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EXTERNAL REFERENCE / VERSION

System Requirements Document-SRD

SRD-41 (Coil Power Supply and Distribution (CPSDS))

This SRD contains all of the functional, design, safety, operational and quality requirements for the Coil Power Supply and Distribution System.

Approval Process			
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Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: External Management Advisory Board, AD: IDM_Controller, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: IT , LG: [CCS] CCS-All for Ext AM, LG: [CCS] ...**		

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Change Log			
SRD-41 (Coil Power Supply and Distribution (CPSDS)) (28B6XQ)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	23 Aug 2007	
v1.1	In Work	05 Sep 2007	
v1.2	In Work	15 Oct 2007	
v1.3	In Work	28 Apr 2008	
v1.4	Signed	01 Oct 2008	
v1.5	Signed	17 Nov 2008	
v1.6	Approved	11 Dec 2008	
v2.0	Signed	17 Nov 2010	Changes brought about by the acceptance of PCR-200 into the baseline.
v2.1	In Work	13 Dec 2010	Revisions in response to reviewers' comments to v2.0, having been updated, due to PCR 187, and compliancy-checked with v4.6 of the PR
v2.2	Approved	15 Dec 2010	Revisions in response to author's comments to v2.1, reviewers' comments to v2.0, and changes due to PCR 187 and compliancy-checking against v4.6 of the PR
v3.0	Approved	24 Jan 2013	Modifications as a result of PCR 442, resulting in a scope change, and some subsequent editorial changes
v4.0	Revision Required	20 Dec 2018	This SRD-41 has been updated in order to implement the approved PCR-738 (the new Staged Approach strategy). this version includes the reconciliation of the SRD with the ITER Technical Baseline, notably the revised PR as recorded in the RPM and the system's DRD.
v4.1	Approved	22 Feb 2019	The document (SRD) was revised with a full consideration on the constructive comments from reviewers, to make the parent requirements more properly propagated and provide clearer guide to the requirement implementation.
v5.0	Approved	01 Oct 2024	To reconcile with PR v6.3/F
v6.0	Approved	04 Dec 2025	Updated in consistency with PCR-001600 (Baseline 2024) and daughter PCR-001656 Updated in consistency with PCR-001560 (HSCC requirements)

Table of Contents

List of Figures

List of Tables

PURPOSE

[41s1002-I] This System Requirements Document (SRD) lists the technical requirements and constraints to be satisfied by Coil Power Supply & Distribution (CPSD) during its whole lifecycle (including interfaces with the other systems of the ITER Facility). This SRD also acts as the parent document for the technical requirements that need to be addressed in lower level design description documents.

[41s1440-R] There are some outstanding topics on in this SRD version, which are under investigation as detailed in the dedicated Reconciliation Report (RR, [ADc59]). The implementation of this SRD into the system's design shall include the agreed resolutions of these issues, as traced in this RR.

Table 0.1: Record of changes induced on this document by PCRs

SRD version	Section / Paragraph identifier	PCR reference
v1.0 to v2.0	Whole document	PCR-200
v2.1 to v2.2	Whole document (due to the editorial changes of the SRD Harmonisation process)	PCR-187
v3.0	Whole document (due to scope change, and then subsequent editorial changes)	PCR-300 PCR-442
V4.0	Whole document (due to scope change, and then subsequent editorial changes)	PCR-738
V4.1	The document (SRD) was revised with a full consideration on the constructive comments from reviewers, to make the parent requirements more properly propagated and provide clearer guide to the requirement implementation.	PCR-738
V4.1/C	To reflect approved CNs (42CD57, 27K6PW, 9R7PCT). The applicable version of Plant Control Design Handbook (ITER_D_27LH2V) was changed from v7.0 to v7.1 through REFS-41 (XQJ74U).	PCR-738, PCR-1008, PCR-1481
V5.0	To reconcile with PR v6.3/F	PCR-738
V6.0	To update for Baseline 2024 under PCR-1600 To implement PCR-1560 (HSCC requirements in Section 1.3)	PCR-1600 PCR-1560

SCOPE

[41s1004-I] This SRD contains all of the top level functional, design, safety, operational and quality requirements for the Coil Power Supply and Distribution System (CPSD) (PBS 41). It complies with ITER project-level requirements that are propagated from ITER Project Requirements (PR) document [ADi1] (as per the RPM [ADi33]).

[41s1236-I] Sections 1 to 6 of the SRD describe the system in its final configuration and the associated requirements that CPSD has to satisfy to undertake the full Deuterium-Tritium (DT) operation campaigns (i.e. required capabilities to start the DT-2 phase). The section 7 presents specific requirements (if any) that the system has to satisfy for the planned construction and operation campaigns prior to DT-2 (i.e. during each of the 2 phases: Start of Research Operation (SRO) and the first Deuterium-Tritium campaign DT-1).

DEFINITIONS

[41s1006-I] For a list of system-specific abbreviations, see the ITER Abbreviations [R2] and Electrical Design Handbook - Part 2 (Terminology and Acronyms) [ADc5].

REFERENCES

[41s1320-R] The system shall be compliant with the applicable versions for each Complementary and Input Applicable Documents that are given in the IDM document (ITER_D_XQJ74U.

[41s1206-I] This SRD makes reference to the following documents, and to the Interface Control Documents (ICDs) that are listed in Section 1.5.

Complementary Applicable documents

[41s1321-I] The following documents, which contain mandatory technical requirements to be satisfied by the system, are complementary to this SRD. Complementary applicable documents (ADc) include the Interface Control Documents (ICDs) that are listed in section 1.5. Propagation and compliance of the system with the requirements recorded in these documents must be demonstrated in the same manner than this SRD.

[41s1324-ADc] [ADc4] EDH Part 1: Introduction (ITER_D_2F7HD2

[41s1325-ADc] [ADc5] EDH Part 2: Terminology and Acronyms (ITER_D_2E8QVA

[41s1326-ADc] [ADc6] EDH Part 3: Codes and Standards (ITER_D_2E8DLM

[41s1327-ADc] [ADc7] EDH Part 4: Electromagnetic Compatibility (EMC) (ITER_D_4B523E

[41s1328-ADc] [ADc8] EDH Part 5: Earthing and lightning protection (ITER_D_4B7ZDG

[41s1349-ADc] [ADc9] ITER Site Master Plan (ITER_D_27X5FM

[41s1329-ADc] [ADc10] Load Specifications (LS) (ITER_D_222QGL

[41s1330-ADc] [ADc11] Plant Control Design Handbook (ITER_D_27LH2V

[41s1332-ADc] [ADc12] Plant Control Design Handbook for Nuclear control systems (ITER_D_2YNEFU

[41s1350-ADc] [ADc13] Static and Transient Magnetic Field Maps in Tokamak Building (ITER_D_3BQBVY

[41s1352-ADc] [ADc15] Protection Important Functions and Components Classification Criteria and Methodology (ITER_D_347SF3

[41s1353-ADc] [ADc16] Quality Classification Determination (ITER_D_24VQES

[41s1333-ADc] [ADc19] ITER Human Factor Integration Plan (ITER_D_2WBVKU

[41s1334-ADc] [ADc20] ITER Site Signage & Graphics Standards (ITER_D_4ALJEU

[41s1335-ADc] [ADc21] ITER Seismic Nuclear Safety Approach (ITER_D_2DRVPE

[41s1336-ADc] [ADc22] Load Specification Annex-Internal Explosions: Hydrogen Deflagration in Tokamak Complex (ITER_D_BMQ9XM

[41s1337-ADc] [ADc23] Safety requirement Roombook (ITER_D_KF63PB

[41s1338-ADc] [ADc24] ITER Fire Protection Approach (ITER_D_25SDBD

[41s1339-ADc] [ADc25] IO cabling rules (ITER_D_335VF9

[41s1341-ADc] [ADc27] Safety Functions, Systems, Signals Definition for I&C CSS Design (ITER_D_3R7ECW

[41s1342-ADc] [ADc28] Appendix I to 3R7ECW I_C_ safety functions PBS 41 (ITER_D_SBV4B3

[41s1343-ADc] [ADc35] ITER site meteorology (ITER_D_2UT36S

[41s1369-ADc] [ADc36] ITER Coordinate System and Coils Polarities (ITER_D_QRUDS6

[41s1370-ADc] [ADc37] Convention de raccordement de L'installation ITER au Réseau Public de Transport d'Electricité N° 16-13 (LGA-2016-C-10) (ITER_D_UKJFKA

[41s1371-ADc] [ADc39] ITER Operational States (ITER_D_54L85L

[41s1372-ADc] [ADc40] Chemical composition and impurity requirements for materials (ITER_D_REYV5V

[41s1373-ADc] [ADc41] ITER Materials Properties Handbook - Introduction (ITER_D_2NRCSB

[41s1438-ADc] [ADc42] Radiation Maps During Plasma Operations (Mode-0) (ITER_D_RJLLFY

[41s1374-ADc] [ADc43] Dose Rate Contribution of Activated Components and Structures During Mode 1 (ITER_D_V35THE

[41s1375-ADc] [ADc44] Heat and Nuclear Load Specifications (ITER_D_2LULDH

[41s1376-ADc] [ADc45] Contents of PF scenario database (ITER_D_34263N

[41s1377-ADc] [ADc48] Codes and Standards for ITER Mechanical Components (ITER_D_25EW4K

[41s1378-ADc] [ADc50] System Load Specifications for the DC Busbars (ITER_D_2KQXAR

[41s1379-ADc] [ADc51] System Load Specifications for TF PMS and TF FDU switches (ITER_D_37U9YV

[41s1380-ADc] [ADc52] Load Specification for IVC Busbar Lot1 FDR (ITER_D_3EEZF8

[41s1381-ADc] [ADc53] Load Specification for PBS41 IVC Busbar LOT-2 design (ITER_D_6RENJW

[41s1443-ADc] [ADc56] Methodology for the Hard Core Components (ITER_D_RMP3AC

[41s1444-ADc] [ADc57] ITER Investment Protection Handbook (ITER_D_3VUMVW

[41s1445-ADc] [ADc58] ITER Configuration Management Implementation Plan (CMIP) (ITER_D_27LHHE

[41s1446-ADc] [ADc59] Reconciliation report for SRD-41 (Coil Power Supply and Distribution) [28B6XQ] with ITER Technical Baseline (ITER_D_EU3PMG

Input Applicable documents

[41s1322-I] The following documents have been used as input to produce this SRD. It means that all the technical requirements they contain that are applicable to the system have been fully propagated to this system and that the resulting system requirements have been recorded in this SRD and/or one of its complementary applicable documents. Compliance with an Input Applicable Document (ADi) to this SRD will be demonstrated via the achieved compliance of this SRD and its ADc. An ADi only partially propagated to the system is identified as ADc until its propagation is complete.

[41s1344-ADi] [ADi1] Project Requirements (PR) (ITER_D_27ZRW8

[41s1346-ADi] [ADi33] RPM from PR to SRD-41 (ITER_D_VDMYTA

Reference documents

[41s1323-I] A reference document is a document only "For information". It provides background information to improve the understanding of the project, system and its requirements. There is no need for the supplier to demonstrate compliance with an information (except for some information classified as Defined Requirement by SD that must be transmitted down the supply chain for awareness).

[41s1348-I] [R2] ITER Abbreviations (ITER_D_2MU6W5

[41s1351-I] [R14] MQP L1 ITER Quality Assurance Program (QAP) (ITER_D_22K4QX

[41s1331-I] [R18] Staged Approach Configuration - PBS Level 3 (ITER_D_SNE6G8

[41s1340-I] [R26] PBS 41 PIC Detailed list (ITER_D_JF5TU7

[41s1354-I] [R29] Decree No. 2012-1248 dated 9 November 2012 authorising IO to create a nuclear facility called “ITER” - EN (ITER_D_CZK7M5

[41s1355-I] [R30] ASN Decision 2013-DC-0379 dated 12 November 2013 establishing the prescriptions applicable to ITER Organization for the licensed nuclear facility INB No. 174 called ITER - FR (ITER_D_LYH6QS

[41s1356-I] [R31] Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN (ITER_D_7M2YKF

[41s1357-I] [R32] Accident Analysis Report (AAR) (ITER_D_2ZTMLF

[41s1382-I] [R46] Preliminary Safety Report (RPrS) ((ITER_D_3ZR2NC)

[41s1383-I] [R49] Staged Approach Configuration - Preliminary Functional Description (ITER_D_TVG7YK

[41s1439-I] [R54] Arrêté du 4 juillet 2003 relatif aux prescriptions techniques de conception et de fonctionnement pour le raccordement direct au réseau public de transport d'une installation de consommation d'énergie électrique

[41s1384-I] [R55] IS-11-41-001 (ITER_D_2ZZRCS

[41s1447-I] [R59] IC/STAC-25/4.1. Progress on the quantification of the possible degradation of the TF conductor with electromagnetic and thermal cycling and IO's risk mitigation plan (ITER_D_YG2GMA

[41s1448-I] [R60] Management of Configuration Management Model (CMM) (ITER_D_V2ERKH

[41s1449-I] [R61] GIN 015 - Implementation of EU construction products regulation no.305/2011 (CPR regulation) to cables used for construction works within the ITER Project- Derogation (ITER_D_WQA2B6

1 FUNCTIONS, BASIC CONFIGURATION, CLASSIFICATION AND SYSTEM BOUNDARIES

1.1 System Functions

[41s10-R] The Coil Power Supply and Distribution System (CPSD) shall receive power from the High Voltage (HV) Grid and distribute it to the pulsed loads of the Coil Power Supply System (CPSS), Heating and Current Drive (H&CD) power supplies.

[41s667-R] The Coil Power Supply and Distribution System (CPSD) shall limit the net reactive power flow and voltage fluctuations of the "Réseau de Transport d'Electricité" (RTE) grid that are induced by ITER operations, to levels agreed with RTE.

[41s666-R] The Coil Power Supply and Distribution System (CPSD) shall supply continuous controlled DC current in the Toroidal Field (TF) coils.

[41s665-R] The Coil Power Supply and Distribution System (CPSD) shall provide controlled voltage/current in the Central Solenoid (CS) and Poloidal Field (PF1 and PF6) coils for plasma initiation, plasma current, shape and position control.

[41s702-R] The Coil Power Supply and Distribution System (CPSD) shall provide controlled voltage/current for stabilization of plasma vertical displacements, varying differential current in the coils PF2 - PF5 (stabilizing feedback loop VS1), varying differential current in the coils CS2U and CS2L (stabilizing feedback loop VS2), and varying current in the VS in-vessel coils (stabilizing feedback loop VS3).

[41s915-R] The Coil Power Supply and Distribution System (CPSD) design shall keep the capability of improvement of plasma vertical stabilization by: increasing on-load voltage in VS1 from 6kV to 9kV; and utilizing the VS2 circuit with maximum on-load voltage of 6kV. The decision to upgrade the plasma vertical stabilization can be taken at a later stage.

[41s664-R] The Coil Power Supply and Distribution System (CPSD) shall provide controlled voltage/current in the Correction Coils (CC) for error field correction.

[41s1150-R] The Coil Power Supply and Distribution System (CPSD) shall provide controlled voltage/current for control of edge localized modes (ELMs) and/or resistive wall modes (RWMs) in ELM coils and for control of vertical displacement event (VDE) in VS coils.

[41s663-R] The Coil Power Supply and Distribution System (CPSD) shall protect all ITER superconducting coils by fast discharge of their stored energy in case of quench.

[41s662-R] The Coil Power Supply and Distribution System (CPSD) shall protect the coils against overvoltage or/and overcurrent due to abnormal or faulty operation of power supplies, or in case of plasma current disruption.

[41s661-R] The Coil Power Supply and Distribution System (CPSD) shall measure all quantities within the CPSD that are required for instrumentation and control.

[41s660-R] The Coil Power Supply and Distribution System (CPSD) shall provide earthing circuits and earth leakage current sensing in the coil power supply circuits.

[41s659-R] The Coil Power Supply and Distribution System (CPSD) shall isolate and earth the coils for safe access during maintenance periods.

1.2 System Basic Configuration

[41s22-I] The CPSD consists of the following subsystems:

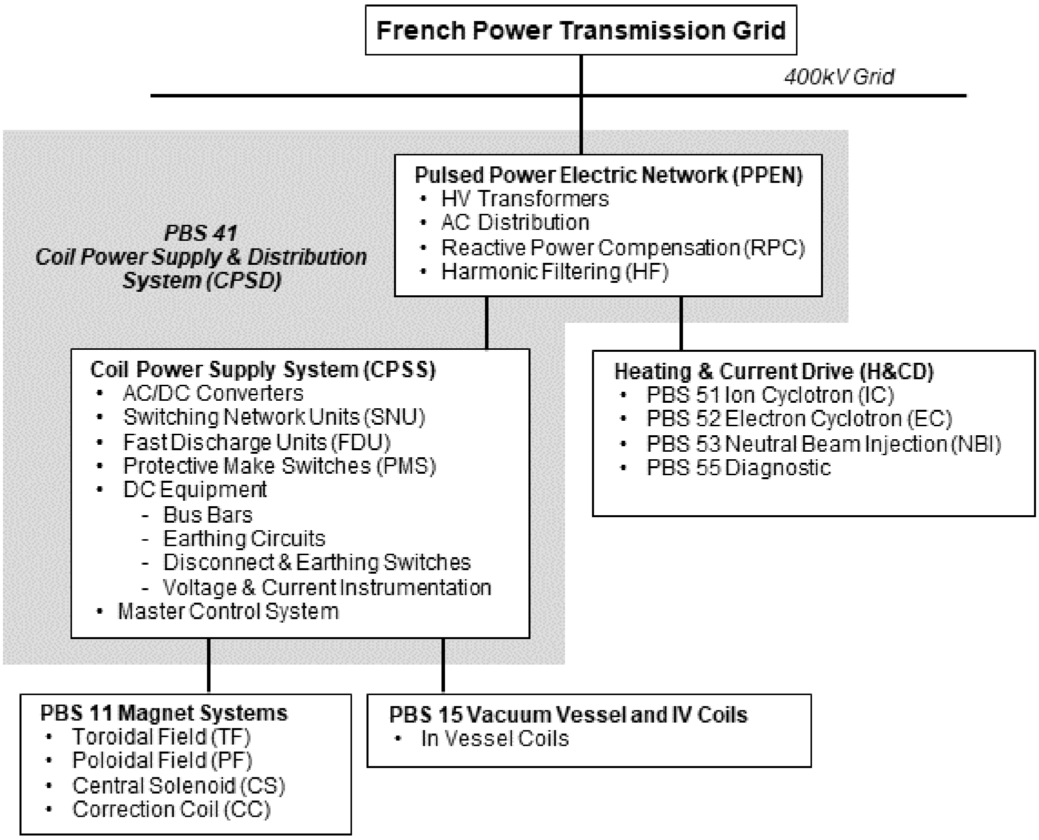
- Pulsed Power Electric Network (PPEN) which receives AC power from the HV grid and distributes it at intermediate voltage (IV) and medium voltage (MV) to the pulsed loads of ITER, comprising of the CPSS and H&CD PS.
    - HV Transformers and AC Distribution;

- Reactive Power Compensation and Harmonic Filtering (RPC&HF) System connected at intermediate voltage (IV) compensates the reactive power and reduces harmonic distortion caused by AC/DC Converters and Heating power supply to level acceptable system operational requirements.

- Coil Power Supply System (CPSS) which receives AC power from the PPEN and supplies controlled power to the TF, PF, CS, CC, ELMs, and VS3 coils and stabilizing feedback loops VS1 and potentially VS2 (the decision can be taken at a later stage).

[41s703-I] A block diagram of the CPSD showing major interfacing systems is given in the following figure.

Figure 1.2: Block Diagram of CPSD



1.2.1 Pulsed Power Electric Network (PPEN)

[41s27-I] The PPEN comprises the following elements:

- HV switchgear and Step-Down transformers;
- AC power distribution;
- Reactive Power Compensation and Harmonic Filtering (RPC and HF);
- Local control systems and auxiliaries.

