JT-60SA Magnet Commissioning Experience

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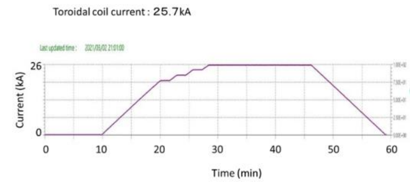
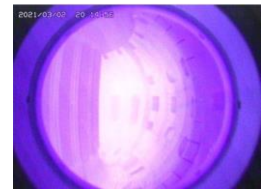
WPSA General Meeting, 4-6 May 2022

JT-60SA integrated commissioning



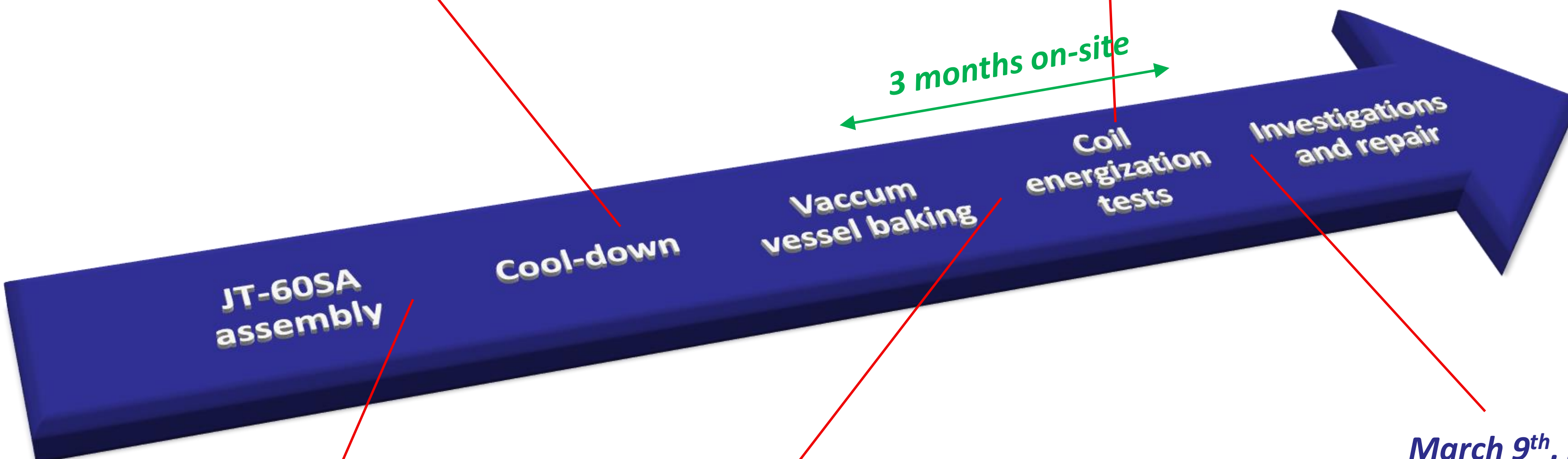
March 2nd, 2021

TF @ nominal current
+ ECR plasma



November 26th, 2020

All coils superconducting



March 9th, 2021

EF1 incident (electrical arcing+ cryostat vacuum loss)

January 13th, 2021

First coil energization (EF1 @ 1kA)

