INSTRUMENTATION ARCHITECTURE FOR ITER DIAGNOSTIC NEUTRAL BEAM POWER SUPPLY SYSTEM

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Abstract

A Neutral Beam (NB) Injection system is used for heating or diagnostics of the plasma in a Tokamak. The Diagnostics Neutral Beam (DNB) system for ITER (International Thermonuclear Experimental Reactor) based on acceleration of negative ions; injects a neutral (H_o) beam at 100keV with specified modulation into the plasma for charge exchange recombination spectroscopy. DNB Power Supply (DNBPS) system consists of various high voltage power supplies, high current power supplies and RF Generators. The system operates in a given operating sequence; very high electromagnetic transients are intrinsically generated during frequent short circuit at the accelerator grid (breakdowns) and sudden loss of load (Beam off).

Instrumentation is to be provided to operate the DNBPS system remotely with required control and protection in synchronisation with ITER operation as directed by CODAC (COntrol Data Access and Communication); the central control system for ITER. Instrumentation functionality includes 1.Operation and control of DNBPS subsystems and associated auxiliaries 2.Protection of DNB components and power supplies using interlock system, 3.To ensure safe operation of high voltage hazardous systems 4. Acquisition of injector performance parameters and 5.To facilitate test and maintenance of individual subsystem.

This paper discusses about proposed DNBPS instrumentation architecture. The design generally follows the protocols from the ITER- Plant Control Design Handbook (PCDH).

INTRODUCTION

The DNB Power Supply system [1,2] feeds the required controllable electrical power to the DNB beam source (BS), the Residual Ion Dump (RID) and the Active Correction and Compensation coils (ACCC). The system comprises of various high voltage, High Current power supplies and RF generators for plasma generation in the ion source, with integrated controllers.

Table 1: DNBPS Main Subsystems, their control, monitoring and protection parameters

Sub Systems	Controlling parameter	Measurements	Protection events
Acceleration Grid PS (AGPS) 96kV, 75A	Voltage, Modulation	Voltage, Current, Cooling water parameters	Breakdown, Beam off, Failure in RID voltage, Short circuit at power supply end
Extractor Grid Power Supply (EGPS) 12kV, 140A	Voltage, Modulation	Voltage, Current , Cooling water parameters	Breakdown, Beam off, Short circuit at power supply end
Residual Ion Dump Power supply (RIDPS) 8kV, 60A	Voltage, Operation time	Voltage, Current, Cooling water parameters	Short circuit
RF Generators 4 X 200kW	Frequency, RF power, Modulation	Frequency, Phase, Power, Cooling water parameters	Break down, Beam off (Reduce RF power to notch level)
Active Correction Coil Power Supply (ACCPS) 1.4kV, 440A	Current	Current, Magnetic field around DNB cell, Cooling water parameters	Short circuit protection
Plasma Grid Bias Power Supply ; 30V, 600A	Current, Voltage	Current, Voltage, Cooling water parameters	Short circuit protection
Plasma Grid Filter Power Supply;15V, 4kA	Current, Voltage	Current, Voltage, Cooling water parameters	Short circuit protection
Cs oven	Shutter control, Temperature	Temperature	-

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The DNB Injector is installed in the main Tokamak building whereas the DNBPS sub systems are installed in adjacent buildings approximately 130 metres from the injector itself. The connection between the DNB Beam source and their PSs will be done through a HV transmission line.

Table 1 gives different subsystems of DNBPS with major specifications and required measurements, controls and protection against possible damaging events.

BASIC DESIGN REQUIREMENTS

DNBPS instrumentation architecture is mainly devised in compliance with ITER PCDH. Plant systems should interface with CODAC using Plant operation, Timing and Data network. These networks are managed by CODAC including assignment of IP addresses. DNBPS Controller acts as a master controller for different DNBPS subsystems and provides single point interface with the CODAC.

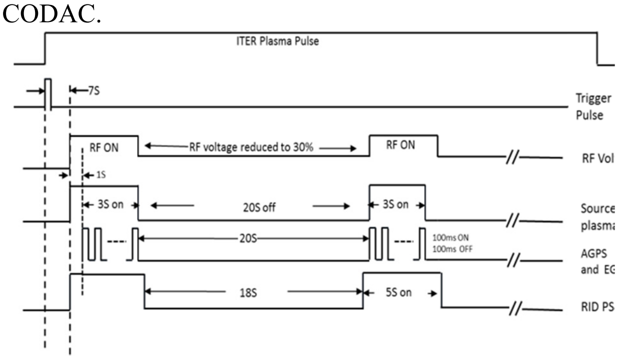

Figure 1: DNBPS Operating Sequence.

