Power Supply Commissioning to Achieve DC Power Control for Superconducting Coils in JT-60SA

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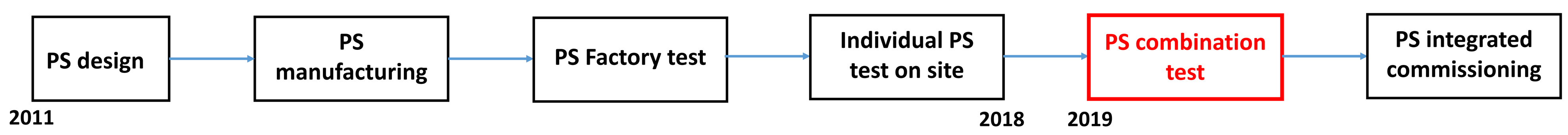
ABSTRACT

- The commissioning of the power supplies (PS) for superconducting coils in JT-60SA has started with dummy load in June 2019 and all test items have been completed successfully in November 2020.
- The most important result is that Integrated operation of the various PS components was completed successfully:
  - High voltage generation of the rated voltage of 5 kV by Switching Network Unit (SNU) [1] was performed as designed.
  - DC current interruption with rated current by Quench Protection Circuit (QPC) [2] was achieved.
- These results are the prerequisite for the execution of the integrated PS operation with superconducting coils in JT-60SA and contribute to the PS commissioning for ITER having the similar PS configuration including the SNU.

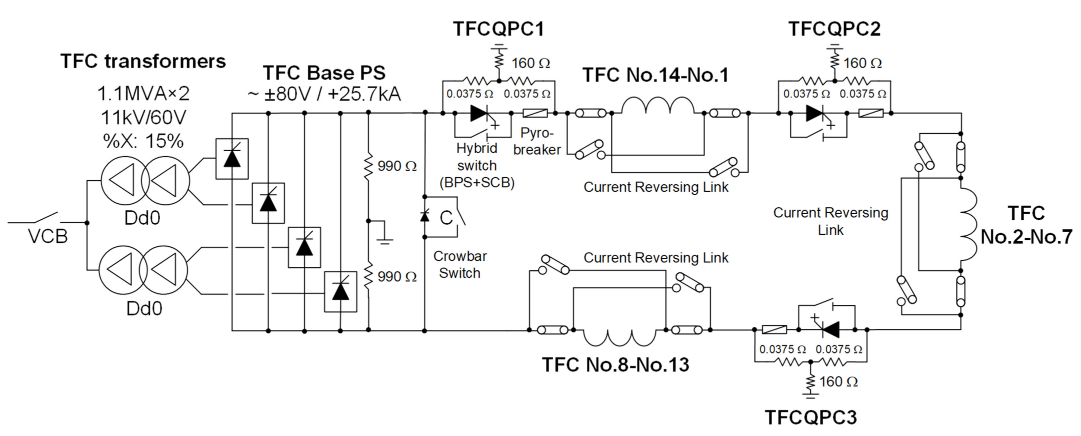
BACKGROUND

- The detailed design of power supplies to provide the needed DC power to Toroidal Field (TF) and Poloidal Field (PF) superconducting coils for JT-60SA was started in the year 2011 and the installation and individual test for each power supply component was completed by 2018, with a strong collaboration between Japan and EU.
- It is essential to verify the integrated performance with the various PS components before plasma experiment with superconducting coils in JT-60SA.
- Power Supply commissioning (hereby called PS combination test) aimed to verify the performance of the overall system using dummy load (DL) was started in 2019.



