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VERSION CREATED ON / VERSION / STATUS
07 Oct 2025 / 1.1 / Approved
EXTERNAL REFERENCE / VERSION

Interface Sheet-IS

Interface Sheet IS-41PPAJ-41_IVCPowerSupplies-001

Physical and functional interface between 22kV PPEN (41.PP.AJ) and IVC Converters (41.EL, 41.V3)

Approval Process			
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Information Protection Level: Non-Public - Unclassified *RO: Tsedri Thibault*			
Read Access	**LG: DA RO to sign off ICDs, GG: AIF- CEA SSA Liaison Committee Members &experts, LG: F4E-Architect/Engineering company, GG: MAC Members and Experts, GG: STAC Members & Experts, GG: CEA Decommissioning Experts, LG: CEA view, GG: DA Heads, Co-ordinators and Management, AD: ITER, AD: External Collabor...**		

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Change Log			
Interface Sheet IS-41PPAJ-41_IVCPowerSupplies-001 (DY6EG9)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	14 May 2025	
v1.0	Revision Required	26 Jun 2025	This new version supersedes the two following documents : https://user.iter.org/?uid=AX8GEY Interface Sheet IS-41PPAJ-41_ELMConverter-001 https://user.iter.org/?uid=9PLXGM ITER_D_9PLXGM v1.1 - DRAFT Baseline 2024 : Interface Sheet IS-41PPAJ-41_ELMConverter-001 Comments raised in the two documents were addressed and these documents were obsoleted.
v1.1	Approved	07 Oct 2025	Consideration of the comments of the SIRO

Table of Contents

1 Purpose

The purpose of the present IS is to define the interface requirements associated to the interfaces between the In-Vessel-Coil Power Supplies (PBS 41.EL.MV) and the 22kV Pulsed Power Electrical Network (PBS 41.PP.AJ) in agreement with the Interface Control Document between PPEN (PBS41.PP) and AC/DC Converters (PBS41.xx) [AD1].

2 Acronyms

CDR	Conceptual Design Review
ELM	Edge Localized Mode
ICD	Interface Control Document
IEC	International Electrotechnical Commission
IP	Interface Point
IR	Interface Requirement
IVC	In Vessel Coils Power Supplies
IS	Interface Sheet
MV	Medium Voltage
NA	Not Applicable
PA	Procurement Arrangement
PBS	Plant Breakdown Structure
PPEN	Pulsed Power Electrical Network
PS	Power Supply
RMS	Root Mean Square
SRD	System Requirements Document
TBD	To Be Defined
THD	Total Harmonic Distortion
VDE	Vertical Displacement Event
VS3	Vertical Stabilization 3

For a complete list of abbreviations and acronyms, refer to Abbreviations.

3 Applicable Documents

Reference	Title	UID	Version
[AD1]	Interface Control Document between PPEN (PBS41.PP) and AC/DC Converters (PBS41.xx)	2KSK3W	4.0
[AD2]	SRD-41 (Coil Power Supply and Distribution) from DOORS	28B6XQ	5.0
[AD3]	Electrical Design Handbook (EDH)	2DSPT6	Applicable version
[AD4]	ITER_41PP_SLD_002: PPEN One Line General Diagram	35RMBK	3.3
[AD5]	IO cable catalogue	355QX2	6.13
[AD6]	Staged Approach Configuration - PBS Level 3	SNE6G8	4.0
[AD7]	ITER research plan	YS74S9	NA

4 Reference Documents

Reference	Title	UID	Version
[RD1]	ELM-PS MV substation diagram for call for tender	DJRG4D	1
[RD2]	ITER_41PPAJ_CBD_001: Cabling Diagram 22kV PPEN Part	NPCDVK	5.3
[RD3]	ITER_41PPAJ_SLD_004: One-Line Diagram 22kV - Board 4	3LZPGQ	7.0
[RD4]	ITER_41PPAJ_SLD_006: One-Line Diagram 22kV - Board 6	NTAVHH	1.4
[RD5]	PPEN Power Load	2DXJJF	3.2
[RD6]	2017 PPEN ETAP model	SECGBG	2.1

5 Interfaces Identification

The physical interface between PPEN (41.PP) and the IVC Power Supplies is with the IVC 22kV substation (41.EL.MV).

The functional interfaces are both with the substation and with the individual power supplies (41.EL, 41.V3).

