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Technical Summary for Procurement of Design, Manufacturing, Testing, Installation and Commissioning of the Stage 2 Main Coil Power Converters

This document outlines a summary of the technical requirements of the Stage 2 Main Coil Power Converters (MCPC) that needs to be procured by the ITER Organization (IO).

The Stage 2 MCPC include the following items: 2 units of PF AC/DC power converter; 6 units of CS AC/DC power converter; 4 units of VS1 AC/DC power converter.
These units are to be procured by the IO, with a full turnkey contract that will include, but not limited to, the design, manufacturing, testing, installation, ...

Technical Summary for the Call for Nomination for the Call for Tender for:

Design, Manufacturing, Testing, Installation and Commissioning of the Stage 2 Main Coil Power Converters

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1 Purpose

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The Stage 2 MCPC include the following items:

- 2 units of PF AC/DC power converter;
- 6 units of CS AC/DC power converter;
- 4 units of VS1 AC/DC power converter.

These units are to be procured by the IO, with a full turnkey contract that will include, but not limited to, the design, manufacturing, testing, installation, commissioning and SAT of the power converters and their auxiliary systems (High & Low Voltage electrical distribution, instrumentation and control systems, cooling water distribution, mechanical structures and the DC busbars).

This document has the objective to provide preliminary information to potential companies or consortia that are interested in participating in the call for nomination for this tender and subsequent contract. The final technical specifications will be issued later and will be the only technical document to be considered for biding.

2 Background

2.1 ITER

The ITER Organization (IO) is a joint international research and development project for which the initial construction activities are underway. The seven members of the IO are the European Union (represented by F4E), Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA.

The project aims to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes and to gain necessary data for the design, construction and operation of the first electricity-producing fusion plant. It will also test a number of key technologies, including the heating, control, diagnostic and remote maintenance that will be needed for a full-scale fusion power station.

The ITER site is in the Bouches du Rhône district of France. It includes the Headquarters of the IO and a construction worksite. The construction of the facility is on-going. Further information is available on the IO website: http://www.iter.org.

2.2 Coil Power Supplies and Distribution System Overview

ITER Coil Power Supply & Distribution Systems (PBS 41) comprise of following major subsystems/plants:

- 400/66/22 kV Pulse Power Electrical Network (PPEN);
- 66 kV Reactive Power Compensation and Harmonic Filtering (RPC & HF);
- Coil Power Supply AC/DC Converters;

- Switching Networks Units (SNUs), Fast Discharge Units (FDUs), Protective Make Switches (PMSs), DC Busbars and Instrumentation.

PPEN receives power from the 400kV Grid and distributes (@ 66kV& 22kV level) it to the pulsed loads of Coil Power Supply Systems (CPSS) and Heating & Current Drive (H&CD) Systems.

RPC & HF system reduces the voltage fluctuations in the Grid and PPEN by control of reactive power flow and harmonic filtering.

AC/DC power converters, with a total installed power of about 2.2GVA, provides the controlled voltage/current to the ITER superconducting magnet coils for plasma initiation, plasma current, shape and position control, and error field correction.

FDUs provide protection of the coils by fast discharge of the stored energy in case of quench. SNUs provide voltage for plasma initiation, supplementing the a.c./d.c. converters.

2.3 Stage 1 and Stage 2 Main Coil Power Converters

The Main Coil Power converters, which are required to supply the TF, PF, CS and CC coils, are procured in 2 stages:

- Stage 1 power converters are already in commissioning stage;

- Stage 2 power converters are to be procured in accordance with the new ITER baseline 2024.

In ITER baseline 2024, the DT experimental phase is consolidated into a singular phase termed "Start of Research Operations" (SRO). There is a solitary assembly stage before SRO, named "Pre-Start of Research Operations Assembly" (Pre-SRO Assembly), and a subsequent assembly phase, "Post-Start of Research Operations Assembly " (Post-SRO Assembly), dedicated to installing systems required for the inaugural DT phase, DT-1. Therefore, both the stage 1 and stage 2 power converters are required for SRO and should be assembled in the stage of Pre-SRO Assembly.

The power converters of Stage 1, including all the accessories have been provided as in-kind contribution by the Chinese and Korean Domestic Agencies. These converters are utilizing thyristor-based line commutated converter technology. The procurement process is currently at the stage of on-site installation and commissioning.

