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System Load Specifications

HVPS Load Specification

HVPS Load Specification of PBS 52

Approval Process			
	Name	*Action*	*Affiliation*
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Change Log			
HVPS Load Specification (65Q4B3)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	05 Nov 2021	
v1.0	Revision Required	02 Aug 2022	First issue
v2.0	Revision Required	10 Nov 2022	The version has been modified according to the comments to ver.1
v3.0	Revision Required	11 May 2023	All comments to ver 2 were taken into account.
v3.1	Approved	05 Jul 2023	All comments to ver 3 were taken into account.

Table of Contents

1 Purpose

The purpose of this document is to specify the individual loads and load combinations to be applied the HVPS. This load specification follows the requirements detailed in [1].

2 Scope

HVPS of PBS 52 is in the scope of three PAs: PA.52.P4.EU.01, PA.52.P4.IN.01 and PA.5.2.P3.JA.01.
The Load Specification is applied to the HVPS components described in section 12.1 and listed in Table 12.1.
The building openings that cables are passing through, stand-alone electrical devices like circuit breakers, fuses, wires, resistors, coils, capacitors, AC/DC converters etc are beyond the scope of the separate load specification since the latter is considered as a part of HVPS components listed in Table 12.1.
All SSC of HVPS analysed in this Load Specification are described in section 12.2.
The scope of the current Load specification is applicable to Building 15 where HVPS components are installed.

This document specifies the individual loads and combinations to be applied in the structural analysis of the HVPS of PBS 52. The purpose is to:

- Describe the loads affecting the HVPS and their load path through the mechanical connections for the verification of the structural integrity;
- Define the interface loads with Building 15 and with services;
- Satisfies requirements defined in the three PA Annex B [2], [3] and [4].

Notes:

- There will be up to 3 different designs of HVPS and differences for the loads will be highlighted in this document;
- The loads were derived from the set of Project LS [5] and only the applicable single and combination loads are propagated;
- The HVPS system has been designed to withstand all the loads and load combinations described in this document;
- There is no PIC in the HVPS;
- There are no HVPS components neither in-vessel not ex-vessel, so there are not included in the load specification.

The scope of this Load Specification covers:

- The list of all the single loads and the load combinations to be considered to verify the structural integrity of the HVPS system, and the load category of all load combinations;
- The specification of all load values related to individual loads that must be considered to verify the structural integrity of the HVPS;
- The number of load cycles to be considered for each load;
- The identification of all states of the HVPS system.

3 Scope of reviewers

Table 3.1 Scope of the reviewers

Reviewer	Scope
Natalia Casal	PBS52 RO shall review that • The general applicability of the information included in the load specification is correct; • The scope is correctly defined in terms of geometry; • The Load Specification covers the required damage limits for all the applicable loading categories, the related design criteria and the functional requirements for all the parts of the HVPS.
Giovanni Dell Orco	PBS26 RO shall review • The consistency of this Load Specification with the referenced interfaces with PBS 26, and the correctness of the related conclusion.
Lionel Lamberlin	PBS63.15 RO shall review • The consistency of this Load Specification with the referenced interfaces with PBS 63.15, and the correctness of the related conclusion.
Miguel Dapena	PBS52 SRO shall review that • The Safety requirements are met, accordingly to the safety class of the HVPS.
Patrick Vertongen	PBS52 QA shall ensure that • The QA requirements are met, accordingly to the quality class of the HVPS.
Sergio Barletta	IEA reviewer shall review that • The requirements described in [1] are implemented in the Load Specification.
Jean-Lou Perrin	B15 DIS area manager shall review • The list of interfaces and any additional aspects related to the HVPS Integration.
Alberto Loarte	SCOD reviewer shall review the use of the HVPS according to the different plasma scenario.
Xiaotan Zhang	IEA reviewer shall review that the seismic loads.
Riccardo Roccella	EM loads

4 References

[1]. Instructions for ITER System Load Specifications, ITER_D_33TTPJ v3.2
[2]. EC HVPS PA 52.P4.EU.01 Annex B 6KMPG5 v2.3
[3]. EC HVPS PA 52.P4.IN.01 Annex B, ITER_D_9C3H4F v1.3
[4]. Annex B1 for the PA on EC Anode and Body Power Supplies with JA-DA, ITER_D_S9EANH v1.1
[5]. ITER Load Specifications (LS), ITER_D_222QGL v6.2
[6]. EC PS Component Classifications, ITER_D_33PMFZ v1.6
[7]. 5.2.P4.EU.01 Justification of Quality Class reclassification ITER_D_5N665H v1.0
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[10]. Interface Sheet (IS) between RF Heating Building (PBS 63-15) - Electron Cyclotron H&CD System (PBS 52), ITER_D_2UUMTY v1.10
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[12]. EU-DA Report – PA 6.2.P2.EU.02 - Methodology to be Used to Generate the Seismic Floor Response Spectra for Ancillary Buildings at ITER, ITER_D_PN36V6 v3.1
[13]. PCR-001091, Regrouping of PBS51 and PBS52 switchgear procurement, ITER_D_XP55HP
[14]. PCR-001151 Modifications of B15 South Dummy Load shelter (15-AN-03) from DA Deviation request ITER_D_3CPQF7
[15]. PCR-001134 B15 and Annexes implementation of integrated sequence of activities and IO early Accesses ITER_D_38D4PH
[16]. PCR-680 Layout requirement for Building 15 ITER_D_QPMDAF
[17]. PCR-508 EC MHVPS rating increase ITER_D_ETLCLG
[18]. PCR-422 EC PS technical specifications ITER_D_ETJQ7U
[19]. PCR-264 Simplification of the EC system procurement allocation ITER_D_ETGBDT
[20]. PCR-636 - Cost Savings proposal for EC Power Supply Procurement ITER_D_PWV7KL
[21]. PCR-562 - Revision of the IN-DA PS Procurement scope ITER_D_JN4BJM
[22]. PCR-679 - Procurement of APS and BPS for JA gyrotron ITER_D_QE6VZZ
[23]. 5.2.P4.EU.01 Deviation Request - Specific Applicability of the General Management Specification - F4E DACC Process #157177 66765F v1.0
[24]. 5.2.P4.EU.01 Deviation Request 01 - Clarifications on REQs QC8JK8 v1.0
[25]. 5.2.P4.EU.01 Deviation Request 02 - Adaptation of the PA delivery schedule to the new date for RFE of the ITER Building #15 S7KUFN v1.1
[26]. 5.2.P4.EU.01 Deviation Request 03 - Optic fiber transmission of analogue signals RHU2TY v2.0
[27]. 5.2.P4.EU.01 Deviation Request 04 - Deviation Request for the modification of the gyrotron characteristics curve SN29GH v1.0
[28]. 5.2.P4.EU.01 Deviation Request 05 - Deviation Request for the removal of the procurement and installation of cable trays from scope U8TFK4 v1.0
[29]. 5.2.P4.EU.01 Deviation Request 06 - Deviation Request for the short pulse dummy load resistance and temperature monitoring system SND4BS v1.0
[30]. 5.2.P4.EU.01 Deviation Request 07 - Short Circuit Current Value RHU5FE v1.1
[31]. 5.2.P4.EU.01 Deviation Request 07 - Short Circuit Current Value - impact report SMYSA8 v1.0
[32]. 5.2.P4.EU.01 Deviation Request 08 - Deviation Request from Supplier - Factory Tests LPDL configuration SNGC3C v1.0
[33]. 5.2.P4.EU.01 Deviation Request 09 - New Seismic Requirements SNKHMP v1.1

[34]. 5.2.P4.EU.01 Deviation Request 09- New Seismic Requirements - impact report UKEL8Z v1.0
[35]. 5.2.P4.EU.01 Deviation Request 10 - Specification of a new PLC series model T7AQNF v1.0
[36]. 5.2.P4.EU.01 Deviation Request 11 - Summary of DR 01-10 UKFPVW v1.1
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[38]. 5.2.P4.EU.01 Deviation Request 13- F4E DACC Process #126159 - PA monthly reports 4UKMKU v1.0
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[42]. Installation Procedure for APS/BPS cubicle 4RULET v1.1
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[44]. Floor response spectra for the qualification of the equipment in Auxiliary Buildings PUBVV8 v 1.3
[45]. ICD-26.CC-52 Interface Control Document for Component Cooling Water System (PBS26.CC) and the Electron Cyclotron Heating and Current Drive System (PBS 52) 2FR5AS v.3.2
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[50]. CCWS-2A and CCWS-2D Piping stress analysis report in Building 15 and Building 15 Annex YJAMVZ v 1.1
[51]. Ga-building 15 distribution board 5ABZNA_v4
[52]. EDH Part 4: Electromagnetic Compatibility (EMC) (4B523E v3.0)
[53]. EDH Part 3: Codes & Standards, ITER_D_2E8DLM v 1.3
[54]. Change Notice based on "PCR-562 - Revision of the IN-DA PS Procurement scope" for "EC HVPS PA 52.P4.IN.01 Annex B (9C3H4F v1.3)": review and approval ITER_D_UL2AR8 v 1.0

5 System Classifications

The detailed quality classifications for the HVPS components are listed in [6]. Additional quality classes for the physical parts of EU-DA HVPS are defined in [7]. The ITER general classifications for the HVPS are listed in Table 5.1. Note that the listed classifications correspond to the component with the highest rating of the entire subsystem. In most cases, however, the components forming a given subsystem have a lower rating.

Table 5.1 General classifications for the HVPS

Quality	Safety	Seismic	Vacuum	Tritium	Remote Handling	ESPN	ESP
QC2	Non SIC	NSC	NA	NA	NA	NA	Yes (A)

Note (A): The EC PS water cooling systems operates above 0.5bar and is therefore under the French decree 99-1046 dated 13 December 1999 and French order dated 21 December

1999. As long as the maximum allowable pressure remains below 10 bar and fluid temperature below 110°C, then the EC PS cooling system design is under article 7 of ESP – "l'art en usage (good trade practice)".

6 Codes and standards

HVPS systems shall be manufactured in compliance with applicable International Electrotechnical Commission (IEC) standards, as well as all applicable French Standards.

Anchorages under static or quasi static loading used to fix the cabinet base frames into the concrete are designed in accordance with EN 1992-4:2008 and EOTA Technical Report TR 055.

7 Definitions

7.1 Units

The units used in this analysis are the standard SI base and derived units listed in Table 7.1. Standard prefixes are also used. Temperature is given in degrees Celsius. To avoid misinterpretations, it must be prevented that units are specified globally and that load values are given without unit. Therefore, all values given in the load specification shall be given with their units and no global unit specification shall be made.

Table 7.1 Units

Quantity	Unit Name	Unit Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Temperature	Celsius	°C
Acceleration	-	$m \cdot s^{-2}$
Force	Newton	N
Moment	-	$N \cdot m$
Pressure	Pascal	Pa ($N \cdot m^{-2}$)

7.2 Coordinate systems

The global coordinate system considered for the engineering analysis shall be the TGCS (Tokamak Global Coordinate System) [8]. Unless stated otherwise, all loads are specified in this coordinate system. The axes / directions of the TGCS are named: radial, toroidal, and vertical; also the directions "poloidal" and "toroidal" are used for load directions, as reported in Figure 7-1 below.

