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The Electron Cyclotron Heating & Current Drive (EC H&CD) Power Supply Procurement

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Overview

- Introduction: the ECRH system for ITER
- The 2001 technical specifications
- The Design Review and new requirementsfrom ITER Organization
- Outline schedule and conclusions

The ECRH system for ITER

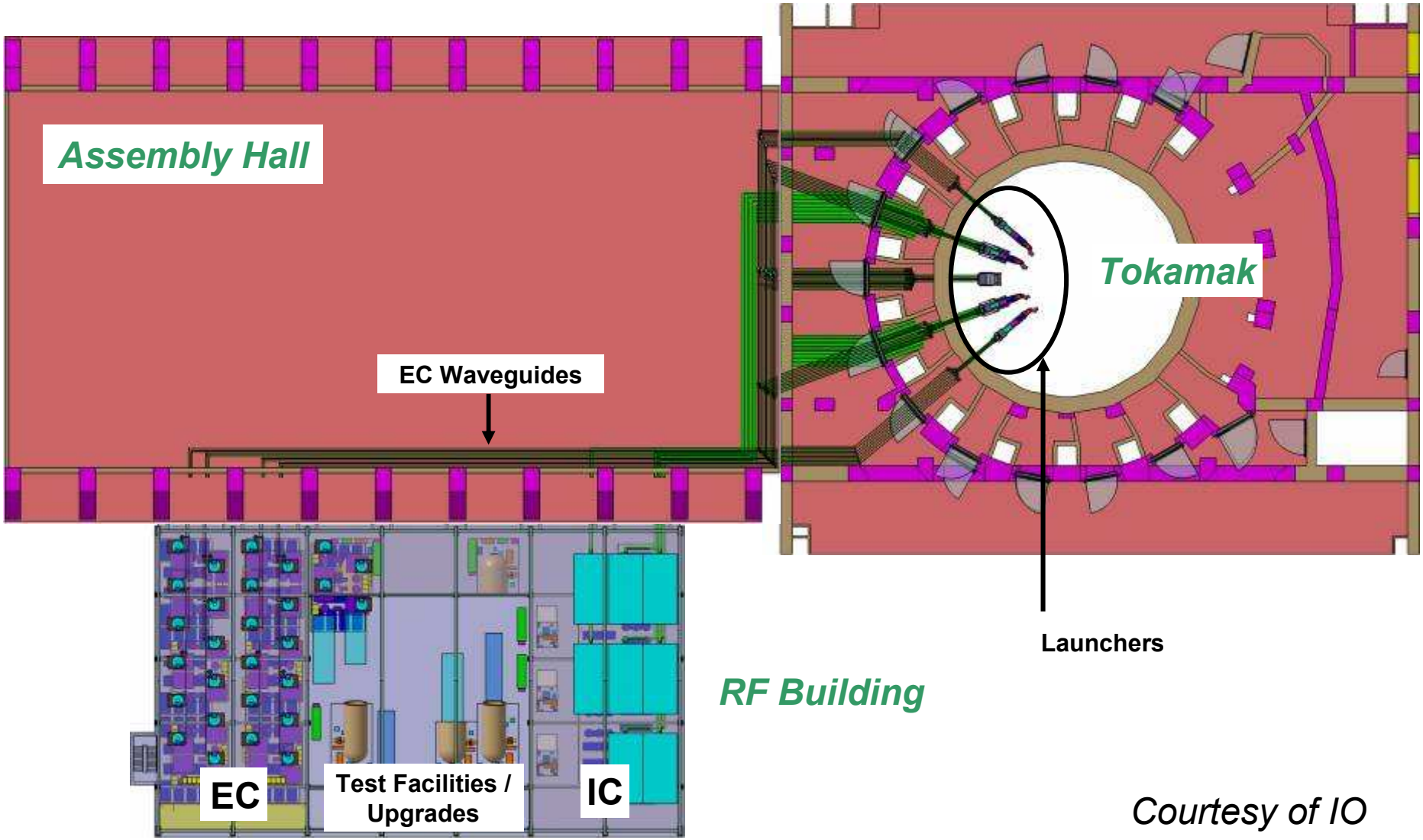
Functionalities (System Requirements Document Oct.08)

- **Heat the plasma** (ref.20MW) to achieve Q=10 (fusion power twice the auxiliary heating) and assist in accessing H-mode.
- Provide *steady state* on-axis and off-axis **current drive**.
- Control **MHD instabilities** by localized current drive.
- Assist **initial breakdown and heat during current ramp-up**.

