DESIGN OF MACHINE PROTECTION SYSTEM FOR THE PEFP 100 MEV LINAC*

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Abstract

The 100MeV proton linear accelerator of the Proton Engineering Frontier Project (PEFP) has been developed and has been installed at the Gyeong-ju site. After the 100MeV machine is installed, the beam commissioning will be performed in 2012. A machine protection system (MPS) to shut off the beam and to protect the 100MeV machine against failure and excessive beam losses has been designed. The MPS must handle inputs from a variety of sources including beam loss monitors, RF and high voltage converter modulator faults, fast closing valves for vacuum window leaks at the beam lines and so on. These sensors exist at various places across the full length of the 100MeV accelerator and beam lines. A beam loss monitor (BLM) system has been designed with scintillators and photomultiplier tubes (PMT) to identify potential faults. With a hard-wired protection for fast interlocks, the beam should be shut off within a few macro-seconds. Hardware-based MPS has been fabricated and tested for the 100MeV machine. Analog circuit interlock chassis for the MPS have been fabricated, and its response time was within 3 μs. The interlock chassis has the circuit to select latch mode and auto reset mode. The EPICS control system has been also designed to monitor the MPS status as a PLC. This paper will describe the MPS design being developed for a fast interlock and a hardware construction for the 100MeV machine.

INTRODUCTION

The Proton Engineering Frontier Project (PEFP) 100MeV proton linac including the 20MeV linac operated at the KAERI site has been developed and has been installed at the Gyeong-ju site [1-2]. The PEFP 100MeV linac consists of a 20MeV DTL, a 100MeV DTL, 20MeV beam lines, and 100MeV beam lines. The 100MeV machine will be installed, and then the beam commissioning will be performed at the end of this year. The accelerator design has been carried out with the objective of limiting beam losses to less than 1 W/m during normal operation. This limitation is a generally accepted figure which should keep the induced radioactivity in the vicinity of machine at a level sufficiently low to permit hands-on-maintenance during shutdown periods [3].

The linac operation will need systems to protect critical components from beam induced damage such as excessive beam losses and faults at high power components [4-5]. The machine protection system (MPS) must therefore identify a variety of faults across a full length of the 100MeV machine, and the MPS must be able to turn off the beam within a few macro-seconds before damage is caused. The MPS will use the status of the critical sub-systems such as the high power components and losses measured by a fast beam loss monitor (BLM) system including photomultiplier tube (PMT) using plastic scintillator [6].

The MPS will also monitor fast closing valves and safety blocks at the beam lines to supply the proton beam for users. The MPS for a fast interlock will trip the machine operation via fast trip direct analog circuit without software and the MPS status can be monitored and controlled at the EPICS control system via the programmable logic controller (PLC).

MPS DESIGN

The hardware based MPS for a fast interlock has been designed and constructed. Figure 1 shows the hard-wired MPS block diagram for the 100MeV linac. The beam interlock sensors exists across the full length of the 100MeV linac and the beam lines, and the local interlock units handle inputs from a variety of the faults including the BLM, arc and faults of the high power RF systems and high voltage converter modulators (HVCM), and fast closing valves and safety blocks at the beam lines. The PEFP 100MeV machine has ten beam lines to provide the proton beam for users. To supply the beam for users safely, fast closing valves and safety blocks will be installed at the end of the beam lines, and the faults from them will be connected to the MPS. Each local interlock unit send the interlock signal to the interlock unit 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 for a fast interlock. Then, the MPS status can be also monitored and controlled at the EPICS control system via the PLC.

In the case of the faults from the RF system and the HVCM, the local interlock units also send the interlock signal to a switch in the low-level RF system to shut off the RF power to each cavity. The failure at cooling systems and magnet power supplies are monitored and controlled at the EPICS.