Table 5-1 identifies the interfaces between the two interfacing PBSs.

Table 5-1: Interfaces Identification

IP No.	Locations	PBS 41				PBS 41			
		Designation	**Reference**	**PIC (Y/N)**	**Procurement**	**Designation**	**Reference**	**PIC (Y/N)**	**Procurement**
1	13-L1	22kV power cables	41.PP.AJ	N	TBD	IVC-PS MV substation incoming cell	41ELMV SWG-0001	N	IO (ELM-PS contract)
			41.PP.AJ	N	TBD	IVC-PS MV substation incoming cell	41ELMV SWG-0002	N	IO (ELM-PS contract)
2	13-L1	Functional interface	41.EL.MV	N	N/A	ELM Power Supplies	41.EL	N	IO (ELM-PS contract)
3	13-L1	Functional interface	41.EL.MV	N	N/A	VS3 Power Supply	41.V3	N	IO (VS3 contract)

6 Interfaces Description

PPEN transforms and distributes power from the 400 kV power grid to the 66 kV and 22 kV levels.

The IVC-PS system takes the power from 22 kV feeders and supplies the ELM and VS3 coils. It comprises of:

1. A MV substation that interfaces the IVC PS with PPEN
2. The Edge Localized Mode (ELM) Power Supplies system,
3. The Vertical Stabilization 3 (VS3) Power Supply system,

The IVC-PS MV substation interfaces the PPEN feeders with each of the IVC-PS (one VS3-PS and the ELM-PS consisting of 3 rectifier groups each with 9 inverter stages). The design, procurement and installation of the IVC-PS MV substation is in the ELM-PS system scope

6.1 IP1: 22kV power cables (physical interface)

For 22 kV power cables, the general interfaces between PBS41.PP and PBS41.EL.MV are depicted in Figure 1.

