COMPUTER CONTROL OF HIGH POWER KLYSTRON MODULATORS

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Abstract

Two computer control systems are described for providing remote monitor and control of high power klystron modulators. The first system utilizes a Macintosh II FX control computer with National Instruments LabView software to control a number of devices. These include a GPIB CAMAC crate controller, CAMAC analog and digital I/O modules, a digital delay generator, and an oscilloscope. A top level software screen allows the operator to view the overall status of the modulator and control high level operator functions. Status indicators inform the operator of general modulator conditions (whether interlock chains are satisfied, etc.). Lower level screens can then be brought up which show individual interlock status, allow control of the digital delay generator, and allow setup and acquisition of waveforms from the digital oscilloscope. The second computer control system represents a more complex system in which more functions are monitored and controlled by the computer. Up to 150 signals are controlled with this system, which is based upon the use of a 486 type computer with National Instruments LabWindows software to control a set of VME I/O modules. As with the previously described controller, a top level computer display screen shows the operator the high level modulator functions, including general interlock status, high voltage power supply levels, and klystron support equipment status. Additional sub-screens can be brought up to turn on and adjust all of the modulator sub-systems, including the high voltage power supplies, pulse transformer bias power supply, thyratron auxiliaries, klystron magnet power supplies, klystron heater power supply, klystron vac-ion pump power supplies. Other features include software and hardware debugging routines and automatic data logging.

Introduction

The lower cost and increasing performance of personal computers (performance/dollar) as well as commercially available software allows computer control of high power modulators to be cost effective from both a development and maintenance standpoint. One control system can be developed for different types of modulators and small software changes made to adapt from one modulator to another. In addition an inexpensive stand alone control system will verify the operation and computer interface of a modulator before integrating the modulator into a larger system such as an accelerator facility. The stand alone system can be used to troubleshoot a modulator off-line from the main system. Other advantages of computer control are that all control panels are centralized in one location and the layout of the panels can be easily changed for improved operator ergonomics. A large number of I/O channels can be easily handled and displayed with computer control systems.

Two computer control systems have been successfully tested in three different high power klystron modulators. The first system is a Macintosh based control system running National Instruments LabView software and interfacing with the modulator's hardwired controls by means of CAMAC modules. This computer control system controlled a modulator with the parameters shown in Table 1.[1]

Table 1

Parameter	Value
Output Voltage	600 kV
Output Current	870 A
Pulse Width	14 μs
Pulse Top	10 μs
Pulse Flatness	0.5%
Peak Power	520 MW
Average Power	350 kW
Repetition Rate	50 Hz

Depending on a control key lock setting, the modulator could be controlled from either a manual panel at the modulator, a remote manual panel at the remote site, or the computer station at the remote site. The computer control station is described in detail in this paper.

The second computer control system was a more complex system. This system was a 486 PC based system running National Instruments LabWindows and C code developed with Microsoft C++ software. The control system interfaced with the modulator's hardwired logic controls through VME modules. The computer control system was used on two different klystron modulators with no hardware changes and only software changes to address the differences in the modulators. The parameters of the two modulator types that this control system operated is given in Table 2.[2]

Table 2

Parameter	CCL Modulator	DTL Modulator
Output Voltage	215 kV	125 kV
Output Current	230 A	60 A
Pulse Width	75 μs	105 μs
Pulse Top	60 μs	90 μs
Pulse Flatness	0.5% p-p	0.5% p-p
Peak Power	46 MW	8 MW
Average Power	34 kW	8 kW
Repetition Rate	10 Hz	10 Hz

Macintosh Based Controller

The Macintosh based control system was implemented on a Macintosh II-FX computer with 4 MB Ram, 80 MB hard drive, and 13" color monitor (color required to run LabView). A National Instruments GPIB interface board installed into the computer provides the interface between the computer and the CAMAC modules. The computer was intended to be used as the final facility computer for operating the klystron at the final site. The facility hardware, modulator, and computer would be integrated by connecting the facility hardware to the GPIB bus and including the modulator software as a sub module in the overall system software.

Macintosh Controller LabView Software

LabView software from National Instruments provides a graphical programming environment where programs are built up through modules called Virtual Instruments (VI's)[3]. Modules are created and can be tested before including them in the system software thus shortening software development time. Building up from sub modules allows the modulator software to be developed and tested before including it as a part of the facility software.

For operating the modulator, a control panel is displayed on the computer monitor. The on-screen control panel has buttons, knobs, switches, and panel meters much like a hardwired manual control panel. The buttons and knobs are actuated with the mouse and analog values are adjusted with the mouse or by keyboard entry.

The master control panel shown in Figure 1 is the top level control screen. This screen presents an overall view of modulator status and provides and interface for controlling the modulator. Items displayed at the top level include modulator power up level, emergency off status, control location, interlock status, filter bank charge voltage, klystron heater power, and high voltage power supply setpoint. Control of the high level functions including high voltage power supply output, modulator on/off and reset functions, and emergency off. Other modulator control and monitor functions are accessed from sub-level screens which are accessed from the main panel.

