Marx Modulator Interlocks

2/21/18

This document is intended to be a brief overview of the interlocks system for the new Marx modulators. The interlocks system is primarily designed to protect the modulator, power amplifier and cavity from damage. The system is NOT designed to protect personnel from electrical hazards associated with the Marx modulator. Proper LOTO procedures must be followed before accessing the modulator cabinet or charging supply.

The interlocks for each station are controlled by a PLC with a touchscreen interface located in the same rack as the station oscilloscope and controls hardware. Most of the inputs are digital; analog signals are interpreted by a separate Analog Interlocks card before reaching the PLC. The status of the interlock system is viewable on the touchscreen on the *MARX Interlocks* page; local control can be enabled by moving the remote/local toggle switch. Once in local, new station control options (*On* and *Reset*) become visible on the touchscreen. In general, the Marx interlocks have an input (In) and latched (Lt) bit. A reset will make up the input for all valid interlocks, and turning on the station will latch the bits A permit will be issued until one of the monitored channels is tripped.

Each station has two ACNET parameters, *L:MXnST0* and *L:MXnST1* (where *n* is the station number), which mirrors the interlock system. The convention is to display trip bits in red and status bits in either yellow or white in ACNET. In addition, *L28 Marx Status* combines the interlocks for each of the Marx modulators into one program. Some interlocks can be reset remotely via either of these options. Interlocks which must be reset locally are displayed in red on the touchscreen at the station.

Individual interlocks are described below, roughly in the order of how they appear at the local interface.

Marx Interlocks

Air Flow 1 (Digital)

Three air flow sensors (left side) in series, limits set at sensor. Measures air flow in the modulator cabinet. Must be out of tolerance on the order of seconds to trip the interlock.

Air Flow 2 (Digital)

Three air flow sensors (right side) in series, limits set at sensor. Measures air flow in the modulator cabinet. Must be out of tolerance on the order of seconds to trip the interlock.

MARX Doors (Digital)

Door switches on the Marx cabinet. One at the top and bottom of each door, eight in total.

CPS Doors (Digital)

Door switches on the charging supply cabinet. Two switched at the top of each door, ten in total.

Emergency Off Button (Digital)

Emergency off button below Marx touchscreen interface. Must be pulled out to make up the interlock.

Safety System (Digital)

Enclosure interlocks/keys/etc. status. Makes up when the Linac Electrical Safety System permit is issued. The Marx modulators do not run the cavities at partial gradient during access and should be turned off accordingly.

Smoke Detector (Digital)

Smoke detector inside Marx cabinet. This can only be reset by cycling power to the cabinet at the distribution panel. Requires local reset.

Note: As of the writing of this document these are bypassed at all stations pending a redesign.

UPS Good (Digital)

UPS located below the touchscreen interface. Trips if UPS loses AC input. Provides 120V for station controls, touchscreen, oscilloscope and CPS controls. Good for approximately 60 minutes without power.

Cell Trip Sum (Digital, Fast Trip)

Summation of the *Cell Status* page. The *Cell Status* page displays charge and fire status for each individual cell. If any one of these goes bad, the summation fails.

Fast Trip Sum (Digital)

Summation of all fast trip interlocks.

Phase Loss (Digital)

Monitors 3-Phase at the contactor.

CPS Ross Aux (Digital)

Status of shorting switch in the charging supply at the summing bus for supplies responsible for charging standard Marx cells. Shorts as response to trips.

Special Ross Aux (Digital)

Status of shorting switch in the charging supply. For the single supply which charges the special cell (cell 1). Shorts as response to trips.

Contactor Aux (Digital)

Status of shorting switch in contactor. Contactor opens in response to trips.

Shorting Switch (Digital)

Status of Marx-to-PA discharge cable shorting switch. Shorts in response to trips.

CPS Fault Sum

PS control and chassis control cards are in the charging supply racks. The station FPGA sends charge and fire information to the single PS control card. This is read by another FPGA internal to the control card which generates the charging sequence provided to each of the chassis control cards. The chassis control card sums CPS faults and returns a single digital status to the interlock system.

PSx EN

Lumina supply *x* sequence enable pulse.

