Integrating a Machine Protection System for High-Current Free Electron Lasers and Energy Recovery Linacs

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Abstract

A fully integrated Machine Protection System (MPS) is critical to efficient commissioning and safe operation of all high-current accelerators. The MPS needs to monitor the status of all devices that could enter the beam path, the beam loss monitors (BLMs), magnet settings, beam dump status, etc. This information is then presented to the electron source controller, which must limit the beam power or shut down the beam completely. The MPS for the energy recovery linac (ERL) at the Jefferson Lab Free Electron Laser [1], generates eight different power limits, or beam modes, which are passed to the drive laser pulse controller (DLPC) (photocathode source controller). These range from no beam to nearly 2 megawatts of electron beam power. Automatic masking is used for the BLMs during low-power modes when one might be using beam viewers. The system also reviews the setup for the two different beamlines, the IR path or the UV path, and will allow or disallow operations based on magnet settings and valve positions. This paper will describe the approach taken for the JLab 10-kW FEL. Additional details can be found on our website http://laser.jlab.org [2]

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1. Introduction

The system controlling electron beam current and providing protection from burn-through is divided into to parts; the Machine Protection System and the Drive Laser Pulse Controller. The key component in the MPS is a set of VME boards that generate permits based on the path the electron beam will travel (Machine Modes) and permits based on the maximum allowed average beam current (Beam Modes). The Machine Mode is used to ignore devices that are not in the defined beam path while the Beam Mode is used to allow a given average power of electron beam. The MPS passes these permits to the DLPC where they are translated to control of the Electro-Optical (E/O) cells on the photocathode drive laser.

2. Machine Protection System (MPS)

A VME board was designed to provide both the Machine Mode and Beam Mode information. Three of these receive status information of the accelerator components and based on programming in a Field Programmable Gate Array (FPGA) the appropriate mode is generated. These machine and beam modes are passed to a summation board that passes the valid mode on fiber-optic cable to the DLPC.

2.1 Machine Modes

The machine mode is determined by the status of the gun power supply, the position of magnet power supply switches and magnet currents. The system was designed for eight different modes but currently

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there are just 4; Mode 1 is to an injector beam stop, Mode 2 is through the linac to an straight-ahead beam dump, Mode 3 is through the IR wiggler and recirculation path back through the linac and extracted to the (100KWatt) energy recovery dump, mode 4 is through the UV wiggler and also through to the energy recovery dump.

If the gun high voltage power supply is off there is no possibility for beam. Under this condition all restrictions are removed. This mode is used both for commissioning of the various accelerator system and for commissioning and alignment of the drive laser.

2.2 Beam Modes

The Beam Modes primarily review the status of insertion devices and act to limit the average current of the electron source. There are a number of types of beam viewers that have different maximum allowed current, each are grouped into one of the eight beam modes.

2.3 Timing Issues & Summation Board

All of the Beam Mode inputs are considered *slow* (~ 1millisec) except the Beam Loss Monitors (BLM) and the RF system permit (~1microsec). Each of the VME boards are daisy chained together sharing 4 bits each; 3 bits to define the 8 modes and 1 bit for heart beat. The slow inputs are on copper and the fast inputs are on fiber-optic cable.

3. Drive Laser Pulse Controller (DLPC)

3.1 Pulse Selection and Machine Permissions

Given that the MPS provides available beam modes (current limits) as fail-safe fiber-optic inputs, the DLPC is the integrated set of controls hardware that generates the signal that gates the E/O cells of the drive laser for the purpose of defining the time structure (macropulse and micropulse frequency) of the resultant electron beam from the photo-cathode. The system is also responsible for *implementing* the limitations on average current as defined by the MPS.

The DLPC is treated as two separate systems in the same package that work together but are not dependant on each other. They are: (1) the E/O Cell Pulse Generator Electronics which is designed to maximize the flexibility in time structure (rep-rate, pulse width, micropulse frequency, synchronization, etc.) and to provide other accelerator components with variations of beam sync and timing options; and (2) the Average Current Limiting Hardware which is designed to operate the given interlock devices (MPS shutter, ND2 filter, E/O Cells and possibly others) based on the state of the Beam Modes provided by the MPS and the state of the E/O Cell Pulse Generator Electronics. The duty factor is calculated by monitoring the control settings of the E/O Cell Pulse Generator.

4. Conclusion

By defining the beam path the process of phased commissioning as well as maintenance of the accelerator are much easier. When in Mode 1 or 2 the injector and/or linac can be run without the danger of running beam into a beam valve on another part of the accelerator. It also allows for commissioning of the UV optics and diagnostics while operating the IR machine.

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6. References

[1] G.R. Neil, et al., Physical Review Letters **84**, 662 (2000).

[2] http://laser .jlab.org/mps
http://laser.jlab.org/dlpc
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