The converters required for the Stage 2 are to be procured and commissioned and will be in series connected with the existing stage 1 converters. This procurement is to be a turn-key project: a single contract including from design, manufacturing until the successful site commissioning and handover of components.

The table below indicates the type, rating and number of power converters units in Stage 1 and 2.

Table 2-1 Type and number of converter units in 2 stages

Type	Total units	Ratings of each unit	Stage 1 units (already manufactured)	Stage 2 units (to be procured)
Toroidal Field (TF)	1	±160/650V, 68 kA	1	0
Poloidal Field (PF)	16	±1050 V, ±55 kA	14	**2**
Central Solenoid (CS)	12	±1050 V, ±45 kA	6	**6**
Vertical Stabilization (VS1)	6	±1050 V, ±22.5 kA	2	**4**
Correction Coil (CC)	9	±300 V, ±10 kA ±85 V, ±10 kA	9	0

The following block diagram presents the configuration, ratings of powers converters in two stages and the procurement sharing of stage 1. The stage 2 power converters are highlighted in the purple rectangles.

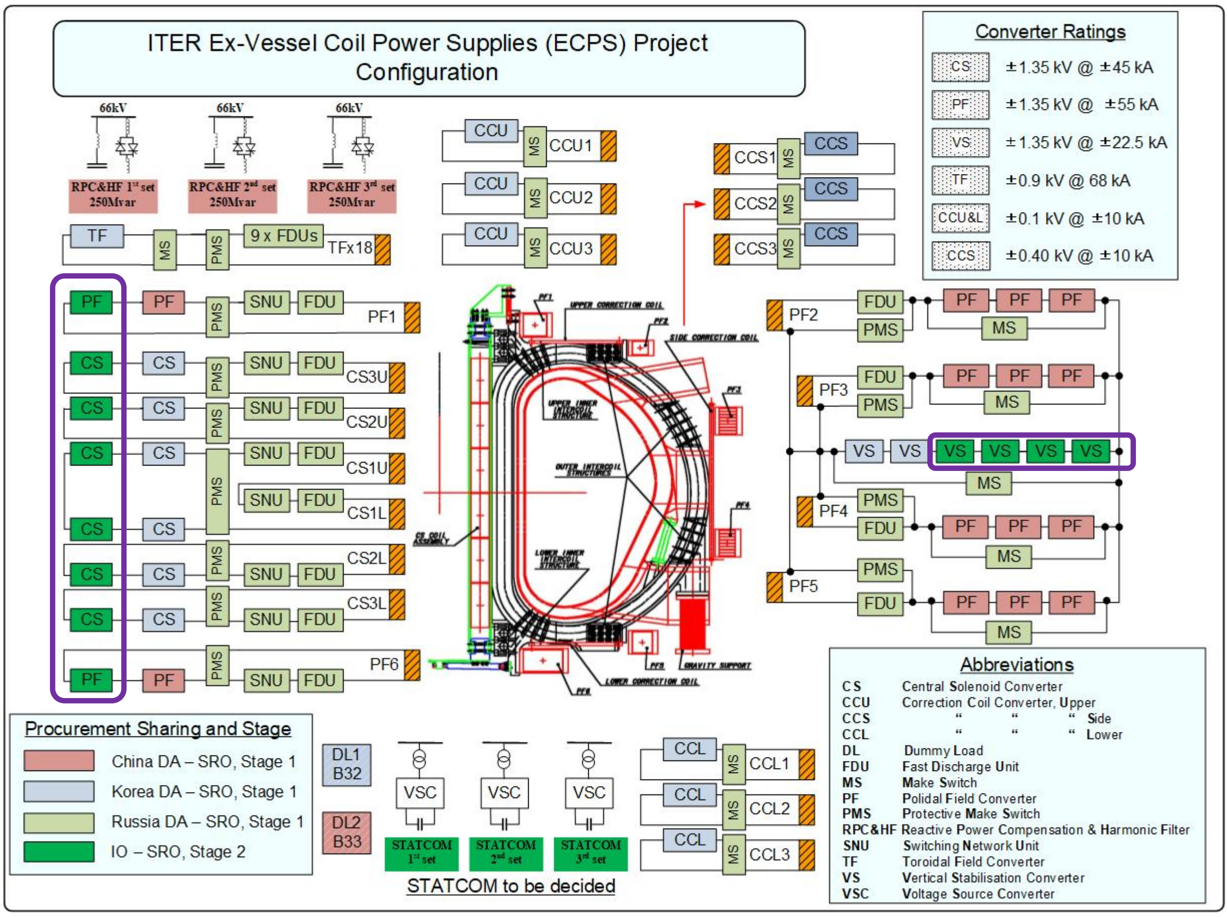

Figure 2-1 Block diagram of ECPS system ratings and procurement sharing

3 Technical Requirements and Scope of Supply

3.1 Functional requirements

Each converter unit shall be connected in series to the existing stage 1 converter(s) in designated electrical circuit (PF1, PF6, CS and VS1) through the DC interconnecting busbars, and perform the following main functions:

1. Receive power from the 66kV AC busbar, convert the AC power and supply the DC power to the superconducting coils;

2. Supply the DC voltage (within the range of ±1.05kV, on-load) per commanded by the corresponding circuit controller (command frequency at 1 kHz); the voltage response to command shall be linearly rate limited such that:

   - The response time of the voltage from (+) to (-) and from (-) to (+) is symmetric;

   - The full scale voltage change from (+) to (-) and from (-) to (+) is accomplished within two electrical cycles (40 ms based on 360° at 50Hz) for PF and CS, or 1 electrical cycle (20 ms based on 360° at 50Hz) for the VS converters;

3. Continuous-duty supply current (within ±22.5kA for VS1, ±45kA for CS and ±55kA for PF) without polarity change of DC busbar connections (i.e. four-quadrant operation).

4. The power converters supply superconductive magnets, which are characterised by very high inductance and stored energy. Therefore, it is necessary to prevent the possibility of opening the current circulation circuit. The following requirement are specially required because of the superconductive loads:

   - Current polarity change with continuous current circulation (i.e. no dead time during current zero-crossing).

   - Freewheeling path of the load current in case of turning-off the semiconductor devices of the inverter/rectifier bridge.

5. Provide control functions consisting of:

   - Real time operational control and monitoring (for voltage control and current control);

   - Interlocks for investment/equipment protection and emergency shutdown;

   - Personnel safety control and monitoring.

3.2 Applicable standards and codes

For electrical and power electronics components, the applicable standards to be considered for the design, manufacturing, installation and operation of the stage 2 converter are listed in the ITER Electrical Design Handbook - Codes & Standards (TR-20-005), available on the ITER website. However, the main ones are listed hereafter:

- NF C 13 200: High voltage electrical installations*
- NF C 15 100: Low-voltage electrical installations*

- NF C 18 510: Operations on electrical network and installations and in an electrical environment*
- IEC 60146: Semiconductor converters
- IEC 60076: Power transformers
- IEC 61000: Electromagnetic compatibility

* Considering the specificity of the French standards, the IO will involve its technical experts or an external third party during the execution of the contract and the gate reviews to guide the contractor in the implementation of these standards. After the completion of the installation, an inspection will be performed by an independent entity, to check the compliance of the system with the applicable French standards (NF C 13 200, NF C 15 100 and NF C 18 510 mainly). The completion of this inspection will be a condition to close this contract.

For mechanical structural components (including their fixations…), mechanical integrity verifications will have to be produced by the contractor, using the set of Eurocodes and/or ESME codes.

3.3 Technical solutions

The converter topology and technology adopted for the Stage 1 main coil power converters is based on the industrial products available in 2010 when the Conceptual Design was developed. The industry is currently developing new products and two technical solutions may be considered for implementing the Stage 2 power converters:

1. Thyristor-based Converters (also known as Line Commutated Converters);

2. Voltage Source Converters.

The Stage 1 power converters are based on Thyristor-based converter technology, which has been widely used in the power supplies of the existing Tokamaks and industrial high current DC applications. In this power converter, the key semiconductor devices are high power thyristors (half-controlled device).

The Voltage Source Converter (VSC) technology is expanding the industrial areas of applications including high power applications. The semiconductor devices of this power converter are high power full controlled semiconductor devices, such as IGBT, IGCT etc. The additional controllability gives many advantages, notably the ability to switch the semiconductors on and off many times per cycle in order to improve the harmonic performance, the fast response of DC voltage output, and the fact that (being self-commutated) the converter no longer relies on AC system for its operation. Considering the thyristor based solution is selected for stage 1 and the potential of VSC technology, IO requires the supplier to provide:

- thyristor based solution for 2 PF and 6 CS converters;
- either thyristor-based or VSC based solution for 4 VS1 units.

