Annex 1

EUROfusion Engineering Grants 2020

List of positions

Contents

WP SAFETY AND ENVIRONMENT

1. DEMO Nuclear Waste Management

Positions ref. EEG-2020/01

Contact person: Maria Teresa Porfiri – mariateresa.porfiri@enea.it

Job Description

DEMO Breeder Blanket (BB), Divertor (DIV) and Vacuum Vessel (VV) are the most exposed components to high neutron fluence getting the highest doses. The structural materials are SS316 for VV and Eurofer (low activation) for BB and DIV. In addition Tungsten, Copper-alloys, ceramic, or liquid metal breeders (LiPb) and Beryllium are used in plasma facing components (PFC), in BB modules and in the cooling loops. BB and DIV will be replaced according to a maintenance planning.. The VV is supposed to work for the whole plant life.

The study will have the scope to perform a waste management study starting from the current DEMO material activation data. It will include the handling of the components, their packaging and transfer / transport to processing facilities (e.g. via cask), processing and storage/disposal. This will be done for the operational waste, the refurbishment waste (exhausted components), the waste in consequence of Design Basis Events and accidents and the decommissioning waste.

Among operational waste, particular attention should be given to tokamak dust, for which it is necessary to provide for treatment and conditioning processes favouring tritium recovery.

Identification and separation of waste materials with low activation or contamination, suitable for recycle will be a key part of this work because minimization of long lived activation products is an important objective for DEMO.

Tritium recovery from these components is important for economic, safety/environment and waste minimization reasons. Means of tritium recovery have to be assessed to determine those most applicable to DEMO for the tritiated streams identified. An important early step to define such streams will be to review the bounding Design Basis Events including accidents so that the waste consequences can be evaluated. For this, it will be important to examine the impact that safety measures may have on waste production such as the use of water which will increase the demands on management of tritiated and other waste. Technical and economical solutions will be sought throughout, for example in elaborating the needs for increased tritiated water storage and clean up.

The candidate will be required to become proficient in waste management and its application to large-scale fusion (DEMO). He/she has to gain knowledge of and/or experience in the following main areas:

- becoming fully conversant with the relevant regulatory codes and standards especially the requirements for classification, clearance and recycling, transport and disposal of radioactive wastes.
- developing waste processes to address the waste types and quantities identified, including the assessment of secondary waste.
- gaining experience with relevant computer codes e.g. those for neutron activation, calculating waste generated in accident sequence, and tritium recovery.
- understanding the experimental work in support of the above computer code calculations and identifying any gaps where this should be strengthened for application to this work. Of particular importance are the opportunities to recycle metals used in the DEMO reactor and future power plants. The work to be carried out will aim to identify and focus on developing solutions to these issues.
- working with experts in the DEMO design to assist in determining feasibility of proposed approaches and in particular their integration into the DEMO design,
- developing and pursuing contacts with other specialists at laboratories and industries.

The work will be carried out at Technische Universität München (TUM), PMU and ENEA as well as laboratories and industries specialized in waste treatment.

Eligibility: Master degree in engineering or chemistry or metallurgy or nuclear engineering

Main Work Package Involved: WPSAE, MAT, BB, DIV, PMU

Facilities to be used: Computer facilities at the hosting Research Unit and University

WP MAGNETS

2. Structural analyses of DEMO magnets

Position ref. EEG-2020/02

Contact person: Valentina Corato, valentina.corato@enea.it

Job Description

Superconducting magnets represent a crucial technology for the development of plasma fusion devices and for a Demonstration Fusion Power Plant (DEMO), in particular. Strong magnetic fields are necessary to assure the successful operation of a tokamak machine and the magnets play a critical role in every phase of its operation.

It is therefore mandatory to thoroughly assess the structural integrity of all the DEMO magnets (i.e. CS, PF and TF coils), including the respective support structures, and to demonstrate that it is maintained for all their life. All normal and off-normal operative conditions must be evaluated and both static stress and fatigue life acceptance be confirmed. The structures of the magnet systems comprise different metallic and non-metallic composite materials that undergo complex non-linear 3-dimensional deformations. Furthermore, the design of each magnet system is yet to be frozen and several different options are being investigated in parallel.

Given the high-complexity of the problem, a parametric Finite Element Analysis (FEA) is thus the tool to be employed. Hence, besides a deep understanding of the operation of all the magnet systems and of the performance of all different materials employed, the ideal candidate must also acquire a thorough understanding of the numerical analysis procedures that can be employed in this context (e.g. material homogenization and sub-modelling). Therefore, the candidate shall:

- Review all literature material available and past analyses completed;
- Complete all electromagnetic analyses necessary to define all normal and off-normal load conditions;
- Complete the structural assessment of all the design options of the DEMO magnet systems (i.e. CS, PF, TF coils and relative support structures) by modelling all normal and off-normal operative conditions;
- Assess the static stress and the fatigue life of all magnet system components;
- Review all the acceptance criteria that must be applied, update them or formulate new ones, if necessary.

In particular, besides completing the assessment of all DEMO magnet systems already defined, the candidate shall also develop a systematic and parametric modelling procedure that can be employed to complete the evaluation of any other possible magnet system design that might be discussed. The aim is to complete a detailed documentation that shall represent the state of the art of numerical FEA related to fusion magnets of tokamak machines. If necessary, the candidate will also suggest additional requirements for the qualification of the materials to be employed and/or a revision of the respective acceptance criteria (e.g. additional material properties that would be necessary to experimentally assess).

The ideal candidate must therefore be capable in a broad range of engineering fields, from material science to structural and systems engineering, and numerical analyses. The candidate will be embedded in a project-oriented team and required to interact with other international groups and laboratories. As such, despite the majority of his or her activities will be conducted independently, the candidate must be capable of rapidly adapting to different technical contexts.

Eligibility: Master degree or PhD in an engineering discipline

Main Work Package: WPMAG

Interlinks with other Work Packages: LSI

Facilities to be used: NA

WP BREEDING BLANKET

3. System Engineer for the Breeding Blanket Project

Position ref. EEG-2020/03

Contact person: Lorenzo Boccaccini Lorenzo.boccaccini@kit.edu

Background

In the implementation of the documentation for the Gate Meeting concluding the pre-conceptual design phase and in preparation of the conceptual design phase, more emphasis has been done on a solid foundation of the DEMO Programme developing the System Engineering through all the PPPT activities. The PMI in Garching is responsible for the developing the overall DEMO plant architectural model, managing and structuring the requirements, and identifying interfaces. In do this task the PMI needs support from scientists operating in the different Projects (like the Breeding Blanket) ensuring that the plant architecture is consistent with, and can be mapped to systems level architecture. This includes the preparation of requirement documents, interface documents and load specifications at system level. This work has been defined as SEPOC (System Engineering Person of Contact). In the BB Project this activity is included in the tasks managed by the MDIT (Management Support and Design Integration Team) the group located in KIT to support the PL in the day to day work in the Project.

Job Description

This position is aimed for the development of the candidates engineering skills in relation with the DEMO Breeding Blanket (BB), including the blanket itself and the related Tritium Extraction/Removal (TER) Systems. It represents a unique opportunity to work within a team developing the integration and systems engineering approach for such a complex system. The work will be focused on the different aspects of the adopted systems engineering approach in the project as well as the on the development of an integrated model of the Breeding Blanket System.

Candidates with knowledge in one or more of the following areas are encouraged to apply:

- a fair knowledge of the issues related to the development of a Breeder Blanket of DEMO reactor;
- knowledge of neutronic, thermo-hydraulic and structural mechanics, including the capacity to analyze and adopt different solutions for the optimization of the design (e.g. parameters and geometry);
- a fair knowledge in plant integration;
- a fair knowledge on CAD software;
- a fair knowledge on the safety methodology for nuclear components (accident analysis, FMEA, etc.).

The successful applicant will be expected to spend time mainly in KIT in direct contact with the MDIT. He/she will also interact frequently with the teams in charge of the design of the specific BB systems (HCPB BB, WCLL BB and related TER Systems) to help in the definition of requirements, identification of interfaces, CAD integration, etc. He/she has to interface with the PMI in Garching that will represent one of the most important interfaces during the entire duration of the work; in particular a training phase should be foreseen in Garching with the PMI in order to acquire method and knowledge in the System Engineering applied in the DEMO Programme. Exchanges with other EFLs with relevant experiences in System Engineering will be promoted.

He/she will be a liaison with other Projects responsible of the development of other DEMO systems that are relevant interfaces to the Breeding Blanket Project; in particular with the Primary Heat Transfer Systems, the Remote Maintenance, Safety and the Fuel Cycle.

Eligibility: Engineers holding a Master degree or PhD

Main Work Package: WPBB (connection with PMU, WPBOP, WPSAE, WPRM, etc.)

Facilities to be used: none.

WP BREEDING BLANKET

4. Scientist for the development of the DEMO Pb-16Li loop

Position ref. EEG-2020/04

Contact person: Lorenzo Boccaccini Lorenzo.boccaccini@kit.edu

Background

To complete the conceptual design of the DEMO Pb-16Li loops it is needed to solve several technical issues related to thermo-fluid dynamics analysis during operational and transient conditions, structural integrity, power removal capability, tritium extraction, liquid metal purification, etc. Many of these issues must be addressed in the R&D phase (2019-2024), dedicated to investigate single effects at laboratory level.

R&D activities are required to assess the performance of Pb-16Li loops and to support the conceptual and later on engineering design of the various subsystems, like the Tritium Extraction System, the helium exhaust tank used to remove helium from Pb-16Li, the pumping system and the instrumentation for Pb-16Li.

Job Description

This call aims at developing engineering skills and know-how in the field of liquid metal technologies for Breeding Blanket of Fusion Tokamak Reactor. The candidate will develop the skills necessary to support the conceptual and later on engineering design of Pb-16Li loops focusing on the detailed analysis of Pb-16Li system technologies and instrumentations.

This call aims to address mainly the following aspects:

- support the engineering design of DEMO Pb-16Li loop, taking into account the design of main equipment and the integration of all instrumentations, valves, storage tank and pumping system in the loop;
- to perform the Engineering design of equipment and test section to be installed in TRIEX-II loop for the qualification of the Tritium Extraction system based on Permeator Against Vacuum technology.

The activities will include experimental operation and support mainly on IELLLO and TRIEX-II Pb-16Li loops.

Candidates with knowledge in one or more of the following areas are encouraged to apply:

- a fair knowledge of the issues related to liquid metal Breeder Blanket of DEMO reactor;
- knowledge of system thermal-hydraulic codes, such as RELAP5, including the capacity to analyze and adopt different solutions for the optimization of the design (e.g. parameters and geometry)"
- a fair knowledge on CAD software;
- a fair knowledge on the design of components and systems for liquid metal loop (pump, heat exchanger, vessel, valves, etc..)
- a fair knowledge on instrumentations suitable for Liquid metal loops (e.g. mass flow meter, pressure meter, level meter, etc.)