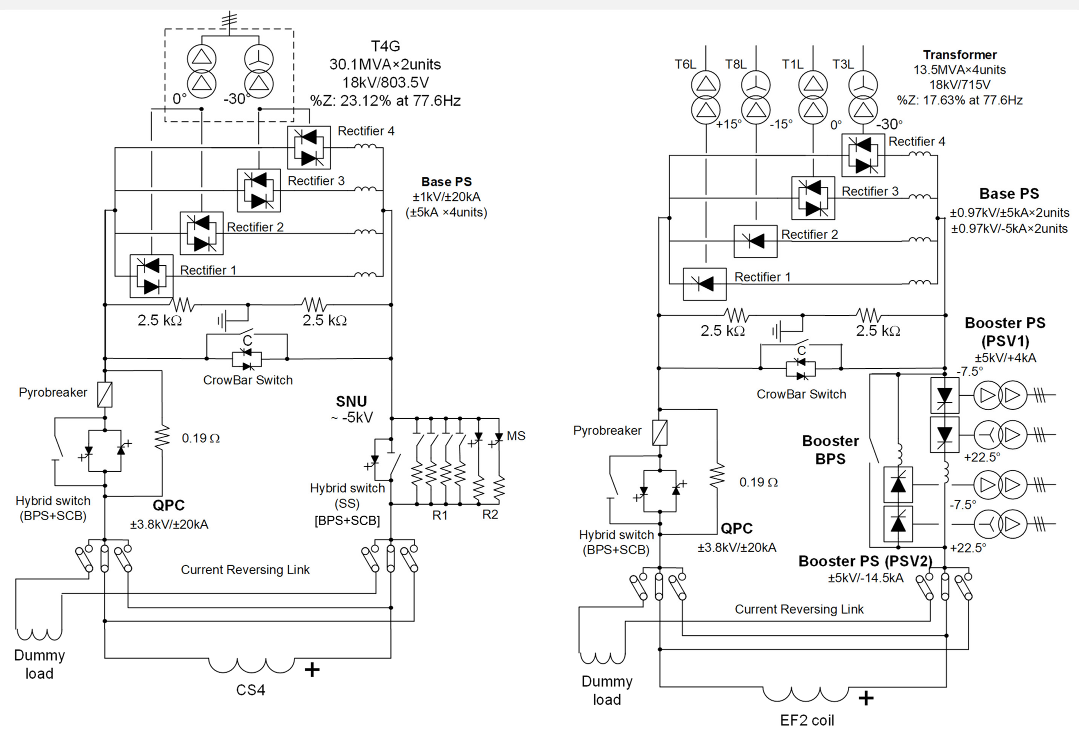
Power Supply commissioning (PS combination test)

- Main goal of PS combination test is to verify the coordinated operation that the various power supply components (Base PS, SNU, QPC and Booster PS), following the time sequence, the commands and the references generated by the PS Supervisory Control system (PS-SC, Real-time OS based) [3].



- DC25.7 kA (corresponding to 2.25T) operation with continuous ratings
- To reduce to 1.4kV the insulation voltage to ground in TF coils: Interleaved installation of QPCs and TF coil groups (1 QPC every 6 coils) and midpoint grounding of dump resistor in each QPC
- Similar TFC circuit configuration to ITER

TFC circuit configuration



- Configuration of Base PS for low voltage operation and SNU / Booster PS for high voltage generation to optimize/minimize the capacity of the PS components
- SNU to generate high voltage in the inner PF coils (CS1-4, EF3 and EF4) in plasma ignition and used for all PFC circuit in ITER
- Booster PS to achieve flexible plasma shape control with high voltage in the outer PF coils (EF1, EF2, EF5 and EF6) during plasma initiation

