Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Power supplies in DTT

ILO Industrial Opportunities Days

Osservatorio Astronomico di Capodimonte, Naples, Italy
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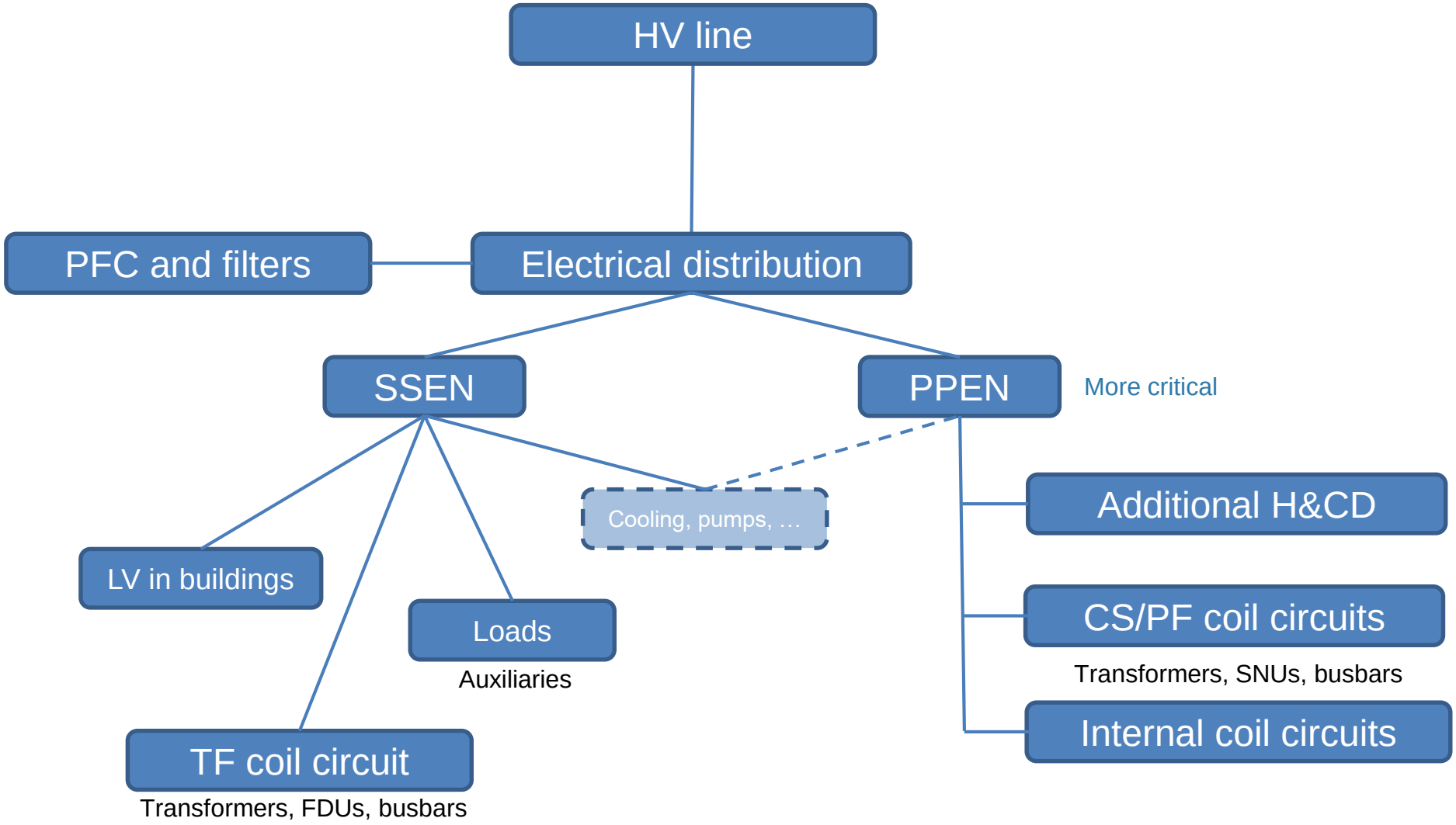
Topics of the presentation: PSS Procurements

Power supply System (PSS) = everything electrical in the DTT project

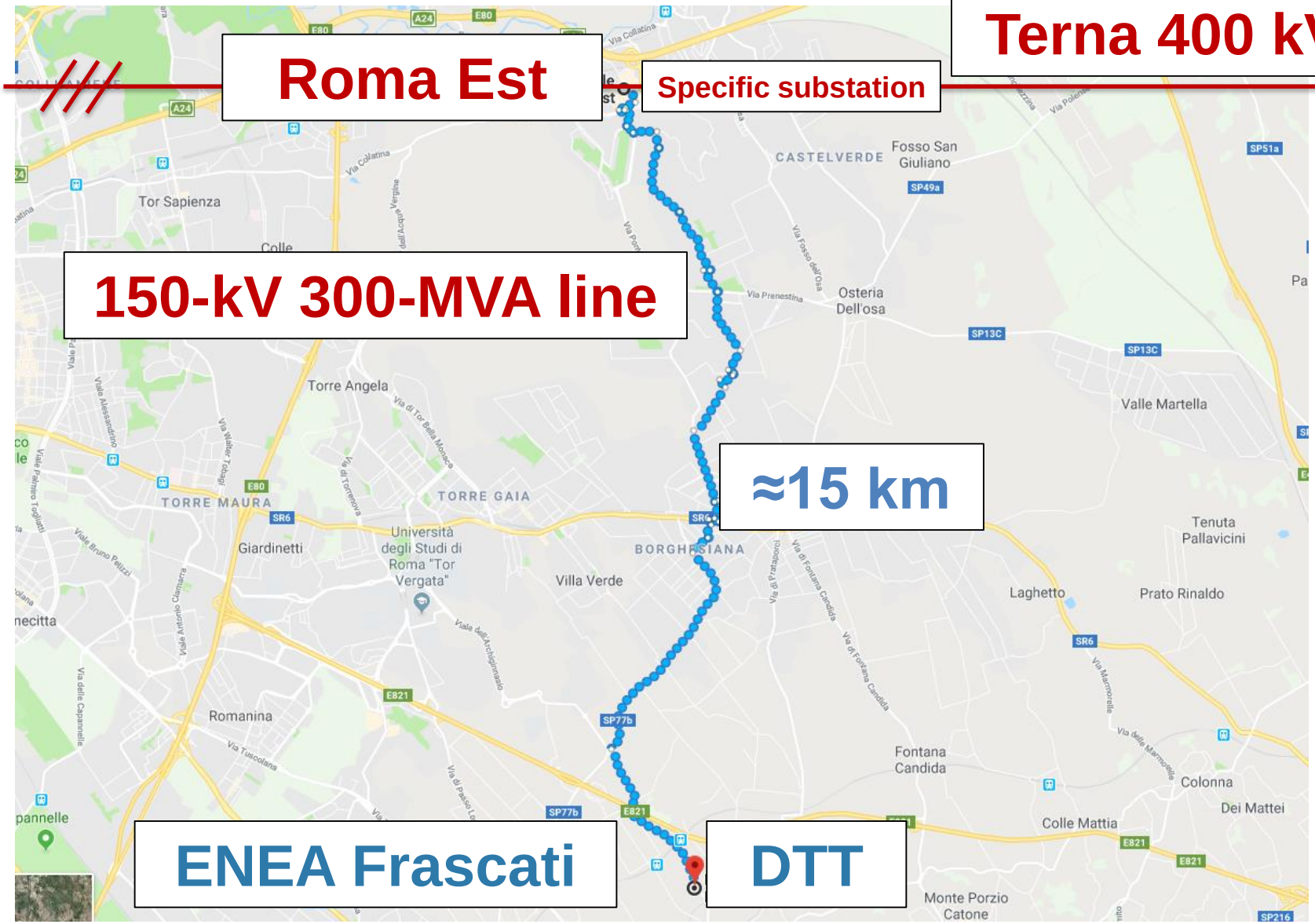
Excluding (partially):

- The standard low voltage distribution inside the buildings
  - Included in the BUI/site procurements
- The Additional Heating (ECRH, ICRH, NBI) PSs
  - I am partially in charge
- PSs for control of ELMs, RWMs
  - Not yet totally defined