1.2.1.1 HV Switchgear and Step-down Transformers

[41s33-R] The interface with the local grid operator occurs at the HV switchgear, which shall provide the following functions:

- Connection, disconnection, isolation, and earthing of the load side (ITER) equipment from the source side (grid operator) during normal operation, maintenance, and fault conditions;
- Protective relaying to detect abnormal conditions and initiate disconnection;
- Instrumentation to monitor voltages, currents, and power flow.

[41s36-R] The step-down transformers shall transform the voltage from RTE 400 kV input to an intermediate voltage (IV) level of 66 kV, and medium voltage (MV) level of 22 kV, suitable for distribution to the loads, and provide an impedance which limits the power deliverable to faults in a manner that is coordinated with the downstream equipment.

1.2.1.2 AC Power Distribution System

[41s1007-R] The AC power distribution shall receive AC power from the HV step-down transformers and distribute it to the pulsed power loads of ITER, comprising the AC/DC converters of the CPSS and H&CD power supply systems.

[41s39-R] The CPSS and H&CD loads shall be supplied at the intermediate voltage level (66 kV) and the medium voltage level (22 kV) after transformation by step-down transformers depending upon their power rating. (Normally loads of, and less than 20 MVA are connected to the 22 kV bus.)

1.2.1.3 Reactive Power Compensation and Harmonic Filtering (RPC and HF)

[41s704-R] The RPC&HF shall provide dynamic control of reactive power flow under steady state and transient state operation in order to

- Limit the voltage rise on the busbars in the event of fast switch off of inductive load;
- Limit the voltage variation on the 66 kV bus bar between 62 kV to 72.5 kV (that is, -6%/ +10%) under steady state operation and, as a consequence, to limit the voltage variation on the 22 kV bus bar to ±10% under normal operation;
- Limit the net reactive power flow from the grid to acceptable level by supplying a controlled source of leading reactive power to compensate for the lagging reactive power demand of the AC/DC converters and the Heating power supplies, in order to limit the voltage variation on the grid to a maximum of 3% over and above the normal voltage;
- Limit the individual harmonic (of 50 Hz) and total harmonic distortion (THD) to a level defined in applicable French codes, IEC 61000-3-6 1996 or latest release, in order to reduce the voltage distortion in the grid and within PPEN.

1.2.1.4 Local Control System and Auxiliaries

[41s42-R] A local control system shall be provided for each sub-system (namely the PPEN, RPC and HF) to monitor all the parameters of the system, and shall have features included for local operation of the system in case of maintenance or failure of the central control system. It shall also convey all the operating parameters to the central control system. Local Control System shall segregate the Conventional Control, Interlock Control and safety Control.

1.2.2 Coil Power Supply System (CPSS)

[41s46-R] The CPSS shall comprise the following elements:

- Line Disconnectors and earthing switches;
- AC/DC converters and converter transformers;
- Switching Network Units (SNU) to provide plasma initiation loop voltage;
- Fast Discharge Units (FDU) to protect the coils in case of quench;
- Protective Make Switches (PMS);
- DC bus bars and bus links;
- DC circuit earthing and earth current sensors;
- DC disconnecting earthing switches;

- Instrumentation for control and protection;
- Master control system, local control systems and auxiliaries.

1.2.2.1 Line Disconnectors

[41s917-R] The line disconnectors shall be part of the AC/DC converter system, used for electrical isolation of two systems: that is, the AC distribution and the AC/DC converter system.

1.2.2.2 AC/DC Converters

[41s55-R] The AC/DC converters shall receive input AC power through converter transformers connected at the intermediate or medium voltage level (66 kV and 22 kV), depending upon the power rating, and provide a controlled DC voltage and current in the coils.

1.2.2.3 Switching Network Units (SNU)

[41s57-R] The SNUs shall comprise DC circuit breakers which open upon command for plasma initiation to divert the coil current into discharge resistor banks, thus developing a high loop voltage and corresponding high power level, supplementing the AC/DC converters and the grid.

1.2.2.4 Fast Discharge Units (FDUs)

[41s59-R;Defined Requirement] The FDUs shall comprise DC circuit breakers which open rapidly upon command in case of coil quench or other types of fault events through signals raised by CSS-N (Central Safety System - Nuclear) [ADc28], to divert the coil current into discharge resistor banks, serving to discharge the magnetic energy stored in the coils. FDU resistor banks shall be separate from those used with the SNU. The TF FDUs, in particular, are PIC/SIC components.

1.2.2.5 Protective Make Switches (PMS)

[41s707-R;Defined Requirement] The PMSs shall comprise fast acting mechanical closing switches which serve to provide a current path bypassing the AC/DC converters and SNU under fault conditions. The TF PMS, in particular, is SIC. The CS/PF PMSs are classified as Non-SIC.

1.2.2.6 DC Bus-Bars and Bus Links

[41s61-R] The DC bus bars shall connect the TF, CS, PF, CC, ELMs and VS coils to the AC/DC converters, FDUs and SNUs. The bus links shall provide the facility to reverse the connection of unipolar devices, where required, to permit current flow in both directions in the magnets, and provide the means of reconfiguring VS3 coil circuit.

1.2.2.7 DC Earthing and Earth Current Sensors

[41s63-R] The DC earthing shall earth the coil circuits through high impedance resistors. The earth current sensors shall monitor the leakage current to earth, and shall detect and alarm abnormal conditions.

1.2.2.8 DC Disconnecting and Earthing Switches

[41s67-R] The DC Disconnecting and Earthing Switches shall provide a means for disconnecting the coil circuits from the AC/DC converters, and earthing the coil circuits.

1.2.2.9 Instrumentation for Control and Protection

[41s69-R] Instrumentation shall be provided for control and protection, including precision voltage and current transducers which shall measure the current in each coil, each branch of the CPSS and the voltage at each coil terminal to earth.

1.2.2.10 Master Control System, Local Control System and Auxiliaries

[41s1151-R] Master Control System shall ensure, at the CPSS system level, the coordination, interlock, self-protection and control of the individual components.

[41s709-R] A local control system shall be provided for each sub-system (namely, the AC/DC Converters, SNU, FDU under CPSS) to monitor all the parameters of the system, and shall have features included for local operation of the system in case of maintenance and failure of the central control system. It shall also convey all the operating parameters to the central control system. Local Control System shall segregate the Conventional Control, Interlock Control and Safety Control.

1.3 Classification of Systems, Structures and Components (SSCs)

[41s1276-R;Defined Requirement] CPSD Systems, Structures, and Components (SSC) shall be designed and operated (including qualification, manufacturing, installation, maintenance, preservation, commissioning and testing) in accordance with the requirements imposed by the following classifications:

- Quality Class (QC), in accordance with the ITER Quality Classification Determination [ADc16].
- Investment Protection Class (IPC), in accordance with ITER Investment Protection Handbook [ADc57].

[41s1008-R;Defined Requirement] Quality classification:

- TF FDU, TF PMS, PF/CS FDU, PF/CS PMS, SNU, TF/PF/CS/CC bus-bars and Instrumentation for control and protection shall be classified as QC-2;
- All other CPSD components shall be classified as QC-3;
- Individual parts used to fabricate CPSD components shall be classified as QC-4.

[41s1385-I] CPSD Systems, Structures and Components (SSC) that play an important role in the protection of ITER and its environment, are classified as Protection Important Components, as considered in the INB order of the 7th February 2012 [R31]. PIC that play an important safety role, and that contribute in respecting ITER Generic Safety Objectives during an abnormal event, is classified as Safety Importance Class (SIC) 1 or 2 or Safety Relevant (SR), following the criteria and methodology that is described in [ADc15], based on the consequences of their failure. The top-level criteria for the identification are:

- Criterion A: their failure can directly initiate an incident or accident leading to significant risks of exposure or contamination;
- Criterion B: their operation is required to limit the consequences of an incident or accident that leads to significant risks of exposure or contamination;
- Criterion C: their operation is required to ensure the functioning of the other SIC components.

[41s1009-R;Defined Requirement] CPSD system shall be designed with the following safety classification (refer to [ADc15] and [R26]):

- TF FDU, TF PMS, TF bus-bars (in B11), TF Flexible links, DC busbar (and its support), and penetration through B11 shall be classified as SIC-2, category B
- The isolation from the power supply in the PF and CS coils through the closing of Protected Make Switch (PMS) has been considered a function having a light relevance to safety: PF/CS PMS shall be classified as SR, category C. It shall be interfaced with CSS-N [ADc27][ADc28];
- All other CPSD components shall be classified as Non-SIC.

[41s1010-I] Tritium classification: not applicable.

[41s1011-I] Vacuum classification: not applicable.

[41s1012-I] RH classification: not applicable.

[41s1013-I] ESPN classification: not applicable.

[41s1014-I] PED classification: not applicable.

[41s1015-R;Defined Requirement] CPSD shall be electrically powered as follows:

- The PIC-CPSD components shall be powered by one of the following safety power supply networks, in compliance with safety requirements:
    - SSEN Class III-Safety network (temporary interruptible AC power) powered by SSEN Class IV-OL during normal operation, and in case of LOSP and SBO by the SSEN Safety-diesel generators with 72 hours autonomy.
    - SSEN Class II-Safety network (uninterruptible AC power) powered by SSEN Class IV-OL during normal operation, and in case of LOSP and SBO by Class III-Safety network and batteries of 1 hour autonomy.
- The IP-CPSD components shall be powered by one of the following IP power supply networks, in compliance with the Investment Protection (IP) requirements:
    - SSEN Class III-IP network (temporary interruptible AC power) powered by SSEN Class IV-OL during normal operation, and in case of LOSP and SBO by SSEN IP-diesel generators with 24 hours autonomy.
    - SSEN Class II-IP network (uninterruptible AC power) powered by SSEN Class IV-OL during normal operation, and in case of LOSP and SBO by Class III-IP network and batteries of 1 hour autonomy.
- The CPSD components whose functionality is not required for IP or Safety in case of LOSP and SBO, shall be powered by one of the following networks:
    - SSEN Class IV (Ordinary Load) network (indefinitely interruptible steady-state AC)
    - PPEN (predominantly pulsed power loads of CPSD)
    - RTE 400kV AC transmission network (predominantly PPEN power distribution components)
    - where it is noted that CPSD components powered by PPEN or RTE 400kV network may in addition receive auxiliary power from SSEN

[41s1016-R;Defined Requirement] Seismic classification shall be determined in accordance with the ITER Seismic Nuclear Safety Approach [ADc21]:

- TF FDU, TF PMS shall be classified as SC1/SF, while TF bus-bars (only the parts necessary for the fast discharge operations), fast discharge resistors and power cables connecting resistors shall be SC1/S;
- PF/CS FDU, PF/CS PMS, SNU, IVC power supplies, TF/PF/CS/CC/IVC bus-bars (in B74, B75 or B11) and Instrumentation for control and protection are classified as SC2;
- All other CPSD components that cannot impact PIC operation shall be classified as NSC.

[41s1452-R;Defined Requirement] The CPSD SSCs identified as HSCC shall be designed and qualified in compliance with the methodology and requirements defined in the Methodology for ITER Hard Core Components [ADc56].

[41s1453-R;Defined Requirement] The function of a HSCC shall not be jeopardized by the failure of a non-HSCC.

1.4 Design Basis Conditions and Events

[41s1019-R;Defined Requirement] The CPSD components shall be designed, constructed and qualified through a qualification program that shall demonstrate that each component is able to perform its functions or remain stable in all normal and accidental conditions and events foreseen for its functioning, in accordance with Protection Important Functions and Components Classification Criteria and Methodology [ADc15]. PBS 41 SIC SSCs shall be demonstrated to withstand the loads, hazards and environmental conditions during its whole service time. The demonstration shall be done through analysis, tests, relevant operational experience or a combination of those (refer to Load Specifications [ADc10] and Load Specification Annex – Internal Explosions: Hydrogen Deflagration in Tokamak Complex [ADc22] for detailed load conditions, and Safety requirement Roombook [ADc23] for reference safety conditions).

[41s1020-R;Defined Requirement] CPSD shall be committed to its due performance to the maximum extent as follows:

- For all CPSD components, the loads resulting from normal situations including:
  - Loads due to normal activities during construction, operation and maintenance (static and dynamic loads);
  - Loads due to normal environmental conditions:
  - Outdoors (wind, snow, rain, temperature, hygrometry, sun),
  - Inside buildings (temperature, hygrometry, pressure, magnetic fields, electromagnetic interferences, radiofrequency, ionizing radiations);
  - Loads due to the components design and operation (e.g. component dead weight, cables/cubicles heating, water pressure in pipes, vibration of rotating machines)
  - Loads from plasma operations (e.g. plasma initiation phase, plasma disruptions during normal operation including vertical displacement events, coils discharges MFD);
  - The required combinations of these normal loads.
  - For all CPSD components classified as PICs, the loads resulting from incidents, accidents, and/or aggressions during/after which the PIC components must perform their safety functions. These events may include the following abnormal events, depending on their location and required functions:
  - Internal events such as:
  - High/low temperature, hygrometry, pressure due to e.g. failure of HVAC, LOCA or He leak;
  - Plasma disruption events (MD and VDE Cat III/IV);
  - Internal fire;
  - Internal flooding;
  - Internal missiles that may be generated by pipe whipping, explosion, failure of a machine with moving parts, etc.;
  - Electromagnetic field from the ITER magnets;
  - Electromagnetic interference from electrical components, including internally generated electrical transients such as fast transients, switching surges, voltage ripple, harmonics, and inrush;
  - Erroneous operator action;
  - Equipment failure.
  - External events such as:
  - Earthquake (see Section 2.5);
  - Lightning;
  - External fire;
  - External electricity supply interruption/variation (LOSP/SBO);

- Extreme climatic conditions (wind, snow, rain, temperature);
- External flooding (including 100-year returns with 20% margins);
- Aircraft crash;
- Overpressure wave or projectiles induced by a potential explosion located outside the ITER side boundary fence.

- The required combinations of these abnormal loads (such as SL2 + internal fire or flooding).

[41s1386-R] The ITER loads during normal and abnormal conditions that shall be implemented into the design and operation of CPSD, its sub-systems and components shall be compiled into dedicated system load specifications, in compliance with the applicable ITER load specifications:

- ITER site meteorology [ADc35];
- ITER Load Specifications (LS) [ADc10];
- Heat and Nuclear Load Specification [ADc44];
- Safety requirement Roombook [ADc23];
- Static and Transient Magnetic Field Maps in Tokamak building [ADc13];
- Radiation maps [ADc42][ADc43];
- ICDs for ambient conditions in buildings (interface with HVAC) – see ICDs in section 1.5.

[41s1387-R;Defined Requirement] The PIC/SIC CPSD sub-systems/components shall be designed to maintain the safety functions under normal operation and specific accidental conditions identified in the System Load Specifications [ADc50][ADc51][ADc52][ADc53].

1.5 System Boundaries and Interfaces

[41s697-I] The matrix of direct interfaces, with description of boundaries, is given in the following table. PBS elements that are not listed have no interface with the CPSD.

Table 1.5: CPSD Boundaries

PBS	Description	PPEN	CPSS
11	Magnets		Coil terminal boxes in Tokamak Building
15	Vacuum Vessel and IV Coils		Feedthrough Clamp Blocks in Tokamak Building
22	Machine Assembly & Tooling		Physical & Functional Interface
26	Cooling Water System	Supply & Return manifolds in Reactive Power Compensation Building	Supply & Return manifolds in Magnet Power Conversion, Diagnostic and Tokamak Buildings, the busbar bridges
41	Coil PS & Distribution System	Input terminals of AC/DC converter transformer disconnect switches	Input terminals of AC/DC converter transformer disconnect switches
43	Steady State Electric Power Network	Low voltage (LV) distribution panels supplying AC power to PPEN & RPC & HF equipment	Low voltage (LV) distribution panels supplying AC power to CPSS equipment
44	Cable Trays	Power/Control/Signal Cables for AC Power distribution & RPC & HF System	Power/Control/Signal Cables for AC Power distribution for AC/DC Converters, DC Cables for SN, FD circuits
45	CODAC	Cubicles in Main AC Power Distribution Bldg. B36 for both PPEN and RPC & HF	Cubicles in Magnet Power Conversion, Diagnostic and Tokamak Building
46	Central Interlock System	Cubicles in Main AC Power Distribution Bldg. B36 for both PPEN and RPC & HF	Cubicles in Magnet Power Conversion, Diagnostic and Tokamak Building
47	Plasma control System		AC/DC Converters, SNU, FDU
48	Central Safety Systems	Cubicles in Main AC Power Distribution Bldg. B36 for both PPEN and RPC & HF	Cubicles in Magnet Power Conversion Buildings
51	IC H&CD	Input terminals of AC/DC converter transformer disconnect switches	

PBS	Description	PPEN	CPSS
52	EC H&CD	Input terminals of AC/DC converter transformer disconnect switches	
53	HNB & DNB	Input terminals of AC/DC converter transformer disconnect switches	
55	Diagnostics	Input terminals of 22kV power supply transformers for AC/DC converter	provide current for the calibration of continuous External Rogowski coils
61	Site	Roads, Parking and Laydown Areas (RO), Special Foundations (SF), Equipment Fencing (CF) and Outdoor Lighting Equipment (OL), Trenches, slabs etc.	Plant Bridges (PB), Roads, Parkings and Laydown Areas (RO), Special Foundations (SF) and Outdoor Lighting Equipment (OL), Trenches, slabs etc.
62	Tokamak Complex & Support		The components of the CPSS system; the penetrations from the busbar bridges and with the fast discharge resistors; the busbars and appropriate routes/shafts through the building to and from the magnet CTB
63	Steel Frame Buildings	Envelope of AC Power Distribution and Reactive Power Control Building	Envelope of Magnet Power Conversion and Switching Network resistor & Fast discharge resistor building
65	Liquid & Gas Distribution		Compressed air supply manifolds in Magnet Power Conversion, Diagnostic and Tokamak Building
66	Radwaste Treatment and Storage		Radwaste from IVC busbar

1.5.1 PPEN

[41s1388-I] Detailed information about the PPEN interfaces with other plant systems is given in the Interface Control Documents (ICD) that are listed next. PPEN complies with them in order to allow the systems of ITER to perform all their required functions, safety or not.

[41s76-R] PBS 26-CC (CCWS):

• Physical and functional interface;

• Interface Control Document (ICD) between Component Cooling Water System (PBS-26CC) and Coil Supply & Distribution (PBS-41) (ITER_D_2FPYX7;

• The Component Cooling Water System provides cooling water to PPEN;

[41s77-R] PBS 41 (Coil Power Supply and Distribution System):

• Physical and functional interface;

• Interface Control Document between PPEN (PBS41.PP) and RPC&HF System (PBS41.R1, R2, R3) (ITER_D_2KSK4F;

• Interface Control Document between PPEN (PBS41.PP) and AC/DC Converters (PBS41.xx) ((ITER_D_2KSK3W);

• The PPEN shall provide power to the CPSS and RPC and HF.

[41s1023-R] PBS 43 (Steady State Electric Power Supply Networks):

• Physical and functional interface;

• Interface Control Document (ICD) between Steady State Electrical Network (PBS 43) - Coil Power Supply and PPEN (PBS 41) ((ITER_D_35BQZA);

• The PBS 43 provides auxiliary power, to PPEN and RPC and HF equipment.

[41s1024-R] PBS 44 (Cable Trays):

• Physical and functional interface;

• Interface Control Document between Pulsed Power Electric Network (PBS 41.PP) and Cable Tray Systems (PBS 44) (ITER_D_D7RJM4;

• Interface Control Document between RPC & HF System (PBS 41.P2.CN.02) and Cable Tray Systems (PBS 44) (ITER_D_32LSAB;

• Providing cable routing to other systems, including via service trenches.

[41s1025-R] PBS 45 (CODAC):

• Physical and functional interface;

• S-ICD PBS 45- PBS 41 (ITER_D_2NKSW9;

• The interface lies at the cubicles in the Main AC Distribution Buildings, and Reactive Power Control Building.