PFC circuit configuration

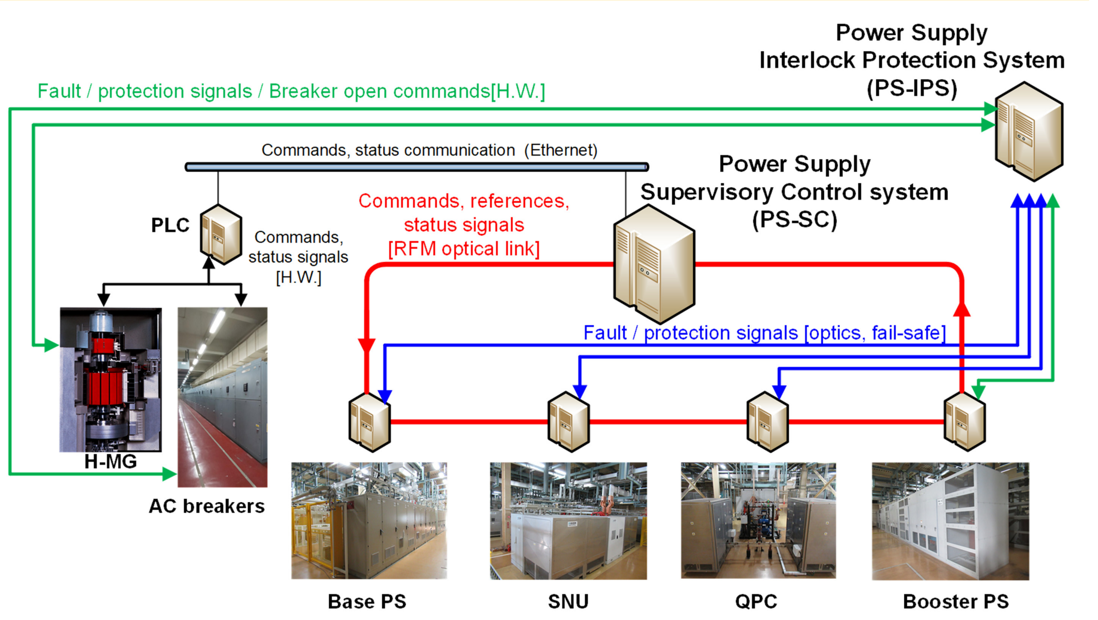
Coils	Base PS	SNU	Booster PS	QPC
TF	±80V / +25.7kA	-	-	+1.93kV / +25.7kA (*)
CS1	±1kV / ±20kA	-5kV to 0kV	-	±3.8kV / ±20kA
CS2	±1.25kV / ±20kA	-5kV to 0kV	-	±3.8kV / ±20kA
CS3	±1.25kV / ±20kA	-5kV to 0kV	-	±3.8kV / ±20kA
CS4	±1kV / ±20kA	-5kV to 0kV	-	±3.8kV / ±20kA
EF1	±1kV / -20kA to +10kA	-	±5kV / -14.5kA to +4kA	±3.8kV / ±20kA
EF2	±0.97kV / -20kA to +10kA	-	±5kV / -14.5kA to +4kA	±3.8kV / ±20kA
EF3	±0.97kV / ±20kA	-5kV to 0kV	-	±3.8kV / ±20kA
EF4	±0.97kV / ±20kA	-5kV to 0kV	-	±3.8kV / ±20kA
EF5	±0.97kV / -20kA to +10kA	-	±5kV / -14.5kA to +4kA	±3.8kV / ±20kA
EF6	±1kV / -20kA to +10kA	-	±5kV / -14.5kA to +4kA	±3.8kV / ±20kA