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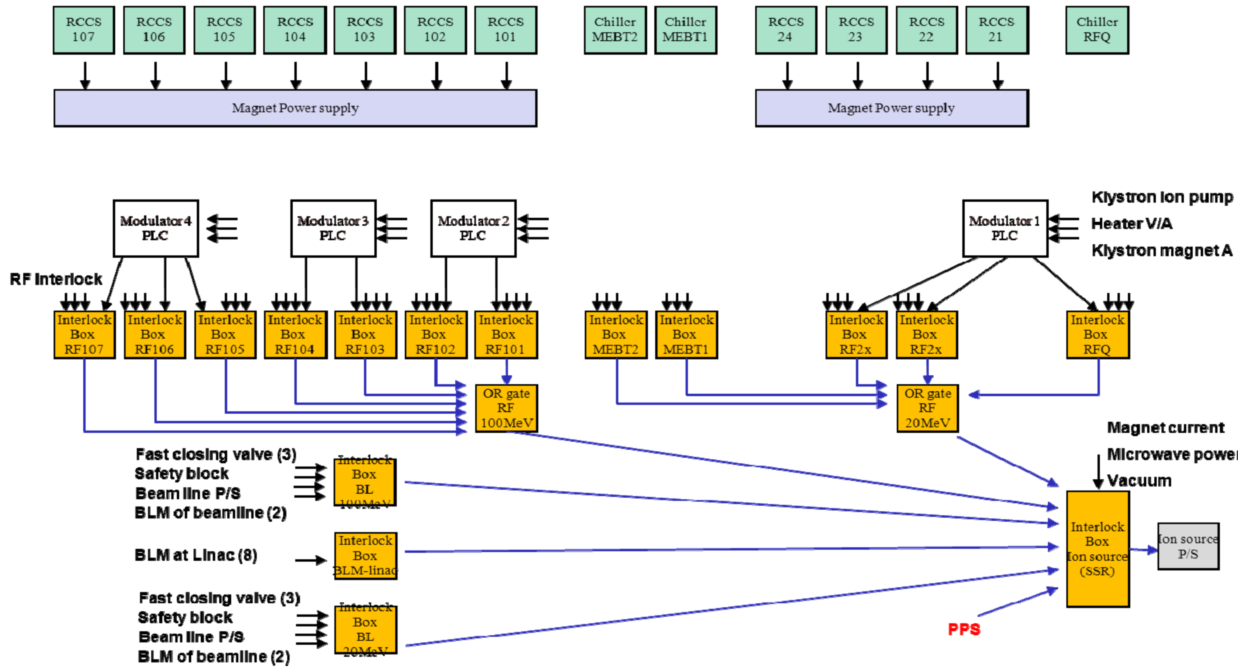

Figure 1: MPS block diagram for the 100MeV Linac.

INTERLOCK HARDWARE

The block diagram for the local interlock unit is shown in Figure 2. Actually, Figure 2 shows the local interlock unit for the RF faults. The other interlock units such as the BLM and beam lines are similar with this block diagram. The interlock units include a fast analog interlock module with comparators and latches, an auto-reset module, a VSWR module for only RF interlock unit, and a power supply. The interlock unit has 8 channel inputs and is connected to the EPICS control system to monitor the MPS status. The interlock units have been fabricated to 19" 2U rack as shown in Figure 3. The response time of the fabricated local interlock unit was measured within 3 μs as shown in Figure 4.

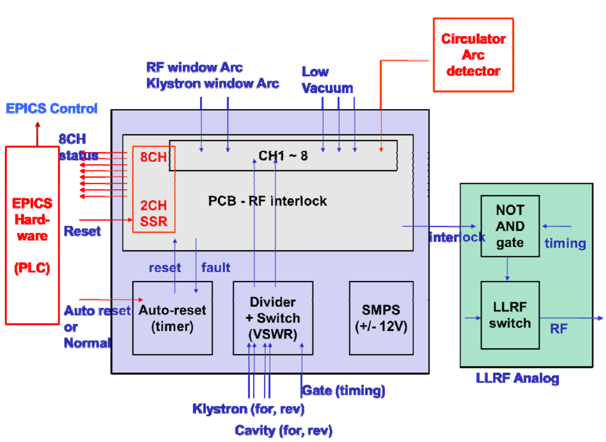

Figure 2: Block diagram of the local interlock unit. This is for the local RF interlock unit.