Major steps for DNB operation, to be taken care by instrumentation are:

- Preoperational preparation of different sub systems and auxiliaries.
- To start beam operation, start different sub systems in a predefined sequence.
- During operation modulate the beam using AGPS and EGPS, control beam energy and monitor performance.
- Stop/Restart the beam.

All power supplies need synchronized operation; the relative time sequence for major power supplies is as shown in Figure 1.

Few power supplies require local controller with real time operating system and very deterministic signal generations by Fast controller with control loop rate faster than 100 Hz. High voltage auxiliaries like switchgears and transformers need to be monitored as well, which can be done by slow controller (like PLCs) working at a rate of less than 100Hz. Hence, DNB instrumentation design consists of

1. Fast controller for control and data acquisition
2. Slow controller for control and data acquisition
3. Sensors, actuators and signal conditioning modules

In addition to above, the instrumentation has to take care of investment protection and personnel safety in coordination with central interlock and central safety system respectively.

I&C FUNCTIONAL AND PHYSICAL LAYOUT

Figure 2 shows conceptual functional and physical layout of DNBPS instrumentation for operation, control and data acquisition. (Interlock and safety part of architecture is excluded in this Figure).

DNBPS controller in Figure 2 is a master controller with single point interface with CODAC. ISEPS

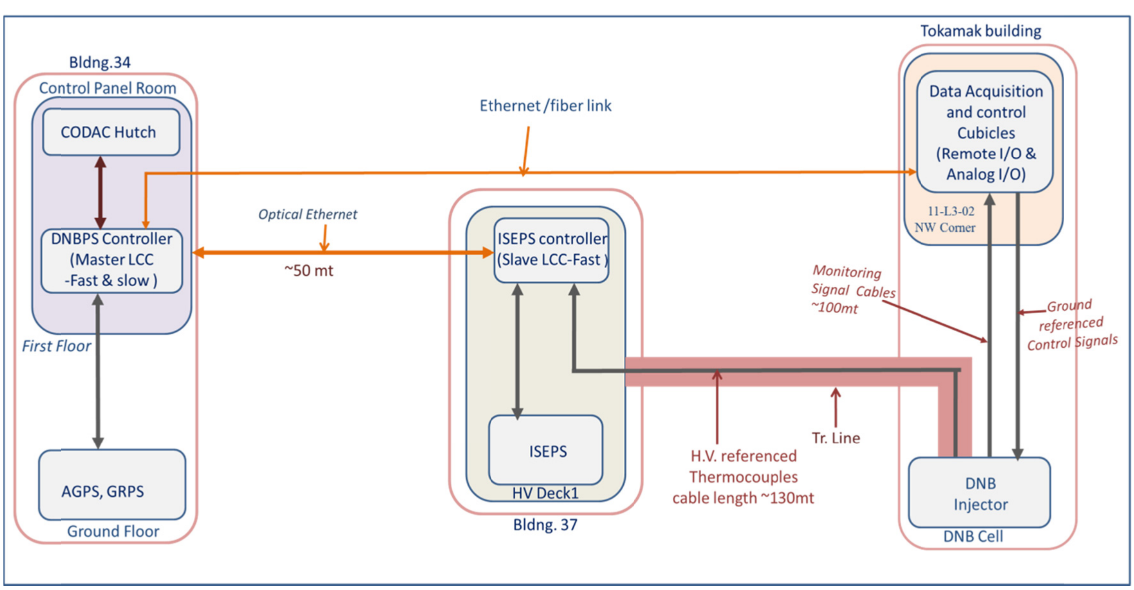

Figure 2 : DNB I&C functional and physical layout.

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controller is a slave controller working at ground potential of 100kV; takes care of ISEPS and a group of other power supplies operation. Ion Source related sensor signals routed through transmission line are acquired here. ISEPS controller communicates to DNBPS controller through optical Ethernet.

EGPS, AGPS and RF generators need synchronous operation with tolerable delay of 100µS and also synchronized switch off in case of break down events.