Note: (*) Three units

DC power supply system in JT-60SA

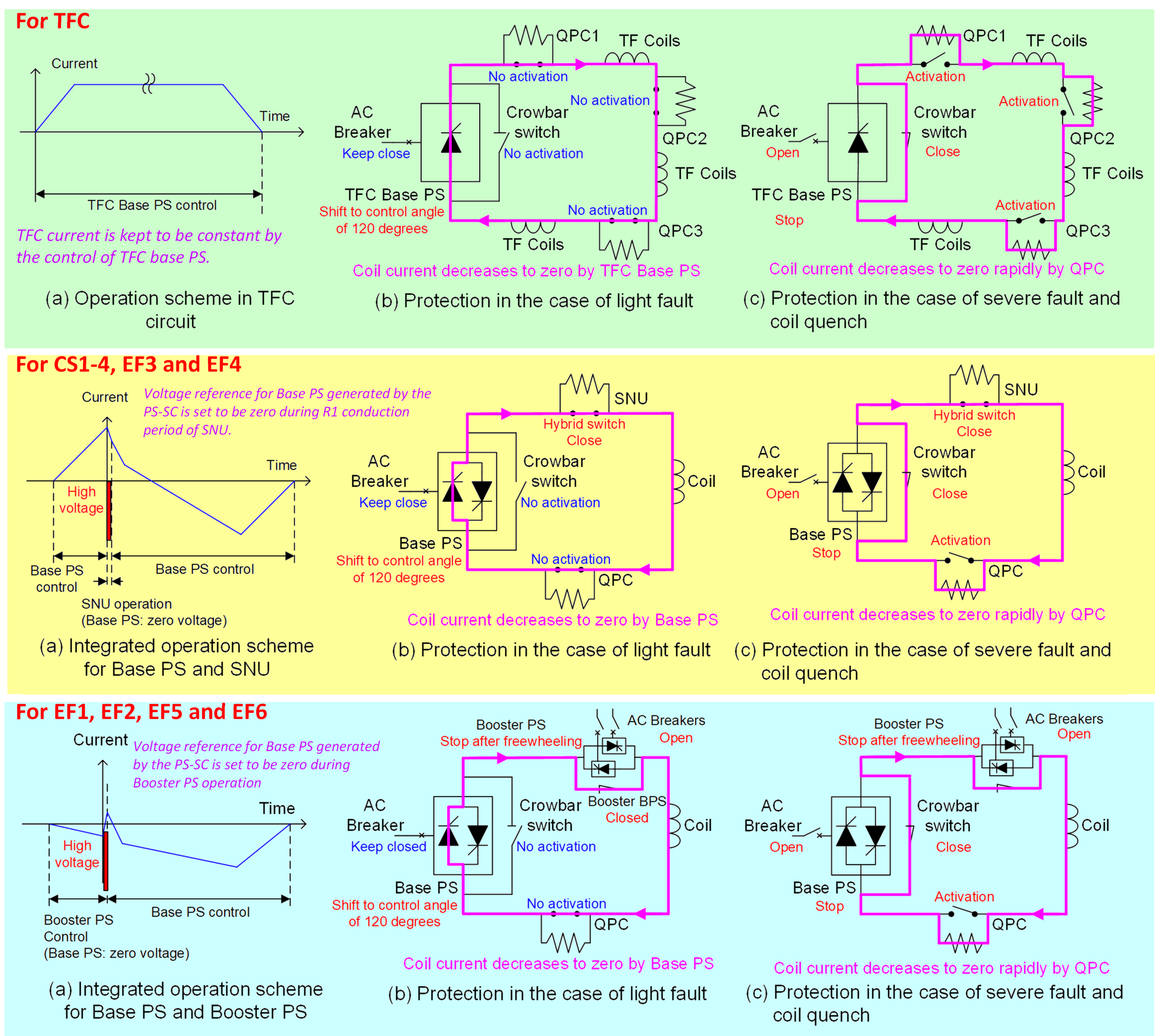
Test circuit condition

TFC combination test:
Short-circuit (dummy load not available)
PFC combination test:
Dummy Load (Inductance: 7.64 mH, Resistance: 6.995 mΩ, reused)



- Control and management for all PS components by PS-SC according to the desired operation scenario
- Signal communication (commands, references) via Reflective Memory (RFM)
- Real-time control system with 4 kHz
- Protection for all PS components managed by PS Interlock Protection System (PS-IPS, FPGA-based) via optics with fail-safe logic

