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Fabrication and installment of the hard-wired I&C Works for the Neutral Beam Injection system of the KSTAR Project

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Abstract

Instrumentation and Control(I&C) of the neutral beam injection(NBI) system for the K-STAR national fusion research project has been working from the start of the project to answer diverse requests arising from various facets of the development and construction phases of the project. In a parallel effort with the software oriented I&C development, there has been existing an enormous amount of hard-wiring I&C works for the NBI facility to be developed and fabricated in schedule. Circuits and hardwired functions have been designed, tested, fabricated, and finally installed to the relevant parts of the system. Some examples of those hard-wired I&C works are related to the vacuum system, gas feeding system, arc detector circuit, ion source monitoring, bending magnet and calorimeter. They are one of those integral parts for the proper operation of the NBI system. Examples of those hard-wired I&C works are introduced in this presentation.

1. Introduction

For a big physical facility such as the NBI system(chamber dimension : 3mx4mx5m; Figure 1) of the K-Star Project to operate properly, there should be many functions to support the system to work in a coordinated manner. Vacuuming, power supply for the ion source operation, coolant water circulation, gas feeding to the system, beam line operation, temperature monitoring of the calorimeter and ion dump, control room operation, etc are some of those functions. I&C is one of those functions and has been supporting the NBI facility from the initial stage of the development and construction phases. Hardware oriented efforts have been there for I&C implementation as well as the software oriented ones. Vacuum control and monitoring, gas feeding system, ion source monitoring and arc detection, bending magnet operation, calorimeter operation are a few examples of the hard-wired I&C works for the NBI facility.

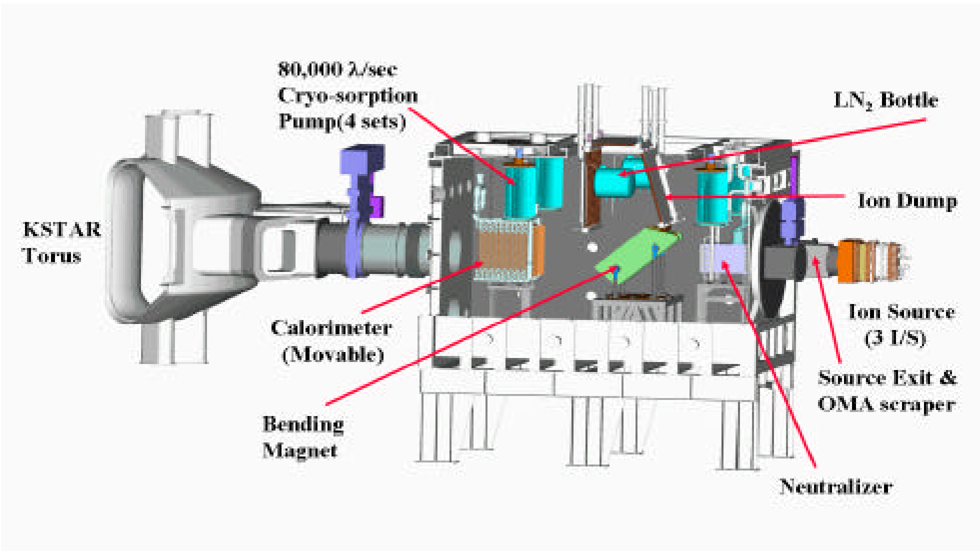

Figure 1. Neutral Beam Injection System of the K-Star Project

Circuits and hard-wired functions have been designed, tested, fabricated, and finally installed to the relevant parts of the system. They are now some of those integral parts for the proper operation of the NBI system. A few examples of the accomplishments made by I&C hard-wiring functions for the K-STAR - NBI facility are introduced.

2. Basic electronic circuits as building blocks for the I&C

Some of the basic electronic circuits which constitute the building blocks for further functions in the NBI I&C needs were designed and fabricated. They are the temperature measurement circuits and the optical signal transceiver circuits.

2.1. Temperature measurement circuits

The temperature measurement circuits utilizing the AD595 thermocouple signal conditioning and amplifying chip(Analog Devices), with the signal isolating function using the ISO122 isolation amplifier(Texas Instruments), was designed and its artworks were made to the form of printed circuit board(PCB). In the circuit, the conditioned and amplified signal by the action of AD595 was then fed to the input of the ISO122 for the signal isolation. The ISO122 chip can transfer the signal through up to ~1500V DC potential differences. The circuit has been utilized in the temperature measurements for the developmental phases of the prototype ion sources.