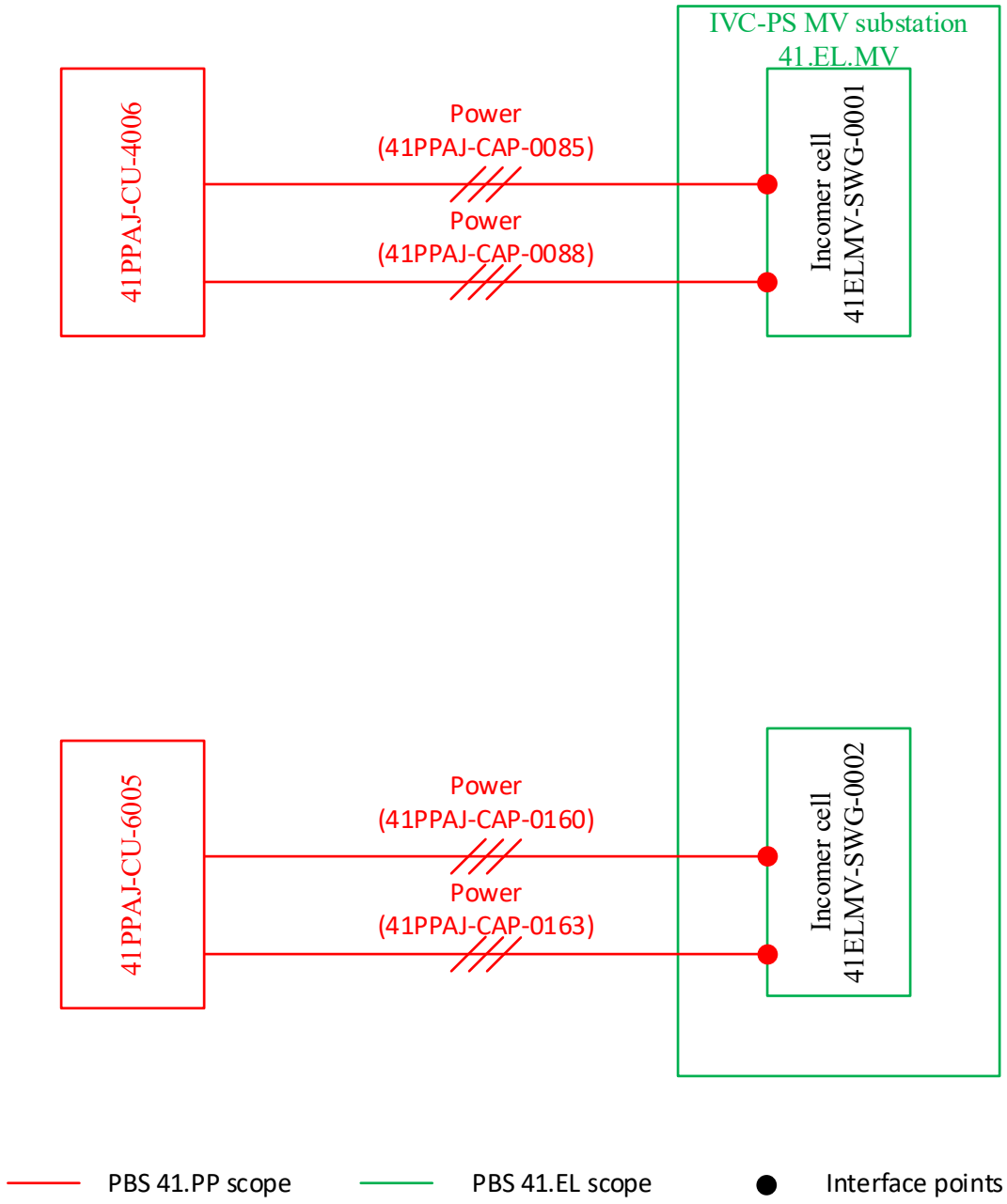

Figure 1: Physical interface points between PPEN and IVC-PS MV substation (PBS41.EL.MV) for power cables.

6.1.1 Technical description of the interface points

The interface points between the IVC-PS MV substation and the PPEN are located at the incoming cells' input terminals of the IVC-PS MV substation as depicted in Figure 2. The conceptual diagram of the MV substation is provided in [RD1].

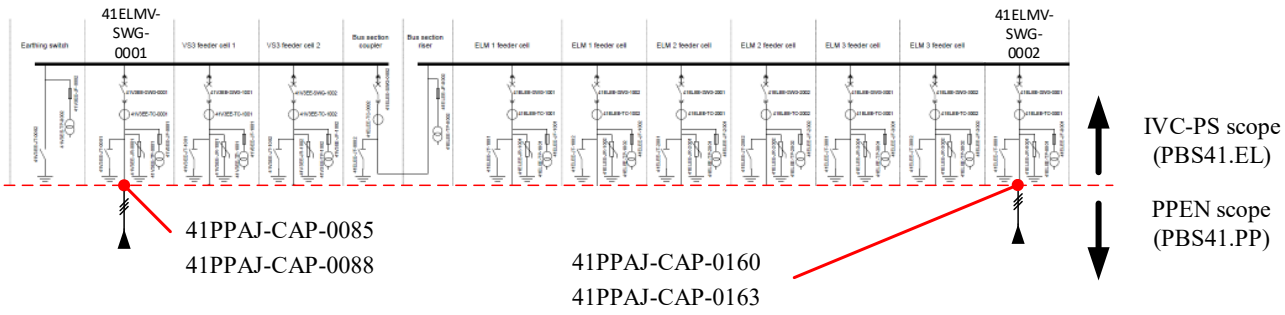

Figure 2. Conceptual schematic of the ELM power supplies system (from [RD1]).

The scope of supply between PBS 41.PP and PBS 41.EL is shown in Figure 3.

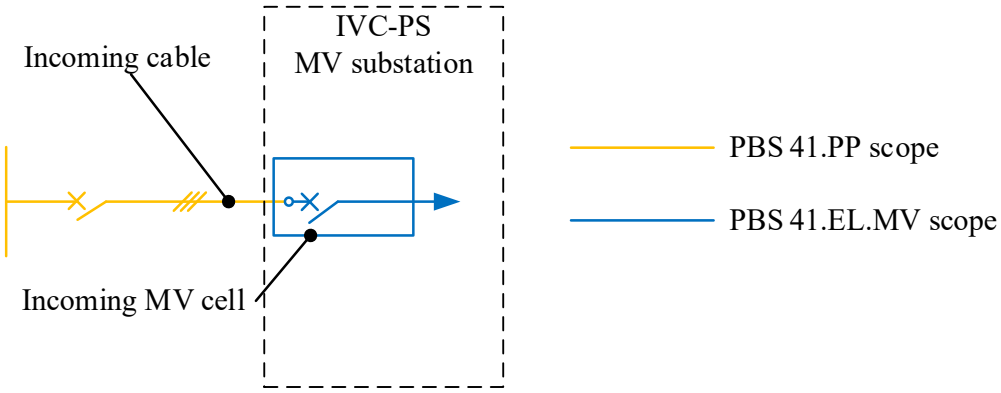

Figure 3. Detail of responsibilities at interface point between PBS 41.PP and PBS 41.EL (for power cables).