[41s79-R] PBS 46 (Central Interlock System):

• Physical and functional interface;

• Interface Control Document (ICD) Coil PS & Distribution (PBS 41) - Central Interlock System (PBS 46) (ITER_D_2M58GX;

• The interface lies at the cubicles in the Main AC Distribution Buildings, and Reactive Power Control Building.

[41s1026-R] PBS 48 (Central Safety System):

• Physical and functional interface;

• Interface Control Document (ICD) Coil PS & Distribution (PBS 41) - Central Safety System (PBS 48) (ITER_D_2MGN4U;

• The interface lies at the cubicles in the Main AC Distribution Buildings, and Reactive Power Control Building.

[41s1027-R] PBS 51-HV (ICH&CD Power Supplies):

• Physical and functional interface;

• Interface Control Document (ICD) between IC Power Supply (PBS 51.HV) & Pulsed Power Electrical Network (PBS 41.PP) (ITER_D_2ZV9HY;

• The PPEN shall provide power to IC H&CD Power Supply.

[41s1028-R] PBS 52 (ECH&CD):

• Physical and functional interface;

• Interface Control Document (ICD) between (PBS41-PP) - Electron Cyclotron H&CD system (PBS52) (ITER_D_2KSK9Z;

• The PPEN shall provide power to EC H&CD Power Supply

[41s78-R] PBS 53 (NB Heating and Current Drive):

• Physical and functional interface;

• Interface Control Document (ICD) between (PBS41-PP) - Neutral Beam H&CD system (PBS53) (ITER_D_2KSKCB;

• The PPEN shall provide power to NB H&CD Power Supply.

[41s1154-R] PBS 55 (Diagnostics):

• Physical and functional interface;

• Interface Control Document (ICD) between PPEN (PBS41.PP) - Diagnostics (PBS55) (ITER_D_6KMRB2;

• The PPEN shall provide power to the CTS Diagnostics Power Supply.

[41s1030-R] PBS 61-00-CF (Equipment Fencing):

• Physical and functional interface;

• Interface Control Document (ICD) between Equipment Fencing (PBS 61-00-CF) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2W3KPD.

[41s1033-R] PBS 61-00-OL (Outdoor Lighting Equipment):

• Physical and functional interface;

• Interface Control Document (ICD) between Outdoor Lighting Equipment (PBS 61-00-OL) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EQ5R3.

[41s1035-R] PBS 61-00-RO (Roads, Parking and Laydown Areas):

• Physical and functional interface;

• Interface Control Document (ICD) between Roads & Parking & Laydown Areas (PBS 61-00-RO) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPS4B.

[41s1036-R] PBS 61-00-SF (Special Foundations):

• Physical and functional interface;

• Interface Control Document (ICD) between Special foundations (PBS 61-00-SF) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPTUF.

[41s80-R] PBS 63-36 (Main AC Distribution Building):

• Physical and functional interface;

• Interface Control Document (ICD) between Main AC Distribution Building (PBS 63-36) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EQ262;

• The interface of the PPEN with the Steel Frame Buildings (PBS 63) lies at the envelope of the Main AC Distribution Control Building.

[41s1389-I] There is no direct interface with 63-15 (RF Heating Building) since PPEN SSCs do not locate in the Building 15. PPEN has interface with PBS-51.HV outside Buildings 15.

1.5.1.1 At the incoming 400 kV AC power source

[41s1390-R] The interface with the French 400 kV transmission grid “Réseau de Transport d'Electricité” (RTE) occurs at the terminations of the outdoor conductors that come from the 400 kV switchyard of RTE. The RTE terminations shall connect to the 400 kV incoming line disconnectors of the ITER 400 kV switchyard. This is depicted in Figure 1.5.1.

[41s1391-I] Interface requirements between PPEN and RTE is stated in Specification for Connection to RTE Network [ADc37] including, but not limited to:

- maximum active power of PPEN: 500 MW
- maximum reactive power of PPEN: 200 Mvar

Figure 1.5 1: 400 kV interface between ITER (PPEN & SSEN) and RTE

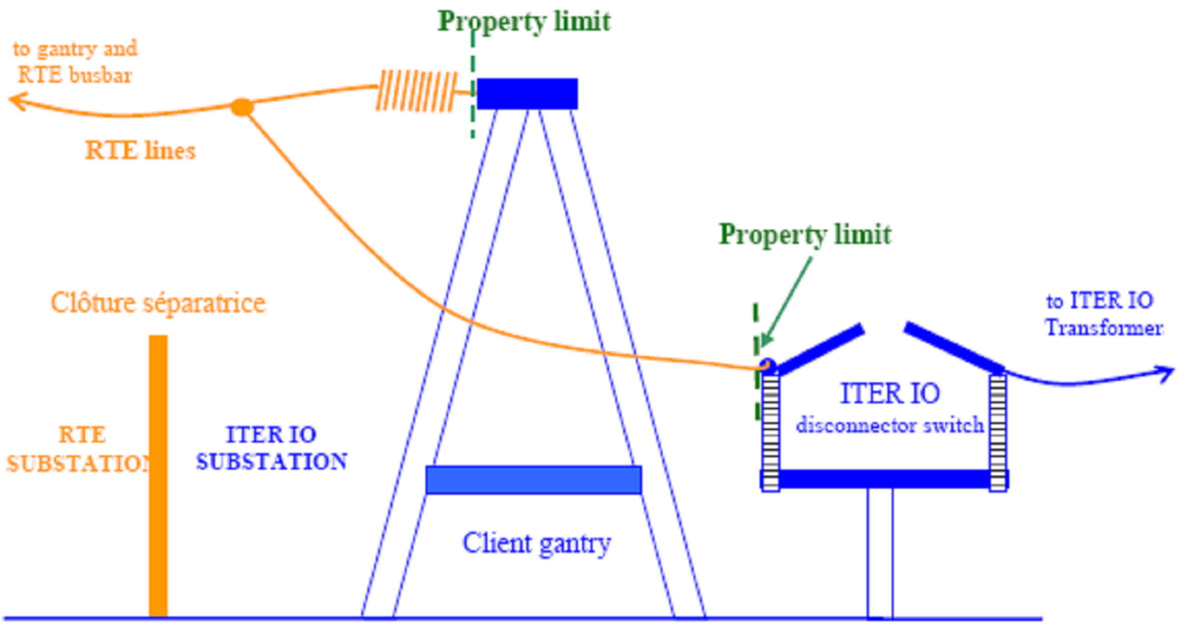
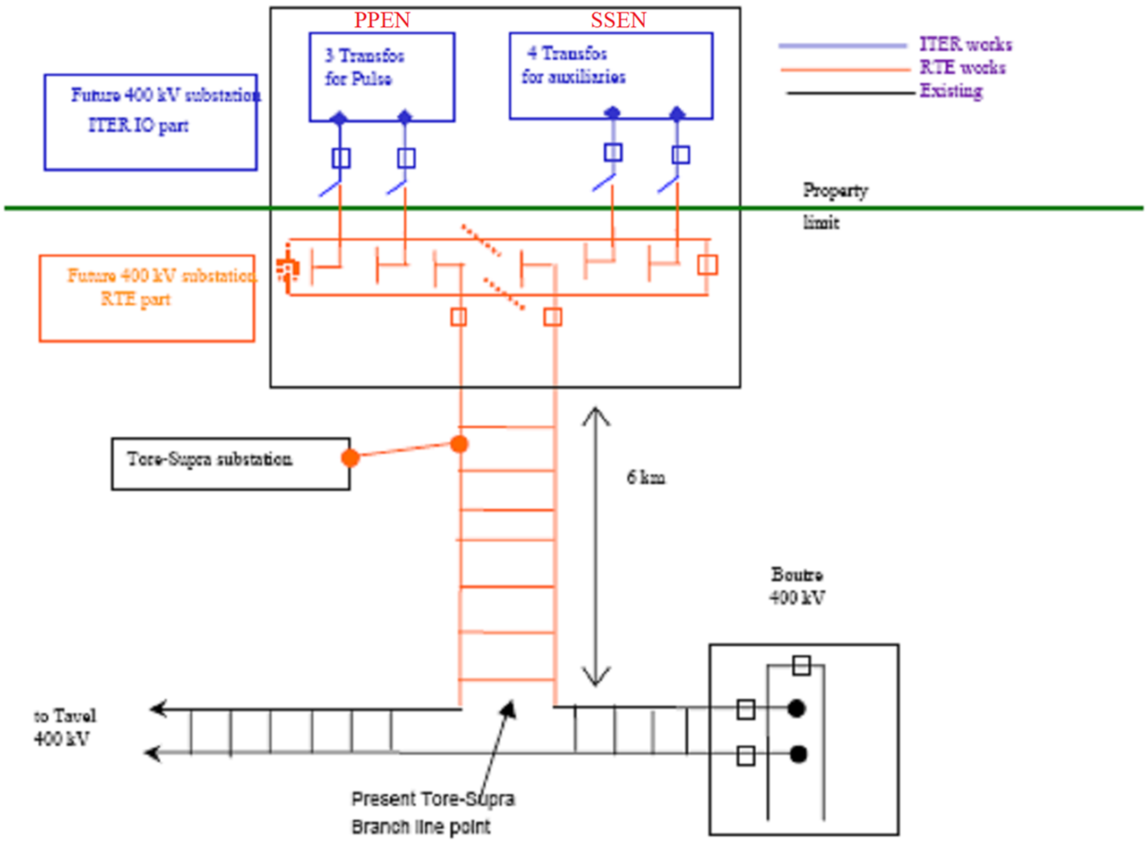


Figure 1.5 2: common platform for two abutting substations (PPEN and SSEN)



1.5.2 CPSS

[41s1394-I] Detailed information about the CPSS interfaces with other plant systems is given in the Interface Control Documents (ICD) that are listed next. CPSS complies with them in order to allow the systems of ITER to perform all their required functions, safety or not.

[41s83-R] PBS 11 (Magnet System):

• Physical and functional interface;

• ICD 11-41 (ITER_D_2X5D5W;

• The CPSS shall provide power to the Magnet System.

[41s1119-R] PBS 15-IV (In-Vessel Coils):

• Physical and functional interface;

• Interface Control Document (ICD) between Coil Power Supply and Distribution (PBS 41) and In-Vessel Coils (PBS 15-IV) (ITER_D_3MSYPA;

• The CPSS shall provide power to the In-Vessel Coils.

[41s1361-R] PBS 15-VV (Vacuum Vessel):

• Physical and functional interface;

• Interface Control Document (ICD) between Coil Power Supply and Distribution (PBS 41) and the Upper Port Ducts of the Vacuum Vessel (PBS 15.VV.PT) (ITER_D_UX5YCZ;

• PBS15.VV.PT provides the brackets on the Upper Port Duct walls (inner shell) for the busbar supports of PBS41 to be bolted on.

[41s1032-R] PBS 22 (Machine Assembly and Tooling):

• Physical and functional interface;

• Interface Control Document (ICD) between Plant Installation Tooling (PBS-22) and Coil Supply & Distribution (PBS-41) (ITER_D_33ACF8;

• Supply of standard handling tools required to handle and install the complete CPSD Systems from the temporary storage (or lay down area) to their permanent location in buildings 11, 32, 33, 74, and 75.

[41s84-R] PBS 26-CC (CCWS):

• Physical and functional interface;

• Interface Control Document (ICD) between Component Cooling Water System (PBS-26CC) and Coil Supply & Distribution (PBS-41) (ITER_D_2FPYX7;

• The Component Cooling Water System provides cooling water to CPSS.

[41s85-R] PBS 41 (Coil Power Supply and Distribution System):

• Physical and functional interface;

• Interface Control Document (ICD) between (PBS41-PP) - AC/DC Converters (ITER_D_2KSK3W;

• Interface Control Document between AC/DC Converters (PBS41) and SNU, FDU & DC Busbars (PBS41) ((ITER_D_3QAKXZ);

• Interface Control Document (ICD) between 41.MC (Master Control System) and 41 PAs ((ITER_D_CXMLZN);

• The PPEN provides power to the CPSS.

[41s86-R] PBS 43 (Steady State Electric Power Supply Networks):

Physical and functional interface;

Interface Control Document (ICD) between Steady State Electrical Network (PBS 43) - Coil Power Supply and PPEN (PBS 41) (ITER_D_35BQZA;

PBS 43 provides power to PBS 41 (CPSS).

[41s1037-R] PBS 44 (Cable Trays):

• Physical and functional interface;

• Interface Control Document between AC/DC Converter Systems (4.1.P2.CN.01) and Cable Tray Systems (PBS44) (ITER_D_CX8LT3;

• Interface Control Document between AC/DC Converter Systems (4.1.P2.KO.01) and Cable Tray Systems (PBS44) ((ITER_D_CV2AWK);

• Interface Control Document between SNU & FDU Systems (4.1.P3.RF.01) and Cable Tray Systems (PBS44) ((ITER_D_CZRX7Q).

[41s87-R] PBS 45 (CODAC):

• Physical and functional interface;

• ICD-41-45 Interface Control Document for Coil Power Supply & Distribution (PBS 41) and CODAC (PBS 45) (ITER_D_2NKSW9 ;

• The interface lies at the cubicles in the Magnet Power Conversion Buildings, Diagnostics and Tokamak Buildings.

[41s88-R] PBS 46 (Central Interlock System):

• Physical and functional interface;

• Interface Control Document (ICD) for Coil PS & Distribution (PBS 41) - Central Interlock System (PBS 46) (ITER_D_2M58GX;

[41s1038-R] PBS 47 (Plasma Control System):

• Functional interface;

• ICD-41-47 Interface Control Document for Plasma Control System (PBS 47) and Coil Power Supplies & Distribution (PBS 41) (ITER_D_33KFL9;

• PCS provides voltage/current reference signals via CODAC network to individual AC/DC converters.

• PCS defines coil polarities and current circulation in the coils, according to ITER Coordinate System and Coils Polarities [ADc36].

[41s1039-R] PBS 48 (Central Safety System):

• Physical and functional interface;

• Interface Control Document (ICD) for Coil PS & Distribution (PBS 41) - Central Safety System (PBS 48) (ITER_D_2MGN4U;

• The interface lies at the cubicles in the Magnet Power Conversion Buildings, Diagnostics and Tokamak Buildings.

[41s1135-R] PBS 55 (Diagnostics):

• Functional interface;

• ICD-41.V3-55.A0 Interface Control Document for InVessel Vertical Stabilisation (VS3) Coil Power Supply Circuits (PBS 41.V3) - Magnetic Diagnostics (PBS 55.A0) (ITER_D_CZZ9JV;

• The CPSS shall provide current to VS coils for the purpose of calibration of Continuous External Rogowski Coils.

[41s1040-R] PBS 61-00-CF (Equipment Fencing):

• Physical and functional interface;

• Interface Control Document (ICD) between Equipment Fencing (PBS 61-00-CF) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2W3KPD.

[41s1041-R] PBS 61-00-OL (Outdoor Lighting Equipment):

• Physical and functional interface;

• Interface Control Document (ICD) between Outdoor Lighting Equipment (PBS 61-00-OL) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EQ5R3.

[41s1042-R] PBS 61-00-PB (Plant Bridges):

• Physical and functional interface;

• Interface Control Document (ICD) between Plant Bridges (PBS 61-00-PB) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPTDP.

[41s1043-R] PBS 61-00-RO (Roads, Parking and Laydown Areas):

• Physical and functional interface;

• Interface Control Document (ICD) between Roads & Parking & Laydown Areas (PBS 61-00-RO) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPS4B.

[41s1044-R] PBS 61-00-SF (Special Foundations):

• Physical and functional interface;

• Interface Control Document (ICD) between Special foundations (PBS 61-00-SF) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPTUF.

[41s1045-R] PBS 62-11, PBS 62-74 (Tokamak Complex):

• Physical and functional interface;

• Interface Control Document (ICD) between Tokamak & Diagnostic Buildings (PBS 62-11 & PBS 62-74) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EJX37;

• The components of the CPSS system; the penetrations from the busbar bridges and with the fast discharge resistors;the busbars and appropriate routes/shafts through the building to and from the magnet CTB.

[41s1460-R] PBS 62-13 (Assembly Building):

• Physical and functional interface;

• Interface Control Document (ICD) between Coil Power Supply and Distribution (PBS41) and Assembly Building (PBS62.13) (ITER_D_9MPWW6

[41s1137-R] PBS 62-11-BP (Bioshield Port Plug):

• Physical and functional interface;

• Interface Control Document (ICD) between Bioshield Plug (PBS 62.11.BP) - Coil Power Supply and PPEN (PBS 41) (ITER_D_4D9C6S.

[41s89-R] PBS 63-32, PBS 63-33 (Magnet Power Conversion Buildings):

• Physical and functional interface;

• Interface Control Document (ICD) between Magnet Power Conversion Buildings 1 & 2 (PBS 63-32 & PBS 63-33) and Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPSTN;

• The interface of the CPSS with the Steel Frame Buildings (PBS 63) lies at the envelope of the Magnet Power Conversion Buildings.

[41s1153-R] PBS 63-38 (Reactive Power Control Building):

• Physical and functional interface;

• Interface Control Document (ICD) between Reactive Power Control Building (PBS 63-38) and Coil Power Supply & Distribution (PBS 41) (ITER_D_2EQ4PA;

• The interface of the CPSS with the Steel Frame Buildings (PBS 63) lies at the envelope of the Reactive Power Control Building.

[41s1046-R] PBS 63-75 (FD and SN Resistors Building):

• Physical and functional interface;

• Interface Control Document (ICD) between FD & SN Resistors Building (PBS 63-75) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPW9U;

• The interface of the CPSS with the Steel Frame Buildings (PBS 63) lies at the envelope of the FD and SN Resistor building.

[41s1047-R] PBS 65-00-CA (Compressed Air System):

• Physical and functional interface;

• Interface Control Document (ICD) between Compressed Air (PBS 65-00-CA) - Coil Power Supply & Distribution (PBS 41) (ITER_D_2EPY7D;

• Compressed air supply manifolds in the Magnet Power Conversion, Diagnostic and Tokamak Buildings.

[41s1395-R] PBS 66 (Radwaste Treatment and Storage):

• Physical and functional interface;

• Interface Control Document (ICD) between Coil Power Supply and Distribution (PBS41) and Radwaste Treatment and Storage System (PBS66) (ITER_D_9SFFUC;

• Radwastement from IVC busbar during decomissioning

2 DESIGN REQUIREMENTS

2.1 General requirements

2.1.1 Operating lifetime

[41s161-R] All CPSD equipment shall be designed for:

- At least 20 year operating life and an active (D-T) phase lasting at least 14 years, with a total of 30,000 pulses ;
- The commissioning periods for all its systems and the Tokamak Machine.

[41s1396-R] The CPSD containing water shall be designed to minimize leakage.

[41s1461-R] Means shall be provided to localize a leakage from components containing liquids.

2.1.2 Site

[41s711-R;Defined Requirement] Equipment shall be transported and stored (if required) prior to their installation at ITER Site, Cadarache, France, taking into account the meteorological conditions, and the risks of abnormal conditions. The meteorological conditions, and some Cadarache-specific criteria that are imposed by French and European norms, are reported in Project Requirements [ADi1] and ITER site meteorology [ADc35].

[41s1397-I] Site ambient conditions are given in the following table.

Table 2.1.1: Site Ambient Conditions

Elevation (meters above sea level)	315
Relative Humidity, 24 hour average	<=95%
Relative Humidity, 30 day average	<=90%
Ice Coating (mm)	<=10
Pollution Level (according to IEC 60071-2)	1(light)

[41s716-R;Defined Requirement] In addition, CPSD PIC components not completely protected by PIC civil structures shall be designed against the following conditions:

- The extreme permanent winds up to 29 m/s at 10 m above ground level.
- The air temperature down to -25ºC or up to +45ºC under extreme outdoor conditions.
- The snow conditions; a normal loading up to 80 daN/m^2 and an exceptional loading up to 150 daN/m^2

[41s712-R] External CPSD components shall comply with the ITER Site Master Plan [ADc9].

