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ABSTRACT.
The paper reports on the status of the JET ITER-Like ICRF Antenna project and highlights main challenges that have come up during its design phase.

1. INTRODUCTION

The design phase of the JET ITER-like ICRF Antenna [1] is completed and the pro-curement phase is now under way. It is expected that the launcher will be available for installation on the JET torus by mid 2004 permitting an experimental campaign starting spring 2005, aimed at validating the proposed antenna concept in terms of ELM resilience at a power density of 8 MW/m^2 in conditions relevant to ITER. Key challenges of this design are its compatibility with worst case scenario disruptions and the high accuracy required for the in-vessel capacitor positioning systems. For predictive evaluation of the expected performance of the launcher as well as in support of the development of a suitable matching algorithm, a substantial modeling effort has been carried out [2]. In addition to testing the ELM tolerance of the ITER-like antenna, 3dB couplers will be used to provide resilience to load variations on two of the existing JET A2 antenna modules [3]. A third scheme based upon trombone-based conjugate-T matching is also under assessment by the UKAEA [4]. The High Power Prototype 5 (HPP) of one of the four loops has been completed by US teams of ORNL and PPPL and is under test at ORNL.

2. MAIN CHALLENGES

2.1 DISRUPTION LOADS:

For the JET ITER-like antenna (Fig.1), the compatibility with worst case for 6MA/4T plasmas disruptions on JET - taking into account assembly procedures and requirements on maintenance of the in-vessel matching capacitors - constitutes one of the main mechanical challenges. The induced mechanical loads are mainly due to the massive copper cylinders and flanges of the matching capacitors located well inside the main toroidal magnetic field. These loads appear as torques about the axis of the capacitor's electrodes as well as perpendicular to it. Therefore, the design of the capacitors (CAP) – Inner Vacuum Transmission Line (VTL) – Vacuum Window (VCW) system, has been modified, respect to the original concept, in order to minimise, and resist to, the EM induced forces. Design validation tests on mock-ups have also been carried out. In particular, the capacitor's OHFC copper to ceramic brazes has been re-enforced, its outer envelope redesigned and copper partially replaced by SS and the shaft of the variable electrode has been designed to be able to react the torque of about 600Nm induced on the electrode. After redesign, a torque of about 5 kNm remains, which is reacted through the inner-VTL by the RF vacuum window. In order to allow for this the inner-VTL has been stiffened and the RF window increased in size.

2.2 MATCHING ALGORITHM :

One of the outstanding challenges is the design of a matching algorithm that is able to take into account the complexity of the matching problem of several coupled Resonant Double Loops (RDL).

Even for a simple RDL and not taking into account the cross-coupling between straps, the matching capacitors must be adjusted within a few tenths of mm in order to achieve the desired resilience to resistive load variations (Fig.2). Cross-coupling and load variations that may not be purely resistive further compound the issue 6,7 and a global solution is to be found that keeps the VSWR as low as 1.5 for real ELMs on JET.

2.3 ACTUATORS:

The actuators positioning the matching capacitors will be based on servo hydraulics. Originally a solution based on vacuum compatible electric-motors was identified, and currently used on the HPP, that had to be abandoned after the detailed calculation of the induced perturbation on the in-vessel magnetic field. Consequently, the layout of Antenna Pressurized Transmission Lines (APTL), interfacing the main transmission lines with the RF vacuum windows, has been made compatible with routing of cable and piping for the antenna in-vessel capacitors and servo-hydraulics components and instrumentation, and for 2 nd containment and vacuum inter-space monitoring services. Prototype testing in order to determine minimum hydraulic pipe diameters, hydraulic fluid properties as well as assess the accuracy of this system is nearing completion: at the time of writing the an accuracy in positioning well below 0.1mm and even below 50mm is demonstrated.

2.4 PROJECT MANAGEMENT:

Finally, a non negligible challenge on the level of the management of the project is formed by stringent procurement rules imposed by the European Commission and the nature of the constitution of the project team: distributed administratively and geographically over the different associations in Europe as well as the US, each taking care of a specific component (see table 1) or prototyping effort for the global project.