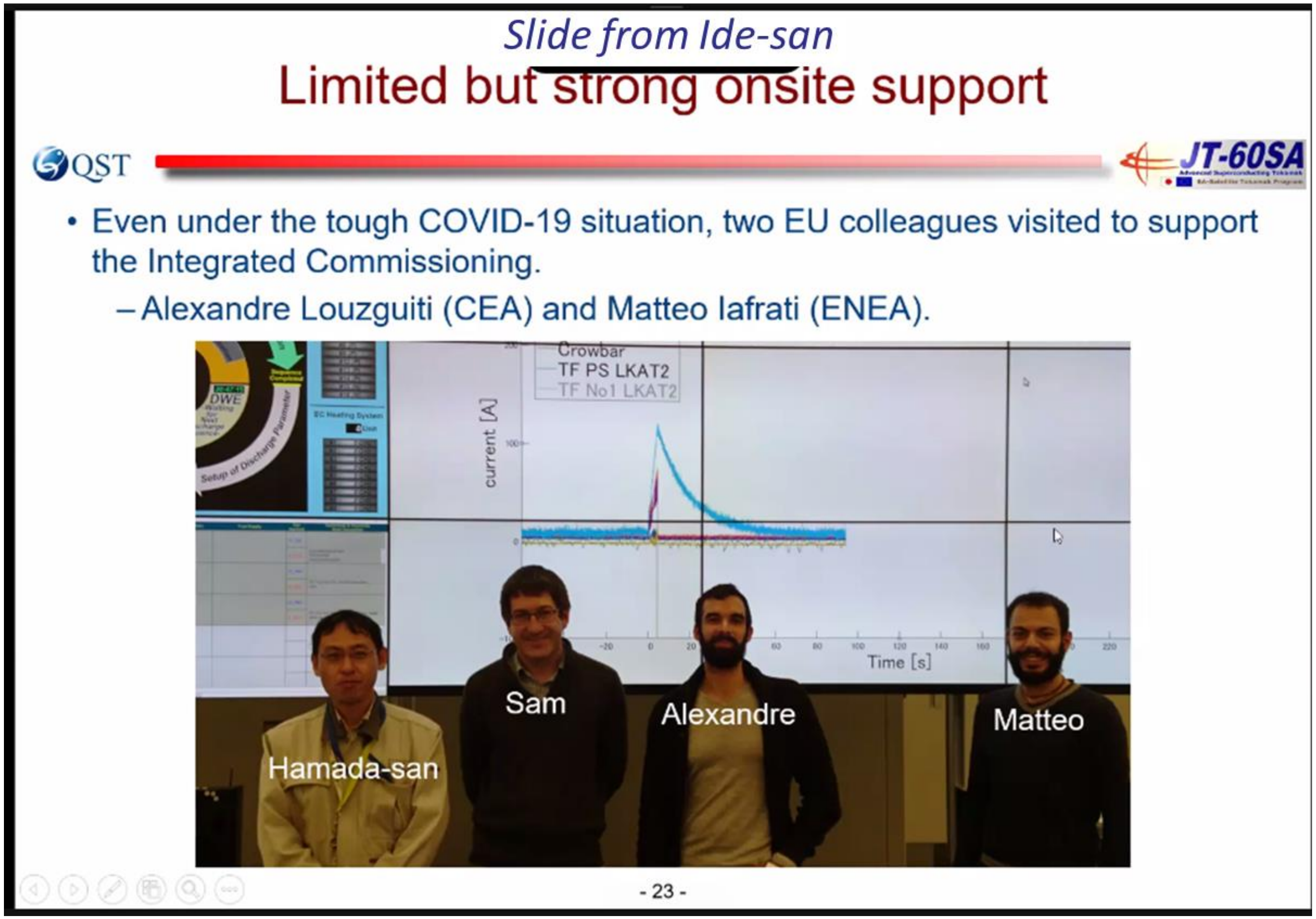
March 31st, 2020

End of assembly

Pictures from https://www.jt60sa.org/

Mission on-site

- Arrival in Japan on 08/12/2020
- Pandemic context (14 days quarantine in hotel, tests, masks, etc.)
- Stay on QST site from 23/12/2020 to 05/03/2021 = 2.5 months
- Active participation to coil energization tests