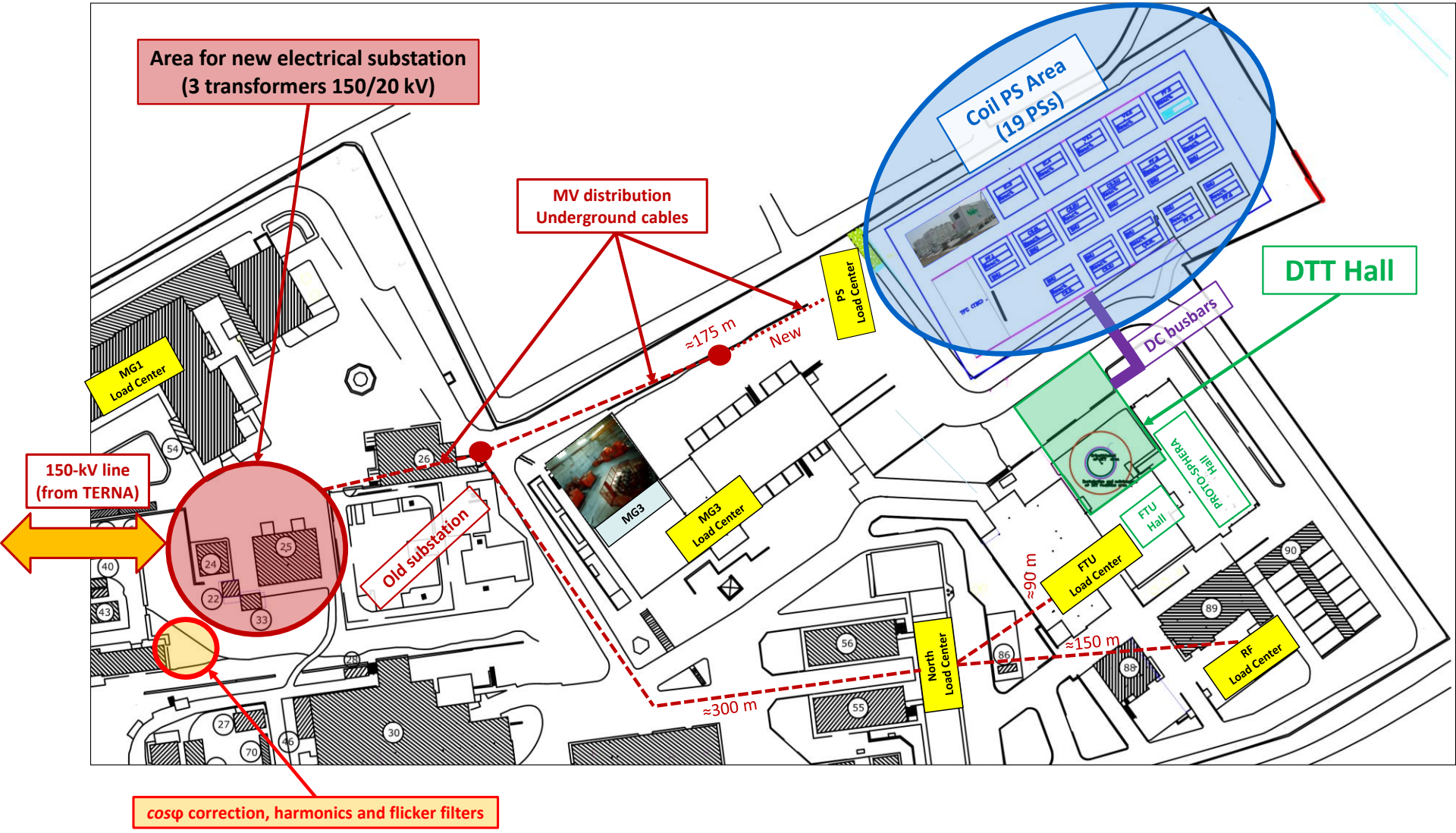
Description follows flow of power



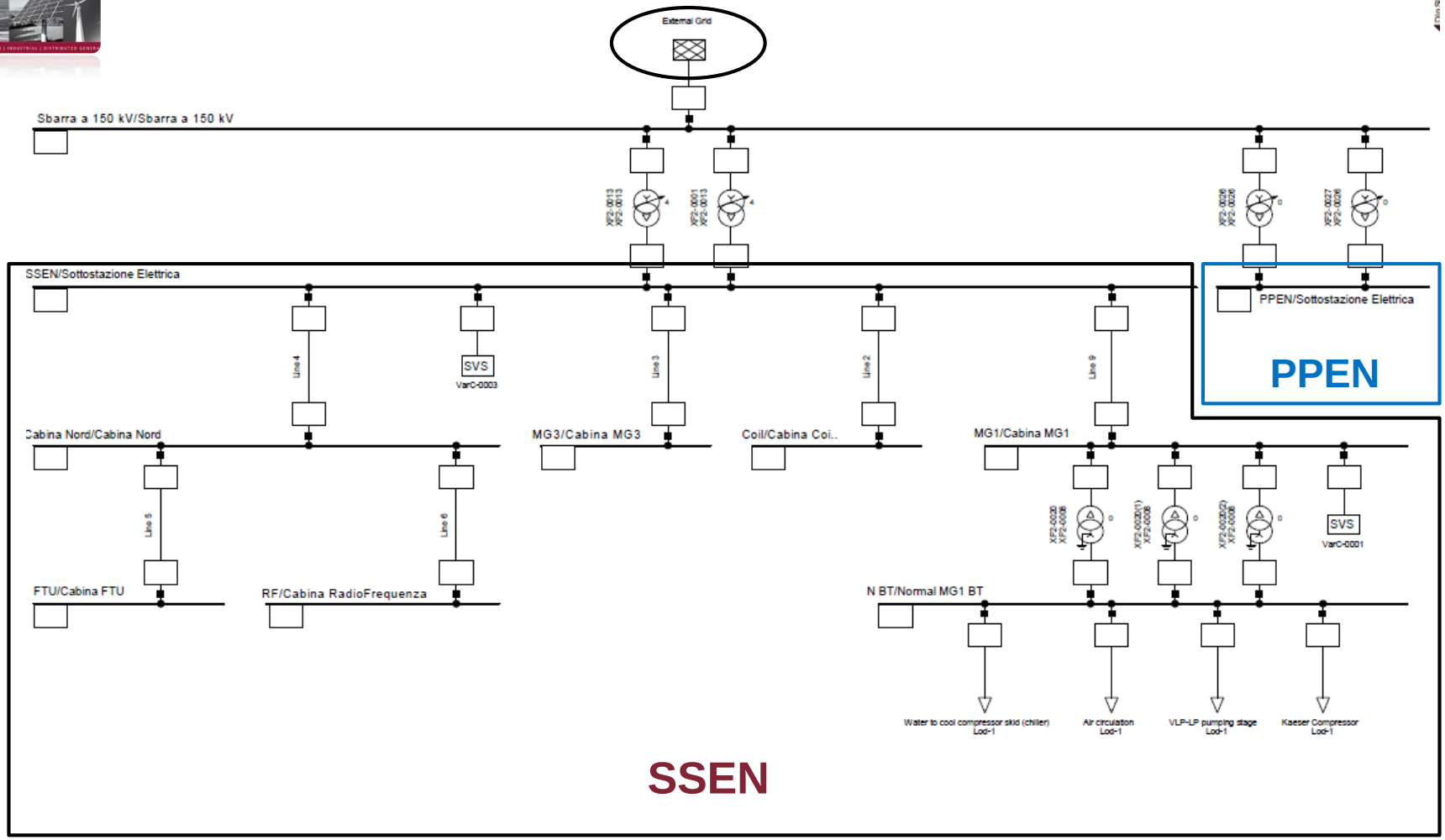
HV line (approximate) path



PS layout in ENEA Center

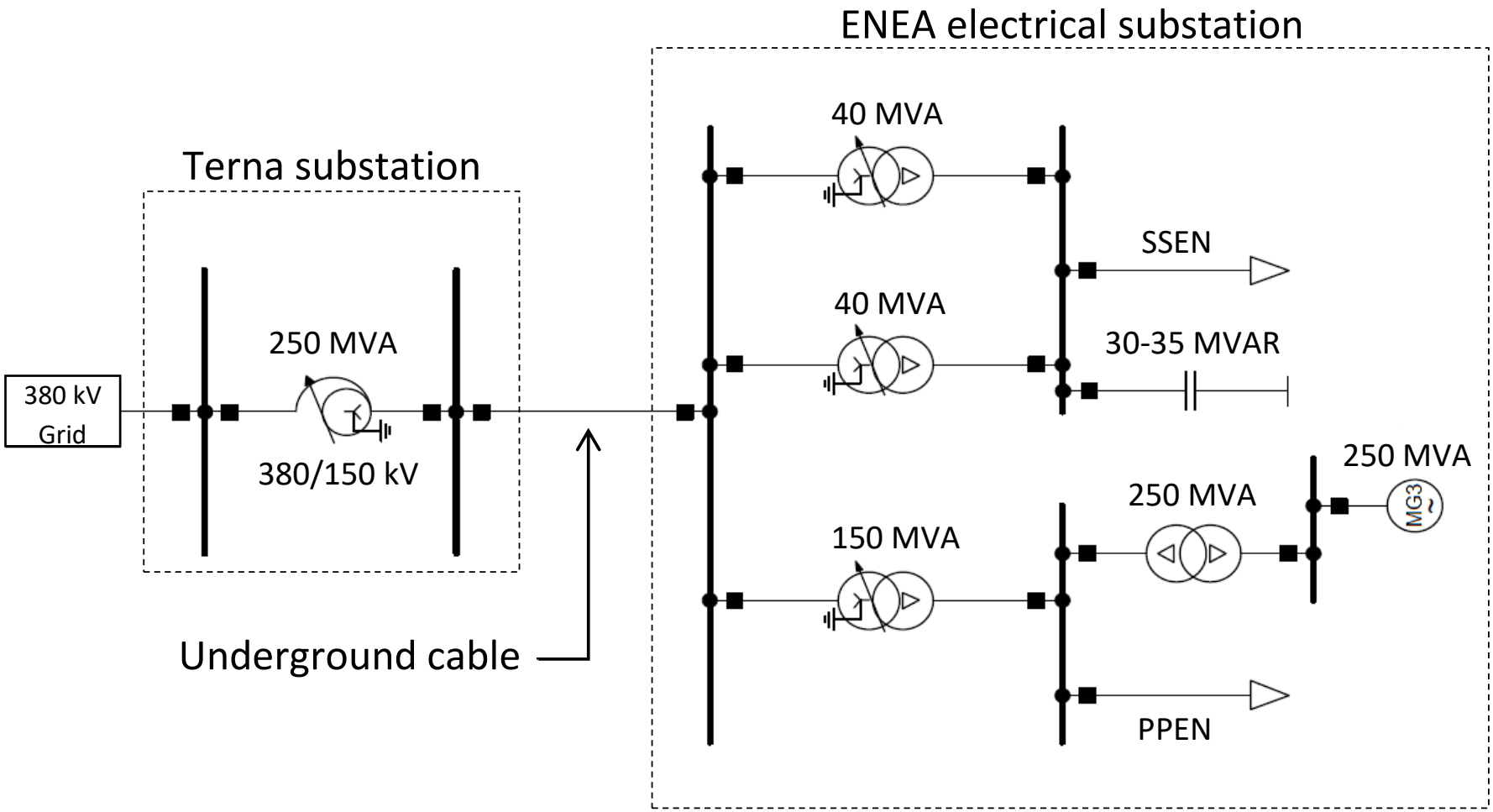


Single Line Diagram

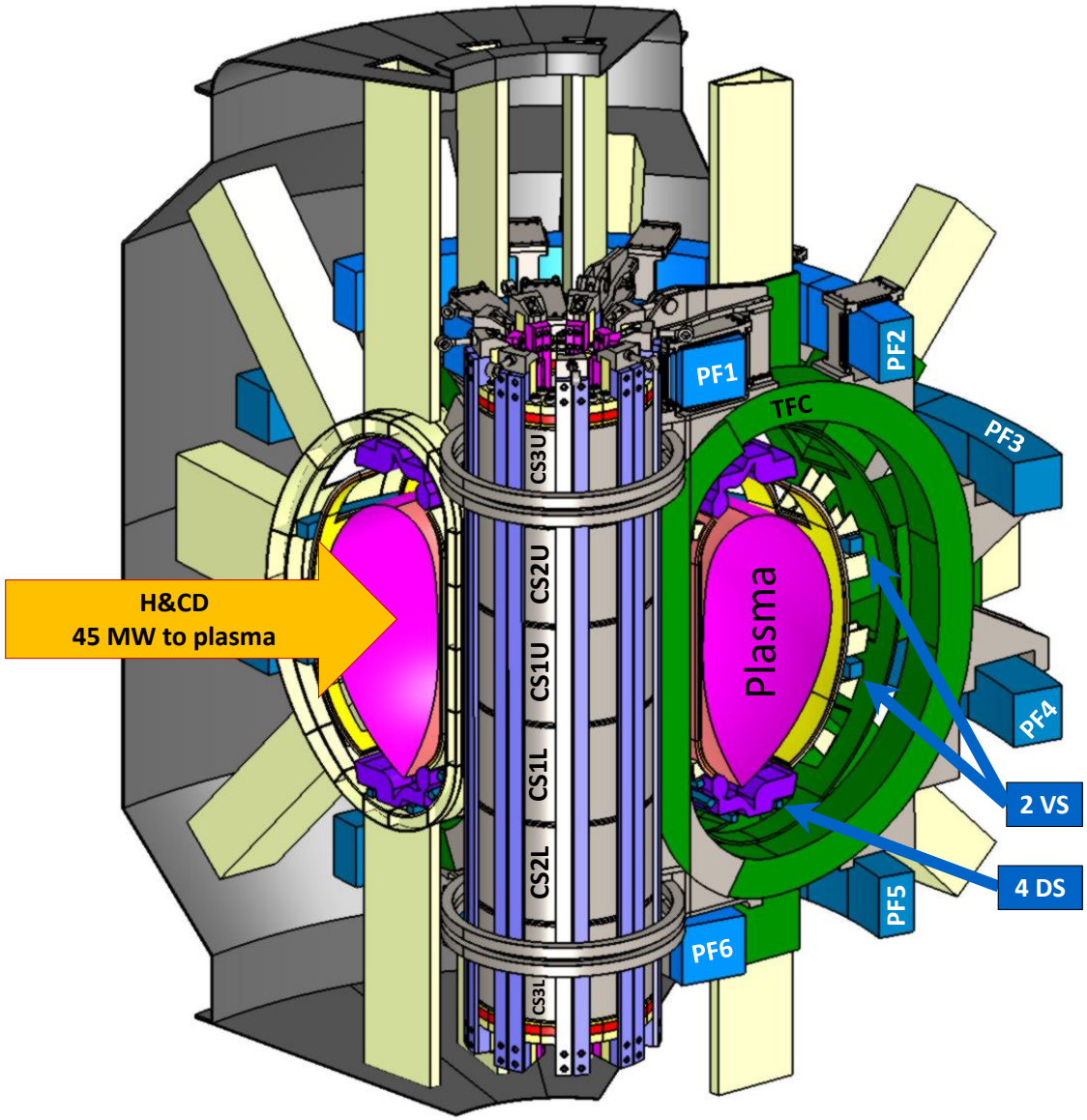


Options for power factor correction (+harmonics, flicker…)