The successful applicant will be expected to spend time at ENEA Brasimone (ITALY), operating on IELLLO and TRIEX-II loop to gain an in-depth understanding of state-of-art liquid metal systems for fusion application. Exchanges with other EFLs with relevant experiences in PbLi technologies will be promoted.

Eligibility: Engineers holding a Master degree or PhD

Main Work Package: WPBB

Facilities to be used: IELLLO and TRIEX-II

WP PLANT LEVEL SYSTEM ENGINEERING, DESIGN INTEGRATION AND PHYSIC INTEGRATION

5. Design of DEMO magnet systems

Position ref. EEG-2020/05

Contact person: Christian Bachmann Christian.bachmann@euro-fusion.org

Job Description:

The Toroidal Field and the Poloidal Field magnet systems, including the Central Solenoid for DEMO, are the core of the basic machine and must be designed to satisfy the system requirements and operating environment in compliance with the design criteria. They represent significant advances in the state-of-the-art in superconducting magnet technology and their required high reliability must be achieved by designs based on relevant experience, comprehensive analyses, and component verification in a well-coordinated development program.

The objective of this call is to provide the suitable candidate with (a) sufficient engineering skills both for the coarse dimensioning of the magnet structures in operating conditions and for refined analyses (e.g., FEM) to assess the detailed designs; (b) the ability to develop design concepts to satisfy manufacture, assembly and maintenance requirements.

In particular, the candidate will develop his/her skills on:

- Design of magnet systems, including conductor and winding pack design. Proposals of design concepts to satisfy manufacture, assembly and maintenance requirements.
- Scoping analyses, using crude representations of the magnet system but considering a range of major geometric variations and magnet concepts.
- Evaluate the impact of the identified solutions with accessibility of the divertor and the rest of the machine, aiming at trading off the two different requirements, including assessments of ports and inter-coil structures;
- Detailed electro-magnetic, structural calculations for various load cases, to look in depth at the most promising concept.
- Design of magnet support and inter-coil structures, including stress calculations.
- Fault analyses, to look at the magnet behavior under fault conditions that may act in some areas as design drivers.

Interact with plasma scenario developers with the aim of producing an optimized design into account geometrical requirements (*e.g.* port space, or size variations).

The candidate will be embedded in the Lead System Integrator team, and is required to spend time in various EU laboratories. As such, the candidate must be able to work in a group and rapidly adapt to different technical contexts and contribute effectively in a multi-disciplinary team of engineers and scientists.

Eligibility: Master degree or PhD in an engineering discipline

Main Work Package: WPPMI

Interlinks with other Work Packages: WPMAG, WPDTT1

Facilities to be used: NA

WP PLANT LEVEL SYSTEM ENGINEERING, DESIGN INTEGRATION AND PHYSICS INTEGRATION

6. DEMO RAMI analyst

Positions ref. EEG-2020/06

Contact person: Sergio Ciattaglia Sergio.ciattaglia@euro-fusion.org

Job Description

Demonstration Power Plant (DEMO) will be a prototype of fusion reactor designed to prove capability to produce electrical power in a commercially acceptable way. Then, key elements of any engineering development of the reactor are definition of reliability and availability requirements (or targets), reliability and availability analysis, reliability testing, and "reliability growth", the structured process of finding root causes for reliability problems and predicting and monitoring the increase of system's reliability through successive phases. Since reliability and availability are strictly related to maintenance and inspection activities performed on the plant during the operating phases, the integrated approach in reliability and availability optimization is based on the four issues: Reliability, Availability, Maintainability and Inspectability (RAMI).

Many factors are important to achieve a satisfying RAMI level: design of systems; manufacturing quality; the operational environment; the design and development of the support systems; the level of training and skills of the people operating and maintaining the system; the availability of spare parts to repair the system; and the diagnostic aids and tools (instrumentation) available to check system processes and capability to detect normal and abnormal operating parameters. All these factors must be understood to achieve a plant with a desired level of RAMI. During pre-conceptual design phases, the most important activity is to understand the rationale of the plant, the related functions, requirements and constraints for the different systems. During plant development, the most important RAMI activity is to identify potential failure mechanisms and to make design changes to remove them or to mitigate consequences of the failures. During realization and installation, the most important RAMI activity is to ensure quality in manufacturing so that the inherent RAMI qualities of the design are not degraded. Finally, in operations and support, the most important RAMI activity is to monitor performance in order to facilitate retention of RAMI capability, to enable improvements in design (if new plant upgrading will be foreseen), or of the support system (including the support concept, spare parts storage, etc.).

Inadequate reliability or failed failure indications of components deemed safety critical items may directly jeopardize the public and worker safety. For that reason deterministic and probabilistic safety assessments (PSA) have to be strongly integrated with the RAMI assessments.

Once reliability and safety of plant operation is assured, further objective is to obtain plant's product and/or plant's mission at minimum cost. Then, cost/benefit analysis to justify and prioritize plant changes, modifications and enhancements during design and operation have to be undertaken and have to be matched with RAMI and PSA during the overall phases of plant life.

The above relationship between the facility design process and the parallel development of the facility safety analysis lets us to set the RAMI programme in a widest context called more generically the reliability assurance programme for DEMO.

The grantee will work with RAMI and nuclear safety specialists in the Research Unit (RU) hosting the Engineering Grant. Periods working with specialists at other RUs participating in WPPMI, WPBOP and WPSAE, at associated universities, and/or at the DEMO Programme Management Unit in Garching may also be included in the work programme.

The candidate should have knowledge of nuclear reliability and safety issues, be able to identify components and their related operating functions from design documents and design drawings, and be competent in scientific/engineering computing, with the capability of setting up complex computer models. In the course of the grant, the successful applicant will gain a good understanding of fusion systems and aspects of the DEMO design, will further deepen his/her knowledge of RAMI and nuclear safety principles and their application to fusion, and gain good experience of setting up and using complex engineering computer models for RAMI analyses.

Interim and final reports on the work will be written by the grantee. The work may also be presented at international fusion conferences and papers published in their proceedings. Attendance a two/three such conferences in the course of the grant will also give the grantee valuable exposure to the broader world of scientific and engineering research for fusion power.

Eligibility: Engineers holding a Master degree or a PhD

Main Work Package: WPPMI

Facilities to be used: Computer facilities at the hosting Research Unit.

WP EARLY NEUTRON SOURCE

7. ENS Deterministic Safety Analyses

Positions ref. EEG-2020/07

Contact person: Angel Ibarra - angel.ibarra@ciemat.es

Job Description

Deterministic analyses developed in recent years for implementation of Safety in IFMIF-DONES design started with systematic Failure Mode and Effect Analysis, functional in most cases, according to the available status of system designs. As a result of the FMEA exercises, close to 20 Reference Accident Scenarios (RAS) were screened out as candidate for Design Basis Accidents in view of facility licensing. In a second step (but coincident in time in most cases) computer code modelling was started to explore phenomenology around the identified RAS. On the other hand, the engineering activities themselves for many systems progressed in parallel to much more precise details of configuration.

As a result of the exploratory modelling, deterministic analyses are available for Lithium Systems (as main carrier of radioactive inventory), Test Systems including ancillaries, Accelerator Systems and neighbour systems, and Main Building, this one charged with confinement safety functions.

There are three main areas for which deterministic analysis have been oriented thus far. Firstly, the deterministic analyses of the RAS were directed to estimate the mobilization of radionuclide inventory taking into account conservative assumptions and design aspects still not fully available. Therefore, while conservative assessments were the main driver of analyses, further refinement of results can be necessary in a new phase, especially if they are promising to provide further safety margins. A main idea in this area has been to demonstrate the good configuration of safety barriers (including penetrations and extension of barriers) to avoid dose to the public and to the worker. It must be stated that in some cases the developed models can provide a good or reasonable approach to scenarios but they show inherent limitations due to the limited scope of implemented models in the computational code. This point may also deserve further work by means of validation modelling and suggestions of further improvements to developers.

Secondly, important system safety requirements depend on estimates of loads during design basis accidents, as pressures and temperatures evolution. In addition to predictions for design basis accidents, of particular importance is the exploration also in deterministic analysis of the region for beyond design basis accidents. In particular, the lithium fire events are of main interest because they must demonstrate which are the ultimate safety margins taking into account that this type of events might show cliff-edge consequence results. Therefore they deserve systematic attention in new phases of deterministic analysis.

Thirdly, an important chapter in the Safety Report is the definition of Technical Safety Requirements, or in other words, the complete set of parameters and operational ranges allowed by safety control systems before the protection system inhibits operation. This chapter has been started to address in limited cases thus far, but it needs a more mature status of analysis. In licensing, it is expected that this chapter will be scrutinized by the regulatory body. Implementation of safety signals in deterministic analysis will contribute to the final proposal of TSR in IFMIF-DONES systems.

On the other hand, the main computational model itself applied in present analysis, the Melcor-fusion code, has undergone recent developments by INEL development group that deserves attention as it can be more useful for IFMIF-DONES application. An example is the implementation of TMAP into MELCOR, which can be used for further estimates of tritium permeation and general behaviour in the facility.

The grantee will work with nuclear safety specialists in the Research Unit (RU) hosting the Engineering Grant and other WPENS participants in deterministic analysis. A period of time in reference groups in charge to analyse similar problems will be included in the work programme, as well as a formation period in INL MELCOR-fusion development group to improve skills in code application.

The candidate should have knowledge of basic nuclear safety issues and fundamentals of relevant phenomenology (fluid mechanics, heat transfer, etc.) and be competent in scientific/engineering computing, with the capability of setting up complex computer models. In the course of the grant, the successful applicant will gain a good understanding of safety issues (also relevant for fusion systems up to some extent) including nuclear safety principles and phenomenology, and gain good experience of setting up and using complex engineering computer models for safety analyses.

Interim and final reports on the work will be written by the grantee. The work may also be presented at international fusion conferences and papers published in their proceedings. Attendance a two/three such conferences in the course of the grant will also give the grantee valuable exposure to the broader world of scientific and engineering research for fusion power and accelerator systems.

