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COMPUTER CONTROL OF LAMPF's 201.25 MHz RF*

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Abstract

LAMPF's 201.25 MHz power systems consist of four individual stands, three of which are identical, each utilizing a three megawatt final amplifier stage. The fourth stand consists of two 250 kilowatt amplifiers operating in parallel. The turn-on sequencing and fault protection of each of the amplifiers is built into the hardware associated with the stand. This paper presents a general discussion of the scope, organization, and operator interface of a Fortran software system that has been devised to automate the control of the 201.25 MHz stands.

The programs contain the following general features. Upon operator command, the system will turn on any combination of the four amplifiers in a parallel manner from a cold start, monitor their operation on a continuous basis and attempt to recover from a fault-initiated shutdown. If a computer recovery is impossible, the system attempts to diagnose the problem and inform the operator of the cause. At the operator's discretion, the system will shut the stands completely down or merely turn the high voltage off, keeping the amplifiers in a standby mode.

The system logs the resets issued to the equipment and the messages written for the operators during the turn on and monitoring phase.

The software system consists of twelve Fortran programs with a total of some 15,000 words, one executive program, and two data files constructed to run in LAMPF's SEL 840 MP control computer.

I. INTRODUCTION

LAMPF's use of an on-line digital computer to operate the machine gives the ability to automate the control of large rf systems. There are a substantial number of these stands involved in the machine and several areas of automation are desired. Four of these areas are: (1) the ability to monitor the stand's operation and notify the operator of a failure, (2) turning on all or some part of the stands in a parallel manner, (3) recovery from a fault if possible, and (4) keeping records on equipment performance.

This software system attempts to incorporate all the above areas into one system for the control of the 201.25 MHz stands. Although the 201.25 MHz stands represent a small percentage of the total, they tend to be more complicated and more fault prone than the 805 MHz klystrons. Hardware differences between the two types of amplifiers precluded covering all the rf stands under one software system at this time.

II. RF STANDS

The four 201.25 MHz rf stands are essentially identical at the computer interface; therefore, hardware differences can be ignored from a control and monitoring standpoint. The stands can then be broken down into three different areas of concern: (1) the control and monitoring of the low voltage systems and the high voltage power supply, (2) the fault protection logic and crowbar, and (3) the accelerator structure and phase and amplitude control.

III. HIGH AND LOW VOLTAGE

The low voltage systems are activated by a single ON/OFF command. Binary information consisting of summations of water, air, safety and other interlocks are fed back to the computer. Interlocking for equipment protection and personnel safety is accomplished through the stand controls. Once the low voltage command is issued, the stand controls cycle the various power supplies involved. An interlock summation from these supplies is sent to the computer by the stand controls. When this summation is complete, the turn-on of the high voltage power supply is permitted. In addition to an ON/OFF command channel, the computer can adjust the level of the high voltage supply via a stepping motor. The high voltage,

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forward and reflected power, cavity field and other variables can be read via analog channels.

IV. LOGIC AND CROWBAR

The fault protection logic is comprised of two sections, the logic indicators and the counters. The logic indicators detect a fault during a machine pulse and inhibit the amplifiers for the remainder of that pulse. They also set a flag for the computer showing that a fault has occurred and the flag must be reset before another fault can be registered. There are four such indicators associated with each stand. The counters receive an input from the indicators. When the rate of faults exceeds a preset level, the counter trips, sets a computer flag, and inhibits the amplifiers until the counter is reset.

In the event that the fault does not clear when the logic removes the pulse from the stand, the crowbar fires. This firing turns off the high voltage supply and shorts the energy storage bank. The crowbar must be reset, and there is a delay while the induction voltage regulator for the high voltage supply runs down. Only then can the high voltage supply be recycled.

V. ALVAREZ AND PHASE AND AMPLITUDE CONTROL

LAMPF's accelerator structures are tuned via the temperature controller on the cooling water systems. At the high average rf power levels used, it is impossible to merely turn the amplifiers on at full power due to the limitations of the temperature controllers. When large transients in power drive the structure off temperature, the stand faults off due to the high VSWR in the transmission line. So one must bring the rf power systems up slowly to full power while monitoring the resonance of the structure.