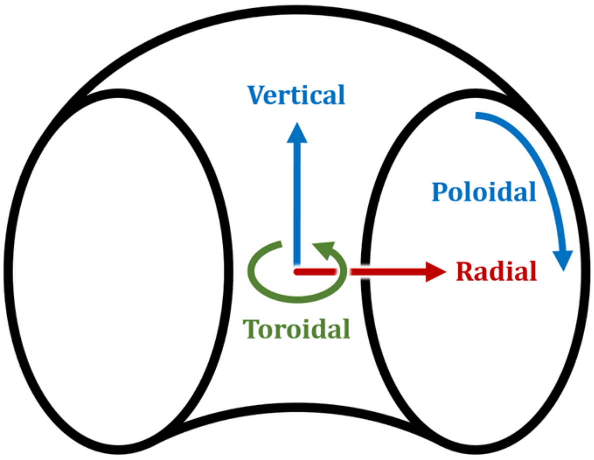


Figure 7-1 Definitions of the plasma CS (red) and the cylindrical CS (blue)

7.3 Abbreviations

The ITER Active Web Abbreviations Dictionary and the official list of abbreviations can be found in [9]. See below a list of abbreviations used on this document:

APS	Anode Power Supply
BPS	Body Power Supply
BPS DL	Body Power Supply Dummy Load
C&S	Codes & Standards
CCWS	Component Cooling Water System
DA	Domestic Agency
DC	Direct Current
EC	Electron Cyclotron
EM	Electromagnetic
ESPN	Equipement Sous Pression Nucléaire
EU-DA	European Doemestic Agency
F4E	Fusion For Energy
FP	First Plasma
FRC	Floor Response Spectra
GHz	Gigaherz
HVPS	High Voltage Power Supply
H&CD	Heating & Current Drive
ITER	International Thermonuclear Experimental Reactor
I&C	Instrumentation & Control
ICD	Interface Control Document
IN-DA	Indian Domestic Agency
IS	Interface Sheet
JA-DA	Japan Domestic Agency
kHz	kilo Herz
LOCA	Loss of Coolant Accident
LPDL	Long Pulse Dummy Load

MHD	Magneto Hydro Dynamic
MHVPS	Main High Voltage Power Supply
MW	Mega Watt
ms	millisecond
NSC	Non-seismic Classified
PA	Procurement Arrangement
PFPO	Prefusion Plasma Operation
PR	Project Requirements
PCR	Project Change Request
QA	Quality Assurance
RAMI	Reliability, Availability, Maintainability & Inspectability
RF	Radio Frequency
SAT	Site Acceptance Test
SIC	Safety Importance Class
SPDL	Short Pulse Dummy Load
TBC	To Be Confirmed
TBD	To Be Defined

8 Types of Loads

The loads acting on HVPS can be classified within 8 categories:

- **Inertial loads**: caused by accelerations due to gravity and to seismic events.
- **Pressure loads**: include pressure due to the CCWS-2A water cooling.
- **Thermal loads**: caused by losses in the electrical equipment due to its operation. Losses shall be distributed in cooling water and building HVAC system in order to cool down the electrical equipment. These loads are internal loads of the electrical equipment, depends on the operation of HVPS.
- **Environmental loads**: due to the ambient conditions (temperature, humidity) and to the stray magnetic field coming from the tokamak. The layout of the component allows a sufficient distance between the components to avoid any effect due to stray magnetic field coming from the components themselves.
- **Assembly loads**: applied to the HVPS during the assembly phase.
- **Interface loads**: loads generated due to interfacing systems external to the HVPS**.**
- **Accidental loads**, such as fire, loss of coolant events, load drop, pipe whip, etc.
- **Other loads** (e.g. during fabrication, transportation).

9 Main Loads

Table 9.1 provides a list of the main loads applicable to the HVPS. Design information for these loads can be found in the relevant sections provided.

Table 9.1 Characteristic loads from HVPS

Load Event	Section	Characteristic loads
Self-weight (DW)	14.1.1	Load due to the component self-weights

Pressure (Po)	14.1.4	Cooling water pressure during operation
Thermal loads (TH)	14.2	Room temperature (range)
SL-2, SL-1, EC8	14.1.5	Seismic events

10 Path of the Main Loads

The nominal paths of loads are shown in Figure 10-1 which presents the main interfaces involved in carrying these loads to ground.

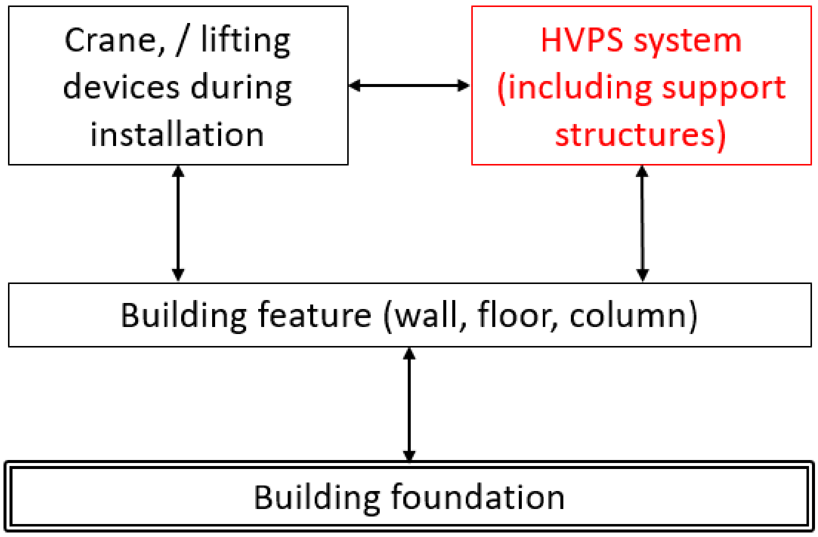


Figure 10-1 ITER structural load path diagram, showing relevant EC subsystems

11 Load Categories and Classifications

The ITER loading conditions are categorized into four classes [5] based on the expectation of occurrence:

Category I: Operational Loading Conditions,
Category II: Likely Loading Conditions,
Category III: Unlikely Loading Conditions,
Category IV: Extremely Unlikely Loading Conditions.

Other events or events combinations that are beyond design basis may be classified in an additional category (V). Those events do not need to be considered for the design of the mechanical components. The typical process of component design involves the following steps:

1) Identify and specify all events (e.g., Seismic, Gravity, Disruptions, etc.);
2) Identify and categorize events combinations (e.g., Seismic + Disruption);
   - Evaluate loads arising from each condition combination;
   - Calculate the stress / strain to be applied to subsystems / assemblies due to each load combination;
3) Establish the acceptable damage limit for each condition combination (e.g., Normal, Upset, Emergency, or Faulted) also based on whether the component has any safety importance;

4) Applicable codes and standards (C&S) for the HVPS design and manufacturing are defined in [53] and section 6;
5) Establish the structural service criteria for each damage limit (e.g., Type of damage and criteria, according to the design code selected);
6) Compare the evaluated stresses against the established criteria.

The flow diagram of a typical design and assessment process is given in Figure 11-1. The damage limit associated to each load condition is reported in Table 11.1 indicates the relationship between Load Combination Category (loads and likelihood categories) and acceptable damage limit as a function of the component safety class (PIC or non-PIC).

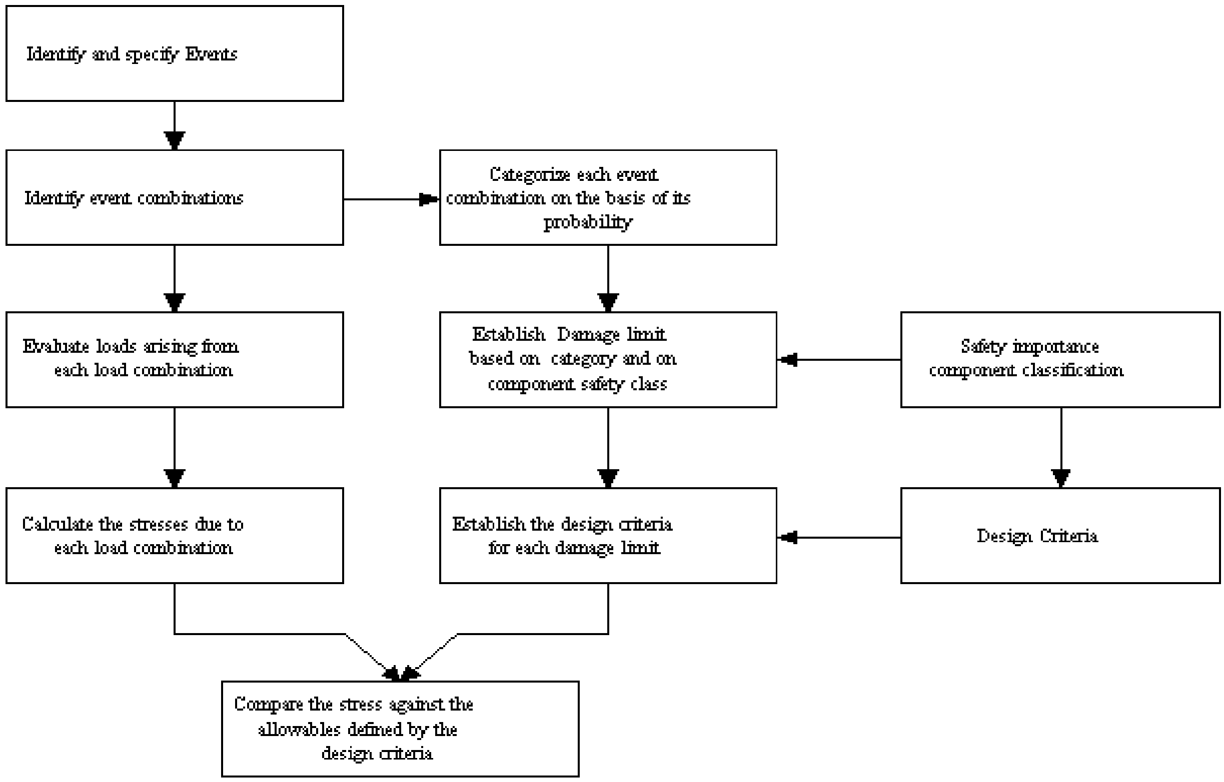


Figure 11-1 Flow Diagram of Typical Design and Assessment Process

Table 11.1 Damage limit to Component Level

Load Condition	Damage limit to Component level
Normal / Design / Test	The component should maintain specified service function.
Upset	The component must withstand these loadings without significant damage requiring special inspection or repair.
Emergency	Large deformations in areas of structural discontinuity, such as at nozzles, which may necessitate removal of the component from service for inspection or repair. Insignificant general permanent deformation that may affect safety function of the component concerned. General strains should be within elastic limits. Active components should be functional at least after transient.

Load Condition	Damage limit to Component level
Faulted	Gross general deformations with some consequent loss of dimensional stability and damage requiring repair, which may require removal of component from service. Nevertheless deformation should not lead to structural collapse which could damage other components. The fluid boundary is maintained but degraded; however the safety function is maintained. The confinement of radioactive material is maintained. Active components may not be functional after transient.

Table 11.2 below defines the damage limit for the HVPS components.

Table 11.2 Definition of function to be accomplished by each loading condition and associate damage limits

Loading Category		Category I: Operational/ Design Loading	Category II: Likely Loading	Category III: Unlikely Loading	Category IV: Extremely Unlikely Loading	Test Loading
HVPS Component (all components listed in Table 12.1)	non-SIC	Normal	Upset	Emergency	Faulted	Normal / test

The selected C&S given in section 6 define the service level or service criteria (allowable value) to satisfy the damage limits. Table 11.3 shows the correlation between damage limits and the service levels defined in EN 1992-4:2008 for Cabinet Anchorages.

Table 11.3 Correlation between damage limits and EN 1992-4:2008 Service Levels

Damage Limit	EN Service Level
Normal	Reversible Serviceability Limit State
Upset	Reversible Serviceability Limit State
Emergency	Irreversible Serviceability
Faulted	Ultimate
Test	Reversible Serviceability Limit State

12 System Description

12.1 Design status and geometry

The HVPS and its components:

- have passed with success the Delivery Readiness Review stage for the ones designed by the EU-DA and the JA-DA.
- are being developed for the Final Design Review stage for the ones designed by the IN-DA.

As PA Annex B [2], [3] and [4] have been already been signed, three DAs should take into account the versions of the reference documents listed in PA Annex B [2], [3] and [4]. This document reflects the current versions of the reference documents in chapter 4 available in IO IDM.

The description of the system design is reflected in section 12.2.

Since its Conception design review, a series of PCRs have been proposed and implemented to the HVPS design of the EU-DA:

- PCR-001091 Regrouping of PBS51 and PBS52 switchgear procurement [13];
- PCR-001151 Modifications of B15 South Dummy Load shelter (15-AN-03) from DA Deviation request [14];
- PCR-001134 B15 and Annexes implementation of integrated sequence of activities and IO early Accesses [15];
- PCR-680 Layout requirement for Building 15 [16];
- PCR-508 EC MHVPS rating increase [17];
- PCR-422 EC PS technical specifications [18];
- PCR-264 Simplification of the EC system procurement allocation [19].

PCRs have been proposed and implemented to the HVPS design of the IN-DA:

- PCR-001091 is dedicated to the Regrouping of PBS51 and PBS52 switchgear procurement [13];
- PCR-680 Layout requirement for Building 15 [16];
- PCR-636 - Cost Savings proposal for EC Power Supply Procurement [20]
- PCR-562 - Revision of the IN-DA PS Procurement scope [21]
- PCR-508 EC MHVPS rating increase [17];
- PCR-422 EC PS technical specifications [18];
- PCR-264 Simplification of the EC system procurement allocation [19];
- Change Notice based on "PCR-562 - Revision of the IN-DA PS Procurement scope" for "EC HVPS PA 52.P4.IN.01 Annex B (9C3H4F v1.3)": review and approval [54].

PCRs for the HVPS design of the JA-DA:

- PCR-679 - Procurement of APS and BPS for JA gyrotron [22].

