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Big Science Business Forum 2022

The ITER power supply systems: present status and business opportunities

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Session title

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization

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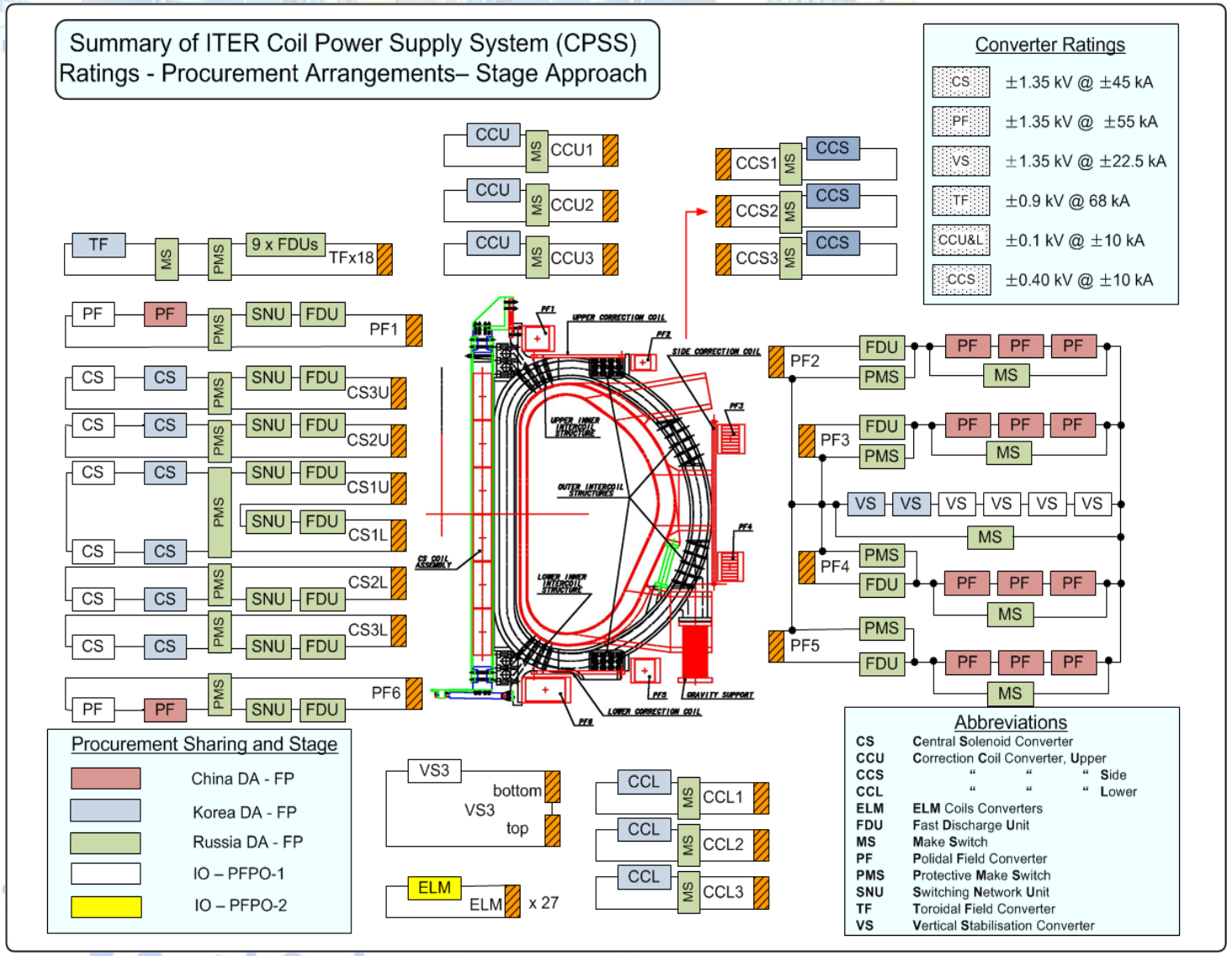
china eu india japan korea russia usa

Outline

1. Overall system description and general design requirements applicable to:
   a. Stage 2 Main Coil Power Supplies;
   b. In Vessel Coils Power Supplies.
2. Procurement strategy and business opportunities in 2023-2025.

MCPS System configuration

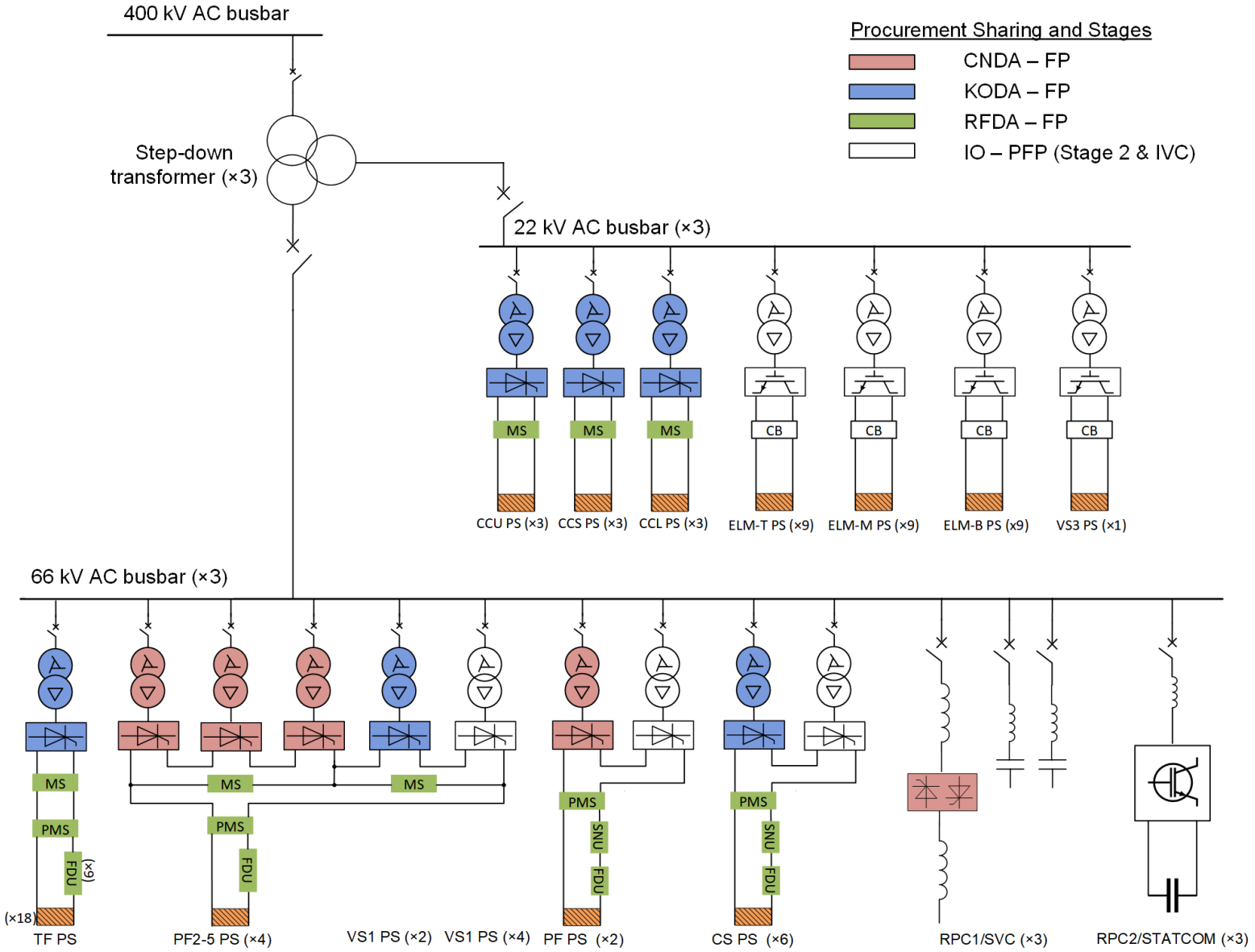


Stage 2 Main Coil Power Supply (MCPS)

- 6 CS power converter Units;
- 2 PF power converter Units;
- 4 VS power converter units;
- 10 sets of AC feeding circuits (66 kV);
- 12 sets of DC circuits;
- 3 units of STATCOM (66 kV);
- Cooling water system;
- I&C;
- Others.

The Stage 2 MCPS shall be physically and functionally integrated with the existing ITER system.