Eligibility: Engineers holding a Master degree or a PhD

Main Work Package: WPENS

Facilities to be used: Computer systems at the hosting Research Unit

WP EARLY NEUTRON SOURCE

8. Liquid metal technology for IFMIF-DONES

Position ref. EEG-2020/08

Contact person: Angel Ibarra - angel.ibarra@ciemat.es

Job Description

In the future fusion power plants the structural materials will be critically exposed to high energy neutrons fluxes, up to 14 MeV. The study of the mechanical properties degradation during the reactor operation is a key factor in the design and licensing processes. The full qualification of candidate materials is foreseen to be carried out in an accelerator–based neutron source facility named IFMIF-DONES. Such an irradiation facility will be able to generate a neutron flux, by Li(d,n) stripping reactions, with a broad peak at14 MeV, by accelerated deuterium beam of 40 MeV impinging on a flowing liquid lithium target.

Among the different aspects of the liquid lithium technology involved in the design of the IFMIF-DONES plant, some activities needs to be deeply investigated with appropriate R&D and experimental support. Design, construction and operation of facilities are in particular needed to develop a number of topics including: i) the investigation of materials corrosion/erosion effects under flowing lithium, ii) the definition of the pre-heating procedures to warm up the components which host and generate the liquid lithium target, or iii) the definition and validation of the technologies to be used for Li impurities monitoring and extraction, including H isotopes. These facilities are in line with the current and future EUROfusion work program.

The development of these topics imply the analysis of problems related to fluid-dynamics, thermomechanical, heat transfer, chemistry, test preparation, test conduction and test results examination. This position is aimed for the development of the candidate's skills in relation with the IFMIF-DONES facility and represents a unique opportunity to work within a team developing the associated technologies. The work will be focused on different aspects of the Li technologies, one of the key specific characteristics associated with the IFMIF-DONES but with a significant number of cross-cutting synergies with other Li application in fusion or with other liquid-metal technologies of great impact on other fusion-related components.

Different aspect of the Li technology will be considered in the development of the work including:

- Fluido-dynamics and thermohydraulic design of Li loops
- Li safety
- Li impurities monitoring and extraction, including H isotopes
- Li flow and radiation diagnostics

In the course of the grant, the successful applicant will gain an understanding of liquid metal systems and liquid metals technologies. The grantee will work with liquid metal and plant design specialists in the Research

Unit (RU) hosting the Engineering Grant. Periods working with specialists at other RUs participating in WPENS and/or at associated universities may also be included in the work programme.

The candidate should have knowledge of liquid metals technologies.

Interim and final reports on the work will be written by the grantee. The work may also be presented at international fusion conferences and papers published in their proceedings. Attendance a two/three such conferences in the course of the grant will also give the grantee valuable exposure to the broader world of scientific and engineering research for fusion power.

Eligibility: Master or PhD in Engineering

Main Work Package: WPENS

Facilities to be used: Computer facilities and laboratories at the hosting and associated Research Units

WP DIVERTOR

9. Component engineering for first wall limiters

Position ref. EEG 2020/09

Contact person: Jeong-Ha You (you@ipp.mpg.de)

Job Description

Divertor targets and first wall limiters are supposed to withstand the most severe thermal loads in a fusion power plant where the plasma-facing components (PFCs) of them will be subjected to extreme high heat flux transients (divertor targets: up to 40 MW/m² for several seconds, limiters up to several GW/m² for several milliseconds) in addition to stationary heat flux loads. Furthermore, the PFCs will be exposed to intense bombardment of energetic particles and fast neutrons causing erosion and embrittlement, respectively. Such a harsh loading environment poses a critical engineering challenge for developing PFCs for future fusion power plants, such as demonstration reactor DEMO.

In the framework of Work Package "Divertor" of EUROfusion Consortium, dedicated R&D efforts are being carried out to develop the PFCs of first wall limiters for the European DEMO. Emphasis is placed on employing advanced technologies for novel materials (armor, heat sink) and joining. The technologies are evaluated by extensive high-heat-flux qualification tests using small-scale mock-ups and post-mortem examination of damage. Further topics of PFC engineering under study are fixation of a swirl tape in a cooling pipe and attachment of target PFCs on a divertor cassette.

The aim of this EEG program is to train a qualified young engineer in the field of PFC engineering with the focus on the topics mentioned above. A successful candidate of this EEG program is expected to have basic knowledge and relevant skills in materials engineering (metallurgy, testing, microscopic characterization) and/or mechanical/nuclear engineering (solid mechanics, heat transfer, hydraulics, fabrication). Practical experience in finite element method (FEM) and computer-aided design (CAD) is of advantage.

The candidate is supposed to be integrated in the WPDIV team contributing to its R&D programs w.r.t. the PFC engineering issues for divertor target and first wall limiter of DEMO in close collaboration with the other project members within WPDIV.

Due to the highly integrated and international nature of the project, it is essential requirement for the candidate to possess good skills of organization and communication. The candidate will be consulted and supported by the supervisor of hosting institute and the Project leader in administrative as well as technical affairs, but high degree of self-initiative is desired.

Eligibility: Master degree or PhD in an engineering discipline

Main Work Package: WPDIV

Interlink with other Work Packages: WPPMI, WPPFC

Facilities to be used: high-heat-flux test facilities, manufacturing facilities in industry

WP DIAGNOSTIC AND CONTROL

10. Development of optical diagnostics for DEMO

Position ref. EEG-2020/10

Contact person: Wolfgang Biel w.biel@fz-juelich.de

Job Description:

The DEMO plasma control system requires a number of accurate measurements related to all relevant plasma properties to be controlled. While a large number of diagnostic methods have been successfully developed and applied on existing fusion devices, their application for plasma control on DEMO is facing severe limitations: First, all diagnostic front-end components on DEMO will be subject to extreme load conditions (e.g. high flux and fluence of neutron and gamma radiation, high flux and fluence of CX neutrals, high thermal loads and ambient temperatures), and second the space for diagnostic implementation will be quite limited, in order to maximise the tritium breeding rate and to preserve first wall integrity. As a consequence, DEMO control will have to rely on a limited set of diagnostic systems and channels, which are mounted in protected (retracted) positions and hence will provide only limited performance.

The training and work steps within this fellowship are aiming towards the development of durable and reliable optical diagnostics (spectroscopy from X-ray until IR wavelength range, radiation power measurements, IR interferometry/polarimetry) for plasma control on a DEMO fusion reactor. The work programme should comprise a major part of the following points:

- Review and assessment of plasma diagnostic methods relevant to plasma control on a DEMO fusion reactor, with respect to the measurement process and the technical realisation. Systems level design of the layout of optical diagnostics on DEMO, and quantitative prediction of the expected measurement performance (accuracy, time resolution, spatial resolution, reliability) under DEMO conditions.
- Specific studies on the design and integration of optical diagnostics and their components (e.g. mirrors, mirror holders, filters, windows, detectors, spectrometers) on DEMO, including CAD, optical design, neutronics studies, and compatibility to remote handling.
- Quantitative analysis of the degradation of diagnostic front-end components (e.g. first mirrors) under typical DEMO load conditions (diagnostic lifetime assessment, reliability analysis).

Eligibility: Engineers holding a Master degree or PhD in a relevant area of mechanical, electrical or optical engineering

Main Work Package: WPDC

Facilities to be used: To be defined as part of the proposal, as required e.g. to prototype testing or demonstration experiments

WP MATERIALS

11. Test technologies for the characterization of materials after neutron irradiation

Position ref. EEG-2020/11

Contact persons: ***Gerald Pintsuk, g.pintsuk@fz-juelich (WPMAT-PL)***

Mike Gorley, mike.gorley@ukaea.uk (WPMAT-EDDI GL)

Job Description

The development and qualification of radiation resistant structural and armour materials is the key objective of the EUROfusion research programme. This objective is directly linked to engineering fusion power plant design studies and focusses on the enhancement of the materials technology readiness level as well as the determination of material properties and limit data for the application in engineering design rules and design code standards. The area is also among the priorities in the Fusion Horizon 2020 Roadmap, where materials development activities are pursued by the EUROfusion Consortium through the WPMAT Project.

Applications are invited from individuals interested in contributing to the new development or further development of testing techniques for neutron irradiated materials and/or components. This addresses amongst others the small available irradiation volume and related size and number of specimens to be provided by future fusion neutron sources like DONES or IFMIF and the performance under fusion relevant loading conditions. This covers a wide range of testing options from small scale mechanical testing techniques to operationally relevant high heat flux testing as well as a combination thereof. The main questions to be addressed is the qualitative and quantitative comparability of the testing techniques with available and well-established techniques for non-irradiated materials.

The selected candidate is expected to focus his/her research on one or more of the following areas:

- Development of small scale testing technologies (theory and tools) for the determination of mechanical and/or physical data relevant for engineering design.
- Development of testing technologies for the determination of materials and components performance under fusion relevant loading conditions (theory and tools), ideally also focussing on small scale specimens.
- Qualification of the respective testing technology or technologies (experiment and modelling) using one of the existing baseline materials (EUROFER97, tungsten, CuCrZr).

Eligibility: Master degree or PhD in materials sciences or an engineering discipline

Main Work Package: WPMAT

Interlinks with other Work Packages: WPMAT-EDDI, WPENS

Facilities to be used: Relevant facilities dealing with neutron irradiated and therefore radioactive materials available in European RUs

WP REMOTE MAINTENANCE

12. Remote Maintenance Equipment Parameter and Performance Characterisation

Position ref. EEG-2020/12

Contact person: Antony Loving, antony.loving@ukaea.uk

Job description

Due to the access and space constraints and the nature of the hazards present in a fusion power plant, safe operation of DEMO will be reliant on a complex maintenance system. This system will require a substantial number of different maintenance tools to be developed, and in practice the overall system is likely to include both commercial off-the-shelf (COTS) items, such as industrial robots, working with more complex bespoke devices such as those envisaged for handling and transportation of the divertor and the breeding blankets.

Efficient and effective development of such a maintenance system will rely heavily on digital simulation models, which are capable of providing fully dynamic assessments of the behaviour of the RM hardware and payloads. These models rely on detailed and accurate equipment parameters and performance characterization. These models will be required throughout the design process and enable more accurate assessment of the viability of DEMO plant maintenance early in the design cycle, de-risking the proposed solutions and reliance on extensive mock-up trials. Initially the simulation models will enable rapid assessment of maintenance strategy options, looking at overall plant or maintenance tasks, and evaluating the impact of alternatives, for example the use of transport casks vs controlled 'hot-cells'. Beyond this the simulation models will enable design and optimization of individual items of hardware, either as entirely bespoke items, or modifications and tooling to be used with COTS hardware. This optimization would include assessment of the functional capability of designs, using fully simulated control environments, study of failure modes and hence rescue/recovery for these. Finally, these simulation models will be used for structural assessments to meet relevant codes and standards.

The analysis and assessment will be reliant on extensive details of the performance capabilities and physical parameters of a wide range items associated with the maintenance hardware. For development of bespoke or modified tooling, the details of component parts such as bearings, gearboxes, actuators will be required. At the plant or maintenance task level this would also be supplemented with data about available COTS systems like industrial robots, remote operated vehicles or cranes and other lifting devices.

