DATA ACQUISITION AND CONTROL SYSTEM FOR THE PROTOTYPE KSTAR NB HEATING SYSTEM

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Abstract

A data acquisition and control system for the prototype KSTAR NB heating system based on NI PXI modules and Labview has been designed and constructed. In order to secure three different levels of the ground system, which is to limit the large surge current within in the circuit of the high voltage power supply, the PXI modules are housed in three different PXI racks depending on the potentials of the signals. The first rack is located on a beam line vacuum chamber for the signals with the same ground as the beam line vacuum chamber, the second rack is on the high voltage deck for the signals in a high voltage potential, and the main rack is on the control room to collect the signals with the same ground as the control room. Two PXI sub-racks are connected to the main rack via 60 m long optical fibers in order to insulate the potentials of high voltage deck and beam line vacuum chamber from that of the control room. The data acquisition and control system has a capability to acquire 200 thermocouple signals in 10 Hz and 120 analog signals in 1 kHz.

INTRODUCTION

Two Neutral Beam (NB) systems [1] will be installed in KSTAR tokamak [2] to provide heating and current drive and the first NB system with three ion sources is expected to be installed in 2006. Each beam line should provide 8 MW of deuterium beam power with an energy of 120 keV for 300 seconds. A test stand for KSTAR NB system has been assembled at Korea Atomic Energy Research Institute (KAERI) with all the major components to test the components and to obtain operational experience. The data acquisition and control system (DACS) has been set up using Nuclear Instrument (NI) PXI system and Labview software to collect data and help diagnostics of the NB system.

NB SYSTEM

The test stand of the NB system had been designed to meet the high power and long pulse operation requirement such that all the major components have to be actively cooled. The test stand shown in Fig. 1 consists of an ion source, a neutralizer, a bending magnet, an ion dump and a calorimeter.

Ion Source

The prototype ion source has been constructed using the Long Pulse Ion Source (LPIS) of TFTR at Princeton as a base model and making several modifications for the KSTAR NB system. The ion source consists of plasma generation components, ion acceleration components, and ion beam extraction components. Because of high voltage operation to accelerate ion beams, high voltage insulation and safety measure has to be taken for personnel and equipments.

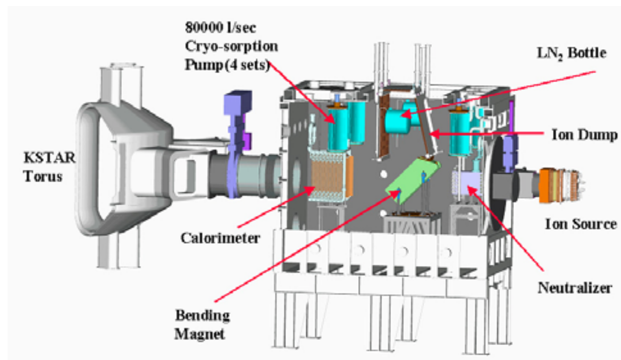

Fig 1: Layout of NB system.

The specifications relevant to DACS of the ion sources are as follows:

- Beam Energy : 120 keV (90 keV).
- Beam Current : 64A (45A).
- Beam Species : D^+, H^+.
- Pulse Length : 300 sec (20 sec)

Beam Line Vacuum Chamber

The beam line vacuum chamber with a dimension of 3 m × 4 m × 5 m (60 m^3) contains major components of NB system except for the ion source. The vacuum chamber is kept at pressure of ~1 × 10^{-9} torr so that all the components inside the chamber have to be vacuum-compatible.

Neutralizer

The neutralizer with a dimension of 16.5 cm × 50.0 cm × 125.0 cm uses the same species of accelerated ions to neutralize the ions up to 40%. The cooling structure is made of Hypervapotron, a Cu-Cr-Zr alloy originally developed at Joint European Torus (JET). The maximum heat removal is 1 kW/cm^2.

Bending Magnet and Ion Dump

The bending magnet bends positive ions toward the ion dump located at 1.8 m above the beam line to increase the purity of neutral beam. The magnetic field at the center of the bending magnet is 2.1 kG so that the bending magnet bends 120 keV D^+ beam upward by 70° with a coil current of 16,800A. The total power to produce ions is 23 MW which is split into 8 MW of neutral beam to

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Tokamak and 15 MW of ion beam to ion dump. The cooling structure of the ion dump is made of swirl tubes with a designed thermal load of 10 MW/m^2. The coolant is purified water with an inlet temperature of 30°C.