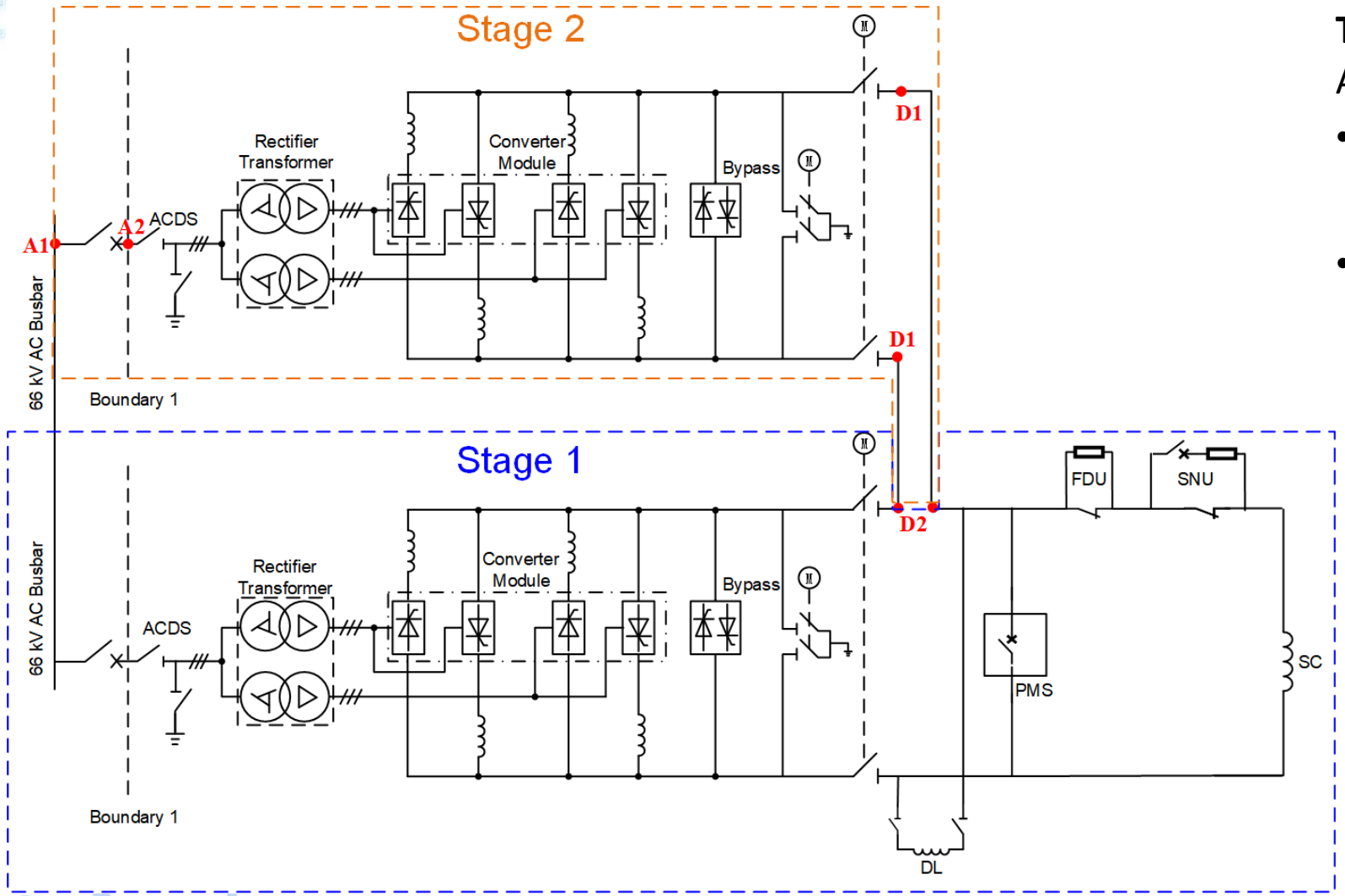
MCPS power distribution



Abbreviations

AC: Alternating Current
CB: Crowbar
CS: Central Solenoid
CCU: Correction Coil Upper
CCL: Correction Coil Lower
CCS: Correction Coil Side
ELM-T/M/B: Edge Localized Mode-Top/Middle/Bottom
FC: Fixed Capacitor
FDU: Fast Discharge Unit
FP: First Plasma
IVC: In-vessel Coil
MCPS: Main Coil Power Supply
MS: Make Switch
PF: Poloidal Field
PFP: Post First Plasma
PMS: Protective Make Switch
RPC : Reactive Power Compensator
SNU: Switching Network Unit
STATCOM: Static Compensator
SVC: Static VAR Compensator
TF: Toroidal Field
VS: Vertical Stabilization

Stages 1 and 2 system integration



Typical configuration of Stage 2 MCPS

A1→A2: AC feeding circuit (66 kV);

- A2→D1: Stage 2 Main Coil Power Converter Unit;
- D1→D2: DC circuit (DC interconnection busbars).

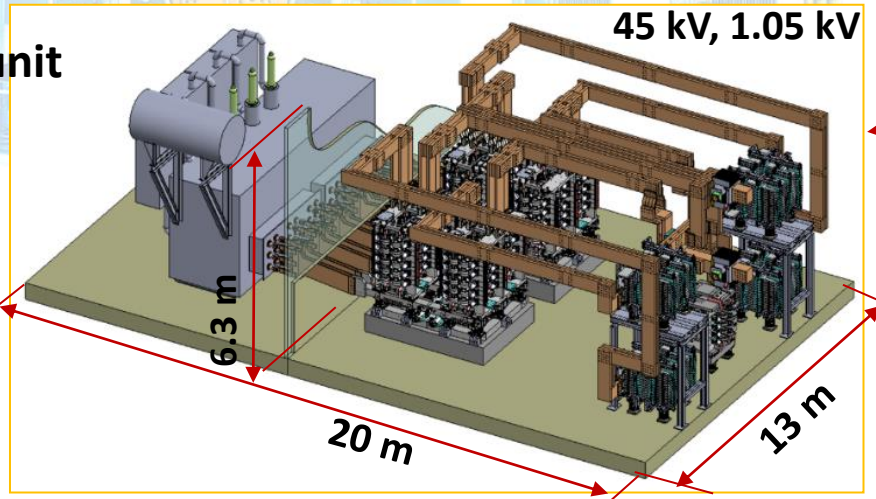
Abbreviations

AC	Alternating Current
ACDS	AC Disconnect Switch
DL	Dummy Load
FDU	Fast Discharge Unit
MCPS	Main Coil Power Supply
PMS	Protective Make Switch
SC	Superconductive Coil
SNU	Switching Network Unit

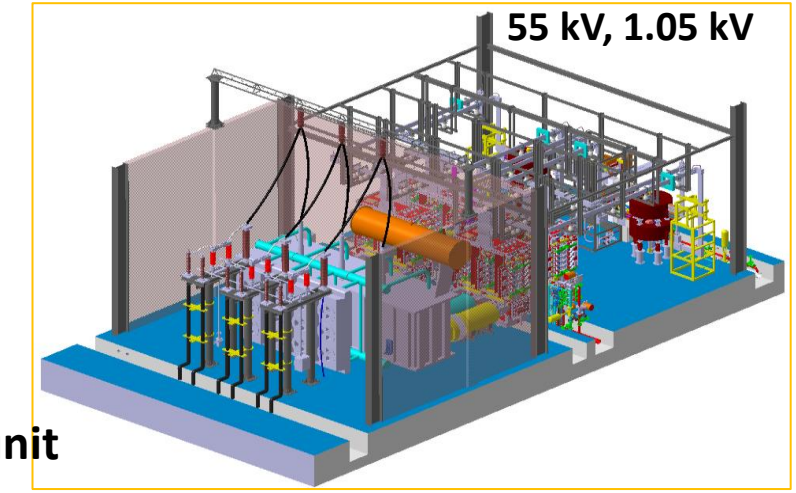
Circuit integration between stage 1 and stage 2 of PF6 converter units

MCPS location (indoor)