Proposed additional functionalities:

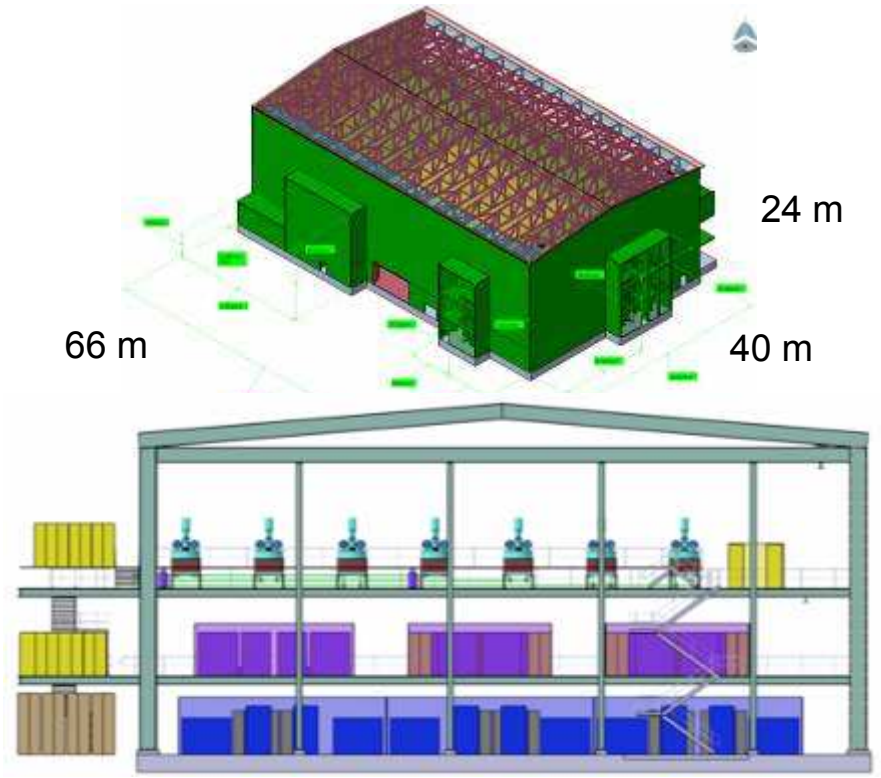
- Provide modulated ON-OFF power to control NTM stabilities

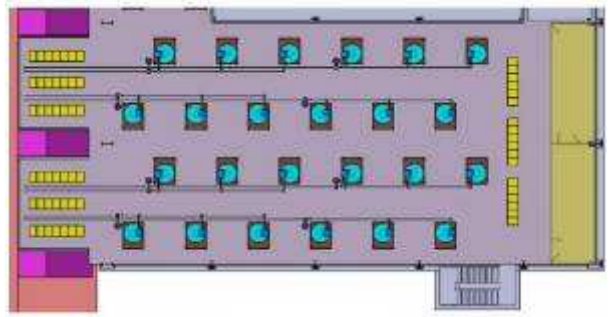
The ECRH system for ITER



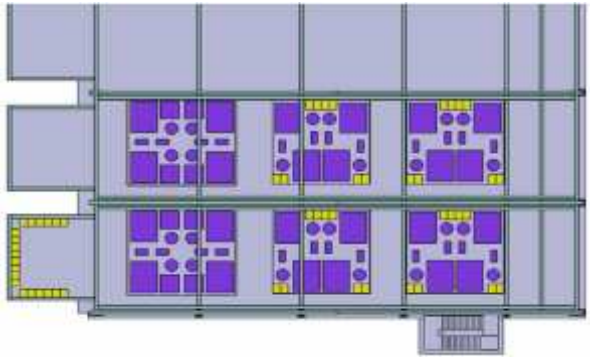
Courtesy of IO

The ECRH system for ITER

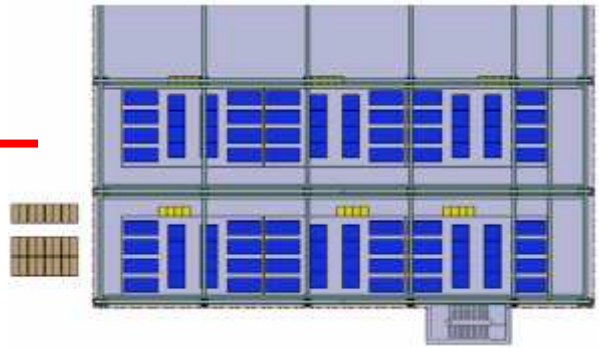




Level 3
- gyrotrons
- control racks
- local control room
- cooling manifold
- TL (false floor)