Even if both thyristor based and VSC solutions are commonly implemented in industrial applications, it is not likely to request a direct supply without R&D or prototyping since the application in ITER coil power supply is regarded as very special in terms of voltage & current level and the control & operation modes. Therefore, the supplier shall develop the full scale prototyping for the stage 2 MCPC. The prototype, once fully demonstrated, can be used as one of the units for the final delivery.

Before launching this procurement for stage 2, IO has already constructed the building and other relevant supporting system based on the stage 1 converter solutions. These interface systems are covered in this document to provide impacting information to the suppliers. However, during the call for tender phase, the bidders will be able to propose their own solutions, with the condition that they respect the mandatory requirements that will be included in the final technical specifications.

3.4 Scope of materials

Each Stage 2 converter shall include the following items with respect to the functional ratings and requirements:

1. AC side line disconnection and earthing devices (to interface with IO feeder cables);
2. Converter transformers and metal-enclosed AC busbars penetrating the wall claddings of B32 and/or B33;
3. AC/DC converters with necessary voltage or current smoothing devices;
4. DC disconnecting and earthing switches;
5. DC interconnecting busbars and links (connecting to existing DC busbar to insert into existing stage 1 power conversion circuits);
6. Water cooling pipes, valves and and instrumentation (to interface with existing cooling water system service points).
7. Instrumentation and control system ancillaries for control and protection (to perform local conventional, interlock and safety control, and interface with existing circuit controller and other control systems).
8. Spare parts and maintenance for 5 years of operation.

Each Stage 2 converter is integrated with an existing circuit. Figure 3-1 shows a simplified diagram of integration of stage 2 with existing System, Structure, and Components (SSCs, applicable for PF and CS cases), and Figure 3-2 shows a 3D model of PF1 converter unit that are used to illustrate the scope of contract objects. For VS1 stage 2 cases, the 4 new units will be in series and insert into the circuit of VS1 with existing VS1-1 and VS1-2 converters.

The DC output terminals of a Stage 2 converter unit must be connected to the DC interconnecting busbars. Figure 3-4 shows a conceptual scheme of DC interconnecting busbars (blue rectangle) to connect PF6 stage 1 and PF6 stage 2 power converters. The design and development of the stage 2 interconnecting busbars and interface links are in the scope of this tender. The ratings of the DC busbars shall be in line with the ratings of the converter circuits.