CS converter unit

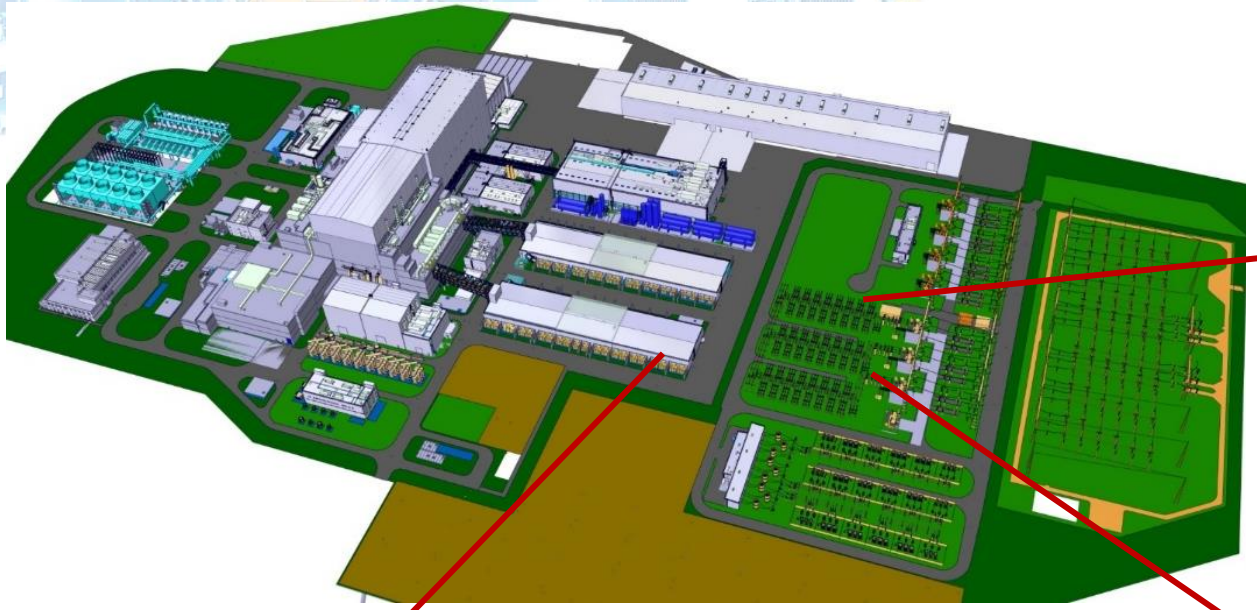


DC interconnection busbars

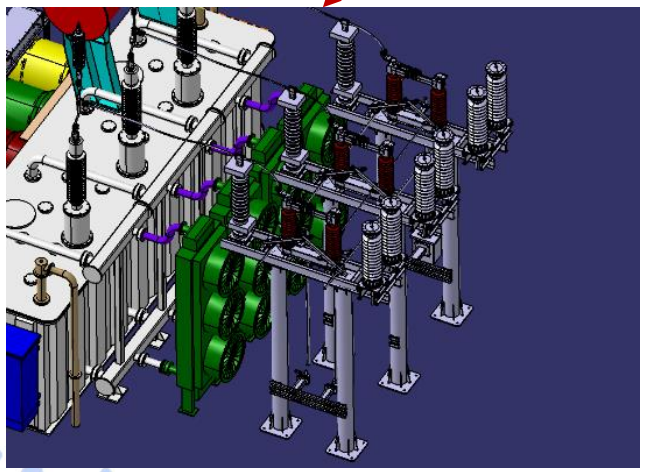


PF converter unit

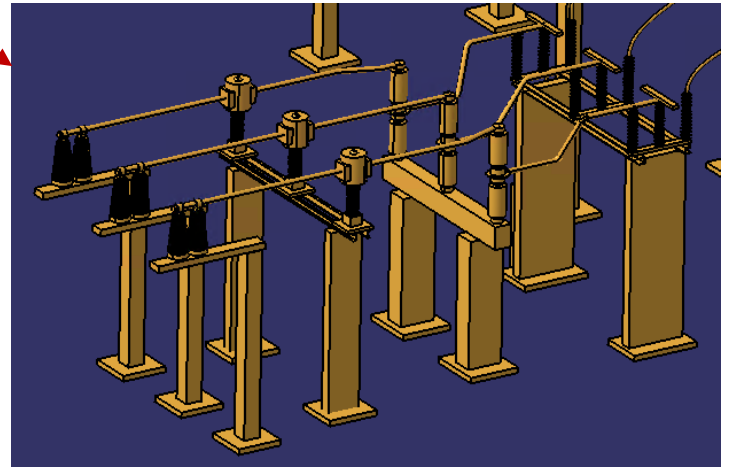
MCPS location (outdoor)



AC feeding circuit (66 kV)



Converter transformer (66 kV)

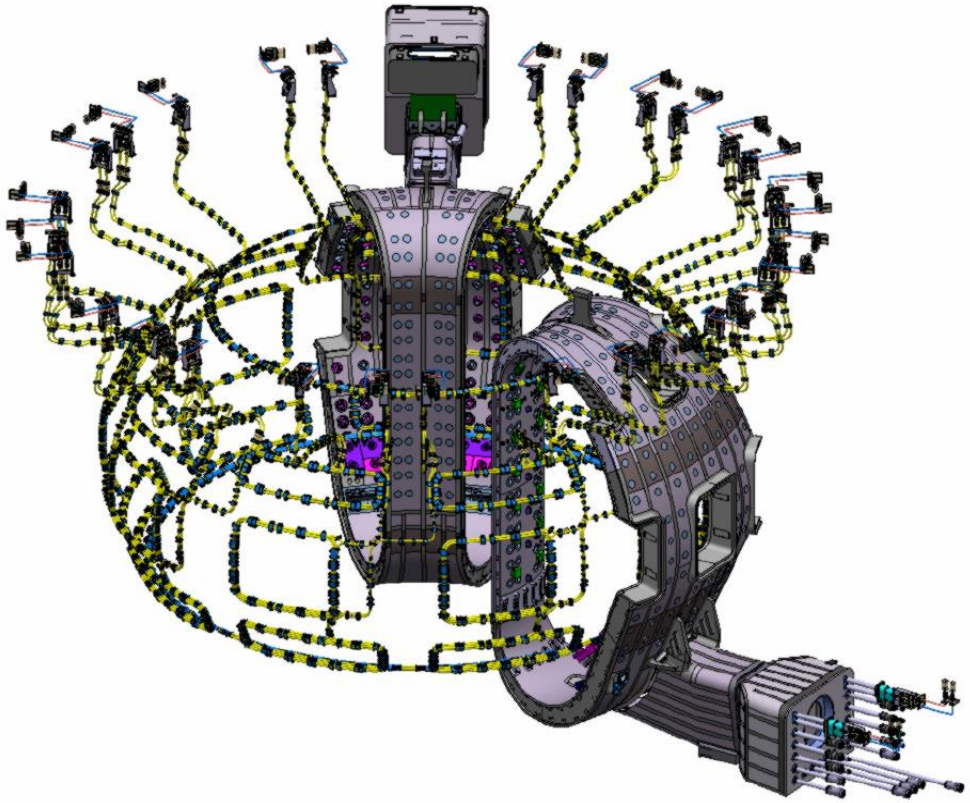


AC feeding circuit (66 kV)

Main electrical design parameters

Parameters	PF converters	CS converters	VS converters
AC input voltage, kV	66	66	66
Rated DC current (continuous duty), kA	±55	±45	±22.5
Rated DC voltage (on-load), kV	±1.05	±1.05	±1.05
Insulation level to ground, kV	12	12	12
Voltage response time, ms	40	40	20
Quantity (Stage 2), units	**2**	**6**	**4**

