Design Initiation of the Interlock Circuitry for the KSTAR - NBI Facility

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1. Introduction

As the KSTAR-NBI test facility construction approaches its final stage, ion beams produced during the tests have become enormous: e.g. ion beams now reach to 80kV/20A, or 1.6MW, for tens of seconds.With such a high power beam line, only an inadvertent shutdown of the coolant circulation could result in a devastating result, especially on the calorimeter. On the other hand, the system is constructed with a huge capacity vacuum system comprising three rotary pumps, a Roots pump, a turbomolecular pump, and four cryosorption panels each powered by a helium compressor, thus swiftly evacuating the neutralized materials resulting from the high current ion beams. The evacuating capacity of the system can reach to $1.8x10^6$ L/sec if they are operated in a coordinated manner. Vacuum failures can be deteriorating to the various components comprising the system, or even dangerous because on some occasions liquid nitrogen consumption could be unacceptably enormous.All these concerns led to designing an appropriate interlock circuitry which is to protect, first of all, the calorimeter and the vacuum components of the NBI facility.

2. Design of the interlock circuitry

Calorimeter and the ancillary cooling line components

A rotor type turbine flow meter was installed onto the inlet of the coolant water supply for the calorimeter. The measuring principle of the flow meter is that the rotor blade cuts the magnetic pick-up, which in turn generates a frequency output signal that is directly proportional to the rotor speed. The frequency is then converted to the voltage signal which starts from 1 volt when there is no flow at all. Signal from the flow meter was utilized for the interlock command generation which will shut the acceleration power supply down and also close the gate valve connecting the beam line and the ion source chamber. The output signal data of the flow meter as a function of the flow rate is shown in Figure 1.

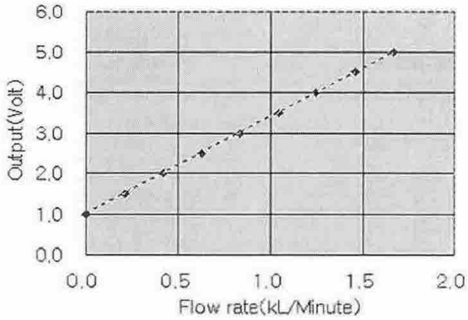

Figure 1. Output voltage of the flow meter as a function of the flow rate.

From the plot of the figure, we can get an equation for the relation between the flow rate and the out voltage as follows:

$V = 2.4 \bullet F + 1$

where F = flow rate in kiloliters/minute and V = output in volt. From the above equation we can make an electronic circuit which sets an interlock signal off under a given output voltage. For the convenience of the beam line operator, we made the flow rate to be the controlling value. Thus we designed an electronic circuit such that produces 1.667 volt when the flow rate is 1,667 kL/min. and so on, so as the circuit will display the value of the flow rate itself. Through the reference of the Johnson's book (1), a circuit implementing these conditions was designed as shown by Figure 2.

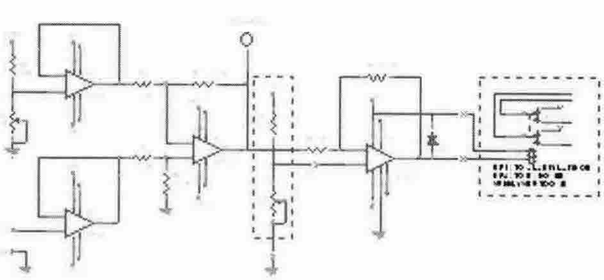

Figure 2. Designed electronic circuit utilizing the flow rate signal for the interlock of the high voltage power supply and the gate valve closure.

At the comparator stage with LM311 just before the relay input, hysteresis is given to the circuit, for fear of the unwanted fluctuations of the relay input at the transition points. The hysteresis voltage range was arbitrarily made to 50 mV(or 21L/min by flow rate), according the following relationship (2):

$$\Delta V_T = V_{TH} - V_{TL} = \frac{R_1}{R_2}(V_{OH} - V_{OL})$$

Here ΔV_T is the hysteresis range we want, $V_{OH} - V_{OL}$ is the difference between each of the op amp saturation voltage, R_1 and R_2 are the input resistance and the feedback resistance, respectively. Because the LM311 is an open collector type, the saturation voltages were just set to be the supply voltages (+15V and -15). Thus the value of $V_{OH} - V_{OL}$ and the ratio R_1/R_2 was calculated to be 30V and 1/600: the values of R_1 and R_2 were made to be 1k and 600k, respectively. The resultant relay outputs are made to be the interlock switch for the closure of the gate valve connected to the ion source and for the shutdown of the high voltage power supply.

Vacuum components

It soon became apparent that different levels of the chamber pressure dictate different interlock measures to be made as shown in Table 1.

Table 1. Necessary interlock actions for different abnormal pressure ranges.

Emergency State	Pressure	Interlock Actions
VE1	>0.001 mbar	Alarm Lamp ON
VE2	>0.01 mbar	-I/S Valve Close -Compressors Off -LN2 supply valve close -LN2 bottle vent valve open
VE3	P>0.05 mbar	TMP GV close

As stated in Table 1, we have three emergency levels of pressure that are to be used for the various interlock functions. The vacuum gauge we adopted for monitoring and controlling function is Model TPG256 vacuum measurement and control unit(or MaxiGauge) of Balzers instruments. TPG256 can accommodate a total of six pieces of sensors (channel 1 to channel 6) and thus the three pressure criteria can be covered with one set of this instrument. The main part of the designed interlock circuit based on the emergency conditions as given by Table 1 is shown in Figure 3. According the designed interlock circuitry, hard-wired interlock circuits are being fabricated, and will soon be installed to the appropriate locations of the NBI system.

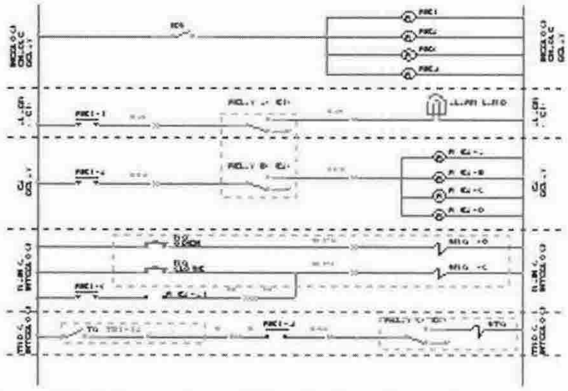

Figure 3. Main section of the designed interlock circuit for the vacuum components.

3. Conclusion

For the safe operation of the KSTAR-NBI system, an interlock circuitry has been designed. Major concern was concentrated to the calorimeter and the vacuum components. According to the designed circuitries, hardwired interlock circuits is now being fabricated and soon be installed to the appropriate locations of the system.

REFERENCES

1. Curtis D. Johnson, "Process Control Instrumentation Technology," 6th Ed., 2000, p.88.
2. S. Franco, "Design with Operational Amplifiers and Analog Integrated Circuits," 2nd Ed., McGraw-Hill, 1998. p.420.