2.1.3 Equipment dimensional constraints

[41s715-R] CPSD shall comply with ITER equipment sizes and weights table given below

Table 2.1.2: ITER equipment sizes and weights

Length L (Maximum)	Width W (Maximum)	Height H (Maximum)	Mass M
19m with an exception for crane beams=47m on a single line	9m	9.1m	600 tons

[41s1240-R] All CPSD equipment design shall take into account possible impact on other SSC, for example due to collapse, debris, leaks and deflagration.

2.2 System specific requirements

[41s720-I] This section consists of performance requirements.

2.2.1 Achievement of plasma scenarios

[41s104-R;Defined Requirement] The CPSD system shall receive AC power from the grid and distribute it to the H&CD PS and to the CPSS, the latter delivering controlled power to the ITER magnets for plasma scenarios.

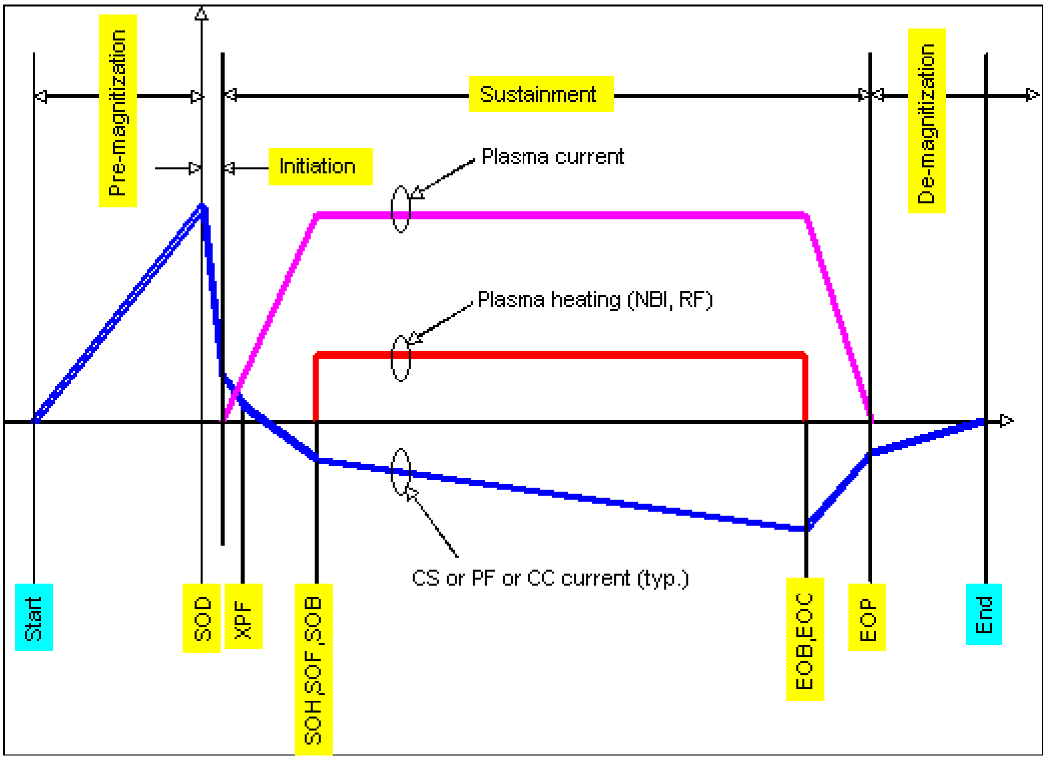
[41s1398-I] The following three plasma scenarios, defined as "reference" scenarios, have been developed as illustrations of scenarios demonstrating the key ITER mission goals:

- Inductive Operation: 500 MW, Q=10, 15MA with heating during ramp-up
- Hybrid scenario
- Non-inductive scenario.

[41s1241-R] The CPSD system shall be upgradable (with additional investment) to operate with a fusion power of 700MW for 100 s. However, in the absence of 700MW reference scenario, it is presently assumed that this 700MW scenario is achievable without any upgrade.

[41s110-I] A conceptual scenario is described in the following figure.

Figure 2.2.1: Conceptual Scenario



[41s721-I] SOD - Start of discharge, XPF- X-point formation, SOH - Start of heating, SOF - Start of flat-top, SOB - Start of burn, EOB -End of burn, EOC - End of cooling, EOP- End of plasma current.

[41s116-I] The plasma scenarios comprise four phases as follows:

I. Pre-magnetization: The CS, PF, and CC coil currents are ramped from zero to their initial values by control of the AC/DC converters.

II. Plasma initiation: The CS and PF coil currents are varied by insertion of SNU resistors and by control of the AC/DC converters to create the necessary loop voltage and magnetic field pattern for plasma initiation. The ECRF and/or ICRF heating systems are started at the SOD assisting the plasma initiation.

III. Plasma sustainment: The currents in the CS, PF, CC, VS3 and ELM coils are varied by control of the AC/DC converters for control of plasma current, position and shape, for reduction of non-axisymmetric error fields, and for control of ELMs and RWMs in the future (if required). The H&CD power supplies are used to heat the plasma and to modify the plasma current magnitude and cross sectional distribution.

IV. De-magnetization: The CS, PF and CC currents are ramped from their final values down to zero by control of the AC/DC converters.

2.2.1.1 Pre-magnetization phase

[41s123-R] The AC/DC converters shall control the CS, PF, and CC currents to follow a linear ramp waveform from zero to any value (up to their rated maximum value) over a time duration range decided by the plasma control.

2.2.1.2 Plasma initiation phase

[41s126-R] The plasma initiation phase has a duration of about 2 seconds, and the CS, PF, and CC currents shall be controlled by the AC/DC converters, along with resistors inserted by the SNUs in the CS, PF1 and PF6 circuits. The SNUs are also required during the following initial phase of plasma current ramp-up (for CS1 up to about 15 s).

2.2.1.3 Plasma sustainment phase

[41s129-R] During the plasma sustainment phase, the CPSS shall be capable to support PF scenarios within the limits on the coil voltages and currents specified in Table 2.2.3 and within the limit on the total power of PPEN, 500 MW.

2.2.1.4 De-magnetization phase

[41s157-R] The AC/DC converters shall control the CS, PF, and CC coil currents to reduce from any value down to zero.

2.2.2 Duty Cycle Requirements

[41s1242-R] CPSD shall comply with Pulse Duration and Duty Cycle Requirement in tables given below.

Table 2.2.1: Pulse Duration and Duty Cycle Requirement

Parameter	15MA inductive scenario	Hybrid scenario	Non-inductive scenario
Plasma Current, Ip (MA)	15.0	12.5	10
Fusion Power, Pfus (MW)	500	420	400
Padd (MW)	50	70	80
Energy Multiplication, Q	10	6	5
Burn time (s)	450	1000	3000
Total heating power, P (MW)	151	154	130

Parameter	Short-burn (< 450 s)	Long-burn (> 450 s)	DT-1 (Q = 10 / 300 s)	DT-2 (> 450 s burn)

Minimum repetition time	1800 s (≥ 2 pulses / h)	4 × previous pulse duration (≥ 25 % duty cycle)	3600 s (≥ 1 pulse / h)	4 × previous pulse duration (≥ 25 % duty cycle)

2.2.3 CPSS requirements

[41s163-I] The CPSS is comprised of the following power supply systems:

- Toroidal Field (TF) Power Supply
- Central Solenoid (CS) and Poloidal Field (PF) Power Supplies
- Vertical Stabilization 1 (VS1) Power Supplies
- Correction Coils (CC) Power Supplies
- ELM Power Supplies
- Vertical Stabilization 3 (VS3) Power Supply.

[41s1399-R] CPSS design shall permit the discharge of multiple coils in the following cases:

- In the event of a TF fault, quench, or other abnormal condition, all TF, CS, PF and CC coils are discharged to divert stored magnetic energy to an external energy sink.
- In the event of a TF fast discharge, all TF, CS, PF and CC coils are fast discharged.
- In the event that a fast discharge of any PF or CS coil is required, a fast discharge of all of the PF and CS coils is invoked. A fast discharge of the PF and CS and CC coils does not trigger the fast discharge of the TF coils.

2.2.3.1 Toroidal Field (TF) Power Supply

[41s165-I] The TF Power Supply is comprised of the following elements:

- Line Disconnector and earthing devices (AC side), converter transformer and AC/DC converter
- Fast Discharge Units (FDUs) to protect the coils in case of quench
- Protective Make Switches (PMS) to bypass the AC/DC converter under fault conditions
- DC bus bars and bus links
- DC circuit earthing and earth current sensors
- DC earthing switches
- Instrumentation for control and protection
- Local control system and auxiliaries.

[41s172-R] The TF Power Supply shall be connected to the 66 kV busbar, and provide controlled DC current to the TF magnet system, which is comprised of 18 superconducting coils. The TF coils shall be connected in series, and grouped into 9 coil pairs interleaved with 9 FDUs and one AC/DC converter.

[41s1400-I] The self-inductance per TF coil is 349 mH, and the total inductance of the 18-coil system is 17.7 H. The TF coils are mutually coupled to conducting elements which link toroidal flux, including the vacuum vessel. Ideally the coupling to the CS, PF and CC coil systems is zero.

2.2.3.1.1 TF AC/DC Converter

[41s178-R] The TF AC/DC converter shall be a 12-pulse 2-quadrant thyristor converter included in the series circuit to charge, sustain and discharge the current during normal operation, with performance requirements as given in Table 2.2.2. The current shall be controllable to any value between zero and the maximum value given in Table 2.2.2.

Table 2.2.2: TF Current Requirements

Parameter	Requirement
Maximum current (kA)	68
Maximum Charge time (min)	120
Sustainment time	Continuous
Maximum Discharge time (slow/accelerated, min)	120/30
# Charge-slow or accelerated discharge cycles	1000*

*Following assessment of the TF coils final design [59], the slow/accelerated discharge cycles of the TF coils shall be reduced to maximize their service lifetime. [59] recommends reducing the TF slow/accelerated-discharge cycles to around 100

[41s179-R] Reversing links shall be provided for reversal of the TF current polarity.

[41s180-R] The AC/DC converter's local controller shall provide closed loop current control.

[41s723-R] The AC/DC converter shall provide Fault Suppression Capability (FSC) defined as follows:

- Thyristors shall be sized in number and rating such that they retain their capability for suppression (blocking reverse voltage) after DC terminal fault, under worst case conditions, following a temperature rise from the maximum normal operating condition.
- All thyristors shall be connected to the AC source through fuses, which shall blow in case of a single thyristor fault, but shall not blow in case of DC terminal fault, under worst-case conditions, following a temperature rise from the maximum normal operating condition.

[41s181-R] The AC/DC converter shall be equipped with thyristor bypass capability, which shall be capable of carrying the load current on continuous duty, with the load current excluded from the AC source converter transformer windings. The bypass shall be controlled by an external command (such as a quench command from the magnet/central control) and internal fault response logic, as applicable.

[41s182-R] The converter controls shall include adjustable settings for minimum and maximum firing angle, and shall include constant margin angle control to limit maximum firing angle in inversion, as a function of input AC voltage and output DC load current.

[41s183-R] The converter controls shall be self-protecting by incorporation of suitable interlocks.

[41s725-R] The converter controls shall permit transition from the rectification mode into the bypass mode, and vice-versa, when conditions permit.

2.2.3.1.2 TF Fast Discharge Units (FDU)

[41s185-R;Defined Requirement] Nine (9) Fast Discharge Units (FDUs) shall be interleaved, in series, with the 9 coil pairs, for rapid discharge of the stored magnetic energy. The equivalent (constant resistance) L/R decay time constant shall be $\tau = 11$ seconds, corresponding to a maximum $\int i^2(t)dt = I_0^2\tau/2 = 2.54 \times 10^{10}$ Amp^2-seconds for a discharge from 68 kA.

[41s1401-R;Defined Requirement] The TF FDU shall be designed to be able to operate for 50 fast discharges over the life of ITER (the fast discharge cycles shall be minimized as much as possible to maximize the TF FDU service lifetime).

2.2.3.1.3 Protective Make Switch (PMS)

[41s186-R;Defined Requirement] The TF PMS shall be provided to bypass the AC/DC converter under fault conditions. The TF PMS shall be able to withstand the $\int i^2(t)dt$ associated with a fast discharge, in case active cooling is lost.

The TF PMS shall be capable of withstanding the maximum prospective fault current of the AC/DC converter.

2.2.3.1.4 DC Bus Bars and Bus Links

[41s728-R] The TF DC bus bars and bus links shall be designed for continuous duty at the rated current, shall be able to withstand the fault current of the TF AC/DC converter, and shall meet the fast discharge $\int i^2(t)dt$ without cooling.

2.2.3.1.5 DC Circuit Earthing and Earth Current Sensors

[41s730-I] See Section 2.8.

2.2.3.1.6 DC Disconnecting and Earthing Switches

[41s732-R] DC earthing switches shall be provided, to earth the circuit containing the coils and FDUs, to allow safe personnel access. The switches shall be designed for automatic operation under no-load conditions, and shall include mechanical and electrical interlock features, to ensure that change of state can only occur under appropriate conditions.

2.2.3.1.7 Instrumentation for Control and Protection

[41s734-I] See section 2.9.1.

2.2.3.1.8 Local Control System and Auxiliaries

[41s736-I] See section 2.9.2.

2.2.3.2 Central Solenoid (CS) and Poloidal Field (PF) Power Supplies

[41s188-I] The CS and PF Power Supplies are comprised of the following elements:

- Line disconnectors and earthing devices (AC side), converter transformers and AC/DC converters;
- Switching Network Units (SNUs) to provide plasma initiation loop voltage (CS, PF1 and PF6 only);
- Fast Discharge Units (FDUs) to protect the coils in case of quench;
- Protective Make Switches (PMS) to bypass the AC/DC converters and SNUs under fault conditions;
- DC bus bars and bus links;
- DC circuit earthing and earth current sensors;
- DC disconnecting and earthing switches;
- Instrumentation for control and protection;
- Local control system auxiliaries.

[41s196-R] The CS and PF Power Supplies shall be connected to the 66 kV busbars, and provide controlled voltage/current to the superconducting PF system for plasma initiation and control of plasma current, position and shape. The PF system is comprised of the segmented CS and the six PF coils. The CS consists of six modules. All PF coils and all CS modules, except for the two central modules (CS1U and CS1L), shall have independent power supplies, used for the plasma current, position and shape control. The two central modules of the CS shall be connected in series to a common power unit. At SOD, the CS modules and coils PF1, PF6 carry large currents, which are rapidly decreased during the initial phase of the PF scenario [ADc45], to provide the needed flux change. In order to limit the power requirements for these coils, they are connected, at this time, to their converters through the resistors of the SNUs. The remaining PF coils (PF2 to PF5) are directly connected to their main converters.

[41s205-R] The power supplies shall be capable of operating the superconducting PF system that is used for plasma initiation and control of plasma current, position and shape with the voltage and current levels defined in Table 2.2.3.

Table 2.2.3: The CS and PF Power Supplies current ratings and maximum voltages used for plasma initiation and control of plasma current, position and shape

Coil	Maximum current* (kA)	Voltage from Switching Network Units (kV)	Maximum Voltage from Converters (on-load) **(kV)	Maximum voltage at plasma initiation (kV)
CS3U	45	8.5	2.1	10
CS2U	45	8.5	2.1	10
CS1U	45	6.0	2.1	8.1
CS1L	45	6.0	2.1	8.1
CS2L	45	8.5	2.1	10
CS3L	45	8.5	2.1	10
PF1	48	8.5	2.1	10
PF2	55	-	3.15	3.15
PF3	55	-	3.15	3.15
PF4	55	-	3.15	3.15
PF5	52	-	3.15	3.15
PF6	52	8.5	2.1	10
VS1	22.5	-	6.3	-

[41s737-I] Note:

(*) For the purpose of standardization, following modular topology and reduced operational inventory/spares AC/DC converters maximum current ratings being defined as 45 kA for all CS Converters, 55 kA for all PF Converters and 22.5 kA for VS1 Converter.

(**) Maximum voltage from AC/DC converters depends on the number of units connected in series in the circuit. The basic types of converter unit required are :

- CS: ±1.05 kV/±45 kA;
- PF: ± 1.05 kV/±55 kA;
- VS1: ± 1.05 kV/±22.5 kA.

[41s1402-I] The voltage and current levels in Table 2.2.3 refer to the final configuration defined in the Staged Approach; the applicable voltage and current levels for the intermediate stages are listed in Section 7.

[41s216-I] The CS and PF coils are mutually coupled to conducting elements which link poloidal flux, including the plasma, vacuum vessel and cryostat. Ideally, the coupling to the TF coil system is zero. Although the CCs link poloidal flux, since each CC circuit is comprised of two coils connected anti-series, the net mutual coupling between CS/PF and CC is (ideally) zero.

2.2.3.2.1 CS/PF AC/DC Converters

[41s738-R] The CS and PF AC/DC converters shall comprise 12-pulse 4-quadrant thyristor converters, connected in series and parallel combination, to supply the converter voltages specified in Table 2.2.3. The CS, PF1 and PF6 converters shall be supplemented with SNUs during the Plasma Initiation Phase, whereas the PF2-PF5 converters shall be sized to provide the full-specified voltage during the Plasma Initiation Phase without the use of SNUs. The AC/DC converters shall be designed to provide the required voltage over the full range of operating conditions including:

- HV grid daily and seasonal voltage variation;
- AC voltage drop due to the PPEN source impedance.

[41s220-R] 4-quadrant operation shall be achieved using circulating current mode around current zero crossing such that the load coils are never open circuited. Depending upon the voltage requirement from plasma control, and number of converter units connected in the circuits, the converter controller shall apply a control strategy that reduces the reactive power demand.

[41s221-R] The AC/DC converter's controller shall provide two control modes, namely open loop voltage control with the feed-forward of input AC voltage and output DC load current and closed loop current control.

[41s739-R] All AC/DC converters shall provide Fault Suppression Capability (FSC) defined as follows:

- Thyristors shall be sized in number and rating such that they retain their capability for suppression (blocking reverse voltage) after a DC terminal fault downstream to the DC reactor, under worst case conditions, following a temperature rise from the maximum normal operating condition;
- All thyristors shall be connected to the AC source through fuses, which shall blow in case of a single thyristor fault, but shall not blow in case of a DC terminal fault, and DC short upstream of the DC reactor, under worst case conditions, following a temperature rise from the maximum normal operating condition.

[41s740-R] Parallel rectifier bridges within the converters shall be connected through inductors which serve to:

- limit the circulating current between rectifiers under fixed firing angle conditions;
- limit the transient circulating current between rectifiers under transient firing angle conditions;
- limit the rate of rise and prevent overshoot of fault current due to a short circuit at the converter terminals.

[41s222-R] All AC/DC converters shall be equipped with bipolar (both current directions) thyristor bypass capability, which shall be capable of carrying the load current for a duration no less than the time required for the current to fully commutate from the converter to the mechanical protection device, with the load current excluded from the AC source converter transformer windings. The bypass shall be controlled by an external command, and internal fault response logic, as applicable.

[41s223-R] The converter rate of change of voltage shall be linearly rate limited such that:

- The response in change of voltage from (+) to (-) and from (-) to (+) is symmetric;
- The full scale change from (+) to (-) and from (-) to (+) is accomplished within two electrical cycles, or less (40 ms based on 360° at 50Hz).

[41s227-R] The converter controls shall include adjustable settings for minimum and maximum firing angle, and shall include constant margin angle control to limit maximum firing angle in inversion, as a function of input AC voltage and output DC load current.

[41s228-R] The converter controls shall be self-protecting by incorporation of suitable interlocks.

2.2.3.2.2 CS, PF1 and PF6 Switching Network Units (SNUs)

[41s230-R] SNUs shall be provided in the CS, PF1 and PF6 circuits to provide, in series with the AC/DC converters, a high loop voltage during plasma initiation and plasma current ramp up. Each SNU shall comprise a DC circuit breaker that opens upon command and diverts the coil current into a resistor bank. The resistor bank shall be subdivided into two sub-banks, R1 and R2, the second of which is connected sequentially by a make switch such that the total effective resistance decreases in two stages.