Phase and amplitude control are somewhat independent of the computer except for determining that the control loops are locked. Settings for phase and amplitude of the tanks are accomplished with other computer programs that are not discussed in this paper.

VI. SOFTWARE - GENERAL

This program attempts to incorporate several different functions associated with the rf stands into one package, thus utilizing the same software to accomplish different tasks. The highest level of the system monitors the operation of the equipment and detects stand failures. Large rf systems often have a substantial level of faults occurring during normal operation. Thus, the next step after having detected the fault is to have the computer issue the necessary resets in an attempt to recover the stand. The level of faults in the equipment exceeding certain levels often is a precursor of equipment problems. The computer programs for monitoring and recovery become ideal for logging the number of faults occurring. Preventive maintenance based on these data can then be performed before catastrophic equipment failures occur. Since a stand recovery is much the same as a stand turn-on, the ability to turn the stands on simultaneously is included. Lastly, when problems develop in large systems, a diagnosis of the problem by the computer is of great advantage to the operator responsible for its repair. This feature should be especially valuable at LAMPF since the personnel responsible for making minor repairs to the equipment are not specialists in the equipment. By incorporating the knowledge of the original design personnel into the software, substantial savings in down time should be attained.

The basic idea of the system is that the operator has essentially one ON/OFF button for the rf stands. The system turns the equipment on when commanded and monitors its operation. In the event the equipment trips off, the system automatically turns it back on. If recovery is impossible, it tells the operator where the problem lies. As long as the equipment is operating properly, there is no output to the operator. The system alerts the operator as soon as it detects a stand failure. The operator is again notified of the success or failure when the system has finished running. Upon operator demand the status of the stands is displayed.

Due to the expense and the long times involved in repairing the hardware, the programming guarantees that the computer does not loop around one or more resets and destroy the equipment involved if a real problem exists. The computer also guards against operational situations that can be harmful to the hardware.

The computer involved does not have unlimited core, and there are many other jobs involved in operating an accelerator that must run simultaneously with the rf monitoring and control. It becomes obvious that one must either be very fast or very short. Since cycling of rf systems tends to be a slow process, the short approach was taken. A system of small programs that call one another off the disk storage was chosen. In this manner the overall programming is longer but no more than one or two of the short programs should be in core at one time. A common storage area, which remains in core, is reserved and used to preserve and pass information. A functional diagram of the system is shown in Fig. 1 and a short discussion of each block ensues.

VII. CCI

The CCI is an alphanumeric scope located at the console and is used to transmit information between operator and computer.

VIII. OPERATOR INTERFACE PROGRAM

The Operator Interface program is the primary communication link between the operator and the software system. When demanded from the console, the program displays one line on the CCI scope. The line gives the module numbers and three functions to the operator - ON, OFF, and HIGH VOLTAGE OFF. The program demands the CCI Updater which runs every three seconds. When the operator has indicated which function to perform and depresses the end key on the console, the Operator Interface program is activated by exec and interrogates its line on the CCI scope. It then loads the appropriate information into common storage, commands DATA-SCAN, cancels both its line and the Updater's line on the CCI, and drops both programs from core.

IX. CCI UPDATER

When called by the Operator Interface program, the CCI Updater interrogates the common storage area and displays the status information stored there on the next line of the CCI scope. The information is displayed for the operator in numerical form, coded the same way as it is stored in common storage. The line is updated with fresh information from common storage every three seconds. When the Operator Interface program exits, it also drops this program and cancels its line on the CCI scope.

X. DATA SCAN

In order to insure that a stand is operating properly, only two pieces of information are necessary. One is the presence of forward power or cavity field during the pulse and the other is that the phase and amplitude control loops are locked. When monitoring the stands, these two pieces of information are taken for each stand every ten seconds. DATA-SCAN is an executive program designed to take periodic data on the machine and, in this case, is used to call another program (DATA-SCAN Interpreter) if the two pieces of data are outside limits which were previously established.

XI. DATA-SCAN INTERPRETER

This program serves as an argument translator between DATA-SCAN and the System Monitor program.

