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KLYSTRON CONTROL SOFTWARE IN THE SLC*

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ABSTRACT

Triggering, control, and monitoring of 240 high-power klystrons will be supported by the SLC control system this summer. The control software is distributed among a VAX host computer, a local microprocessor cluster, and a dedicated intelligent CAMAC module. The functions performed by these three components and the algorithms used are discussed.

1. INTRODUCTION

Computer control of klystrons is distributed among a central host VAX computer, approximately thirty Intel 8086/8087 microprocessors (one per sector of the linac), and ~240 Parallel Input Output Processors (PIOP's). In a typical linac sector, each microprocessor controls eight klystrons and a subbooster, and there is one PIOP per klystron or subbooster. Each PIOP interfaces with a Modulator Klystron Support Unit (MKSU) and an RF phase and amplitude detector (PAD) for the klystron. In general, direct hardware control and responsibility for klystron protection decreases from the PIOP to the microcluster to the VAX.

2. CONTROL IN THE VAX

The SLC control program (SCP) running in the VAX contains the operator interface, supporting a number of klystron control and display functions. Operators may control the phase and amplitude of klystrons from knobs, producing updates to the database and causing messages to be sent to the appropriate microclusters to perform the corresponding updates to the PIOPs.

Control of klystron triggering is currently being implemented, and the control interface in the SCP will allow operators to request that klystrons be triggered at specified rates and in particular timeslots, as well as support related displays.

In addition to the SCP, the VAX runs a process called PARANOIA,[1] which logs error and informational messages, and monitors the status of the klystron subjob and other subjobs running in the microprocessors.

3. CONTROL IN THE MICROPROCESSORS

The microprocessor contains some of the klystron control algorithms and various interfacing functions. One of the approximately ten subjobs running in the micro is dedicated to klystron control, and another subjob responsible for the timing of triggers to klystrons and other devices is also closely involved.[2] The klystron subjob handles downloading of the PIOP's program and updating of the PIOP's internal database. Algorithm support in the klystron subjob includes:

1. Calculation of the phase increment required to satisfy a phase trim request from the VAX.
2. Calculation of polynomial fits to correct for nonlinearities in the subbooster's electronic phase shifter.

The klystron subjob contains a general "sequencer" routine to allow one- or two-stage operations involving the PIOP's to be performed approximately in parallel in all of the PIOP's in the sector belonging to that microprocessor. The sequencer routine also supports operations involving a single klystron's or subbooster's PIOP.

4. CONTROL IN THE PIOPs

The PIOP is directly responsible for controlling and monitoring the klystron. A 32 word Status Block is maintained containing current measurements of database values, such as Phase and Amplitude means and variances. A 67 word block, the Fast Time Plot block, is used by the SCP control program to generate diagnostic displays such as Beam Voltage or RF Phase versus Time.

The PIOP's software can be divided into the following areas:

1. Phase and Amplitude Detector calibration and Phase Nulling. The PIOP uses a DAC controlled phase shifter in the PAD to null the phase detector and to determine the devices sensitivity.
2. Calculation of Phase and Amplitude. Sets of data points (32 points) are analyzed to obtain the mean and variance. Typical variances are quite low (~ 0.2 degrees), and large values are symptomatic of abnormal system behaviour.
3. Triggering of Klystron Modulators. Various signals, such as the last pulse's reflected RF power and beam voltage, comprise a "software" trigger permissive. Many other signals comprise a "hardware" protection (relay based) in the MKSU. Klystron triggering rate is software controlled.
4. Fast Time Plot Diagnostics. The normal FTP is analogous to a sampling oscilloscope, in that it samples a quantity on each of a succession of 64 beam pulses, with the time delay relative to the beam incremented by a fixed amount on each pulse. If the increment to the delay is zero, then one can obtain a measure of the jitter in the quantity being measured. FTP's (both normal and jitter forms) are available from the SCP for phase, amplitude, klystron forward and reflected RF power, and klystron pulse beam volts and current.

