PRELIMINARY DESIGN CONCEPTS FOR THE CONTROL AND DATA ACQUISITION SYSTEMS OF THE ITER NEUTRAL BEAM INJECTOR AND ASSOCIATED TEST FACILITY

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Abstract - **ITER is a joint international research and development project aiming to demonstrate the scientific and technical feasibility of fusion power. The ITER Neutral Beam Injector (negative H or D ion source, 1MV acceleration voltage, 40A ion current, 16.5MW beam power, 1 hour continuous operation) is a major and innovative component of ITER and will be supported by a dedicated Test Facility. The neutral beam injector and test facility are being designed with the goal to have one injector fully operational on the ITER device in 2016. The two items need separate, but closely interacting, control and data acquisition systems. The first control and data acquisition system will manage the neutral beam injector and will be installed at the ITER site; the second control and data acquisition system will manage the test facility and in particular will enable extensive scientific exploitation of the injector before its final installation at the ITER site. The paper reports on the design activity for both control systems, including the definition of the system requirements, the functional system structure and the preliminary system architecture.**

INTRODUCTION

ITER [1] is a tokamak, to be constructed in France, in which the ionized gas (plasma) is heated up to ignition by additional heating and current drive systems injecting either radio frequency or neutral beams. The ITER beam injector (NBI) [2] will produce a beam in H or D that will be launched into the plasma. In order not to be deflected by the magnetic field in the plasma region, the beam will contain only neutral atoms. ITER will be equipped with two NBIs, with an option to add a third one. Injectors having the technical characteristics required for the ITER NBI have never been built and their construction is a scientific and technological challenge. The parameters of the ITER NBI are reported together with the JET parameters for the neutral beam enhancement currently in progress.

To support the development of the neutral beam injectors, ITER decided to build a dedicated experiment, the Neutral Beam Test Facility (NBTF), to test the NBI at full performance before installing it on the tokamak. The NBTF will be constructed in Padova, Italy and the first ITER neutral beam injector is scheduled to be tested from 2012 to 2016.

Table 1 – ITER NBI vs JET NBI enhancement parameters

Parameter	ITER	JET [3]
Ion	H^- or D^-	H^+ or D^+
Beam energy	1 MeV (D^-) / 800 keV (H^-)	125 keV
Beam current	40 A	65A
Pulse length	3600 s	20s
Beam divergence	< 7 mrad	---

Neutral beam injector

Fig. 1 shows a view of the NBI outlining its main components. The beam line is housed within a metallic **Vessel**. Negative ions are produced inside an ionization chamber by radio frequency (**Ion source**). The ions are extracted and accelerated by a set of grids at increasing potential from -1MV to ground level (**Accelerator**). The beam ions are neutralised by colliding with neutral gas of the same species in the **Neutraliser**. Emerging from the neutraliser will be a neutral beam (60% of the original negative ion beam) and negative and positive ion beams (each with ~ 20% of the initial power/current), all having an energy of 1 MeV. The residual ions are deflected by applying an electrostatic or magnetic field in the **Residual Ion Dump** onto a water-cooled collector system designed to accept the high power-density. The beam of neutral atoms is either injected into the ITER plasma or intercepted inside the injector by a movable **Calorimeter** which can accept the full neutral beam power. To maximize ionization and avoid reionization, the injector incorporates a large cryopump in order to exhaust the gas that is fed into both the ion source and the neutraliser. The injector is permanently connected to the ITER primary vacuum and a **Fast Shutter** provides a low conductance between the injector and the torus except during beam injection. A **High Voltage Bushing** system carries the voltage to feed the acceleration grids and the in-vessel components. A **Passive Magnetic Shield** and **Active Compensation Coils** cancel the magnetic field produced by ITER on the in-vessel components. A power supply system not shown in figure provides the voltage to feed the ion source and the accelerator.

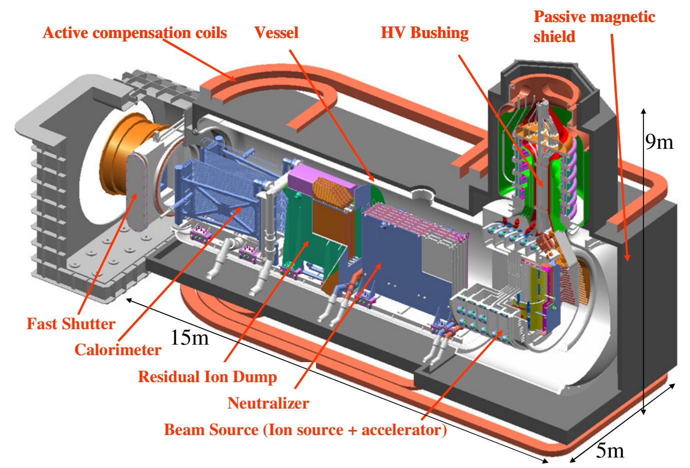

Fig. 1 – Design view of the ITER neutral beam injector
Ex-vessel power supply equipment is not shown

