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Preliminary design of safety and interlock system for indian test facility of diagnostic neutral beam☆

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HIGHLIGHTS

- Indian Test Facility being built to characterize DNB for ITER delivery.
- Interlock system required to safeguard the investment incurred in building the facility and protecting ITER deliverable components.
- Interlock levels upto 3IL-3 identified.
- Safety instrumented system for occupational safety being designed. Safety I&C functions of SIL-2 identified.
- The systems are based on ITER PIS and PSS design guidelines.

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ABSTRACT

Indian Test Facility (INTF) is being built in Institute For Plasma Research to characterize Diagnostic Neutral Beam in co-operation with ITER Organization. INTF is a complex system which consists of several plant systems like beam source, gas feed, vacuum, cryogenics, high voltage power supplies, high power RF generators, mechanical systems and diagnostics systems. Out of these, several INTF components are ITER deliverable, that is, beam source, beam line components and power supplies. To ensure successful operation of INTF involving integrated operation of all the constituent plant systems a matured Data Acquisition and Control System (DACS) is required. The INTF DACS is based on CODAC platform following on PCDH (Plant Control Design Handbook) guidelines.

The experimental phases involve application of HV power supplies (100 KV) and High RF power (~800 KW) which will produce energetic beam of maximum power 6MW within the facility for longer durations. Hence the entire facility will be exposed tohigh heat fluxes and RF radiations.

To ensure investment protection and to provide occupational safety for working personnel a matured Safety and Interlock system is required for INTF. The Safety and Interlock systems are high-reliability I&C systems devoted completely to the specific functions. These systems will be separate from the conventional DACS of INTF which will handle the conventional control and acquisition functions. Both, the Safety and Interlock systems are based on IEC 61511 and IEC 61508 standards as prescribed by the ITER PCDH guidelines.

1. Introduction

In ITER two Heating Neutral Beams and one Diagnostic Neutral Beam (DNB) [1] systems are expected to be operated. The DNB line is expected to deliver 18–20 A of 100 keVbeam of hydrogen neutrals to the ITER plasma. The beam with a 3s ON/20s OFF duty cycle and modulated at 5 Hz, shall be used to diagnose the He ash content in D-T phase of ITER machine using the charge exchange recombination spectroscopy (CXRS).To understand the challenges

☆ This paper describes the design methodology involved in arriving at preliminary design of these systems along with the technical specifications of these systems and the present status.

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Table 1
Plant Systems and Functions.

Sr. no	Plant subsystems	Function
1	Ion source systemand Grid Assembly	To produce plasma with help of power supply plant system
2	Power Supply	
	a) RF Generators: 800 kW, 1 MHz	To help in plasma production
	b) Filament, Filter field, PG Bias	Beam extraction Ion deflection at RID
	c) EGPS: 12 kV,140 A	
	d) AGPS: 96 kV,75 A	
	e) GRPS: 8 kV, 60 A	
3	Beam Line Componen	
	a) Neutralizer	Neutralizing the beam
	b) RID	Ion deflection
	c) Calorimeter	Dumping the beam
	d) Second Calorimeter	
4	Cryogenic system	To help in creation of UHV
5	Hydraulics: 130 lpm @ 5.4 bar	To provide active cooling to components
6	Gas Feed System (0.3–1.5 Pa)	Providing Gas injection for plasma production and neutralization.
7	Vacuum System Speed = 5000 l/s	Maintaining and producing vacuum
8	Diagnostics System	Plasma and beam characterization
	a) Source Spectroscopy	
	b) Beam Spectroscopy	
	c) CFC based Diag.	
	d) IR Camera	
	e) CRDS	
	f) Beam tomography	
	g) Probes	
9	Cesium Oven and TL	Production of negative ions

in ITER DNB operations, ITER approved Indian Test Facility (INTF) [2] is currently under construction at IPR, India.

The INTF will have full size ITER ion source with 8 numbers of driver, 4 numbers of Radio Frequency Generator of 200 KW each. INTF will be operated for long beam duration of 3600 s with 3s ON/20s OFF duty cycle and 5 Hz modulation. INTF is a complex facility involving multiple subsystems ranging from Cryogenics, Cooling water, power supplies to Beam Line Components (BLC). To undertake safe and reliable operations of INTF system a Data Acquisition and Control System (DACS), referred as INTF-DACS [3] is designed based on ITER CODAC [4–6] framework, that will integrate and operate all plant sub-systems

Since INTF is an experimental facility with aim to characterize DNB several operations will be undertaken to ensure the full utility of the facility. The operations will involve application of high power RF (~800 kW) and high voltage power supplies for beam extraction and acceleration. It is of utmost importance that any failure of plant system during the operations does not jeopardize the investment of the facility. For this purpose a dedicated high reliability system will be used in INTF.

Occupational safety is also important concern during the operations and due to the nature of facility; the involved personnel are exposed to certain risks. Hence occupational safety will be looked after by a dedicated safety system.

2. Strategy for occupational safety and investment protection

2.1. Occupational safety: safety system

The nature of operations at INTF poses a certain degree of risk for the personal involved. The presence of High voltage power supplies along with RF radiations, use of cryogens for vacuum purpose and use of Hydrogen for plasma generation are certain risks which the working personnel are exposed to. The cryogens if released accidently can cause ODH (Oxygen Deficiency Hazard). Due to this a dedicated Safety system is planned for INTF which will be implementing the I&C related safety functions.

For safety system also we have followed the ITER Plant safety system design guidelines [7]. As per the recommendations the HIRA [8] (Hazard identification and RiskAssessment) is being conducted for INTF. A team has been formed in this direction and the recommendation will be implemented for INTF. Wherever the I&C related safety functions are found, they will be implemented in SIL certified hardware of Safety system as per IEC 61511[9] standard.

Currently the Safety System is in conceptual stage and as the HIRA analysis matures the design of safety system will be finalized.

2.2. Investment protection: interlock system

INTF is not an ITER deliverable but a test facility to characterize DNB. INTF will operate with several ITER deliverable components like ion Source, Beam Line components and power supplies. From operational point of view INTF has been divided into following plant systems:

All the above plant systems have a specific role in operations and any deviation or failure to perform the standard function can lead to damage to components. This will not only cause a loss of investment but also affect the operational timeline. To avoid any such scenario high integrity interlock system will be included in INTF DACS which will monitor the health statuses of all plant systems during operation. The INTF DACS architecture is described in Fig. 1. The Interlock system will be based on IEC 61508 [10] standards as suggested in ITER PIS design guidelines [11].

Currently FMEA (Failure Mode and Effect Analysis) [12] report of INTF is in advanced stage of completion. FMEA report was conducted with reference to [13]. This report has helped in identifying the I&C related Interlock functions and where ever possible design margins. This report has provided a deeper insight for identifying top level I&C interlock functions. As the report matures, the Interlock system will also mature to a level where it can be commissioned.

The facility operates with high power RF and high voltage power supplies. It is a possibility that under certain conditions the important plant systems like Ion Source and Beam Line Components can get damaged.Due to the simultaneous presence of high temperature, high gashigh voltage and power, a malfunction or damage couldhave severe consequences for equipment. Table 1 provides a brief overview of various plant systems on INTF.

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