Control and protection system in PS combination test



Simplified scheme of PS operation and protection

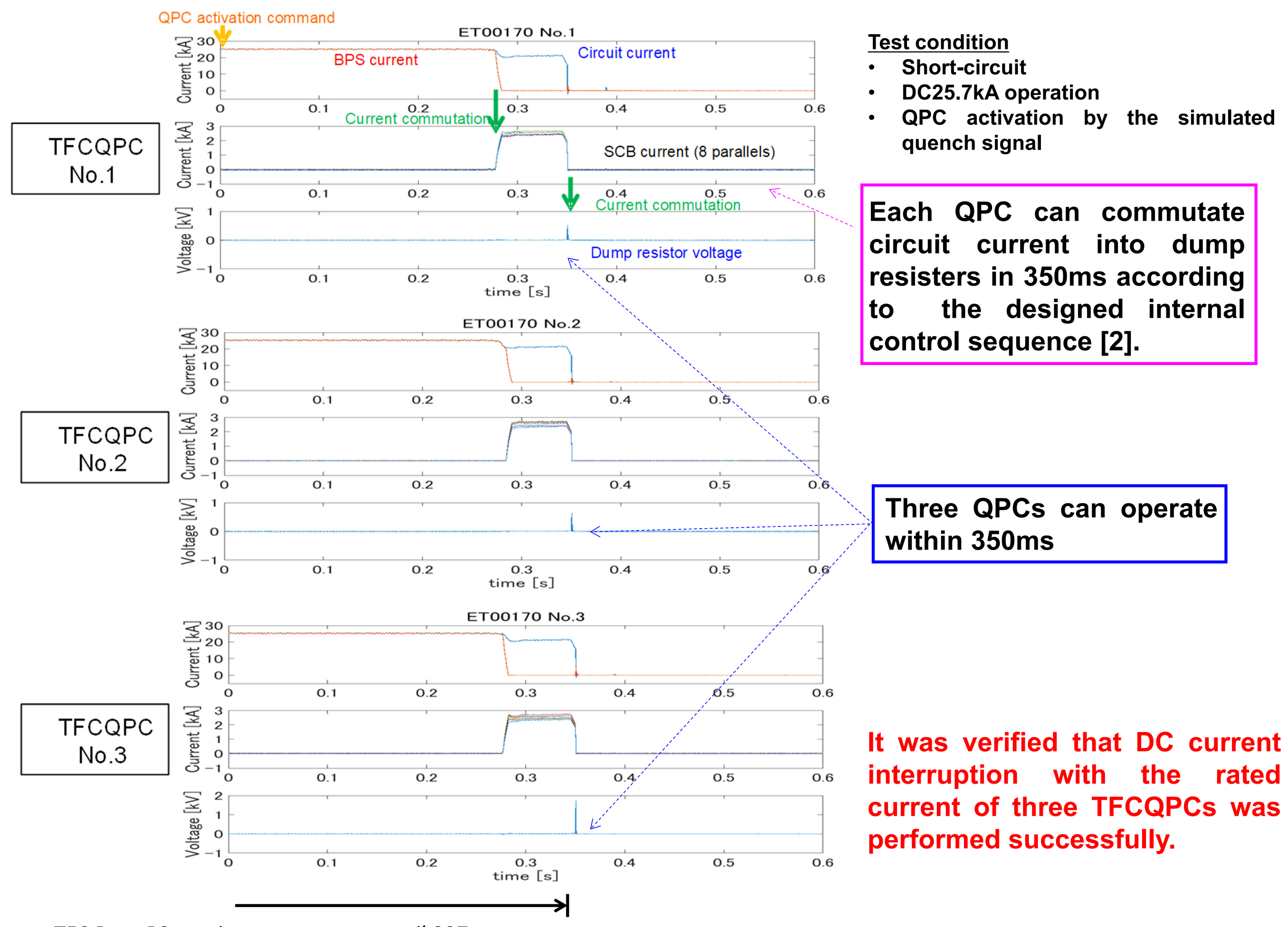
Main results in PS combination test

TFC COMBINATION TEST

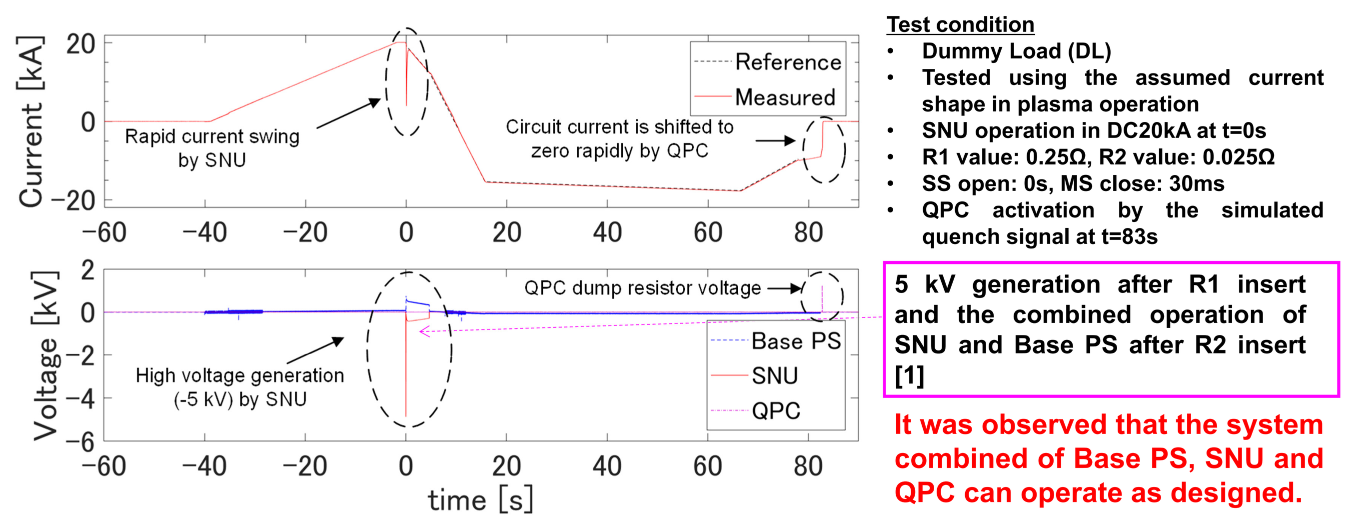
- 25.7 kA rated DC current interruption by three TFCQPCs was achieved in TFC circuit.

PFC COMBINATION TEST