[41s231-R] The resistance of each SNU resistor stage shall be adjustable by bus link selection of the number of parallel resistor elements such that a range of resistance covering minimum, nominal, and maximum conditions is provided as given in the following table.

Table 2.2.4: Range of minimum, nominal, and maximum conditions for definition of SNU resistor range

	CS1	CS2, CS3, PF1	PF6
V_{max} (kV)	6.0	8.5	8.5
V_{min}	33.33%	33.33%	33.33%
V_{min} (kV)	2.0	2.83	2.83
I_{max} (kA)	45	45	35
I_{min}	40%	40%	40%
I_{min} (kA)	18	18	14

[41s232-R] The energy rating of the resistors shall be such that the full stored energy of the CS and PF system can be absorbed based on an L/R decay from any viable initial condition, comprising of a particular resistor bank combination within the design range and corresponding initial current, constrained by $V=I \times R \leq V_{max}$. The requirement is that the SNU and resistors shall not be damaged in this scenario, which comprises a worst-case fault event. No limit is placed on the cool down time for this scenario.

[41s234-R] For normal operations, the maximum time duration of SNU operation shall be up to 15 s in the CS1 circuit, and 3.5 to 4.0 seconds in the other circuits. Under these conditions, the resistance value shall be maintained within 10% of nominal value up to the time of plasma breakdown during a pulse, and from one pulse to the next. The repetition period shall be 1800 seconds, minimum.

[41s235-R] Interlocks shall be provided to prevent operation with I x R value which would result in a voltage (after initial transient) greater than that specified in the table above.

[41s236-R] Voltage transients between the SNU terminals due to switching shall be limited to 110% of the nominal current x resistance value.

[41s233-R] The design number of operating cycles shall be equal to the number of ITER pulses over its lifetime (see Section 2.2.3).

[41s742-R] Equipment shall be designed for indoor installation.

2.2.3.2.3 CS/PF Fast Discharge Units (FDUs)

[41s238-R] For the CS coils, the equivalent (constant resistance) L/R decay time constant shall be $\tau \leq 7.5$ seconds, corresponding to a maximum $\int i^2(t)dt = I_0^2\tau/2 = 7.59 \times 10^9$ Amp^2-seconds for a discharge from 45 kA. For the PF coils, the equivalent (constant resistance) L/R decay time constant shall be $\tau \leq 14.0$ seconds, corresponding to a maximum $\int i^2(t)dt = I_0^2\tau/2 = 2.12 \times 10^{10}$ Amp^2-seconds for a discharge from 55 kA.

[41s240-R] The FDUs in the CS and PF coils shall always be operated in unison.

[41s1403-R] The temperature coefficient of the resistance of resistor materials shall be exploited such that peak discharge voltage occurs after switching operation, and is not greater than 80% of the initial voltage, which would occur with constant resistance discharge.

[41s743-R] The CS/PF FDU shall be designed for 500 fast discharges of CS/PF coils over the ITER lifetime.

[41s1244-R] The CS and PF FDUs shall be ready for plasma operation within 2 hours following a fast discharge of the CS, PF or CC circuits.

2.2.3.2.4 CS/PF Protective Make Switches (PMS)

[41s745-R] The CS/PF PMSs shall be provided to bypass the AC/DC converters and SNUs under fault conditions. The CS/PF PMS shall be rated to carry the CS/PF current on a continuous basis with active cooling, and shall be able to withstand the $\int i^2(t)dt$ associated with a fast discharge in case active cooling is lost. The PMS which bridges the AC/DC converter shall be capable of withstanding the maximum prospective fault current of the AC/DC converter.

2.2.3.2.5 DC Bus Bar and Bus Links

[41s747-R] DC bus bars and bus links shall be designed for continuous duty at the rated current, and shall be able to withstand the fault current of the CS/PF AC/DC converter.

2.2.3.2.6 DC Circuit Earthing and Earth Current Sensors

[41s749-I] See section 2.8.

2.2.3.2.7 DC Disconnecting and Earthing Switches

[41s751-R] DC disconnecting and earthing switches shall be provided, to isolate and earth the High Voltage equipment to allow safe personnel access. Switches shall be designed for automatic operation under no-load conditions, and shall include mechanical and electrical interlock features, to ensure that change of state can only occur under appropriate conditions. Disconnect switches shall be designed for continuous duty at the rated current, and shall be able to withstand the fault current of the CS/PF AC/DC converter.

2.2.3.2.8 Instrumentation for Control and Protection

[41s753-I] See section 2.9.1.

2.2.3.2.9 Local Control System and Auxiliaries

[41s755-I] See section 2.9.2.

2.2.3.3 Vertical Stabilization (VS1 & VS2) Power Supplies

[41s757-R] Stabilization of plasma vertical displacements through ex-vessel coils shall be performed by the stabilizing circuit VS1.

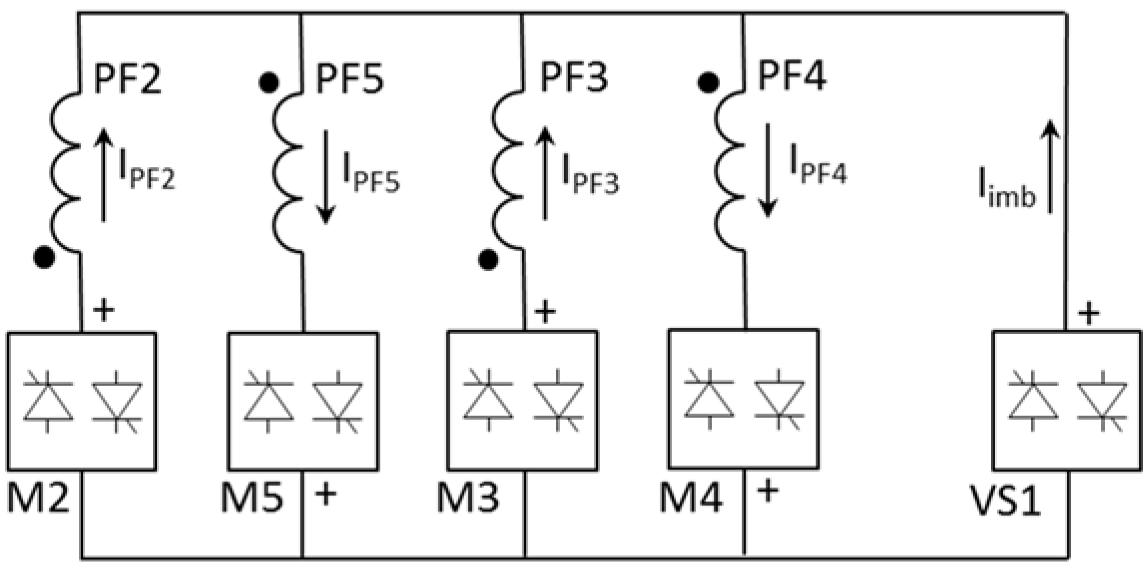
[41s758-I] The quasi-symmetrical configuration of the PF coils allows the use of one AC/DC converter, dedicated to plasma vertical stabilization (VS1). The VS1 converter is connected to the coils PF2 to PF5, as shown in the simplified schematic of Figure 2.2.3.

[41s1404-R] The VS1 and VS2 converter shall be capable of generating the output voltage and current ratings listed in Table 2.2.5.

[41s919-R] The converter rate of change of voltage shall be linearly rate limited such that:

- The response in change of voltage from (+) to (-) and from (-) to (+) is symmetric;
- The full scale change from (+) to (-) and from (-) to (+) is accomplished within one electrical cycle, or less (20 ms based on 360° at 50 Hz).

Figure 2.2.3: The vertical stabilization circuit: VS - the vertical stabilization converter (VS1); M2-M5 are the main converters of the coils PF2-PF5



[41s765-R] In the case of failure of the in-vessel coils (VS3), the vertical stabilization system based on external coils shall be upgradeable in the following way:

- The necessary busbar connections allowing the possible use of coils CS2U and CS2L as a component of the external vertical stabilization circuit (designated VS2) shall be made available

[41s1405-R] The VS1 and VS2 power supply shall be designed, constructed, installed and operated to contribute to the vertical stabilization of the plasma for a total number of maximum uncontrolled vertical drift events of 30,000 over the lifetime of ITER, with such large amplitude events limited in frequency and number of occurrences per pulse to 0.1Hz and 3, respectively.

Table 2.2.5: The VS1 and VS2 Power Supplies current ratings (kA) and maximum voltages (kV)

VS circuit	Baseline VS		Upgraded VS (in case of VS3 failure)	
	Current (kA)	Voltage (kV,on-load)	Current (kA)	Voltage (kV, on-load)
VS1	22.5	6	22.5	9
VS2	-	-	≤ 45	6

2.2.3.4 Correction Coil (CC) Power Supplies

[41s244-I] The CC Power Supplies comprise the following elements:

- Line disconnector, converter Transformers and AC/DC converters;
- Make Switch and Thyristor Bypass Switch
- DC bus bars and bus links;
- DC circuit earthing and earth current sensors;
- DC disconnecting and earthing switches;
- Instrumentation for control and protection;
- Local control system and auxiliaries.

[41s250-I] The CCs comprise 9 pairs of superconducting coils. Each coil in a pair covers a 60o toroidal sector, and the two coils comprising a pair are located diametrically opposite to one another, and are connected in anti-series such that the net mutual coupling to the CS/PF coils is zero.

2.2.3.4.1 CC AC/DC Converters

[41s251-R] Power supplies shall be provided for each of the 9 CC circuits, comprising of directly connected coil pairs, to provide controlled DC current. Power supplies shall be 12-pulse, 4-quadrant thyristor converters, with the voltage and current ratings given in the following table.

Table 2.2.6: Correction Coil Power Supply Requirements

CC location	# CC circuits	Rated On-load Voltage*	Rated Current
Top	3	+/-85 V	+/- 10kA
Side	3	+/-300 V	+/-10kA
Bottom	3	+/- 85V	+/-10kA

[41s766-I] * Voltages required for dynamic control of error fields, using plasma response, need to be better defined.

[41s252-R] 4-quadrant operation shall be achieved using circulating current mode around current zero crossing, such that the load coils are never open circuited.

[41s253-R] The AC/DC converter's controller shall provide two control modes, namely open loop voltage control with the feed-forward of input AC voltage and output DC load current and closed loop current control.

[41s767-R] The AC/DC converters shall provide Fault Suppression Capability (FSC) defined as follows:

- Thyristors shall be sized in number and rating such that they retain their capability for suppression (blocking reverse voltage) after a DC terminal fault, under worst case conditions, following a temperature rise from the maximum normal operating condition;
- All thyristors shall be connected to the AC source through fuses, which shall blow in case of a single thyristor fault, but shall not blow in case of a DC terminal fault, under worst case conditions, following a temperature rise from the maximum normal operating condition.

[41s768-R] Parallel rectifier bridges, within the converters, shall be connected through inductors, which serve to:

- limit the circulating current between rectifiers under fixed firing angle conditions;
- limit the transient circulating current between rectifiers under transient firing angle conditions;
- limit the rate of rise and prevent overshoot of fault current due to a short circuit at the converter terminals.

[41s254-R] All CC AC/DC converters shall be equipped with bipolar (both current directions) thyristor bypass capability, which shall be capable of carrying the rated load current for a duration no less than the time required for the current to fully commutate from the converter to the mechanical protection device, with the load current excluded from the AC source converter transformer windings. The bypass shall be controlled by an external command, and internal fault response logic, as applicable.

[41s255-R] The converter rate of change of voltage shall be linearly rate limited such that:

- The response in change of voltage from (+) to (-) and from (-) to (+) is symmetric;
- The full scale change from (+) to (-) and from (-) to (+) is accomplished within two electrical cycles, or less (40 ms based on 360° at 50 Hz).

[41s256-R] The converter controls shall include adjustable settings for minimum and maximum firing angle, and shall include constant margin angle control to limit the maximum firing angle in inversion, as a function of input AC voltage and output DC load current.

[41s257-R] The converter controls shall be self-protecting by incorporation of suitable interlocks.

2.2.3.4.2 Fast Discharge Requirement

[41s770-R] In case of a quench, the CC Fast Discharge shall be performed by AC/DC converters; fast discharge units are not required. However, in case of converter fault, the PMS shall be triggered and sufficient DC resistance shall be included in the CC circuits such that the L/R decay time constant is less than or equal to 18 seconds (Table 9 in [R55]).

[41s1406-R] The CC Fast Discharge System shall be designed for 500 fast discharges of CC coils over its lifetime.

2.2.3.4.3 DC Bus Bars and Bus Links

[41s774-R] The DC bus bars and bus links shall be designed for continuous duty at the rated current, and shall be able to withstand the fault current of the CC AC/DC converter.

2.2.3.4.4 DC Circuit Earthing and Earth Current Sensors

[41s776-I] See Section 2.8.

2.2.3.4.5 DC Disconnecting and Earthing Switches

[41s778-R] DC disconnecting and earthing switches shall be provided, to isolate and earth High Voltage Equipment, to allow safe personnel access. Switches shall be designed for automatic operation under no-load conditions, and shall include mechanical and electrical interlock features, to ensure that change of state can only occur under appropriate conditions. Disconnect switches shall be designed for continuous duty at rated current, and shall be able to withstand the fault current of the CC AC/DC converter.

2.2.3.4.6 Instrumentation for Control and Protection

[41s780-I] See section 2.9.1.

2.2.3.4.7 Local Control System and Auxiliaries

[41s782-I] See section 2.9.2.

2.2.3.5 ELM Power Supplies

[41s772-I] The ELM Power Supplies are comprised of the following elements:

- Circuit breaker, converter transformers and power converters;
- Bus bars and bus links;
- Circuit earthing and earth current sensors;
- Disconnecting and earthing switches;
- Instrumentation for control and protection;
- Local control system and auxiliaries.

[41s1157-I] In ITER, there are 27 in-vessel copper coils for ELM control (9 upper, 9 equatorial and 9 lower coils)

[41s1407-R] The ELM Power Supplies shall provide independently controlled current to each of the ELM coils for control of Edge Localized Modes (ELMs).

[41s1408-R] The ELM Power Supply system shall permit to rotate the Resonant Magnetic Perturbation (RMP) field distribution at rates up to five periods per second at full RMP amplitude (full coil current oscillations at 5 Hz, each coil current phase shifted according to the distribution of the rotating field with toroidal mode number n greater than 0).

[41s1166-R] The ELM coil circuits and power converters shall be designed and operated to withstand transient overcurrent and overvoltage conditions induced by both normal plasma operation and disruptions.

2.2.3.5.1 ELM Power Converters

[41s1159-R] The ELM Power Converters shall provide controlled current to each of the 27 ELM coil circuits. The converters shall be capable of 4-quadrant operation, with the voltage and current ratings given in Table 2.2.7.

Table 2.2.7: ELM Power Supply Requirements

ELM coils location	# of ELM circuits	On-load voltage	Rated current (DC or peak AC)
Upper	9	≥ 180 V	15 kA
Equatorial	9	≥ 180 V	15 kA
Lower	9	≥ 180 V	15 kA

[41s1409-R] The ELM Power Supplies shall be connected to the 22 kV MV AC distribution system.

[41s1161-R] Each ELM Power Converter's local controller shall provide two control modes, namely closed loop voltage control and closed loop current control.

[41s1163-R] The converter rate of change of output voltage shall be linearly rate limited such that:

- The response in change of voltage from (+) to (-) and from (-) to (+) is symmetric;
- The full scale change from (+) to (-) and from (-) to (+) is accomplished within 20 ms.

[41s1165-R] The converter controls shall be self-protecting by incorporation of suitable interlocks.

2.2.3.5.2 Busbars and Bus Links

[41s1168-R] The bus bars and bus links shall maintain their functions during normal operation as well as postulated abnormal events, the latter including, but not limited to, the fault current of the ELM power converter and currents induced by plasma disruptions.

[41s1248-R] The busbars and/or busbar links inside interspace interfacing with IVC feedthrough shall be designed to accommodate 500 baking cycles from commissioning phase to end of life of ITER.

2.2.3.5.3 Circuit Earthing and Earth Current Sensors

[41s1170-I] See Section 2.8.

2.2.3.5.4 Disconnecting and Earthing Switches

[41s1172-R] Disconnecting and earthing switches shall be provided, to isolate and earth the coil circuits, to allow safe personnel access. Disconnect switches shall be designed for continuous duty at rated current, and shall be able to withstand the fault current of the ELM power converter as well as any induced currents in the ELM coil circuits during normal plasma operation and disruptions .

2.2.3.5.5 Instrumentation. Control and Protection

[41s1174-I] See Section 2.9.1.

2.2.3.5.6 Local Control System and Auxiliaries

[41s1176-I] See Section 2.9.2.

2.2.3.6 VS3 Power Supply

[41s1178-I] The VS3 Power Supply is comprised of the following elements:

- Circuit breaker, converter transformer and power converter;
- Bus bars and bus links;
- Circuit earthing and earth current sensors;
- Disconnecting and earthing switches;
- Instrumentation for control and protection;
- Local control system and auxiliaries.

[41s1179-I] In ITER there are two sets of toroidal ring copper coils (VS coils) which provide fast vertical stabilization control of the plasma. One set of coils located in the upper half of the machine just above the upper ports and one set of coils located in the lower half of the machine just above the triangular support.

[41s1180-R] The upper and lower VS coils shall be connected and operated in an anti-series arrangement (saddle configuration) and fed by a single power supply system.

[41s1410-R] The VS3 Power Supply shall permit the connection and operation of the upper and lower VS3 coils in arrangements other than anti-series connection, for specific operating cases such as during commissioning.

[41s1411-R] The VS3 coil circuit shall be reconfigurable such that in case of failure of one coil turn, the faulty turn can be isolated. In such degraded operating scenarios, symmetry between upper and lower coil is typically to be maintained, which involves isolating a (healthy) turn on the opposite coil.

[41s1189-R] The VS3 coil circuits shall be designed and operated to withstand transient overcurrent and overvoltage conditions induced by plasma disruptions.

2.2.3.6.1 VS3 Power Converter

[41s1412-R] The VS3 Power Converter shall be capable of supplying pulsed power to the VS coils for fast vertical stabilization control, with the pulse duration, repetition rate and voltage and current levels as listed in Table 2.2.8.

Table 2.2.8: VS3 Power Supply Requirements

	Major VDE*	Minor VDE	Noise
No-load voltage	≥ 2.4 kV		
Peak current	60 (80*) kA	/	/
RMS current	/	TBC	2.9 or 3.9 kA (TBC) (bandwidth 1kHz)
Pulse duration	0.32 s	TBC	Continuous
Pulse period	10 s	TBC	
Number of events per plasma operation	3	TBC	
Total number of events	≤ 30000	TBC	-

[41s1437-I] * Minor VDE capability will be sufficiently covered by Major VDE ratings (to be rephrased)

[41s1250-R] * In case of 6-turn operation following the failure of one of VS coil turns, the VS3 power converter shall be capable of providing sufficient current to continue vertical stabilization control (4/3 of peak current).

[41s1185-R] The VS3 Power Converter shall be capable of 4-quadrant operation, i.e. supplying bipolar voltage and bidirectional current to the load coils.

[41s1186-R] The VS3 Power Converter's local controller shall provide two control modes, namely closed loop voltage control and closed loop current control.

[41s1187-R] The VS3 Power Converter's voltage response time from zero to full positive or full negative output voltage, starting from no-load conditions, shall be less than or equal to 1 ms.

[41s1188-R] The converter controls shall be self-protecting by incorporation of suitable interlocks.

2.2.3.6.2 Busbars and Bus Links

[41s1191-R] The bus bars and bus links shall be designed to meet VS3 power supply requirements, and shall be able to withstand the fault current of the power converter.

[41s1192-R] Bus links shall be provided, allowing any of the individual VS coil turns to be either included or excluded in the circuit.

[41s1251-R] The busbars and/or busbar links inside interspace interfacing with IVC feedthrough shall be designed to accommodate 500 baking cycles from commissioning phase to end of life of ITER.