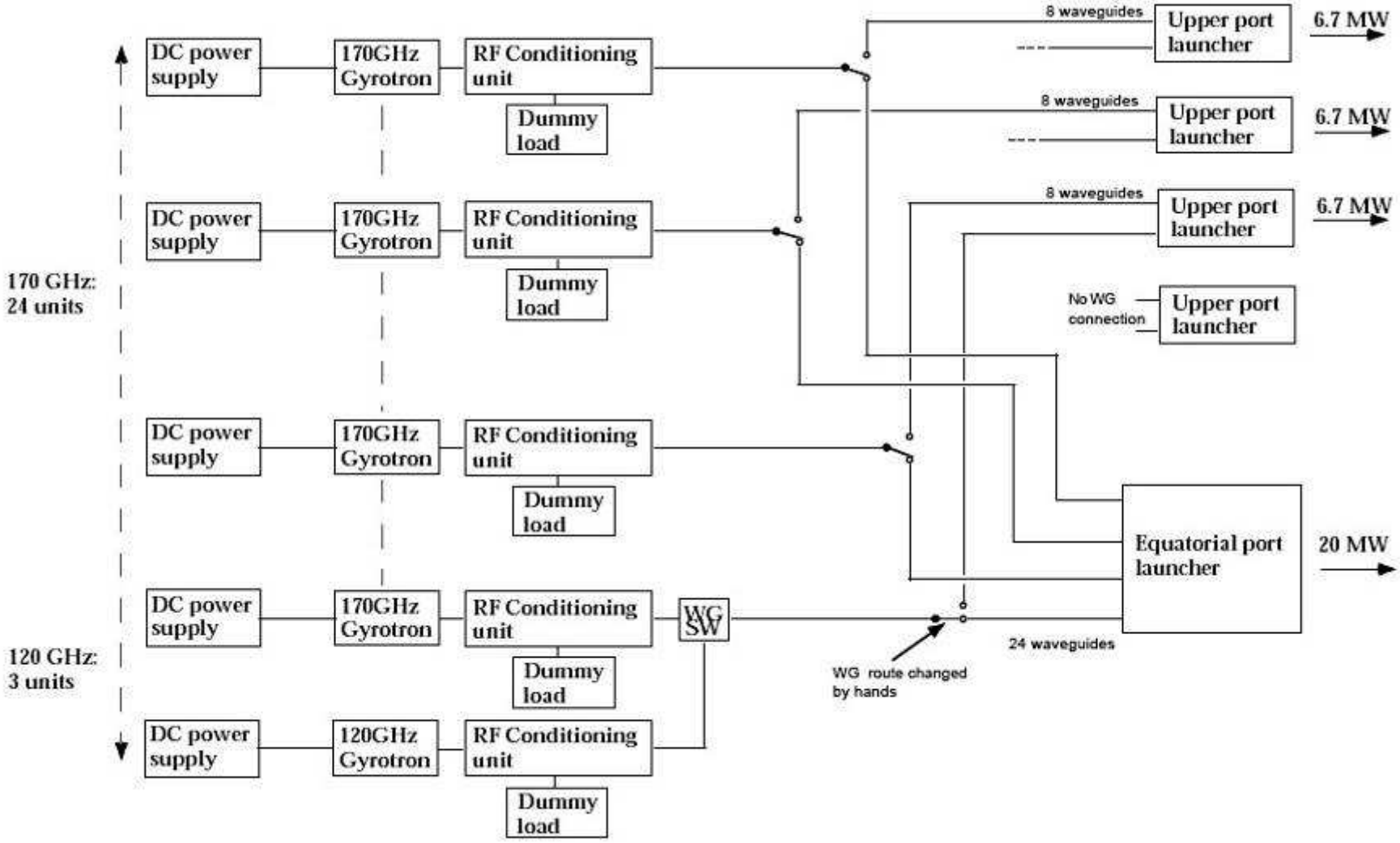
Level 2
- **body PS**
- **anode PS**
- cathode PS
- control racks



