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Software Redundancy for Machine Interlock System of KOMAC

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1. Introduction

The Korea multi-purpose accelerator complex (KOMAC) 100-MeV proton linac has been developed and has been installed at the Gyeong-ju site[1]. The KOMAC consists of low-energy components including a 50-keV ion source, a low-energy beam transport (LEBT), a 3-MeV radio-frequency quadrupole (RFQ), and a 20-MeV drift tube linac (DTL), as well as high-energy components, including seven DTL tanks for the 100-MeV proton beam. The KOMAC includes 10 beam lines, 5 for 20-MeV beams and 5 for 100-MeV beams.

The radiation of the beam loss and faults of the linac components can cause substantial damage to the devices. Therefore, the KOMAC active protection system needs to minimize the beam loss radiation and ensure the safe operation of the machine. The purpose of an interlock system is to turn off beam and components when an interlock occurs. The interlock system consists of two parts which are a hardware-based Machine Protection System (MPS) using analog circuit and a software-based interlock system using Experimental Physics and Industrial Control System (EPICS) and Programmable Logic Controller (PLC). The software-based interlock system was design to double-check a MPS operation and support sequential operation by interlock signals.

2. Machine Protection

In order to protect the essential equipment, the Machine Protection System (MPS) must be designed to identify a variety of device failures around the linac and beam lines. The machine operation must be done in some reliable protection system. As a fast interlock system to protect the devices, the goal of the MPS is to turn off the RF system or the beam of a microwave ion source within a few macro-seconds when some failure of the RF or beam loss occurs during the operation mode in which beams are switched to beam lines. The fast interlock signals are composed of very sensitive equipment, such as beam losses, High Voltage Converter Modulators (HVCM), high power RF sources, RF cavity, Fast Closing Valves (FCV) and Safety Blocks (SB) at the 10 beam lines etc.

In order to prevent beam when a device failure is activated, the hardware and software interlock system are designed as shown in Fig. 1. Each local MPS sends the interlock signal to the MPS for the ion source, and the beam is shut off by turning off the extraction power supply of the ion source. It is also possible to shut off the RF power of the RFQ to decelerate the beam in the linac. When the interlock signals of the RF system and the HVCM occur, the local MPSs also send the interlock signal to a switch in the low-level RF system to shut off the RF power to each cavity.

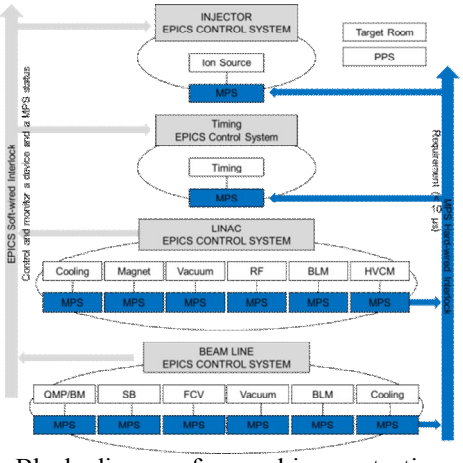

Fig. 1. Block diagram for machine protection system and EPICS channel access, interlock system based on hardwired and soft-wired logic