1. STATCOM (SVC)
2. Rotating synchronous compensator (condenser)



Summary of the 19 coil PSs



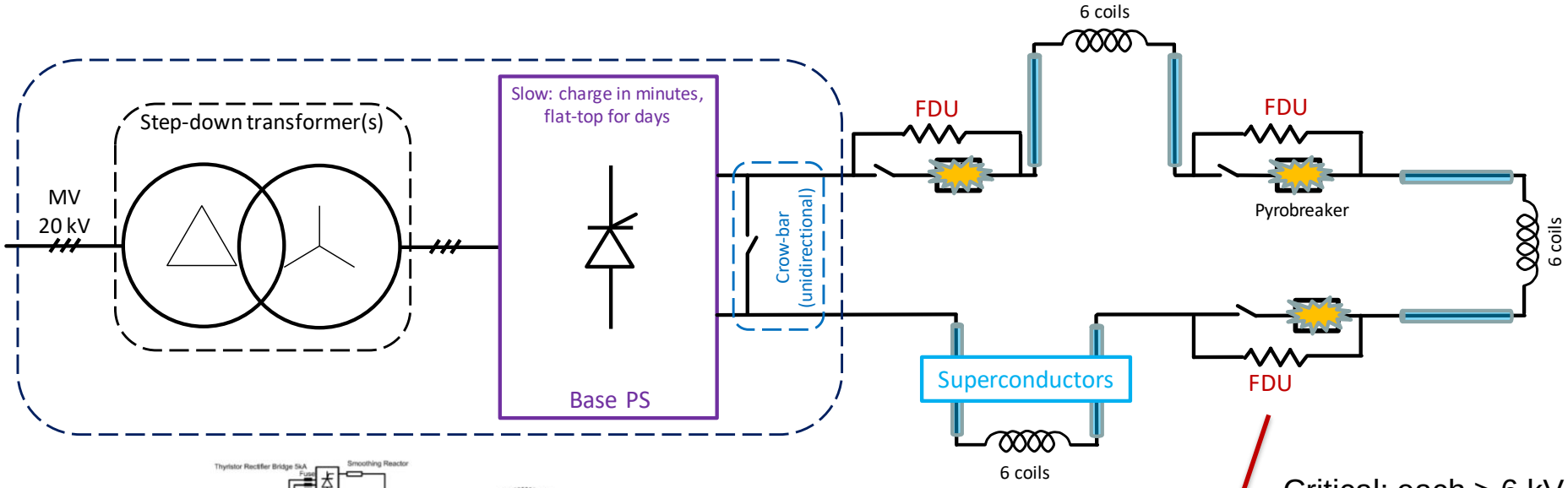
Operation: ≈100 s
Period: every 3600 s

Superconducting coils:
- 12 CS/PF

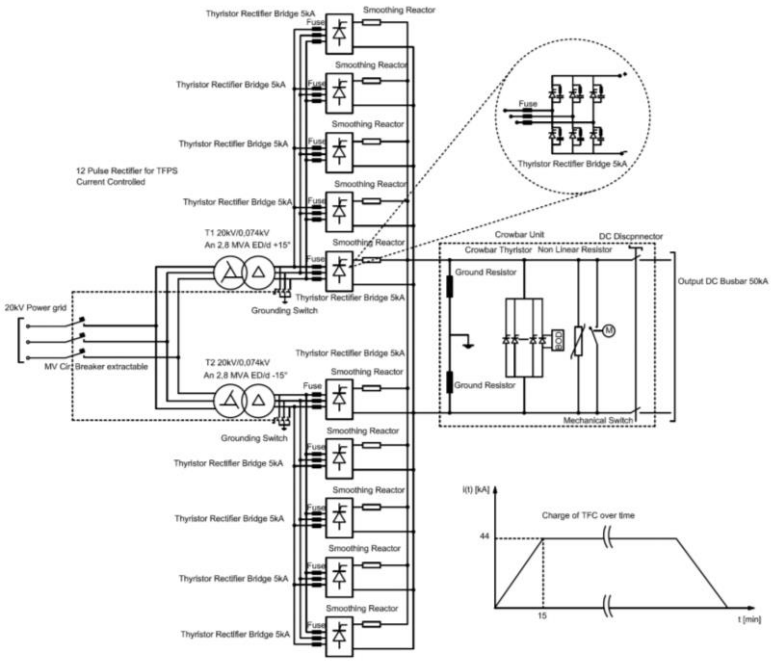
Copper coils:
- 2 VS (equatorial)
- 4 IV (under divertor)
- ELM, RWM