Main coil energization tests

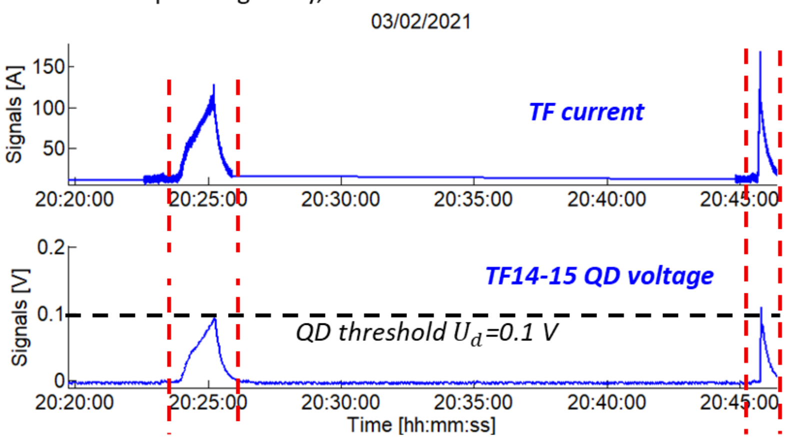
- Low Current Quench Detection Test
- PF current tests
- TF current tests
- PF voltage tests

Low Current Quench Detection Test

- **Each superconducting coil is protected with a quench detection (QD) system**. In case of quench detection, the coil is rapidly discharged (TF time constant < 14s, indiv PF < 4s)
- For **safety** purposes, we have led investigations on how to **test the QD system in real tokamak conditions** before injecting high currents in the coils (simulations & calculations for magnet safety analysis, resistance calculation, etc.)
- **Procedure defined & successfully applied to TF15 & EF3:**
  - Start from superconducting coil
  - Stop Helium flow in the coil to warm it up with the static heat loads until a small coil resistance appears (typically R_c>1mΩ)
  - Inject small current (typically I_c<0.5kA) until QD is triggered (i.e. when $R_c I_c > U_d$)

Tests on TF 15

warmed-up during 1 day, measured resistance before test ≈1 mΩ



Slow ramp-up (1 A/s)

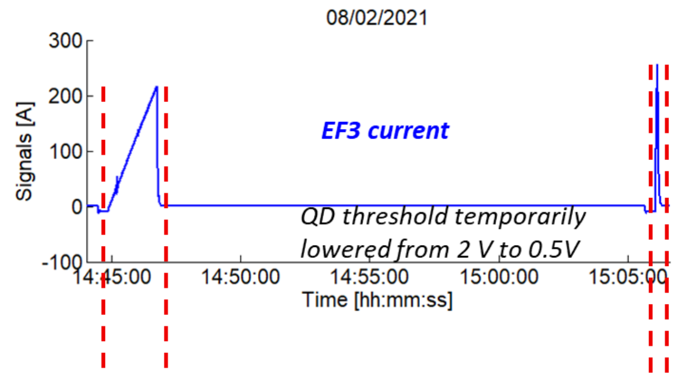
✓ QD triggered just over 100 A

Fast ramp-up (25 A/s)

✓ QD triggered just over 120 A

Tests on EF 3

warmed-up during the week-end,
measured resistance before test ≈2 mΩ

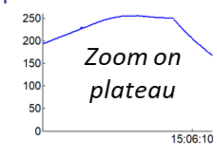


Slow ramp-up (2 A/s)

✓ QD triggered at 216 A

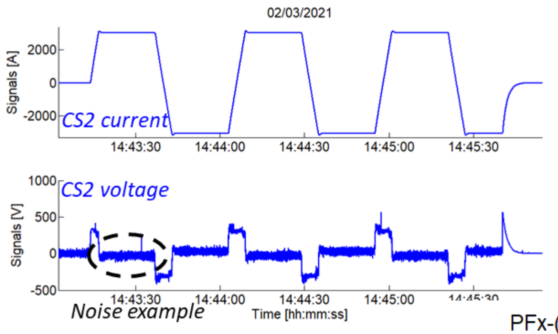
Faster ramp-up (50 A/s)