Additionally, several deviation requests were raised during the design phase and implemented to the HVPS design of the EU-DA:

- 5.2.P4.EU.01 Deviation Request - Specific Applicability of the General Management Specification - F4E DACC Process #157177 [23]
- 5.2.P4.EU.01 Deviation Request 01 - Clarifications on REQs [24]
- 5.2.P4.EU.01 Deviation Request 02 - Adaptation of the PA delivery schedule to the new date for RFE of the ITER Building #15 [25]
- 5.2.P4.EU.01 Deviation Request 03 - Optic fiber transmission of analogue signals [26]
- 5.2.P4.EU.01 Deviation Request 04 - Deviation Request for the modification of the gyrotron characteristics curve [27]
- 5.2.P4.EU.01 Deviation Request 05 - Deviation Request for the removal of the procurement and installation of cable trays from scope [28]
- 5.2.P4.EU.01 Deviation Request 06 - Deviation Request for the short pulse dummy load resistance and temperature monitoring system [29]
- 5.2.P4.EU.01 Deviation Request 07 - Short Circuit Current Value [30]
- 5.2.P4.EU.01 Deviation Request 07 - Short Circuit Current Value - impact report [31]
- 5.2.P4.EU.01 Deviation Request 08 - Deviation Request from Supplier - Factory Tests LPDL configuration [32]
- 5.2.P4.EU.01 Deviation Request 09 - New Seismic Requirements [33]

- 5.2.P4.EU.01 Deviation Request 09- New Seismic Requirements - impact report [34]
- 5.2.P4.EU.01 Deviation Request 10 - Specification of a new PLC series model [35]
- 5.2.P4.EU.01 Deviation Request 11 - Summary of DR 01-10 [36]
- 5.2.P4.EU.01 Deviation Request 12 - Design Solution of the Long Pulse Dummy Load (LPDL) in the 15-AN-03 (Shelter) building [37]
- 5.2.P4.EU.01 Deviation Request 13- F4E DACC Process #126159 - PA monthly reports [38]
- PA 5.2.EU.P4.01 - summary of deviations issued during Design Phase [39]

A deviation request to the HVPS design of the JA-DA:

- Deviation Request - Gyrotron HV cable insulating material [40].

12.2 System Design Description

The Electron Cyclotron Heating and Current Drive system (EC H&CD, or in short, EC) provides radio-frequency (RF) heating and current drive to the ITER plasmas. A total of 20 MW of RF power at the frequency of 170 GHz in plasma will be available from the EC system.

The EC system is composed of High Voltage Power Supplies (HVPS), RF power sources, the transmission lines, the launcher port plugs plus auxiliary sub-systems and services, control systems and test facilities. Main components layout is described in Figure 12-1 below.

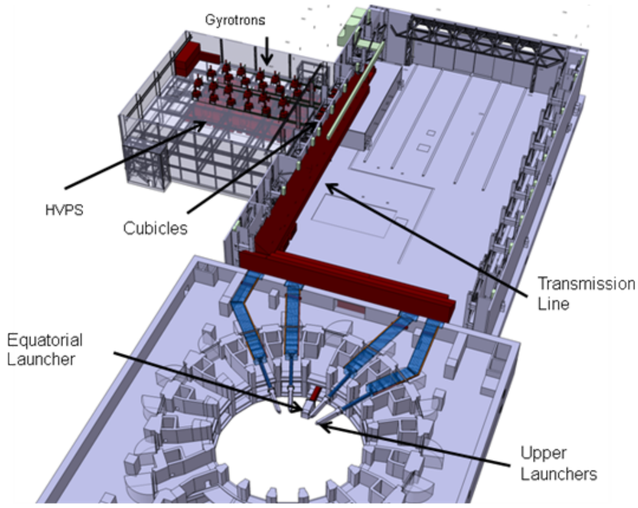


Figure 12-1 EC H&CD system layout; the auxiliaries are not shown

12.2.1 System, Components, Parts

The scope of the EC PS system consists of 12 sets of HVPS, dummy loads and auxiliaries. 8 HVPS sets are designed and will provide voltage and current to the diode type gyrotrons and 4 HVPS sets to the triode type gyrotrons. The full HVPS system shall provide an output power of 48MW required by the EC RF Sources for an output power of 24MW to be installed on the ITER site. The components of the HVPS are listed in Table 12.1 and shown from Figure 12-6 to Figure 12-17. HVPS is located in B15 L1 and L2. The general arrangement drawing of HVPS system in B15 at L1 and L2 is shown in [51]. Representation of the HVPS in Evovia is shown from Figure 12-3 to Figure 12-5.

22 kV Switchgears are fed from PPEN, the EC PS system that requires low voltage power is fed by the LV distribution boards of PBS 52. The HVPS system control equipment is fed by uninterruptible AC power network Class II distribution boards of PBS 52. The equipment that does not require uninterruptible AC power network is fed from Class IV distribution boards of

PBS 52. Overview of the electrical interconnections between HVPS components is shown in Figure 12-2.

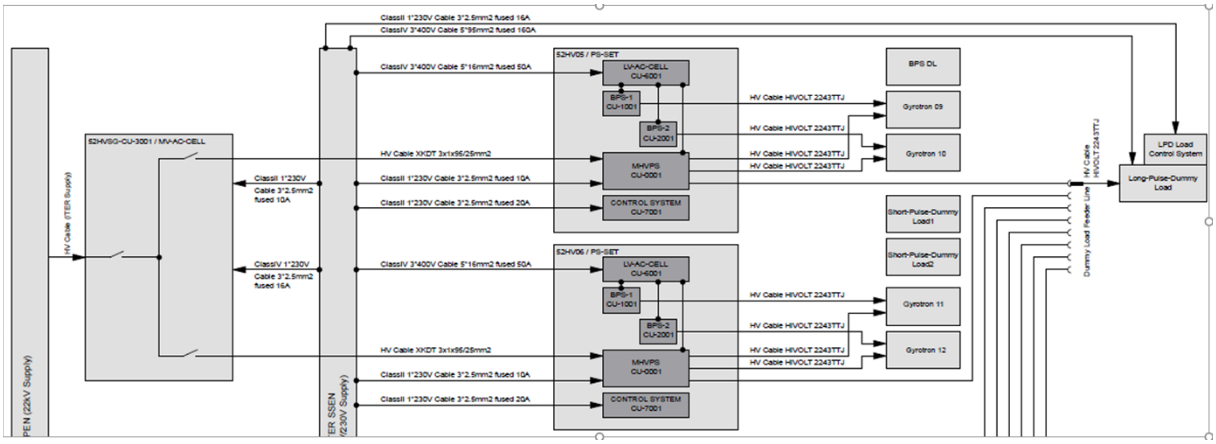


Figure 12-2 - Overview of the interconnections between HVPS components (example for set 05 and set 06 from EU-DA)