Objectives

The broad nature of the analyses required dictates the need for a database of characteristics that can be called upon by each analysis tool. These characteristics would ideally be obtained by performing a range of characterisation tests using suitable test rigs and hardware. This call is to provide research within the following areas:

- Understanding of the most important parameters required for the simulation models, and ongoing development of a database for these parameters.
- Identify and prioritize components to be characterized, focusing effort on items with the biggest impact on the overall behaviour of the hardware.
- Devise, plan and conduct characterisation tests on selected components (aiming to evaluate high priority items first). Identification of generic test methodologies that could be applied to a wide range of different types of components.
- Evaluate and update existing models for components based on measurements made, and assess the ability to extrapolate from existing measurements to models for a wider range of components, especially considering sensitivity and uncertainty for assumed characteristics.
- Demonstration of potential for automation of workflow utilizing these characteristics within expected simulation models.

The successful applicant will be expected to spend some time at the RACE facility in Culham, making use of testing hardware and facilities on site, utilizing both existing JET and RACE robotic hardware, to perform the practical testing, and working with other members of the WPRM team developing virtual engineering software, situated both at RACE and ENEA

It is expected that the applicant will also collaborate with existing WPRM EEG's. For example, the current EEG considering the development of automated RM systems will be reliant on accurate simulation models to provide dynamic tracking of all the items within the system. Furthermore the current EEG on condition monitoring is reliant on the characterization of real RM components to provide key performance data points and verify any behaviour models generated.

Eligibility: Master degree or PhD in an engineering discipline

Main work package: WPRM

Interlinks with other work packages: WPRM EEGs

Facilities to be used: RACE and JET Remote Handling and Robotic Facilities

WP TRITIUM, FUELLING AND VACUUM PUMPING

13. DEMO fuel cycle simulation

Positions ref. EEG-2020/13

Contact person: **Christian Day** Christian.day@kit.edu

Job Description

DEMO has to demonstrate tritium self-sufficiency, which is one of the 8 missions stated in the European Roadmap for the realisation of fusion energy. Hence, DEMO will be the first fusion facility that includes a closed fuel cycle.

In the previous years of the DEMO programme, a novel fuel cycle architecture was delineated, pointing to tritium inventory limitation as the major design driver. The DEMO fuel cycle will be based on three integrated loops. The innermost loop introduces a separation function close to the divertor, which extracts pure fuel and recycles it directly to the fuelling systems. This shortcut re-routes at short processing time the major part of the tritium in the exhaust gas, so that only a minor fraction will have to be routed through the tritium plant. The latter fraction again is distributed in a faster loop with protium removal and isotope re-balancing which is adjustable to produce DT in the wanted composition, and an outermost loop for the tritium recovery duties of the remaining gas and the integration of the streams from the breeding blankets (extracted tritium and tritiated coolant). On top of the improvements given by the smart architecture itself, batchwise processes will be replaced by continuously working technologies wherever possible. First estimates showed that this architecture successfully reduces the tritium inventory to values well below 1 kg.

This call aims at deepening existing experience in the application of modern design tools for chemical plants in a nuclear environment. To date, the ASPEN Custom Modeller software is being used and the existing fuel cycle simulator correctly describes all sub-systems of the novel architecture with 0D, partly 1D equations. In this engineering grant, the existing code shall be expanded in three directions.

(i) All sub-systems shall be described with an engineering (up to 2D) model that is running under dynamic conditions at acceptable convergence times;
(ii) The simulator shall not only focus on inventories but also allow to find the optimum operational parameters of the sub-systems;
(iii) Control loop strategies shall be implemented and a baseline for real-time tritium monitoring and control shall be delineated to provide the necessary information for regulatory and non-proliferation experts.

With this grant, it is aimed to get a tool in hands that identifies optimum operational points at three system levels of the fuel cycle, namely the single sub-system, the loop, and holistically the optimum design point of the integrated three-loop DEMO fuel cycle.

The successful applicant will be closely involved in the TFV integration team located at KIT, but strong interactions with the other Research Units included in the project will be required. A degree in Chemical Engineering and already existing background in fuel cycle technologies is considered to be most helpful to speed up the starting phase.

Eligibility: Master degree or PhD in an engineering discipline

Main Work Package: WPTFV

Interlinks with other Work Packages: WPBB, WPSAE, WPDC

Facilities to be used: n/a

WP BALANCE OF PLANT – PLANT ELECTRICAL SYSTEMS

14. Study and modelling of the power flow in the DEMO plant

Positions ref. EEG-2020/14

Contact person: Elena Gaio – elena.gaio@igi.cnr.it

Job Description

The Plant Electrical System (PES) function is to deliver to the grid the power produced by the generator but the recirculating power necessary to supply all the DEMO plant loads.

The PES represents a large fraction of the overall DEMO plant, therefore the development of an effective design capable to address the specific needs, to mitigate the impact of some issues and to improve Reliability, Availability, Maintainability, Inspectability (RAMI) can have a not negligible impact on the investment cost and on the efficiency of future operation.

The studies conducted so far have been addressed to understand, on the one hand the specific design challenges with respect to an equivalent system for a fission power plant, and on the other hand the additional issues with respect to the ITER electrical system. The activities in the present pre-conceptual phase have been addressed to outline a tentative design of some of the largest subsystems, according to an ITER-like approach. The results for the Power Supply (PS) systems of poloidal superconducting (SC) coils based on thyristor converters, showed a not acceptable reactive power demand.

Another issue identified is related to the power peaks for plasma formation, significantly higher than in ITER due to the much larger volume of DEMO; the first outcome is that they could not be provided either by the generator or by the electrical grid.

For these reasons, R&D has been launched to explore suitable electrical energy storage systems and advanced power converter topologies to maximize the energy exchange within the plant, so as to be able to satisfy the power needs for the DEMO operations [1, 2].

The Grantee will operate in this context, contributing to the on-going activities on the PES conceptual design and R&D tasks and he/she will focus the activity in particular on the study of the power flow in the DEMO plant.

The preliminary work in this regard will be addressed to:

- contribute to the update of the estimation of the power needs in the different phases of the plasma pulse both for the pulsed and steady state loads;
- study the existing simulation tools for power flow to evaluate their suitability for the DEMO PES case;
- study in particular the work done for ITER on this topic
- contribute to the outline design of the main PES components according to an ITER-like design approach;
- participate in the activities to explore alternative promising design solution

Then, the key topic of this proposal is the development of models of the PES main sub-systems useful for an integrated evaluation of the plant operation. An analytical approach based on state space models, like that one developed for the studies of the combined operation of the ITER main ac/dc converters and Reactive Power Compensation System [3] will be considered with particular attention.

This EEG work is expected to give a substantial contribution toward the final aim to prepare an overall model of the PES plant, capable to describe the power flow and identify possible instabilities or other issues.

During the 3-year grant period, the Grantee will work with specialists in the Research Unit (RU) hosting the Engineering Grant and associated universities. Exchanges with specialists of other WPs and of the DEMO Programme Management Unit in Garching will also be part of the work programme. In addition, it is also expected that the Grantee will spend some time at ITER.

Interim and final reports on the work will be prepared by the grantee. Attendance and presentations at international fusion conferences and preparation of papers to be submitted for publication will be encouraged.

Eligibility: Master degree or PhD in Electrical, Power Electronics, Energy Engineering or similar fields

Background knowledge and competences on the design and operation of power supply systems for superconducting coil and/or H&CD systems, and experience on the use of numerical simulation tools for electrical networks and systems are elements of preference.

Main Work Package: WPBOP-PES

Facilities to be used: Computer and experimental facilities at the hosting Research Unit

[1] A. Ferro et. al, The reactive power demand in DEMO: Estimations and study of mitigation via a novel design approach for base converters, Fusion Engineering and Design, In press, corrected proof, available online 1 May 2019

[2] F. Lunardon et al., MEST, a New Magnetic Energy Storage and Transfer System: Application Study to the European DEMO, accepted for presentation at the next ISFNT conference, Budapest, Sep. 2019

[3] C. Finotti et al., Continuous state space model of the ITER pulsed power electrical network for stability analysis, Fusion Engineering and Design, Volume 139, February 2019, Pages 62-73

WP BALANCE OF PLANT – PLANT ELECTRICAL SYSTEMS

15. DEMO Electrical Engineer for Ultracapacitors-based Energy Storage Systems for future Fusion Power Plants

Positions ref. EEG-2020/15

Contact person: Elena Gaio – elena.gaio@igi.cnr.it

Job Description

In future power plants like DEMO one of the main open challenges consists in developing power supplies able to feed the coils without having a huge effect on the electrical grid, through one or more of the latest energy storage system technologies.

In DEMO the duration of a plasma shot lasts for about 2h (for the present EU DEMO proposal) and the main origin of high stored energy needs is the application of thyristor based converters in combination with highly inductive loads (magnets). Other peaked loads might be requested by the additional heating systems (e.g. to support the plasma breakdown). Plasma position control coils for example require rapid change of very high currents (up to 100 kA) within very short time (less than some milliseconds). This situation is even worse in comparison to any existing Tokamak due to the fact that the distance between plasma and vessel has to be much higher to provide space for the breeding blanket [1]. Since the vessel has a passive stabilization effect on the plasma due to eddy currents counteracting plasma displacement events, and this effect decreases with distance, plasma elongation in a future DEMO may be limited to smaller values than in present day experiments.

To deal with these problems it would be advantageous to replace thyristor based converters by DC link based topologies providing high energy content local storage (the DC link). In this case, the reactive power would be invisible from the grid side which has to provide only the much smaller active power. Stored energy would oscillate locally between converter and load. To reduce the space requirements of such DC links, it would be advantageous to make use of the upcoming Ultracapacitors technology with much higher power density than classical foil capacitors.

The modular multilevel converter topology (MMC) would be well suited for the relatively low operating voltage of currently available Ultracapacitors modules with a concomitant capability of balancing different Ultracapacitors module stacks [2]. Moreover, the features of such topology, such as the modular structure with identical modules, the possibility to substitute failed modules, low losses and a simple mechanical construction, make it fit for DEMO pulsed loads.

The aim of this EUROfusion Engineering Grant (EEG) is to validate the MMC topology to be adequate for DEMO needs. In order to do so the candidate must be able to develop the required power electronics, to test specific Ultracapitor modules chosen for such task and to realize a small-scale prototype able to be extended for DEMO operation.

The EEG will perform the experiments mentioned above in a EUROfusion Research Unit (RU) with expert Electrical Engineers. Periods working at an associated University will also be included in the work program.

