
EMG.SW
制御トランス異常
FAN(MAIN)1
MRE18-BBHG
FAN(MAIN)2
MRE18-BBHG
EMG. SW
T1
CN1
CN2
CN3
CN4
CN5
CN6
CN7
CN8
CN9
CN10
CN11
CN12
CN13
CN14
CN15
CN16
CN1A
CN2A
J1
J2
J3A
CN3
RTB
IPM-PSV1基板へ
IPM-DRV1基板へ
Io.FB
Io.MON
CR-DIV1 基板より
CR-DIV2 基板より
Cr.MON
AC100V IN
EMG STOP
制御ユニット
(Z17113)
OC (SW)
IPM.GATE
CT1
CT2
O.C (AC)
AC Power
Fan
Case Temp.
Trans Temp.
SW Temp.
予備
Fan ON
AC ON
AC遅延 ON
V.mon
地絡検出
V.mon 外部モニタ用