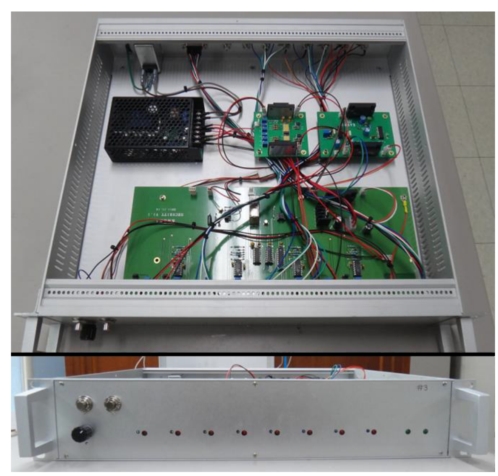

Figure 3: Fabricated local interlock unit.

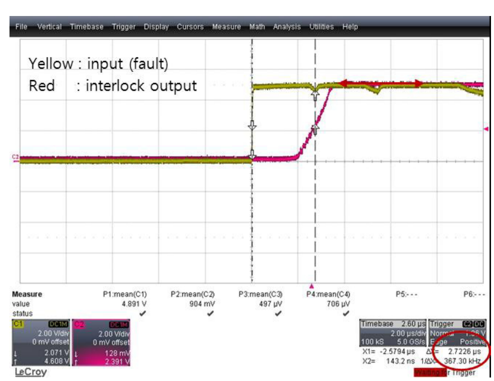

Figure 4: Response time measurement of the local interlock unit.

BEAM LOSS MONITOR

The BLM is the important part of the MPS to mitigate the uncontrolled or irregular beam loss which can be caused by a misaligned beam or faulty condition of accelerator elements and vacuum problems, and they can cause damage of beam pipe, radio-activation of equipment, and equipment damage. There are many types of the BLM such as the ionization chamber, scintillator, PIN diode, neutron detector and so on. Among the many types of the BLMs, the PMT using plastic scintillator and the proportional counter are selected as the BLM at the PEFP 100MeV proton linac because of a fast detection and a sensitivity at the low energy section of the accelerator (below 100 MeV, DTL section).

The response time is typically a few nano-seconds and their sensitivity roughly 1000 times higher than the ionization chamber, also the sensitivity of PMT can be adjusted by high voltage. They are fast enough to study the time resolved beam loss and to transfer the trip signal induced by the beam loss to the MPS as soon as possible.

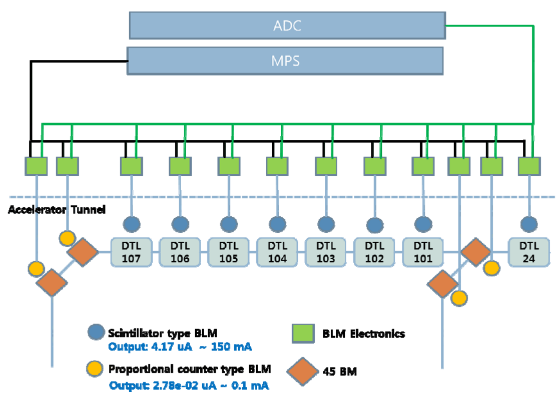

Figure 5: BLM positioning at the 100MeV linac.

For the beam commissioning of the 100MeV proton linac, the limited number of the BLMs will be installed at the initial stage of the accelerator operation. Eight PMT type beam loss monitors will be installed at each DTL tank, and four proportional counter type beam loss monitors will be installed at the 20 MeV and 100 MeV beam line. Figure 5 shows the schematics of the BLM positioning.

SUMMARY

The PEFP 100MeV linac has been installed at the Gyeong-ju site. The beam commissioning will start at the end of this year. The hardwired MPS for the 100MeV linac operation has been designed and the hardware has been constructed to protect critical components from beam induced damage such as excessive beam losses and faults at high power components. The local analog interlock units for a fast interlock have been fabricated and its response time was within 3 μs. The PMT using plastic scintillator and the proportional counter are selected as the BLM at the PEFP 100MeV proton linac because of a fast detection and sensitivity at the low energy section of the accelerator, and the BLM positioning was determined across the 100MeV machine including beam lines.

The MPS will be installed and tested shortly for the 100MeV linac operation.

ACKNOWLEDGEMENTS

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