Under normal operation (both 22 kV PPEN feeders and IVC-PS MV substation are operational), one PPEN feeder provides power to the VS3-PS system whereas the second one provides power to the ELM-PS system.

If one feeder is out of operation or if the IVC-PS system requires so (during maintenance for example), both the VS3-PS and ELM-PS systems will be fed by the remaining single feeder through a coupler that is present in IVC MV substation.

During operation, 41.EL.MV has the following responsibilities:

[41PP41EL-001i1-R] 41EL.MV shall avoid the configuration in which the two 22 kV PPEN feeders are connected together through this coupler.

[41PP41EL-001i2-R] PBS 41.EL.MV shall not energize IVC-PSs at the same time and shall wait a given period of time (tens of seconds) between the energization of IVC-PSs.

6.1.2 PPEN 22kV parameters

[41PP41EL-001i3-R] PBS 41.PP shall provide voltages with power quality described in Table 6-1.

Table 6-1: Power quality of PPEN power quality

Rated nominal voltage (kV)	Maximum voltage variation (%)	Nominal AC voltage frequency (Hz)	Total Voltage Harmonic Distortion -THDv (%)	Grounding system
22 kV	± 10%	50 Hz ± 1%	< 8% (1)	IT(2)

(1) The effective value of each harmonic shall be measured in accordance with IEC 61000-4-30 and IEC 61000-3-6 with a time interval of 10 minutes.
(2) Note: PPEN 22kV feeders are connected to the ground via a Zig-zag transformer and resistor, which is designed to limit the phase-to-ground short circuit current not more than 500 A for 10 seconds.

6.1.3 Current Capacity of PPEN 22kV Feeders

The capacities of each PPEN 22 kV feeder are listed in Table 6-2 below.

Table 6-2: The capacity of PPEN 22kV feeders for IVC-PS systems

	Baseline Configuration		
Feeder	Max. Load Current (A)(1),(2),(3)	Max. Admissible Currents (A)(4),(5)	Isc max/min (kA eff)
41PPAJ-CAP-0085 41PPAJ-CAP-0088	682/779 A TBC	702 for 2x3x(1*185) mm^2 803 for 2x3x(1*240) mm^2 TBC	28.1 (TBC)
41PPAJ-CAP-0160 41PPAJ-CAP-0163	682/779 A TBC	702 for 2x3x(1*185) mm^2 803 for 2x3x(1*240) mm^2 TBC	28.1 (TBC)

(1) The maximal load current 779A is defined under -10% voltage variation, i.e 19.8 kV.
(2) RMS value of maximum load current including all harmonics.
(3) The final value will be confirmed by PBS 41.EL.MV before the PDR of PBS 41.EL.MV.
(4) RMS value of admissible current, i.e. including all harmonics with an assumption of Installation method 14 with max. ambient temperature at 40°C.
(5) The final cable configuration will be confirmed before the FDR of PBS 41.PP.

Colour Legend:

41.EL.MV Client maturity

Conceptual design

Preliminary design

Final design

Manufacturing design

Commissioning & installation

As built

6.1.4 Power demand at the interface points

[41PP41EL-001i4-R] PBS 41.PP shall provide PBS 41.EL.MV electrical components with the power requested in the Table 6-3 below.

Table 6-3: Power demand on PPEN feeders

Baseline Configuration						
End Equipment	**Feeder**	**Active Power (MW)**	**Reactive Power (MVAR)**	**Power factor**	**Factor of Simultaneity**	**Factor of Utilization**
41ELMV-SWG-0001	41PPAJ-CAP-0085 41PPAJ-CAP-0088	23	13.2	> 0.85	<1	<1
41ELMV-SWG-0002	41PPAJ-CAP-0160 41PPAJ-CAP-0163	23	13.2	> 0.85	<1	<1

As the detailed design of both IVC-PS is still to be developed, the listed values must be understood as preliminary. E.g. depending on the selected ELM rectifier technology the active and reactive power demand may be reduced or slightly increased. Reductions of simultaneity and utilization factors may equally be possible.

