In Vessel Coil Power Converters

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Remote ITER Business Meeting

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Outline

1. Overall system description and general design requirements applicable to the VS3 and the 27 ELM power converters;
2. The VS3 power converter;
3. The 27 ELM power converters;
4. Procurement strategy and business opportunities.

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Part 1: Overall system description and general design requirements

- Overall system description,
- Design requirements, environmental conditions and layout constraints,
- **Applicable to the VS3 and the 27 ELM power converters.**

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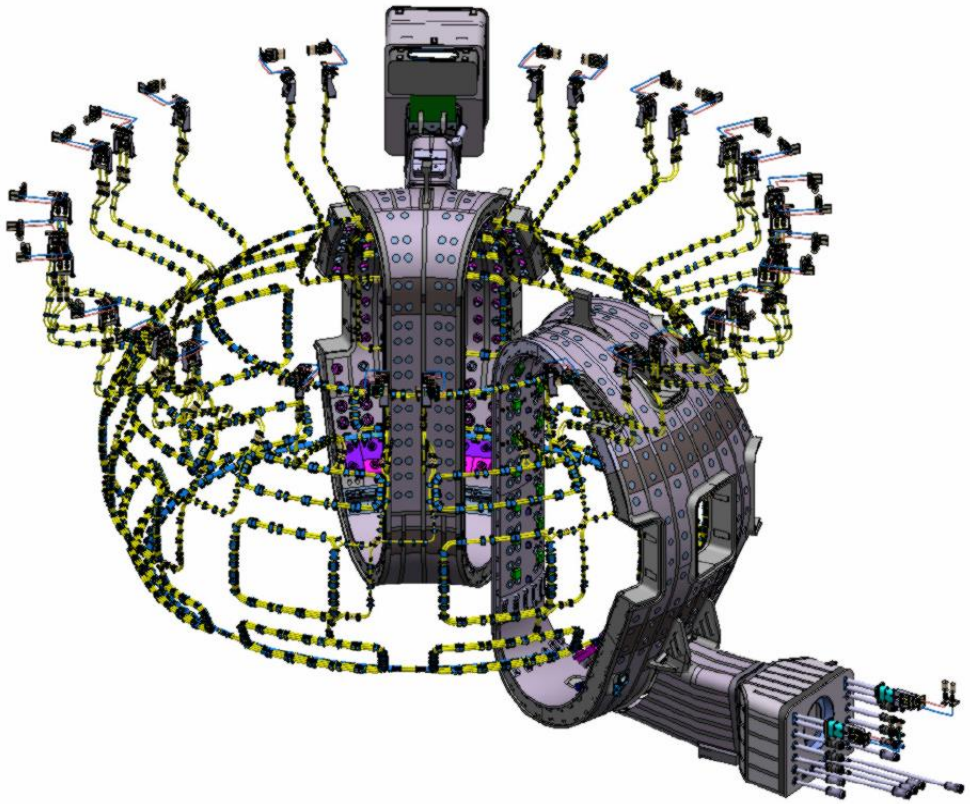
The In-Vessel Coils



- 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 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.

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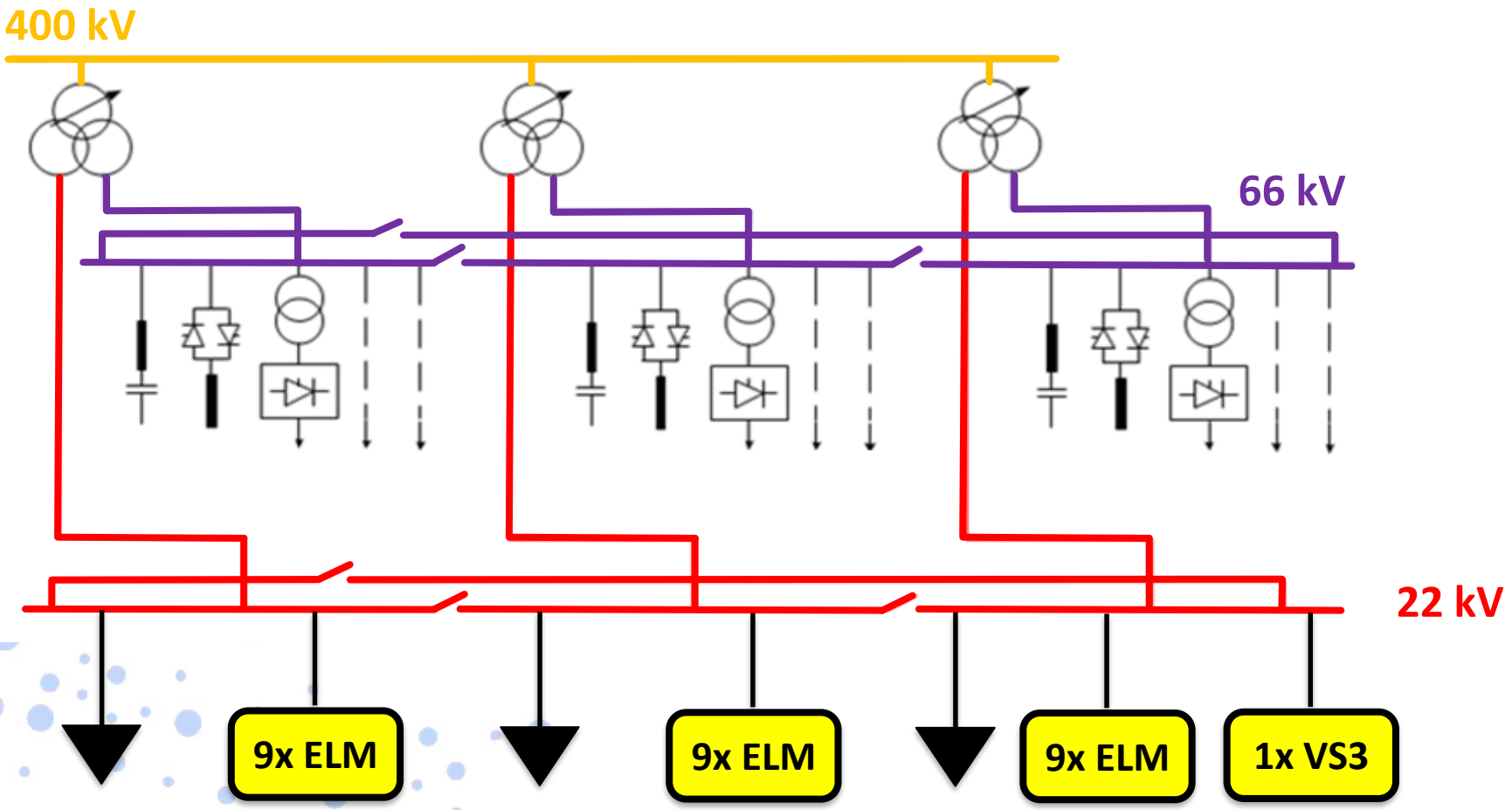
22 kV AC supply from the ITER Pulsed Power Electrical Network

The PPEN provides the pulsed power for energizing the TF, PF, CS, CCs, and In-Vessel Coils to generate, confine, and control de plasma. **In-Vessel coils power supplies connections are at 22 kV level.**



Power estimates :