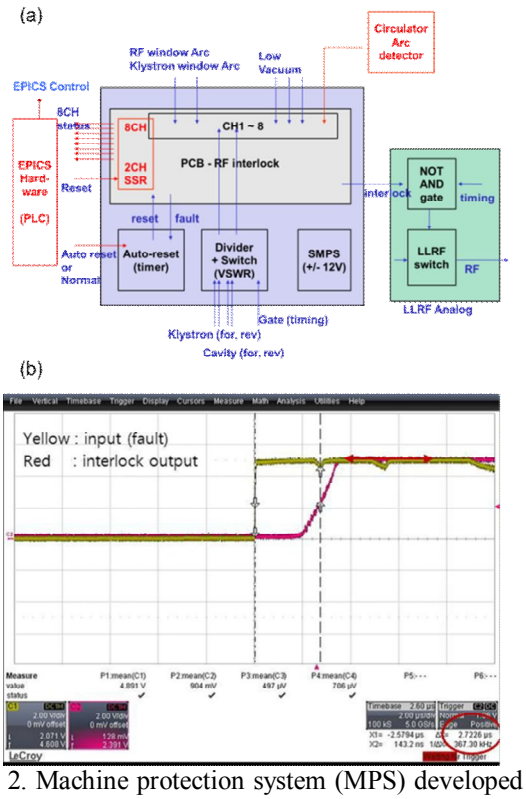

Fig. 2. Machine protection system (MPS) developed by fast trip direct analog circuit, (a) block diagram of signal path, (b) response time within 3us when input of a fault signal is activated

The block diagram of the MPS which is developed using fast trip direct analog circuit is shown in Fig. 2 (a).

The MPS which has 8 channel outputs and 2 channel inputs is controlled and monitored by an EPICS-based control system. The MPS consists of fast analog interlock modules like comparators and latches, an auto-reset module, a VSWR module for only RF interlock unit, and a power supply. The response time of the fabricated MPS was measured within 3μs as shown in Fig. 2 (b) [2]. The response time has been satisfied for the KOMAC machine protection which must stop the beam within a few milliseconds when any device failure occurs in 60 Hz beam operation.

3. Implementation

The interlock systems are the essential devices for personnel safety and machine protection by turning off beam. Also in order to support sequential operation based on interlock signals, a software interlock system is designed by using Experimental Physics and Industrial Control System (EPICS) framework and industrial PLC [3]. The PLC collects local interlock signals from local components, such as vacuum, magnet power supply, cooling system, and so on. The PLC I/O chassis is distributed into the linac gallery and communicated with a main PLC CPU system via ControlNet. An EPICS Input Output Controller (IOC) for the interlock system, which is connected with PLC via EthernetIP, is integrated with the KOMAC main control systems through the EPICS Channel Access (CA). Fig. 3 shows EPICS-based Graphic User Interface (GUI) for monitoring the low level RF and klystron interlock status.

Fig. 3 Graphic User Interface (GUI) for monitoring operating status of RF and klystron interlock system

The beam permission in the linac and beam lines is controlled by interlock signals of the Linac MPS, Personnel Protection System (PPS), and Target Room (TR). One of a failure to the linac critical device, a failure on the personnel safety, or an emergency in a target room will activate the beam stop. Fig. 4 describes a rough view of a procedure for beam operation under ready condition of linac, personnel safety, and beam target room.

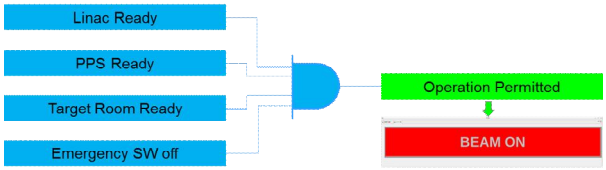

Fig. 4 Hardwired interlock for switching on beam in linac and beam lines under ready condition of LINAC, Personnel Protection System (PPS), and Target Room (TR)

The interlock signals are connected to MPS by using hardwired. Through the logic “Beam On” can be switched on under “Linac Ready”, “PPS Ready”, and “TR Ready” condition. The “Linac Ready” condition will check the list of interlock signals of MPS and linac subsystems like vacuum, magnet power supply, cooling system, and so on. In order to accelerate beam to the linac and beam lines, “Linac Ready” should hold with “gate valve open”, “fixed value of power supply”, and “reliable cooling”.

4. Conclusions

The interlock system is based on hardware and software interlock system with redundancy to protect the sensitive devices from the radiation on the beam loss and faults on the equipment. The local MPS for a main interlock have been fabricated, and its response time was within 3 μs. This response time has been satisfied to meet the machine protection, which must prevent a beam within a few milliseconds during beam operation of 60 Hz. The interlock systems can inhibit a beam whenever one of the control systems detects an error from the local devices. A beam can be accelerated under machine and personnel protection condition

ACKNOWLEDGMENT

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