The candidate should have knowledge of Electrical Engineering and be competent with the power electronics environment. In the course of the grant, the successful applicant will gain a good understanding of fusion systems and aspects of the DEMO design, and will further deepen his/her knowledge of electrical engineering principles and their application to fusion power plants.

Interim and final reports on the work will be written by the grantee. The work may also be presented at international fusion conferences and papers published in their proceedings. Attendance a two/three such conferences in the course of the grant will also give the grantee valuable exposure to the broader world of scientific and engineering research for fusion power.

Eligibility: Engineers holding a Master degree or a PhD in Electrical Engineering

Main Work Package: WPBOP

References:

[1] L.V. Boccaccini et al., 'Objectives and status of EUROfusion DEMO blanket studies', L.V. Boccaccini et al., Fusion Engineering and Design 109–111 (2016) 1199–1206.

[2] S. Rohner et al., 'Modulation, Losses, and Semiconductor Requirements of Modular Multilevel Converters', Steffen Rohner, Steffen Bernet, Marc Hiller, and Rainer Sommer, IEEE Transactions on Industrial Electronics, VOL. 57, NO. 8, AUGUST 2010.

WP BALANCE OF PLANT

16. Nuclear Engineer in Support of DEMO PHTS component design and Balance of Plant operation

Position ref. EEG-2020/16

Contact person: Luciana Barucca; Luciana.Barucca@ann.ansaldoenergia.com

Job description

Many different engineering tasks are performed in support of operation of nuclear fusion power plant with the aim of carrying out an effective and safe exploitation. The Balance of Plant (BoP) of DEMO encompasses those systems devoted to the extraction of fusion generated power and its conversion into electricity. As part of the BoP, the Primary Heat Transfer Systems (PHTSs) of the DEMO In-Vessel components play a central role in the heat transfer chain of the machine, dealing with continuous variations of the working parameters due to the pulsed operation of the tokamak and harsh environmental conditions proper of many nuclear systems, like highly radioactive coolant, high pressure and temperature. These extreme operating conditions might have a negative impact on the plant equipment challenging their qualified lifetime. Furthermore, a deep study of the loads that the components of DEMO BoP are expected to withstand often requires a multi-scale and multiphysics approach covering several branches of the fusion power plant physics and engineering. For instance, a proper assessment of the activity concentration induced within the water circuits of In-Vessel and Ex-Vessel components due to its interaction with neutrons is a clear example of coupled neutronic/fluid-dynamic problem that has to be contextually solved in order to evaluate those nuclear loads to which the PHTSs and their surrounding equipment will be subjected under working conditions.

The call aims to develop methods and/or procedures to integrate the capabilities of different thermal-hydraulic, thermofluid-dynamic, neutronic (and thermo-mechanical) codes in a single computational tool to be used for the analysis of both steady-state and transients operations of DEMO BoP systems and components.

This work also aims at the development of good engineering skills and experience in the areas of thermal-hydraulics, thermofluid-dynamics and neutronics in support of DEMO Balance of Plant component design and operation.

The candidate is expected to:

- Work alongside experienced component and plant designers and safety experts.
- Prepare an integral plant model, in which each hydrodynamic system, heat structure, protection and control systems, and the components itself are developed individually, starting from the appropriate design information.
- Set-up a water coolant activation model, taking into account a 3D simulation of its interaction with neutrons, and implement it into the thermal-hydraulic model of BoP to properly assess the consequences

of radioactive isotopes passive transport due to coolant on the working conditions of PHTS components and their main surrounding equipment.
- Perform coupled thermal-hydraulic and neutronic analysis of normal operation sequences and specific transient scenarios to assess their impact on Balance of Plant components.
- Evaluate potential design changes and revisions to the BoP lay-out and implement them to integrate plant simulation tool with ad-hoc modelling improvements.
- Identify needs of BoP design ameliorations
- Analysis the impact that design modifications in components or systems have on the interactive global operation of the plant and evaluate impact of improving Plant Availability

Ideally the candidate should have a good knowledge of nuclear power plant thermal-hydraulics, thermofluid-dynamics and neutronics as well as some experience in the field of plant transient analysis.

Eligibility: Engineers holding a PhD or a Master degree in Nuclear Engineering / Energy Engineering / Mechanical Engineering or similar

Main Work Package: WPBOP

Interlinks with other Work Packages: WPBB, WPDIV, WPSAE, PMU-Integration

Facilities to be used: Computer and experimental facilities at the hosting Research Unit

WP PREPARATION AND EXPLOITATION OF W7-X CAMPAIGNS

17. Engineering in support of hardening of IR/vis divertor imaging observation systems for steady-state operation of W7-X

Position ref. EEG-2020/17

Contact person: Andreas Dinklage - andreas.dinklage@ipp.mpg.de

Job Description:

Hardening diagnostics against heat loads is key for steady-state experiments in next-step fusion devices. In the forthcoming campaigns of W7-X with water-cooled plasma facing components, single IR and the two visible observation windows for each of the eight immersion tubes need to hardened with respect to the increased thermal loads from plasma and ECRH stray radiation in steady-state operation. Experience gained on W7-X can be transferred to other steady-state machines.

Specifically, engineering to cope with thermal loads with □-wave background is to be conducted. This covers mechanical analyses including hydraulic components. Requirements result from specific conditions at the interface of plasmas radiation and microwave stray radiation. An important aspect relevant to exploiting the optical instruments is to address systematic effects on the measurements due to warmed window. Thermal calculations and meaningful test procedures should be developed and assessed in terms of requirements for safe steady-state operation. Moreover, ECRH stray radiation protection solution for the diagnostic components inside the immersion tube needs to be found and optimized keeping the integrity with respect to imaging requirements. In order to ensure the full use of NBI, window protections for NBI-loss need to be assessed and revised.

Eligibility: M.Sc., mechanical engineer

Main Work Package: WPS1

Synergies with other Work Packages: other experimental WPs

WP PREPARATION OF EFFICIENT PFC OPERATION FOR ITER AND DEMO

18. Fusion-Diagnostic Engineering: Development of manipulator probes for comparative plasma-wall interaction and material qualification studies in high and low flux plasma devices

Position ref. EEG-2018/18

Contact person: Sebastijan Brezinsek (s.brezinsek@fz.juelich.de)

Job Description:

Fusion diagnostics commonly need to combine engineering aspects of mechanical and electrical engineering, vacuum technology and optical design. This particular project furthermore requires consideration of compatibility of the probe material and design with plasma operation. In addition, rigorous project management and quality assurance play an important role in the successful implementation of fusion diagnostics projects.

This specific project will cover development of manipulator probes for edge plasma characterization and material exposition at the stellarator Wendelstein 7-X, MAGNUM-PSI, PSI-2 and other plasma devices. It includes probe electronics, vacuum interface for injections as well as Quartz-Micro Balances as in-situ diagnostics in the probe head. The aim is to integrate multiple sensors and material samples into a set of single probe heads ensuring that standardised material probe samples (dimensions optimized for post-mortem analysis within WP PFC) can be universally used. Probe heads should be made compatible with interfaces of manipulators at the various plasma experiments in order to allow for comparative studies.

Multi-functional probes allow for different exposition or characterization experiments in a flexible way without probe exchange, which is important in particular for superconducting machines with limited access. Probe electronics should be designed to be compatible with a number of probes requiring minor adaptions (preferably automated) during probe exchange. Besides comparative studies in steady-state facilities at high and low plasma fluence mimic ITER divertor and first wall conditions, a major benefit of the approach envisaged is the characterization of probes in a well known environment before application in the second stage to manipulators at Wendelstein 7-X.

The candidate will be introduced to the established design process of a sophisticated diagnostic covering both engineering and physics aspects. A team of skilled physicists, engineers and technicians in FZJ with access to high level engineering and physics simulation tools, a manipulator test stand as well as access to PSI-2, optical and electrical plasma diagnostics, and machining facilities - all located in FZJ - will be provided to the successful candidate.

Eligibility: Candidates should hold MSc degree in engineering.

EUROfusion Work Packages involved: WP PFC

Facilities to be used: *after successful design and testing in FZJ and PSI.2: W7-X (Greifswald, Germany), MAGNUM-PSI (Eindhoven, Netherlands).*

WP PREPARATION AND EXPLOITATION OF W7-X CAMPAIGNS

19. Engineering in support of the design of the divertor Lyman_alpha Laser induced Fluorescence (LIF) diagnostic in the VUV ($\lambda \approx 122$ nm)

Position ref. EEG-2020/19

Contact person: Andreas Dinklage - andreas.dinklage@ipp.mpg.de

Job Description:

A crucial aspect for the understanding of divertor operation – as a prerequisite for steady-state operation – is the distribution of neutral atoms in the SOL. A direct approach for measuring the atomic densities is laser induced fluorescence (LIF) applied to the 3D divertor region of W7-X. Ly□LIF diagnostic can measure neutral hydrogen densities in the divertor and the assembly of the diagnostic has been started. The excimer and dye lasers are set up and access of the laser beam to the torus hall wall has been provided. The laser beam path through the torus hall has already been designed.

Engineering in support of the diagnostics development will need to cover:

- Design of the vacuum test and calibration chamber (laser frequency tripling cell) in the lab
- Design of the laser beam injection components inside the W7-X port: laser frequency tripling cell at or inside the port, beam alignment system, cooled front mirror, etc.
- Design of the in vacuum observation telescope inside the observation port, including alignment system and water cooling; ECRH stray radiation compatible design
- Design and test of the feedback controlled mirror system to guide the laser beam through the torus hall

Eligibility: M.Sc., mechanical / optics engineer

Main Work Package: WPS1

Synergies with other Work Packages: other experimental WPs

WP PREPARATION OF EFFICIENT PFC OPERATION FOR ITER AND DEMO

20. Engineering of active and passive optical diagnostics for PWI studies in Radiation areas

Position ref. EEG-2020/20

Contact person: Sebastijan Brezinsek (s.brezinsek@fz.juelich.de)

Job Description:

The candidate will work in an interdisciplinary field encompassing fusion-related material science & technology, nuclear & optical engineering, and development of plasma-material diagnostics (optical spectroscopy, laser-based PWI diagnostics, and mass spectrometry) in controlled areas and hot cells, respectively. Assessment of fuel retention (including **T**ritium **T**) and material composition of toxic (including **Be**ryllium **Be**) and neutron-damaged metallic probes exposed to linear plasma devices (incl. PISCES-B), high heat load facilities (JUDITH), and JET(-2), by above mentioned diagnostics, after their nuclear-compatible design, and qualification, is envisaged.