- **2.5 MW for VS3**
- **1.9 MW per ELM**

In the scope

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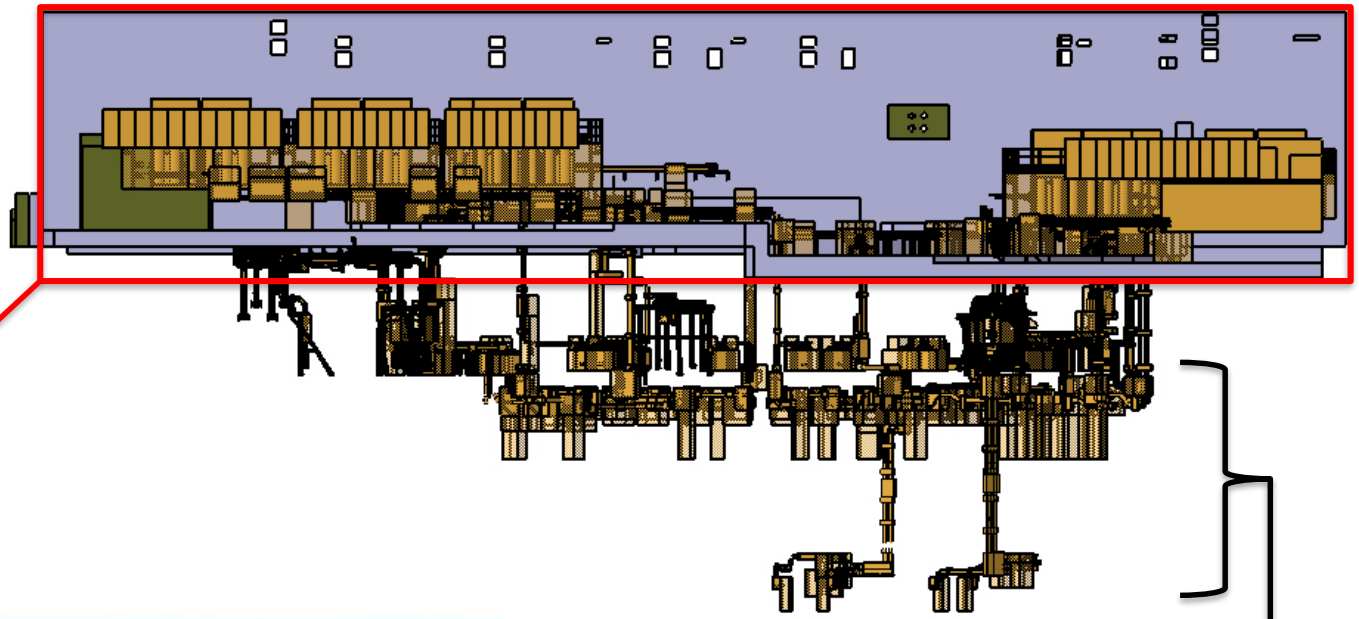
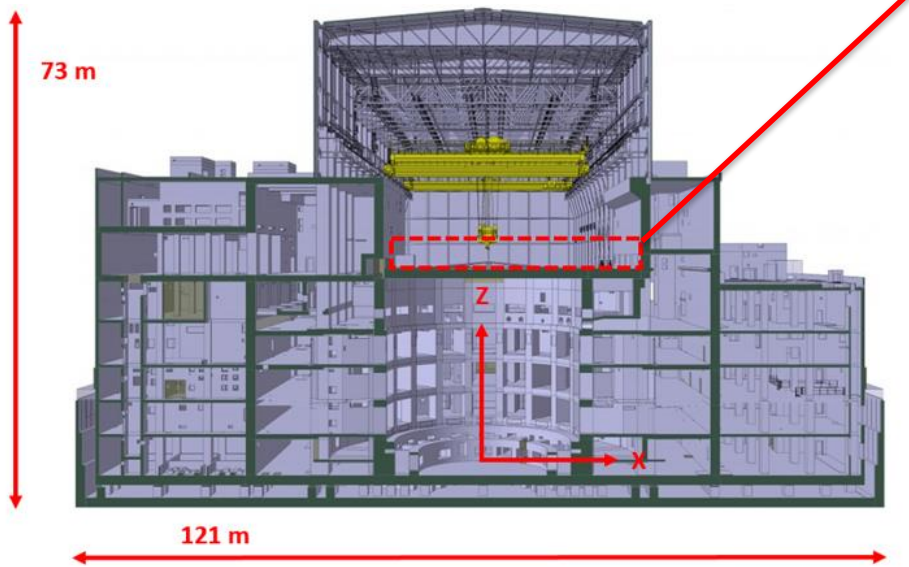
Installation area : Tokamak Building – level L4

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





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

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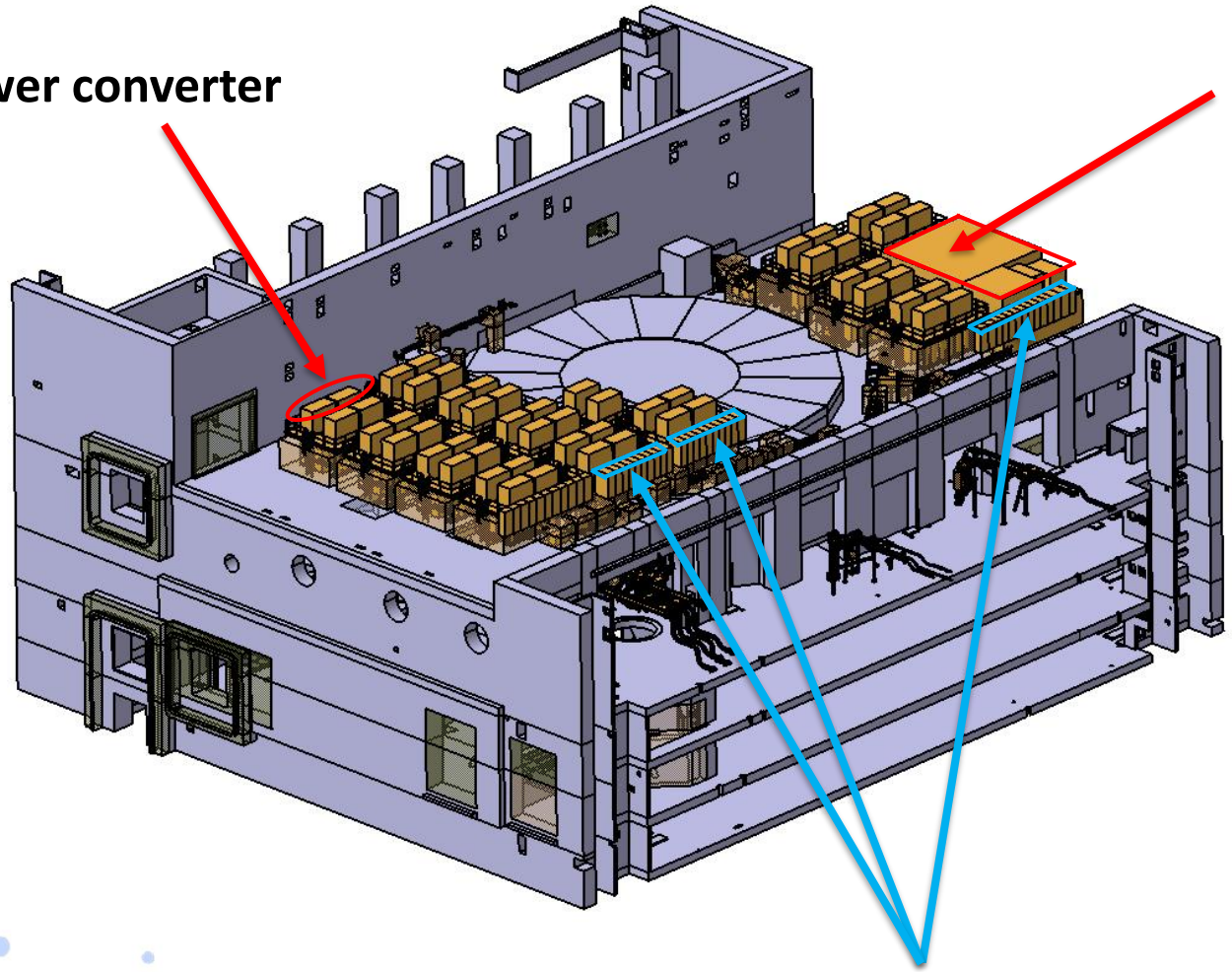
Tokamak Building environmental conditions