XII. SYSTEM MONITOR

When a monitored stand trips off, the System Monitor program receives information concerning the fault from DATA-SCAN via the DATA-SCAN Interpreter. It then checks with the software system common and decides if the rest of the system should be demanded or not. In order to demand the rest of the system, it loads the information into system common storage and demands the Logic Counter Reset program. Each of the other programs check the system common storage to determine which stands they are to work on. As soon as the System Monitor program receives information that a stand is down or back on, it displays this information to the operator in the form of an operator note.

XIII. LOGIC COUNTER RESET

The only stand trip-off one can recover from before the tanks drift off resonance is to reset a tripped counter. Such trips need to be reset as quickly as possible, both to conserve machine downtime and to prevent the tanks from losing resonance. Once a tank is out of resonance, restart times can become of the order of 10 to 15 minutes. The Logic Counter Reset program's sole purpose is to reset these counter faults.

The program commands DATA-SCAN back into a monitoring mode and exits if the counter reset was successful in getting the stand back on the air. An operator note indicating that the stand is back on is displayed on the CCI. The number of resets issued is recorded in the Disk Log.

If the program is unsuccessful in the counter reset, it demands the Message Output program and passes it the message numbers it wishes displayed for the operator. DATA-SCAN is commanded to call the system again when the stand is back on. The status of the stand is logged as an equipment failure in the system common. An operator note is displayed saying the stand is down and control is being released to the operator. The program then exits without demanding any other programming. The system makes no further effort to turn the stand on unless commanded to do so by the operator, since serious problems may exist and turning back on should be an operator decision.

A third state exists in which the counters either were not tripped or were reset and the stand is still not back on. In this case, the program demands the Turn-On program.

Logic Counter Reset and the rest of the system's programs are capable of handling in parallel any combination of the four rf stands.

XIV. TURN-ON

This program holds the responsibility for turning on the low voltage, the high voltage, and running up the high voltage while keeping the accelerator tanks in resonance. It also diagnoses any problems in the stand. The program is long and there are many delays associated with the turn-on. Instead of holding core during the delays, the program does as much as it can with the stands assigned, stores the information that is necessary for its next run in the system common, and exits with a call for itself to run at a later time.

The message output and sequencing after the program is finished is the same as that in the Logic Counter Reset program.

XV. CROWBAR RESET

This program is basically a subroutine for Turn-On. It was split off into a separate program in an effort to keep the Turn-On program as short as possible. Turn-On demands and turns control over to it when a crowbar fired is detected. The program then resets the crowbar and returns control and information on the success of the reset to the Turn-On program. The number of resets for each stand is also logged in the Disk Log. A message is generated for the operator when the reset is successful, since an excessive number of crowbars over a shift or a day indicates serious equipment problems.

XVI. MESSAGE OUTPUT TO CCI

The output to the operator is handled by this program. All the message formats are stored in the program. There can be as many as eight messages written on the CCI on any one call by a program. The format number and time of day are stored in the Disk Log when the messages are written. At a later time, control is given to this program by the Information Retrieval program and the messages along with their time of display are printed on the line printer. The formats involved occupy a considerable amount of core so this program is not demanded until the calling program has finished. The messages are color coded: green - indicating a successful operation; yellow - indicating that a problem exists but the system is still working on it, and red - indicating what the problem is and that the system has given up and released control to the operator.

XVII. MESSAGE ERASE

The messages are only displayed for 15 seconds and this program is demanded after a time delay of 15 seconds by the Message Output to CCI program. The program then erases the messages displayed on the CCI.

XVIII. LOGIC INDICATOR RESET

Since the logic indicators only inhibit the stand on a pulse to pulse basis, it is not necessary to reset them as soon as a fault occurs. They must, however, be reset before a new fault can be recorded. The program runs every 2 minutes to reset the indicators and log which ones are tripped in the Disk Log. Since it is not imperative for the equipment operation to have these indicators reset, this function becomes merely one of keeping track of the number of faults occurring.

This program is also used to check for modes of operation that may be harmful to equipment, overdissipation of power tubes, etc. If it detects such a mode, it will correct for it, if possible; if not, it will notify the operator.