The work can be divided into two main parts:

Complete (nuclear-compatible) diagnostic design and qualification of in-situ laser-based diagnostics (in-situ Laser-Induced Breakdown Spectroscopy **LIBS** Land Laser-Induced Ablation – Quadrupole Mass Spectrometry **LIA-QMS**) in the **H**ot **M**aterial **L**ab (**HML**) in Forschungszentrum Jülich including application at **JULE-PSI** (**JU**elich **L**inear **E**xperiment – **P**lasma-**S**urface **I**nteraction) located in a hot cell. The diagnostic design solution is based on presently applied in-situ LASER-based diagnostics qualified in the linear plasma devices PSI-2 and MAGNUM in “cold” labs operating under the work package PFC. Complementary, passive optical diagnostics for in-situ surface characterization based on surface reflection and polarization, and IR thermography.

Plasma-facing material characterization in the nuclear environment (HML). Practical of above mentioned diagnostics on different samples from FZJ, JET(-2), WP MAT, and WP PFC and accompanied material research techniques (e.g. microscopy, NRA, metallography). Fuel accumulation determination thus, surface and global contents of deuterium and tritium in metallic PFCs by different techniques in-situ in JULE-PSI (LIBS & LIA-QMS) and in the existing and operating FREDIS facility (TDS & LIDS).

Note, FREDIS is also the reference facility in Europe for LIDS on Be which is proposed as in-situ diagnostic in JET (if prolonged) and ITER (tritium monitor diagnostic). The candidate might complementary to the HML contribute in the design and operation of a LIDS system in JET in case of JET prolongation.

Eligibility: Master degree or PhD in an engineering discipline.

EUROfusion Work Packages involved: WP PFC, WP JET2. Samples from WP MAT.

Facilities to be used:

- PSI-2 (linear plasma test device), MAGNUM, PISCES-B (short visits) and JULE-PSI (linear device in the hot material lab)
- Hot material lab in Forschungszentrum Jülich including FREDIS facility
- JET-2 and its Be handling facility including the TDS station
- Material research laboratories: e.g. microscopy, ion beam analysis methods, mechanical testing within WP PFC and JET-2

WP PREPARATION AND EXPLOITATION OF JT-60SA

21. EU enhancement projects for JT-60SA: interfaces and integration on the machine

Position ref. EEG-2020/21

Contact person: **Gerardo Giruzzi (Gerardo.GIRUZZI@cea.fr)**

Job Description:

JT-60SA is a large tokamak device being built jointly by Europe and Japan at the Naka site of QST (*National Institutes for Quantum and Radiological Science and Technology*), and due to start operation in 2020. EU activities for JT-60SA include a number of Enhancement Projects, carried out jointly by Fusion for Energy (F4E) and EUROfusion, within the EU scientific strategy.

One of these projects is already in the procurement phase (EDICAM wide angle video camera). Other sub-systems will be designed and procured in 2019-2021, aiming at commissioning in 2022 and start of use in the 2023 campaign: Thomson scattering, VUV spectrometer for divertor, Cryopumps, Pellet system, Massive Gas Injection system, Fast Ion Loss Detection system.

Although each sub-system will have specific interfaces with the machine many of them will be common to all the projects and should be managed by dedicated EUROfusion and F4E staff, located in Garching (Germany).

In this context, the grantee will be trained and actively contribute to the success of the enhancement projects, by accomplishing the following main functions:

- assist the Project Leaders of the Enhancement Projects (located in various EU fusion Institutes) in the optimization of the engineering design and in particular:
- engineering requirements of sub-systems to be installed on JT-60SA
- interfaces of the sub-systems with the machine
- requirements for the Procurement Arrangement and related documents
- monitoring quality assurance for the enhancement projects
- requirements for the installation and commissioning procedures
- liaising with the Japanese QST team, also with missions to the Naka site

Expertise in mechanical engineering and use of CAD is required. Previous expertise in fusion devices and sub-systems is highly desirable.

Eligibility: Engineers with a Master or PhD (preferably with experience on a fusion facility)

EUROfusion Work Packages involved: WPSA

Facilities to be used: JT-60SA

WP PREPARATION AND EXPLOITATION OF JT-60SA

22. JT-60SA cryomagnetic system commissioning and optimisation

Position ref. EEG-2020/22

Contact person: Gerardo Giruzzi (Gerardo.GIRUZZI@cea.fr)

Job Description:

JT-60SA is a large tokamak device being built jointly by Europe and Japan at the Naka site of QST (*National Institutes for Quantum and Radiological Science and Technology*). Integrated commissioning, culminating with plasma operations, will start in 2020.

The superconducting magnets forming the backbone of the tokamak were contributed by CEA, ENEA and QST. The toroidal field coils were all manufactured and tested (including quenching) in the EU before delivery. The associated cryoplant, which supplies helium to cool the magnets, was manufactured, installed and commissioned by Air Liquide under the supervision of CEA.

The grant recipient will work on site in Naka, Japan during magnet commissioning phase (about six months) as part of the Integrated Commissioning Team formed from EU and Japanese staff. S/he will be seconded to the site operator QST and will support the tokamak commissioning. The challenging commissioning schedule assumes 2-shift operation.

After this phase, the data on the cryomagnetic system acquired during the full campaign will be analysed and advanced modelling will be developed in order to optimise the operation of the system and extend the limits of its working range. The grant recipient will help ensure the reliable operation of the cryoplant and the magnets. This will include:

- participation in the operation of the magnets and the cryoplant;
- actively participate in inspections, fault finding, repairs or optimizations;
- communicating with engineers in institutes and companies in Europe;
- ensuring safe operation limits are determined and enforced;
- contribute to development of operating procedures.
- data analysis on cryomagnetic system commissioning, using ad-hoc simulation tools
- assessing and modelling system performances by adapted simulation tools.
- facilitating machine and control system improvements with dedicated analyses;

Requirements:

- MEng or equivalent in a relevant engineering discipline
- Excellent interpersonal, teamwork and communication skills, including a good command of spoken & written English

Preferable:

- Experience in cryoplant and / or superconducting magnet operation
- Experience working in an international environment

Eligibility: Engineers with a Master degree or PhD

EUROfusion Work Packages involved: WPSA

Facilities to be used: JT-60SA

WP PREPARATION AND EXPLOITATION OF JT-60SA

23. JT-60SA magnet power supply commissioning and improvements

Position ref. EEG-2020/23

Contact person: **Gerardo Giruzzi (Gerardo.GIRUZZI@cea.fr)**

Job Description:

JT-60SA is a large tokamak device being built jointly by Europe and Japan at the Naka site of QST (*National Institutes for Quantum and Radiological Science and Technology*). Integrated commissioning, culminating with plasma operations, will start in 2020.

The magnet power supplies and the associated switching network units and quench protection circuits were contributed by CEA, ENEA and Consorzio RFX. They were manufactured in the EU and installed and commissioned on site under the supervision of F4E and the Contributors.

During the integrated commissioning, the superconducting magnets will be cooled down for the first time after installation and will be energized using their power supplies, progressively increasing the current and performing the combined operation sequence including the operation of Switching Network Units and Quench Protection Circuits.

The grant recipient will work on site in Naka, Japan as part of the Integrated Commissioning Team formed from EU and Japanese staff. S/he will be seconded to the site operator QST and will support the tokamak commissioning. The challenging commissioning schedule assumes 2-shift operation. The grant recipient will help ensure the reliable operation of the power supplies and the magnets. This will include:

- participation in power supply operation;
- performing inspections and troubleshooting, repairs, optimizations;
- communicating with engineers in institutes and companies in Europe;
- maintaining adequate spare parts on site;
- ensuring safe operation limits are determined and enforced;
- developing operating procedures.
- assessing and / or modelling performance and facilitating improvements;
- maintenance and improvement of control systems.

Requirements:

- MEng electrical engineering or equivalent
- Excellent interpersonal, teamwork and communication skills, including a good command of spoken & written English

Preferable:

- Experience in high current (>5kA) power supplies or superconducting magnets
- Experience in high DC current interruption systems
- Experience working in an international environment

Eligibility: Engineers with a Master degree or PhD

EUROfusion Work Packages involved: WPSA

Facilities to be used: JT-60SA

WP ASSESSMENT OF ALTERNATIVE DIVERTOR GEOMETRIES AND LIQUID METALS PFCs

24. Materials performance for I-DTT

Position ref. EEG-2020/24

Contact person: **Fulvio Militello (fulvio.militello@ukaea.uk)**

Job Description:
The Italian Divertor Tokamak Test (I-DTT) facility is conceived and devoted to test alternative heat exhaust solutions prior to DEMO construction phase [Albanese, R. DTT: a divertor tokamak test facility for the study of the power exhaust issues in view of DEMO. Nucl. Fusion 57, 016010 (2017)]. As indicated in the EUROFusion roadmap, if the power exhaust built for ITER would not to be suitable for DEMO, the realisation of fusion could be delayed by 10 years [Donné, T. et al. European Research Roadmap to the Realisation of Fusion Energy. (2018)].

One of the greatest challenges faced by the divertor materials in DEMO is to operate in an incredible harsh environment of high thermal (5-10 MW/m^2) and particle fluxes (10^{12} $n/cm^2/s$) [DTT Divertor Tokamak Test facility - Interim Design Report. Ed by ENEA. ISBN 978-88-8286-378-4. April 2019 ("Green Book") https://www.dtt-project.enea.it/downloads/DTT_IDR_2019_WEB.pdf]. Chosen materials and design will need to operate up to doses well above 1 dpa (up to 30 dpa for steel and 5-10 dpa for tungsten or copper) and temperatures around 1000 K. In addition to properties such as good radiation tolerance, high thermal conductivity and corrosion resistance, the chosen materials should maintain good mechanical and thermal properties throughout operation. The success of the DTT facility relies therefore on a good integration between material science and engineering.

The main objective of this project is to provide experimental data that will guide the choice of materials and the design finalisation for I-DTT components including vacuum vessel and solid and liquid metals divertors. The present design of the vacuum vessel consists of a structure with two shells of SS AISI 316 LN, filled with water/borated water that includes in inboard an additional sandwich-like neutron shield made of borated ceramics and metals to reduce the nuclear heating on the superconducting toroidal field coil[3]. The corrosion effects of ultrapure water or borated water on stainless steel and boron carbide need to be assessed during both the operation and baking stages of the I-DTT. The main responsibility of the candidate will be to analyse in detail the operability of the system taking into account the different configurations of materials available, the coolant flow rate and the choice of additives to be used to keep under control the water pH.

The synergistic effect of corrosion and neutron irradiation will also need to be investigated with particular emphasis on materials activation and consequent transport of activated materials in the system. Unwanted contamination due to activation of materials in contact with the coolant will indeed affect the maintenance operations and plant design.

The last task to be investigated considers the application of liquid metals for divertor applications which will ensure greater performance in terms of erosion resistance and thermal conductivity.