- Seismic constraints
- Maximal loading: **1x 180 Tons – VS3**
- Maximal loading: **27x 32 Tons – ELM**
- Maximal static magnetic field: 70 mT
- Water-cooling : 31 ° C

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Design requirements and layout constraints **applicable to the VS3 power converter.**

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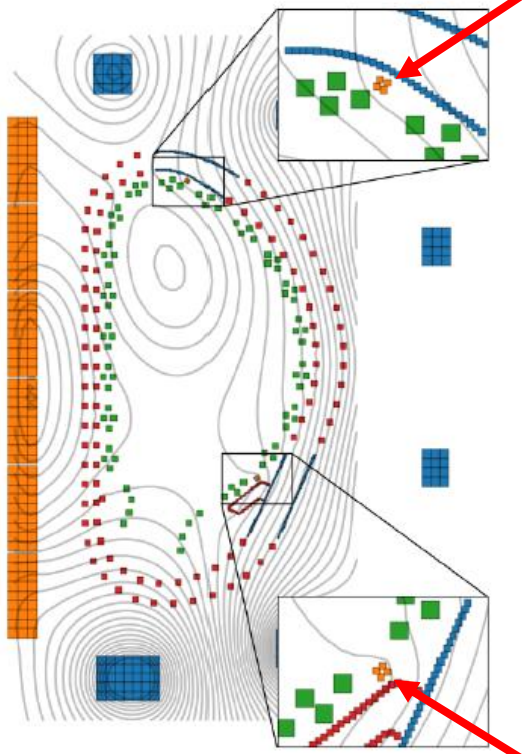
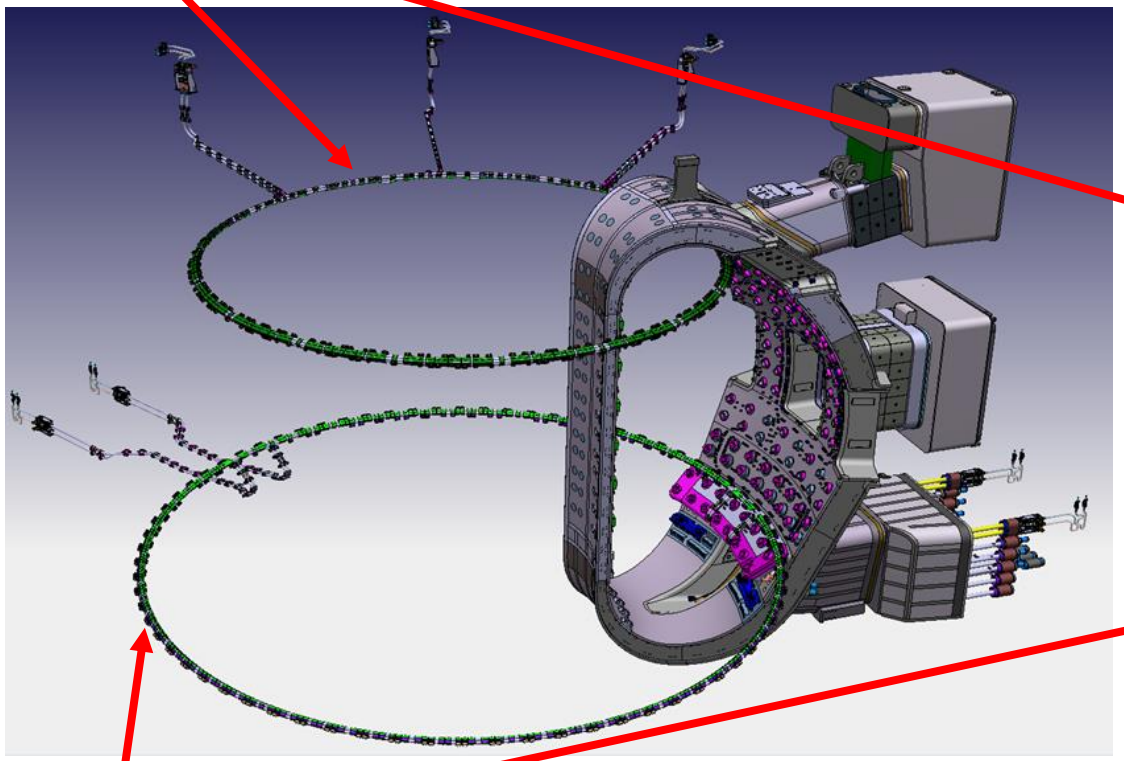
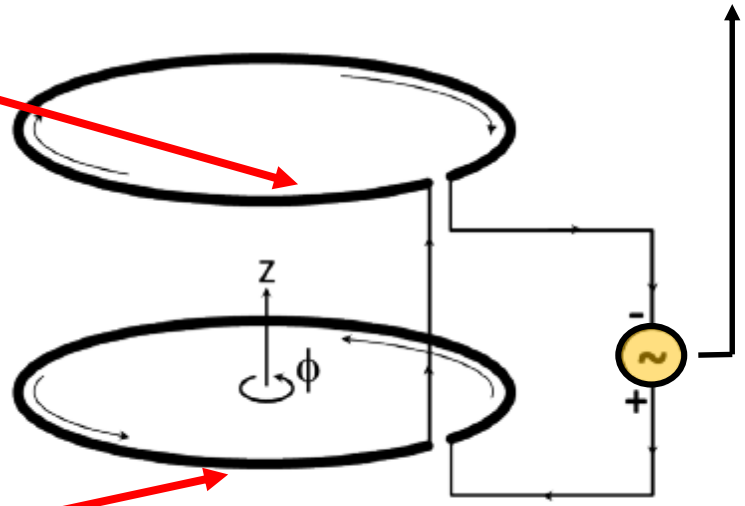
From Physics to Power Supply Requirements