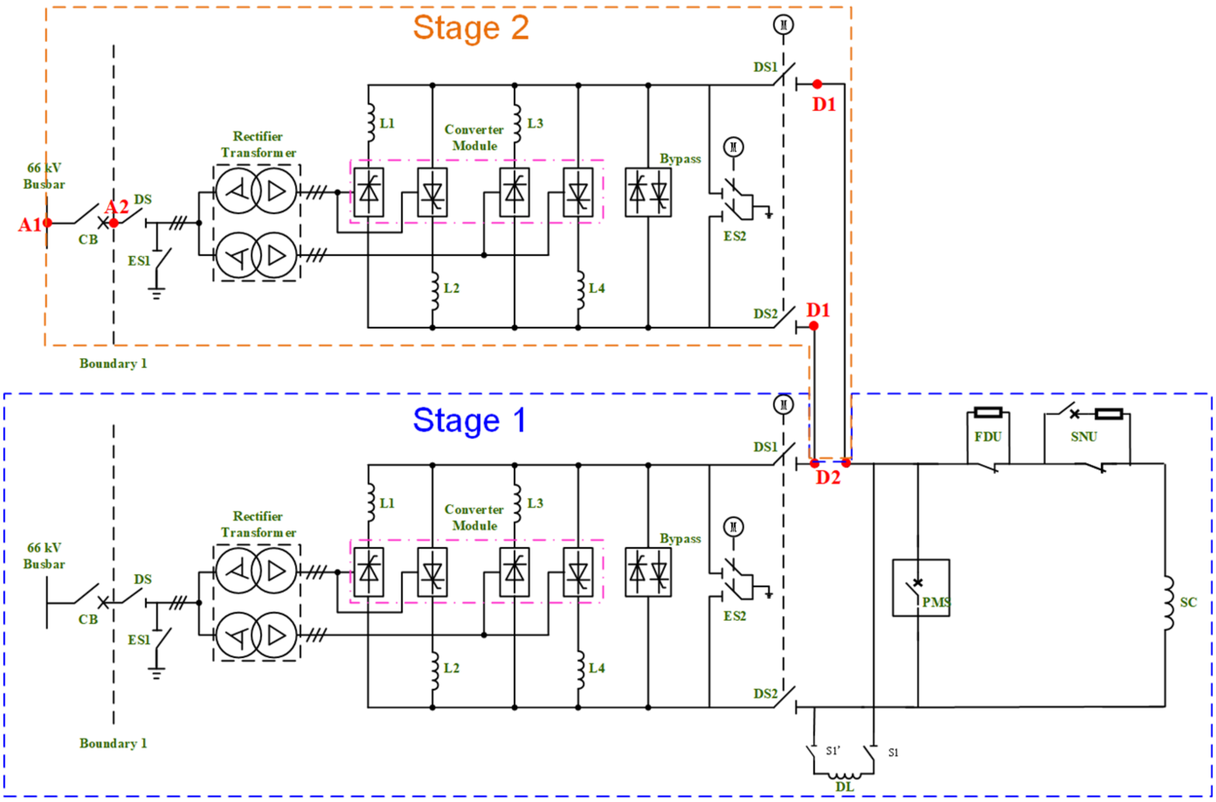

Figure 3-1 simplified diagram of PF1 power supply with configuration of stage 1 and stage 2

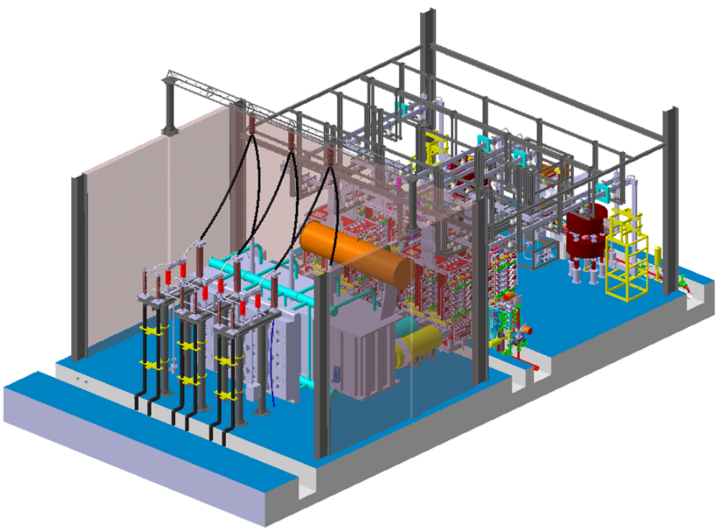

Figure 3-2 3D model of PF1 converter unit (stage 1) with foundation and supports

3.5 Building, interface and constraints

The section provides general description of the critical interfacing systems and requirements. The detailed list of the interface systems and requirements will be specified in the tender technical specification.

3.5.1 Building and site

Stage 2 power converters will be installed in B32 and B33, as shown in Figure 3-3. The geographical layout of Stage 2 power converters in B32 and B33 is arranged as shown in Figure 3-4 (the location for each converter unit can be re-arranged).

The installation and commissioning of stage 2 power converters shall follow applicable ITER worksite policy and procedures, which is in accordance with French labour code and other relevant regulations.

A dummy load of 6.76mH inductor is equipped for each building (DL1 for B32 and DL2 for B33). The contractor shall use the respective dummy load to commissioning the power converters in the commissioning stage.