6.1.5 Power cable and termination characteristics

Table 6-4 lists the characteristics of the 22kV cables used, as defined by 41.PP.

Table 6-4: characteristics of PPEN Feeders

Feeder	**From equipment-To Equipment**	**Cable Configuration [1] (mm^2)**	**Ext. diameter D (mm)**	**Cable bending Radius[2] (mm)**		**Cable access to 41ELMV swgr[3]**	**Lugs characteristics[4]**	**Connection place characteristics**
				Cable pulling	**After installed**			
41PPAJ-CAP-0085 41PPAJ-CAP-0088	41PPAJ-CU-4006 to 41ELMV-SWG-0001	2x3x(1*185) or 2x3x(1*240) TBC	41	TBD	TBD	Bottom		
41PPAJ-CAP-0160 41PPAJ-CAP-0163	41PPAJ-CU-6005 to 41ELMV-SWG-0002							

Notes:

1. In this column, we define the configuration of the cables: Single pole cable, three-pole cable etc.. The cable sizing is estimated on basis of the figures defined in [AD5]
2. In this column, the minimum bending radius as per [AD5] is defined, that the cable can exhibit during installation and after installed.
3. In this column, we define how the connection of the MV cables to the switchgear will be: from the bottom, from the top etc…
4. In this column, we describe the characteristics of the connection place of the MV lugs, to ensure a proper connection. PBS 41.PP can offer the cable termination kit for connection to PBS 41 ELM-PS MV switchgear; however, compatibility of the same shall be assured by the ELM-PS MV substation supplier. In case of incompatibility with ELM-PS MV substation switchgear, PBS 41.EL.MV should procure the termination kit based on switchgear selection.
5. In this column, we define the physical interface point with margins due to the uncertainty of layout at current phase.

6.1.6 Interface points location

Table 6-5 lists the 3D coordinates of PBS 41.EL.MV switchgear in location 13-L01.

Table 6-5: 3D coordinates of Interface points

3D Coordinates information			
Building	PBS 41 Interface Point	Description	Coordinates[1]
13	41ELMV-SWG-0001	Incoming cell #1 of the IVC-PS MV substation	X = 10,5 m (± 6 m) Y = -73,7 m (± 2 m) Z= 1,2 m (± 0.5m)
13	41ELMV-SWG-0002	Incoming cell #2 of the IVC-PS MV substation	X = 10,5 m (± 6 m) Y = -73,7 m (± 2 m) Z= 1,2 m (± 0.5m)

(1) At this stage, the TGCS coordinates are given as information and correspond to the current conceptual design of the IVC-PS MV substation. They will be confirmed at a later stage, for the PDR of the MV substation.
(2) Nevertheless, since a false floor will be implemented below the MV substation, PBS 41.PP can consider these coordinates to route their cables. If the location of the interface points change, it will have a minor impact on the cable routing.

6.1.7 Mechanical or integration related requirements

To be defined, if required.

6.1.8 Protection functions required by IVC-PS substation

[41PP41EL-001i5-R] PBS 41.PP shall provide the protection functions and/or services listed in section 6.1.8 (and its subsections) of this interface sheet.

6.1.8.1 Under- and over-voltage protection

Does the client need protection, regarding under voltage and over voltage?

☐ Yes, it is required

☒ No, it is not required

Equipment	Under voltage (Voltage % during x seconds)	Over voltage (Voltage % during x seconds)
41ELMV-SWG-0001	N/A	N/A
41ELMV-SWG-0002	N/A	N/A

6.1.8.2 Protective functions required by Client/Consumer

Does the client need protective functions?

☒ Yes, it is required

☐ No, it is not required

For each feeder, the Client/Consumer must choose the protection desired. The Client/Consumer must put N/A where the function is not required and values where the protection is required.

Protection type	Phase over current (Instantaneous and time)	Ground fault (Instantaneous and time)
AINSI CODE	50/51	50G/51G
41PPAJ-JA-4006	TBD	TBD
41PPAJ-JA-6005	TBD	TBD

6.1.8.3 Protections from PPEN

[41PP41EL-001i6-R] PBS 41.PP shall set their relay settings in accordance with the IVC-PS substations configuration and settings

6.1.8.4 Coordination between PPEN and Client protective devices

The inputs of 6.1.8 are given by the Client/Consumer and PPEN to design an electrical system in which the upstream Client protective device (circuit breaker) nearest to the system fault clears the fault without affecting the PPEN protective devices that are upstream from it. Settings of these devices are required during the installation and commissioning phase.