VS Upper coil : 4 Turns





VS3 power converter



VS Lower coil : 4 Turns

Movie to launch

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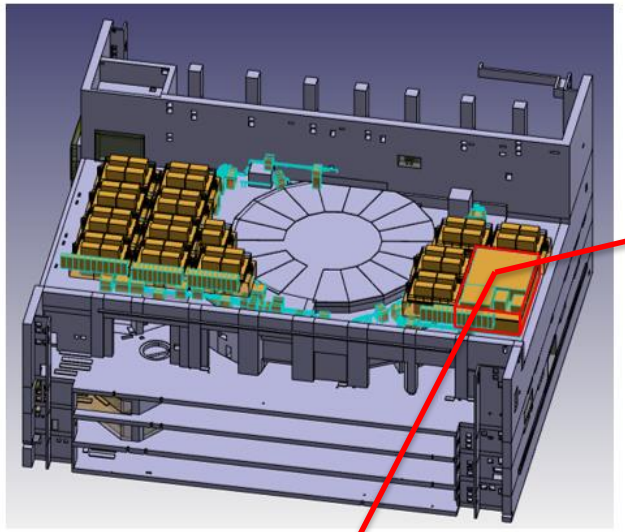
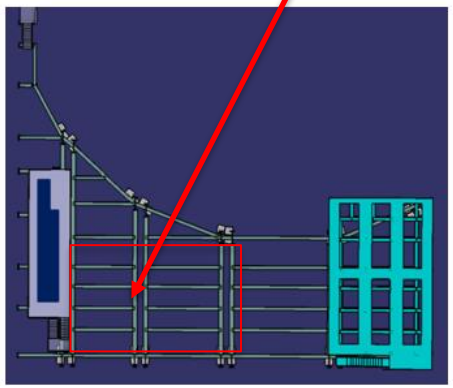
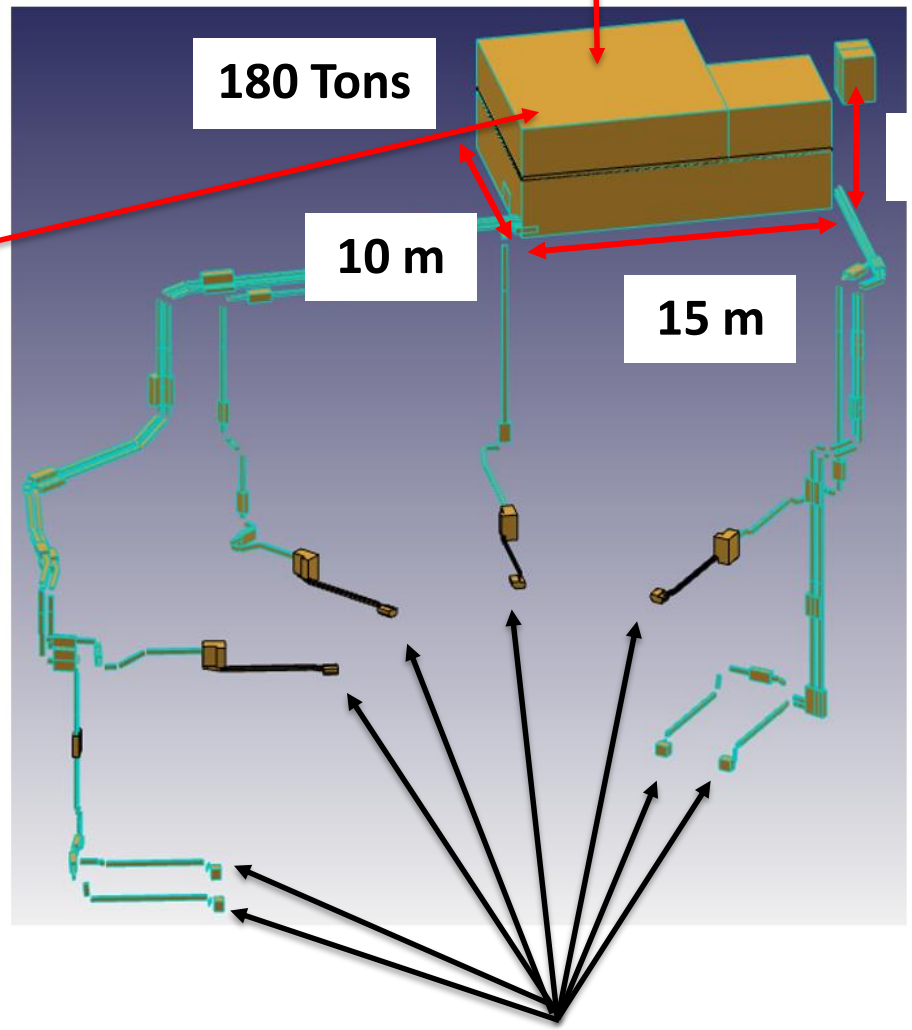
VS3 Layout Integration Constrains

- **Modular** design
- Withstand to **seismic activities**
- Weight limitation including structure and ESCB : **180 Tons**







- **IVC busbars per VS Turns**

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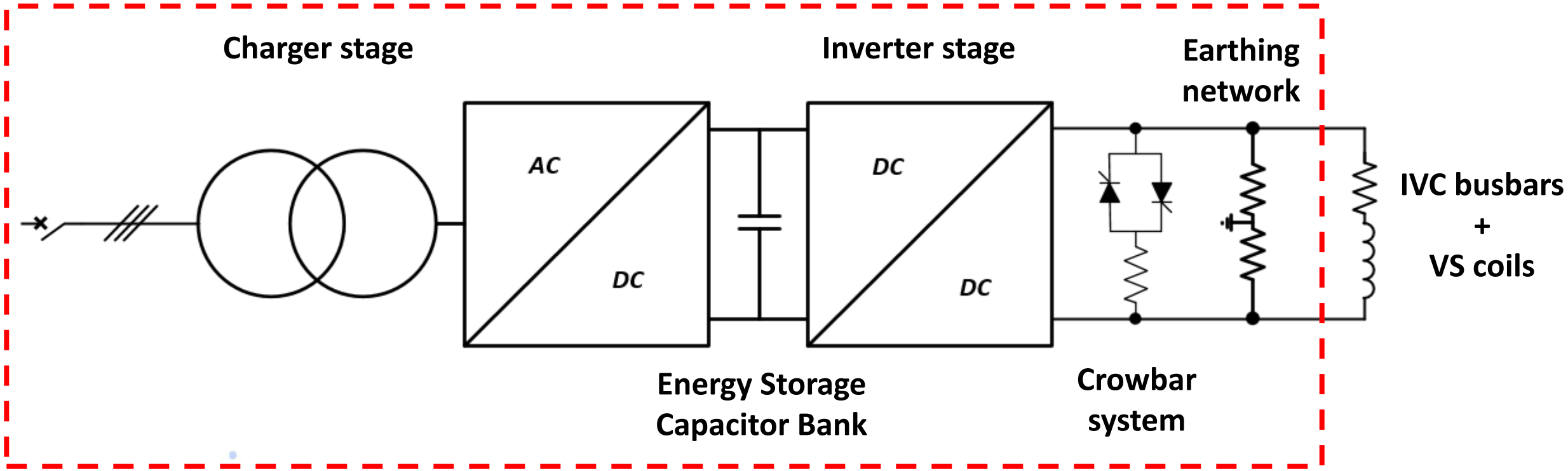
VS3 Power Converter (one unit)

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.