Neutral beam test facility

At the ITER site, centralised auxiliary systems guarantee the operation of components by providing, necessary supplies such as refrigerated water for cooling, liquid He for cryogenic parts, gas flow and electric power. These services (and many other) must be present also at the NBTF to allow the exploitation of the NBI at full performance. Control, data acquisition, interlocks and safety management are among the functions that must be implemented at the NBTF. In ITER these functionalities are centrally provided by a super-system including three components : the Control, Data Access and Communication system (CODAC), the Central Interlock System (CIS) and the Central Safety System [4]

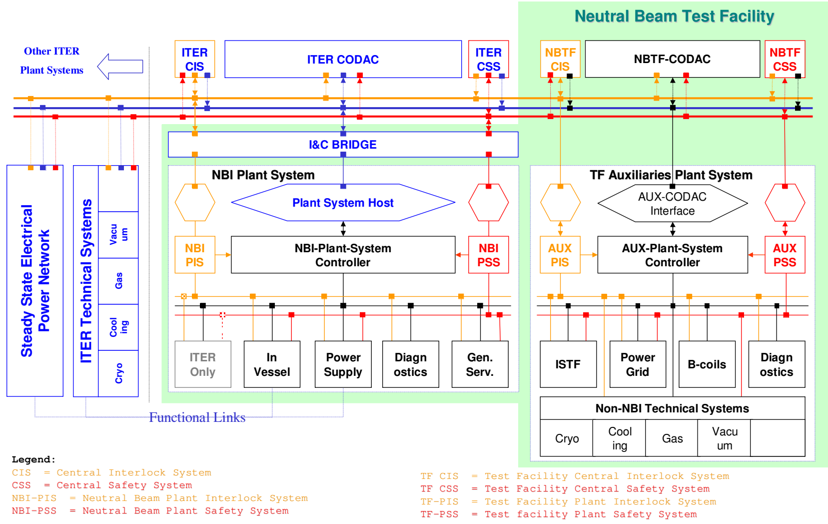

Fig. 2 System functional breakdown of ITER neutral beam test facility

References

[1] ITER document, Plant Design Specification, ITER_D_22ER4F v 3.0
[2] ITER document, Design Description Document (DDD5.3), Neutral Beam Heating and Current Drive (NBH&CD), ITER, N 53 DDD 29 01-07-03 R 0.1.
[3] D. Ćirić, D.P.D. Brown, C.D. Challis, B. Chuilon, S.J. Cox, B. Crowley, I.E. Day, D.C. Edwards, G. Evison, L.J. Hackett, et al., Overview of the JET neutral beam enhancement project, Fusion Engineering and Design, in press, Sept. 2007
[4] Jo Lister, Jon Farthing, Martin Greenwald, Izuru Yonekawa, Status of the ITER CODAC conceptual design, this conference, ROAA01

System functional breakdown and preliminary requirements

The NBTF has been divided into hierarchical blocks, called systems and subsystems, including components that are functionally related. Fig. 2 illustrates this functional subdivision. The NBTF comprises five systems:

- **NBI plant system**, i.e. the device under test;
- **Auxiliaries plant system** including all technical services to operate the neutral beam injector;
- **NBTF-CODAC**, control and data acquisition system in charge of reliable operation of the facility;
- **NBTF-CIS,** central interlock system in charge of investment protection;
- **NBTF-CSS,** central safety system to guarantee people and environment safety.

The NBI plant system will be under control of NBTF-CODAC, NBTF-CIS and NBTF-CSS when under test at the test facility site, whereas it will be under control of ITER-CODAC, ITER-CIS and ITER CSS when installed at the ITER site.

The modular approach will help in system integration in the transition from test facility to ITER sites.

The **NBI plant system controller** is in charge of the NBI integrated control, while the Plant Interlock System (**NBI-PIS**) and the Plant Safety System (**NBI-PSS**) provide system-wide machine protection and safety functions, respectively.

The Aux plant system is organized with the same structure of the NBI plant system.

The NBI plant system is interfaced to either ITER or NBTF CODAC through the plant system host and the I&C bridge. These are standard interface components defined and provided by ITER CODAC. The I&C bridge is a is a standard for physical communication between Plant Systems and the communication system. The plant system host will be provided as an embryonic computer equipped with standard interface applications (OPC, SCADA, etc.) to connect ITER-CODAC to the plant system.

Table 2: preliminary estimation of parameters for dimensioning control and data acquisition

Type	Quantity
Sampling frequency	< 5 MHz
Time resolution / precision	< 200 / 50 ns
Nr. of input analogue ch's (NBI)	< 1000
Nr. of input analogue ch's (AUX)	< 3000
Control points	10,000 – 30,000
Data acquisition throughput	< 200 MB/s
Data acquired per pulse	< 20 GB
Data acquired per year	< 60 TB

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