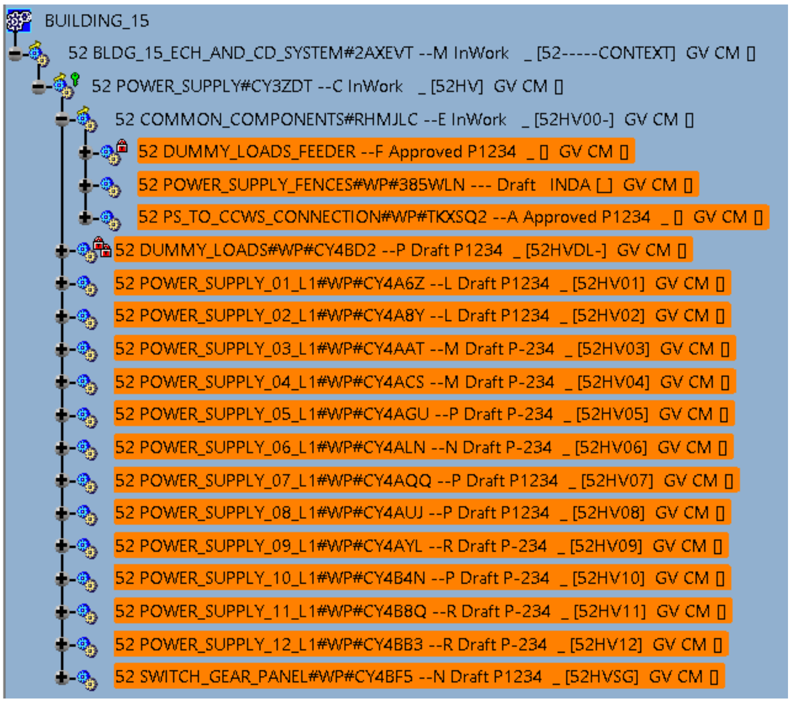


Figure 12-3 –HVPS Location in Enovia tree in L1

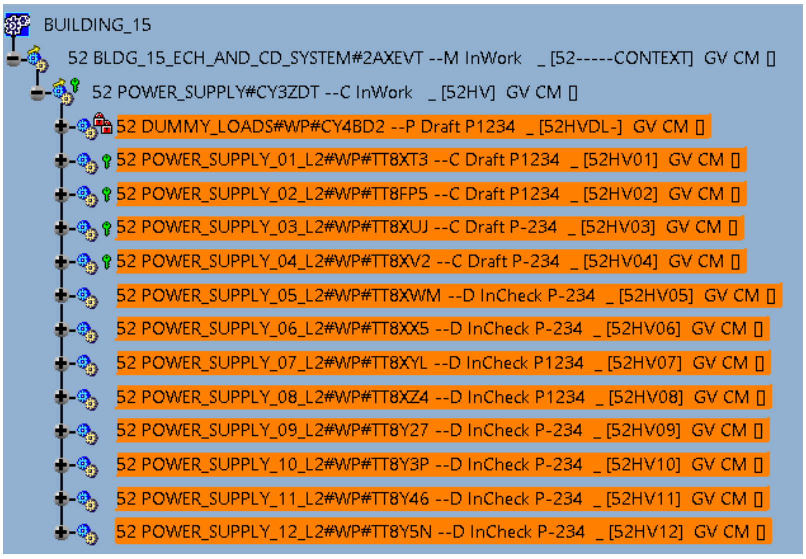


Figure 12-4–HVPS Location in Enovia tree in L2

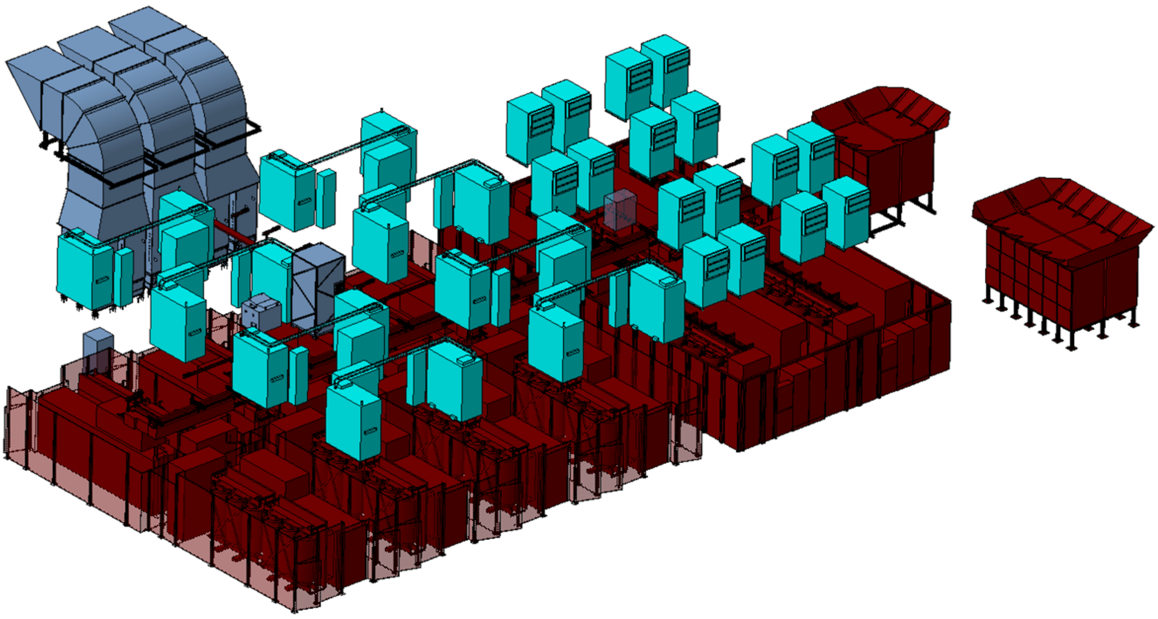


Figure 12-5-Overview of the HVPS in L1 and in L2 in Enovia

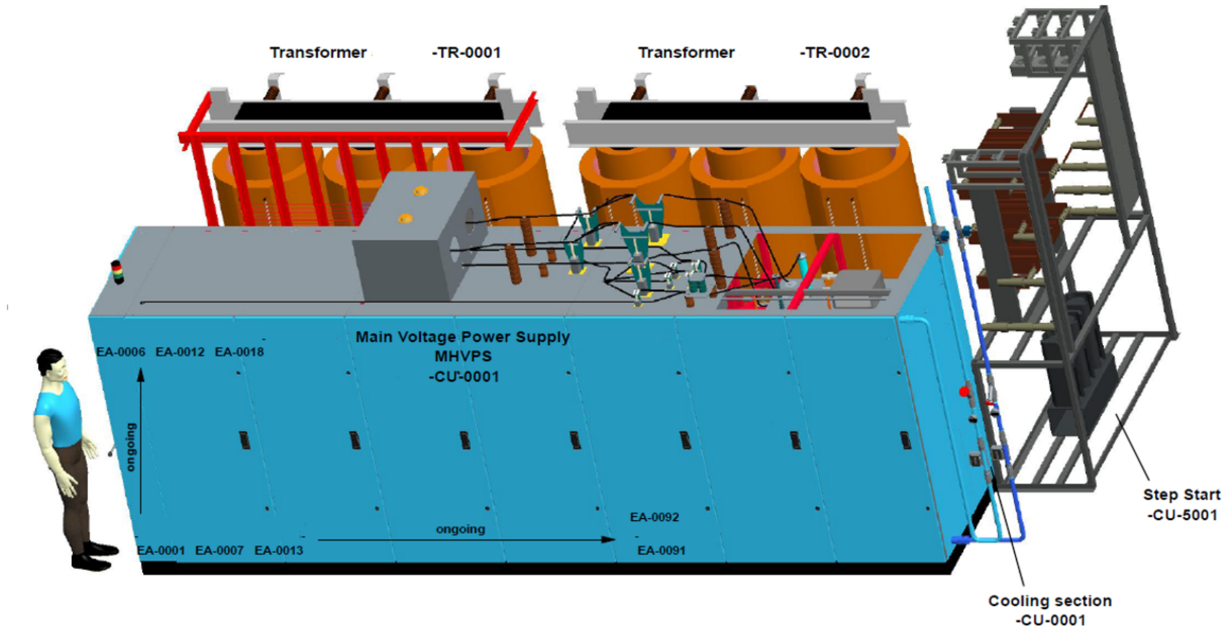


Figure 12-6 HVPS system layout at B15-L1 of EU-DA

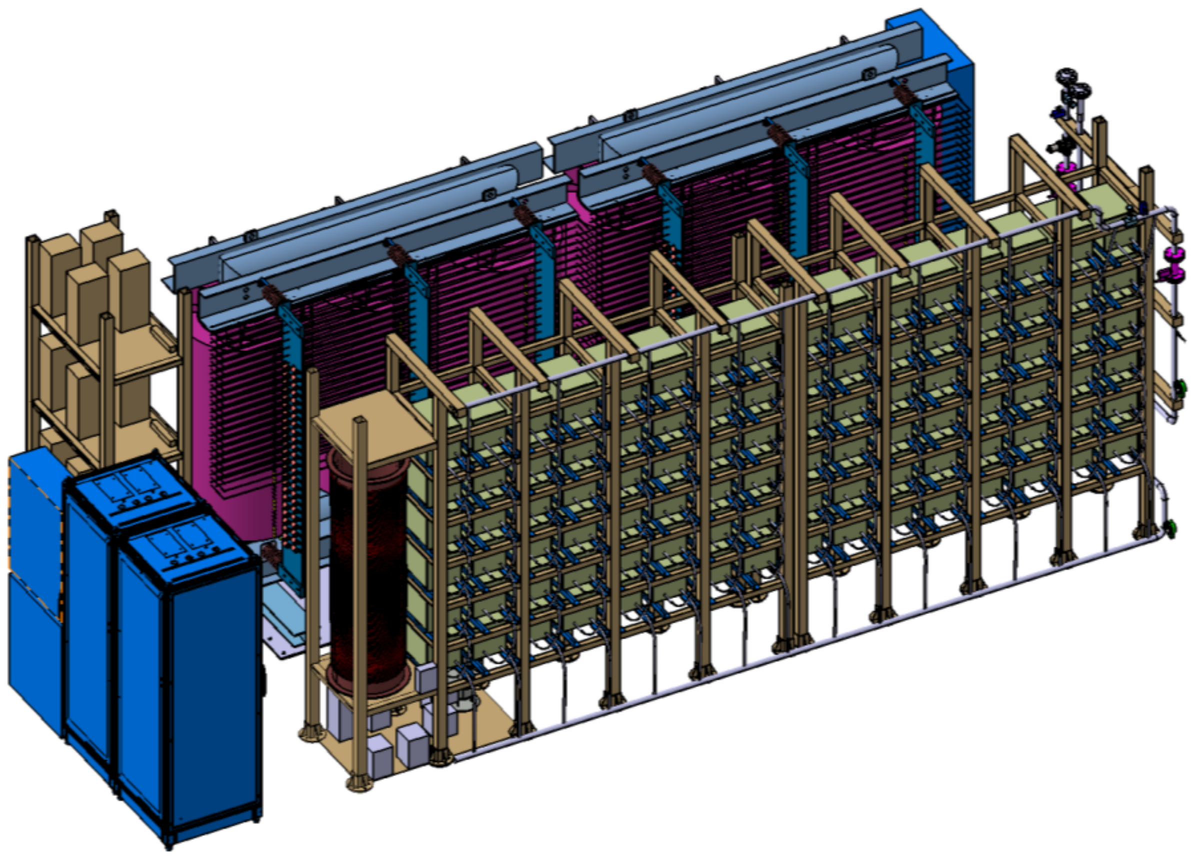


Figure 12-7 HVPS system layout from ENOVIA at B15-L1 of IN-DA

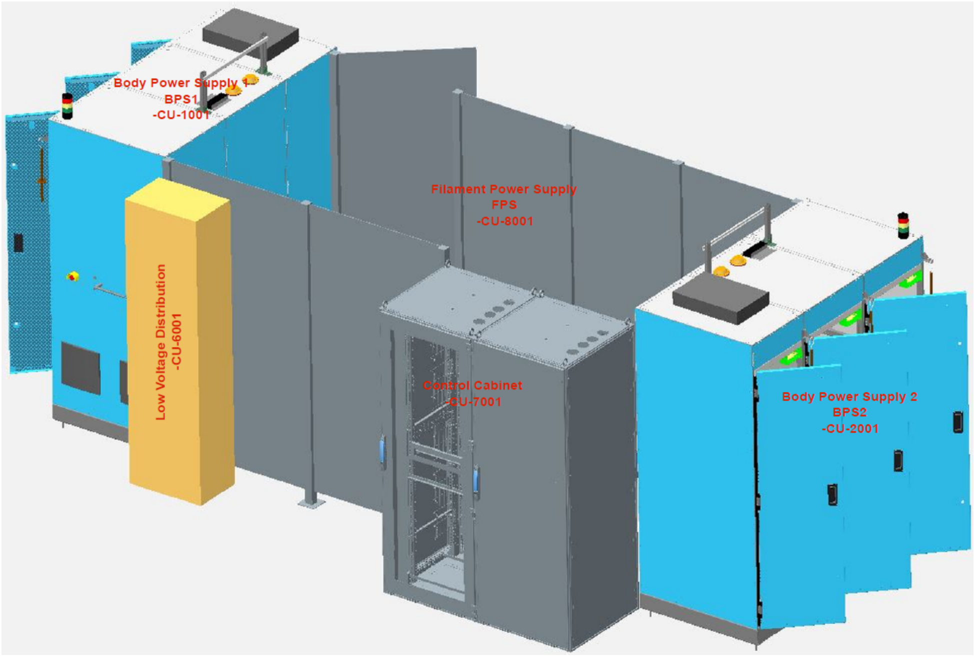


Figure 12-8 HVPS system layout at B15-L2 of EU-DA

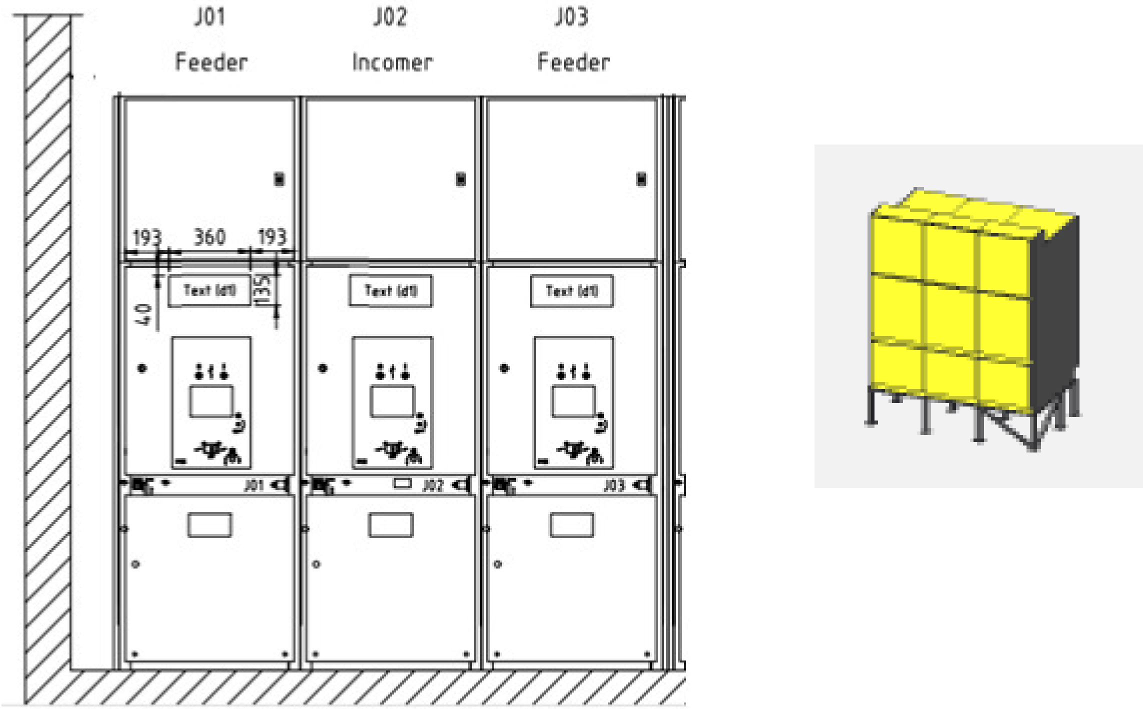


Figure 12-9 24kV switchgears of HVPS system layout at B15-L1

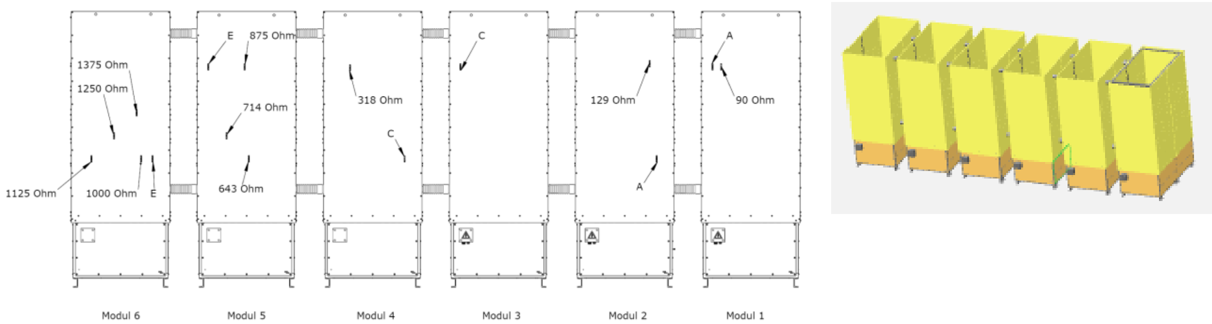


Figure 12-10 LPDL of HVPS system layout at B15-L1

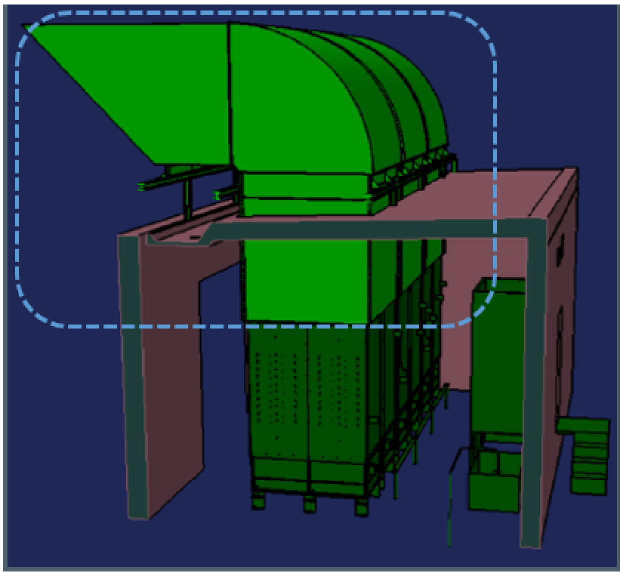


Figure 12-11 Air ducts of LPDL at B15-AN-03 (highlighted in blue)