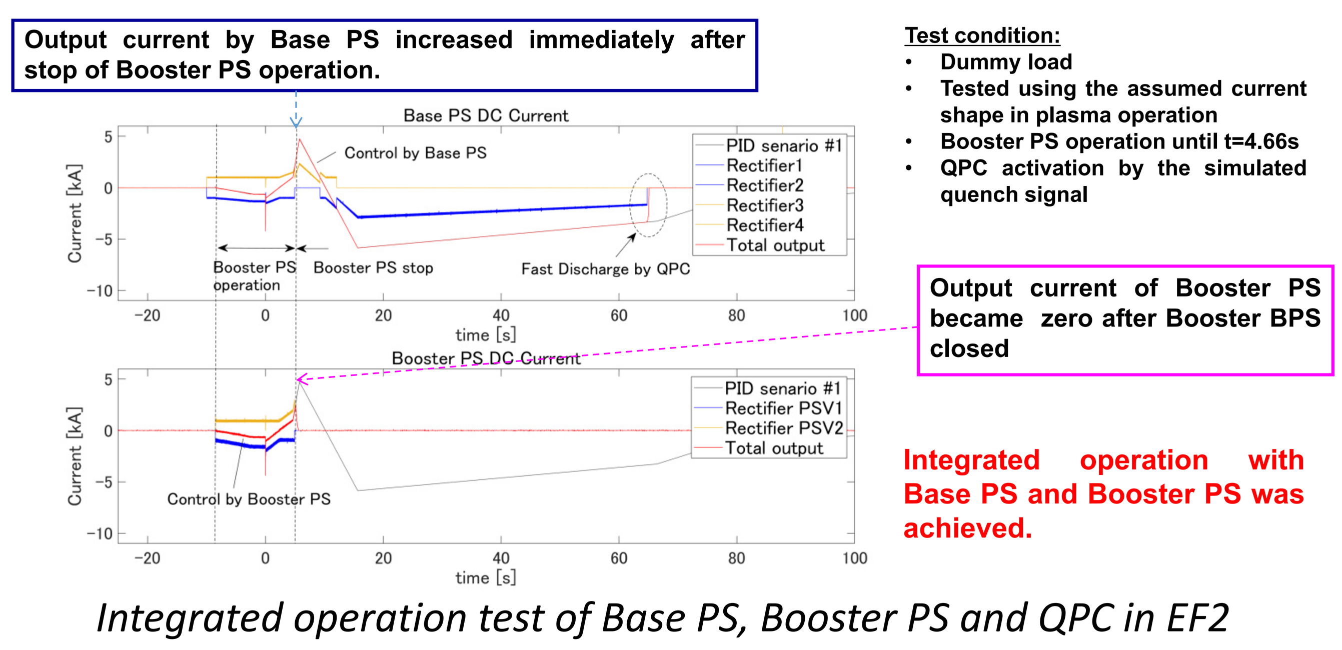
- Integrated operation of Base PS, SNU and QPC was completed successfully.
- High voltage generation of the rated voltage of 5 kV by the SNU was performed as designed.
- Integrated operation of the Base PS and the Booster PS was completed successfully.
- DC current interruption by PFCQPC was achieved.