3. STATUS OF SUPPORTING AND PROTOTYPING ACTIVITIES

Supporting prototyping activities are coming to completion: the main one, the HPP allows to benchmark the modeling efforts and to design and test to some extend the matching algorithm, to assess the final operation limits of the design and allow to tweak the design prior to starting the manufacturing of the antenna components. In the operational diagram shown in figure 3, the voltages obtained on the HPP for short sub-second pulses show that there are margins with respect to the voltage stand-off required to couple 8MW generator power to a plasma with a base coupling of 2Ohm/m. Further tests, in particular long high voltage pulses, are scheduled in the near term.

Other tests concern the finger contact at the front of the matching capacitors (on-going at CEA(F) at the time of writing), required for the assembly and maintenance of the matching capacitors, and the validation of the spring damper that is part of the ex-vessel support structure (completed successfully at ENEA(I)) and limits the inertial forces appearing on the Main Horizontal Port during disruptions as well as the displacement of the launcher with respect to the JET Torus Hall floor. In order to validate and consolidate the manufacturing processes one first of a series vacuum window

(UKAEA(UK)) and two capacitors (LPP-ERM/KMS(B)) will be produced , both prior to the start of the main EU procurement contracts.

4. PROJECT STATUS AND CONCLUSIONS

As outcome of the design phase the procurement of the hardware was divided into 12 packages shown in table 1 and figure 1. At the time of writing all but one packages were successfully tendered for and approved by European Fusion Development Agreement's (EFDA) Administrative and Financial Advisory Committee (AFAC). The manufacturing times confirmed by the selected manufacturers are in line with the project plan and the 2004 shutdown. One remaining package on the capacitors' actuator hydraulic system will be presented at the committee's next meeting.

If, aside of the main ITER-like ICRF Antenna project, also all presently foreseen extensions to the JET ICRF plant come to implementation, several strategies aiming at mitigating the effects of the ELMs on the matching of ICRF launchers will be available at restart of the experimental campaign after the 2004 shutdown: a high power density ITER-like launcher with in-vessel matching capacitors, a variation of the conjugate-T approach implemented on 2 of the A2 arrays and the 3dB hybrid couplers as on ASDEX-Upgrade implemented on the remaining 2 A2 arrays. The comparison of the relative performance of these circuits will most certainly reveal further insight and valuable information guiding the design the ITER ICRF system. Furthermore the demonstration of high power density achieved by using short straps should validate ICRF as a strong candidate for plasma heating on ITER.

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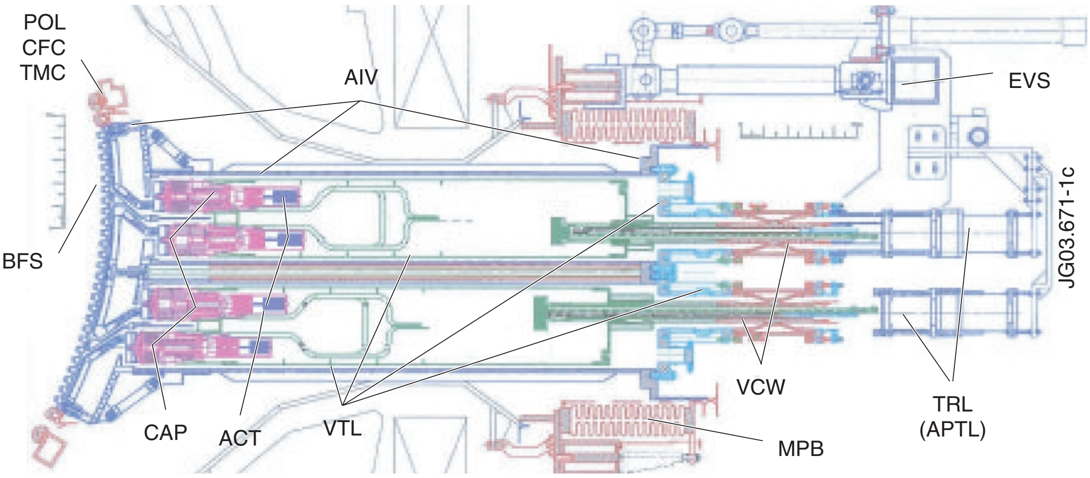

Figure 1: Cut view ITER-like ICRH Antenna showing the procurement packages (Table 1).