5. PHASE AND AMPLITUDE CONTROL

The phase of a klystron can be "trimmed" to a desired value and can also be adjusted in a continuous manner with a knob. The desired phase and the tolerance on the phase are kept in the database, and either of these may be adjusted by an operator running the SCP. When a trim to the desired phase is requested, the SCP sends a message to the klystron subjob in the micro. The klystron subjob reads the phase from the PIOP. If the phase is out of tolerance, the klystron subjob does the following:

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1. Take the difference between the desired phase and the actual phase read from the PIOP, and add this increment to the current klystron phase request value in the database.
2. Send the new phase request to the PIOP, which sends a command to the Fox phase shifter to move the phase by the desired amount.
3. Read the new phase from the PIOP, updating the micro's database. At this point one could iterate if the phase were still out of tolerance, but in practice this has been found to be unnecessary, as the phase is within tolerance after one try if there are no problems causing the trim not to be performed at all.
4. Update the VAX database and send a message back to the SCP telling it that the operation has completed successfully (if there were problems at an earlier stage of the trim, causing the micro to abort it, a message to this effect would have been sent back).

When the klystron phase is adjusted using a knob, no trimming is done. As the desired phase is changed, the corresponding phase request is changed and sent to the PIOP.

The requested drive for each klystron is kept in the database and is adjustable from the SCP, either by entering a desired value from a touch panel button or by turning an assigned knob. It is also possible to obtain a plot of amplitude output versus drive input, using a modification of the Fast Time Plot facility. This plot is obtained by measuring the amplitude as the drive is incremented on a series of 64 machine pulses. Once such a plot has been made, one can request the SCP to saturate the klystron by entering the value of drive request at the point of maximum amplitude on the plot into the database, and sending a message to the micro to update the PIOP.

6. KLYSTRON TRIGGERING

Triggering of klystrons is accomplished with the use of triggers or trigger information from the following sources:

1. Each klystron has a 36 pulse "trigger mask". The mask is used to regulate whether the modulator is permitted to fire the next pulse. With a base rate of 360 triggers per second, the trigger mask allows the operators to activate a klystron station at a rate of n $\times$ 10 pulses per second.
2. Each CAMAC crate has a dedicated Programmable Delay Unit (PDU) trigger channel which fires at 360 Hz approximately 30 microseconds after beam time. This channel is used to generate "standby" triggers for each klystron, and is different on a sector-to-sector basis.
3. Each klystron has a dedicated PDU trigger channel which conditionally fires 7 microseconds prior to beam time. A trigger is produced from this channel whenever a beam is scheduled which requires acceleration from the the klystron.

Whenever the "trigger mask" permits triggering, the klystron modulator trigger is derived from one of the described channels. Since the "accelerate" trigger precedes the "standby" trigger, the klystron is successfully triggered on the accelerate trigger if it is present and on the standby trigger otherwise.

The Modulator Klystron Support Unit (MKSU) has an internal delay of 0-7.5 microseconds which allows compensation for such delays as thyrotron triggers and cable lengths.

7. DISPLAYS AND DIAGNOSTICS

One of the most important diagnostics in the klystron software is the Fast Time Plot (FTP) facility. The FTP's are obtained by sending a control block from the micro to the PIOP, containing a specification of the type of FTP requested. The PIOP returns the data in the 67 word FTP block (a three-word header followed by a word of data for each of 64 points). The FTP block is relayed by the micro back to the SCP, where the data is formatted and displayed. The FTP block is also used to send back the data for another important display. In this case, the data is a number of different types of quantities such as PIOP voltages, PAD and MKSU cable statuses, PAD temperature, trigger masks, etc.

It is also necessary to have a way of telling whether the orientation of the Fox phase shifter is really what the PIOP thinks it is. Phases are measured with respect to a "home" position, which can be detected by sensing an LED. Upon receiving a request from the SCP to check the orientation of the Fox phase shifter, the klystron job in the micro does the following:

1. Have the PIOP go to the home position, noting what value of phase request it took to get there, and then go back to the value of phase request corresponding to the original physical position of the phase shifter.
2. Find the difference in the value of the phase request before and after the PIOP's homing operation. An error message is issued if this difference is greater than a specified tolerance.

Obviously this procedure temporarily disrupts the acceleration of beams and is also fairly time-consuming (can take a few seconds for each PIOP). Thus the sequencer routine is used to do all the PIOPs in the sector in parallel.

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