# Abstract

The Fermilab's Superconducting RF Beam Test Facility currently under construction will produce electron beams capable of damaging the acceleration structures and the beam line vacuum chambers in the event of an aberrant beam pulse. The accelerator is being designed with the capability to operate with up to 3000 bunches per macro-pulse, 5Hz repetition rate and 1.5 GeV beam energy. It will be able to attain an average beam power of 72 kW at the bunch charge of 3.2 nC. Operation at full intensity will deposit enough energy in niobium material to approach the melting point of 2500 °C. In the early phase with only 3 cryomodules installed the facility will be capable of generating electron beam energies of 810 MeV and an average beam power that approaches 40 kW. In either case a robust Machine Protection System (MPS) is required to mitigate damage effects due to such large damage potentials. This paper will describe the MPS system being developed, the system requirements and the controls issues under consideration.

# Introduction

The beam at Fermilab's New Superconducting RF Beam Test Facility [1], when operational, will need systems to protect critical components from beam induced damages such as beam pipe collision and excessive beam losses. The MPS must therefore identify hazardous conditions and then take the appropriate action before damage is caused. Since the loss of a full bunch train can result in significant damage, the MPS must be able to interrupt the beam within a macro-pulse and keep the number of bunches below the damage potential once the protection system reacts; the goal is to keep the number of bunches on the order of 3-4 bunches. With the high possible bunch frequency of 3 MHz this necessitates a reaction time in the range of 1-2 μs with cable delay included for the 134 meter long machine. The MPS will use the status of critical sub-systems and losses measured by a Fast Beam Loss Monitor (BLM) system, using scintillators and photomultiplier tubes (PMT) to identify potential faults. Once a fault is detected, the MPS can then stop or reduce beam intensity by removing the permit from different beam actuators, including the laser pulse controller. The simplified overview block diagram of the proposed MPS is shown in Figure 2. The MPS has connections to several external devices and sub-systems. The top layer comprises signal providers such as fast beam loss monitors, RF signals, quench protection, control systems, transmission, vacuum, magnet power supplies and more. All devices in this category send status information to the MPS logic layer (permit system). Only simple digital signals (e.g. on-off, OK-not OK) are transmitted. All devices or subsystems that are determined to be pertinent to protecting the machine or necessary for machine configuration are included here. The state of the machine is determined from this comprehensive overview of the inputs and allowable operational modes are determined based on this information by the middle logic layer. The main goals for the MPS system as a whole are:

- Provide precise protection of all critical components by first determining the fault severity (high, intermediate, etc) and then taking the appropriate action to avoid damage.
- Allow for high availability by ensuring that the maximum required beam intensity is allowed for the detected fault severity.
- Monitor MPS components and perform periodic self-checks in order to ensure robustness and a high level of reliability.
- Provide well-integrated, user-friendly tools for fault visualization, control and post-mortem analysis.

# Cryogenic Beam Test Facility

Although loss monitors are typically one of the main diagnostics for protecting the accelerator from beam induced damage. Most accelerator facilities do not cover the cold sections of the machine with loss monitros. To address these issues a Cryogenic Loss Monitor (CLM) ionization chamber capable of operation in the cold sections of a cryomodule has been developed and will be installed and tested [2]. The monitor electronics have been optimized to be sensitive to DC losses and the signals from these devices will be used to study and quantify dark current losses in particular, see figure 4. In order to increase the resolution bandwidth and the response time of the devices a new scheme which uses a Field Programmable Gate Array (FPGA) based Time-to-digital converter (TDC) method is implemented [3] instead of a standard pulse counting method.

# Controls System

The MPS will need server support for the various hardware systems to View, Configure and Diagnose the system. Already there are currently several servers under development for the beam loss monitor system and the laser pulse controller. These servers were implemented using the PowerPC 5500 series boards running VxWorks 6.4 and implementing the ACNET protocol. Some of the main requirements for these servers include:

- Time-stamping at a sub-microsecond resolution in order to allow for data correlation.

A control system that is well integrated with all MPS components, from the various front-ends to the high level applications, is critical to leveraging the full functionality of that control system.

# Summary

Significant effort is underway towards developing a reliable MPS for this new facility. System integration and commissioning challenges lay ahead.

## References

