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1 Purpose

The objective of this service contract is providing the engineering support for the Tokamak cryogenic system simulator development, including the cooldown/warm-up of Tokamak, the re-cooldown after fast discharge of CS, PF/CC. Therefore, the development of superconducting coil models are foreseen, which wounded by Cable-In-Conduit Conductors (CICCs).

2 Scope

This work focuses on the process analysis of cryoplant under defined operating modes, I-CD, R-CD and warm-up. The cryoplant is responsible for the operation of superconducting coil system, CS, TF, TF-ST, PF/CC and CP system. Five cryo-distribution systems, ACBs, provide refrigeration power from the Cryoplant. The dynamic simulation model has been developed as three CBs connected to five ACBs. The subcooler of each ACB is pumped through CCB and return to the low pressure side of CBs. The variation of heat loads from each system is implemented to a subcooler of ACB and the refrigeration power from each CB has to be well-balanced and –distributed to each ACBs. The current model does not include the superconducting coil system so that the modelling of coil system (CS, TF, TF-ST, PF/CC) are required, which will be utilized to pursue the global cooldown/warm-up of Tokamak and R-CD after the fast discharge. The project requirement specifies that the Tokamak should be cool-down in one month and the R-CD should be in 2 hours before ready for the next POS.

3 Definitions

ACB	Auxiliary Cold Box
CB	Cold Box
CC	Correction Coil
CCB	Cold Compressor Box
CICC	Cable In Conduit Conductor
CP	CryoPump
CS	Central Solenoid
FED	Fast Energy Discharge
I-CD	Initial Cool-Down
He	Helium
LTM	Long Term Maintenance
PF/CC	Poloidal Field coil/Correction Coil
POS	Plasma Operation State
R-CD	Re-CoolDown of magnet after fast discharge
SHe	Supercritical Helium
ST	(magnet) Structure
TF	Toroidal Field

4 References

L. Serio "Challenges for cryogenics at ITER", Advances in Cryogenic Engineering Vol. 55, 2010, pp. 651-662.

5 Estimated Duration

The duration of the service shall be 12 months maximum. The completion date is assumed to be in 2015 with respected to the signature of the contract in 2014.

6 Work Description

All work will be performed with a developed dynamic simulation model by EcosimPro. The sequence programs and/or operating conditions will be directly implemented to the software, which requires profound knowledge of process control logic as well as sequence programing via C++. The dynamic simulation model for the Cryoplant will be provided and the work should focus on the Tokamak system modelling and the process control and optimization of Cryoplant operation. There are two subtasks for the technical support activities, described as following.

Subtask-1: Modelling of superconducting coil system and TF-ST

The Contractor shall work on the development of superconducting coil model and TF-ST which shall be integrated to the Cryoplant model. The coil system consists of different types of CICCs with their own winding arrangement. The developed model shall capture thermo-hydraulic behaviour of superconducting coil under dynamic heat loads and transient conditions.

There are two types of CICCs, TF, CS and PF utilize CICC with a central cooling channel to remove the dynamic heat loads due to AC losses, while CC utilizes conventional CICC. The modelling approach might be different for two cases but in both cases, the thermo-hydraulic behaviour of SHe has to be well-captured. Furthermore, the model shall be able to take into account the thermal diffusivity of stainless steel conduit which substantially influences the heat conduction within the coil winding pack during the cooling/warm-up processes.

The fidelity of modelling will be benchmarked against other numerical codes.

Subtask-2: Optimization of process control under I-CD, R-CD and W

The Contractor shall implement the developed superconducting model in Subtask 1 to the Cryoplant model as optimizing the three operating modes: I-CD; R-CD and W. The developments of sequence programs for the gradual cooldown/warm-up operation are required. The transition of cooling paths within the CBs should be smooth and not disturb the stability of overall operating conditions. Each mode has time constraint and the process has to be optimized to fulfil the requirement.

I-CD requires the sequential operation of cold box which is designed to provide the high pressure helium gas with a specified cooldown speed to the Tokamak. The main issue is process control of LN_2 heat exchangers with respect to the supply temperature control for the Tokamak. The optimization of initiating the turbine operation ensures the smooth transition and achieves the required cooldown speed of Tokamak. The temperature gradients within the coils system and/or TF-ST should be kept below 50 K. The master control halts the cooldown process as increasing the temperature gradients of more than 50 K. W operation should be comparable with I-CD, with reversal process.