2.2. Signal converters for the optical transmission

Signal converters that transform input voltage signals to the corresponding optical ones which are then transmitted through the optical cables made of plastics or silica glasses have been designed and fabricated to the form of PCBs. Counterpart circuits converting the input optical signal to the original voltage signal were then designed and made to the form of PCBs.

One of the fabricated circuits utilizes the ADVFC32 V/F-F/V converter supplied by Analog Devices. This circuit converts the voltage level to the corresponding frequency at the transmitter stage, and then converts the frequency to reproduce the original analog voltages at the receiver module.

The other optical transceiver circuit we used was based on the PCBs developed by Dawon System which adopts the AD7891 AD converter and the parallel to serial transformation of the digitized signals for the optical transmission of the digitized signals. The serialization of the digitized data was made by using a programmed Altera EPM7064 CPLD chip. The receiver accepts the serial data, deciphers the serialized signals and then transforms them to reproduce the original analog signals using the same CPLD chip and AD667 DA converter. This coding method was found to endow the signal reproduction more fidelity than the V/F - F/V method. The fabricated optical transceiver circuits accepted +/- 10V signals with a 15 kHz low pass filter on the input stage, reproducing them at the receiver module.

3. Hard-wired Components supporting the NBI facility operations

3.1. G2 current monitoring

The ion source has four electrodes named as G1, G2, G3, and G4. There arose the need for the G2 current measurement, but G2 resided on about 80% of the potential applied to the G1 electrode where inlet power was not available. The current signals could have the negative as well as the positive polarity. The optical transceiver PCB circuit supplied by Dawon Sys as described above was considered suitable for those current measuring requirements. As G2 electrode does not have AC inlet power, we adopted a battery powered circuit for the current measurements. The optically transmitted current signal was reproduced at the control room area using the optical receiver module that was also supplied by Dawon Sys Co. Schematic diagram of the fabricated G2 current monitoring circuits are shown in Figure 2.

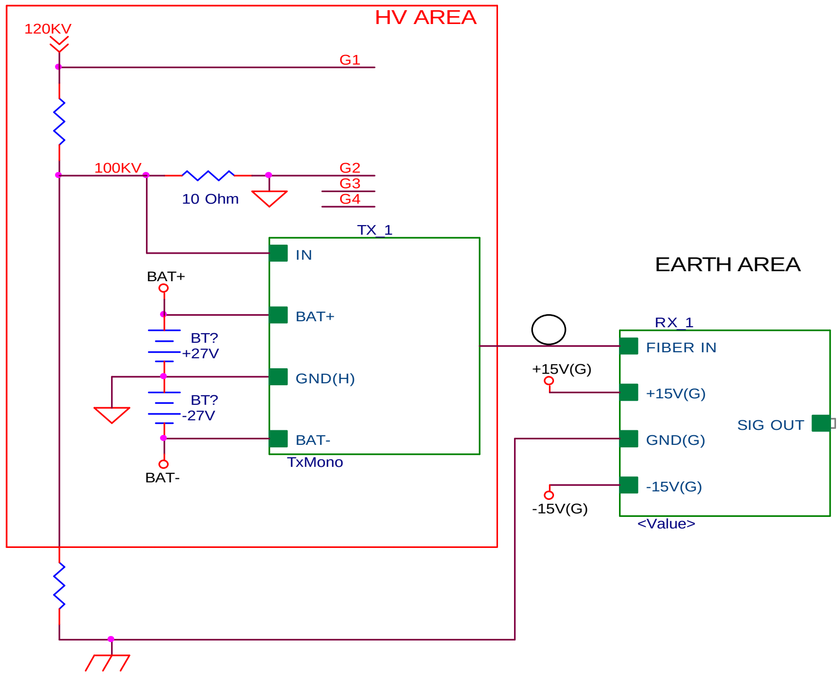

Figure 2. Schematic diagram of the G2 current monitoring circuit

3.2. Optically Isolated Gas Flow Controlling circuit

Gas feeding to the NBI components also requires isolated signal transfer between the control room and the controlled elements. Components that require the isolated gas feeding provisions are the ion source and the neutralizer. Modules which send the gas feeding signal to as well as the flow rate signal from the controlled elements were fabricated using the basic electronic circuits that were described above. Thus for each mass flow controller pairs consisting of the reading module and the flow controller, an appropriate optical signal transceivers were constructed and then installed to the relevant locations of the system. Circuits for the ground region which counterparts those ones at high voltage regions were also fabricated using the basic circuits as shown before.