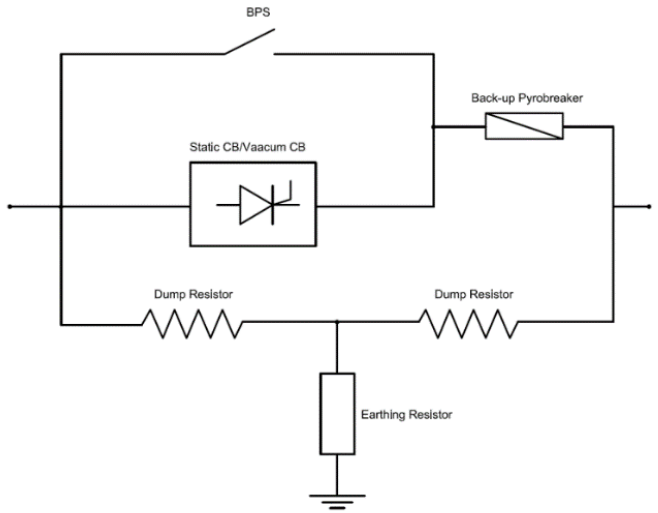
Continuative (days):
- 1 TF

TFC PS: 45 kA, 100 V



Critical: each > 6 kV





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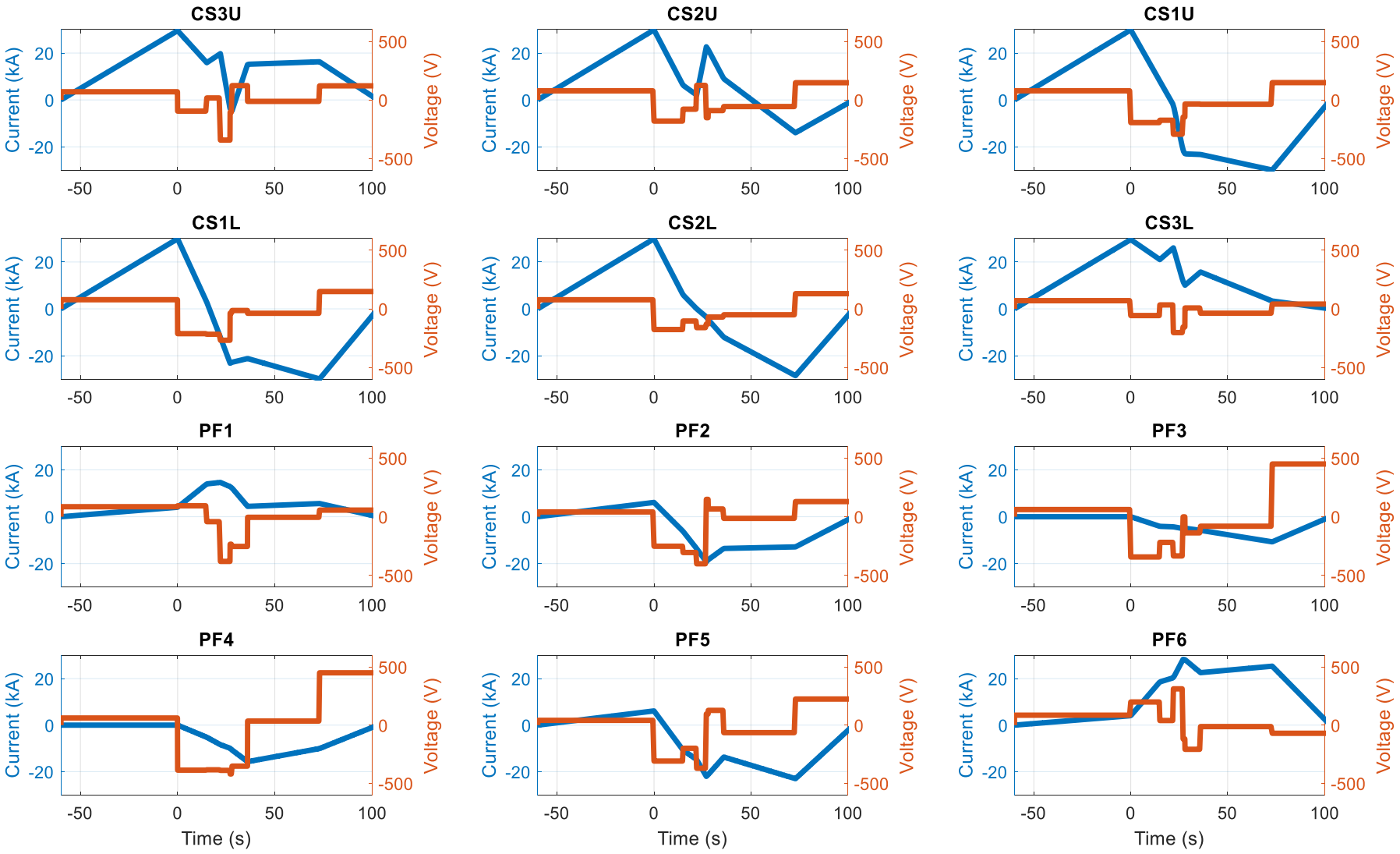
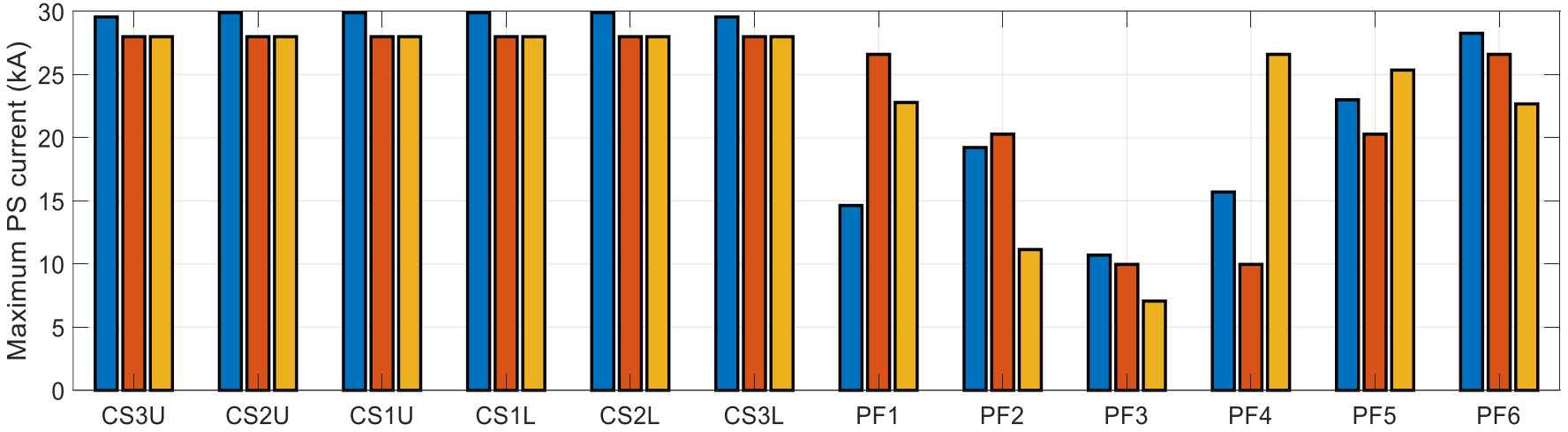
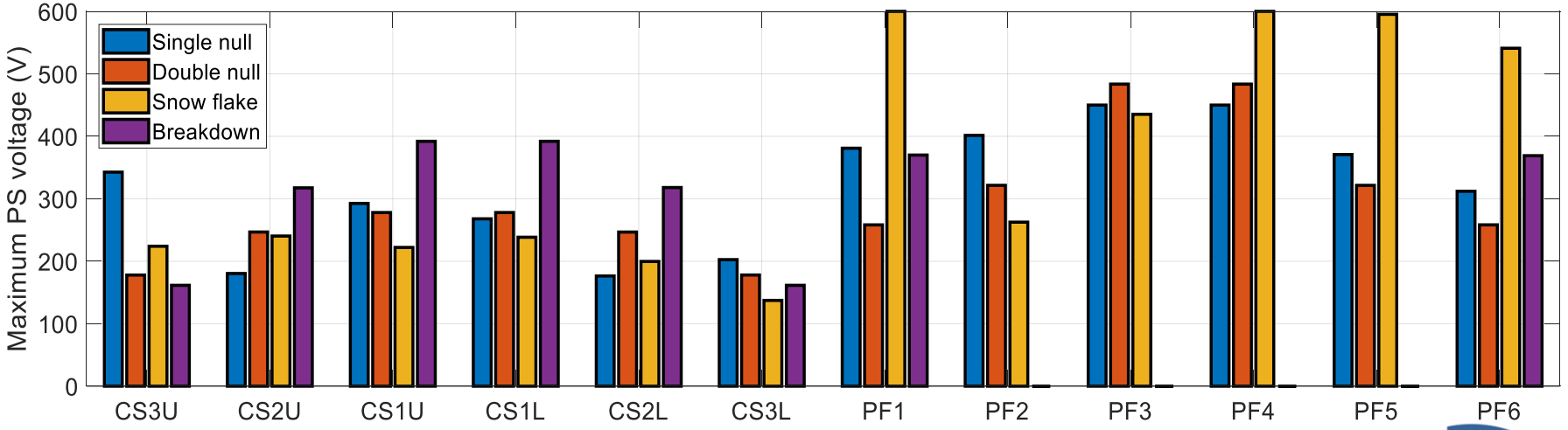


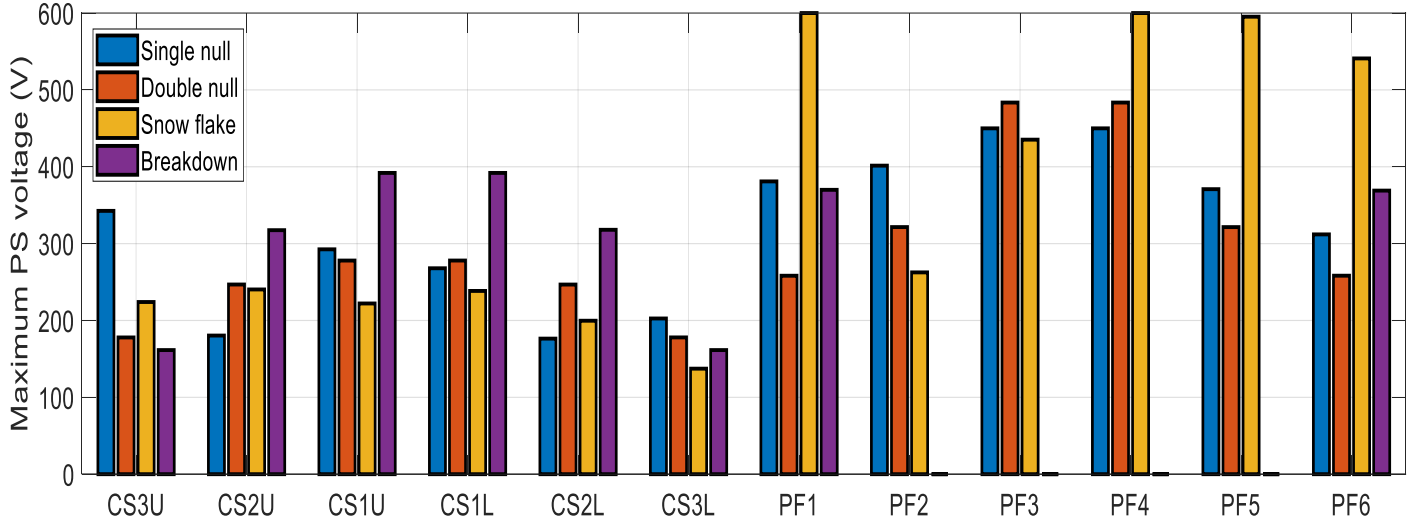
Max I, V ratings (old DN, SF)