Current interruption test with the rating current of 25.7 kA by TFCQPCs



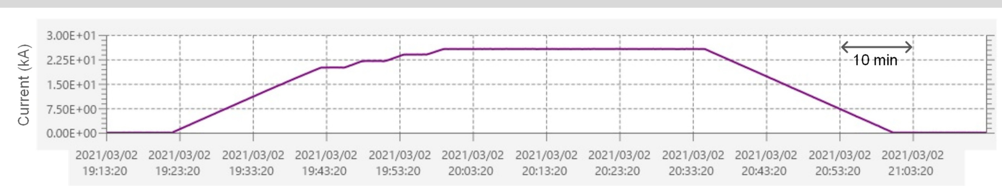
Integrated operation test of Base PS, SNU and QPC in CS4



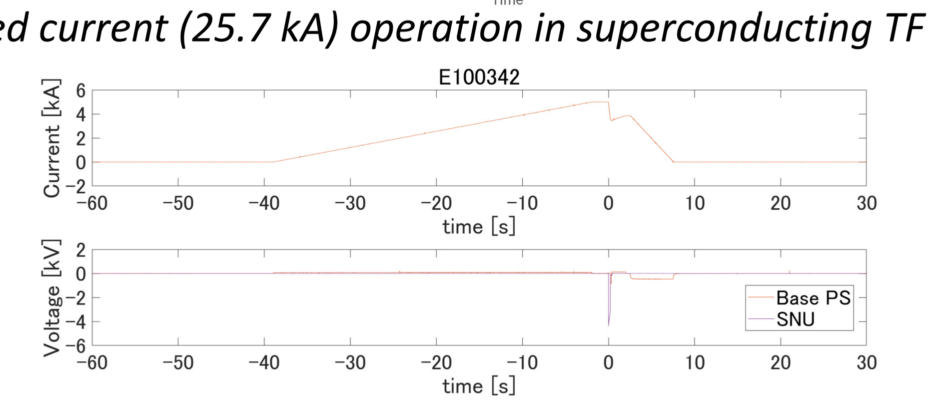
Integrated operation test of Base PS, Booster PS and QPC in EF2

PS integrated commissioning

- PS integrated commissioning with superconducting coils in JT-60SA has started in Jan. 2021. Important test results were obtained.



The rated current (25.7 kA) operation in superconducting TF coil



SNU operation at 5kA in superconducting EF4 coil

CONCLUSION

- In order to verify the performance of the overall system of PS components (in particular, integrated operation with various PS components) to achieve the proper DC power control with superconducting coil, all test items of the commissioning with the dummy load for the power supply system in JT-60SA has been completed successfully in November 2020.
- The completion of the PS combination test is one of the important achievements to start plasma operation with superconducting coils in JT-60SA and is expected to be one of contributions to future PS commissioning in ITER.

REFERENCES

[1] A. Lampasi, et.al., Energies 11 (2018) 996
[2] E. Gaio, et. al., Nucl. Fusion 58 (2018) 075001
[3] S. Hatakeyama, et. al., Fusion Eng. Des. 146 (2019) 1652