3.3. Vacuum system

Various electrical hardware supports are necessary for the operation of the NBI vacuum system :

1) Electrical power supplies for the various pumps

2) Control of the valves connecting each of the vacuum components and the monitoring of the valves status.

Many pumps are used for the operation of the NBI facility : rotary pumps, Roots pump, turbomolecular pumps, and cryosorption pumps. Schematic diagram for the outer side NBI vacuum system are shown in Figure 3.

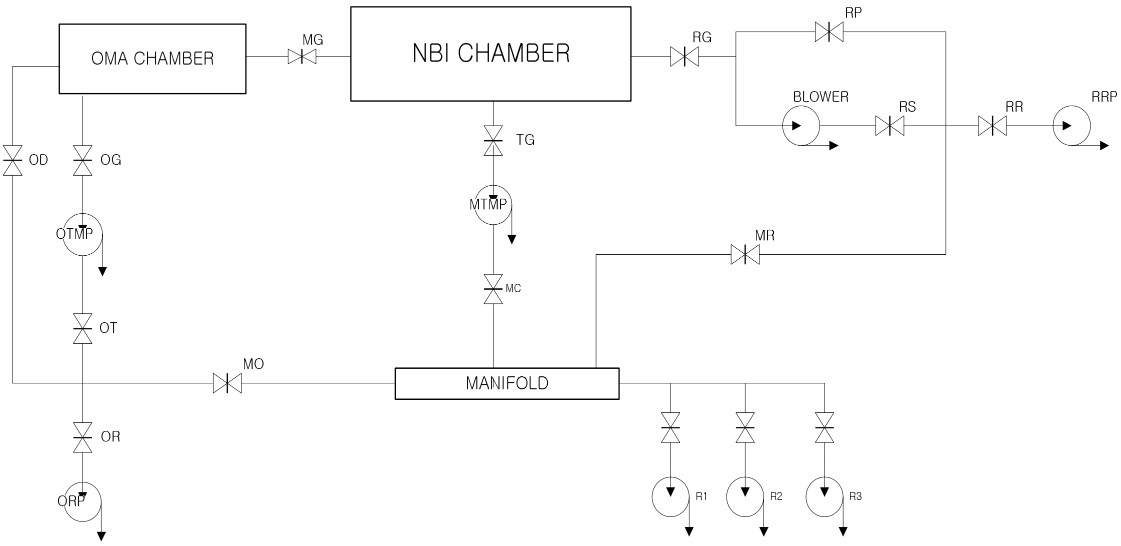

Figure 3. The outside vacuuming components of the NBI system

Rotary action pumps

Of the many pumps that are used in the NBI vacuum system, rotary pumps and the Roots pump are based on the rotary action of the motors. A dedicated power supply module incorporating many magnetic switches and electronic overcurrent relays(EOCR) was installed for the necessary power of the basic vacuum needs. For now, rotary pumps attached to the manifold are fed of their necessary running powers from this module. In an operation of pumps that are using motors for their operations, the most important point to be checked is the running currents that should strictly be within each of their rated values. For such needs to be met without failure, all of the pumps adopting the motor actions were equipped with EOCRs which can cut the abnormally high currents flowing into the motor before any of the overheated states appear.

A Roots pumping system(Stokes, 6", 615 M series Blower accompanied with Stokes Model 212 rotary pump) that acts by collection of air from the vacuuming chamber before the conventional rotary venting stage was installed for the swift evacuation of the NBI chamber in the initial stages of the vacuuming. This system needs a total power of 440V AC(3Φ), 46A for its operation and was also protected by the EOCRs from any of the possible overcurrent failures. The system also necessitates large space and makes heavy noise with vibrations, so an attached pump house to the facility building with some noise and vibration dampening measures was built to accommodate the blower and the rotary pump as well as the accompanying electrical hardwired works.

Even with the large evacuating capacity of the installed Roots pump system, it was soon apparent that the extremely large volume of the NB chamber(3m X 4m X 5m) overrides the Roots pump action when initially we operated the blower at the testing stage of the system. Thus as a guess for a safe time duration before the blower to start, we gave 30 minute for the rotary pumps to operate as a preparatory vacuuming. The result showed a safe operation of the blower without surpassing its rated operational conditions.