Level 1
- **Main PS**
- **Transformers**
- **HV distribution**
- Water circuits
- loading bay

Draft version of the RF building made available by IO on February 09

The original (2001) EC Procurement Package



The original (2001) EC Procurement Package

EU Contribution to the ITER ECRH Power Sources: Gyrotrons and Power Supplies

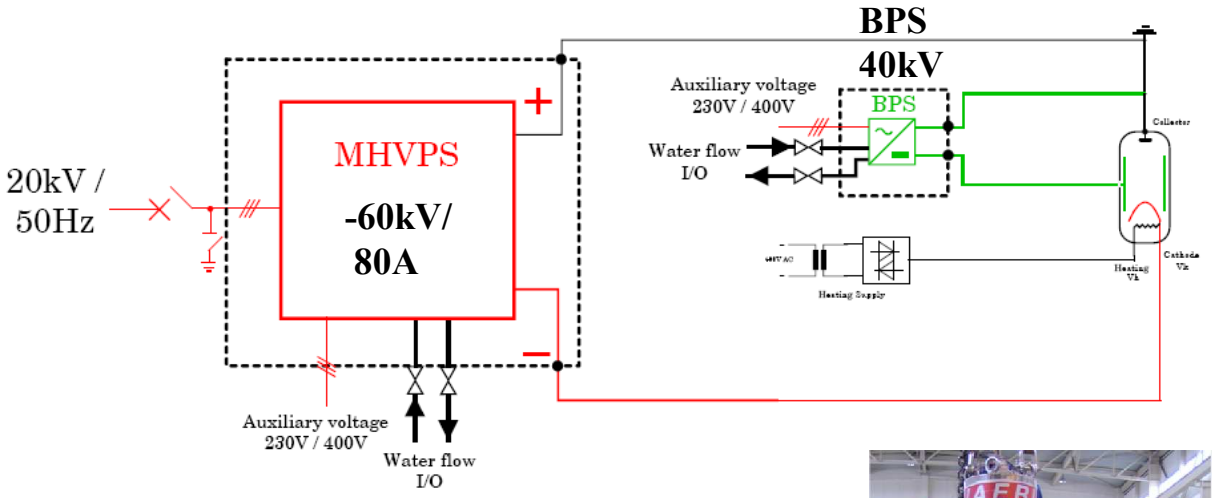
According to N-12 Sharing (2005)

- The European Domestic Agency is responsible for the procurement of 8MW generated RF power at 170GHz (one third)
- The power supplies (Procurement package # 52.P4) **feeding the complete H&CD system** (start-up system procured by IN DA)
- The IO Procurement Arrangement will be **functional specifications** to be issues by IO

PP	Description	EU	JA	RF	IN
52.P3	EC Power Sources	31%	31%	31%	8%
52.P4	EC Power Supplies	92%			8%

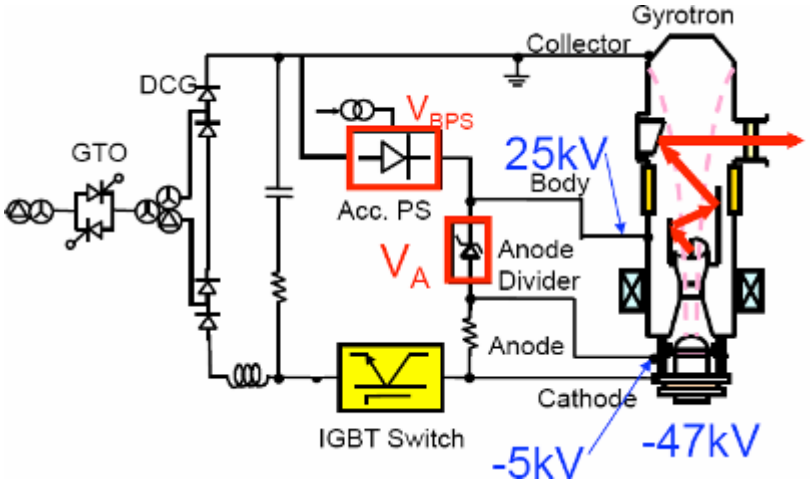
The original (2001) EC Procurement Package

The main components



Acceleration voltage 90-100kV

The EU 2MW gyrotron



The original (2001) EC Procurement Package

Scope of the EC H&CD power supply system:

Main HV power supply:

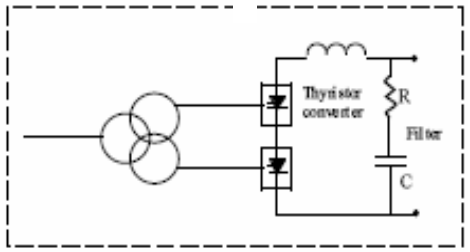
➔ step-down transformers 69/28 kV, 42MVA;

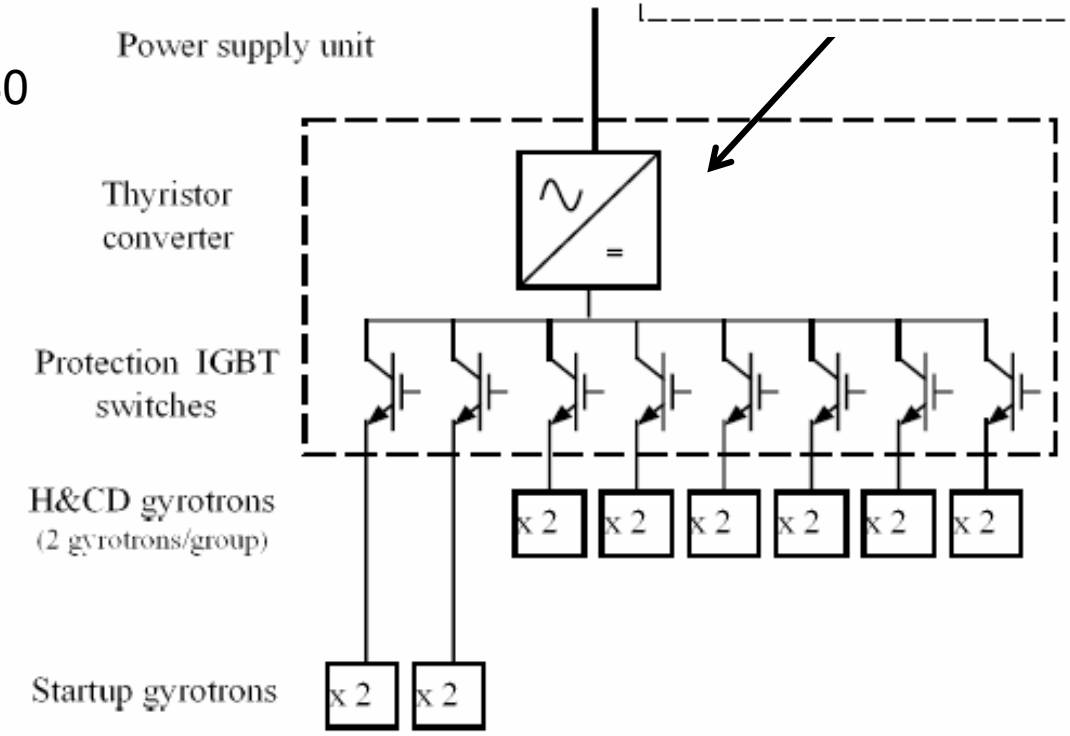
➔ 2AC/DC 12-pulse thyristor converters, rated 55kV, 540 A each;

➔ 2 L-C-R filters, rated 55 kV, 540 A each;

➔ 12 IGBT switches and diodes, rated 55 kV, 90 A each;

➔ 2 protection crowbars, rated 55kV;