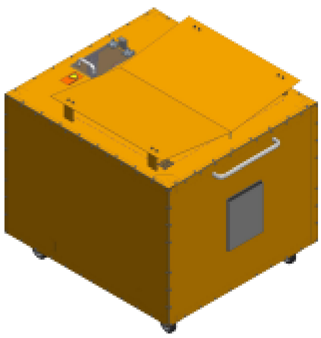
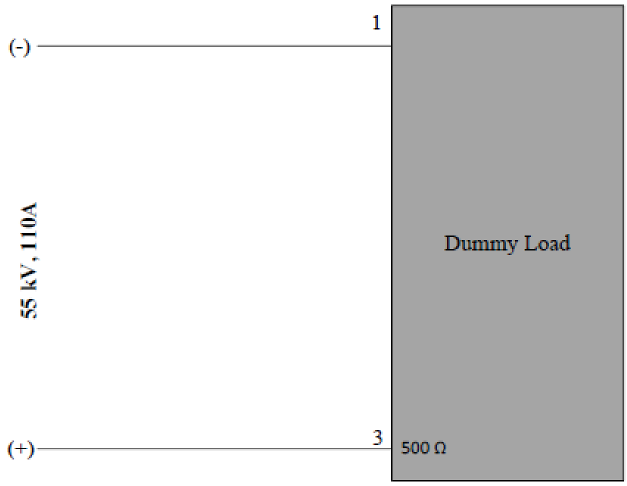


Figure 12-12 SPDL of HVPS system layout at B15-L2



DL = 500 Ω

Figure 12-13 SPDL of HVPS system layout at B15-L1

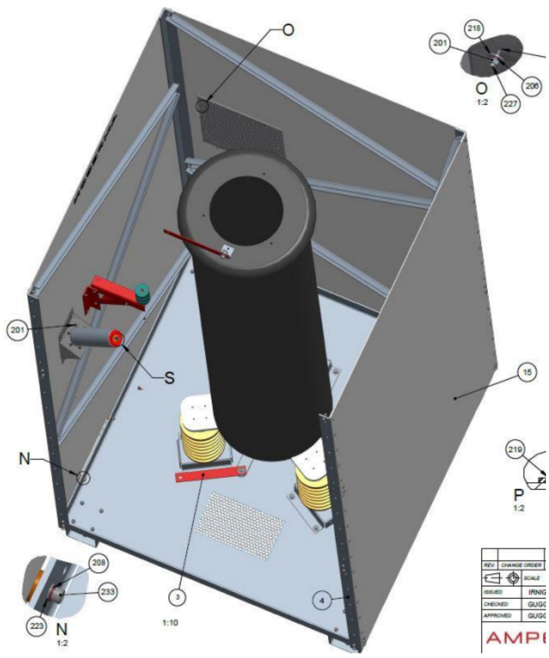


Figure 12-14 BPS DL of HVPS system layout at B15-L2

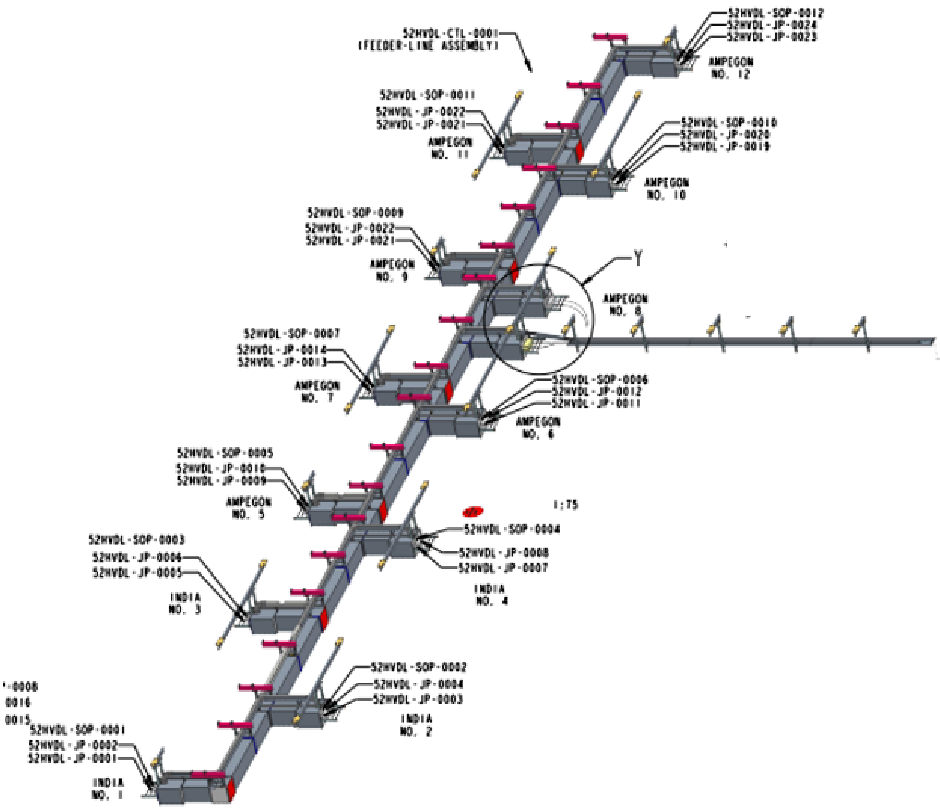


Figure 12-15 Feeder line of HVPS system layout at B15-L1

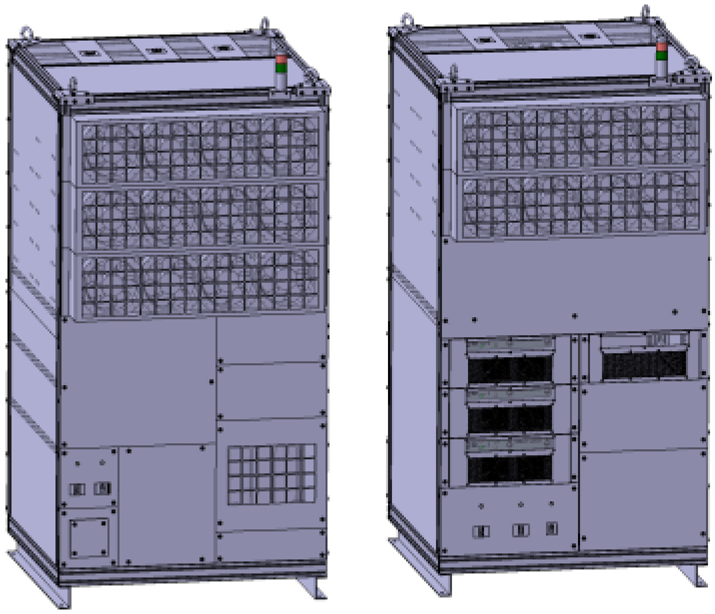


Figure 12-16 APS switch and APS/BPS cubicle of HVPS system layout at B15-L2 of JA-DA

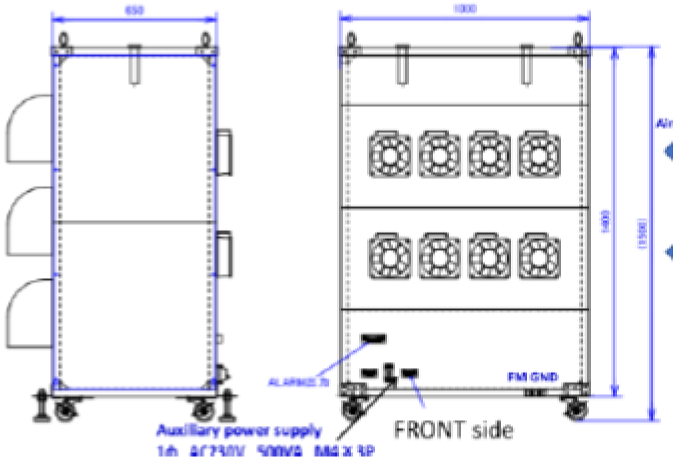


Figure 12-17 APS/BPS DL cubicle of HVPS system layout at B15-L2 of JA-DA

Table 12.1 HVPS components

HVPS components	EUDA HVPS Sources	JADA HVPS Sources	INDA HVPS Sources
MV switchgear	x	-	-
MHVPS cubicle (with the AC/DC power modules)	x	-	-
HV racks (with the AC/DC power modules)	-	-	x
Step Start cubicle	x	-	x
Power Transformers	x	-	x
BPS cubicle (with the AC/DC power modules)	x	-	-
LV-AC cubicle	x	-	-
Control cubicle	x	-	-
LPDL cubicle with the air ducts	x	-	-
SPDL cubicle	x	-	x
BPS DL cubicle	x	-	-
Feeder line	x	-	-
Anode switch cubicle	-	x	-
APS/BPS cubicle	-	x	-
APS/BPS dummy load	-	x	-

12.2.2 The materials of HVPS system

The HVPS components are manufactured from the materials listed in Table 12.2, Table 12.3, Table 12.4.

Table 12.2 The materials used in HVPS components of EU-DA

Component	Location	Material
24 kV EC switchgears	15-L1-03	Mild steel sheet
LPDL, The air duct structure for the LPDL (as per PCR [14])	15-AN-03	Stainless steel AISI 304, Mica
MHVPS cubicle	15-L1-01	Galvanized steel DX51D, Galvanized steel DD11, Stainless steel AISI 304L, Stainless steel AISI 316L, Aluminium AlSi1MgMn, Aluminium AlMg1,

		GPO-3
Step start	15-L2-01	Steel S235JR hot-dip galvanized
Transformer	15-L1-01	Copper (ETP), Epoxy, Silicon Steel
LV cubicle	15-L2-01	Galvanized steel
BPS cubicle	15-L2-01	Galvanized steel DX51D, Galvanized steel DD11, Stainless steel AISI 304L, Stainless steel AISI 316L, Aluminium AlSi1MgMn, Aluminium AlMg1, GPO-3
Control cubicle	15-L2-01	Galvanized steel
SPDL	15-L2-01	Galvanized steel DX51D
BPS DL	15-L2-01	Aluminium AlMg1
Feeder line	15-L1-01	Aluminium AlMg1, Steel S235JR hot-dip galvanized

Table 12.3 The materials used in HVPS components of IN-DA

Component	Location	Materials
Transformer	15-L1-01	Copper (ETP), Epoxy, Silicon Steel (CRGO)
HV Rack-1 & 2	15-L1-01	FRP, Steel, Plastic, Epoxy
Equipment Control Cubicle	15-L1-01	Steel, Aluminum (6061), Plastic, Copper (ETP), Epoxy, EPR/EPDM
LV distribution board and Field monitoring cabinet	15-L1-01	Steel, Aluminum (6061), Plastic, Copper (ETP), Epoxy, EPR/EPDM
Local Control Unit	15-L1-01	Steel, Aluminum (6061), Plastic, Copper (ETP), Epoxy, EPR/EPDM
SPDL	15-L1-01	Steel, Aluminum (6061), Plastic, Copper (ETP), Epoxy, EPR/EPDM, Ceramic/Mica
Key Interlock & exchange cubicle	15-L1-01	Steel, Aluminum (6061), Plastic, Copper (ETP), Epoxy, EPR/EPDM
LV & MV Cable	15-L1-01	Copper (ETP), EPR/EPDM
Soft Charging Device	15-L1-01	Copper, Chromium Nickle Alloy, Porcelain, Epoxy, Galvanized Steel

Table 12.4 The materials used in HVPS components of JA-DA

Component	Location	Materials
Anode switch cubicle	15-L2-01	Aluminum, Steel, Epoxy resin, Phenolic resin, SUS plate
APS/BPS cubicle	15-L2-01	Aluminum, Steel, Epoxy resin, Phenolic resin, SUS plate
APS/BPS DL cubicle	15-L2-01	Aluminum, Stainless Steel, Epoxy resin, Phenolic resin

12.2.3 Fabrication, assembly in factory, testing and transportation

The HVPS components have to be delivered to the ITER site after being properly manufactured/ assembled and tested. During manufacturing, assembly, testing and transport the components will suffer loads due to their handling. The ground floor shall be checked for maximum load capacity before installation. Weights of individual components can be found with the shipping documentation or document describe the individual equipment weight.

12.2.4 Function / Normal Operation

The time diagram of a generic microwave power pulse (see Figure 12-18) corresponds to the envisioned application of the EC power for various HC applications. The ability to modulate or vary the HCD power depends strongly on the functional capabilities of the PS. For example the ability to modulate the EC power at 5kHz can only be achieved if the power supplies can vary the applied voltages to the gyrotrons at such frequencies. The Figure 12-18 illustrates a typical trace that sums the various EC power applications, which the PS requirements are based upon. The different phases of the sequence in Figure 12-18 are described in Table 12.5.