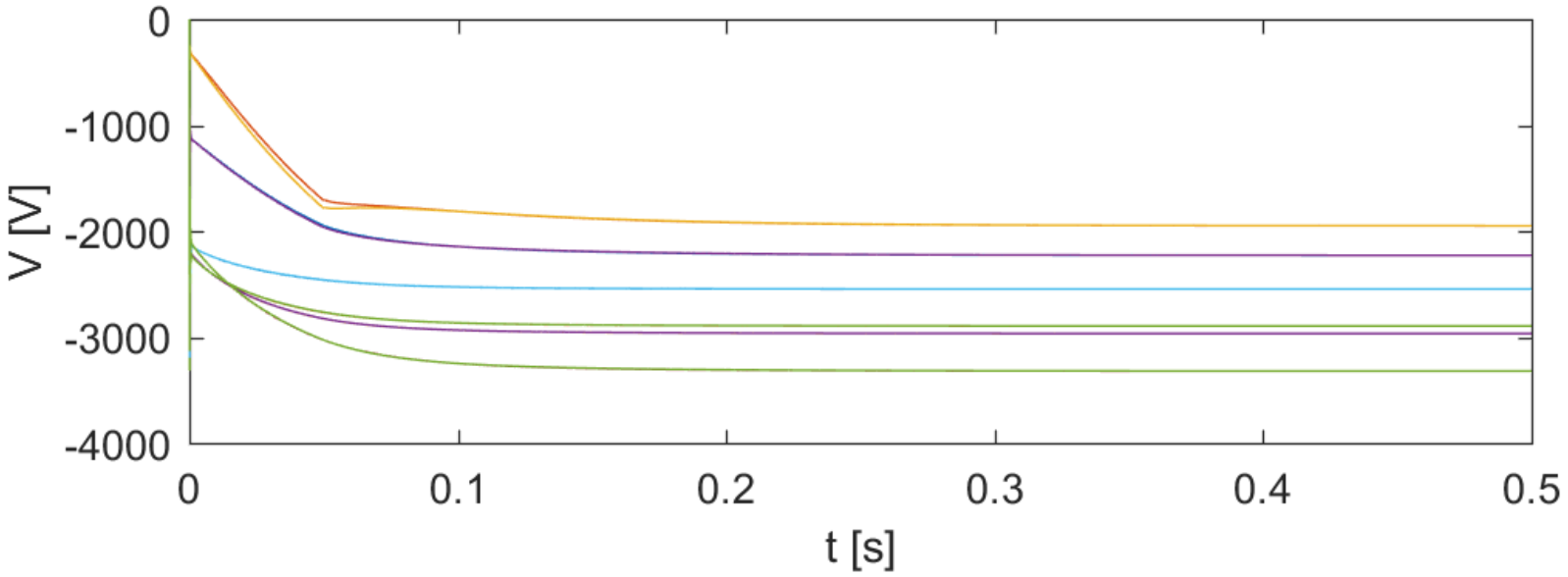


SF had a lot of power in the middle of the scenario

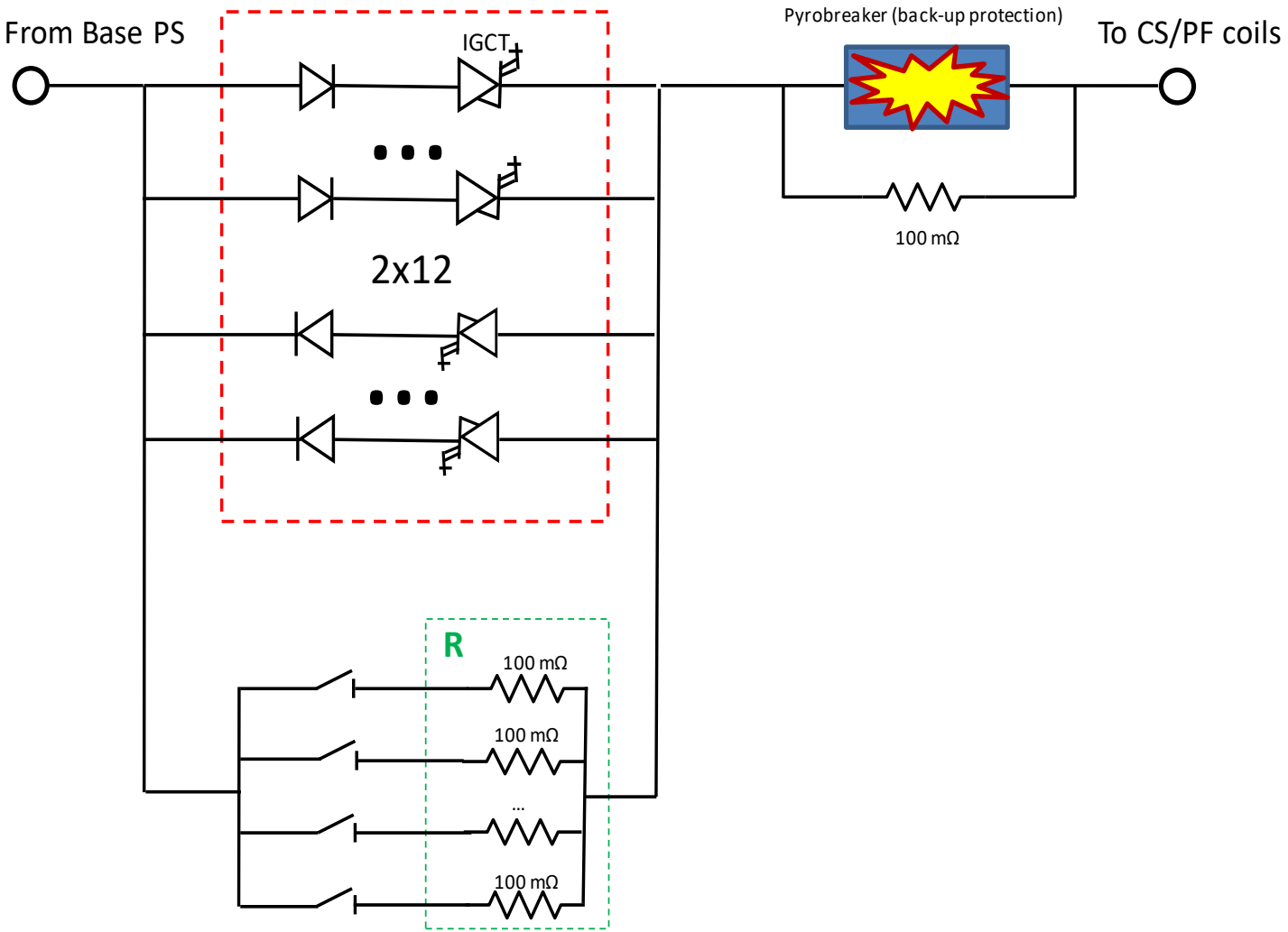


Breakdown with dynamic compensation

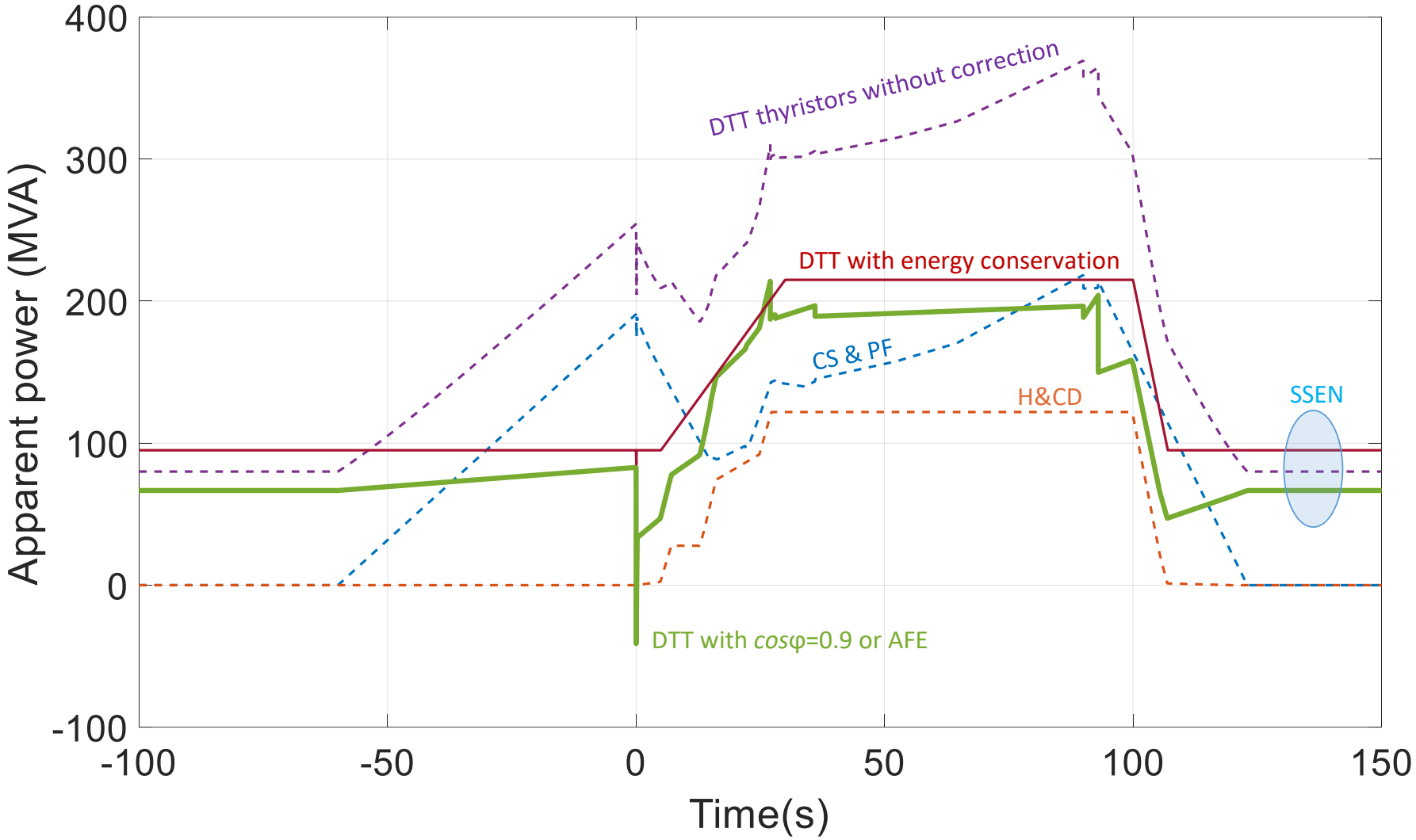




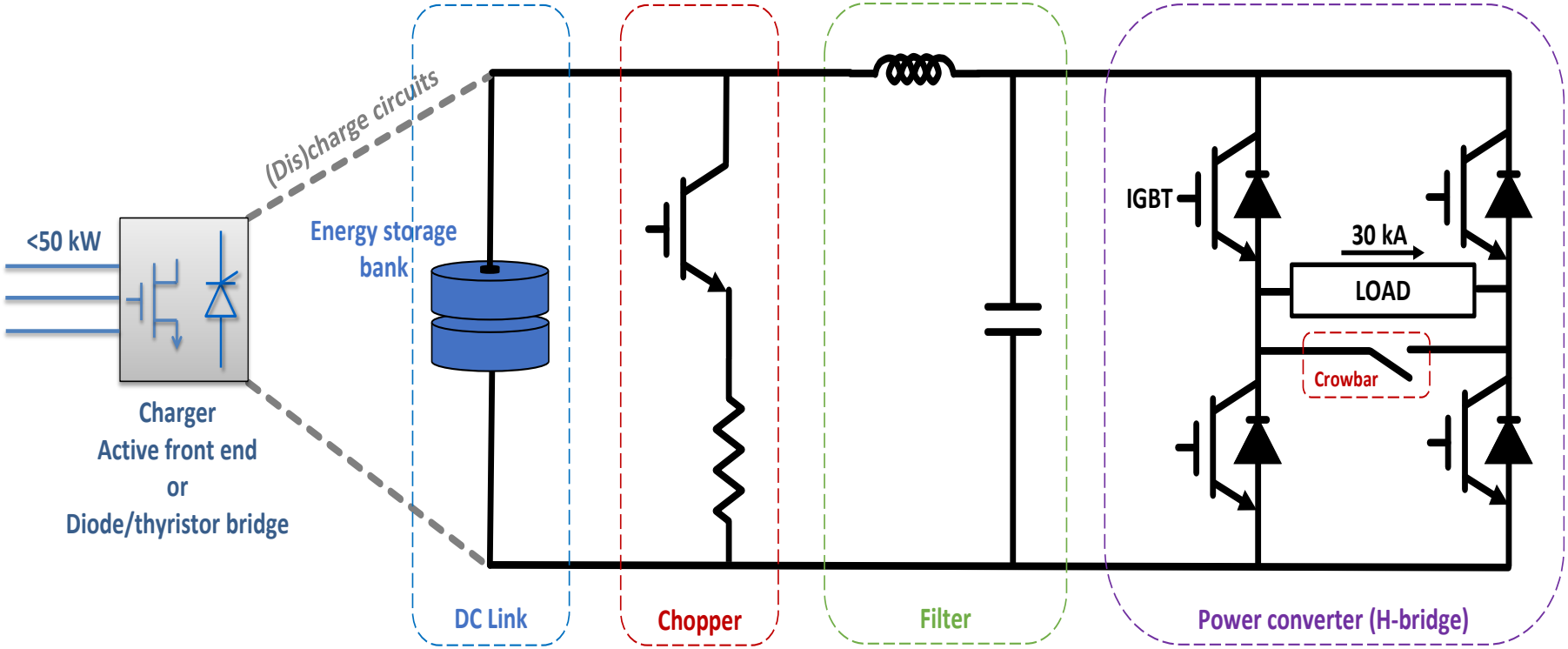
Functional scheme of a SNU (with external FDU)



Official scenario for Terna



6 CS + 6 PF PS topology



Basic principles:

- Low impact on the external grid
- Low power input: 20 kV, <100 kW (energy recovery)
- Dynamic compensation during breakdown
- Modularity

Working prototype

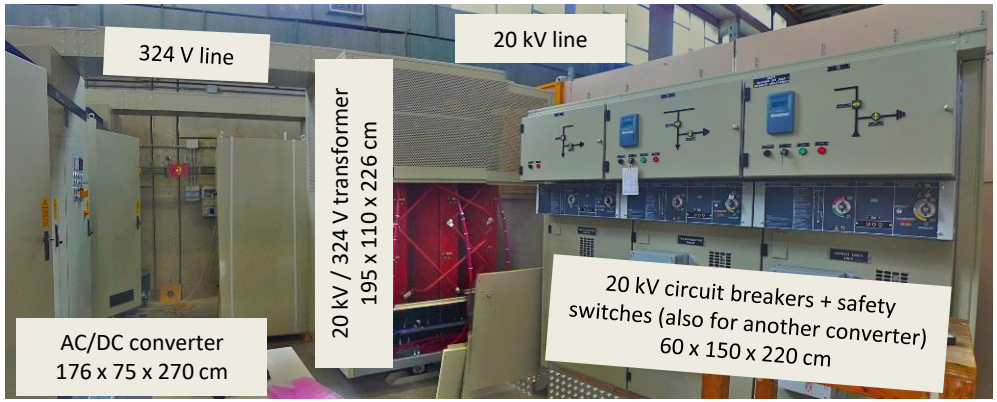
SCPS: 2 kA, 10 s

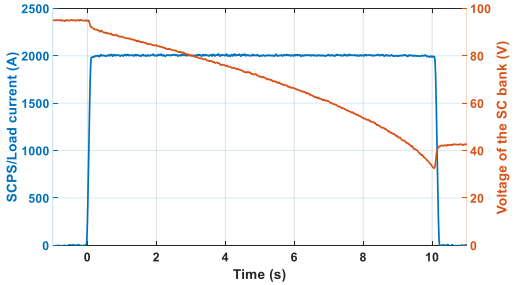
Dimensions:
120 x 60 x 190 cm
= **1.4 m³**

Wheels to move it!

Connections: just the plug and the load

Previous system: 2 kA, 1 s





Total dimensions:
> 10 m³ (> 7 times)
+ dedicated 20-kV line
and 324-V line

Fixed installation
with many connections

Rough estimation of possible final configuration

- Total Energy Storage for 12 PSs: 600 MW, 3600 MJ, 960 kWh
- Moreover, ENEA has SMESs and flywheels
- Comparison:
  - Korea: 25 MW supercap in several facilities
  - Endesa STORE, Canary Islands, Spain supercap: 4 MW, 20 MJ
  - Terna, Sicilia + Sardegna supercap: 1+1 MW, 1+1 MJ
  - Terna has some battery systems in order of 10 MW
  - DTT could be an “electrostatic lake” (Italy has 4 hydro-storage lakes at 1 GW)