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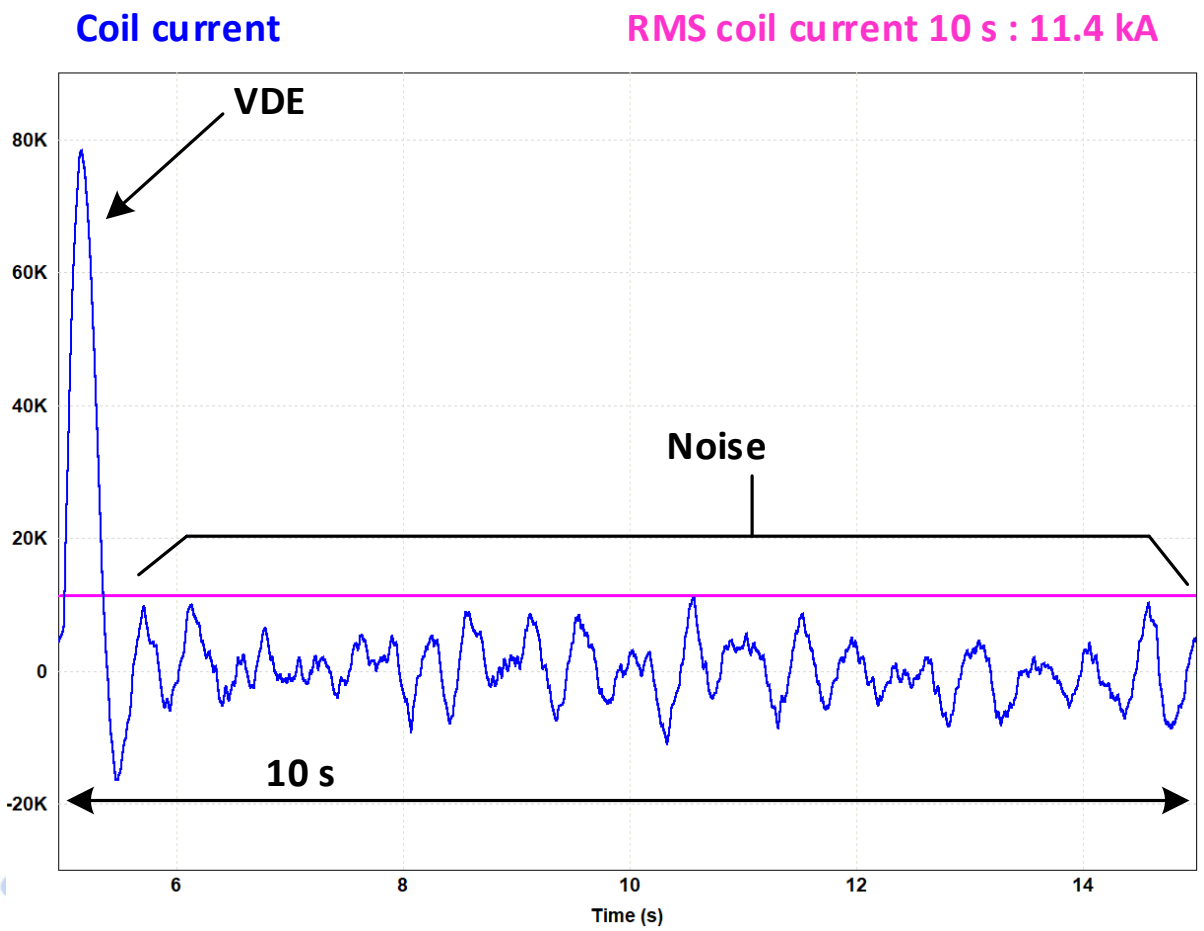
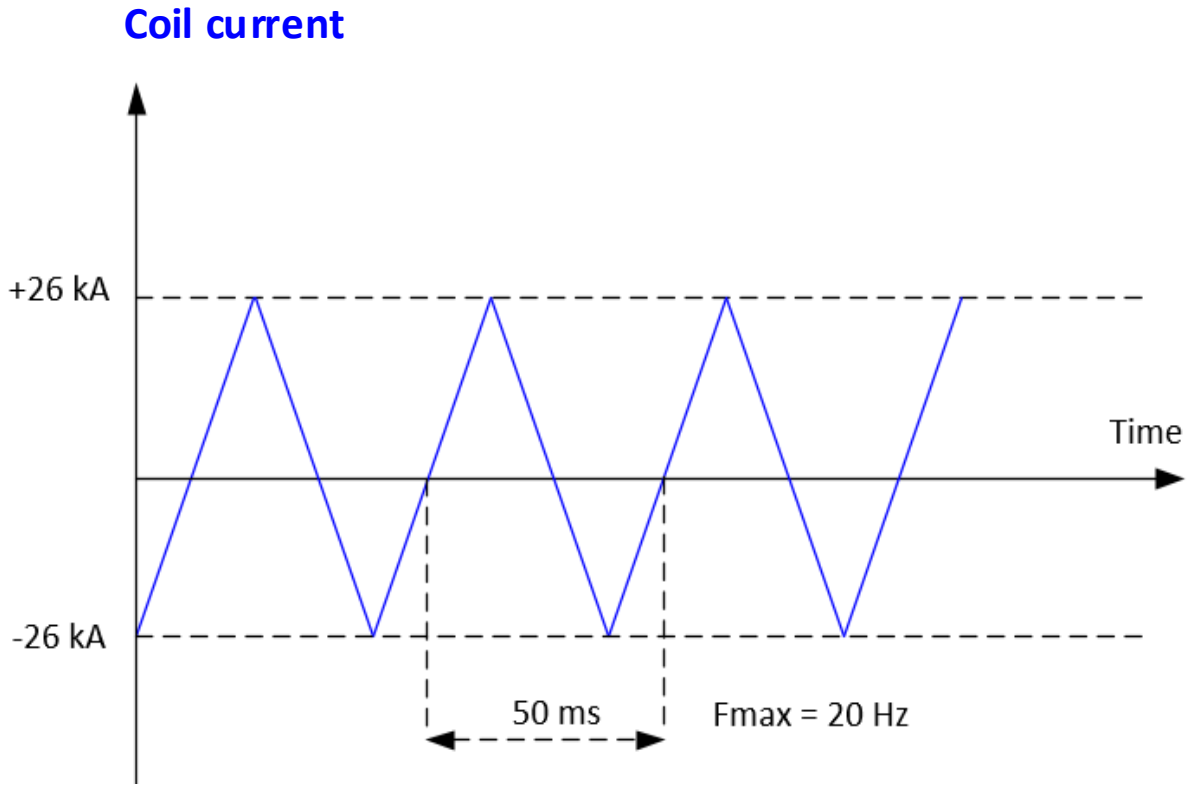
VS3 load current cycles

Scenario 1: Three consecutive events, one every 10 s



Scenario 2: regular waves



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VS3 main design ratings

- 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**
- **S**tatic **M**agnetic **F**ield **C**ompatibility
- Reduce **dV/dt** and Reduce **EMC**

- Scenario 1 Estimate :
  - Charger stage **> 1.8 MW**
  - DC link stored energy **> 15 MJ**
- Scenario 2 Estimate :
  - Charger stage **4 MW**

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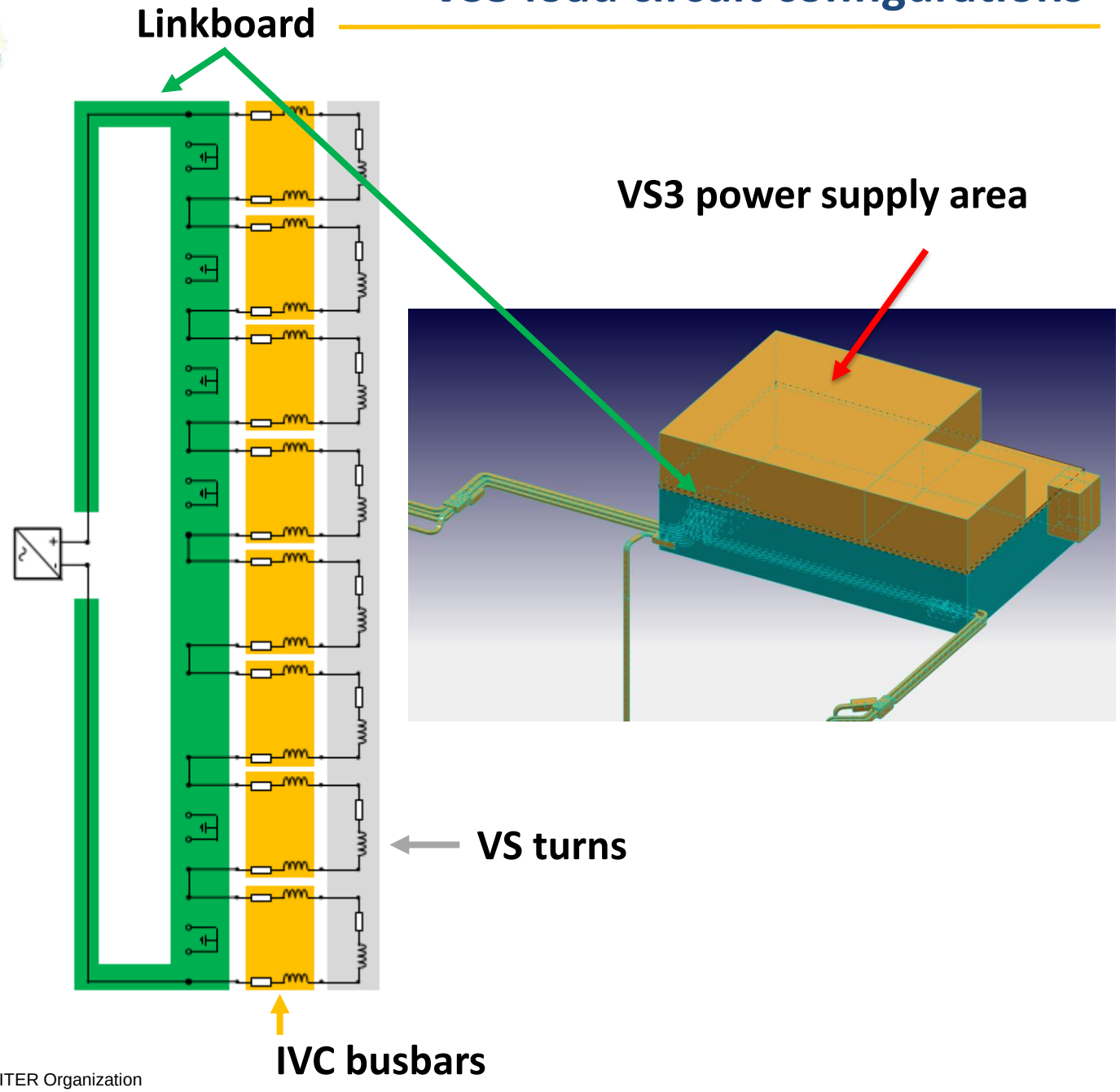
VS3 load circuit configurations