6.2 IP2: ELM Power Supply (functional interface)

IP2 is an indirect functional interface between PPEN and the ELM Power Supply, which is a PPEN Client connected through the IVC-PS 22kV substation. This section describes the active and reactive power profiles, as well as the harmonics generated by the three groups of ELM power supplies. Note that the values in this section have already been aggregated with those of VS3-PS and reported in Table 6-3.

6.2.1 Power and current profiles of IVC-Power supplies

Table 6-6 provides the power consumptions of each group of the ELM-PS system.

End Equipment	Active Power (MW)	Reactive Power (MVAR)	Duty
ELM-PS group 1	6.5	4	Constant power during operation + Low frequency power fluctuations under nominal operation (< 5 % of the absorbed power)
ELM-PS group 2	6.5	4	
ELM-PS group 3	6.5	4	

Table 6-6. Power demand of ELM power supplies

At present, the technology of the ELM-PS front-end rectifier is still open. For the definition of reactive power and generated harmonics in this version of the IS, a conservative approach has been followed by assuming Current Source Rectifiers (thyristors/diodes). Consequently, the harmonic levels have been defined in consideration of 12 pulse rectifiers

Table 6-7 lists the harmonics content generated by the ELM-PS system.

End Equipment	RMS Value of Current (A)	RMS value of fundamental Current(A)	Total Harmonic Distortion THDI (%)							
			550 Hz	650Hz	1150Hz	1250Hz	1750 Hz	1850 Hz	< n x 50 Hz[3]	
ELM-PS group 1	222	188	17	15	7.5	7.5	5.4	5.1	I_{50Hz}/n^3	12
ELM-PS group 2	222	188	17	15	7.5	7.5	5.4	5.1	I_{50Hz}/n^3	12
ELM-PS group 3	222	188	17	15	7.5	7.5	5.4	5.1	I_{50Hz}/n^3	12

Table 6-7 Current harmonics generated by the ELM-PS system

Notes :

1. The currents are computed for the lowest PPEN voltage (20 kV)
2. The values are based on theoretical values for diodes/thyristors rectifiers and does not consider harmonics due to operating profiles of ELM-PS system requested by the Plasma Control System. For the operating profiles, more details are given in section 6.2.2
3. The effective value of each harmonic shall be measured in accordance with IEC 61000-4-30 and IEC 61000-3-6 with a time interval of 10 minutes.
4. Above 1850 Hz, the odd harmonics are supposed to be decreasing and their RMS value can be approximated with I_{50Hz} /n, where I_{50Hz} being the RMS value of the fundamental harmonic and *n* being the harmonic rank.

Typical waveforms of the assumed 12-pulse rectifier stages for ELM-PS are presented in Figure 4.