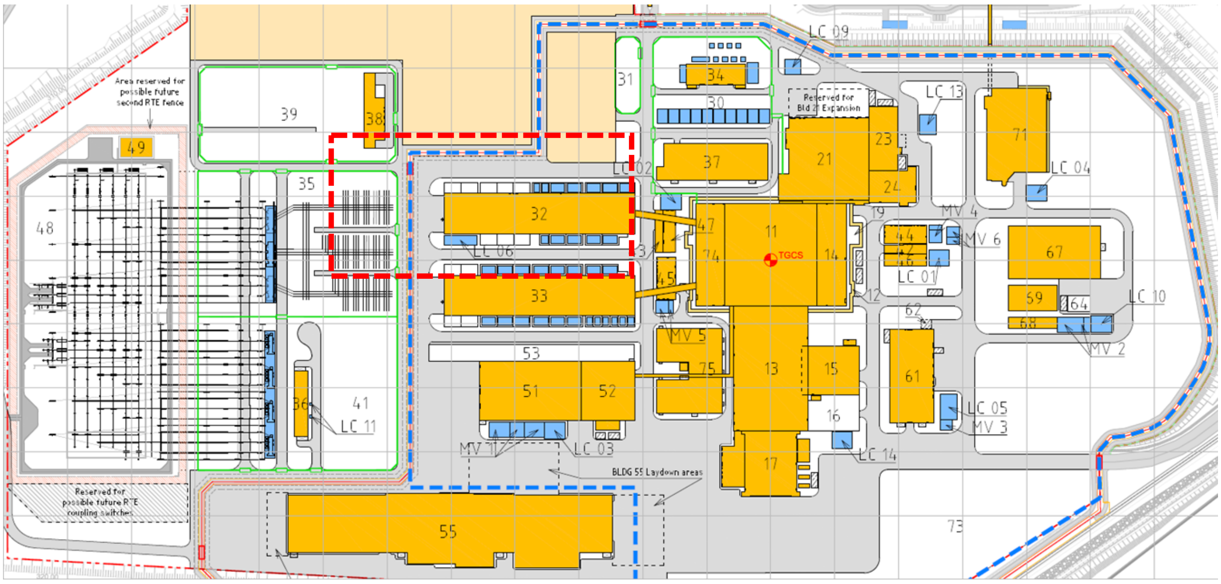

Figure 3-3 Scope definition of contract objects

Figure 3-4 Layout of main coil power supplies in B32 and B33

3.5.2 AC distribution system

IO will provide the 66kV AC cables respectively to the outside of B33 and B32 for the connection of each stage 2 power converter AC line disconnector.

The 66kV AC busbars will provide AC voltage within the range and distortion limit per specified by IEC standards.

3.5.3 Stage 1 circuit

The DC terminals of the stage 2 DC interconnecting busbars must be connected to the exiting corresponding stage 1 circuit. In the tender specifications, IO will provide a conceptual design for the stage 2 DC interconnecting busbars and the interfaces between stage 2 busbar and the stage 1 circuits. The contractor will be responsible to start from the proposed conceptual design and continue the preliminary and final design for the solution for the interface with stage 1 circuit.

3.5.4 Instrumentation and control

In addition to the development of local control system for the conventional, protection and safety control for the stage 2 power converters and their subsystem, the tender will include the development and implementation of controller(s) to interface and communicate the existing plant control and/or central control systems to achieve the following list of control functions:

- Operation command and states (reference voltage command, converter DC currents, operational states, etc) bi-directional real time communication with ITER PFCS Master Control System/central control system;
- Fault states and protections hardwired connection and network communications to the Plant Interlock Controllers.

3.5.5 Cooling water and LV power

The converter unit supply shall include the necessary pipes to the existing auxiliary services points close to the reserved installation space of cooling water and steady state AC power. The supply shall design and install, within the physical constraints, the necessary auxiliary services out of what current ITER plant can provide.

4 Scope of Work

This contract is to be a full turnkey contract. The scope of work includes the design, manufacturing, Factory Acceptance Tests (FAT), delivery, installation, commissioning and after-sales support of the complete system.

In addition, the Contractor is expected to provide all the technical documentation packages required to fulfil the IO’s design procedures (design reviews, readiness reviews…).

The preliminary tasks list is indicated hereafter[1]:

(i) Preliminary design:
    a. Technical solution selection for the power converters,

[1] Specific IO procedures and the milestones list for this project will be shared in the call for tender’s technical specifications.

   b. Confirm the technical feasibility of the technical solution (updating the major components design description, load specification and justification plan),
   c. Plan the future steps of design justification (especially qualification tests on the prototype).

(ii) Final Design:
   a. Interface validation and specifications,
   b. Specification of the major components,
   c. Design of the components,
   d. Prototype development and tests,
   e. Control software development,
   f. Justification of the design, using relevant methods and tools (calculations, simulations…),
   g. Preparation of the design reviews, according to the IO's procedures.

(iii)Manufacturing design and preparation:
   a. Refine design definition to a detailed level for the workshop execution (manufacturing drawings, fabrication, etc),
   b. Update all ICD/IS according to the refined design definition,
   c. Generate manufacturing Bill of materials, procurement plan and MIP.