Calorimeter

The movable calorimeter should be able to absorb neutral beam dump of maximum power of 8 MW for 300 sec and to measure neutral beam profile for diagnostics of the NB system. The calorimeter for the test stand is designed to absorb the maximum power of 3 MW for 300 sec for steady state thermal load and the maximum power of 9 MW for 0.2 sec for transient thermal load. The dimension of the calorimeter is 70 cm × 112 cm with a designed heat load density of 0.9 kW/cm^2. The cooling structure is made of Hypervapotron. The maximum temperature increase is expected to be 40.7°C at the center and the average increase is 17.2°C.

DATA ACQUISITION AND CONTROL SYSTEM (DACS)

The DACS should be able to handle analog and thermocouple signals from various components of the NB system for 300 sec and to provide interlocks for safety of personnel and equipments. It is especially important for the DACS to provide quick diagnostic displays during the operation since many components have to be tested to find optimal operational parameters. The DACS of the NB system should have secure links to the KSTAR DACS to exchange necessary data between two systems.

The DACS of the NB system is not to be tightly bound with the KSTAR DACS because the NB system has to be tuned independent of KSTAR before the NB injection. The DACS should have also enough flexibility to accommodate the capacity upgrade of ion source and beam line so that modularization of control, monitoring and data acquisition is highly desired. It is also important that the threshold of learning the DACS is not too high for flexible manpower and resource management.

Interface with KSTAR DACS

Before the operation of the NB system, the KSTAR DACS requests power and timing of NB to the NB DACS. The NB system prepares for the requested NB and waits for the timing pulse from the KSTAR DACS. Once the timing pulse arrives to the NB system, the NB system proceeds to operate various components following the programmed timing sequence. The NB system sends to KSTAR DACS an information about the power in waveform and the beam profile of injected NB.

The NB system needs to have interlocks with KSTAR in case of various troubles in either system so that each system can be gracefully put into proper condition. The NB system is designed to shutdown within 1 msec after receiving interlock signals from KSTAR. Fig. 2 shows various interfaces with the KSTAR DACS.

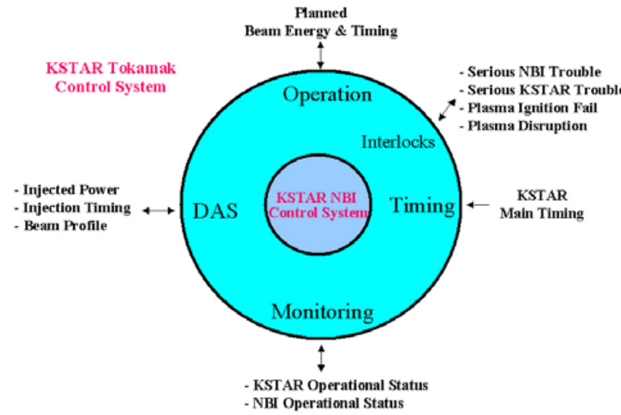

Fig. 2: Interface of NB DACS with KSTAR DACS.

System Layout

Fig. 3 shows the overall layout of the NB DACS. The green dotted boxes show three different levels of the ground system, and the purpose of which is to limit the large surge current within the circuit of the high voltage power supply. The red arrows represent interlock signals. The blue and the green arrows show monitoring and timing signal paths, respectively. The power supply system of the ion source consists of crowbar switches and power supplies for filament, arc, snubber bias, acceleration and deceleration grids. A dedicated system based on VME modules and VxWorks controls the power supply system of the ion source. The NB timing controller receives the NB invoking pulse from the KSTAR DACS and generates a sequence of timing pulses to control various components of the NB system.

NI PXI System

The NI PXI system consists of three PXI racks depending on the potentials of the signals. The first sub-rack is located on a beam line vacuum chamber for the signals with the same ground as the beam line vacuum chamber. The first sub-rack receives thermocouple signals from the neutralizer, the bending magnet, the ion dump and the calorimeter. The calorimeter has been equipped with 60 thermocouples to find the neutral beam profile. The thermocouple signals are connected to a NI PXI 6052E module via SCXI 1102 signal conditioning modules. The sampling rate of these thermocouple signals is programmable and is set to 10 Hz. The first sub-rack also receives thermocouple and flow-rate signals from the cooling system for various components of the NB system. The second sub-rack is on the high voltage deck for the signals in a high voltage potential and receives thermocouple and flow-rate signals from the ion source.