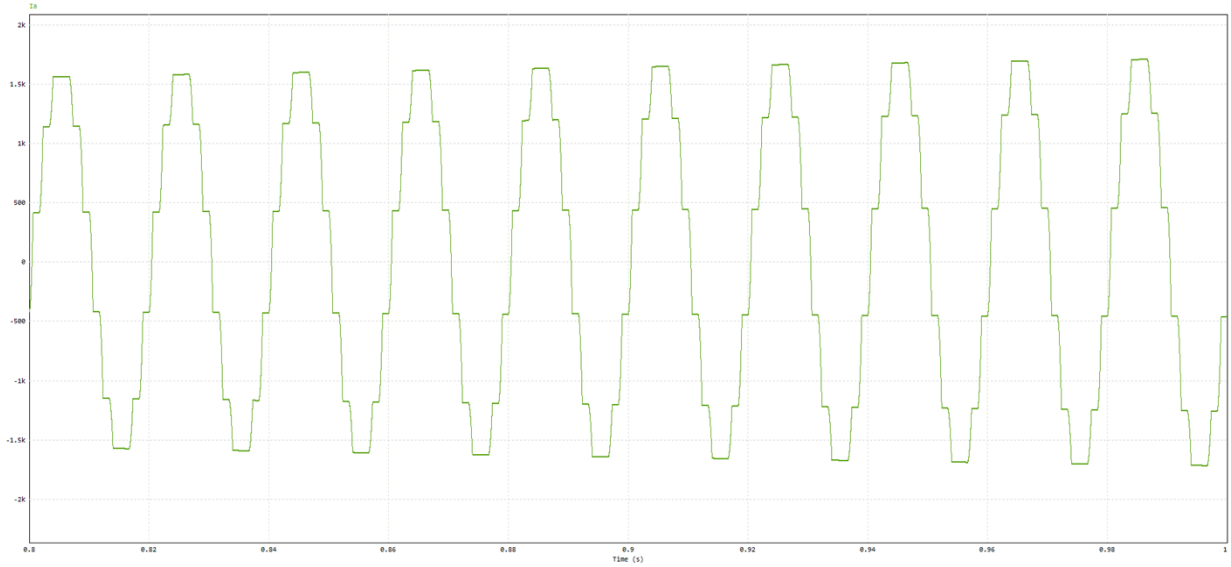

Figure 4. Typical current waveforms of ELM-PS AC-side (for illustration purposes only)

6.2.2 ELM-PS operating profiles during normal operation

According to the ITER research Plan [AD7], the ELM Power Supply shall be available during the entire pulse duration. Consequently, the power defined in this interface sheet are expected to be absorbed during all the operation or commissioning/testing state.

However, because of the control modes of ELM power supplies, low frequency (<10 Hz) fluctuations may appear on the absorbed power.

The impact studies of the ELM-PS operating profiles on the PPEN and other PPEN's clients are not in the 41EL scope. However, 41EL shall provide all the data required to perform these studies.

6.2.3 Inrush currents of ELM-PS System

[41PP41EL-001i7-R] PBS 41.EL ELM-PS shall limit the feeder's inrush currents up to 10 times of the rated current. (i.e. The permanent RMS current during the nominal operation of the ELM-PS).

6.3 IP3: VS3 Power Supply (functional interface)

IP3 is an indirect functional interface between PPEN and the VS3 Power Supply, which is a PPEN Client connected through the IVC-PS 22kV substation. This section describes the active and reactive power profiles, as well as the harmonics generated by the VS3 power supply. Note that the values in this section have already been aggregated with those of ELM-PS and reported in Table 6-3.

6.3.1 Power and current profiles of VS3 Power Supply

The VS3 Power Supply consists of two power converter stages connected in series. Each power converter stage is connected to a dedicated MV cell in the IVC-PS 22 kV substation.

Table 6-6 provides the power consumption of the VS3-PS system.

End Equipment	Active Power (MW)	Reactive Power (MVAR)	Duty
VS3 Power Supply	3.5	1.2	Continuous operation during plasma pulse for vertical stabilization actions ("noise operation") at approximately 500kW, with significant power fluctuations in the low frequency range. Maximum 3 pulses of approximately 3.5MW, each of approximately 10 seconds, during any plasma pulse.

Table 6-8. Power demand of VS3 power supply

The VS3-PS is expected to have an active front-end, which results in close to unity power factor, especially at full load. This is reflected in the values of Table 6-8.

Nevertheless, as the detailed design and particularly the control is still to be developed, a conservative approach has been followed by assuming Current Source Rectifiers (thyristors/diodes). Consequently, the harmonic levels have been defined in consideration of 12 pulse rectifiers.

Table 6-7 lists the harmonics content generated by the VS3-PS system.

End Equipment	RMS Value of Current (A)	RMS value of fundamental Current(A)	Total Harmonic Distortion THDI (%)							
			550 Hz	650Hz	1150Hz	1250Hz	1750 Hz	1850 Hz	< n x 50 Hz[3]	
VS3-PS	108	101	9.1	8.1	4.1	4.1	2.9	2.7	I_{50Hz}/n^3	13

Table 6-9 Current harmonics rejected on the PPEN.

Notes :

1. The currents are computed for the lowest PPEN voltage (20 kV)
2. The effective value of each harmonic shall be measured in accordance with IEC 61000-4-30 and IEC 61000-3-6 with a time interval of 10 minutes.
3. Above 1850 Hz, the odd harmonics are supposed to be decreasing and their RMS value can be approximated with I_{50Hz} /n, where I_{50Hz} being the RMS value of the first harmonic and *n* being the harmonics range.

As stated in Table 6-8, the VS3-PS operates on a continuous basis during a plasma pulse. In the absence of any VDE, the Vertical Stabilization function requires relatively low currents in the VS-coils, amounting to approximately 4 kArms. The resulting AC-side power level is approximately 500 kW, although low-frequency fluctuations are typically present. These fluctuations depend on the plasma control, the size of the capacitor bank and the rectifier control.