(iv)Manufacturing of the system & delivery of the system:
   a. Preparation of the Manufacturing and Manufacturing of the system,
   b. Performance of Factory Acceptance Test according the IO's requirements and the approved test plan,
   c. Shipment of the system to the ITER site,
   d. Management of administrative procedures (customs, export control…).

(v) Assembly and installation

(vi)On-site acceptance testing and commissioning
   a. Preparation of the commissioning plan
   b. Performance of the commissioning. It shall be noted that the magnet under tests cannot be used for commissioning the system
   c. Support to IO for completing the French legal inspection of the system.

(vii) After sales support for operation and maintenance
   a. Provision of spare parts
   b. Performance of preventive and curative maintenance
   c. Possible system updates according to the test results and return of experience (could be considered in future contracts)
   d. Support during integrated commissioning with the magnet under test.

The execution of the contract will be organized in seven activity phases and seven gate reviews as shown in Figure 4-1.

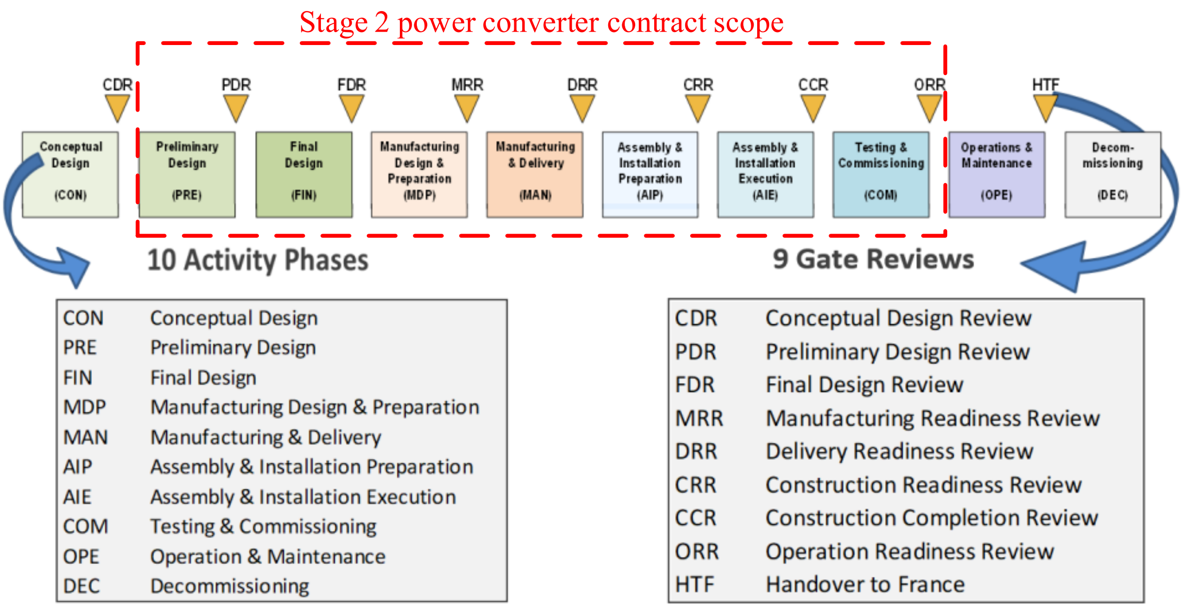

Figure 4-1 Activities phases and gate reviews as per the IO procedures.

Considering the system breakdown and the different subsystems, it will be possible to perform different activity phases and gate reviews in parallel, independently for each subsystem.

Conceptual Design (CON), Operation and Maintenance (OPE) and decommissioning (DEC) activity phases as well Handover to France (HTF) are not included in this contract. However, the supplier will be requested to provide technical and human support to IO during the first years of the Operation and Maintenance.

5 Timeline Requirements

Due to IO internal milestones, the integration of other systems in the area and the design schedule of other interfaced systems, the following milestones shall be considered for this contract:

1. Call for Nomination for the Call for Tender: Dec 2024
2. Launch of the Prequalification phase of the Call for Tender: Jan 2025
3. Bidders conference on ITER site: Feb 2025
4. Launch of the tender phase for the Call for Tender: March 2025.
5. Award of the Contract: Q4-2025
6. Kick-of meeting: Q4-2025.
7. Completion of final design (design and interfaces are frozen): no later than Q3-2027.
8. Beginning of installation in building 32/33: Q3-2029.
9. End of standalone commissioning: no later than Q3-2032.