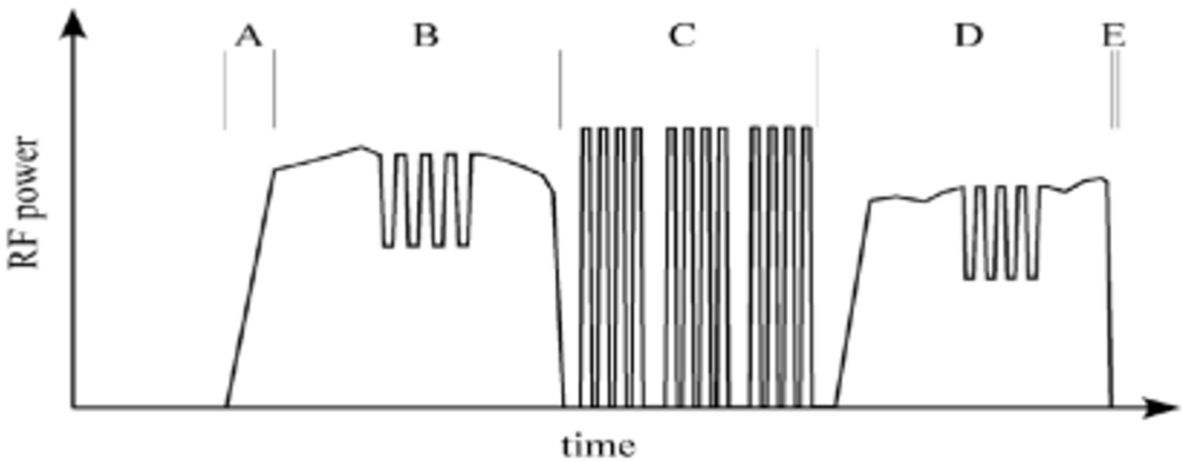


Figure 12-18 Example of an ITER scenario with a sequence of operating phases for the EC system. RF power denotes total power injected into the plasma [2], [3]

Table 12.5 Sequence phases of the labels are referred to Figure 12-18

Phase	Label	RF Power	Voltage	Typical Variations
Start-up	**A**	Ramp-up of RF power	V_k and V_b ramped-up to nominal values	Ramp-up time ≈1 ms

Phase	Label	RF Power	Voltage	Typical Variations
Central Heating and Current Drive	**B, D**	Power constant or slowly varied	V_{kb} constant or slowly varied	Slow modulation: < 100 Hz
Instabilities Stabilization	**C**	Variations to stabilize MHD instabilities	V_{kb} modulation for RF power modulation	Fast variations: ≤ 5 kHz partly, so as to achieve RF power modulation from 100% to ≤50%. < 1 kHz ON/OFF
Shut-down or fast (arc) shut-down	**E**	Ramp-down of power	Voltages reversed with respect to the start-up	Similar to start-up, but < 10 μs in case of arc

A detailed description are given in [2], [3], [4]. However information in reproduce here to provide quick reference to the operation requirement.

12.2.5 Interfaces

A database summarizing all the relevant ICD(s) / IS(s) with their status is available in EC database for interface management.

Intra-system interfaces, that are the interfaces between subsystems within PBS52, are also identified and available in database for interface management in IO\OBS group folder. Key interfaces involving mechanical and / or thermal loads are listed in Table 12.6.

Table 12.6 Subset of the HVPS interfaces with other PBS(s) in terms of the loading conditions

Interface	Description	ICD (IS)
PBS26.CC Cooling Water System CCWS-2A	• Water pressure and thermal stress due to temperature difference in normal operation • Mechanical loads at the interfaced point (seismic and thermal load)	[45] ([43]) [50]
PBS63.15 RF Heating Building	• Mechanical loads (e.g. seismic, weight, dimensions) • Heat loads/ventilation conditions	[46] ([47])

13 States of system and components

The load requirements associated to the HVPS components are specified in the following sections with reference to the various phases of the EC system and its associated components.

The main phases are:

- Fabrication. During this phase, there is the dead weight 14.1.1.
- Assembly. During this phase, there is the dead weight 14.1.1.
- Testing. During this phase, there is the dead weight 14.1.1 and test load during the test at supplier site 14.1.3.
- Transportation. During this phase, there is the dead weight 14.1.1.

- Installation. During this phase, there is the dead weight 14.1.1 and assembly and pretension load 14.1.2.
- Commissioning onsite. During this phase, there is the dead weight 14.1.1, test load during the commissioning 14.1.3 and thermal load during voltage and energization tests 14.2.
- Plasma operation. During this phase, there is the dead weight 14.1.1, coolant pressure load 14.1.4, seismic load 14.1.5 and all loads listed in Sections 14.1.6-14.4.
- Maintenance. During this phase, there will be all loads listed in Section 14.
- Decommissioning phase is not considered as the main phase of HVPS sub-system since HVPS sub-system will not be treated as nuclear waste that requires to be dismantled according to classification Table 5.1. During this phase, the potential load can be dead weight 14.1.1.

13.1 Fabrication, transportation assembly and testing

During manufacturing, assembly, testing and transport the components will suffer dead loads 14.1.1 due to their handling. Additionally the components suffer test load during the FAT described in section 14.1.3.

13.2 Installation and Commissioning

The HVPS are transported from the storage building to B15 installation level using either lifting trucks and cranes, forklift or heavy duty roller gear, for the level 2 and 3 equipment shall be transported using hatch provided in building. Dimension of the hatch and lifting capacity of the building crane shall be considered for transport restriction. The installation is done by aligning, fixation and anchoring the HVPS to the building floor. Aligning, fixation and bolting of the feeder line to the support structures under the ceiling at L1.

The HVPS commissioning tests planned before the FP for those HV equipment required for FP and for the rest of the installed equipment before PFPO-1. Prior to performing the integrated commissioning tests of the HVPS with gyrotrons, commissioning of the individual components of HVPS and commissioning with DL shall be performed.

At the end of the commissioning the following shall be demonstrated:

- Mechanical and visual parameters are verified and satisfied;
- All technical requirements and parameters are verified and satisfied;
- Cooling water is working at the design ranges;
- Sensors are functional and working at the design ranges.

All commissioning tests shall be performed in accordance with the approved site commissioning procedures.

13.3 Plasma pulses

During the heating phase MHVPS, BPS, APS/BPS provide ON/OFF modulation of the output voltage up to a frequency 5kHz with duty cycle 25% and pulse length 3600sec.

In case of a severe fault, as an arc in the gyrotron or in the transmission line, the PS shall be able to switch-off the output voltage with the total charge delivered to the arc less than 10J, shutdown time less than 10µs and transient duration less than 20µs. After the severe fault event, the PS shall recover the output voltage with respect to the pause time at least 200ms.

The HVPS system is energized during the start-up, the pulse modulation, the shut-down stages.

Heat evacuation from DC low-voltage modules incorporated into the MHVPS cabinets is maintained by active water cooling supplied by CCWS-2A and partial losses will be dissipated in the air. Heat of the rest of HVPS equipment is dissipated in the building air. Cooling water system shall evacuate heat from the MHVPS DC low-voltage modules during the tests and operation of HVPS sets. The sensors of MHVPS collect the temperature measures, flow states, provided safe status/ trip for power supply output and send them to the Local Controller that shall send the processed information to the EC Plant Interlock and Control System and to the PS local interlock system.

The general ambient conditions in the B15 are the loads that apply during plasma operation, they are defined in Table 13.1 [48].

Table 13.1 Design Ambient conditions

Parameters	Value
Ambient temperature range	+ 18 to + 30°C on level 3 + 20 to + 25°C on level 3 in EC I&C zone + 10 to + 35°C on levels 1 and 2
Humidity	< 85% RH

13.4 Maintenance

There is no load requirement for the maintenance phase of the HVPS. During the maintenance period, in-service inspection of the HVPS components as required is performed. The manufacturers of HVPS provide the maintenance plan and list for HVPS components where the recommended check frequency shall be specified and all maintenance checks have to be respected during the ITER lifecycle.

14 Single Load cases

14.1 Mechanical loads

14.1.1 Dead Weight (DW)

The maximum weight of main components for all HVPS is defined in the following tables according to [10], depending on the DA in charge of the procurement. Approved version of [10] while preparation of present document shall be basis for the dead weight of the equipment.

Table 14.1 Components and associated masses for the EU-DA HVPS Procurement

Component	Location	#	Mass/component [kg]
24 kV EC switchgears	15-L1-03	6	2250[1]
LPDL	15-AN-03	6	900
Air duct parts of LPDL [14]	15-AN-03	1	3700
Power Supply set 05	15-L1-01	1	33750
Power Supply set 05	15-L2-01	1	5000
Power Supply set 06	15-L1-01	1	33750
Power Supply set 06	15-L2-01	1	5000

[1] Weight for Transportation is 2900kg /1 set

Power Supply set 07	15-L1-01	1	33750
Power Supply set 07	15-L2-01	1	5000
Power Supply set 08	15-L1-01	1	33750
Power Supply set 08	15-L2-01	1	5000
Power Supply set 09	15-L1-01	1	33750
Power Supply set 09	15-L2-01	1	5000
Power Supply set 10	15-L1-01	1	33750
Power Supply set 10	15-L2-01	1	5000
Power Supply set 11	15-L1-01	1	33750
Power Supply set 11	15-L2-01	1	5000
Power Supply set 12	15-L1-01	1	33750
Power Supply set 12	15-L2-01	1	5000

The following EU-DA equipment in Table 14.2 does not exist in the interface sheet [10], however this equipment is needed for functional demonstration of the power supply and participates in building 15 load.

Table 14.2 Exact weight for HVPS procured by EU-DA

Component	Location	#	Mass/component [kg]
SPDL	15-L2-01	2	250
BPS DL	15-L2-01	1	580
Feeder line	15-L1-01	1	2566
The air duct structure for the LPDL (as per PCR [14])	15-AN-03	1	3700

Table 14.3 Components and associated masses for the IN-DA HVPS Procurement

Component	Location	#	Mass/component [kg]
Power Supply set 01	15-L1-01	1	46050
Power Supply set 02	15-L1-01	1	46050
Power Supply set 03	15-L1-01	1	46050
Power Supply set 04	15-L1-01	1	46050
SPDL	15-L1-01	1	250 (preliminary)

Table 14.4 Components and associated masses for the JA-DA HVPS Procurement

Component	Location	#	Mass/component [kg]
Anode switch cubicle set 01	15-L2-01	2	1000
Anode switch cubicle set 02	15-L2-01	2	1000
Anode switch cubicle set 03	15-L2-01	2	1000
Anode switch cubicle set 04	15-L2-01	2	1000

APS/BPS cubicle set 01	15-L2-01	2	3400
APS/BPS cubicle set 02	15-L2-01	2	3400
APS/BPS cubicle set 03	15-L2-01	2	3400
APS/BPS cubicle set 04	15-L2-01	2	3400
APS/BPS DL cubicle	15-L2-01	1	130

14.1.2 Assembly and Pretension Loads (APL)

A forklift, a pallet truck, a crane, a lifting mobile platform could be used for positioning of the HVPS equipment at L1 and L2.

Loads experienced during assembly and installation are enveloped by the Normal Operation loading condition according to the HVPS classification in Table 5.1 and the installation procedure of the EU-DA [41], JA-DA HVPS [42], therefore, they do not need to be considered as an independent load case and can be considered as a part of dead weight 14.1.1.

Installation sequence, instruction, mounting and fixing of the EU-DA HVPS is described in the installation instruction [41], of the JA-DA HVPS in [42]. The instructions for IN-DA HVPS will be provided later.

All assembly activities at the ITER site including tightness of bolts shall be done at ambient conditions specified in Table 13.1.

14.1.3 Tests loads (TL)

Testing at Suppliers – The test required on integrated unit at suppliers (laboratories and industries) are mentioned in [2], [3] and [4].
The MHVPS cabinets are cooled via connections to cooling water piping systems that circulate the demineralized water through the DC power modules and other equipment's as needed.
Water leakage test involving loads will be performed during FAT of HVPS at the manufacturer's side under the test pressure of 1.0 MPa [49].
There will not be additional pressure or other tests involving loads during FAT.