The main deliverables from this project will be:

- Assessment of water and borated water corrosion on vacuum vessel shielding materials (considering flow rate, temperature and additives)
- Analysis of irradiation enhanced/induced corrosion of DTT materials and contamination analysis
- Assessment of the potential for liquid metals divertors

The successful candidate will develop an overall and comprehensive understanding of the I-DTT materials challenges and requirements. This project requires a great collaboration effort between research groups involved in the finalisation of the I-DTT, hence, the candidate should possess good organisation and communication skills. Cross collaboration between several institutions is needed as materials and facilities will be provided by other EUROFusion members.

Eligibility: Engineers with a Master or PhD (preferably with experience on a fusion facility)

EUROfusion Work Packages involved: WP-DTT1/ADC

Facilities to be used: N/A

WP ASSESSMENT OF ALTERNATIVE DIVERTOR GEOMETRIES AND LIQUID METALS PFCs

25. Advanced modelling, verification, and testing of DTT components for divertor and neutral beam injector

Position ref. EEG-2020/25

Contact person: **Fulvio Militello (fulvio.militello@ukaea.uk)**

Job Description:
The Divertor Tokamak Test (DTT) facility is under design within a specific project launched to investigate alternative power exhaust solutions for DEMO, one of the main challenges in the European fusion roadmap. DTT should retain the possibility to test different divertor magnetic configurations, and solutions for the power exhaust problem, with edge conditions as close as possible to DEMO.

The divertor is an engineering challenge for fusion machines, as it is charge of power exhaust and removal of neutral particles and impurities. Such a challenge can be tackled through the design of the heat removal capability (against normal and transient operational scenarios) and simulation of the gas pumping efficiency in high density plasma conditions [1, 2]. Since the addressing of these two drivers can produce opposite effects in the component design, an integrated approach is proposed to study the divertor with:

a. development of the design, verification, and technological issues for heat removal capability;
b. 3D pumping simulation and pumping system design study and testing.

The divertor target will have to withstand extreme thermal loads with local peak power density up to 20 MW/m^2. The heat removal capability of the divertor target against normal and transient operational scenarios requires the development of the conceptual design and the core technologies of the plasma-facing target including devising and implementing of novel structural heat sink concepts [3]. The candidate will develop code-based design study and verifications with elastic-plastic behaviour of the elements and will participate to the verification tests of the fabrication technology applying non-destructive inspections. Structural failure against cyclic loads will be evaluated applying the ratchetting and fatigue criteria in accordance with the ITER Structural Design Criteria for In-vessel Components. Heat transfer conditions in subcooled flow boiling will be studied, analysed, and verified combining customised, three-dimensional, local, non-linear simulation methods with experimental evidences. The gas density distribution at the divertor and to the pumping system will be studied considering the gas flow occurring in different regimes. Pumping scenarios of the DTT divertor will be simulated to study solutions based on cryo-pumps, metal foil pump/linear diffusion pump, or alternative technologies that can be used to maintain or improve the design [4].

Similar gas flow conditions in high-vacuum regime are realised in neutral beam injectors. Obtaining proper vacuum levels along the path of neutral beams is essential to the correct operation of the beam: high vacuum in the ion-beam accelerator, adequate density of background gas in the space-charge compensation region and in the neutralisation cell, high vacuum all along the remaining drift region to the tokamak. The background gas density distribution will be investigated by an integral approach with 3D molecular flow simulation codes [5, 6]. The study will be finalised to the pump design, the characterisation of the pump performance, the verification of the pumping position and/or port size and position, the integration with the in-vessel components. In particular, the design, procurement follow-up and commissioning of the enhancement pumping system for the SPIDER experiment will be carried out by the candidate to get real engineering experience. The same approach will be applied to the DEMO injector, and the candidate will participate in the definition of its vacuum system. The designs will be validated through comparison of the simulation results and experimental measurements.

The successful applicant for this project will play a significant role to the above mentioned engineering and scientific issues (heat removal capability or pumping system design study and testing).

The candidate will be introduced to the existing devices and the ongoing design/procurements and will work in a team of skilled physicists, engineers and technicians.

Eligibility: Scientists with an MSc or PhD in Engineering; preferences will be given to applicants with experiences in numerical simulation of particle distribution in different regimes.

EUROfusion Work Packages involved: WP-DTT1/ADC

Facilities to be used: Experimental time dedicated mainly to the test facilities in Padua, Italy at RFX (SPIDER and MITICA).

[1] S. Varoutis et al, Optimization of pumping efficiency and divertor operation in DEMO , Nuclear Materials and Energy 12 (2017) 668–673

[2] S. Varoutis et al, Effect of neutral leaks on pumping efficiency in 3D DEMO divertor, Fusion Engineering and Design 136 (2018) 1135–1139

[3] F.Crescenzi, ITER-like divertor target for DEMO: Design study and fabrication test, Fusion Engineering and Design, Volume 124, November 2017, Pages 432-436

[4] B.J. Peters et al, Metal Foil Pump performance aspects in view of the implementation of Direct Internal Recycling for future fusion fuel cycles, Fusion Engineering and Design 136 (2018) 1467–1471

[5] Sartori E and Veltri P 2013 Avocado: a numerical code to calculate gas pressure distribution Vacuum 9080–8

[6] Sartori E, Dal Bello S, Fincato M, Gonzalez W, Serianni G and Sonato P 2014 Experimental validation of the 3D molecular flow code AVOCADO IEEE Trans. Plasma Sci.422291

WP ASSESSMENT OF ALTERNATIVE DIVERTOR GEOMETRIES AND LIQUID METALS PFCs

26. Finite Element Analysis to support the design phase of the superconducting magnet system for the DTT tokamak

Position ref. EEG-2020/26

Contact person: Fulvio Militello (fulvio.militello@ukaea.uk)

Job description

The combined effect of all superconducting magnets is fundamental for the operation of a tokamak machine, since they are directly responsible for both plasma confinement and start-up. Their integrity and correct operation must therefore be confirmed in all operative conditions. Finite Element Analysis (FEA) is the trusted mean to complete such assessments.

Superconducting magnets are composed of many different metallic and non-metallic materials that undergo complex non-linear 3-dimensional deformations: the high magnetic field generated (i.e. > 10 T) combined with the extremely high currents applied (i.e. tens of kA) result in extremely large mechanical loads which often demand the implementation of exotic and ad-hoc developed materials. Moreover, these components must work at cryogenic temperatures and under a non-negligible radiation exposure.

The outcome of the FEA will be of fundamental importance for the development phase of any tokamak as it directly connects the design to the manufacturing phase. In the framework of the design & development of the DTT tokamak a candidate shall thus be selected to cover this role. He or she will be integrated in the DTT magnet design team and support all design and development activities of the superconducting magnet systems.

Objective

Given the tight schedule related to the development of the DTT tokamak, the candidate is required to follow as much as possible the standard Finite Element Modelling (FEM) procedures and to complete all the assessments within the defined deadlines.

His or her responsibilities will thus include, and not be limited to:

- Complete a wide set of 2D and 3D multi-physics FEA to assess all normal and off-normal operative conditions of the superconducting magnet systems;
- Assess the static stress and the fatigue life of all the magnets and support structures (e.g. inter-coil structures) and formulate requirements for the manufacturing and testing of full-scale mockups and prototypes;
- Contribute to the design finalization of all magnet systems before their manufacturing is assigned to the industry.

Priority must be therefore given to design-for-manufacturing principles, and all design choices must be compatible with industry standards and capabilities. Preference shall be given to already verified and tested solutions and materials (i.e. employed for other built fusion devices). However, in the case literature material is not sufficient and/or applicable solutions are not available, the candidate might propose an experimental campaign to evaluate alternative options and/or update the material database. Given its position in the European Fusion Roadmap, the DTT tokamak can indeed be a test-bench for any innovative design solution that might be compatible with future reactors, so that the outcome of FEA in the present frame can constitute a valid contribution for the design assessment of the next fusion power plants (e.g. DEMO).

Eligibility: The ideal applicant must have a master's degree in engineering, experience in structural FEA and knowledge of material science. Previous experience in the analyses of superconducting magnets is particularly welcome.

EUROfusion Work Packages involved: WP-DTT1/ADC

Facilities to be used: N/A

WP HEATING AND CURRENT DRIVE

27. Power Supply and Electrical Systems for the ITER Neutral Beam Test Facility

Position ref. EEG-2020/27

Contact person: ***Elena Gaio*** elena.gaio@igi.cnr.it

Job Description:

The ITER Neutral Beam Test Facility (NBTF), in Padova, Italy includes two experiments: MITICA, the full-scale prototype of the ITER HNB injector and SPIDER, the full-size Radio Frequency (RF) negative-ion source, which entered in operation on June 2018.

The SPIDER PS includes the Ion Source and Extraction Power Supply (ISEPS), a system of several types of power supplies, including 4 RF power generators, hosted in a large Faraday cage at -100 kV to ground and the Acceleration Grid Power Supply (AGPS).

The Power Supply system of MITICA is particularly complex due to the unprecedented requirements in terms of voltage and power. It includes three main systems:

- the Acceleration Grid Power Supply (AGPS) producing the 1MV DC voltage, in five stages, 200 kV each, to accelerate the Ion Beam. The AGPS is divided into a low voltage and a high voltage (HV) section, respectively called AGPS Conversion System (AGPS-CS) and AGPS DC Generator (AGPS-DCG)
- the Ion Source PS to feed the Ion Source, similar to the SPIDER ISEPS
- the Residual Ion Dump PS

The installation and commissioning of the MITICA PS individual systems have been completed and the next steps will be devoted to insulation tests and tests addressed to achieve the integrated operation of the overall PS systems.

Actually, the next phases will be very challenging both for SPIDER and MITICA projects. For SPIDER, already in operation, the work will be concentrated in achieving step by step the expected performance.

For MITICA even the integrated power tests will be already so challenging that will require a lot of effort. In addition, both in view of ITER and even more of DEMO, it will be important not only to achieve the target performance, but also to demonstrate reliability, availability, efficiency, and maintainability. In this regard, in particular, the power supply systems play a key role.

The applicant will operate in this context contributing to the on-going NBTF activities. He/she will have the opportunity to greatly develop skills in all these electrical/power supply fields through design activities, development of models to reproduce the operation of components/subsystems by means of numerical simulation, participation in the experimental campaigns on SPIDER and /or commissioning tests of MITICA PS, analyses of experimental data also addressed to models validation.

Interim and final reports on the work will be prepared by the Grantee. Attendance and presentations at international fusion conferences and preparation of papers to be submitted for publication will be encouraged.