2.2.3.6.3 Circuit Earthing and Earth Current Sensors

[41s1194-I] See Section 2.8.

2.2.3.6.4 Disconnecting and Earthing Switches

[41s1196-R] Disconnecting and earthing switches shall be provided, to isolate and earth the load, to allow safe personnel access. Disconnect switches shall be designed for continuous duty at rated current, and shall be able to withstand the fault current of the VS3 power converter.

2.2.3.6.5 Instrumentation. Control and Protection

[41s1198-I] See Section 2.9.1.

2.2.3.6.6 Local Control System and Auxiliaries

[41s1200-I] See Section 2.9.2.

2.2.4 PPEN Requirements

[41s261-R] The Pulsed Power Electric Network (PPEN) shall receive AC power from the HV grid, and distribute it at an intermediate voltage (IV), and a medium voltage (MV) to the pulsed loads of ITER, comprising of the CPSS and H&CD. The PPEN shall include a reactive power compensation system to regulate the AC voltage at the grid interface. The PPEN shall include filtering, to limit the PPEN component of the harmonic distortion of the AC voltage at the grid interface.

[41s1413-R] The PPEN shall be designed, constructed, installed and operated as to comply with all requirements set out in the Specification for Connection to RTE Network [ADc37] and support the performance of the ITER Plasma reference scenarios.

2.2.4.1 Characteristics of HV Grid

[41s265-I] The characteristics of the French national HV grid are described in "ITER Connection to the Grid", RTE Presentation, European ITER Site Studies Meeting EISS 5, January 2006, Cadarache, XF53-MIN-2006-0001.

[41s266-R] The PPEN system and all its components, including protective relaying systems, shall operate and withstand fault conditions over the range of HV grid short circuit power levels specified by RTE, as currently given in [ADc37].

[41s267-I] The French national grid (RTE) will supply a nominal HV voltage of 400 kV with a daily and seasonal variation of +/-5%. Exceptional voltage variations out of this range are possible [R54], as indicated in table 2.2.10.

Table 2.2.10: RTE exceptional HV Grid Voltage Variations

	Variation	Voltage
1 hour, 1 time per year, exceptionally	-20 to -15 %	320 to 340 kV
1.5 hour, a few times per year	-15 to -10 %	340 to 360 kV
5 hours, 10 times per year	-10 to -5 %	360 to 380 kV
20 minutes, several times per year	+5 to +6 %	420 to 424 kV
5 minutes, a few times per year	+6 to +7 %	424 to 428 kV
5 minutes, once every 10 years	+7 to +10 %	428 to 440 kV

[41s268-I] The nominal grid frequency is 50 Hz, with a daily and seasonal variation of +/-1%, corresponding to a nominal range of 49.5 to 50.5 Hz. Other less frequent variations are possible [R54], as indicated in table 2.2.11.

Table 2.2.11: HV Grid Frequency Variations

	Variation	Frequency
1 minute, once every 5 to 10 years, exceptionally	-6 to -5 %	47 to 47.5 Hz
3 minutes, once every 5 to 10 years, exceptionally	-5 to -2 %	47.5 to 49 Hz
5 hours continuously, total 100 hours during service life	-2 to -1 %	49 to 49.5 Hz
1 hour continuously, total 15 hours during service life	+1 to +2 %	50.5 to 51 Hz
15 minutes, 1 to 5 times per year	+2 to +4 %	51 to 52 Hz
1 minute, exceptionally (transitional regime)	+4 to +10 %	52 to 55 Hz

[41s269-R] The PPEN systems shall be designed to withstand worst-case short circuit conditions, based on the maximum short circuit power, maximum voltage and minimum frequency. 400 kV equipment shall be designed for a short circuit current capacity of 40 kA.

[41s275-R] The PPEN protective relaying systems shall be designed to function over the full range of short circuit power, voltage, and frequency which are identified in [ADc37], Table 2.2.10 and 2.2.11, respectively.

[41s276-R] Nominal ITER power systems performance shall be determined based on the nominal short circuit power, nominal voltage and nominal frequency.

[41s282-R] The PPEN and other CPSD equipment shall be designed to supply the ITER load over the nominal range of 380 to 420 kV, and 49.5 to 50.5 Hz, but is not required to supply the load outside those ranges.

2.2.4.2 CPSS Loads

[41s285-I] The CPSS loads comprise the TF, CS/PF, VS1, CC and ELM and VS3 converter loads resulting from the scenarios specified in earlier sections of this document.

2.2.4.3 H&CD Loads

[41s287-R] The PPEN shall be designed to provide the power to H&CD systems based on the baselined heating powers specified in Table 2.2.12. The potential upgrade is not part of ITER Technical Baseline.

Table 2.2.12 –H&CD power to be delivered to plasma for SRO, DT-1 and DT-2 phases

Power delivered to plasma (MW)	SRO	DT-1 *(planned upgrades)*	DT-2 *(planned upgrades)*
EC	40	60 *(67)* Note 1	60 *(67)* Note 1
NB	0	33	33 *(50)* Note 2
IC	10	10 *(20)* Note2	10 *(20)* Note 2
Total	**50**	**103** *(up to 120 depending on triggered upgrades)*	**103** *(up to 137 depending on triggered upgrades)*

***Note 1**: The EC H&CD increase to add 20MW for DT-1 is part of the ITER Technical Baseline, the additional 7MW (up to 67MW) is a planned upgrade (see note 3).*
***Note 2**: The additional ICH/NBH power for DT-1 and DT-2 are planned upgrades (see note 3).*
***Note 3**: The planned upgrades for EC, NB and IC H&CD systems for DT-1 and DT-2 (Notes 1-2) are outside the ITER Technical Baseline, thus needing an ITER Council decision and dedicated Project Change Requests to trigger the works to complete their implementation.*

[41s1414-I] The H&CD loads comprise the electrical input power corresponding to the delivery of IC, EC, NBI and DNB power to the plasma, after accounting for efficiency (output power to plasma ÷ input power) and power factor, as given in interface documents.

[41s288-I] The H&CD loads comprise high and low power components, with fractional power consumption, as given in interface documents. These values are indicative of the power modulation expected during its operation.

2.2.4.4 PPEN Power Distribution

[41s301-R] The PPEN shall utilize multiple step-down transformers, to transform the HV input to intermediate and medium voltage levels, for power distribution to the loads, while providing impedance to limit the short circuit power without causing excess voltage drop under nominal load conditions. The nominal intermediate voltage (IV) level shall be 66 kV, and the nominal medium voltage (MV) level shall be 22 kV. Load assignments and the nominal voltage range during an ITER pulse (assuming HV grid within the nominal range) is summarized in Table 2.2.14.

Table 2.2.14: PPEN Power Distribution System

System	Load assignments	Nominal voltage range	Nominal voltage range
Intermediate Voltage (IV)	TFCS, PF, VS1, NBI	-6% to +10%	62kV to 72.5kV

Medium Voltage (MV)	CC, IC, EC, NBI_Auxiliary, DNB, VS3, ELM, Diagnostics	- 10% to +10%	19.8kV to 24kV

2.2.4.5 *PPEN Reactive Power Compensation*

[41s306-R] The PPEN shall include a reactive power compensation system, to regulate the HV grid voltage and flow of reactive power at the RTE node during an ITER pulse, to within +/- 3% at Boutre Substation.

[41s783-R] Voltage fluctuations at the RTE node during an ITER pulse shall be in conformity with [ADc37].

[41s1415-R] The PPEN and RPC shall be updated to comply with the RTE power quality requirements at the ITER 400kV substation PRIONNET in lieu of BOUTRE if it is demonstrated that the evolution of the RTE network or the connection of a new client requires so [ADc37].

2.2.4.6 *PPEN Harmonic Filtering*

[41s308-R] Harmonic filters shall be installed to limit the distortion of the HV grid at the RTE substation such that each harmonic voltage τh, expressed as a percentage of the supply voltage, shall not exceed the thresholds given in the Table 2.2.15 (compatibility level of harmonic voltage), and the total rate τg shall not exceed 4.8% where:

$$\tau_g = \sqrt{\sum_{h=2}^{40} \tau_h^2}$$

[41s784-R] The effective value of each harmonic shall be measured in accordance with the standard IEC 61000-3-6-1996, with a time interval of 10 minutes.

Table 2.2.15: PPEN Harmonic Filtering Requirements

Odd harmonics: non multiple of 3			**Odd harmonics: multiple of 3**			**Even harmonics**		
Order (h)	**Harmonic voltage (%)**		**Order (h)**	**Harmonic voltage (%)**		**Order (h)**	**Harmonic voltage (%)**	
	22kV	**66kV&400kV**		**22kV**	**66kV&400kV**		**22kV**	**66kV&400kV**
5	6	2	3	5	2	2	2	1.5
7	5	2	9	1.5	1	4	1	1
11	3.5	1.5	15	0.3	0.3	6	0.5	0.5
13	3	1.5	21	0.2	0.2	8	0.5	0.4
17	2	1	>21	0.2	0.2	10	0.5	0.4
19	1.5	1				12	0.2	0.2
23	1.5	0.7				>12	0.2	0.2
25	1.5	0.7						
>25	0.2+1.3(25/h)	0.2+0.5(25/h)						
Total Harmonic Distortion (THD)=at 22kV-8% at 66kV &400kV-3%								

2.3 Structural requirements

[41s315-R] All CPSD equipment shall be designed to withstand electromagnetic forces that are caused by short circuit current flow in the presence of stray magnetic field, self-generated by the CPSD equipment. For equipment that is located in the Tokamak complex, the stray magnetic field shall include that generated by the Tokamak, as defined in Section 2.14.

[41s317-I] The structural design requirements include the seismic loads that are defined in Section 2.5.

2.4 Mechanical requirements (including load conditions)

[41s1416-R;Defined Requirement] The CPSD mechanical components shall comply with Codes and Standards for ITER Mechanical Components [ADc48].

2.5 Seismic requirements

[41s349-R;Defined Requirement] CPSD Structure, System and Component (SSC) that are allocated a seismic class shall be designed, constructed and operated (including its maintenance) such that their capabilities are maintained as credited during/after the SL-2 seism, as defined in ITER Seismic Nuclear Safety [ADc21].

[41s350-R;Defined Requirement] For investment protection, all CPSD components shall be designed to remain functional during and after a seismic level-1 (SL-1) earthquake event from Load Specifications (LS) [ADc10]. The system/equipment shall be designed to re-start and operate after an SL-1 event without special maintenance or test.

[41s1278-R;Defined Requirement] The collapse, falling, dislodgement or any other spatial response of a CPSD component, as a result of an earthquake, shall not jeopardize the functioning of other components that provide a safety function during or after the earthquake.

[41s1279-R;Defined Requirement] The combination of loads from earthquakes with other loading events shall be considered.

[41s786-I] For more detailed and precise data, refer to the Load Specifications (LS) [ADc10].

2.6 Fire protection requirements

[41s1280-R;Defined Requirement] Fire protection for the ITER site shall be provided to meet the following objectives (ITER Fire Protection Approach [ADc24]):

- Prevent fire and fire damage that could lead to the release of radioactive or hazardous material to the environment;
- Limit releases in the case of postulated fires to within acceptable limits;
- Ensure personnel safety;
- Limit damage to the machine and property (investment protection).
- This is a general requirement for all the ITER PBSs, CPSD would not provide active fire protections or detection and is only responsible for passive design/materials to the allocated functions of limiting and/or preventing fire in the scope of PBS 41.

[41s396-R;Defined Requirement] The CPSD provisions concerning fire safety shall comply with the latest versions of the relevant codes and standards. In particular, NF C 13-000, NF C 13-200 and the IEC standards as well as the latest approved versions of the ITER Electrical Design Hand book (EDH) [ADc4][ADc5][ADc6][ADc7][ADc8] shall be taken into account.

[41s1050-R;Defined Requirement] The combustible material shall be kept to a minimum. Equipment shall be designed to limit the fire propagation to adjacent components.

[41s1358-R;Defined Requirement] Potential ignition sources shall be prevented or limited, and where an ignition source is present in a room, area or component appropriate protection measures shall be taken. This also covers the potential subsequent fire due to earthquake event.

[41s1051-R] If the converter transformers are liquid-insulated, K2 or K3 insulating dielectric shall be selected.

[41s1052-R] If the converter transformers are dry type, they shall belong to the F1 or F2 fire behaviour class.

[41s1281-R;Defined Requirement] For CPSD SIC systems that have redundant SIC trains, the redundant SIC components shall be located in independent and separate fire sectors. However, this independence/separation may not be possible in some cases, and when it is required to locate both redundant SIC components in the same fire sector, at least one of these components shall be protected against fire in order to maintain its required functionality.

[41s1283-R;Defined Requirement] In any given room, all the SIC-2 cubicles shall be on the same Train (A or B) for power supply and I&C cabling.

[41s1284-R;Defined Requirement] PBS-41 cables shall be installed in steel cable trays and conduits, which shall provide adequate physical protection and ensure reliable support to the cables during and after installation.

[41s1497-R] In all buildings containing SIC and/or radioactive substances, PBS-41 cable trays shall have a metallic cover to minimize the risk of fire propagation. In addition, a 2-hour fire protection envelope may be implemented on cable trays depending on the level of risk, in case of fire.

[41s1285-R;Defined Requirement] Electric cables that run through a fire sector boundary shall not contribute to the spread of fire by design and/or protection with a flame retardant material, in order to comply with one of the equivalent standards listed below, as specified in IO Cabling rules [ADc25] and [R61]:

- IEC 60332-3 and IEC 60332-1;
- NF 32070 C1;
- For cables in nuclear buildings: Euroclass with minimum class Cca-1sb-d1a1 according to EN50757;
- For cables in non-nuclear buildings: Euroclass with minimum class Cca-1sb-d2-a2 according to EN50757.

[41s1286-R;Defined Requirement] Electric cables that run through a fire sector, and that are required to operate in the event of fire, shall be fire-resistant by design and/or protection with a fire resistant material, in order to comply with the NF C 320-70 (that is, CR1 Class) or IEC 60331 [ADc25]. If it is not possible to design fire resistant cables or protect from fire, it shall be proven that the function of fast discharge can be carried out in case of fire in galleries or in electrical galleries.

[41s1288-R;Defined Requirement] PIC components shall be either protected from possible over-pressure or under-pressure induced by a fire occurring in the room in which they are located or from which they are sampling the atmosphere, or shall be designed to withstand the pressure.

[41s1289-R;Defined Requirement] All CPSD cubicles (SIC-2, non-SIC, SR) located in the same room with at least one non-redundant cubicle SIC-2 shall be equipped with an automatic fire detection and suppression system as defined in reference [ADc11].The redundant SIC-2 cubicles can be implemented with the SR, and non-SIC cubicles in rooms equipped with an automatic fire suppression system. Alarm shall be reported to the control rooms (normal and emergency control room). The minimum distance between SIC-2 cubicles and non-SIC cubicles shall be 2m in cubicles rooms.

[41s1417-R;Defined Requirement] All cables of the CPSD shall be halogen free according to one of the equivalent standards listed below, as specified in IO Cabling rules [ADc25]:

- Zero Halogen (according to IEC 60754-1) and Non toxicity (according to IEC 60754-2) [R61];
- For cables in nuclear buildings: Euroclass with minimum class Cca-1sb-d1a1 according to EN50757;
- For cables in non-nuclear buildings: Euroclass with minimum class Cca-1sb-d2-a2 according to EN50757.

[41s1418-R;Defined Requirement] All cables of the CPSD shall be Low smoke according to IEC 61034 as specified in IO Cabling rules [ADc25].

[41s1419-I] Each train (A and B) of the electrical supply and the I&C cabling of the SIC-1 and SIC-2 cubicles is routed through independent and separate routes (i.e. fire sectors in buildings). However, this independence/separation may not be possible in some cases, and when redundant trains are required to go through the same route - provided approval by IO safety - the intrusive train is protected against fire in order to maintain its functionality for 2 hour-fire, according to Eurocodes. This fire protection on SIC-1 and SIC-2 cabling is implemented by PBS-44.

[41s1420-I] All cables (power and I&C) are installed in cable trays and conduits with the following characteristics (implemented by PBS-44):

- For all cables, trays and conduits are made of steel providing adequate physical protection and ensuring reliable support to the cables during and after installation;

- In addition, in all nuclear buildings, trays have a metallic cover to minimize the risk of cables fire propagation;

[41s1360-R;Defined Requirement] CPSD penetrations through fire barriers sector boundary (like doors, pipes/ducts, cables/busbars, etc., including if any infilling/sealing) shall offer the same degree of fire resistance as the rest of the fire barrier that boundary (alone and/or with a fire-resistant material protection).

[41s1498-R] The CPSD SIC components shall be connected to the same SIC train for their required services (like power supply, I&C, gas & fluid) – for example Train A SIC cubicles only connected to Train A SIC services.

2.7 Electrical requirements

[41s73-R;Defined Requirement] The CPSD shall be in conformance with guidance given in

- ITER Electrical Design Handbook (EDH): EDH Part 1: Introduction [ADc4]; EDH Part 2: Terminology and Acronyms [ADc5]; EDH Part 3: Codes and Standards [ADc6]; EDH Part 4: Electromagnetic Compatibility (EMC) [ADc7]; EDH Part 5: Earthing and lightning protection [ADc8].
- IO Cabling Rules [ADc25].

2.8 Grounding and Insulation Requirements

[41s787-R] The CPSD components and systems shall include appropriate earthing and insulation as specified in EDH Part 5: Earthing and lightning protection [ADc8].

[41s399-R] The earthing system of CPSD shall ensure personnel safety, and preserve the functional performance of all powered equipment. Equipment earthing shall be installed and operated to comply with the applicable French codes and standards (Norme Français, NF), and the European Directives.

2.8.1 PPEN AC System

[41s401-R] The insulation design shall be in accordance with applicable IEC standards, as well as all applicable French Standards. For cases where the IEC and NF standards have not been harmonized, the more stringent standard shall apply. For custom equipment not covered by IEC or NF standards, test plans and procedures shall be developed, and tests shall be performed, to confirm functionality of equipment following good engineering practices.

2.8.2 CPSS DC Systems

[41s406-R] Terminals of each coil group, comprising of one or more coils connected directly in series, shall be connected to a high resistance earthing network, designed to balance voltage to earth at each terminal and to limit current in case of a single earth fault while allowing sufficient current for fault detection purposes. The earthing network shall include the following features:

- Earthing resistors, and capacitors if necessary, to provided voltage balance under transient conditions;
- Earth current monitoring and protection;
- Provision for opening earth connection and insertion of high voltage (HV) test equipment.

[41s410-R] All CPSS components and systems shall be insulated to allow routine maintenance HV testing at a level of 2E+1 kV DC, where E is equal to the maximum voltage across any coil group under any operating mode (including AC/DC converter + SNU voltage (where applicable), or FDU voltage (where applicable), whichever is higher).

2.9 Instrumentation and control requirements

[41s792-R] The CPSD shall have the following protection systems to shut down the TF coil AC/DC convertors in case of a fault:

- TF Local Safety System and related interlock signal pathways, which receive the command to shutdown and to communicate the same to the AC/DC converters;
- AC/DC converter local controls, which suppress gate pulses to the thyristors in case of a shutdown command.

[41s1421-R] The PPEN high and medium voltage I&C system shall be based on IEC 61850.

2.9.1 Instrumentation

[41s1422-R] Sufficient instrumentation shall be included in the CPSD plant system, to monitor component performance, system state, integrity and interlock within the design envelope, in order to ensure human safety/security, to record all system control actions, and to warn plant operators of the onset of operation outside the design margins, or of any off normal event.

[41s324-R] Instrumentation shall be provided to measure Voltage/Current signals that are essential to plasma control, and the operation of ITER as an integrated system.

[41s331-R] Additional instrumentation shall be provided, as required, for the CPSD operators to measure, monitor and troubleshoot the performance of the CPSD. The segregation of signals for plasma control and operation shall be provided.