In case of an (imminent) VDE, the VS3-PS produces a current pulse up to 80 kApk with a duration of approximately 0.3 seconds, the energy of which is mostly sourced from the local capacitor bank. After such pulse the capacitor bank is recharged through the grid-connected rectifier stage in a maximum of 9.7 seconds, with a power level of approximately 3.25 MW.

For any given plasma pulse, the VS3-PS is required to provide only three such VDE pulses. After this, the plasma pulse is either aborted, or continued but with VS3-PS providing only vertical stabilization control ("noise current").

Figure 5 presents a worst-case power profile at the AC-side of the rectifier, consisting of 3 consecutive VDE pulses, each followed by a recharging phase of around 8 seconds. The regular vertical stabilization noise operation is visible in between the pulses.

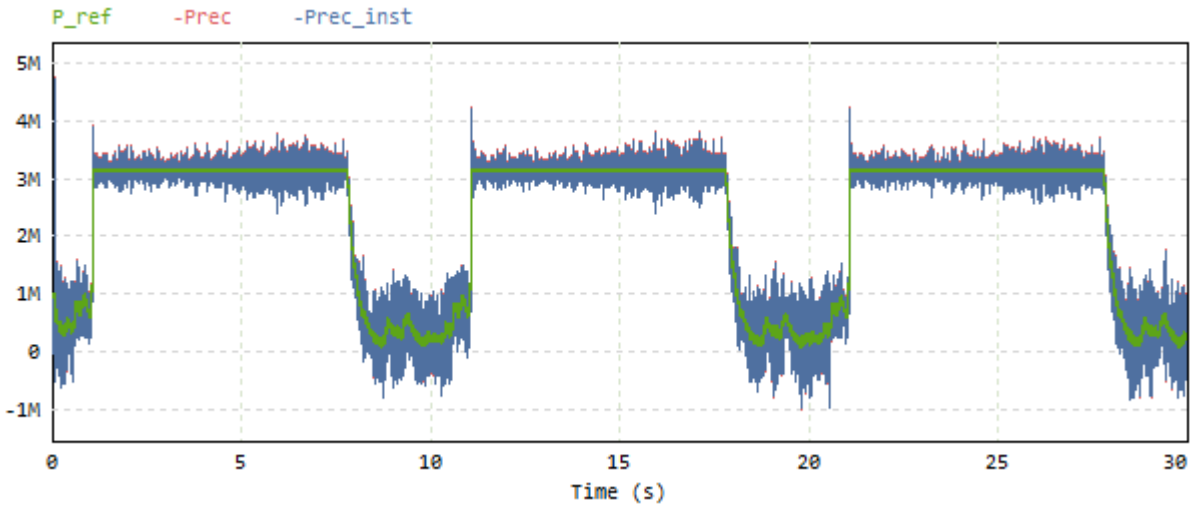

Figure 5. illustrative power waveform (for illustration purposes only)

6.3.2 Inrush currents of VS3 Power Supply System

[41PP41EL-001i8-R] PBS 41.V3 VS3-PS shall limit the feeder's inrush currents up to 10 times of the rated current (i.e. The permanent RMS current during the nominal operation of the VS3-PS).

7 Division of Responsibilities for procurement, installation and commissioning phases

7.1 PBS 41.EL responsibilities

[41PP41EL-001i9-R] PBS 41.EL shall procure and implement the incoming MV cells and their auxiliaries

[41PP41EL-001i10-R] PBS 41.EL shall consider the requirements of PBS41.PP (and PBS 44) to route their cables in the PBS 41.EL space reservation and to support their cable trays if required.

[41PP41EL-001i11-R] PBS 41.EL shall configure their protection relays (or equivalent) downstream the 22 kV feeders, at the IVC-PS MV substation.

7.2 PBS 41.PP responsibilities

[41PP41EL-001i12-R] PBS 41.PP shall design, procure and implement the MV cables up to the interface points.

[41PP41EL-001i13-R] PBS 41.PP shall manage interface requirements with PBS 44 for the cable trays.

[41PP41EL-001i14-R] PBS 41.PP shall connect the MV cables to the interface points of PBS 41.EL.

8 Staged Approach

The Staged Approach for each interfacing PBS entity is defined in [AD6].