Two PXI sub-racks are connected to the main rack with NI PXI-3 and MXI 8335 via 60 m long optical fibers in order to insulate the potentials of high voltage deck and beam line vacuum chamber from that of the control room. The main PXI rack in the control room receives the monitoring signals from the power supply system of the ion source. The sampling rate of these monitoring signals is programmable and is set to 1 kHz. The monitoring

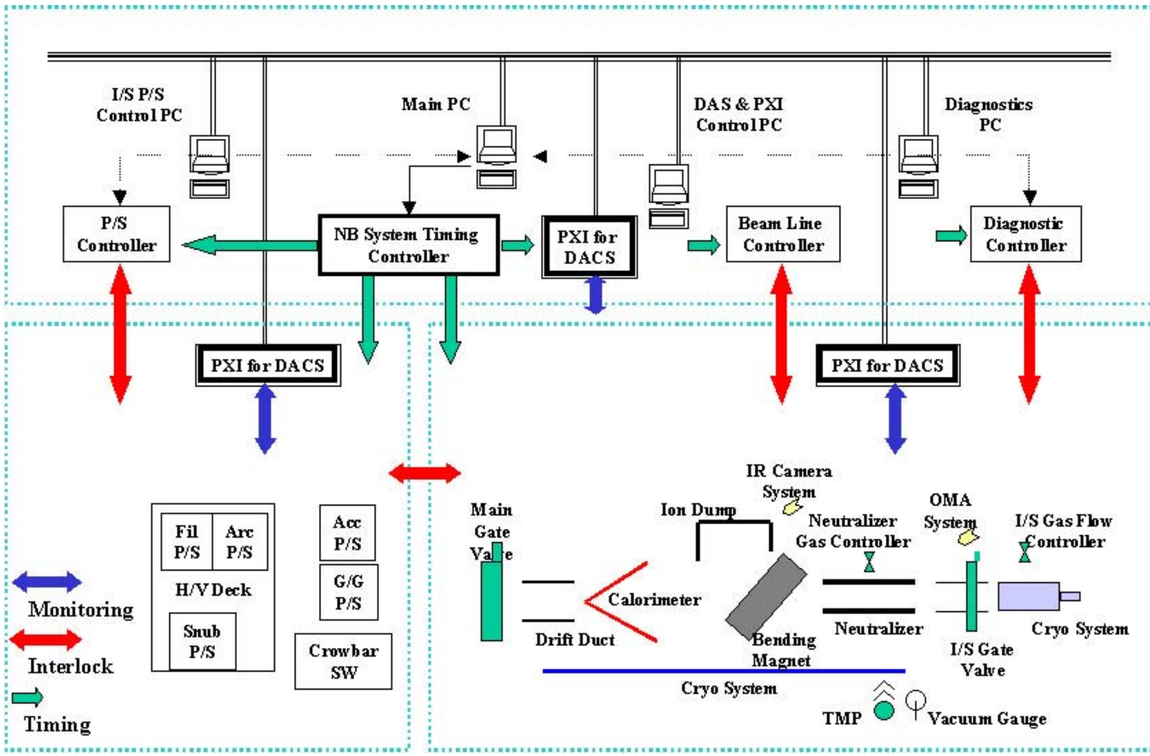

Fig 3: The overall layout of the NB DACS.

signals are connected to a NI PXI 6071E module. The data acquisition and control system has a capability to acquire 200 thermocouple signals in 10 Hz and 120 analog signals in 1 kHz.

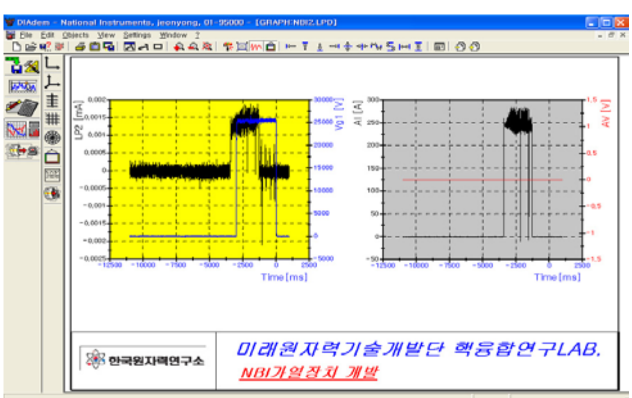

Fig. 4: Data from NB DACS with DIAdem.

The interlock signals for the safety of personnel and equipments come from the thermocouples, the cooling system, the power supply system of the ion source. The output signals to control equipments are generated using NI Labview program and sent via a NI PXI 6534E module. The NI realtime software module will be used to implement the interlock system. To provide operators for quick diagnostic displays, NI DIAdem shown in Fig. 4 is being evaluated.

ACKNOWLEDGEMENT

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