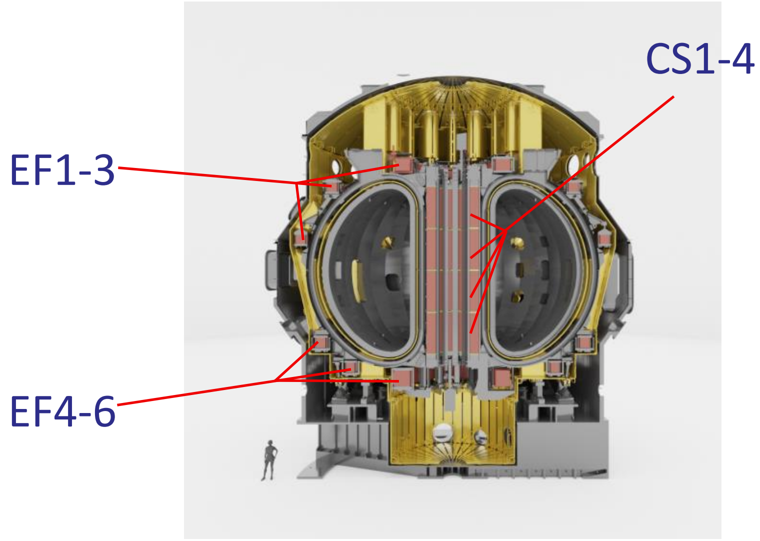
✓ QD triggered 1 s after plateau at 250 A

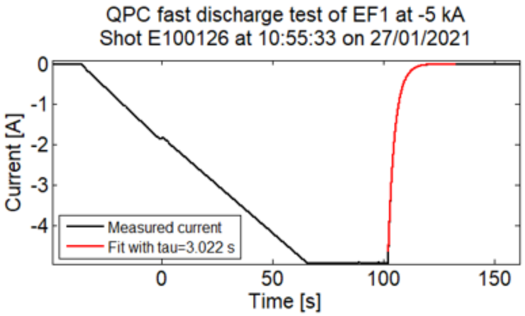


PF current tests

- **Individual coils current tests on 10 PF (4 CS modules+6 EF coils)**
- Calculations to ensure coil safety during tests in case of QD malfunction, analysis of fast discharges, PF coils polarity check
- **All PF coils have been tested up to +/- 5 kA (i.e. 25% of nominal)**, initial objective was 50% but **technical difficulties** were met, mainly caused by:
  - Problems on power supplies (e.g. command, PID, noise, wrong pyrobreaker firing+replacement, current balance in rectifiers, etc.)
  - QD balance, QD noise (capacitors installation+tuning)



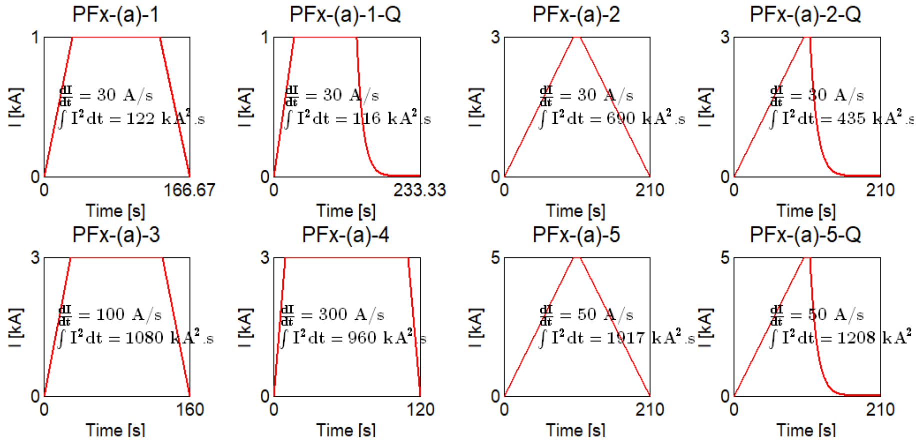




Theoretical time constant τ=2.907 s

I (kA)	Measured τ (s)	Relative difference
1	3.040	+4.6%
3	3.040	+4.6%
5	3.022	+4.0%

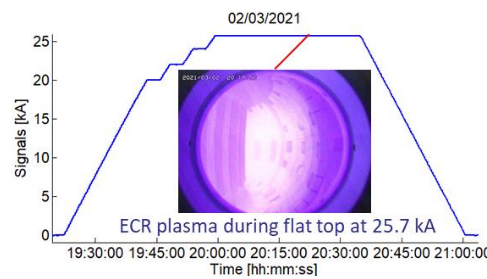
Time constants analysis of fast safety discharges: all measured time constants match the theoretical ones within +/-5 %