PSx- I

Current at nominal value for supply *x*

Note: the special cell supply comes in and out of tolerance as an effect of operating the cell.

PSx On

On/off status signal summed with the *PSx Fault Sum* for supply *x*.

PSx Fault Sum

Fault summation status signal from Lumina supply *x*.

On/Off A (or B)

Reference on/off status signal, reference A or B. Reference B is used for the special cell at each station, Reference A is for the rest of the supplies.

Inhibit A (or B)

Inhibit signal for charging sequence for reference A or B. Generated at the station control FPGA.

PSx Cur (Jumper setting)

Monitoring current via PS internal current monitor. Current is not usually monitored this way.

PSx LEM (Jumper setting)

Monitoring current at the unified bus via DC current monitor.

REF. A (or B) (Jumper Setting)

Analog power supply reference, which reference is being monitored.

+5V (x2)

Control power.

±15V

Control power.

Station Sum Intrlk

Station sum bits are the same inputs that went into the old A5 station interlocks module and are summed by a PLC at the A5 rack into a single status provided to the Marx interlocks system. These can be viewed and reset on the *Station Interlocks* page of the A5 (filament controller) touchscreen. Tripping a station interlock will usually require a HV on or local reset at the A5 racks.

Note: High voltage for the driver is still controlled here.

Driver Crowbar

PA filament Ready

PA Nitrogen

Gas Barrier

Cavity Pressure

Cavity Water

Rad Level

Driver RF Load

High Voltage On

4616 Humidity

4616 Temp

7835 Humidity

7835 Temp

Status Sum

Over Current (Analog, Fast Trip)

As measured by the Marx controls. The trip point is set at the Analog Interlocks module.

Over Voltage (Analog)

As measured by the Marx controls. The trip point is set at the Analog Interlocks module. Requires local reset.

FPGA 3.3V

FPGA control power. Monitors a regulator in the FPGA which delivers 3.3V from a 5V DC supply in the back of the rack. Requires local reset.

FPGA Hrt Bt

FPGA communication heartbeat. The FPGA is responsible for regulating the charge/fire for the Marx cells. Requires local reset.

HPS Hrt Bt

Learning computer communication heartbeat. Located in the FPGA, the HPS is responsible for learning, feedforward, and ramps.

Charge 3.3V

Control power for the charge IGBT controller. Monitors regulator in the controller which delivers 3.3V from a 5V DC supply in the back of the rack. Requires local reset.

Charge Hrt Bt

Charge IGBT controller heartbeat. Requires local reset.

Spark Trip (Analog, Fast Trip)

Monitors voltage drop at Marx output after reaching a current setpoint. Configured at the Analog Interlocks module.

Over Gradient (Analog, Fast Trip)

Cavity over gradient. Sent from A5 rack. Trip points set at the Analog Interlocks module.

Chrg Cap OV (Analog)

Over voltage at charging capacitor. This is a single large capacitor located at the lower left-hand corner of the modulator cabinet between cells 1 and 2.

Reverse Power (Analog)

Station reverse power. Sent from the A5 rack. If bit trips during a pulse the system checks multiple times before turning the station off. Trip points set at Analog Interlocks card.

Driver Power (Analog)

4616 forward power. Sent from the A5 rack. Looking for the driver power to reach a set value a set amount of time after the Marx sends a on command to the driver. If bit trips during a pulse the system checks multiple times before turning the station off. Trip points set at Analog Interlocks card.

FPGA

Fast Trip

Trip state where the Marx is turned off quickly to avoid damage to the power amplifier.

>15Hz Trip

15 Hz monitor. Rep rate limiter.

ZOV Driver Status

Gate driver on the IGBT switch for Marx output pulse. Summation of gate driver status.

ZOV Voltage Status

Voltage status for output switch. Detects desaturation (short circuit condition).

Charge XOR

Used to ensure charge and fire are exclusive.

Fire XOR

Used to ensure charge and fire are exclusive.

Remote Off

Unused.

Rmt Inhibit

Unused.

On Status

PLC Permit

After all bits are cleared good, pressing *On* issues the PLC permit.

FPGA On

PLC grants this after receiving its permit. FPGA state machine is running and generating pulses.