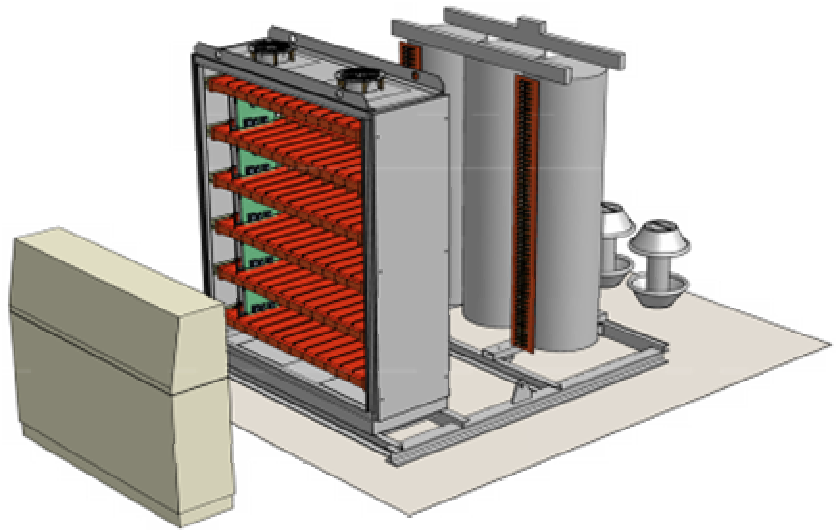


The original (2001) EC Procurement Package

Scope of the EC H&CD power supply system:

Body and anode power supply and others:

- ➔ 24 body power supplies, 50 kV, 0.1A;
- ➔ 24 anode power supplies, 50 kV, 0.1A;
- ➔ 1 dummy load (75V, 90A, 15s every 15 minutes);
- ➔ cubicles
- ➔ control, interlock
- ➔ quality assurance
- ➔ installation and on-site acceptance tests
- ➔ spare parts



The original (2001) EC Procurement Package

Requirements:

Parameter	Value
Number of EC H&CD PS units	Design dependent
Cathode voltage range	- 45 ÷ - 55 kV
Accuracy of the cathode voltage regulation (including ripple, overshoot and undershoot)	TBD (max. ± 3%)
Nominal cathode current	90 A
Maximum power per pair of gyrotrons	5 MW
Acceleration voltage range	0 ÷ + 45 kV
Acceleration voltage ripple in steady state	TBD (included between ± 0.2 - 0.5% of the maximum value)
Maximum acceleration current	0.1 A
Anode voltage range	0 ÷ - 50 kV
Accuracy of the anode voltage dynamic control	TBD (included between ± 0.2 - 0.5% of the maximum value)
Anode voltage modulation range	30 ÷ 100%
Maximum anode voltage modulation frequency	10 kHz
Maximum anode current	0.1 A
Fault energy (short circuit energy in case of load fault)	≤ 10 J

Main interfaces

- Building – space allocation – criteria for installation, operation and maintenance
- Other power supplies of the EC system (e.g. main & body)
- EC Control system
- Cooling (air and water)
- Gyrotron (cabling, load characteristics, arcs)
- ITER Pulsed Power Supply network at 22kV (reactive, effect of loads)

The design review process

Design Review of the EC Power Supply system (2005-2009)

Proposed new requirements

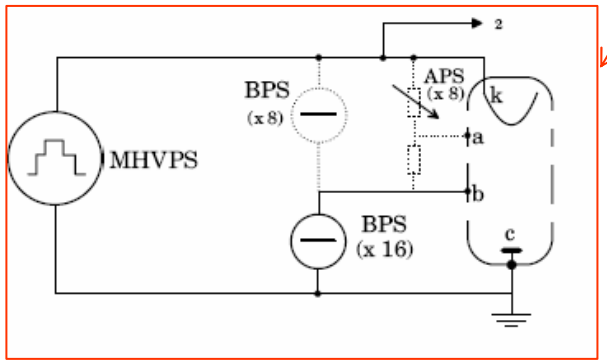
- To be adapted to **three different gyrotron suppliers** ➔ different interfaces (anode power supply)
- up to 1kHz for ON/OFF **modulation**, up to 5kHz for partial modulation up to 50-70% (*also impact on the collector*)
- **Fractional power of gyrotrons** (1.2-1.4MW)
- Further modularity & reliability of the system: **1MHPVS feeds two gyrotrons**
- **Compatible with fast shutdown**

Baseline design

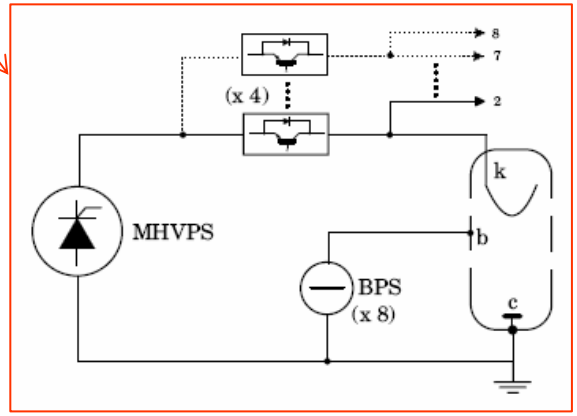
- Unique gyrotron design
- Baseline design: 30kV/1kHz (BPS)
- Nominal gyrotron power 1MW (or 2MW)
- 2 thyristor-based power supplies for 12 gyrotrons (12MW) each
- Detailed specs on gyrotron load characteristics, dynamic behaviour, etc. not specified