Turbomolecular pumps

Two sets of turbomolecular pumps are installed in the NBI vacuum system : MTMP(Osaka Vacuum, TG2820) attached to the main chamber and the OTMP(Varian, TV 1101) attached to the OMA chamber. These pumps are supplied with the necessary powers from anywhere of the general power lines connected to the main chamber operations.

Cryosorption pumps

There are two big cryosorption panels(1.75m X 1.75m; 10^5L/sec/m^2) inside the NBI vacuum chamber)(1) and the four accompanying compressors(two Coolpak 4200s and two Ulvac C40s) are installed on the top of the chamber. The powers for the compressors are supplied from the general 220V AC(3Φ) lines.

The two panels of cryosorption pumps are cooled with liquid nitrogen(LN2) for their operations.(Figure 4)

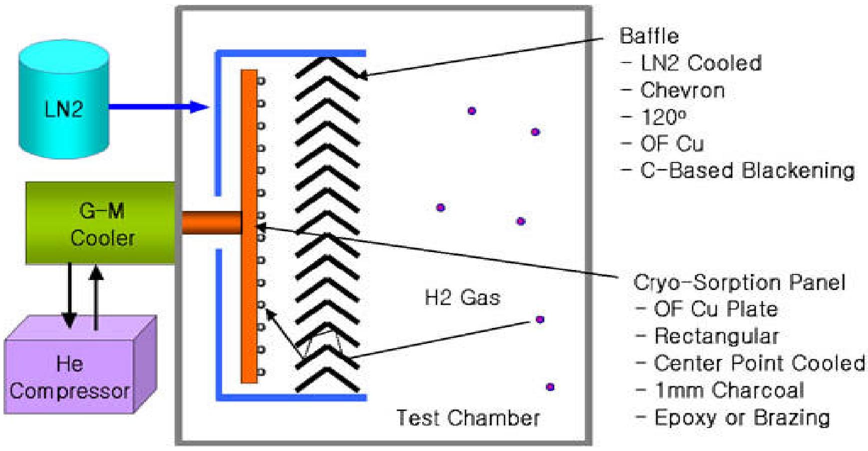

Fig. 4. Schematic diagram showing the operation of the cryosorption pump in action

To achieve the stable cooling action at the panel surfaces, needs for constant temperature of about -181℃ as well as to keeping the level of LN2 and pressure within a tolerable range existed, and a specific valve system with a temperature controller(EC-5500S, supplied by Ohkura Co.) was adopted for this purposes as shown in Fugure 5.

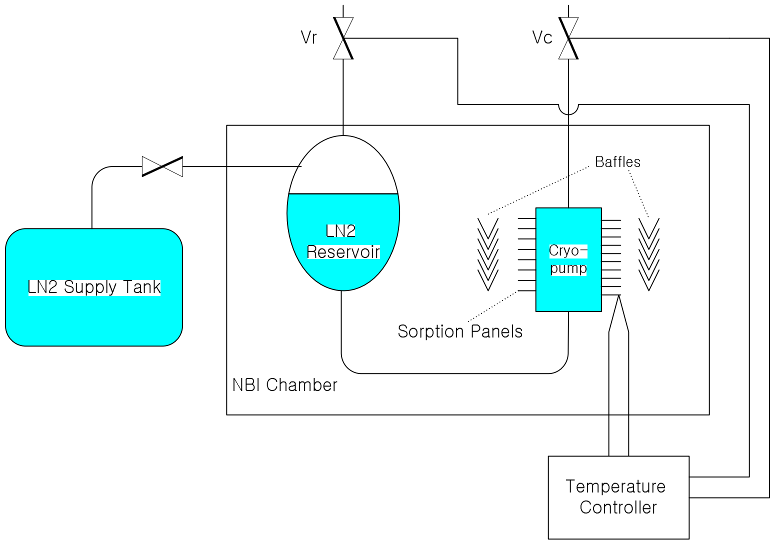

Figure 5. Temperature and the Liquid nitrogen level controlling circuit of the cryosorption pump of the NBI system

The controlling process is as follows : when the temperature goes below the set point, the Vc is closed so as the LN2 can not be evaporated further. Complementary output of temperature controller made it possible for the valve system to close one of the valve pairs while opening the other one, thus ensuring the replenishing action as well as the venting action at every instance of moments. That is, if the temperature of the cryopanel goes higher than the set value, Vc opens and Vr closes so that LN2 level in the panelincleases, thus cooling down the panel. If the panel cools too much that the temperature goes below the set point, a reverse action takes place. This mode of "automatic" valve operation was quite successful, thus eliminating the need for human intervention during the long period of cyclic mode of cryopumping operation.