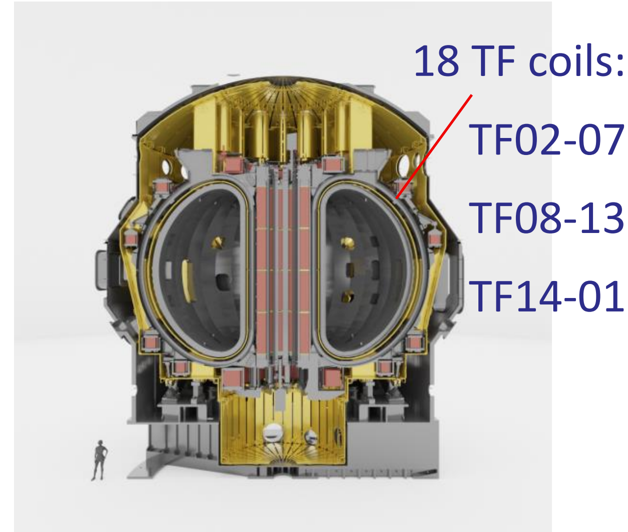


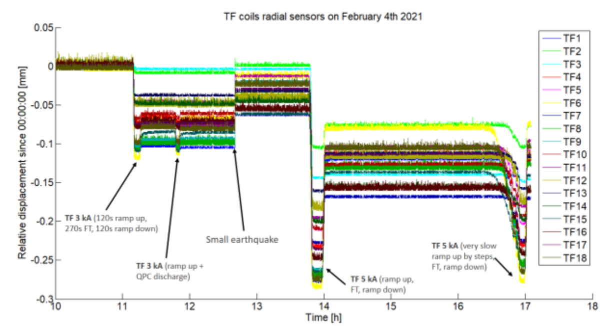
Some waveforms for PF coils current tests
(combinations of ramp-ups, plateaus, ramp-downs, and fast safety discharges on a dump resistor)

TF current tests

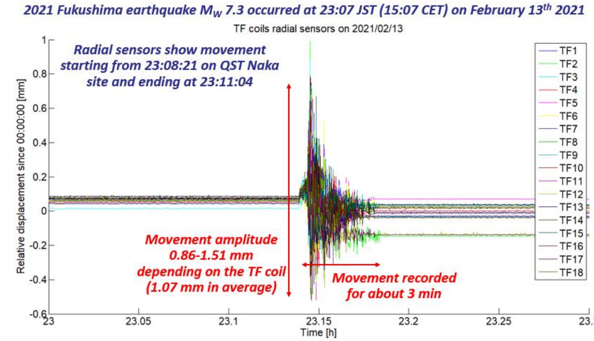
- **Individual TF magnet test** (18 TF coils in series) → current ramps and fast discharges
- Analysis of fast discharges, monitoring of QD system, He temperature & TF displacement during tests and 7.3 M_W Fukushima earthquake
- ✓ **Nominal current 25.7 kA achieved on March 2nd, 2021 + ECR plasma during flat top**