The In-Vessel Coils

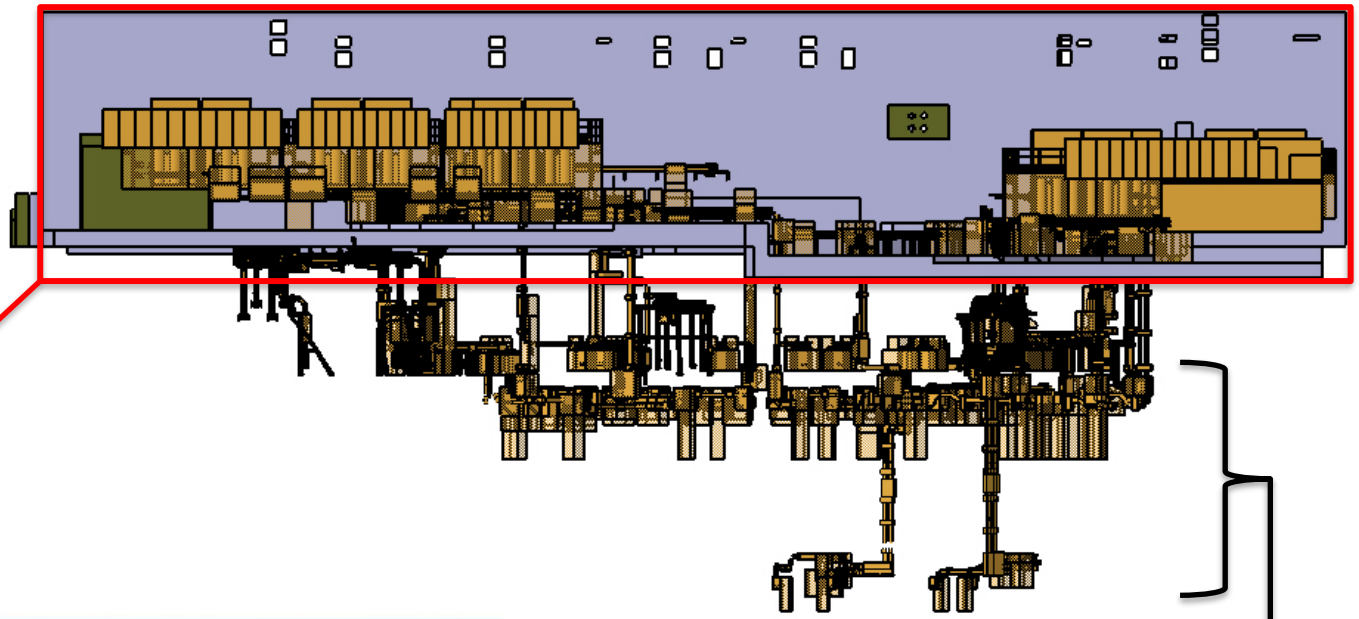


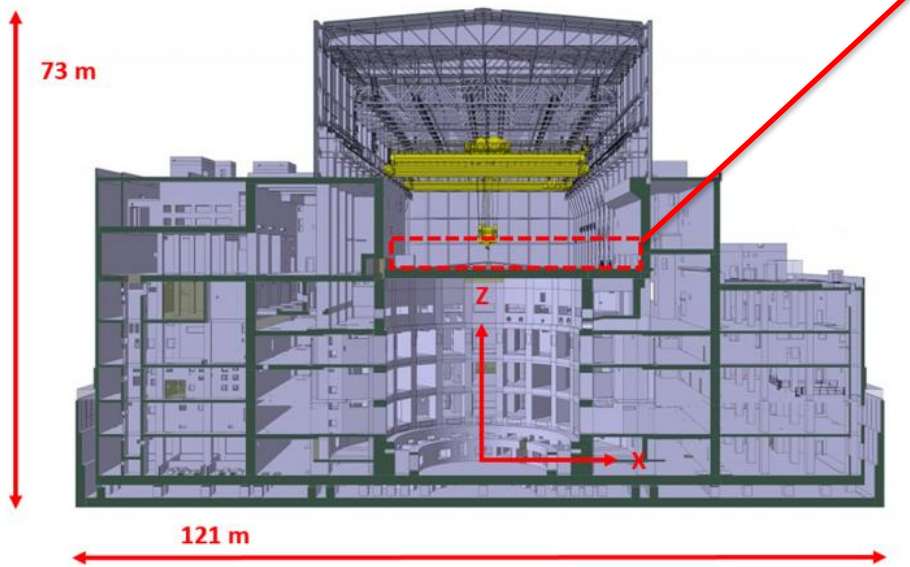
- 2x **V**ertical **S**tabilization coils
- 27x **E**dge **L**ocalized **M**ode coils

- The In-Vessel Coils (IVCs) and they consist of 27 ELM coils and a VS3 coil.
- The ITER In-Vessel Coils System comprised of the “Edge Localized Mode” (ELM) mitigation coils and the “Vertical Stabilization” (VS3) coils.
- The In-Vessel Coils are located just behind the plasma-facing component and are used to balance the plasma equilibrium with fast magnet feedback controls.
- The main function of the function of the IVC power converters is to receive AC electrical power from the Pulsed Power Electric Network (PPEN) and then provide controlled DC power to the IVC coils to ensure plasma stability through magnetic field control.
- There are:
  27 independent power converters for the ELM coils
  15 kA, 180 V, 4 quadrant operation;
  One power converter for the VS coils
  80 kA (pulse), 2.4 kV, 4 quadrant operation.

Installation area : Tokamak Building – level L4

- **Level 4 : Dedicated space for ELM and VS3 power supplies and their Auxiliaries**

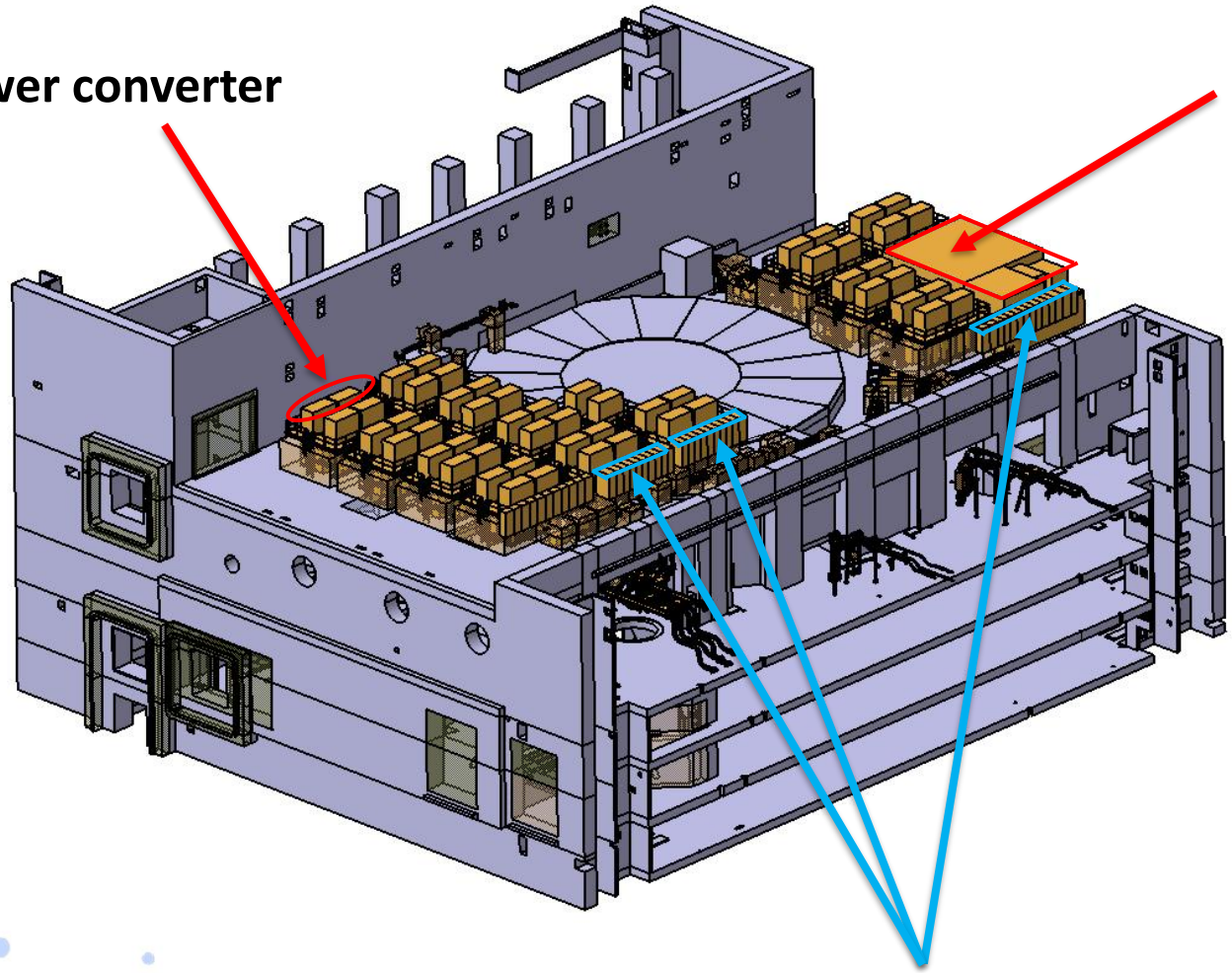




- **IVC busbars**
(Not in the scope)

Tokamak Building environmental conditions

1x ELM power converter



VS3 power converter

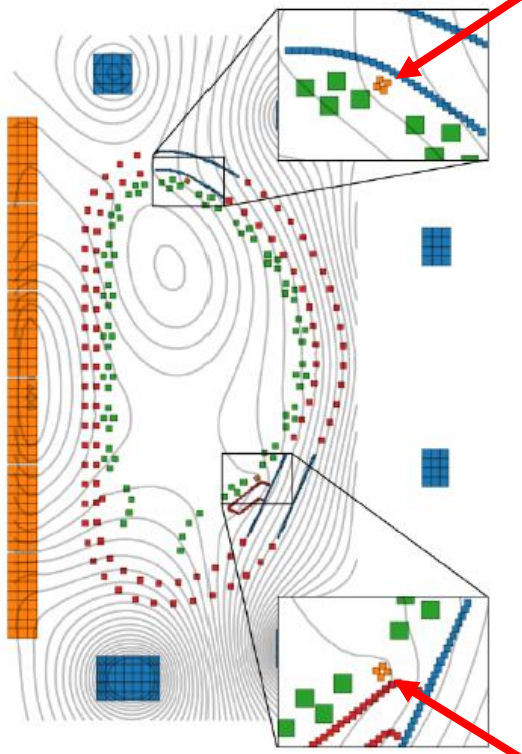
(To be relocated to another location, the freed up space will be allocated to the ELM power converters, hence the budgetary mass and space for the VS3 power converter can increase)