2.9.2 Control

[41s333-R;Defined Requirement] The CPSD shall be controlled via a hierarchical network of local control cubicles (LCCs). The functions of the LCCs are:

- Real time operational control and monitoring;
- Interlocks for equipment protection and emergency shutdown;
- Nuclear safety control and monitoring;
- Personnel safety control and monitoring.

[41s338-R;Defined Requirement] The CPSD instrumentation and control (I&C) shall conform to the standards specifications and interfaces as documented in the Plant Control Design Handbook [ADc11] and Plant Control Design Handbook for Nuclear Control Systems [ADc12].

[41s339-R] The clear separation of control, interlock and safety into three tiers shall follow the recommendation in the Plant Control Design Handbook [ADc11].

[41s1423-R] Protective relaying systems shall be independent from the Local Control System (LCS) and LCCs, but shall have an interface with them, for the purpose of status indication and interlocking.

[41s340-R] Local control shall be instigated only on hand-shake permission, and key interlock administered from the main control room. Local control shall only be permitted in exceptional circumstances (such as local commissioning), but all signals and alarms shall always be visible from the main control room.

[41s341-R] All software operating systems used in local control shall be selected from CODAC's list of approved software, or shall be submitted to CODAC for their acceptance.

[41s342-R] The CPSD shall be capable of autonomous “local” control, as well as operation under supervisory control by CODAC. Local control shall include any, and all, features necessary for dummy load testing, without reliance on CODAC.

[41s343-R] Plasma control real-time inputs to the TF, CS, PF, CC, VS and ELM subsystems shall be as listed in the following table.

Table 2.9: CPSS Real Time Control Inputs

System(s)	AC/DC Converters	SNUs
CS3U, 2U, 1U&1L,2L,3L	Current reference signals (5) or voltage reference signals (5)	Open, Insert 2nd resistor bank, Close (6)

PF1,2,3,4,5,6	Current reference signals (6) or voltage reference signals (6)	Open, Insert 2nd resistor bank, Close (for PF1 and PF6 only)
CCU1,2,3 CCS1,2,3 CCL1,2,3	Current reference signals (9) or voltage reference signals (9)	n.a.
VS1	Voltage reference signals (9)	
VS3	Current reference signal Voltage reference signal	
ELM	Current reference signals (27) Voltage reference signal (27)	

2.10 Computer hardware and software requirements

[41s412-R] The CPSD shall include all the computer hardware and software required for its control, including I/O interfaces and plant system interlocks, as specified in the Plant Control Design Handbook [ADc11].

2.11 HVAC requirements

[41s394-R] CPSD indoor equipment shall be compliant with the HVAC interface requirements, as detailed in the ICDs with buildings, see section 1.5.

2.12 Vacuum Requirements and Vacuum classifications

[41s370-I] None.

2.13 Thermal management requirements

[41s352-R;Defined Requirement] The CPSD components shall include appropriate systems to enable the removal of accumulated heat (from CPSD electrical system) under any design basis situations, in order to protect personal and equipment, in particular SIC components. SSCs that require water-cooling shall be designed to operate with the cooling water conditions defined in the Interface Control Document (ICD) and detailed in the Interface Sheet (IS). As the water-cooled CPSD components involve different materials, such as copper, aluminium and steel, a separate and isolated primary loop in contact with these components shall be provided.

2.14 Electromagnetic requirements

[41s362-R;Defined Requirement] All CPSD equipment shall be designed to operate reliably in the presence of stray magnetic fields that are self-generated by the CPSD equipment (including short circuit conditions).

[41s363-R] All CPSD equipment located in the Tokamak complex shall be designed to operate reliably in the presence of the stray magnetic fields provided in Static and Transient Magnetic Field Maps in Tokamak Building [ADc13].

[41s364-R;Defined Requirement] The control of access to the CPSD equipment shall be in accordance with requirements given in the table 2.14.

Table 2.14: Electromagnetic Field Zones and Conditions

Rules to set-up magnetic zoning for buildings, rooms and areas comprising magnetic fields *(Note 1)*			
Magnetic Zone Name	**Risks to be managed**	**Threshold**	**Access and control condition for personnel**
Any zone	*See below*	*See below*	Posting safety signs at the entrances to the concerned buildings, fenced premises, rooms/areas (as appropriate).
Interference magnetic zone	Interference with active implanted devices, e.g. cardiac pacemakers	Static magnetic fields $\geq$ 0.5 mT	Access prohibited for any persons wearing active implanted devices.
Projectile magnetic zone	Attraction and projectile risk in the fringe field of high field strength sources	Static magnetic fields $\geq$ 3 mT (with source >100 mT)	Measures (temporary/fixed) to be implemented as determined, on a case by case, by the risk assessment.
Controlled magnetic zone	Adverse effects on health of the workers and Public	Magnetic fields < the applicable limit given in Table 7-8 depending on the type of field/effects to be considered	Access prohibited for all Public Access to workers authorized provided: - Workers are suitably trained. - Boundaries are physically delimited (fixed or mobile depending on the situations). - Fixed devices for status warning are implemented.
Prohibited magnetic zone	Adverse effects on health of workers, including adverse sensory effects	Magnetic fields $\geq$ the applicable limit given in Table 7-7 depending on the type of field/effects to be considered	Access prohibited for all Public and workers
Note 1 - Magnetic fields include any electric, magnetic, radiofrequency and electromagnetic fields, static and with varying frequencies between 0 and 300 GHz.			

[41s368-R;Defined Requirement] Entry ways to areas with stray field greater than 0.5 mT shall be marked with appropriate signage.

2.15 Nuclear shielding requirements

[41s358-I] Refer to 41s1298 in section 3.1.

2.16 Chemical requirements

[41s360-R] All CPSD systems/components shall be compatible with the cooling water chemistry. Corrosion, electrochemical, and other effects shall be limited to acceptable levels, over the life of the system.

2.17 Material Requirements

[41s372-R;Defined Requirement] Halogenated materials (in insulating materials, for example) shall be forbidden in areas served by the detritiation systems. Exceptions must be approved by the tritium system and safety section responsible officers.

[41s1424-R] The material of CPSD system shall be selected in accordance with

- ITER Material Properties Handbook [ADc41],
- Chemical composition and impurity requirements for materials [ADc40],
- Interface requirements with the water cooling system (PBS26).

2.18 Manufacturing requirements

[41s374-R] All CPSD systems shall be manufactured in compliance with applicable International Electrotechnical Commission (IEC) standards, as well as all applicable French Standards (Normes Françaises, NF). For cases where the IEC and NF standards have not been harmonized, the more stringent standard shall apply.

[41s1054-R] All CPSD components shall be manufactured consistently with the latest approved version of the ITER Quality Assurance Program [R14].

2.19 Construction requirements

[41s377-I] The construction of the CPSD systems/components will follow the ITER construction plan.

2.20 Assembly requirements

[41s379-R] The assembly of the CPSD system shall be performed on the ITER site. This shall require the use of the handling facilities that are available on the ITER plant.

[41s1055-I] Dedicated handling/lifting devices will be defined according to the buildings and CPSD components (such as size and weight) constraints.

2.21 Installation requirements

[41s1056-R] The CPSD design (including construction, operation and maintenance activities) shall be compliant with ITER Site Mater Plan [ADc9] and ITER buildings layout, as managed via ITER Configuration Management Model (CMM) [R60].

[41s1057-R] The different components/parts of the CPSD systems shall be compatible with the handling facilities (such as overhead cranes) and the accessibility to the buildings.

[41s1058-R] The building structure shall have suitably sized doors, floor openings and corridor space for the installation and maintenance of the CPSD systems/components.

[41s1059-R] The layout of the CPSD systems/components shall be adjusted, as far as possible, so that the components can be removed and replaced within the give access and physical space limitations, where installed, without requiring the removal of other equipment.

[41s1060-R] To the greatest extent possible, CPSD systems/units shall be arranged so as to allow personal access in the surroundings of the equipment of a system, even if the other system/units are energized.

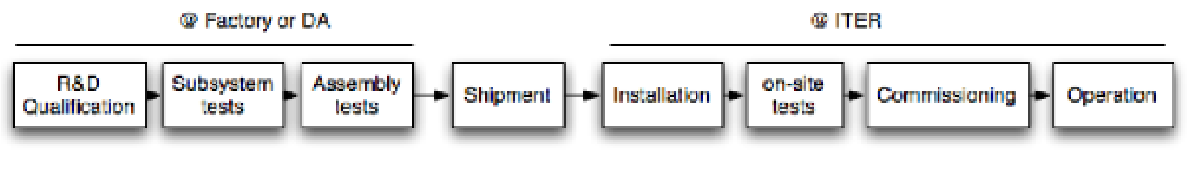
[41s381-R] Ample space shall be provided around CPSD components to permit safe and convenient access for assembly, installation, maintenance and replacement.

2.22 Testing and inspection requirements

[41s384-R;Defined Requirement] The integrated commissioning shall include a mechanical verification.

[41s1425-R] CPSD shall be verified through system test program, prior to integrated commissioning, that CPSD systems operate safely and as expected.

Figure 2.22: Testing and inspection



2.22.1 Factory testing

[41s385-R] All CPSD equipment shall be factory tested, in compliance with applicable International Electrotechnical Commission (IEC) standards, as well as all applicable French Standards (Norme Français, NF), and in an integrated manner with the control system, as much as possible, by using Mini-CODAC. For cases where the IEC and NF standards have not been harmonized, the more stringent standard shall apply. For custom equipment not covered by IEC or NF standards, test plans and procedures shall be developed, and approved by ITER, and tests shall be performed, to confirm functionality of equipment following good engineering practices.

[41s1062-R;Defined Requirement] Component and system tests will be accomplished at the supplier site. These tests shall include:

- The routine and type tests prescribed by the relevant IEC recommendations
- Special tests quoted in the Technical specifications
- Routine tests includes Mini-CODAC.

2.22.2 Site testing

[41s389-R;Defined Requirement] Facilities and procedures shall be developed for testing CPSD components and subsystems on site, during initial commissioning, and later maintenance/troubleshooting. This shall include the following features and equipment:

- Dummy loads with the following characteristics:
  - 12 kV AC insulation capability;
  - 7.75 kA DC continuous;
  - 45 kA for 30 s;
  - 55kA for 20s;
  - 68 kA for 14 s;
  - 15 minutes duty-cycle;
  - Local earthing and protection.
  - Dummy loads shall be supplied for each of the three major systems (TF, CS/PF and CC) with the voltage and current rating based on the largest AC/DC converter rating within each system;
- Bus bars and bus links for isolation from normal loads and connection to dummy loads;
- Autonomous control and interlock systems with provision for dummy load test mode;
- Mini-CODAC for test involving PPEN, RPC, AC/DC Converters, SNU, FDC with dummy load;
- CODAC for integrated test involving Magnets.

2.23 Decommissioning requirements

[41s1426-R] CPSD shall be designed, constructed, operated and maintained in order to permit its safe and efficient decommissioning.

[41s414-R] ITER Organization shall develop a plan to put the CPSD in a safe, stable condition while it awaits dismantling.

2.24 Other Services

[41s1427-R] Where traceability is required (as for example for all PIC systems, structures or components, or for parts whose lifecycle has to be monitored during the life of the project), unique identification of individual items or batches shall be implemented.

[41s1505-R] The construction, operation and decommissioning of the CPSD shall be fully documented in accordance with the requirements of ITER Quality Assurance Program (QAP) [R14] and of ITER Configuration Management Implementation Plan [ADc58].

3 SAFETY DESIGN REQUIREMENTS

3.1 Safety design criteria

[41s420-R;Defined Requirement] The CPSD has a limited role, in terms of nuclear safety (i.e. confinement and radioprotection). However, because of the high level of electrical power and magnetic energy handled by the CPSD, stringent adherence to electrical safety principles shall be essential, in terms of equipment design and layout.

[41s1291-R;Defined Requirement] The CPSD components classified as PIC (see section 1.3) shall comply with the following requirements:

- Single failure criterion on active components based on a case by case analysis;
- When redundant, physical separation on a case by case basis;
- powered by safety class power supply, UPS maintained for 1 hour (in case of total blackout of up to 1 hour);
- Equipment status indication (type of parameters, local, remote);
- Periodic tests requested;
- Routine Maintenance test requested;
- I&C classification;
- Environmental Qualification requested;
- Seismic Class SL2 (SC1-SF for active, SC1-S for passive components);
- QA class 2.

[41s1292-R;Defined Requirement] The design of CPSD safety Structures, Systems and Components (SSC) shall be sufficiently failure-tolerant with active redundant, independent and separated components, to minimize the probability of CMF (Common Mode Failure) and no single failure of SSCs shall result in unacceptable consequences to the workers, public and/or environment.

[41s1277-R;Defined Requirement] For all active safety functions to be performed by the CPSD during/after Design Basis Accident (DBA) like confinement isolation, SIC control, etc., the CPSD shall be designed to provide sufficient redundancy of its SIC sub-systems/components required to achieve this function, as identified by the safety analysis assuming the failure of any of these SIC sub-systems/components.

[41s1293-R;Defined Requirement] Each group of TF-FDU circuit breakers shall be implemented at a distance minimising common mode failure in the event of a fire, from the next closest group of TF-FDU circuit breakers. The CCU (Circuit Commutation Unit) and Pyrobreaker of each of the nine groups should be separated by distance or/and by physical barrier to protect from common mode failure.

[41s1294-R;Defined Requirement] The design of SIC systems, structures, and components shall include all loading events for which the components may be required to perform a safety function. This shall include, as necessary, the ageing effect of the environmental conditions and loads to which a SIC is exposed during its expected service life, followed by the incidental/accidental conditions and loads during/after which the SIC must perform its required safety function.

[41s1295-R;Defined Requirement] The CPSD SIC Structures, Systems and Components shall be designed (including qualification), fabricated, installed, commissioned, inspected and maintained in accordance with the applicable codes, standards, and authorized ITER specifications. Related rules and standards shall be selected for each SIC using the guidelines that are given in Protection Important Functions and Components Classification Criteria and Methodology [ADc15], EDH [ADc4][ADc5][ADc6][ADc7][ADc8] and other applicable codes/standards.

[41s1296-R;Defined Requirement] The CPSD penetrations through a confinement system shall be justified with respect to their impact on the effectiveness of the confinement system.

[41s1297-R;Defined Requirement] The penetrations of PBS 41 SSCs through safety barriers shall be able to maintain the features of the safety barriers they cross:

- Overall safety leak rate limit for Tokamak Building Gallery: < 100% at 300 Pa, < 820% at 0.02 MPa pressure differential;
- Liquid tightness of the floors and walls of gallery: no leak tightness criteria, just the adequate construction quality.

[41s1298-R;Defined Requirement] The CPSD penetrations through a confinement system shall neither increase the likelihood or consequences of failure of the confinement system, nor introduce new failure modes beyond those that are addressed in the safety analysis: a penetration crossing a fire sector boundary or a confinement barrier shall reconstitute the boundary / barrier properties. Provision of adequate reliability may require the use of such items as double barriers, double bellows, double windows, double isolation valves, and robust sealing.

[41s1299-R;Defined Requirement] Operation, inadvertent actuation or damage to CPSD SSC shall not prevent SIC systems, structures, or components from accomplishing their safety functions when required.

[41s1301-R;Defined Requirement] PBS 41 shall not generate drop loads as the components are localised on the floor of B2 gallery and on the floor of building 75. Handling operations on PBS41 equipment (including transfer and lifting systems) shall be developed and performed so to prevent any injury to the personnel and any damage to the handled equipment or surrounding components (especially SIC components and systems containing effluents).

[41s443-R;Defined Requirement] The CPSD shall be compliant with the zoning requirements allocated to the rooms/areas where CPSD components are installed in order to protect people, equipment, and the environment from the effects of perceived hazards during all phases of the facility life cycle. Zoning for nuclear buildings include Ventilation, Radiological, Anti-deflagration, Beryllium, Magnetic, Radiofrequency, Fire, Waste – they are specified in the Safety requirement Roombook [ADc23] for the Tokamak Complex.

3.2 Safety limits

[41s1302-R;Defined Requirement] The design of CPSD system shall include provisions to minimize the potential for other hazards that could challenge confinement systems. These include internal aggressions, such as fire or flooding, and external aggressions, such as earthquakes or extreme weather conditions. Therefore, internal flooding is due to the fire-fighting water or collapse of tank or water pipe break and thus PBS 41 components, monitors, cubicles and cabling shall be located above the flooding level in the rooms. CPSD system/components shall be designed and installed above the maximum flooding level of the rooms/areas where they are located.

[41s429-R;Defined Requirement] The TF FDU shall prevent possible electric arcs that could challenge the confinement function of the VV sectors wherein the TF coils are contained.

3.3 Monitoring requirements

[41s431-R;Defined Requirement] CPSD shall provide adequate monitoring with the required support functions to verify that its SIC components are functional, as credited, in the safety analysis.

[41s1506-R] CPSD SIC SSCs shall be monitored and controlled from the MCR and the ECR as necessary, to put and/or maintain the ITER Facility in the safe state in consistency with the safety demonstration.

3.4 Safety-specific instrumentation

[41s433-R;Defined Requirement] Safety specific instrumentation, control, actuation and their support functions shall be required to ensure that SIC components are functional, as credited, in the safety analysis and shall enable the control of the ITER safety I&C functions by managing the safety thresholds.

3.5 Safety related testing and inspection

[41s435-R;Defined Requirement] CPSD shall provide the capability for initial and periodic testing and inspection required to ensure that its SIC components are available and functional, as credited, in the safety analysis.

3.6 Qualification requirements

[41s1303-R;Defined Requirement] The scope of design verification shall be applied to all safety-related systems, structures, and components. However, certain important non-safety-related systems and structures are included in the design verification (zero halogen, fire retardant Cables, no missile effect in case of SL2).

[41s1304-R;Defined Requirement] If an alternate calculation method or a qualification test method for design verification of a system, structure or component has not been developed or there is difficulty in its application, then the design review shall be used as the design verification method of the system, structure or component. The design review shall be performed either as specific review by one or more independent reviewers competent in a single discipline or by multi-disciplinary review performed by a multi-disciplinary review team.

[41s1305-R;Defined Requirement] If it is possible to verify the design integrity of a system, structure or component by design verification using only design calculation, and an alternate calculation method has been developed, then the alternate calculation shall be used as the design verification method of the system, structure or component.

[41s1306-R;Defined Requirement] If performance of a related component has not been verified due to application of a new design concept, then the qualification test by model test under conditions that simulate the most adverse design conditions shall be used as the design verification method for the component.

[41s437-R;Defined Requirement] System and components that are important for personnel or public safety are classified as Safety Importance Class (SIC). Within the CPSD, the SIC classification (Protection Important Functions and Components [ADc15]) shall be only required for the discharge of the TF coils stored energy and this function is achieved through TF FDU and PMS.

3.7 Safety related operations and procedures

[41s439-R;Defined Requirement] All CPSD operations including plasma operations, troubleshooting, maintenance, repair and decommissioning shall be conducted using written procedures. These procedures shall describe the appropriate organization to guarantee their application, the authorization required as well as actions to be taken in event of an emergency such as in case of a fire, an equipment failure or ITER On-Site Emergency.

[41s440-R] Manual operation of switching devices, used to isolate and earth CPSD components in preparation for personnel access, shall be controlled by keyed mechanical interlocks that ensure the proper conditions for switching and access.

[41s1307-R;Defined Requirement] PBS 41 PIC components and their support systems shall be able to continue to operate (or shall be protected adequately or shall be isolated) in fire conditions [ADi1]; in particular with regards to presence of high variations of pressure, temperature, humidity, soots. Their failure shall send an alarm to CSS-N [ADc27].

[41s1308-R;Defined Requirement] PBS 41 PIC components and structures shall provide their safety function also in presence of the effects resulting from a helium leak in the galleries, the conditions are defined in Load Specifications (LS) [ADc10].

3.8 Occupational safety

[41s1309-R;Defined Requirement] The CPSD design and operation shall undergo Hazard identification and risk assessments (HIRA) in order to:

- identify workplace OHS hazards whose control shall have impact on ITER systems design;

- assess the level of risk related to them in order to control them.