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.



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Lifetime requirements

20 years of lifetime for installation and compatible with **30 000 VDE** current pulses, **1500 Crowbar event** and compatible with **50 000 hours** at the nominal rated voltage.

- **27 000 VDE at ± 60 kA**
- **3000 VDE at ± 80 kA**

Based on this total time exposure of 7600 hours and duty cycle of 25 %, the DC link of the VS3 converter will be under the nominal voltage for approximatively 30 000 hours. In order to cover plasma ramp up and commissioning phase this number is increased to **50 000 hours** of operation under the nominal voltage of the DC link.

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Design requirements and layout constraints **applicable to the 27 ELM power converters.**

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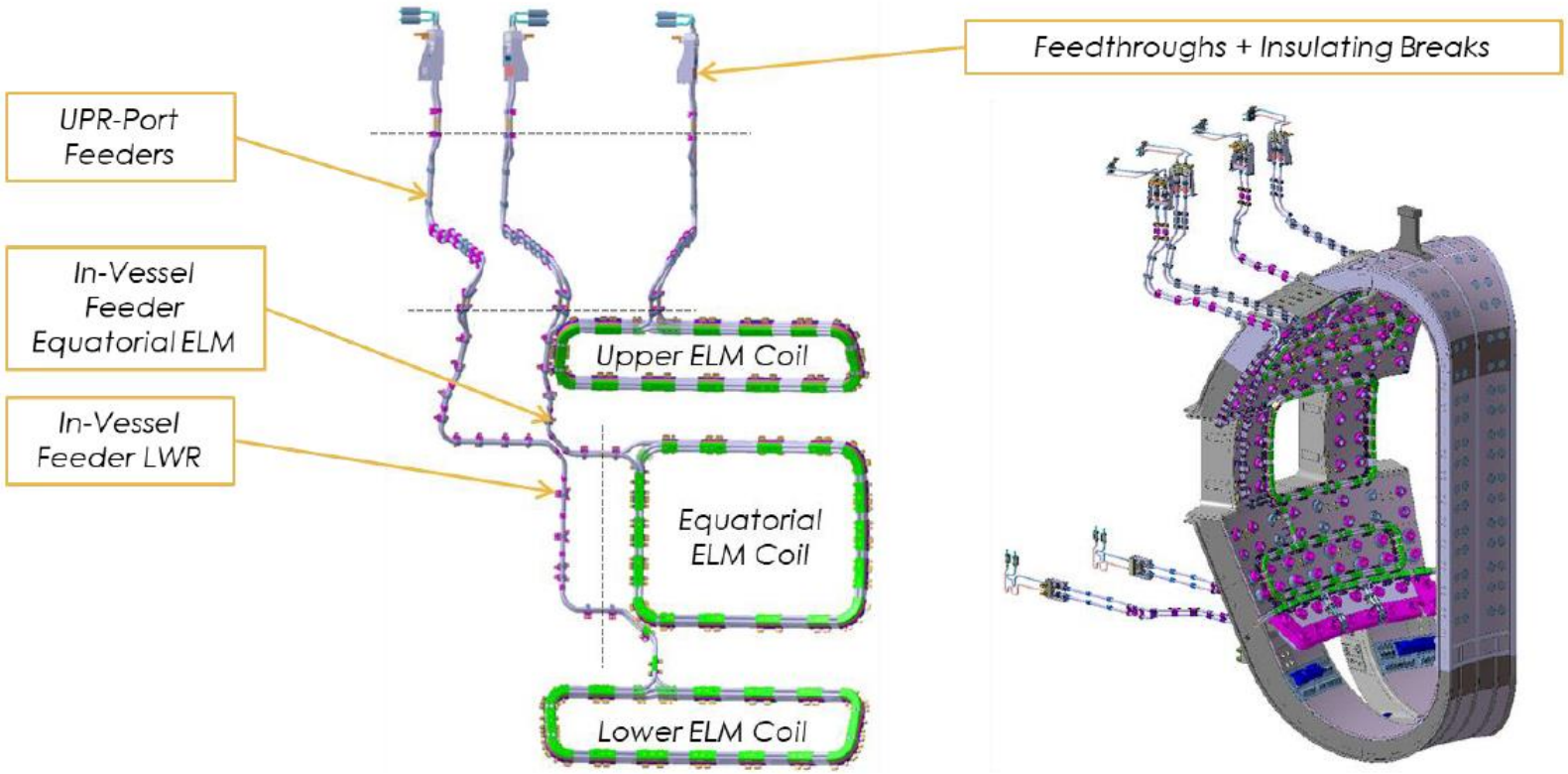
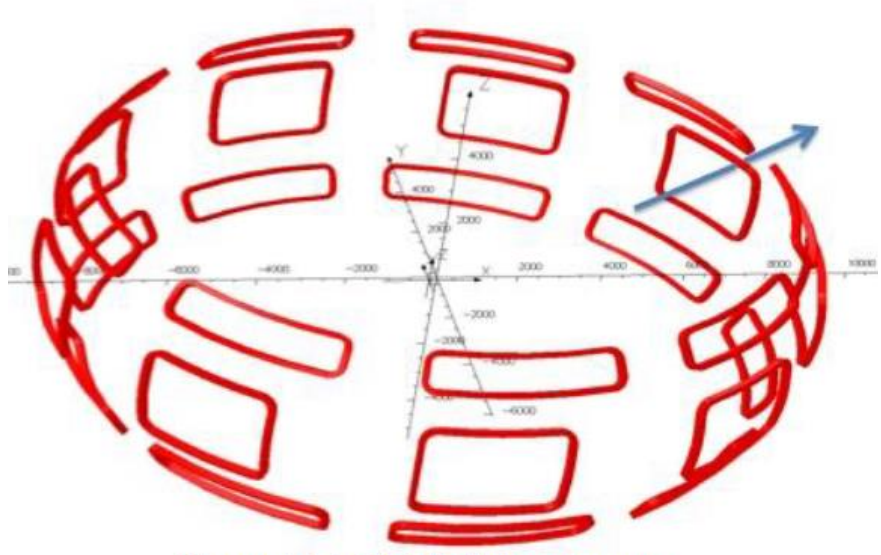
Edge Localized Mode (ELM) coils in the tokamak