Commissioning at ITER - For HVPS components, there will not be additional pressure or other tests involving loads at the ITER reception. The water leakage test and flow rate test of the HVPS pipelines during the commissioning at ITER shall be performed individually and isolated from the CCWS-2A pipeline, the CCWS-2A valves shall be closed.
The MHVPS cabinets are cooled via connections to cooling water piping systems that circulate the demineralized water through the DC power modules and other equipment's as needed. The design pressure values are provided in the applicable interface sheet (see §12.2.5).
Water leakage test will be performed during commissioning of HVPS and test characteristics must be respected:

- test pressure during the HVPS commissioning including the pressure reducer at the internal MHVPS cabinet piping will be performed at 1.2 MPa [49]. However, the selection of the test pressure internal in MHVPS is under the choice of the supplier.
- minimum and maximum acceptable test temperature between 25˚C (or defined by the dew point) and 47˚C [43];
- the pressure reducer has to be installed at the interface point between HVPS pipelines and CCWS-2A pipelines.

14.1.4 Coolant Pressure (Po)

The operating and design coolant pressures (CCWS) are similar in the different states of the system.
The pressure loads described in this section have no significant dynamic amplification associated to them. It is therefore not required to consider dynamic effects due to these loads.
The interface pressure from CCWS-2A to PBS52 is limited to less than 1.0 MPa [43]. The test pressure during the commissioning is reflected in section 14.1.3.

Cooling conditions input - The HVPS cooling water systems shall operate under the following (input) thermal parameters of the CCWS-2A inflow (flow, input temperature, input pressure):

Table 14.5 Thermo-hydraulic input parameters of CCWS-2A [43]

Parameter	Value
Nominal flow rate	1.25 kg/s
Inlet max temperature	31°C
Nominal inlet pressure	0.69 MPa

Cooling conditions output - The HVPS cooling water systems shall assure the respect of the following limits for the output flow (output temperature and output pressure) at the CCWS-2A.

Table 14.6 Thermo-hydraulic output parameters of CCWS-2A [43]

Parameter	Value
Max outlet temperature	47°C
Pressure drop within the client system	0.4 MPa

14.1.5 Seismic Loads

An earthquake consists of an oscillatory movement of the earth's surface. The ground acceleration can be both in the horizontal and in the vertical direction and typically has a spectral content which leads to some level of support reaction load amplification.

A seismic event is, in many cases, the most demanding loading condition, in particular for the support and interface structures (e.g. supports) which must be sized for high strength, and often also for high stiffness.

Seismic load excitation corresponds to the specific selected site for the ITER construction (Cadarache). For buildings and equipment that are classified in seismic class NSC, two levels of ground motion is considered:

- SL-1 corresponds to an event with a probability of the order of 10^{-2} per year and represents an investment protection earthquake level (following the Nuclear Pressure Equipment regulation it corresponds to a foreseeable event). The facility has to be designed to restart and operate after an SL-1 event without special maintenance or test,
- Eurocode 8 - Conception et dimensionnement des structures pour leur résistance aux séismes (EC8) [44].

However as per the deviation request for EU-DA HVPS [33], [34], EU-DA HVPS shall demonstrate that it does not jeopardize B15 structural stability in case of SL-2 event as B15 is SC2 classified.

Unless a detail dynamic analysis is performed and the number of cycles per event is directly calculated, it is recommended to assume for seismic event SL-1 10 equivalent maximum stress cycles whenever a fatigue or a cyclic load analysis is required.

Seismic events - The HVPS shall withstand the loads caused by a seismic event according to the acceptable damage limits of components, to their Safety Class and to the category of the event as defined in section 11.

SL-1 Seismic events - The seismic analysis shall consider SL-1 as a category II event (as a single load event), inclusive of any applicable amplification factor.

EC8 Seismic events - The seismic analysis shall consider EC8 as a category IV event (as a single load event).

SL-2 Seismic events - The seismic analysis shall consider SL-2 as a category IV event (as a single load event).

System and components conditions in seismic analysis – The seismic analysis shall assume the HVPS components in their worst foreseeable conditions, even if related to different operating conditions.

Damping values for elastic seismic analyses - The elastic seismic analysis shall assume the following damping values for the HVPS components in the selection of the FRS given at different damping values; it is recommended to consult [5] for their implementation into the analysis.

Table 14.7 Damping values for seismic analysis

System	Component	SL-1	SL-2
General	Welded steel or bolted steel with friction connection	3%	4%
	Bolted steel with bearing connection	5%	7%
Piping	Piping system	3%	4%
Electrical distribution	Cable tray System - Maximum Cable loading	7%	10%
	Cable tray System - Empty	5%	7%
	Conduit System - Maximum Fill	5%	7%
	Conduit System - Empty	3%	5%
Mechanical and electrical components	Electrical Cabinets, Panels, Motor Control Centers	2%	3%

For analysis convenience damping is generally assumed to be viscous in nature.

The seismic load specification for B15 is described in [11] and additional information is available in [12]. The load path during a seismic event is the same as the load path for gravity. All input data for producing the FRS below are reflected in [11] in sheet “Cover”.

SL-1 FRS for B15 Level 1 floor – For HVPS components located at B15 L1 floor, the applicable FRS is given in [11] and shown in Figure 14-1 at the position of the equipment in B15 z=0.0m.

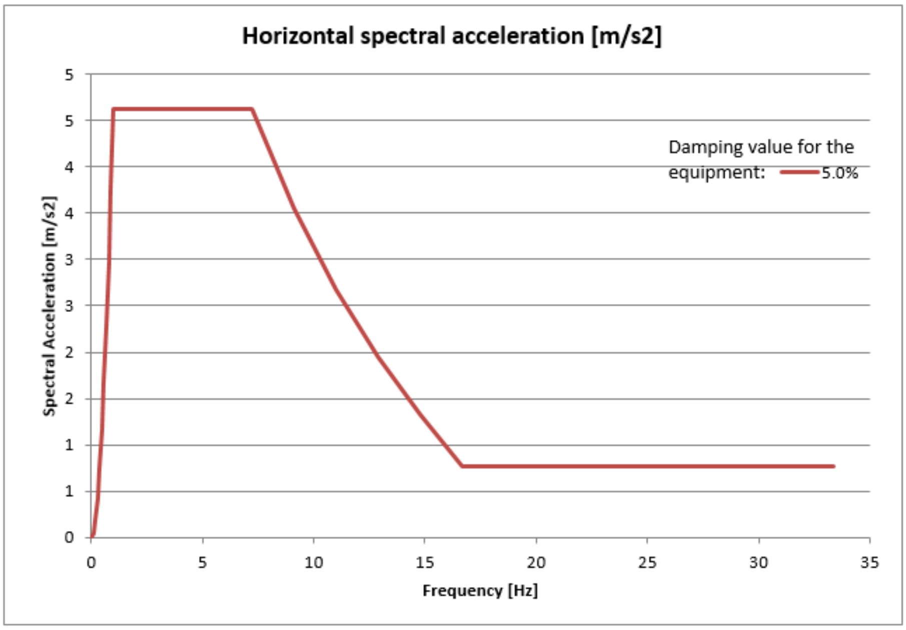


Figure 14-1 SL-1 FRS for B15 Level 1 floor at position of the equipment in B15 z=0.0m

SL-1 FRS for B15 Level 2 floor – For HVPS components located at B15 L2 floor, the applicable FRS is given in [11] and shown in Figure 14-2 at the position of the equipment in B15 z=5.6m.

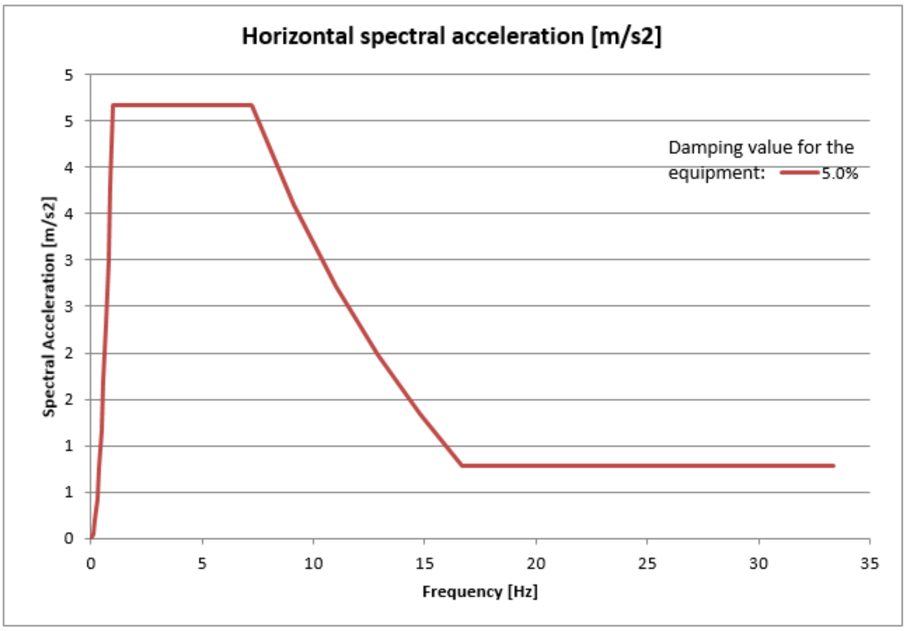


Figure 14-2 SL-1 FRS for B15 Level 2 floor at the position of the equipment in B15 z=5.6m

EC8 FRS for B15 Level 1 floor – For HVPS components located at B15 L1 floor, the applicable FRS is given in [11] and shown in Figure 14-3 at the position of the equipment in B15 z=0.0m.

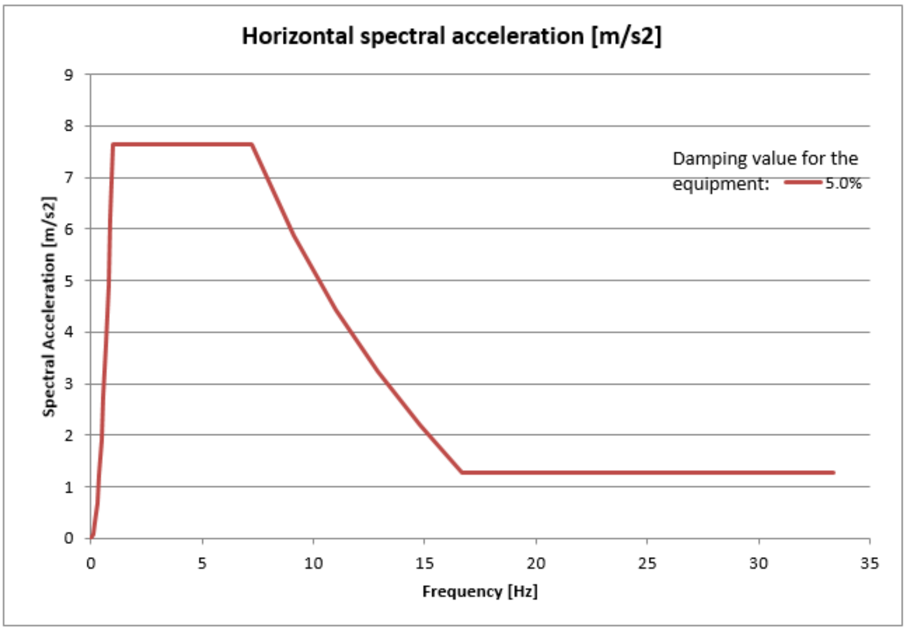


Figure 14-3 EC8 FRS for B15 Level 1 floor at the position of the equipment in B15 z=0.0m

EC8 FRS for B15 Level 2 floor – For HVPS components located at B15 L2 floor, the applicable FRS is given in [11] and shown in Figure 14-4 at the position of the equipment in B15 z=5.6 m.

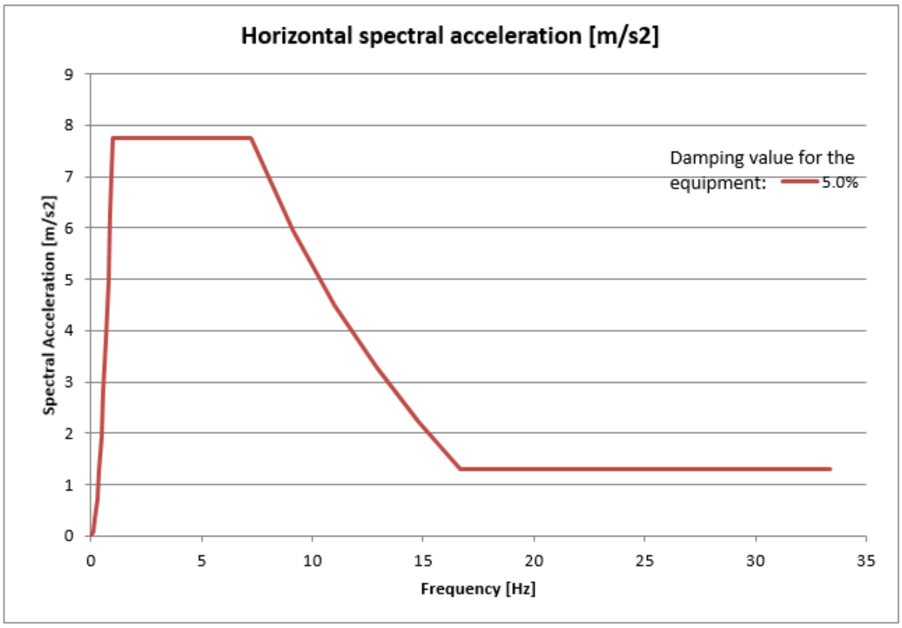


Figure 14-4 EC8 FRS for B15 Level 2 floor at the position of the equipment in B15 z=5.6 m

SL2 FRS for B15 Level 1 floor – For HVPS components located at B15 L1 floor, the applicable FRS is given in [11] and shown in Figure 14-5 at the position of the equipment in B15 z=0.0m.