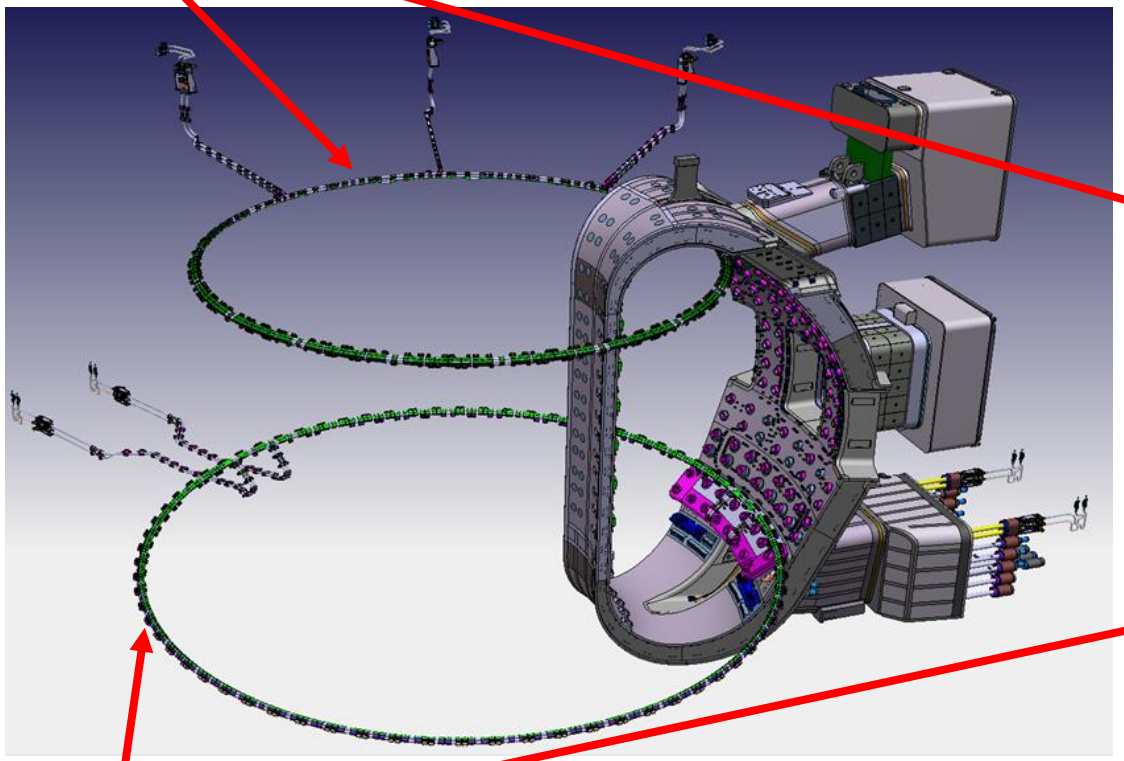
- Seismic constraints
- Maximal loading: **1x 180 Tons** – **VS3**
- Maximal loading: **27x 32 Tons** – **ELM**
- Maximal static magnetic field: 50 mT
- Water-cooling : 31 ° C

3x Switchboard @ 3 ph – 50 Hz – 22 kV

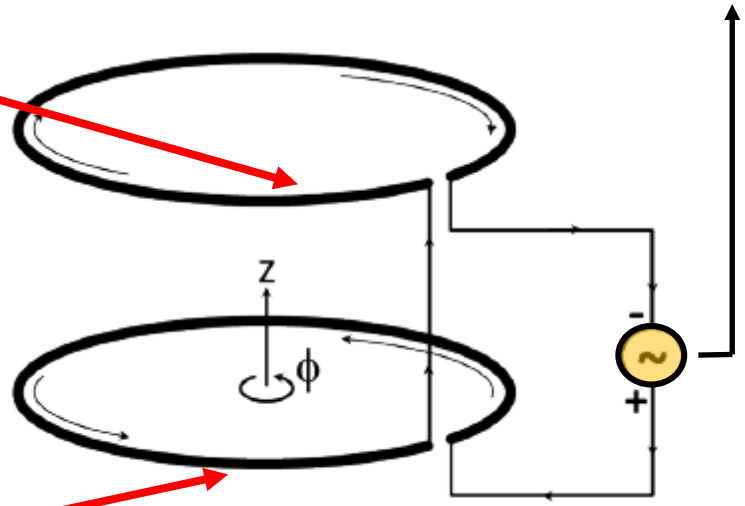
From Physics to Power Supply Requirements

VS Upper coil : 4 Turns





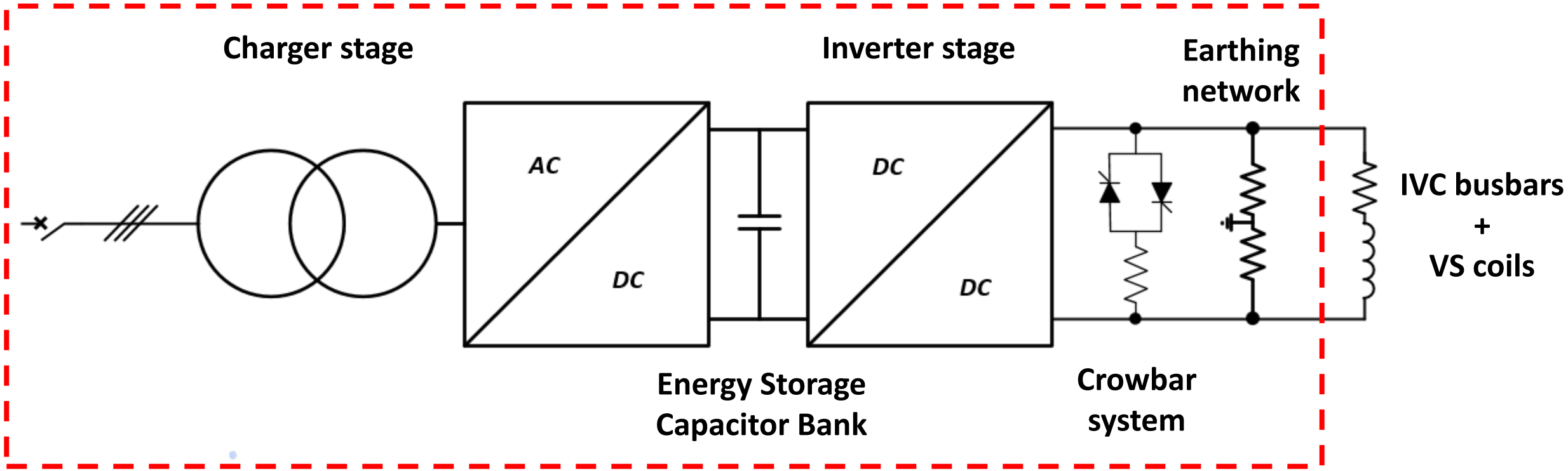
VS3 power converter



VS Lower coil : 4 Turns

VS3 Power Converter (one unit)