[41s793-R;Defined Requirement] The CPSD system and components, and maintenance and operation procedures, shall be designed to minimize occupational radiation exposure and other hazards to contaminated areas, keep the radiation dose to the staff as low as reasonably achievable, and guide onsite personnel to properly respond to alert of contamination level and to take proper protection and/or evacuation measures.

[41s442-R;Defined Requirement] To ensure personnel safety, all aspects of the CPSD design and installation, including operation and maintenance shall conform to applicable French codes and standards, and European Directives.

[41s445-R;Defined Requirement] The design and layout of CPSD equipment shall facilitate maintenance in terms of access, isolation and earthing, and egress under emergency conditions.

[41s1507-R] During SRO plasma operations and Post-SRO Assembly, the maintenance of CPSD shall be performed hands-on.

[41s1063-R;Defined Requirement] Isolation protocols and personnel protection schemes shall be implemented using physical barriers and mechanical interlocks such that equipment shall only be energised when the barriers are closed. The detailed design of these schemes shall form part of the detailed design carried out under the relevant PA.

[41s446-I] See Section 2.14 for limits on magnetic field exposure to workers.

[41s1310-R;Defined Requirement] CPSD design and operation shall implement

- Appropriate protection measures to reduce the frequency or the probability of OHS risks to occur
- The rules to follow for the design, manufacturing, installation and utilization of equipment in order to protect people and equipment from OHS risks.

[41s1311-R;Defined Requirement] Information shall be provided on panels at relevant places to inform people about the risks, the individual protection systems needed, the state of the equipment, alarms and other information relevant to OHS.

3.9 Environmental impact requirements

[41s448-R;Defined Requirement] Design of CPSD components shall strive to minimize the use of materials with adverse environmental impact. All solid, liquid and gaseous toxic products needed for CPSD design and operation shall be identified and their quantity and characteristics shall be estimated for contruction, normal operation, and maintenance operations. The inventory in terms of quantity and level of toxicity for such toxic products shall be limited to the maximum extent possible in the design, and their impact maintained as low as reasonable achievable during operation.

[41s1312-R;Defined Requirement] Specific design provisions shall be undertaken to avoid that solid, liquid and gaseous toxic products affect workers during normal operations and to avoid spread of these materials into rooms accessible to workers. These provisions shall consider potential corrosive, inflammable and explosible issues associated with these toxic products.

[41s1313-R;Defined Requirement] Provisions shall allow monitoring and characterization of gaseous or liquid releases of the toxic products towards the environment.

3.10 Reliability Requirements

[41s450-I] The reliability and availability requirement of CPSD is detailed in Section 4.3 RAMI.

3.11 Other Requirements

[41s453-R;Defined Requirement] Under any design conditions (normal, incidents, accidents, aggressions and combinations) and including the application of the single failure criterion, the CPSD shall be designed, operated and maintained in order to prevent explosion to occur. In particular, the batteries (UPS) shall:

- Minimize as far as possible their release of hydrogen;

- Be switched-off when a hydrogen release or HVAC not operating is detected in the room they are installed.

[41s1508-I] The explosion risk related to hydrogen concentration is managed in an integrated manner with other potential hydrogen sources and buildings ventilation and monitoring systems (refer to relevant ICDs). The hydrogen concentration in air (tritium, deuterium, protium and/or mixtures of these isotopes) must be kept below 1% (i.e. <25% of the hydrogen Lower Explosive Limit (LEL) of 4%)).

4 OPERATION AND MAINTENANCE

[41s1428-R] CPSD shall be designed to be capable of operating for periods of 11 consecutive days while accommodating three-shift daily plasma operation, followed by 3 days of routine maintenance.

[41s1429-R] CPSD shall be designed so that plasma operation can be conducted for periods of up to 16 months continuously in three 8h work-shift daily operating mode to perform the following actions: plasma operations, test, conditioning, routine maintenance.

[41s457-R] The operation of CPSD system shall comply with ITER Operational States [ADc39].

4.1 Operation

[41s1223-R;Defined Requirement] Human performance and human error can have a major impact on the safety of a nuclear installation, as well as in operability, availability, and maintainability and inspectability aspects. The Coil Power Supply and Distribution System design and operation shall take into consideration the human and organisational factors in accordance to the ITER Human Factor Integration Plan [ADc19] and recommendations from the suppliers, to prevent or minimize risks associated with potential human error.

4.1.1 System operation states

[41s1430-I] The Table 4.1.1 shows the Plant Operating States (POS) of the CPSD.

Table 4.1.1: Definition of CPSD Status for each POS

ITER Global Operational State (GOS) *Plant Subsystem*	Long Term Maintenance (LTM)	Short Term Maintenance (STM)	Testing & Conditioning State (TCS)	Plasma Operation State (POS)
PPEN AC Distribution	Shutdown/ON	ON / [OFF]	ON	ON
CPSS TFPS	Shutdown	OFF / [Ready/ON]	OFF / [Ready/ON]	ON
CPSS CSPFPS	Shutdown	OFF	OFF / [Ready/ON]	ON
CPSS CCPS	Shutdown	OFF	OFF / [Ready/ON]	ON
CPSS RPC	Shutdown/ON	ON / [OFF]	ON	ON
CPSS ELPS	Shutdown	OFF	OFF / [Ready/ON]	ON
CPSS V3PS	Shutdown	OFF	OFF / [Ready/ON]	ON

[41s459-I] Notes:

- PS includes all components within the circuits Power Supply, such as AC/DC converters, FDU, SNU.
- [ ] is optional status for their maintenance or other system's activity requirement.
- "/" is OR (selection) status which depends on the specific actions.

[41s463-R] The following definitions shall apply to the status descriptions in the following table.

Table 4.1.2: Definition of CPSD Configuration for each POS Status

Component	Status = Shutdown Safe	Status = OFF Not Safe	Status = Ready	Status = ON
HV, IV, MV, LV AC Power	Circuit Breakers (CB) open and withdrawn, interlocks in trip state	Interlocks in trip state	CBs closed	CBs closed

DC Disconnecting & Earthing Switches	Line switches open, earth switches closed, interlocks set to prevent change in position	Line switches open, earth switches closed	Line switches closed, earth switches open, interlocks set to prevent change in position	Line switches closed, earth switches open, interlocks set to prevent change in state
Other hazards and sources of stored energy	De-energised, disconnected, earthed, and locked out	De-energised, disconnected, and earthed	Connected and not earthed	Connected and not earthed

4.1.2 Operational conditions

[41s795-R] Before the CPSD starts operation, its healthiness in terms of performance and functionality requirement shall be checked before each plasma pulse operation.

4.1.3 Main control room

[41s797-R] Operation of CPSD shall only be controlled from the Main Control room and the emergency control room except when control of CPSD individual systems from local control panels is specifically and exceptionally authorized.

[41s1256-I] There is no permanent occupation by personnel of plant areas, that is, offices or control rooms, within the INB perimeter.

[41s1255-R] CPSD shall not be controlled or configured by personnel outside of the Nuclear Installation (INB) perimeter.

4.2 Maintenance

[41s466-R] Maintenance requirements of the CPSD system shall conform to the maintenance periods defined for ITER.

[41s798-R] No scheduled maintenance shall be required outside these defined periods unless it can be performed during normal plasma operation (hidden maintenance).

[41s474-R] Short term maintenance of CPSD shall be allowed according to the following pattern:

- Daily checks, controls, conditioning of equipment, fluids preparation within less than 8 hours of elapsed time;
- Routine maintenance shall not be required with intervals less than 4 operational weeks. Routine maintenance covers minor adjustments, calibration, replacements of equipment.
- Short term maintenance shall take into account the zoning constraints (access control, environmental conditions) and corresponding time constraints.

[41s799-I] Typical corrective maintenance tasks include:

- Repair of transformer bushing leaks, internal transformer faults, failure of surge protection components;
- Replace thyristors, fuses, gate drive components in ac/dc converters;
- Replace switchgear in the ac distribution system;
- Replace capacitors, thyristors and fuses in reactive power compensation system;
- Replace capacitors in dc filters;
- Repair leaks in cooling system.

[41s800-R] The frequency of such corrective maintenance tasks shall be provided by the supplier.

[41s476-R] Long Term Maintenance shall be scheduled to allow for major scheduled replacements, overhauls / refurbishments, repairs of equipment. ITER requirements for this maintenance interval could be up to two years.

[41s1513-R] Because of the high risk of fire and/or explosion, maintenance activities in rooms housing systems/components containing explosive substances (for example, tritium, hydrogen, diborane, etc.) shall be limited to periods when the processes using such substances are shut down and these substances are appropriately isolated or removed

4.2.1 Maintenance plan

[41s801-R] A maintenance plan shall be prepared by the supplier. The minimum information required within this maintenance plan is the following:

- Scheduled operations (such as controls, checks, adjustments, calibrations, overhauls and replacements) derived from the Safety and Security regulations, and identified as necessary by the supplier in order to ensure the best operation of the system in its intended operational scenario. At least, task-identification and interval is required;
- Critical unscheduled operations (such as replacements and repairs) that may impact ITER availability and/or introduce needs for additional support (such as spares, procedures, training, tools and test equipment, and infrastructure).

[41s1431-R] Maintenance plans shall be developed for all maintenance scenarios with a probability of occurrence greater than 10^{-6}, over the 20-year life of ITER.

[41s1432-R] Maintenance procedures and tools for CPSD shall be provided for maintenance scenarios with a probability exceeding 10^{-1} over the 20-year life of ITER.

[41s1514-R] From their manufacturing until entering in operation within ITER Facility, all CPSD Structures, Systems and Components (SSCs) shall be preserved for Investment Protection. This shall ensure that SSCs retain their required characteristics and performance, including prevention of deterioration over time and protection from external damage, during their shipping, storage, installation, testing, commissioning and maintenance prior to operation.

4.2.1.1 Spares

[41s470-R] Recommendation for spares provisioning shall be provided, both for scheduled and unscheduled maintenance, taking into account the operating conditions. The final decision on spares provisioning will be made by IO.

[41s1433-R] The risk regarding components' obsolescence shall be assessed, and appropriate provisions taken to fix/remove/minimize that risk.

4.2.1.2 Operation and maintenance procedures

[41s805-R] Documents shall be provided to IO for the operation and maintenance of the system equipment on site. These publications shall comply with the ITER template for operation and maintenance procedures. Data shall be provided both in paper and electronic media.

4.2.1.3 Operation and maintenance training

[41s807-R] Initial training shall be provided for the ITER Operation and Maintenance crew. The training shall conform to the training rules set up by IO. The training scope is identical to that of the operation and maintenance procedures.

4.2.1.4 Special tools and test equipment

[41s809-R] CPSD shall provide any special tools and test equipment needed for maintenance of the system's equipment, on site. Any such equipment, that would be additional to items delivered as manufacturing means, installation means, test and commissioning means, shall be fully justified.

[41s812-R] Special pieces of equipment needed for packaging, handling, storage and transportation are also in the scope of the requirement. PBS-41 shall also identify the degree of protection for any packaging equipment. This degree of protection shall be identified based on the IO-defined environmental conditions. In the event of the failure of a handling system, appropriate recovery systems and procedures shall be available when necessary.

4.2.1.5 Facility requirements

[41s814-R] PBS41 shall identify any facility requirements (such as property class, security and utilities) of equipment that need to be tested and maintained outside the Hot Cell Facility (control cubicles, for instance).

4.2.2 Operation tasks

[41s1515-R] Every CPSD operation task (planned/unplanned) shall minimise ALARA workers exposure to radiation.

4.2.3 Remote handling

[41s472-I] No requirement exists towards Remote Handling for the maintenance / repair of the CPSD components.

4.2.4 Hot cell and waste management requirements

[41s815-I] No requirement exists towards Hot Cell for the maintenance / repair of the CPSD components.

4.3 RAMI

4.3.1 Requirements: Reliability. Availability. Maintainability. Inspectability

[41s922-R;Defined Requirement] The CPSD system shall be compliant with the reliability and availability requirements set in the Table 4.3.

Table 4.3: RAMI requirements

System	PBS	A_H (%)	A_{D-T} (%)	Main Function	A_H (%)	A_{D-T} (%)
CPSD	41	85.4	92.8	To supply and distribute power to the pulsed loads	92.0	92.0
				To supply and distribute power to the coils	93.0	93.0
				To ensure proper grounding of the coils	99.9	99.9
				To ensure fast discharge of stored energy	99.9	99.9

[41s1434-I] Where, AH and AD-T are the availability during H-phase and D-H phase, respectively.

[41s1518-R] In order to remove or mitigate risks to investment, the CPSD shall implement adequate measures as identified by the Investment Protection (IP) risk assessment and defined in the ITER Investment Protection Handbook [ADc57].

4.3.1.1 Test and validation of RAMI performance

[41s1066-R] The reliability characteristics shall be demonstrated, as part of the CPSD qualification process.

[41s1067-R] The warranty period shall also be used as a validation period for the reliability characteristics of the system equipment.

[41s1068-R] Deviations from requirements shall be identified, and compensating / correcting actions identified and implemented.

[41s1069-R] The maintainability characteristics shall be demonstrated by the supplier, as part of the qualification process.

[41s1070-I] Critical on-line controls or replacements will be realized during integrated commissioning.

[41s827-R] The demonstrations for the RAMI performance shall ensure accuracy of elapsed times, and efficiency of support equipment needed for task performance.

4.3.2 Risk reducing

[41s1071-I] Those actions that are advocated in various project phases (design, test, operation and maintenance), to lower the criticality of function failures which initial value is higher than the limit above which the risk level is considered as major by the project, are listed next.

[41s468-I] Where appropriate, these actions may be replaced by others if it is ensured that those would lead to equivalent benefits in risk reduction.

4.3.2.1 Design requirements

[41s925-R] In addition, the TF, CS, PF, VS, CC thyristor bridges shall be a redundant design. It means redundancy in each arm (this action is applied to the arms that are in the thyristor bridge but not the thyristor bridge itself). K-out-of-n redundancy could be a solution. A k-out-of-n node can have n paths leading into it and requires that k-out-of-n paths must function for the system to function. For example, if 9 thyristors are needed to accomplish the function, a 9-out-of-10 redundancy could be a solution. Moreover, reliability calculations and availability calculations should be taken into account before acceptance of new design.

[41s926-I] The TF bypass switch is also required to be redundant on thyristors as well as the measurement for current and voltage on the converters.

[41s927-R] A specific attention shall be given to the implementation of alarms to detect:

- 1 ground fault for the TF, CS, PF and CC converter control
- 2 or more ground faults for TF, CS, PF and CC converter control
- AC failure for TF, CS, PF, CC, and VS converter control
- High/low DC voltage, fuse failure, freewheeling failure or no output for the TF, CS, PF, CC, and VS thyristor bridges.

[41s829-I] For the 400 kV, 66 kV and 22 kV circuit breakers, a numeric counter should be added to the design so that a precise tracking of the number of operations can be kept.

4.3.2.2 Operation requirements

[41s831-I] The RAMI analysis does not require any specific operation actions.

4.3.2.3 Maintenance requirements

[41s836-R] In order to optimize the reliability and availability, the system shall be designed in such a way that times to repair are reduced, by ensuring that recommendations for spare parts provisioning shall be provided following the RAMI requirements.

[41s928-I] The full spare list will be provided during the Design Activities.

4.3.2.4 Testing requirements

[41s835-R;Defined Requirement] The control circuit of the CPSD systems shall be fully proven during testing. It shall be tested for EMI/EMC, as per standard.

5 QUALITY REQUIREMENTS

[41s1072-R] The CPSD shall be designed, manufactured, tested, commissioned, operated, maintained and decommissioned in compliance with the ITER Quality Assurance Program [R14].

[41s479-R] CPSD components fall into various quality classes, as listed in Section 1.3, and their design and manufacture shall conform to the corresponding ITER quality assurance requirements (Quality Classification Determination [ADc16]).

6 APPLICABLE CODES AND STANDARDS

[41s490-R;Defined Requirement] The design of the CPSD components and subsystems shall be carried out with all standardised identification, labelling and signage in conformance with the ITER Site Signage & Graphics Standards [ADc20] and assuming the latest version of codes, standards and design criteria listed, here, in priority order from the most important one:

- Code and standards listed in the ITER Preliminary Safety Report [R46];
- Codes, standards and design criteria mutually agreed between the ITER Organization and the Domestic Agencies during the execution of the design work.
- French standards and rules applicable or affecting (according to article 14 of IO Joint Implementing Agreement):
  - Safety (nuclear and personnel safety);
  - Fire prevention, fire detection and/or fire fighting;
- Guidelines and rules for installations;
- Applicable building codes;
- European Directives;
- IEC standards.

[41s500-I] If a code and standard has already been approved by the issuing body/authority, and it is expected to become in force during the construction phase of ITER, IO may decide to apply the new code and standard immediately.

[41s931-R] For cases where the IEC and NF standards have not been harmonized, the rules stated in the Electrical Design Handbook - Part 3, code and standards, shall apply.

[41s837-R] Specific guidance is contained in the Electrical Design Handbook, Part 3: Codes and Standards [ADc6]. The CPSD instrumentation and control (I&C) shall conform to the standards specifications and interfaces as documented in the Plant Control Design Handbook [ADc11].

[41s514-R;Defined Requirement] In general, Safety Relevant Components shall comply with a more stringent level of codes and standards that non-safety relevant Components. The CPSD instrumentation and control (I&C) shall conform to the standards specifications and interfaces as documented in the Plant Control Design Handbook for Nuclear Control Systems [ADc12].

7 ADDITIONAL REQUIREMENTS FOR THE STAGED APPROACH PHASES

[41s92-R;Defined Requirement] The CPSD shall meet basic functionality and performance requirements at different phases of construction, commissioning and operation of ITER specified in Staged Approach Configuration – PBS Level 3 [R18].

7.1 Start of Research Operation (SRO) phase

[41s1519-R] Although the first plasma experiment will be performed at reduced current, the CPSS shall be installed and operational in its full configuration prior to the start of SRO for the full current test.

[41s1520-R] The PPEN shall be installed and operational including commissioning to accommodate with the baselined heating powers at SRO specified in Table 2.2.12.

7.2 Deuterium-Tritium 1 (DT-1) phase

[41s1521-I] No additional requirement for CPSS.

[41s1522-R] The PPEN shall be installed and operational including commissioning to accommodate with the baselined heating powers at DT-1 specified in Table 2.2.12.

[41s1523-R] Although the upgrade of IC H&CD system to 20MW is outside of the current ITER Technical Baseline as stated in Table 2.2.12, PPEN shall be constructed and operated to accommodate with IC H&CD upgrade during Post-First Plasma Assembly phase (before DT-1). This requires, in particular, the space reservation to install the additional PPEN SSCs, and the guarantee that the existing PPEN and associated auxiliary systems can cope or, at least, can be upgraded to operate these additional sources.

[41s1524-R] Although the upgrade of EC H&CD system to 7MW is outside of the current ITER Technical Baseline as stated in Table 2.2.12, PPEN shall be constructed and operated to accommodate with EC H&CD upgrade during Post-First Plasma Assembly phase (before DT-1). This requires, in particular, the space reservation to install the additional PPEN SSCs, and the guarantee that the existing PPEN and associated auxiliary systems can cope or, at least, can be upgraded to operate these additional sources.

7.3 Deuterium-Tritium 2 (DT-2) phase

[41s1525-R;Defined Requirement] During the assembly phase between DT-1 and DT-2, TF FDUs shall be replaced or retrofitted in order to comply with the radiation constraints.

[41s1526-R] Although the HNB3 upgrade is outside of the current ITER Technical Baseline as stated in Table 2.2.12, PPEN shall be constructed and operated to accommodate with HNB3 upgrade during Post-DT1 Assembly phase (before DT-2). This requires, in particular, the space reservation to install the additional PPEN SSCs, and the guarantee that the existing PPEN and associated auxiliary systems can cope or, at least, can be upgraded to operate this third HNB injector.

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