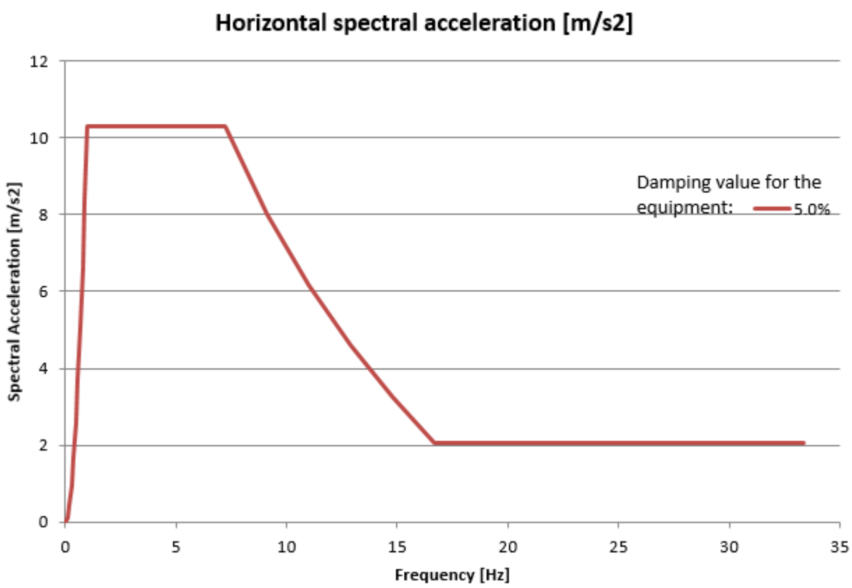


Figure 14-5 SL2 FRS for B15 Level 1 at the position of the equipment in B15 z=0.0m

SL2 FRS for B15 Level 2 floor – For HVPS components located at B15 L2 floor, the applicable FRS is given in [11] and shown in Figure 14-6 at the position of the equipment in B15 z=5.6m.

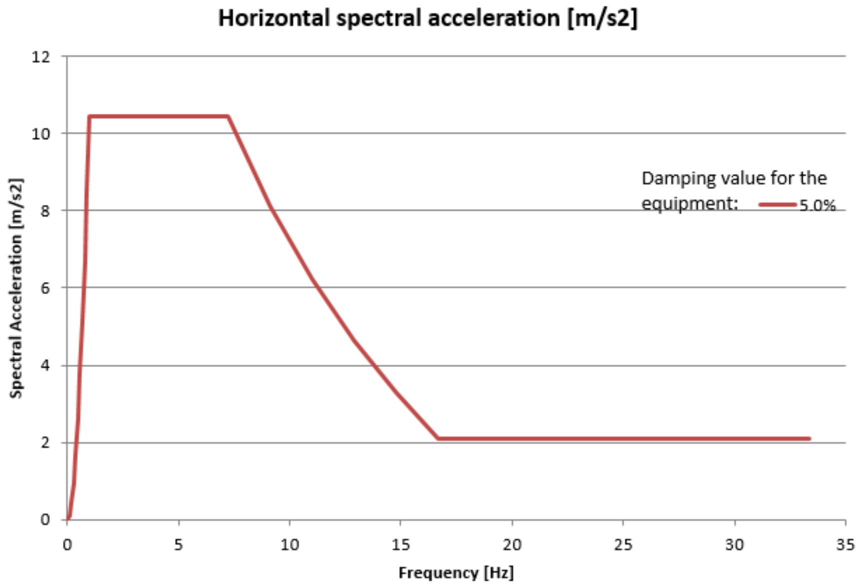


Figure 14-6 SL2 FRS for B15 Level 2 at the position of the equipment in B15 z=5.6 m

14.1.6 Structural Loads due to Component Operation

MHVPS cabinets located in 15-L1-01 are cooled by CCWS-2A during operation. Coolant pressure and the temperature during the operation is described in section 14.1.4. The thermal and seismic loads can cause the pipe displacements at the interface point between PBS52 MHVPS pipes and the related pipes of PBS26. The calculated pipe displacements are summarized in Appendix D of [50].

14.2 Thermal loads (TH)

The thermal loads are independent from the plasma operation as it depends on the operation of the HVPS. The thermal load seen by the HVPS is produced by itself. The thermal loads which are applicable to HVPS are from ambient temperature in Table 13.1.

Table 14.8 HVPS heat load during operation

Component	**Location**	#	**Heat Load** [10] during operation
24 kV EC switchgears	15-L1-03	6	6kW
LPDL	15-AN-03	6	500 kW - heat to be exhaust outside building 15 (not from HVAC)
Air duct parts of LPDL [14]	15-AN-03	1	
Power Supply set 05	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 05	15-L2-01	1	15 kW (BPS)

Component	**Location**	#	**Heat Load** [10] during operation
Power Supply set 06	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 06	15-L2-01	1	15 kW (BPS)
Power Supply set 07	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 07	15-L2-01	1	15 kW (BPS)
Power Supply set 08	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 08	15-L2-01	1	15 kW (BPS)
Power Supply set 09	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 09	15-L2-01	1	15 kW (BPS)
Power Supply set 10	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 10	15-L2-01	1	15 kW (BPS)
Power Supply set 11	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 11	15-L2-01	1	15 kW (BPS)
Power Supply set 12	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 12	15-L2-01	1	15 kW (BPS)
SPDL	15-L2-01	2	4 kW average (is dissipated only during commissioning and maintenance of one HVPS set))
BPS DL	15-L2-01	1	1.75 kW (is dissipated only during commissioning and maintenance of one HVPS set)
Feeder line	15-L1-01	1	1.5W/m (is dissipated only during commissioning and maintenance of one HVPS set)
Power Supply set 01	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables

Component	Location	#	**Heat Load** [10] during operation
Power Supply set 02	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 03	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Power Supply set 04	15-L1-01	1	36kW from Transformer, 26 kW from the HV rack modules and cables
Anode switch cubicle set 01	15-L2-01	2	9.5kW
Anode switch cubicle set 02	15-L2-01	2	9.5kW
Anode switch cubicle set 03	15-L2-01	2	9.5kW
Anode switch cubicle set 04	15-L2-01	2	9.5kW
APS/BPS cubicle set 01	15-L2-01	2	12.75kW
APS/BPS cubicle set 02	15-L2-01	2	12.75kW
APS/BPS cubicle set 03	15-L2-01	2	12.75kW
APS/BPS cubicle set 04	15-L2-01	2	12.75kW
APS/BPS DL cubicle	15-L2-01	1	2 kW (BPS circuit) 0.5kW (APS circuit) (is dissipated only during commissioning and maintenance of one APS/BPS cubicle + Anode switch cubicle set)

14.3 Interfaces Loads

The relevant load characteristic should be defined as per Table 14.9.

Table 14.9 List of interface loads

Interface	Loads description
PBS 26 CCWS-2A [43], [50]	Cooling water pressure, inlet & outlet temperatures (section 14.1.4) (Po). Mechanical connection with CCWS pipes: Thermal (TH) and seismic load. The calculated pipe displacements against thermal and seismic loads at interface points with HVPS are summarized in Appendix D of [50]
PBS 63-15 RF building [48]	Dead weight (DW) (section 14.1.1)

14.4 Not Significant Load Cases

The not significant loads are listed below:

- The HVPS shall not support the loads caused by a fire in B15: they can be damaged in case of fire in B15. HVPS consists of Non-PIC components that are not designed to operate during fire, and is Non-SIC therefore it is not designed or protected against pressure and/or temperature loads induced by a fire event.
- Nuclear loads are not applied to HVPS because it does not generate neutrons and gamma.
- There is no Electromagnetic loads due to plasma scenarios or EM transient that applies to the HVPS because it does not act upon nearly all conductive structures during fast transients.
- During LOCA in B15, there are no particular loads applicable to the HVPS components. The HVPS are switched off.
- Damaged equipment, pipe whipping. Any failure of HVPS component e.g. break of a cooling pipe or an internal electrical device is not able to trigger failure to SIC surrounding components because HVPS is installed in B15 where there are no SIC components.
- During a loss of electrical power (LOOP) HVPS components are switched off, no loads are expected.
- External fire. This load is not applicable, because the civil structure openings shall be designed to be fire resistant.
- Airplane crash. This load is not applicable, because Non-SIC HVPS is located in Non-SIC building 15 and does not perform any safety functions. In case of airplane crash, building 15 and HVPS would be damaged and it shall not prevent performing any safety functions by other relevant systems that are designed for it.
- External flooding. This load is not applicable, because the building openings shall be designed to be withstand this event.
- Lighting. The HVPS components are properly bonded to the civil structures to be protected from lightning [52].
- The load caused by the atmospheric phenomenon e.g. Wind load (W), Snow (S), Rain (R) are not applicable to HVPS being installed inside B15.

15 Load Combinations

All system load combinations must be consistent with [5], which provides a baseline list of combinations to be considered and is based on the probability of conditions considered to present loads to the system. These conditions are considered “probable” if their probability of occurrence is at least 1%, or higher. Those with a probability lower than 1% but still plausible, based on historical experience or other physical bases, are “conceivable”.

15.1 Categorization of Load Combinations

In the absence of more comprehensive probabilistic analysis, conditions are categorized as follows:

- Category I, for a combination of:
  - All Category I conditions when occurring at the same time or "Probable" to be triggered by the initiating condition.
- Category II, for a combination of:
  - The above Category I combinations with other Category I conditions also when they are “Conceivable” to be triggered by the initiating condition.
  - A Category II condition with other Category I and II conditions which are present or “Probable” to be triggered by the initiating condition.
- Category III, for a combination of:

   - The above Category II combinations with other Category I or II conditions also when they are "Conceivable" to be triggered by the initiating condition.
   - A Category III condition with other Category I, II and III conditions which are present or "Probable" to be triggered by the initiating condition.
- Category IV, for a combination of:
   - The above Category III combinations with other Category I, II or III conditions also when they are "Conceivable" to be triggered by the initiating condition.
   - A Category IV condition with other Category I, II, III and IV conditions which are present or "Probable" to be triggered by the initiating condition.

A simpler way to describe these categories is as follows:

Category I: Operational Loading Conditions

Category II: Likely Loading Conditions

Category III: Unlikely Loading Conditions

Category IV: Extremely Unlikely Loading Conditions

The categories are applicable to HVPS that consists of the Non-SIC components listed in 12.2.1 under the scope listed in section 2 .

15.2 Load Combinations

Table 15.1 has been prepared with reference to [5]. The design should take appropriate account of all possible load combinations of significant single events which might arise under foreseeable operating campaign.
Event category IV is considered for HVPS system because of SL-2 and EC8 events that must be taken into account in the design of HVPS system according to [33]. Category III seismic event was not considered in the design of HVPS system according to PAs [2], [3], [4].

Table 15.1 Load combinations

Event category	State	Operating conditions	Initiating event	Incident and Accident event 14.1.6	Number of events	Comment	Correspondence with Load combination in [5] Appendix B
I.1	Plasma operation	DW, Po, TH, APL	-	-	-	-	I.1
I.2	Installation, Maintenance	DW, APL	-	-	-	-	I.1
I.3	Commissioning onsite	DW, TL, TH	-	-	-	-	I.1
II.1	Plasma operation	DW, Po, TH, APL	SL-1	-	5	-	II.10
II.2	Installation, Maintenance	DW, APL	SL-1	-	5	-	II.10
II.3	Commissioning onsite	DW, TL, TH	SL-1	-	5	-	II.10
IV.1	Plasma operation	DW, Po, TH, APL	SL-2	-	1	-	IV.10
IV.2	Installation, Maintenance	DW, APL	SL-2	-	1	-	IV.10
IV.3	Commissioning onsite	DW, TL,TH	SL-2	-	1	-	IV.10
IV.4	Plasma operation	DW, Po, TH, APL	EC8	-	1	-	-
IV.5	Installation, Maintenance	DW, APL	EC8	-	1	-	-
IV.6	Commissioning onsite	DW, TL,TH	EC8	-	1	-	-