4. Data acquisition system(DAS)

For the beam power measurements in the NBI experiments, a lot of temperature measurements at many spots of the beam line components are necessary. For this needs to be met, a National Instruments SCXI 2095 incorporated with the SCXI 1102 PXI were installed as schematically illustrated by Figure 6.

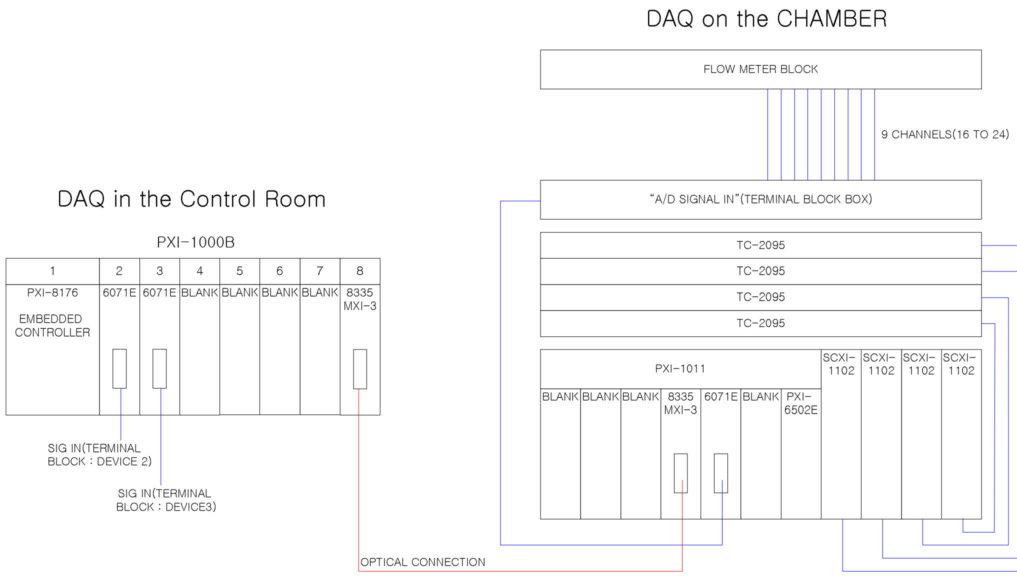

Figure 6. Layout of the DAQ components for the NBI system

Large quantities of the K-type thermocouple lines were installed at the various locations on the beam lines to monitor temperatures as well as the beam power measurements during the beam extraction phases. The location of each of the TC lines are shown in Table 1. All of the TC signals were sent to the four SCXI modules mounted on top of the main chamber, then sent to the control room monitoring computer of the DAQ system via optical signal transmission.

Table 1. Number of thermocouples installed to the various beam line

NAME	Number of Thermocouples
①. ION DUMP	15
②. NEUTRALIZER	8
③. BENDING MAGNET	8
④. CALORIMETER	60

⑤. COOLING LINE	10
⑥. FLOWMETER(in Volt)	9
Total Numbers	110

Beam power measurements also necessitate the measurement of the coolant flow rate. The signal from the installed flow meter comes as voltage. When there is no flow in the system, the reading indicates 1 volt. A total of nine flow meters were installed in the system for their signals to be fed to the DAS system.

Conclusion

In a parallel effort with the software oriented I&C development, there has been existing an enormous amount of the hard-wiring I&C works for the NBI facility to be developed and fabricated in schedule. Vacuum control and monitoring, gas feeding system, ion source monitoring and arc detection, bending magnet operation, and beam line monitoring are some areas of those I&C hard-wiring works for the NBI facility. Most fitted I&C hard-wiring function is still to be developed and fabricated in accordance with the construction schedule of the NBI facility.

References

[1] "Development of Heating System", Report, for Korea Super conducting Tokamak Advanced Research Project, Byung Hoon Oh, *et. al.,* NBI Group, Korea Atomic Energy Research Institute, May 7, 2002.