Eligibility: Scientists holding a PhD or a Master degree in Electrical, Power Electronics, Energy Engineering or similar field**.** Preference will be given to applicants with background knowledge and competences on the design and operation of power supply systems for H&CD systems, and experience on the use of numerical simulation tools for electrical networks and systems.

EUROfusion Work Packages: WP Heating and Current Drive

Facilities to be used: Experimental time dedicated mainly to the test facilities in Padua, Italy (SPIDER and MITICA).

WP HEATING AND CURRENT DRIVE

28. Development and optimization of vacuum system to maximize the negative ion beam efficiency for the ITER Neutral Beam Injector prototypes

Position ref. EEG-2020/28

Contact person: ***E. Sartori*** - Emanuele.Sartori@igi.cnr.it

Job Description

The goal of the Grant is to train an engineer with vacuum knowledge in some specific domains related to NBI. In the medium and long term such experience will be strongly beneficial to the scientific exploitation of SPIDER and in the installation and commissioning of MITICA.

Neutral beam injection is one of the main heating and current drive mechanisms for future fusion devices. On ITER two beamlines with large radio–frequency driven ion sources (1 × 2 m^2) will be installed, delivering a heating power of 16.7 MW each. Negative ions (H-/D-) will be accelerated up to 1 MeV, neutralized and injected into the torus with duration up to 1 h.

The production of negative ions inside the source is based on the interaction of the plasma generated inside drivers with caesiated surfaces. Then, negative ions will be electrostatically extracted and accelerated up to the nominal energy of about 100 keV and 1MeV respectively in the SPIDER and MITICA accelerators, both hosted at the ITER Neutral Beam Test Facility (NBTF) in Padova. Inside the accelerators the dominating process originates from stripping of the accelerated negative ion by collision with the residual molecular deuterium gas, i.e. detachment of the extra-electron from the negative ion [1]. Therefore, the negative ion beam current reaching full acceleration depends on the plasma parameters at the extractor, on the extraction probability, and on the transmission loss along the accelerator, which also comprises stripping losses.

SPIDER operation is ongoing. MITICA is under construction: high voltage tests in vacuum will start in 2020; the dedicated cryogenic pump system was custom designed and its commissioning and performance tests are planned for 2022.

The Grantee’s activity will focus on the investigation of the pressure distribution in the acceleration and beam region and on suitable vacuum and pumping techniques to limit the generation of secondary particles and the beam losses for SPIDER and MITICA, with the final goal of assessing the overall efficiency of the experiments.

In SPIDER, the Grantee will calculate the amount of residual gas species in different operating scenarios: minimising the background gas pressure in the accelerator decreases the stripping loss and limits the generation of secondary particles, thus increasing the overall efficiency of the electrostatic accelerator. From the knowledge of the partial pressure of residual gases, he/she will estimate the negative ion loss inside the accelerator.

Therefore, measurement/characterisation of ion extraction-acceleration efficiency and simulation of the gas pumping conditions are key activities for the optimisation of acceleration and for the design of pump systems for the neutral beam injectors. Gas density conditions in transition-molecular regime, typical in neutral beam injectors, will be investigated by an existing 3D numerical code based on an integral approach [2, 3]. Pumping scenarios will be simulated and tested to study solutions for the optimization of the vacuum level in the accelerator. In particular, the Grantee will participate in the development, design, construction, installation, commissioning and operation of the modified pumping system for SPIDER.

The same type of techniques will be applied to the MITICA experiment. The expected pressure profile in the vessel will be computed, a suitable gauge system will be designed and realised in order to characterize the pumping efficiency of the cryopumps during their commissioning phase.

The Grantee will be integrated in the NBT team. In collaboration with his/her colleagues, he will be trained, on the spot, on the operation and characterization of NBI sources and their parameters. With the team, he will develop be involved in the correlation of the beam parameters with the vacuum ones.

The Grantee will be introduced to the existing devices and modelling tools as well as to the ongoing design and procurement activities and will work in a team of skilled engineers, physicists and technicians at the ITER NBTF.

Eligibility: Master degree or PhD in an Engineering discipline. Preference will be given to applicants with experience in vacuum systems and related numerical analysis. Experience in the design of sources and accelerators for ion beams will be an advantage.

EUROfusion Work Packages: Principal: WP Heating and Current Drive; **Secondary:** WP TFV

Facilities to be used: Neutral Beam Test Facility in Padua, Italy (SPIDER and MITICA). Other facilities relevant for the activities could also be used.

[1] G. Fubiani, Modeling of secondary emission processes in the negative ion based electrostatic accelerator of the International Thermonuclear Experimental Reactor, Physical Review Special Topics – Accelerators and Beams 11, 014202 (2008)

[2] E. Sartori, P. Veltri, 2013 Avocado: a numerical code to calculate gas pressure distribution Vacuum 9080–8

[3] E. Sartori, S. Dal Bello, M. Fincato, W. Gonzalez, G. Serianni, P. Sonato, 2014 Experimental validation of the 3D molecular flow code AVOCADO IEEE Trans. Plasma Sci.422291

WP MATERIALS

29. Integration of Effects of Neutron Irradiation on Material Properties into a FEM Virtual Tokamak Reactor framework

Position ref. EEG-2020/29

Contact persons: ***Gerald Pintsuk, g.pintsuk@fz-juelich (WPMAT-PL)***

<u>Note</u>: This position is in support of a collaboration between the EUROfusion Project WPMAT and the University of California at Los Angeles (UCLA), USA, to assist progress in the development of design of a fusion power plant. It is expected that a mission to UCLA should be included in the Training Program for this appointment.

Job Description:

One of the central objectives of the Materials Project (WPMAT) is the development and evaluation of design criteria and rules, from concept to validation, as well as design methodologies (and analyses) for the assessment of lifetime and failure of in-vessel components, taking into account the expected effects of radiation damage and changes in the mechanical and physical properties (for example thermal conductivity and changes in chemical composition due to transmutation) of materials resulting from their exposure to fusion neutrons. WPMAT activities are fundamentally linked to design studies performed within the framework of in-vessel components.

Recent developments in the simulation methodology showed how to relate the accumulation of defects and the resulting microstructural changes to strains and stresses developing in materials due to irradiation, and how to include these effects in the Finite Element Method simulation framework. This encourages for a next step in the simulation methodology and to develop an approach where a tokamak reactor design is evaluated, in an integrated system, over its entire lifetime. The approach involves the analysis of rates of accumulation of radiation defects in various parts of the reactor structure, taking into account the changes of microstructure due to the accumulation of defects, and changes in chemical composition and thermal conductivity resulting from the exposure to neutrons, which in turn define self-consistently the temperature and stress fields developing in the reactor components. The model is expected to apply not only to the steady state operating conditions but also to study transient events.

The new approach is expected to help extend, adapt for fusion environment and validate design criteria based on experience and experimental data, to the fully digital framework, making full use of the data derived from the recent and on-going experiments on neutron irradiation of candidate materials (RAFM-steels, Cu-alloys, tungsten-based materials). In addition to the new experimental information, the project is expected to make full use of the conceptual and algorithmic advances made in microstructural damage modelling pursued in the framework of a subproject devoted to computational analysis of irradiation effects (IREMEV). The main aim is to establish an integrated ***link between microstructure and continuum level models*** to qualify and quantify irradiation effects on the scale of the entire reactor components, and possibly the entire reactor structure.

The selected candidate is expected to focus her/his research on the following areas:

- Multi-scale modelling of physical processes determining the response of materials to thermal and irradiation conditions
- Mechanical and microstructural changes resulting from the accumulation of defects and dislocations in fusion reactor components.
- Understanding macroscopic failure mechanisms and their effect on the component lifetime.
- Interrelation between microstructural damage and macroscopic material properties.
- Engineering rules and design codes that use information derived from experiments on neutron irradiated materials.

Eligibility: Master degree or PhD in materials sciences or an engineering discipline

Main Work Package: WPMAT

Interlinks with other Work Packages and Subprogrammes: WPMAT-EDDI (Engineering Data and Design Integration), IREMEV (Irradiation Effects Modelling and Experimental Validation), In-vessel component projects.

Facilities to be used: Computer facilities, and programs available at research institutions contributing to WPMAT.

WP MATERIALS

30. Modelling the Response of Tungsten fo Fusion reator Thermal Loading Conditions

Position ref. EEG-2020/30

Contact persons: ***Gerald Pintsuk, g.pintsuk@fz-juelich (WPMAT-PL)***

Note: This position is in support of a collaboration between the EUROfusion Project WPMAT and the University of California at Los Angeles (UCLA), USA, to assist progress in the development of design of a fusion power plant. It is expected that a mission to UCLA should be included in the Training Program for this appointment.

Job Description:

Divertor components in a fusion device are exposed to high thermal and neutron loading conditions. To accommodate requirements of engineering design, and effects of transient thermal loads and steep thermal gradients, as well as neutron irradiation, it is necessary to explore and compare performance of materials with different microstructure and mechanical properties, to arrive at an optimal component design.

Tungsten and tungsten alloys are the primary candidate materials for plasma facing divertor components, where material produced using conventional manufacturing methods is brittle at ambient conditions. Highly mechanically deformed tungsten, however, exhibits high stability under irradiation, retaining its mechanical properties after exposure to ion irradiation.

While experimental and materials development research effort is focused on stabilizing the microstructure of tungsten over a broad range of temperatures, and on the development of industrial methods for manufacturing the material, it is highly desirable to develop ***a self-consistent model for the mechanical properties of this new material and formulate relations and criteria suitable for the incorporation into the engineering finite element framework.***

Applications are invited from suitably qualified individuals interested in contributing to the development of quantitative understanding of the relationship between the factors characterizing the loading conditions (high plasma energy flux resulting in high thermal gradients, accompanied by the exposure of the material to ion bombardment and neutron irradiation) and elastic and plastic deformation, as well as irreversible stresses, strains and deformations resulting from irradiation and accumulation of gases in the tungsten divertor components, to help address and quantify high temperature structural stability of the components under repeated cycles of thermomechanical and irradiation loads.

The selected candidate is expected to focus his/her research in the following areas:

- Multi-scale modelling of physical processes determining the response of the novel tungsten material to thermal and radiation conditions
- Mechanical and microstructural modifications and damage formation in fusion divertor components.

- Understanding macroscopic failure mechanisms and their influence on the component lifetime.
- Engineering rules and design codes.

Eligibility: Master degree or PhD in materials sciences or an engineering discipline

Main Work Package: WPMAT

Interlinks with other Work Packages and Sub-Programmes: WPMAT-IREMEV (Irradiation Effects Modelling and Experimental Validation), WPMAT-EDDI (Engineering Data and Design Integration), WPMAT-HHFM (High Heat Flux materials), WPDIV (Divertor).

Facilities to be used: Computer facilities, and programs available at research institutions contributing to WPMAT.