R-CD is one of the critical operations for Tokamak, which designated to re-cooldown the system after the plasma disruption followed by FED of CS, PF/CC. The system shall be back to its POS in 7200 s. In addition to this, the process analysis should be conducted for R-CD with TF FED. The stored energy of 10 GJ will be released and the coil system temperature increases approximately 53 K. Cryoplant should bring coil system back to its nominal operating condition in four days. Thus, two independent cases should be considered to establish each R-CD process.

The development of SHe pump might be included to represent the system under nominal operating conditions, which can be considered as an option; depending on the time frame of contract.

7 Responsibilities

Contractor:

The Contractor warrants that all personnel supplied under the contract have the necessary qualifications and experience to carry out their work.

The work shall be performed 50% on the ITER site.

ITER:

The contractor will work under the technical instruction of an ITER nominated engineer.

ITER will provide the required information-access to the respective ITER files for executing the work when needed to follow the implementation plan during execution of the work package.

8 List of deliverables and due dates

Each subtask listed in that section 6 will be documented by the expert with a detailed report, including the optimized simulation model. The generation of these deliverables shall be monitored by the IO TRO during execution of the contract and reviewed at the end of each work package. The due date shall be T0+8 months for subtask 1 and T0+12 months for subtask 2.

9 Acceptance Criteria

The acceptance of the work is based on completion of the tasks and goals set on the work plan for each item, as well as on the completion of reports and documents specified in the work plan.

10 Specific requirements and conditions

The following attributes are required to carry out the typical work packages identified in this specification:

- MS in physics or engineering

- Experience in the operation or simulation of a large scale cryogenic system
- Profound knowledge of process control of a large scale cryogenic system
- Familiarity with EcosimPro software
- Experience with the modelling of thermo-fluid analyses on the Cryogenic related issues; heat transfer, fluid dynamics and process study
- Ability to communicate effectively and to write clear and concise reports in English
- Good interpersonal and communication skills
- Ability to work independently when required

11 Work Monitoring / Meeting Schedule

The official language of the ITER project is English.

The work shall require the presence of the Contractor's personnel at the site of the ITER Organization to satisfy 0.5 ppy.

Each work package shall commence with a kick-off meeting.

- A monthly progress meeting shall take place.
- A short review shall take place at the completion of each work package.
- Other regular meetings will take place on an ad-hoc basis as deemed necessary

The Contractor shall prepare short minutes of each kick-off, monthly and milestone progress meeting.

12 Payment schedule/Cost and delivery time breakdown

The detailed payment formalities are stipulated in the Special and General Conditions of the contract.

13 Quality Assurance (QA) requirement

The organisation conducting these activities should have an ITER approved QA Program or an ISO 9001 accredited quality system.

The general requirements are detailed in ITER Procurement Quality Requirements (ITER_D_22MFG4).

Prior to commencement of the task, a Quality Plan must be submitted for IO approval giving evidence of the above and describing the organisation for this task; the skill of workers involved in the study; any anticipated sub-contractors; and giving details of who will be the independent checker of the activities (see Procurement Requirements for Producing a Quality Plan (ITER_D_22MFMW)).

Prior to commencement of any manufacturing, a Manufacturing and Inspection Plan must be approved by ITER who will mark up any planned interventions (see Requirements for Preparing and Implementing a Manufacturing and Inspection Plan (ITER_D_22MDZD).

Deviations and Non-conformities will follow the procedure detailed in ITER Requirements Regarding Contractors Deviations and Non Conformities (ITER_D_22F53X).

Prior to delivery of any manufactured items to the IO Site, a Release Note must be signed in accordance with ITER Requirements Regarding Contractors Release Notes (ITER_D_22F52F).

Documentation developed as the result of this task shall be retained by the performer of the task or the DA organization for a minimum of 5 years and then may be discarded at the direction of the IO. The use of computer software to perform a safety basis task activity such as analysis and/or modelling, etc. shall be reviewed and approved by the IO prior to its use, in accordance with Quality Assurance for ITER Safety Codes (ITER_D_258LKL).