The design review process

Comparison between PSM and thyristor concepts



(ITER Task Agreement with EU-DA / EFDA task 2007)

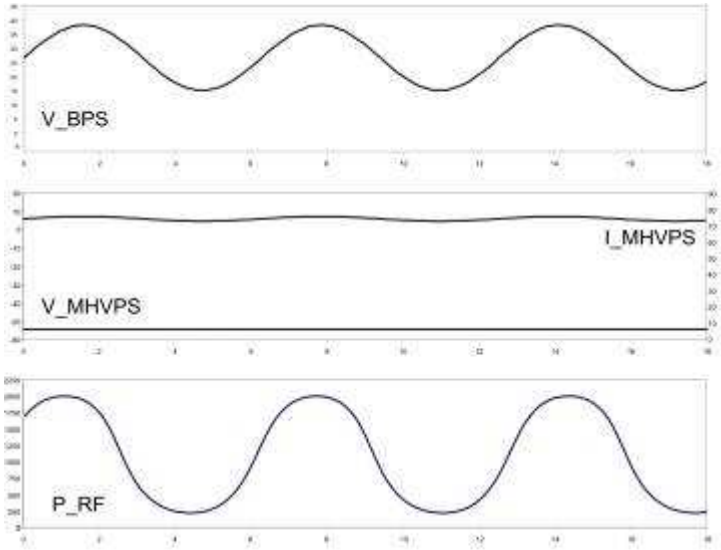


- Both options are able to fulfill ITER 2001 specifications
- Cost neutral (~10%) compared to ***3 thyristor PS*** to cope with 3 gyrotron suppliers
- PSM offers intrinsic advantages in terms of:
  - Reliability/availability: Redundancy of modules
  - Performance: Common voltage to 1/2 gyrotrons instead of 4/8 in a thyristor
  - Flexibility during commissioning and re-conditioning of gyrotrons
  - Fast switch-off and modulation capabilities (~10μs) and ON/OFF modulation: HVSS @ full current & nominal voltage (?)
  - Efficiency >97% (relevant for CW operation)
  - Saving reactive power: A power factor higher than 95% at any point of the operation area;

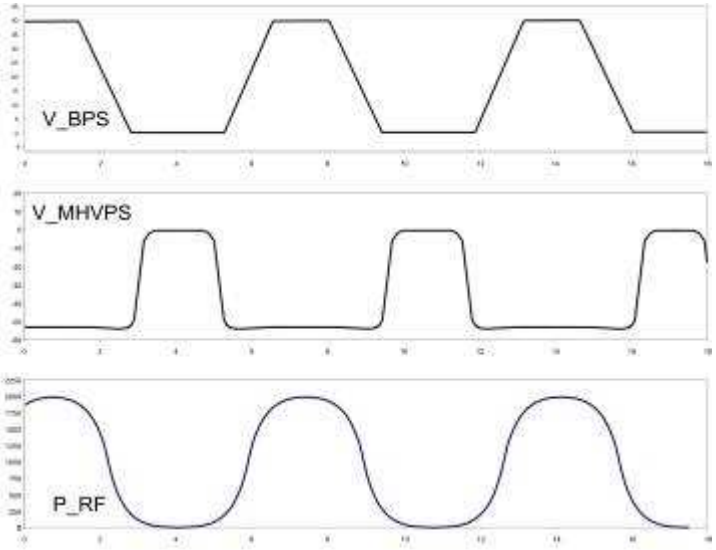
The design review process

Two possible ways for modulating (up to 5kHz)

- BPS output voltage (25kV peak-to-peak)