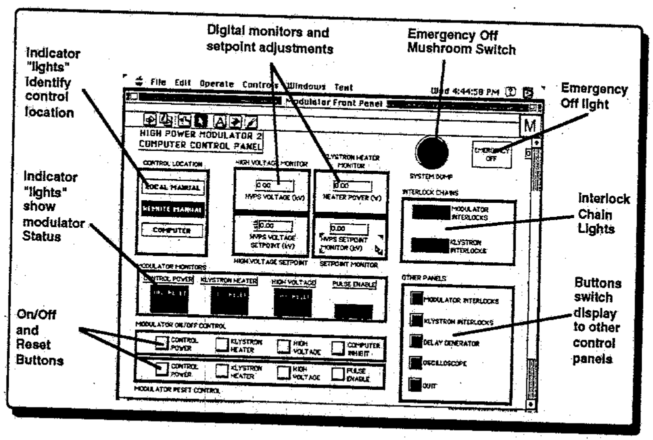

Figure 1. Top level control screen displays modulator status and is interface for top level functions.

The modulator sub level screens provide additional information not contained in the top level screen. The sub level screens are the modulator interlocks, klystron interlocks, delay generator, oscilloscope, and quit screens. The modulator interlocks screen shown in Figure 2 displays the status of all the interlocks associated with the modulator operation. The klystron interlocks screen displays the status of all the interlocks associated with the klystron operation. The timing of the Stanford delay generator is adjusted from the delay generator panel. Output waveforms can be retrieved and displayed at the computer terminal from the oscilloscope screen.

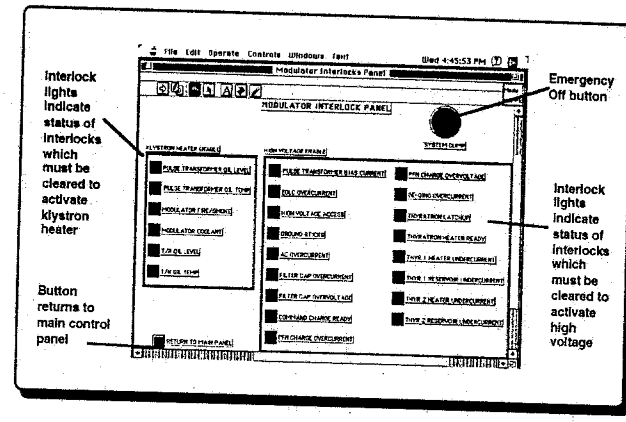

Figure 2. Interlock lights indicate status of interlocks associated with the modulator operation.

Macintosh Controller Computer/Modulator Link

The computer communicates with the modulator through CAMAC modules which provide switch closures (digital outputs), digital readbacks, analog outputs, and analog readbacks. Communication with the CAMAC modules in the CAMAC crate is over a GPIB link using the GPIB protocol. The GPIB link allows facility and modulator hardware to be connected directly to the Macintosh computer. A National Instruments GPIB controller card in Apple Macintosh computer is linked with a Lecroy CAMAC GPIB controller card via a National Instruments fiber optic GPIB link. The fiber optic link isolates the computer from EMI and eliminates GPIB cable length restrictions for remote (≈325 m) operation.

PC Based Controller

The PC based controller was implemented on a generic 486 computer with 16 MB of ram, 230 MB hard drive, and a 14" Color Monitor. A National Instruments VME/VXI controller provides the communication link between the VME modules and computer. The controller card installed in the computer makes the computer perform as an embedded controller in the VME crate. The stand alone controller was used to test and operate both the SSC CCL modulators and DTL modulators. Selection of controller type (CCL or DTL) is determined based on which version of software is selected at startup. Incorporation of the modulator into the SSC facility would require disconnection of the control cables from the standalone control system and connection of the modulator to the SSC control system.

PC Based Controller LabWindows Software

The operating software for the PC based controller was developed using National Instruments LabWindows software and Microsoft C++ software[4]. Much like the Macintosh based system, a control panel interface is displayed on a computer monitor. The on-screen control panel has on/off control buttons, readbacks, displays for analog and digital signals, and pop-up windows for analog inputs. Push buttons are actuated with the mouse and analog values are adjusted through keyboard entry at pop-up windows.

The top level control screen shown in Figure 3 provides an overall view of modulator status. Items displayed are the modulator power up level, PFN charge voltage and average charging current, klystron filament voltage and current, magnet current or currents (three magnets on DTL, one on CCL), ion pump current or currents (two pumps DTL, one pump CCL), and interlock status. The PFN charge voltage can be set and the system shut down (emergency off) from the top level screen. Other sub panels which provide control and information on individual subsystems are also reached from this panel.