In-Vessel or on Tritium Boundary		**Ex-Vessel**
AIV - Antenna In-Vessel Compenents (UKAEA, UK)	VCW - Vacuum Window (UKAEA, F)	EVS - Ex-Vessel Support Structure (ENEA, I)
MPB - Main Port Bellows (UKAEA, UK)	PLB - Poloidal Limiter Beams (CEA, F)	TSB - Testbed Components (UKAEA, UK)
VTL - Inner Vacuum Transm. Lines (ERM, B)	CFC - Material Blanks f. Limiter Tiles (UKAEA, UK)	TRL - Antenna Pressurized Transmission Lines
BFS - Beryllium Faraday Screen (UKAEA, UK)	TMC - Pol. Limiter Tile Machining (CEA, F)	(APTL), Second Stage Matching Components
CAP - Matching Capacitors (ERM, B)	ACT - Servo Hydraulic Actuators (ENEA, I)	and Main Transmission Lines (UKAEA, UK)

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Table 1: Procurement Packages for the ITER-like ICRH Antenna

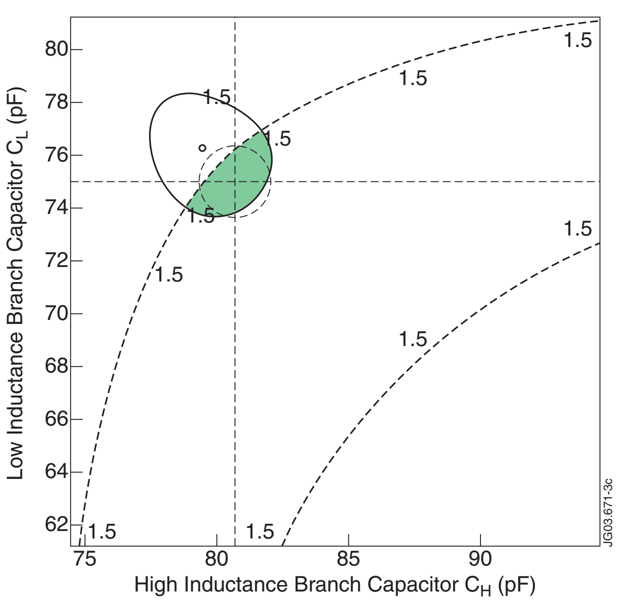

Figure 2: For a single RDL at 55MHz and matching to 6Ω at the junction, without mutual coupling effects, the VSWR 1.5 contours in the domain of the values of the matching capacitors are shown for two different values of the resistive cou-pling with the plasma, 3Ω/m (plain) and 9.5Ω/m (dashed). In order to be resilient to the variation in resistive coupling the position of the capacitors the matching algorithm needs to position the capacitors in the shaded area indicated by the dotted crosshair.

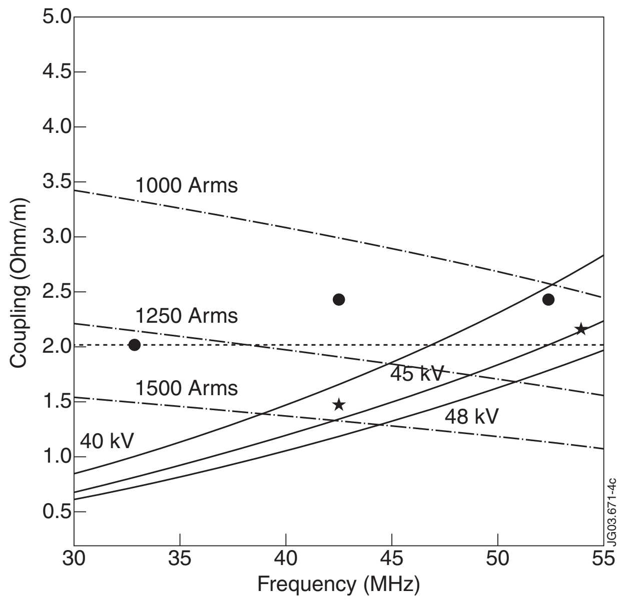

Figure 3: (left) accessible operational domain expressed as iso-curves of capacitor voltage (≈ maximum feeder voltage) and current required to launch nominally 8MW into the plasma in the coupling versus frequency domain. The stars correspond to the voltages achieved on the HPP for short pulses. The circles represent estimates of the coupling of the new launcher whereby the plasma was modeled as a dielectric slab of material in Micro-wave Wave Studio [8].