- Maximum operating voltage : 200 V
- Maximum operating current : 15 kA

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

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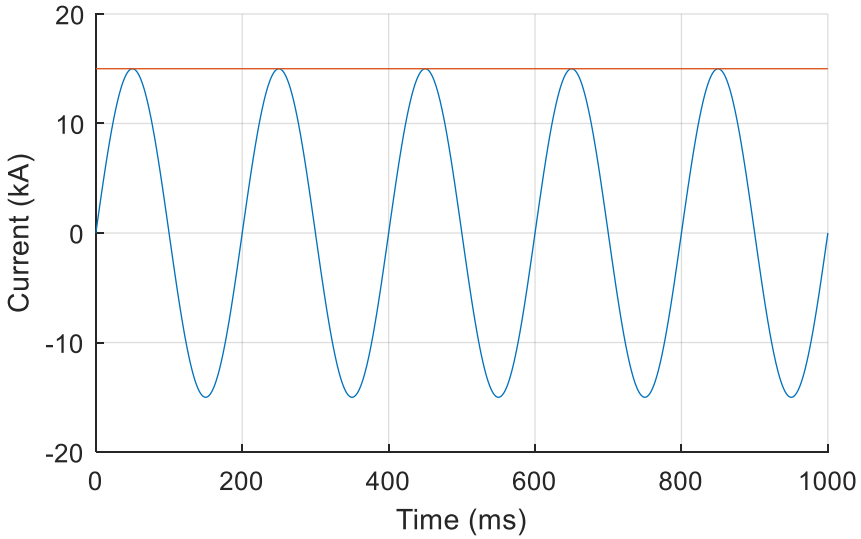
Operating modes of ELM power supplies

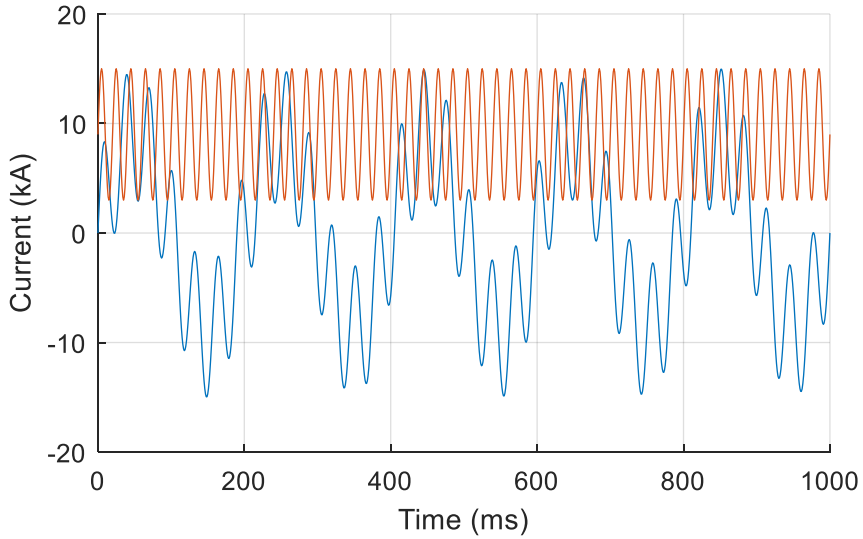
Baseline scenario

Unique frequency



Updated scenario

Superimposed frequencies



- Frequency range : 0 - 50 Hz
- Peak current range : 0 – 15 kA

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Preliminary technical requirements

- Output stage

Nominal output voltage	180 – 200 V
Voltage response time	less than 20 ms
Nominal output current	0-15 kA
Output frequency	0-50 Hz
Maximum active power to be supplied	760 kW
Maximum reactive power to be absorbed	850 kvar
Harmonics distortion rate	Specification in progress

- Input stage

Nominal output voltage	22 kV ± 10 %
Frequency	50 Hz
Global harmonics distortion rate	< 6 %
Global power factor	> 0.9

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Part 4: Procurement strategy and business opportunities

- Procurement strategy;
- Procurement schedule;
- **Business opportunities.**

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Overall procurement strategy

- The IVC Power Converters include:
  - functional requirements that are beyond the common industrial practice;
  - stringent interface requirements (i.e. : available space and permissible footprint load, Static Magnetic Compatibility, supply network, etc.);
- Some conceptual powering architectures have been identified;
- Before to finalise the procurement technical specifications, it is necessary to compare:
  - possible converters topologies and technologies for key devices/components (example the VS3 energy storage bank);
  - engineering best practices suitable to optimise the ratio cost/performances.

- **The procurement strategy will be rolled out in two waves:**
  1. Study contracts for the most challenging components;
  2. Two full turnkey system procurements, respectively for the VS3 Converters and the 27 ELM Power Converters

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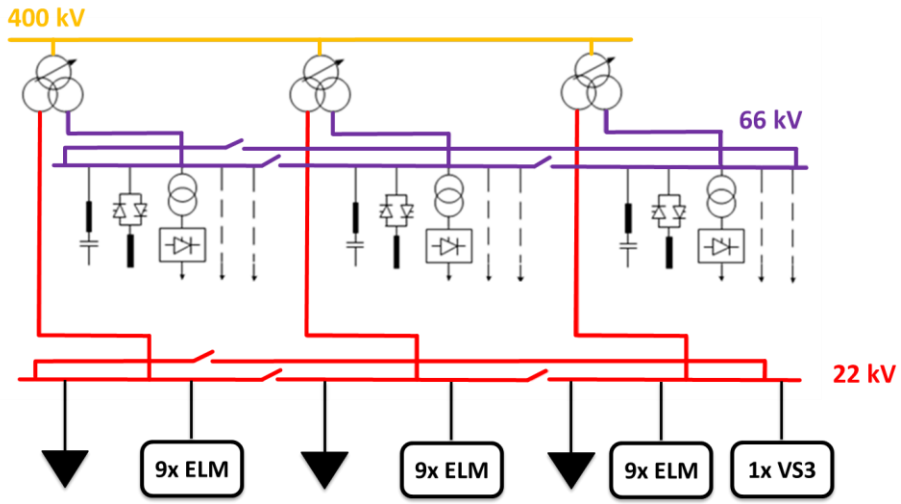
Forecasted studies

System level & integration studies (ITER Org.)
- Reactive & Harmonics filters requirement
- Integration in the existing electrical network

Converter studies (contracts with industry)
- Topologies & architectures benchmark
- Control strategies
- Size and weight estimation



Main procurement

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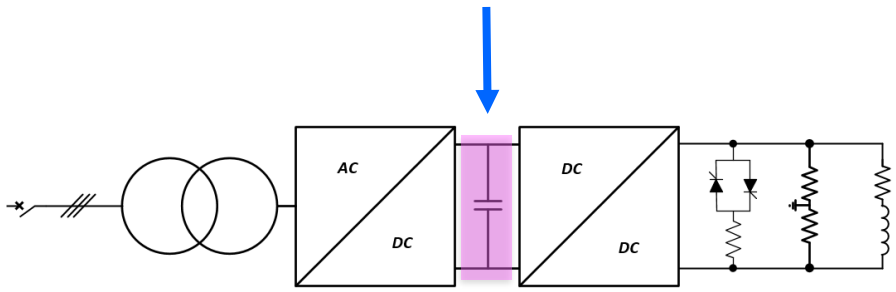
Planned study contracts for the VS3 power converter