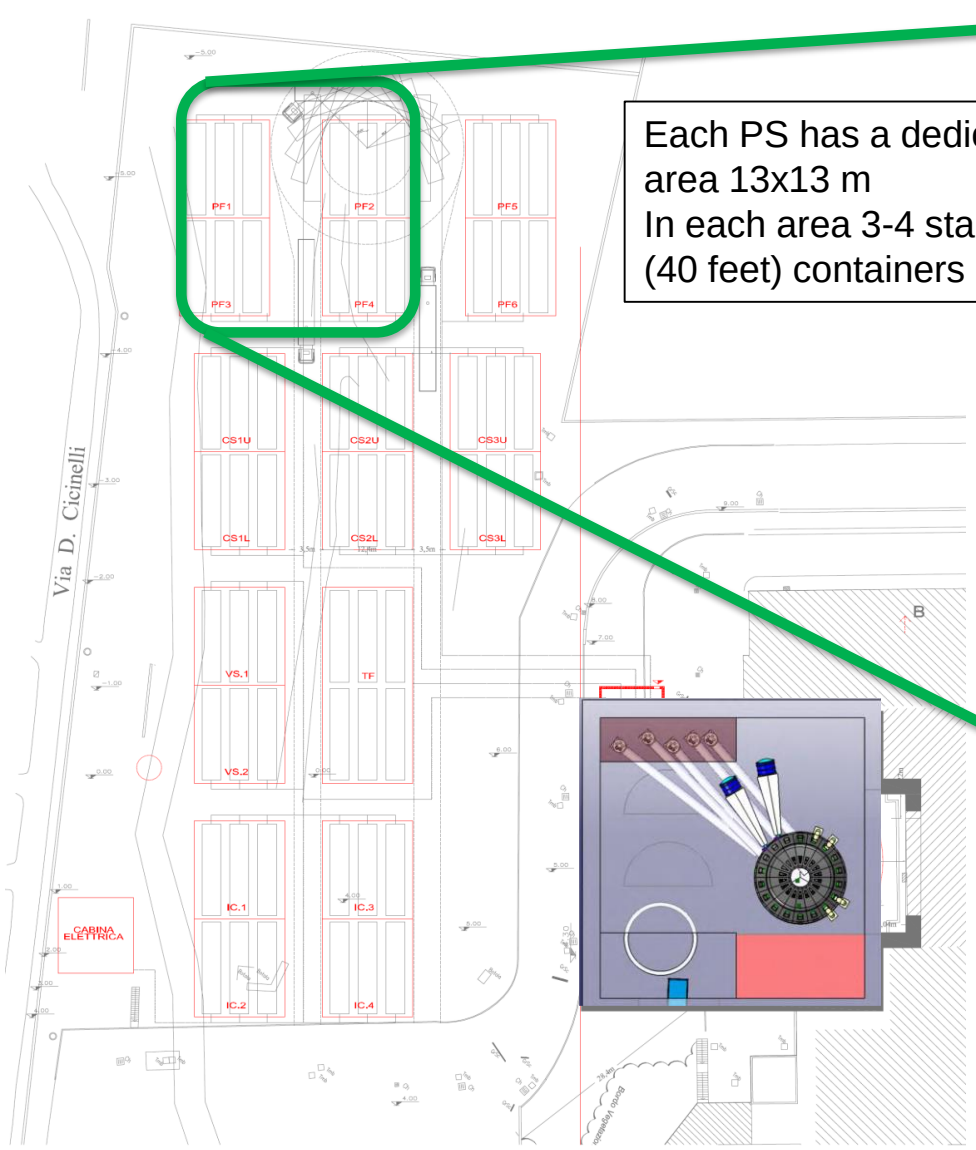
If you like to know more: www.supercap.org

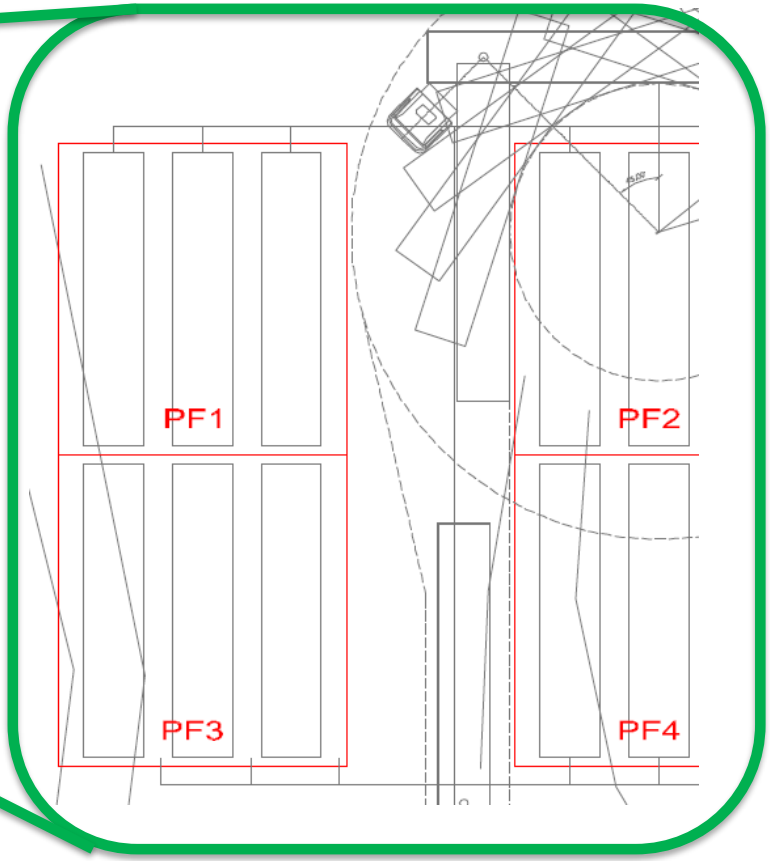
Main characteristics of the base PSs

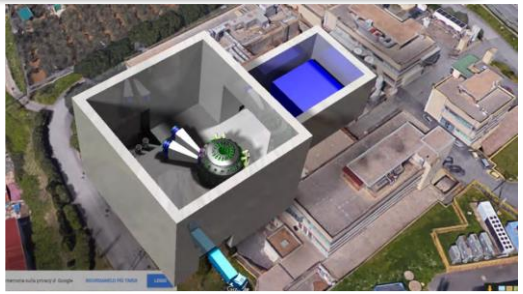
Characteristic	CS/PF PSs	VS coil PSs	IV coil PSs	ELM/RWM PSs
Position	Ex-vessel	In-vessel equatorial	Around divertor	Non-axisymmetric
Load coil material	Superconducting	Copper	Copper	Copper
Number of PSs	12	2	4	To be defined
Number of quadrants	4	4	4 (2 possible)	4
Duty cycle and typical scenarios	<200s/3600s	100s/3600s	Flat-top ≤40 s	100s/3600s
Ramps	Up 60 s, down 30 s	None	To be defined	None
Number of converter transformers	1 (also for more coils)	1	2	To be defined
Adopted topology	DC link storage H-bridge	DC link storage H-bridge	Thyristor bridge	DC link Same input power
Semiconductor technology	IGBT (IGCT)	IGBT	Thyristor	Silicon carbide
Energy stored in DC link per PS	>300 MJ	>100 MJ	None	To be defined
Charger	Diode or AFE	Diode or AFE	None	Diode/thyristor
Input power	<50 kW	<100 kW	>1 MW	<1 MW
Number of basic units	12	10	5	To be defined
Current	±30 kA	±25 kA	±25 kA	To be defined
No-load DC voltage	1000 V	200 V	200 V	To be defined
Worst-case DC voltage	600 V	200 V	200 V	To be defined
Control	Fast	Fast modulation	Slow	Fast
Controlled quantity	Current or voltage	Current or voltage	Current	Current
Supporting SNU	Static	None	None	None
Cooling	Raw water	Raw water	Demi water	Air

Layout of the coil PS area

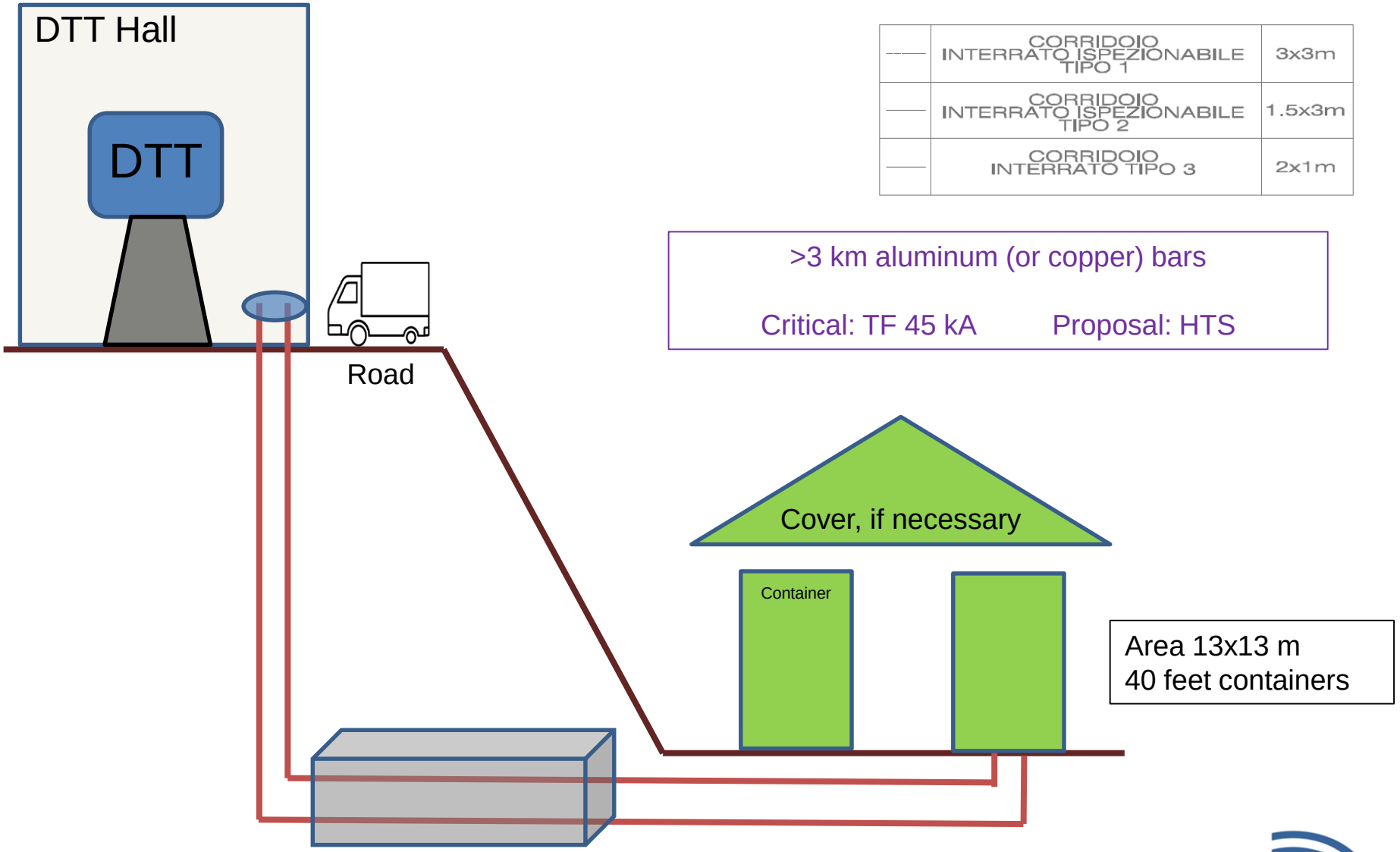
Each PS has a dedicated area 13x13 m
In each area 3-4 standard (40 feet) containers







