MACHINE PROTECTION SYSTEM FOR TRIUMF'S ARIEL FACILITY

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Abstract

Phase 1 of the Advanced Rare Isotope & Electron Linac (ARIEL) facility at TRIUMF is scheduled for completion in 2014. It will utilize an electron linear accelerator (eLinac) capable of currents up to 10mA and energy up to 75MeV. The eLinac will provide CW as well as pulsed beams with durations as short as 10uS. A Machine Protection System (MPS) will protect the accelerator and the associated beamline equipment from the nominal 500kW beam. Hazardous situations require the beam to be extinguished at the electron gun within 10uS of detection. Beam loss accounting is an additional requirement of the MPS. The MPS consists of an FPGA based controller module, Beam Loss Monitor VME modules developed by JLAB, and EPICS -based controls to establish and enforce beam operating modes. This paper describes the design, architecture, and implementation of the MPS.

ARIEL INTRODUCTION

ARIEL will expand the Rare Isotope Beam (RIB) program at TRIUMF by providing for three simultaneous beams allowing for an increased number of hours delivered to users per year. The ARIEL facility will consist of five major components. First is the building to house two new target stations, their remote handling infrastructure, chemistry labs, beam mass separators and front end. Part of the new building is a connecting tunnel connecting the ARIEL building to the existing Cyclotron building, completed September 2013. Second is a superconducting 50MeV, 10mA CW linear electron accelerator and associated beamlines to deliver the high current electron beam to the target stations. The eLinac is scheduled to be operational by the fall of 2014. The next phase will include high resolution mass separators and ion transport beamlines for delivering RIB to the existing ISAC-I and ISAC-II facilities from two new ISOL target stations. An additional proton beamline will be capable of delivering 100uA to the target stations from the cyclotron.

MPS OVERVIEW

The primary objective of the MPS is to protect the accelerator equipment from damage related to mis-steering of the high-power electron beam. A secondary objective is to provide a beam loss accounting tool capable of enforcing limits on long term loss rates.

Operating modes have been defined based on the matrix of Beam Path (a defined start to end point of the beam) and Beam Properties (actual beam energy and intensity). The MPS enforces allowable Operating Modes by accepting or denying operating mode change requests made by the operator by inspecting the status of insertable devices and beam steering elements. Interlocks of critical devices (devices that can either intercept beam or mis-steer beam) are handled by the Control System based on the operating mode. The current operating mode is communicated to the control system by the MPS.

The ARIEL MPS initiates beam property changes (throttling) or beam trips based on input from critical devices and beam loss monitors. Beam loss limits were separated into three categories based on the allowed reaction time of the system:

<u>Category 1:</u>
In the event of a full 500kW or catastrophic beam loss it was calculated that the beam must be extinguished within 10uS to prevent damage.

<u>Category 2:</u>
In the event that the system can determine that a beam loss is imminent due to a device failure or the loss of beam is greater than a predetermined level, but has not reached the catastrophic level a somewhat arbitrary time limit of one second has been chosen before which the beam current from the eGun must be throttled.

<u>Category 3:</u>
In the event of a beam loss greater than the allowable chronic loss limit, but less than the category 2 limit the system must issue alarms to the operator.

Each of the responses will escalate as necessary as the situation changes. The MPS uses a three prong approach depending on the reaction time necessary to prevent damage.

MPS ARCHITECTURE

Figure 1 shows the proposed block diagram of the MPS system. Catastrophic beam losses are handled in hardware using a direct wired connection between the Beam Loss Monitor (BLM) modules and the Fast Shutdown Module (FSD). Beam Intensity is controlled by the MPS via the macro pulse of the eGun. This is accomplished by the use of a signal generator.