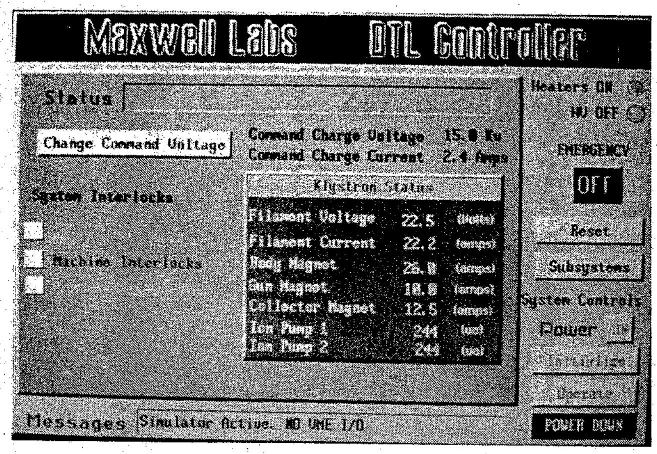

Figure 3. The top level screen provides information on the operation of the modulator.

The sub level screens provide access to each individual subsystem. Each subsystem has different types of I/O so each sub level screen is a grouping of all I/O associated with an individual subsystem. Typical I/O accessed from a sub panel is shown in Table 3.

Table 3
Typical I/O displayed in sub levels

Digital Outputs	On/Off control
Analog outputs	Set output voltages and/or currents
Digital Readbacks	Over and under faults warm-up complete ramp complete power on
Analog Readbacks	Output voltages and/or currents Setpoint values for over and under faults

The sub level screens provide information on each subsystem in the modulator. The klystron filament power supply sub panel displays information and allows adjustment of klystron filament power supply. The modulator sub panel contains the on/off controls and displays the status of the dump sticks, AC power interlocks, and the output voltage and current of the modulator. This panel also allows the status of the circuit breakers, cooling interlocks, and door access panels to be displayed in pop up windows. The thyratron filament power supply sub panel shown in Figure 4 displays information on and allows adjustment of thyratron heater and reservoir. The ion pump screen or screens (two screens DTL, one screen CCL) displays information on the ion pump voltage and current. The klystron magnetics sub panel displays the output voltage and current of the klystron magnet supplies (three supplies DTL, one supply CCL). The output current from each supply is adjustable from this screen. Information and adjustment of the PFN charging power supplies is accessed from the high voltage power supply screen. Information on thyratron grid bias and trigger generator power supply is displayed at the thyratron grid control screen. The PFN subscreen displays the end of line clipper status and information and adjustment of pulse transformer bias supply.

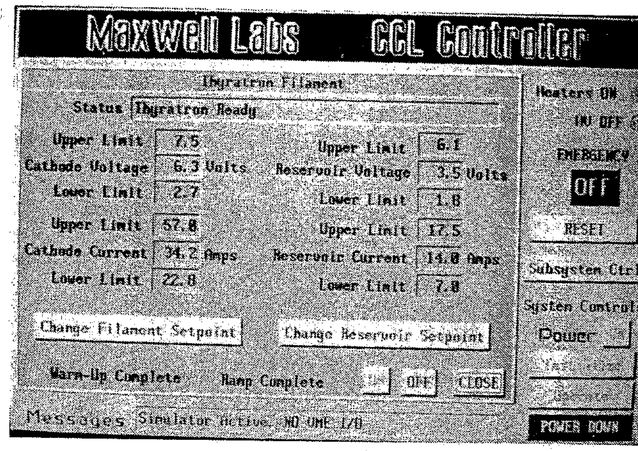

Figure 4. The thyratron filament supply screen displays heater and reservoir information.

In addition to screens associated with subsystems, three sub panels were included in the design for troubleshooting and operation and maintenance purposes. An analog I/O screen displays all analog values from modulator in unscaled format (0-10V). This screen also displays all of the analog outputs in unscaled form (0-4096 bits) and allows outputs to be adjusted. Having the unscaled information is helpful in determining whether scaling problems are associated with software or hardware. Viewing of all analog information simultaneously and altering the value of an input allows crossed channels or signals to be easily identified. A digital I/O screen displays all digital input and output values and allows outputs to be toggled. As was the case for the analog I/O screen, viewing of all digital information simultaneously and toggling the value of an output allows crossed channels or signals to be easily identified. Both digital and analog I/O screens allow problems to be isolated between software and hardware. A third screen is the data logging screen and allows a data logging function which saves all analog and digital inputs and outputs when a fault is detected. This screen is useful for determining a fault which shuts down the modulator.

The computer communicates with modulator through VME/VXI modules using VME protocol. The VME modules provide switch closures, digital readbacks, analog outputs, analog readbacks The National Instruments VME/VXI interface between Intel 486 computer and VME crate allows the desktop computer to act as an imbedded controller in the VME crate. Over 150 I/O control signals to and from modulator are monitored by this control system.

Conclusions

Desktop computers using commercially available software were economically implemented as computer controllers for several high power modulator systems. The SSC controller was used interchangeably between the different CCL and DTL modulators. The computer controllers were used to test the modulators at Maxwell before the systems were shipped to be integrated into the final facility. The Macintosh based system was designed to be implemented as a stand alone computer and/or facility computer depending on the software module that is running. The PC based system was designed to be a standalone controller for different types of modulators based on the software module that is running. Both systems are expandable and adaptable for use on other systems, thus development of a new modulator does not require a complete redevelopment of a computer controller.

References

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