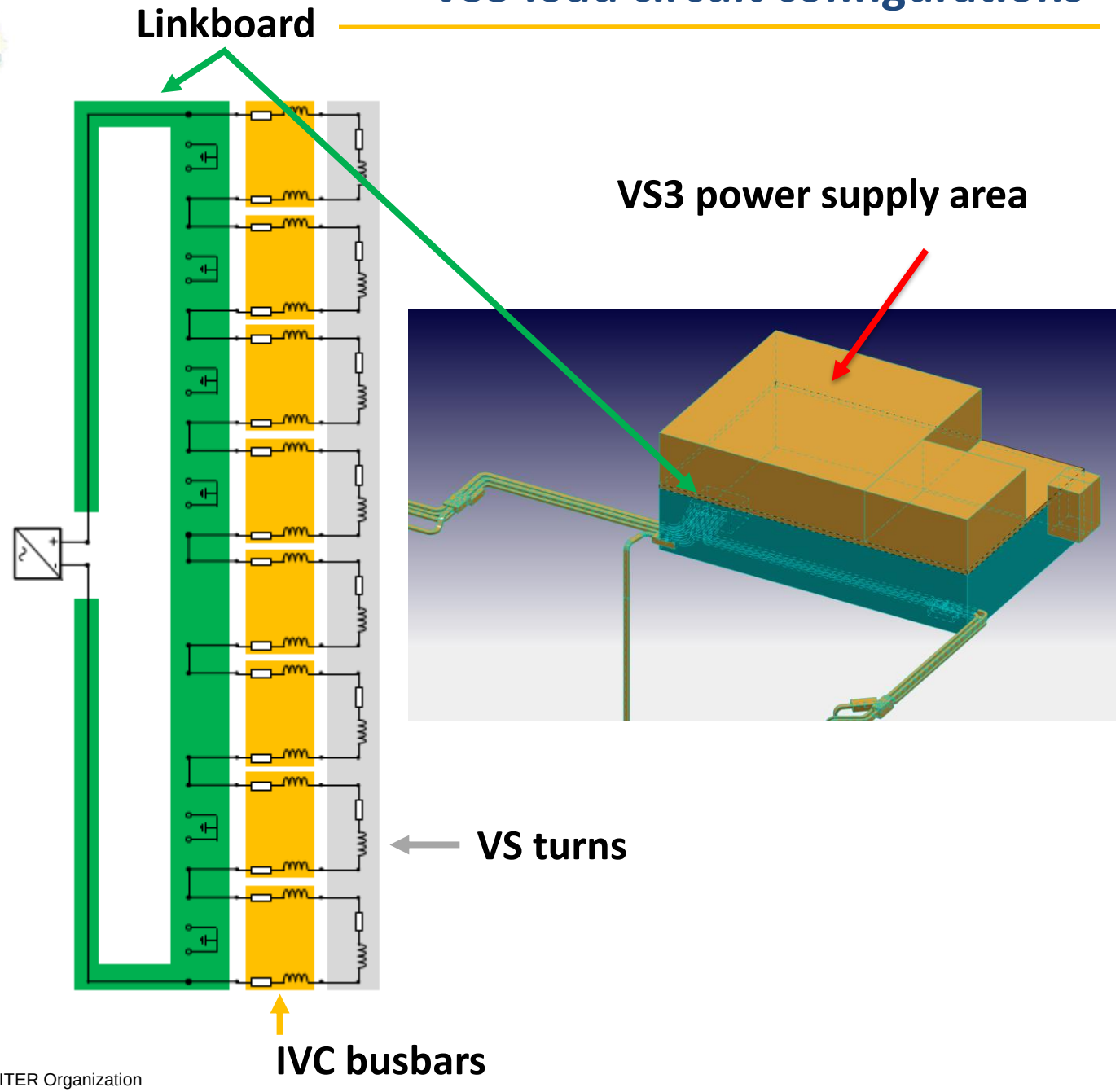
Components to be designed, manufactured, installed and commissioned *.



* Safety ground switches and others protections are not represented, with the exception of Crowbar system and Earthing network.

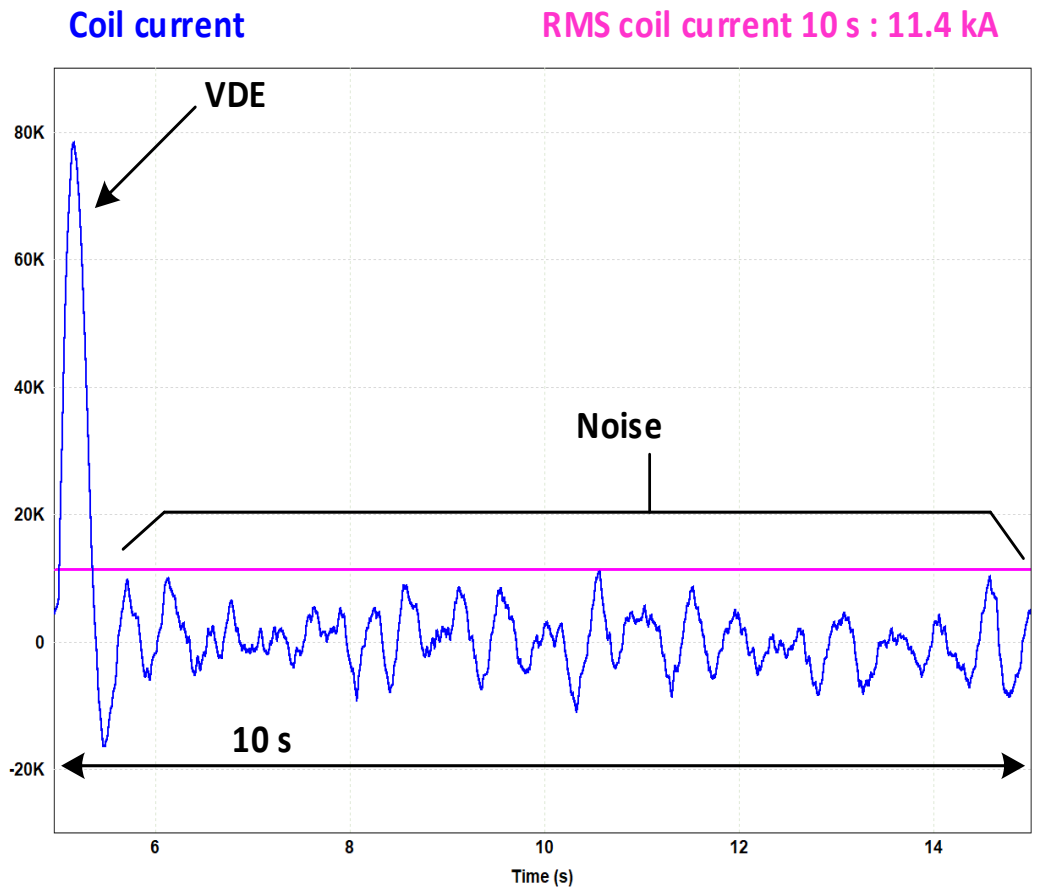
VS3 load circuit configurations

A Linkboard allows reconfiguring the eight turns in the event of coil turn failure or for Diagnostic sensors calibration activities. The connection between VS coils turns can be modified turn-by-turn, allowing operation with a reduced number of turns and allowing several coil connection configurations.