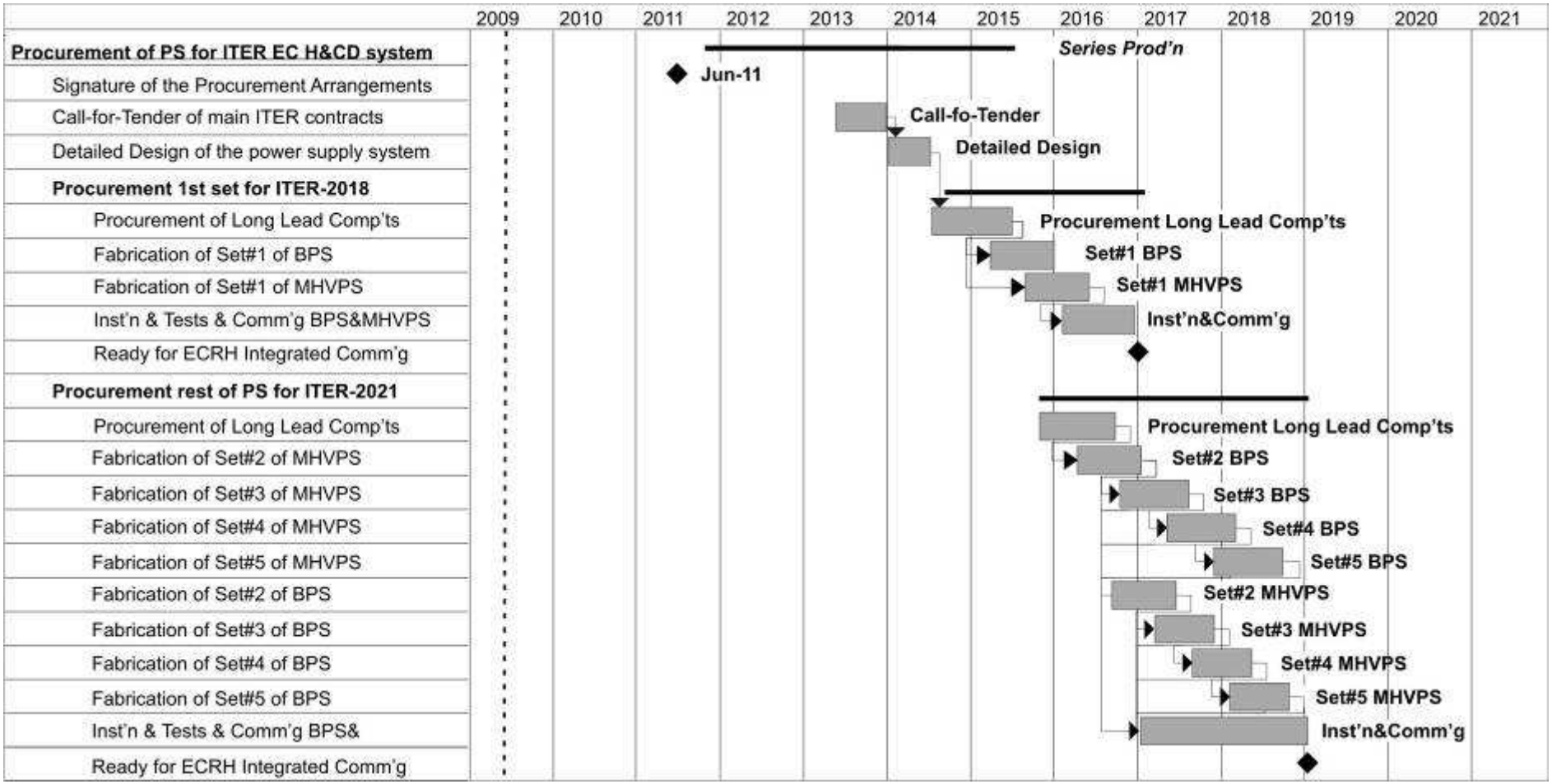


- ON/OFF



In the 2001 ITER baseline design the modulation frequency was 1kHz (DCR under study); ON/OFF modulation not foreseen

Tentative outline schedule



Summary

- Specifications of the EC H&CD power supply system are presently being revised by IO: space allocation, impact of gyrotrons with fractional power (e.g.1.4MW), auxiliary systems, simulation of the effects of 24 gyrotron load on the ITER 22kV pulse Power Network

- ITER Procurement Arrangement planned to be signed in 2011.

- Modulation capabilities (frequency, accuracy of the voltage waveform, amplitude of modulation) are critical for the design of the PS system

- Technological solution for ITER subject to the specifications of PS & gyrotrons, space allocation, power modulation and dynamic requirements.

Thanks for your kind attention.

Acknowledgement to all the EURATOM contributing Associations, Institutes and Companies.