The instrumentation shall be designed to facilitate DNB operation in two different modes.

1. Local operation: for testing of individual system (commissioning mode) and maintenance
2. Remote operation: operation by central control system or CODAC in two different modes.
   - Beam interception on calorimeter (conditioning mode)
   - Beam injection into the Tokamak (injection mode)

EMI ISSUES

The ISEPS controller instrumentation is to work on 100kV ground reference which is supposed to vary during power supply modulation. Moreover it should be immune enough to work in presence of RF radiations likely to be generated from RF generators.

During conditioning and injection operation of the DNB injector, breakdowns can occur frequently and unpredictably. This event demands the fast switching off of AGPS and EGPS to prevent possible damage to the grids. Switching transients is the major cause of electromagnetic interference in addition to stray magnetic field from the tokomak.

Hence the instrumentation design needs to be of stringent quality class. The design shall follow applicable IEC standards viz 61000, 61158, 61508, 61511, 61069, 60709 and IEEE 802.3.

Neutral beam cell environment at ITER site is likely to be with nuclear radiations; the injector related sensor signals need to be transmitted up to the safe distant location for acquisition.

INSTRUMENTATION INTERFACE WITH CODAC

Plant system (different subsystems of ITER) instrumentation is needed to be connected to CODAC. ITER CODAC is the integrated control, data access and communication system; responsible for coordinating all the plant systems. Hence the plant system instrumentation should be compatible with CODAC.

DNBPS Instrumentation Architecture is divided in three layers; Presentation, Control and Equipment as shown in Figure 3. Presentation layer is central control system like CODAC, central interlock system and central safety system. Control layer contains PCDH compliant instrumentation like Plant System Host (PSH), Fast controller and Slow Controllers. Equipment layer contains local controller of different Power supplies.

Most of the controllers in control layer run CODAC Core System based on EPICS with Linux Platform like PSH and Fast controller. Slow controllers are PLCs.

Instructions required to drive the DNBPS controller (like Start, stop, state change) shall be sent by CODAC using EPICS.; DNBPS controller may communicate to PSH for error signal, protection signal and other information exchange.

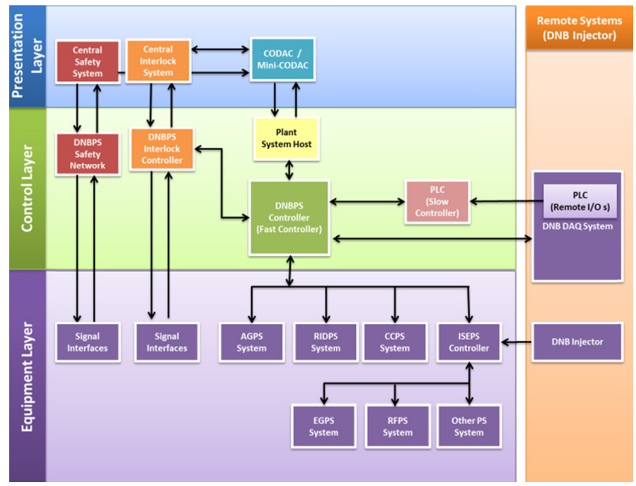

Figure 3: DNBPS I&C Interface with CODAC.

Fast controller can be connected to CODAC directly or through PSH. Slow controller and PSH/DNBPS controller may communicate to each other through standard protocols. PLCs communicate with Remote I/Os with standard TCP/IP protocols.

For local operation HMIs may be needed with each sub system controller. PSH/DNBPS Controller can observe total operation of Slow Controller and log the data. PSH is having EPICS IOC to operate slow controller. PSH has device driver support for slow controllers & fast controllers.

AGPS and RIDPS are directly under DNBPS controller. ISEPS Controller is a slave of DNBPS controller. DNBPS controller transfers CODAC commands to ISEPS controller. ISEPS controller then instructs EGPS, RFPS and Other PS system accordingly. Thermocouples data acquired by ISEPS controller can be transferred to CODAC through DNBPS controller. Some optical Hardwired synchronization shall be provided to AGPS, EGPS & RFPS for synchronous operation during breakdown and beam off events.

Status of DNB subsystems shall be monitored by CODAC through single point contact; i.e. DNBPS controller.

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