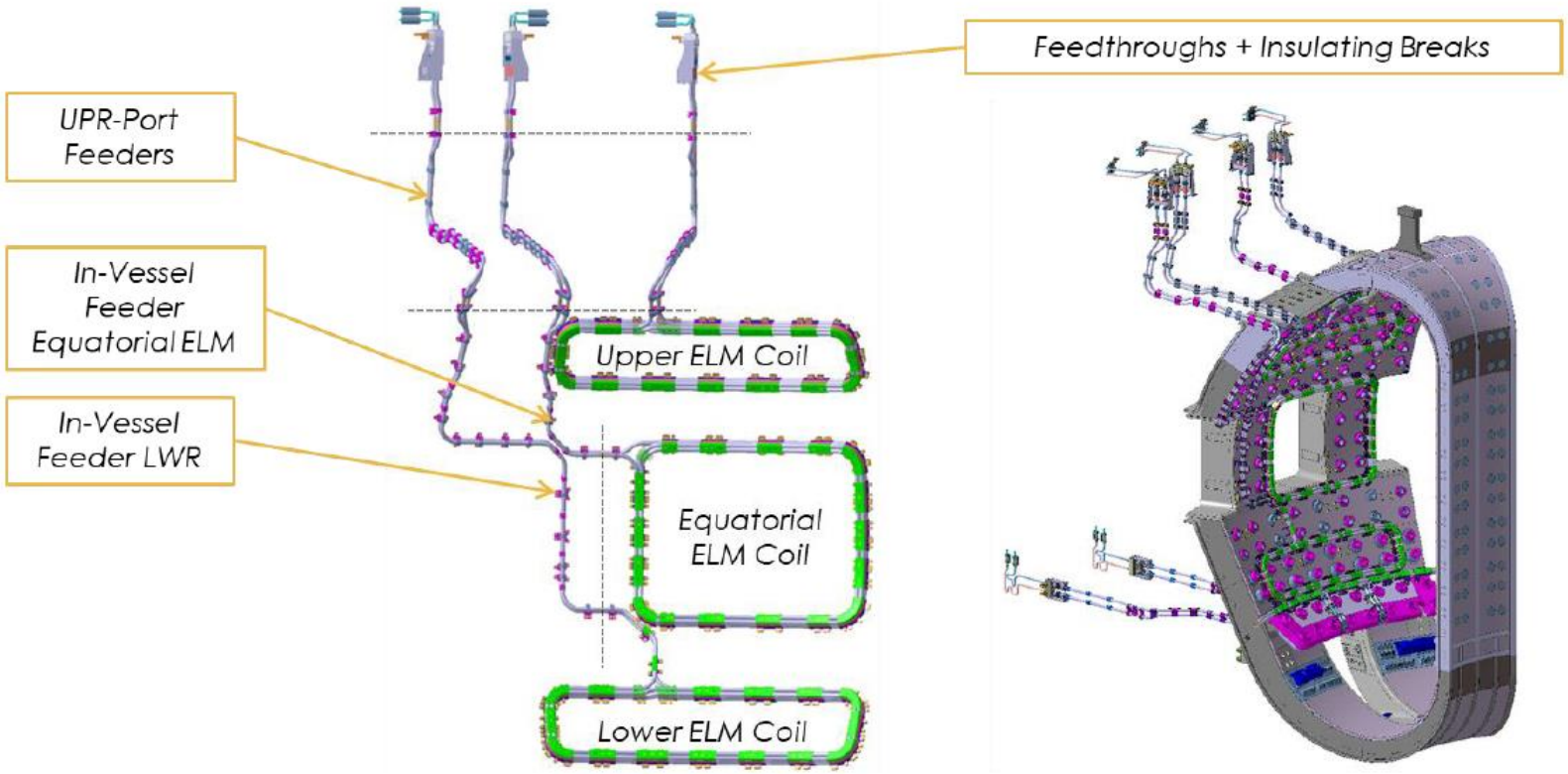


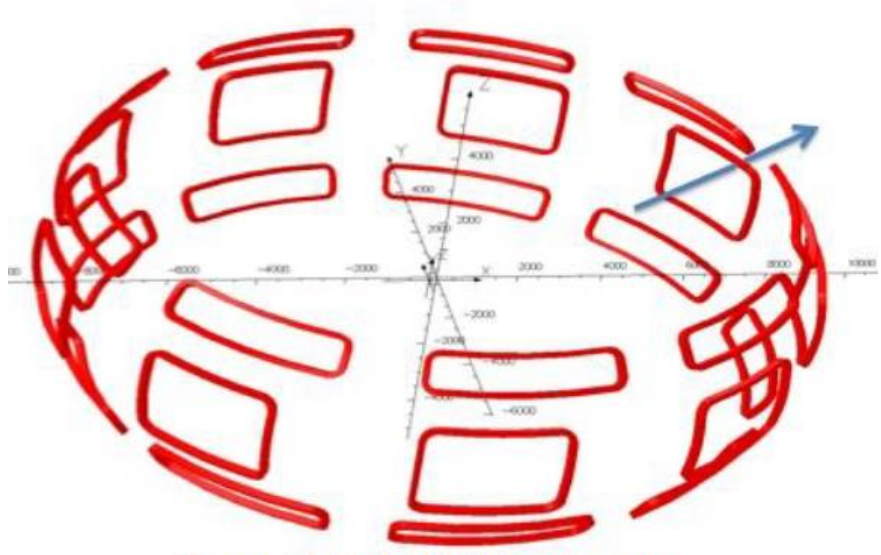
Main Electrical parameters of VS3 Power Converter

- DC : **80 kA Peak** and **4 kA RMS for the Noise**
- Voltage response time is less than **1 ms**
- **Four-quadrant** operation – current accuracy : **0.2 % of Ipeak**
- Maximal DC voltage **2400 V**
- AC 22 kV network power factor **> 0.9**
- Reduced **dV/dt** of the output voltage
- DC link stored energy **20MJ -25MJ**
- Charger power: estimated to be 2.5MW – 4MW depending on the design



Edge Localized Mode (ELM) coils in the tokamak

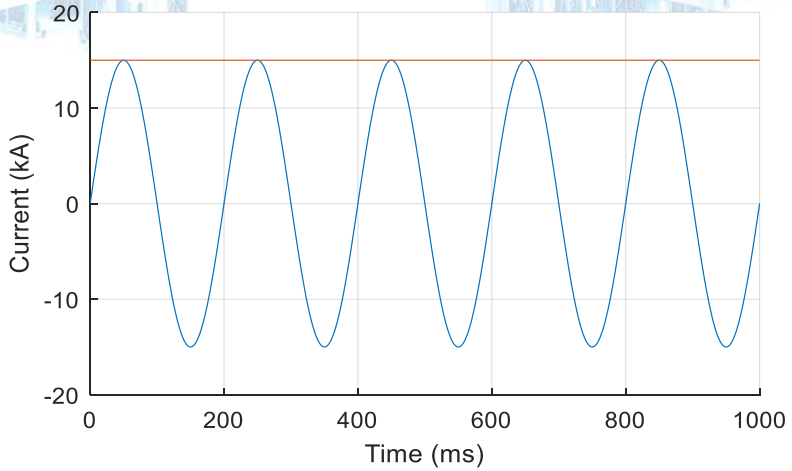


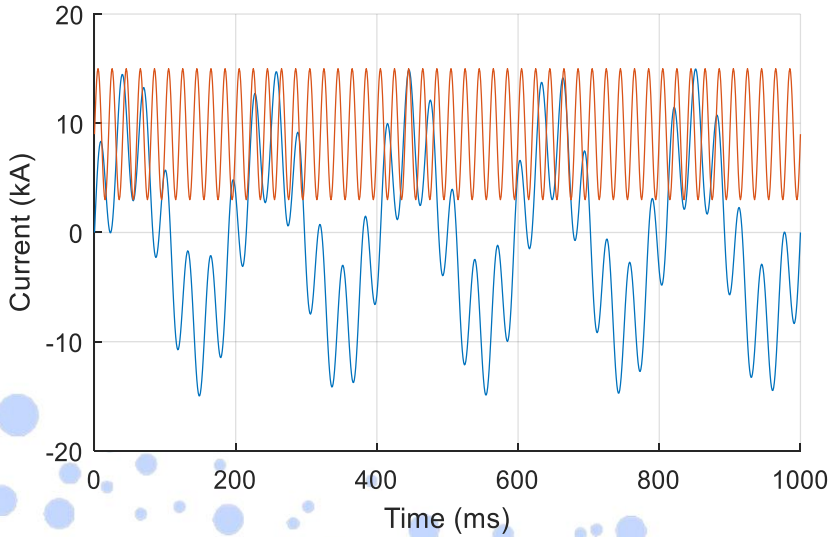


- Operating voltage : 200 V
- Maximum coil current : 15 kA

- Improve plasma stability
- 3 ELM coils per sector
- 9 Sectors in the tokamak

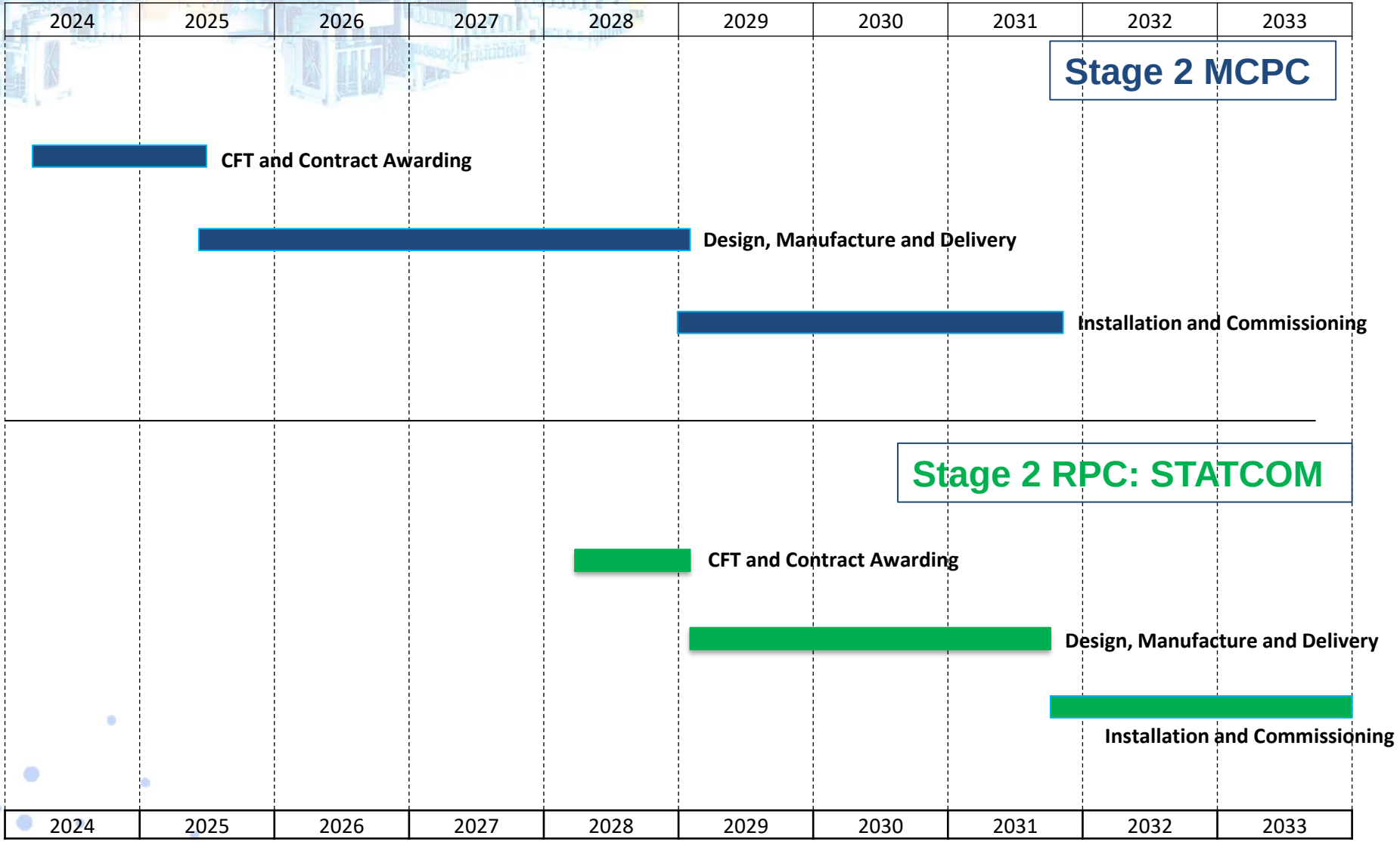
Main Electrical Parameters of ELM power supplies