Energy Storage Capacitor Bank

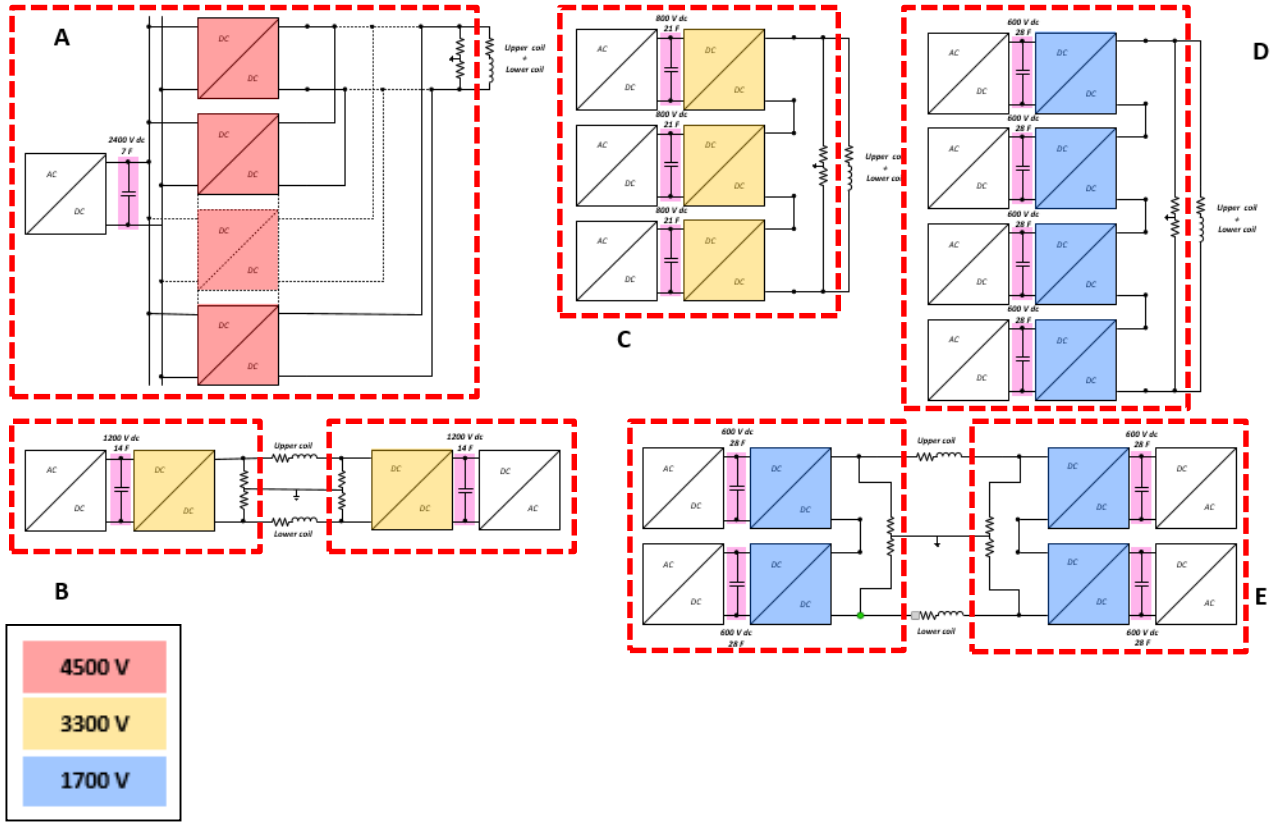
study contract



Converter topologies

study contract

Five Functional Powering Architecture



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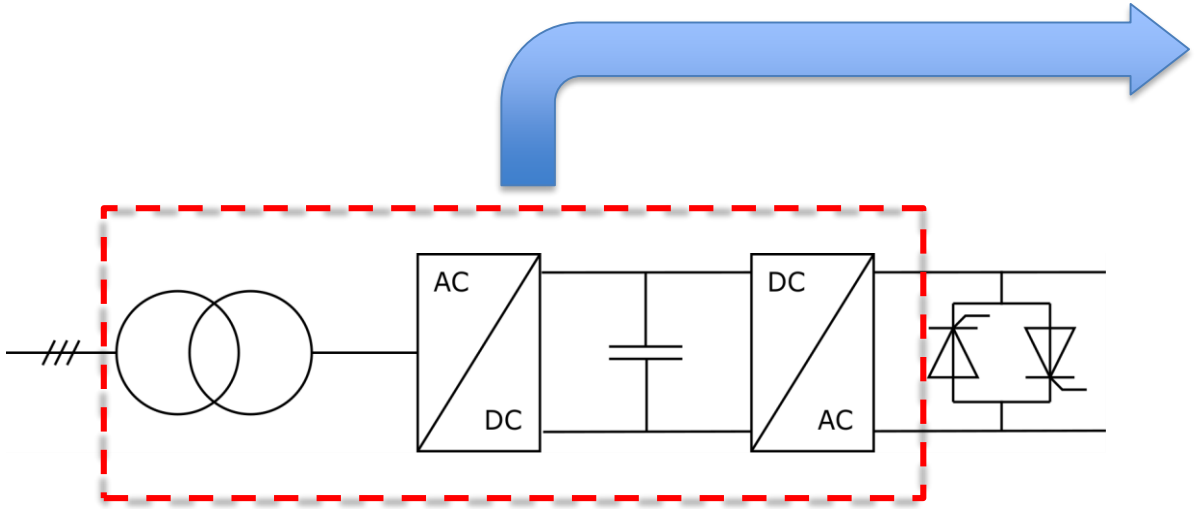
Planned study contracts for the ELM power converters



- Variants to be compared
  - Switches technology (Thyristors, IGBT…)
  - General architecture
  - Transformer technology
  - Control strategies
- Selection of the variants in progress

- Key Performance indicators
  - Weight, volume
  - Harmonics/reactive power
  - Costs, manufacturing time
  - Robustness, reliability & maintenance
  - Flexibility, functionality

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- Planned study contracts:
  - to get inputs for more options and from different suppliers, **each study contract will be awarded to two contractors.**
  - the study contracts currently planned are for the following items:
    - For the VS3 power converter:
      1. The energy storage bank of the VS3 Power Converter;
      2. The main components based on power electronic devices, i.e. ac/dc rectifier, the dc/dc inverter and the protective crow bar.
    - For the 27 ELM power converters:
      1. The main components based on power electronic devices, i.e. ac/dc rectifier, the dc/dc inverter and the protective crow bar.

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Special contractual conditions for the study contracts

- The results of the study contracts will belong to the IO and to ensure fair competition in the future procurements, **the IO reserves the right to attach to any future call for tender the technical results from the study contracts.**

- In the case a Contractor is planning to perform the study contract using background intellectual property or commercially sensitive information to be kept confidential, these **shall be declared soon after the tender invitation so that the ITER Organization can assess whether the offer for the study contract can be accepted**.

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Full turnkey system procurements

- **Turnkey system procurements, 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;
  - 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.
- **Info-day will be organized** before starting the tender processes of the two turnkey system procurements.

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Overall procurement schedule

Study contracts

Scope	Tender process		Contract duration
	launched in	duration	
VS3 energy storage bank.	*Already launched*		4 months
VS3 power electronic components: i.e. ac/dc rectifier, the dc/dc inverter and the protective crowbar.	June 2021	5-6 months	8 months
ELM power electronic components: i.e. ac/dc rectifier, the dc/dc inverter.	September 2021	5-6 months	6 months

Full turnkey procurements

Scope **including associated auxiliary systems, see previous slide.**	**Tender process**		**to be commissioned by**
	launched in	duration	
VS3 power converter	2023	12 months	End of 2028
27 ELM power converters	2023	12 months	End of 2028

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Summary

- One VS3 and 27 ELM power converters to be procured and installed;
- Technical specifications in progress;
- Conceptual studies (by the ITER Organization) to be started by Q3 2021;
- Full turnkey procurement contracts planned to be launched in 2023.

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- **The ITER Organization is interested to get in contact with Companies interested in participating to the planned tenders for:**
  - **the study contracts,**
  - **and the full turnkey procurements.**

Thank you very much for your attention

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