DC busbars and tunnels



———	CORRIDOIO INTERRATO ISPEZIONABILE TIPO 1	3x3m
———	CORRIDOIO INTERRATO ISPEZIONABILE TIPO 2	1.5x3m
———	CORRIDOIO INTERRATO TIPO 3	2x1m

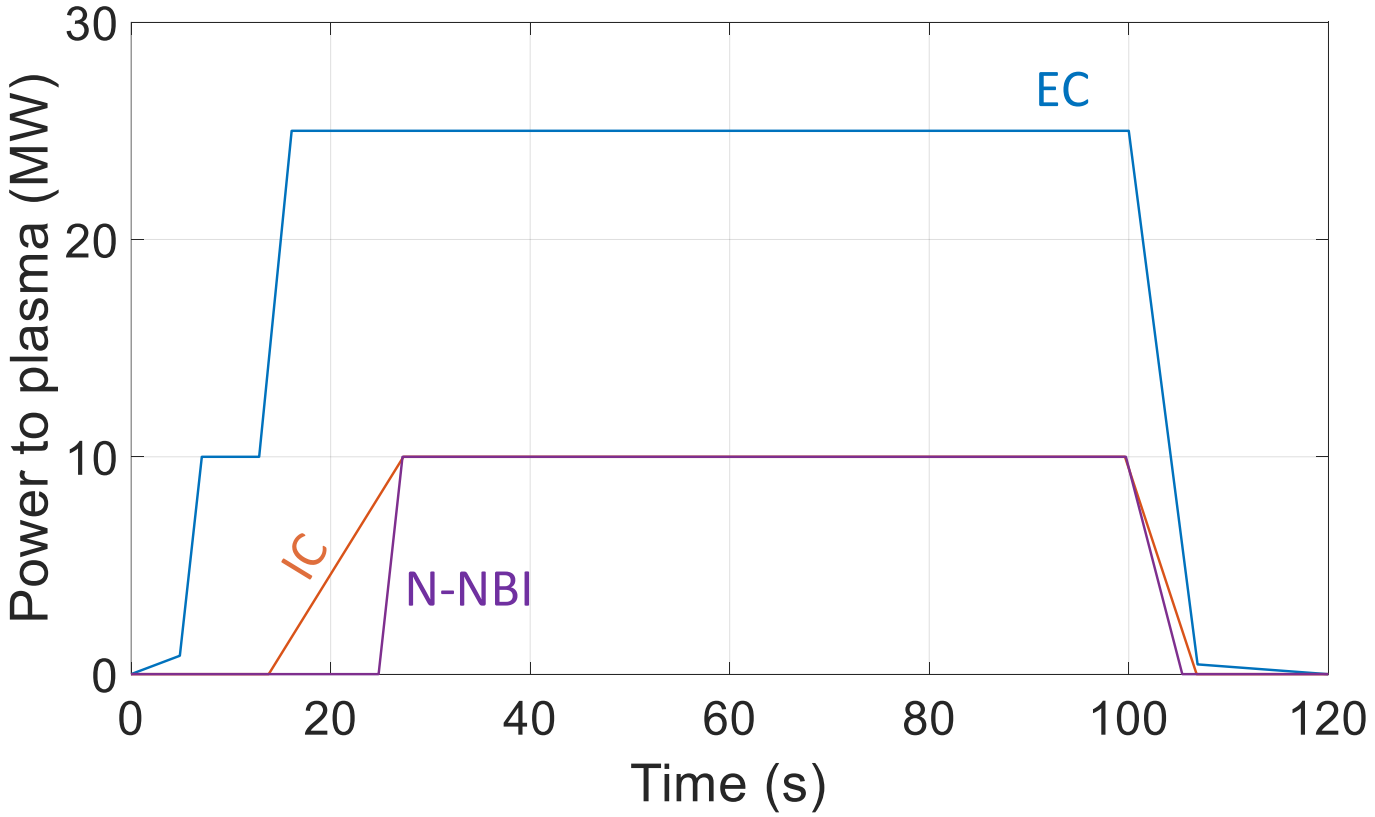
>3 km aluminum (or copper) bars

Critical: TF 45 kA Proposal: HTS

Area 13x13 m
40 feet containers

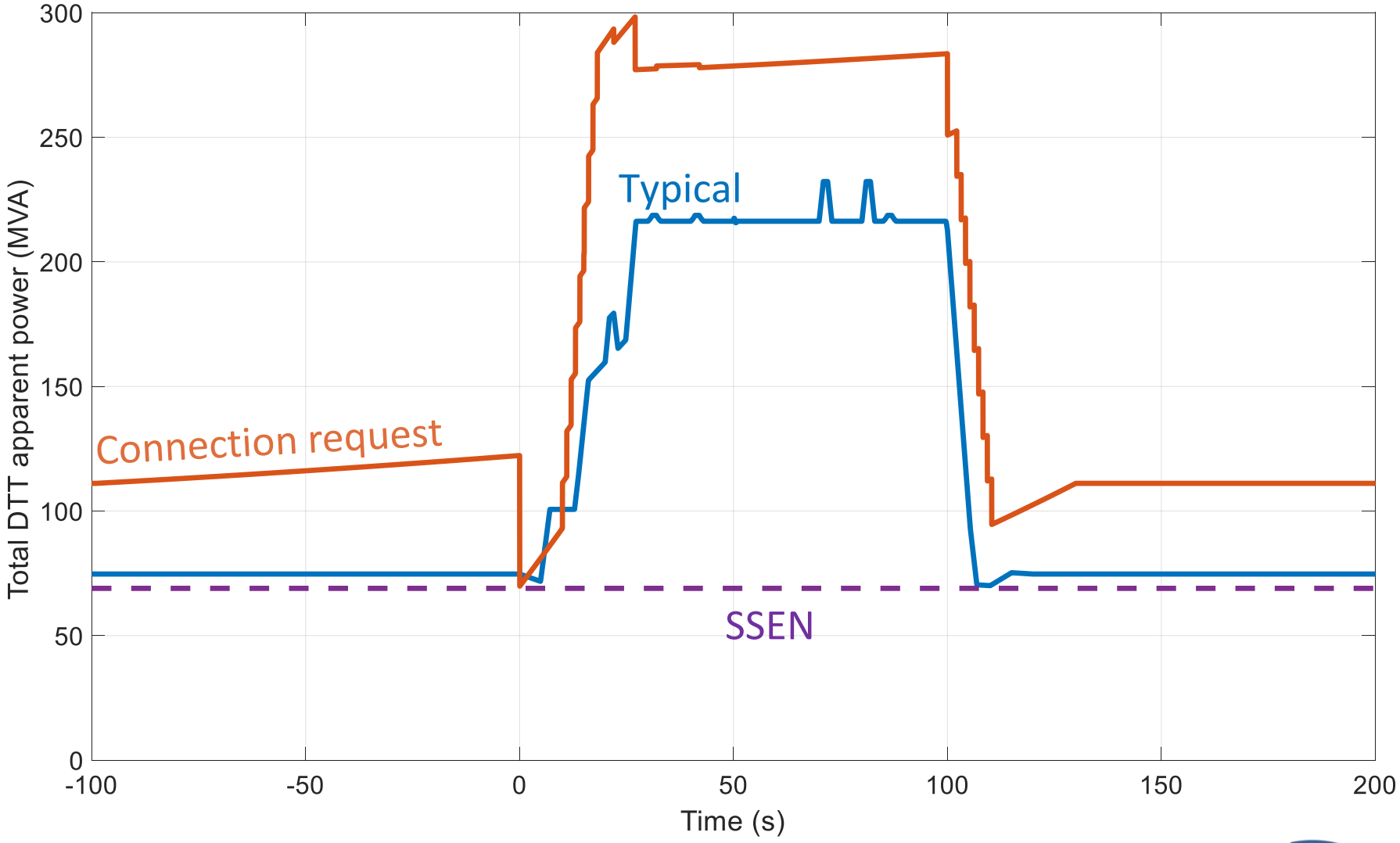
Assumed scenario and performances for additional heating

Poor knowledge of AH scenarios (and real efficiency), including fast variations



H&CD system	Initial mix	Maximum expected upgrade	Wall-plug efficiency η	Power factor cosϕ
ECRH	15 MW	30 MW	35-40%	0.9
ICRH	3 MW	9 MW	40%	0.9
N-NBI	7.5 MW	15 MW	40-45%	0.87

Typical DTT scenario (and official scenario for Terna)



Summary of PSS Calls for Tenders

		2019				2020				2021				2022				2023				2024				2025			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	High-voltage line																												
2	Electrical substation																												
3	Power factor corrrection and filters																												
4	Electrical distribution (SSEN & PPEN)																												
5	Toroidal Field Coil PS																												
6	Toroidal Field Coil fast discharge units																												
7	CS/PF PSs and SNUs (some BPSs)																												
8	Internal Coil PSs																												
9	DC busbars (CS, PF, TF, IC)																												
10	Others (dummy loads, auxiliary, transducers, …)																												

Color code:

Preliminary analysis
Prepare and launch the Call for Tender
Call for Tender
Design
Manufactoring and factory tests
Installation (and procedures for the HV line)
Test
Commisioning

Remember, not including:

- H&CD PSs
- ELM, RWM PSs
- LV in buildings

Short-term planning: test facility for PF, CS, TF coils

- CS and PF PSs are very different from TF PS
- Different PSs also in test facility
- Both ready by 2021 (2022)
- Proposal
  1. A 40'' container for PF6 and CS0, including SNU but with shorter scenario (less energy)
  2. A 40'' container for 18 TF coils, including FDU but with reduced resistance for same τ= 5 s

Thank you for your attention

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