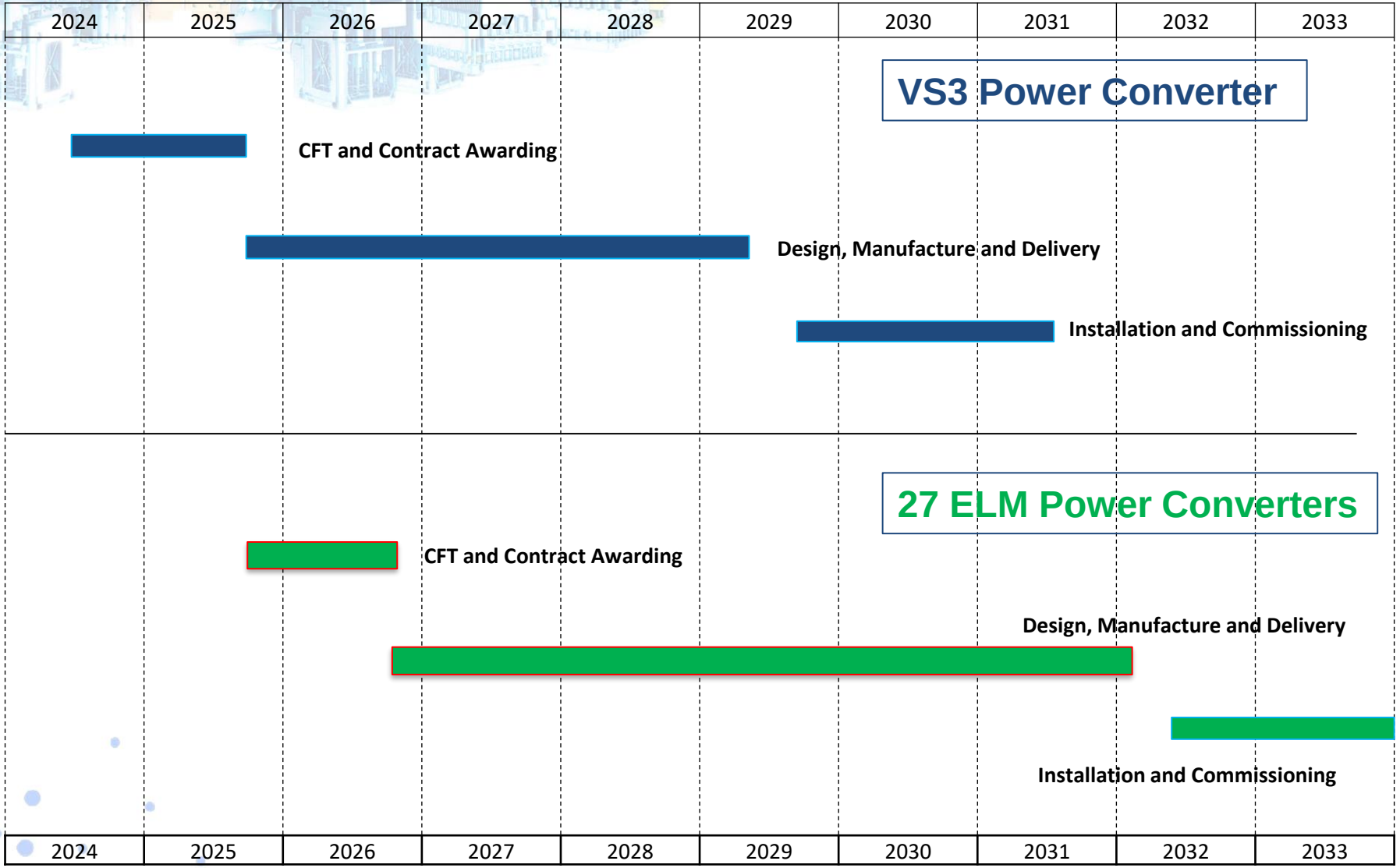


Nominal input voltage	22 kV ± 10 %, 50 Hz
Nominal output voltage	180 – 200 V
Voltage response time	less than 20 ms
Nominal output current	0-15 kA
Output frequency	0-50 Hz
Typical coil parameters	2.6mΩ, 0.24mH

Tentative Time Schedule – Stage 2 MCPC and STATCOM



Tentative Time Schedule – VS3 and ELM



Tentative procurement strategy and plan

Note: Currently under discussion.

Will be reviewed after appointment of the newly nominated Director General of the ITER Organization.

Even if the titles of the procurement contracts refer to the “power converters / coil power supplies”, **the scope of material procurement includes not only the power converters, but also the auxiliary systems** such as: pipes and instrumentation for the connection to the main Cooling Water System, 66 kV (or 22 kV) switchgear and power cables for 66 kV (or 22 kV) AC supply and I&C interfaces.

In summary, **the ITER Organization needs to procure four systems:**

1. **Stage 2 Main Coil Power Converters**
2. **VS3 In Vessel Coil Power Converter**
3. **ELM In Vessel Coil Power Converters**
4. **Stage 2 Reactive Power Compensation System, most likely based on STATCOM technology.**

Full turnkey procurements

- Turn key procurement, from preliminary design to commissioning and Site Acceptance tests.
- Scope of delivery (outline description):
  - The power converter units preassembled in ISO container frames for easy removal and reinstalling, *this requirement mainly applies to the In Vessel Coil Power Converters*;
  - The 22 kV ac feeder cable and switchgear;
  - Connecting dc busbars;
  - Cooling water system (including heat exchanges) from main cooling water collectors;
  - Local I&C and connection to the ITER Command and Data Acquisition (CODAC) system;
  - Dummy loads.

Procurement scope (optional services services)

Return of experience from the procurement of the Stage 1 MCPS and Transmission System Operators:

After the commissioning activities the ITER Organization needs to contract specialised companies for maintenance, operation and improvements.

An option, currently under consideration, is to award procurement contracts which also include the following services:

- turnkey (design, manufacturing, installation, commissioning and SAT),
- maintenance (including consumables),
- extended warrantee (including spare parts),
- and provision (PPY) for improvements.

Planned procurement contracts

Full turnkey procurements

Scope	Tender process		to be commissioned by
	launched in	duration	
Stage 2 Main Coil Power Converters, including a) DC busbar connections; b) Cooling Water System connections to manifolds; c) Update and commission (hardware and software) of the Master Control System (MCS), currently delivered by KO DA for the Stage 1, or, design, manufacture, install and commission a completely new MCS	March 2024	17 months	April 2030
VS3 In Vessel Coil Power Converter	July 2024	14 months	End of 2030
27 ELM In Vessel Coil Power Converters	August 2025	13 months	End of 2033
3 units, Stage 2 Reactive Power Compensation System (STATCOM technology)	February 2028	11 months	September 2032
66 kV and 22 kV switchgear and power cables	March 2024	16 months	November 2029
Civil works for components to be installed outdoors (mainly foundations and platforms)	February 2028	11 months	October 2031

The ITER Organization is interested to get in contact with Companies interested to participate to the planned tenders.

Info-days will be organised before launching the major tenders.

Thank you very much for your attention

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