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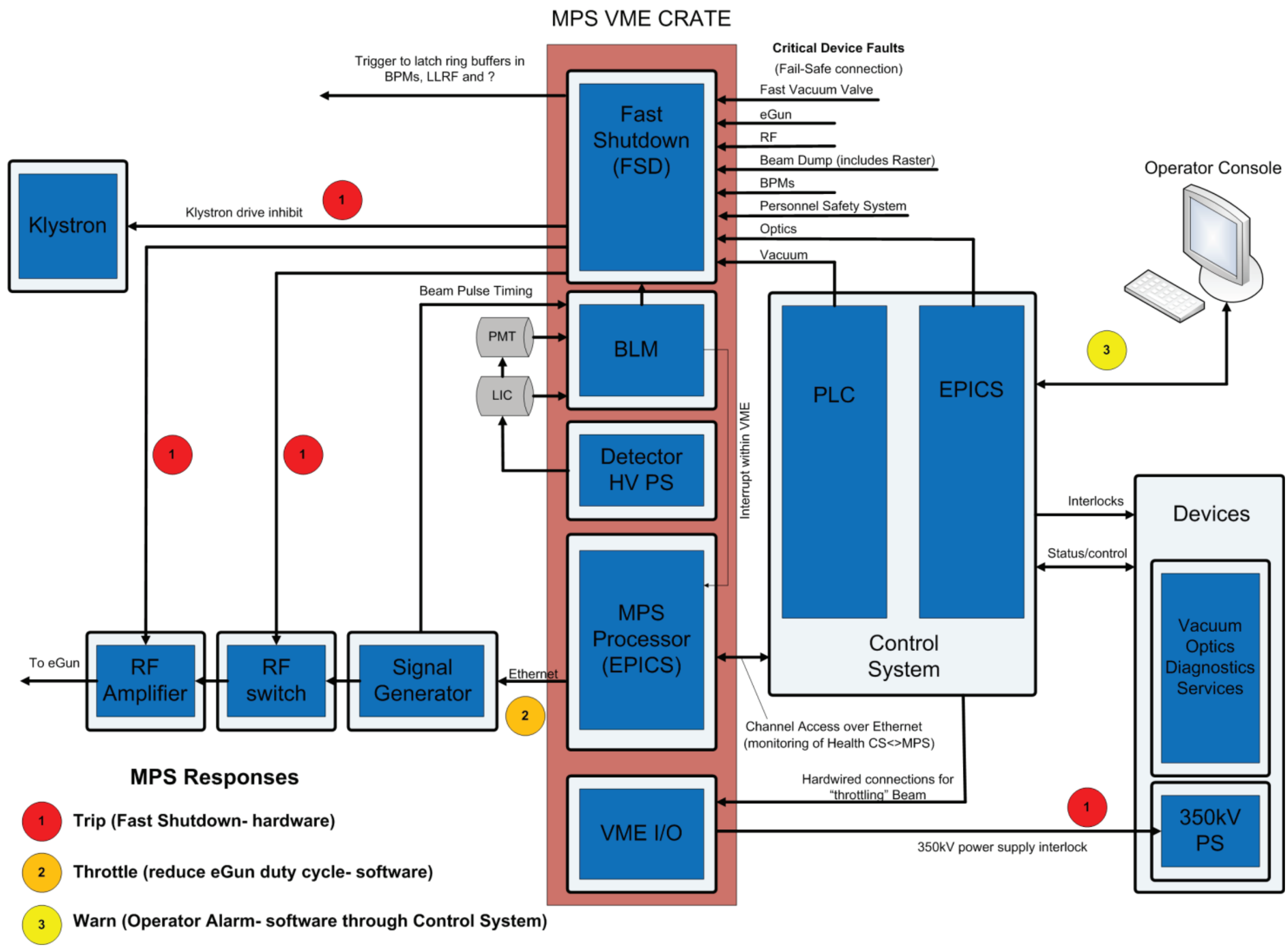

Figure 1: MPS Block Diagram.

Fast Shutdown Module

The FSD is an application-specific VME module designed and built at TRIUMF by the Electronics Development group. It implements a digital "AND" function, monitoring critical devices and system summary statuses, and outputs an inhibit signal to the RF drive of the electron gun (eGun). It also generates triggers for BPM systems, and Low Level RF systems to latch ring buffer data to be used for post-mortem analysis after a MPS-generated trip.

Beam Loss Monitor Module

The BLM module [1] was purchased from Jefferson Lab. The module interfaces to Photomultiplier tubes as beam loss detectors. In addition Long Ion Chambers (LIC) will be utilized in the ARIEL MPS. Additional development will be required to interface the LICs into the MPS. The detectors will be powered by commercial High Voltage power supply VME modules.

MPS Processor, Input/Output Modules

The MPS is tightly integrated with the control system. As such, the MPS will use the same hardware as the control system. An MPS Processor will use EPICS Channel Access to monitor critical devices connected to the control system. The processor is also responsible for throttling the beam during Category "2" situations, as determined by reading beam loss data from the BLM. In addition the processor also monitors the FSD, and removes the enable to the 300kV eGun bias supply after a FSD trip.

MPS Trip Devices

Removing the RF drive to the eGun is the only method able to meet the requirement of extinguishing the beam within 10uS. For redundancy the enable signal to the RF amplifier is removed and the output of the signal generator (which provides the 650MHz reference to the eGun as well as the macro pulsing) is blocked by an RF switch.

MPS Monitored Devices

Any insertable device that can intercept beam is monitored by the control system. This includes vacuum valves and diagnostic devices. Systems, such as the eGun, LLRF, BPMs, Personnel Safety System and the beam

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dump subsystem, will each provide a digital summary "ok" status directly to the FSD.

MPS – Control System Interface

Communication between the MPS and the control system will use both EPICS Channel Access and hard-wired signals. Operator requests for operation mode changes are treated by the control system like the operation of a device. The request is first checked for interlocks and then passed on to the MPS where the request is accepted or denied. In normal operation the control system will pass the control parameters for beam intensity to the MPS, which then sets the signal generator accordingly.

STATUS

A prototype MPS is being installed in the eLinac test stand at TRIUMF. The test stand will allow deliberate controlled beam loss to test the BLM modules coupled to PMTs and LICs under actual conditions, including pulsed operations. Throttling the beam using the signal generator will also be evaluated for speed and practicality using the test stand.

ACKNOWLEDGMENT

The MPS system uses Photomultiplier tubes and Long Ion Chambers for the beam loss monitors. These detectors were designed and constructed by the personnel of TRIUMF's Detector Group.

REFERENCES

[1] J. Yan and K. Mahoney, "New Beam Loss Monitor for 12 GeV Upgrade," ICALEPCS 2009, Kobe, October2009, WEP092, http://accelconf.web.cern.ch/accelconf/icalepcs2009/papers/wep092.pdf

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