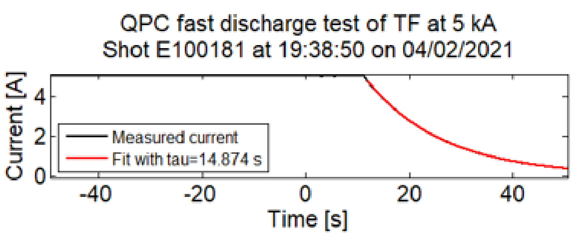






2021 Fukushima earthquake M_W 7.3 occurred at 23:07 JST (15:07 CET) on February 13th 2021





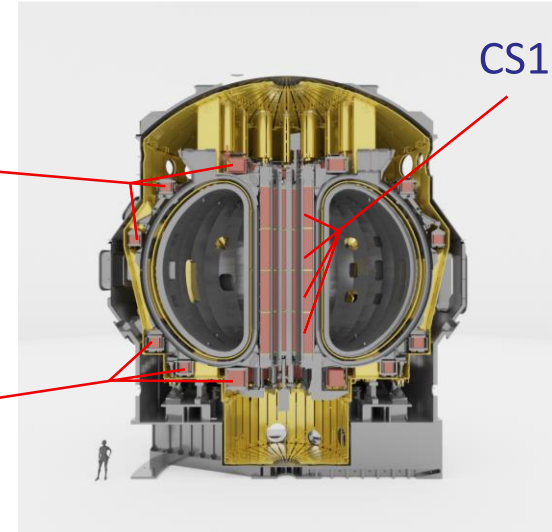
Theoretical time constant* τ=14.028 s

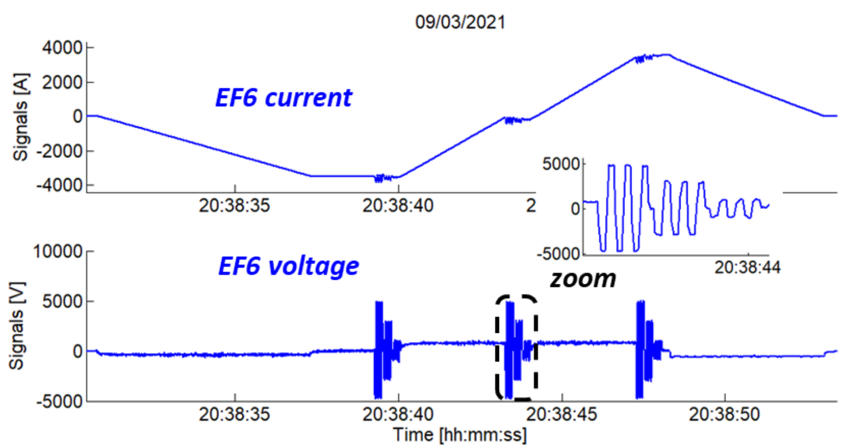
I (kA)	Measured τ (s)	Relative difference
5	14.874	+6.0%
10	14.9	+6.2%
18	12.6	-10.2%

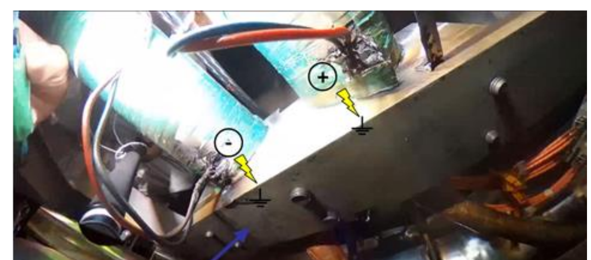
Time constants analysis of fast safety discharges

PF voltage tests

- Individual coils **voltage control tests** up to +/-5 kV on 10 PF (4 CS modules+6 EF coils)
- Voltage & current waveforms = current ramp until plateau and +/- 5, +/- 3 and +/- 1 kV rectangular voltage signal
- **All PF coils except EF1** have been successfully tested up to +/-5 kV
- **Electrical arcing incident** occurred during the very last coil voltage control test sequence (on **EF1**)







Work life at QST & recommendations

- Limited interactions because of language barrier + short lunch break (15 min), no coffee break → difficult to interact and bond with QST colleagues
- Important communication between EU colleagues to share info and avoid duplicated questions to QST
- Focus on one QST contact person rather than several of them (ideally, one per EU person)
- Spend time in control room to get the information and have opportunities to discuss and not lose track
- Respect hierarchy in requests (ask person's supervisor rather than to the person directly)
- Propose your expertise & help pro-actively but respecting QST pace and organization (QST rarely asks you tasks)
- Download app for "visual" Japanese translation (for procedures in JP, etc…)


Control room


F4E colleagues (Sam & Giulio)


Control room from magnet side


QST magnet colleagues (Hamada-san, Fukui-san, …)


Cryomag control room