XIX. SHUTDOWN

The Shutdown program shuts the stands down in a parallel manner. It also checks to insure that the stand is in fact off. If all the stands are completely shut down, the monitoring portion of the system is canceled and the common storage area released. The entire system remains idle until recalled by the operator, and no core or computer time is used. When the stands are not completely shut down, information concerning the status of the stands shut down is loaded into common storage. Thus the system will not attempt to turn the flagged stands back on until commanded to do so.

The program is demanded by the Operator Interface program and offers the operator two options: the stand can be completely shut down through low voltage or the high voltage alone can be shut down, resulting in a standby mode.

XX. INFORMATION RETRIEVAL

This program loads from the information stored in the Disk Log and prints out the reset information in a tabular form on the line printer. By passing control to the Message Output program, the messages and the time that they were displayed for the operator are printed (see Table I). The Disk Log is then reinitialized to zero for the next run. Thus, a complete history of the last run is retrieved in a concise manner.

XXI. SURVIVAL OF COMPUTER CRASHES

When the Operator Interface program commands DATA-SCAN, it also enters the commands into a disk file. In the event of a computer crash, the System Monitor program is demanded on the computer start up. When the System Monitor finds there is no common storage for the system in core, it refers to the disk file for information. If the system was running, DATA-SCAN is reactivated. In the event that the software system was not running at the time the computer crashed, the System Monitor merely exits without reinitializing common or commanding DATA-SCAN.

XXII. OPERATOR CONTROL

By demanding the Operator Interface program from the console, the operator can assign or remove stands from a monitored status. One can also tell the system what he wants to be done by placing the cursor under the written command and pressing the end key. The stands to be commanded can be chosen by blanking out the numbers of the stands one is not interested in commanding. The operator can also see what the status of the stands are on the line below. After he has made his decision and activated the system, the display is removed and the system runs completely autonomously unless it cannot recover a stand. In that event, a message is displayed informing the operator that the stand is down and what the problem is. The operator can then try to turn on by issuing individual commands from the console, or he can call other personnel in the vicinity of the equipment to execute the necessary repairs. The four top lines of the CCI are reserved for operator notes. This software system uses these four lines for the three messages, MODULE X ON, MODULE X OFF, and MODULE X OFF CONTROL TO OPR. These operator notes are intended to let the operator know what the status of the stands is without calling the Operator Interface program.

XXIII. CONCLUSION

At the present time, the system appears to be running quite well. More work is needed concerning the tank resonance problems, particularly in the area of several high voltage tripoffs in a row, which allow the tank to lose resonance. The system is able to cope with most normal turnons and faults. Some problems have been encountered with noisy and bad data in that one bad read can cause the system to make adjustments that are not necessary and are sometimes detrimental. There were some problems with core overloads when other large programs were running but the addition of more core to the machine has apparently solved this problem.

Using the coded numbers on the CCI display for the status of the stands was a mistake. Plans are to change this scheme to one easier to understand and remember.

Effort has begun to incorporate the monitoring portion of this system into a more inclusive monitoring program. The new monitoring program displays the status of all the rf systems in the accelerator on a continuous basis. This makes the operator notes redundant and it is possible that they will be dropped.

There are a multitude of areas for expansion of the system. At present, the system can cope only with faults that trip the stands off. The area of locating intermittent faults that inhibit on a pulse to pulse basis has not been explored. Another area that may be expanded is determining if a channel or transducer has failed or if the rf stand is the source of a problem.

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TABLE I

201 MHz LOGIC RESET TABLE

	Module 1	Module 2	Module 3	Module 4
IPA IP	0	5	12	0
7835 IP	0	18	25	2
IPA VSWR	4	0	0	0
7835 VSWR	0	140	36	24
IP CNT	0	0	0	0
7835 CNT	0	6	0	11
ARC DET	1	4	0	0
CROWBARS				
7835 AMP	0	0	2	3
7835 PW	0	0	1	1
IPA AMP	0	0	0	0
IPA PW	0	0	0	0
MISFIRE	0	0	0	0

5/ 0/ 40
MODULE 1 AMPLIFIERS NOT PUTTING OUT PWR
5/ 0/ 40
TANK 2 FAULTING OFF
5/ 0/ 40
MODULE 3 LV PROB. CAUSE UNKWN
5/ 0/ 40
MODULE 4 AMPLIFIERS NOT PUTTING OUT PWR

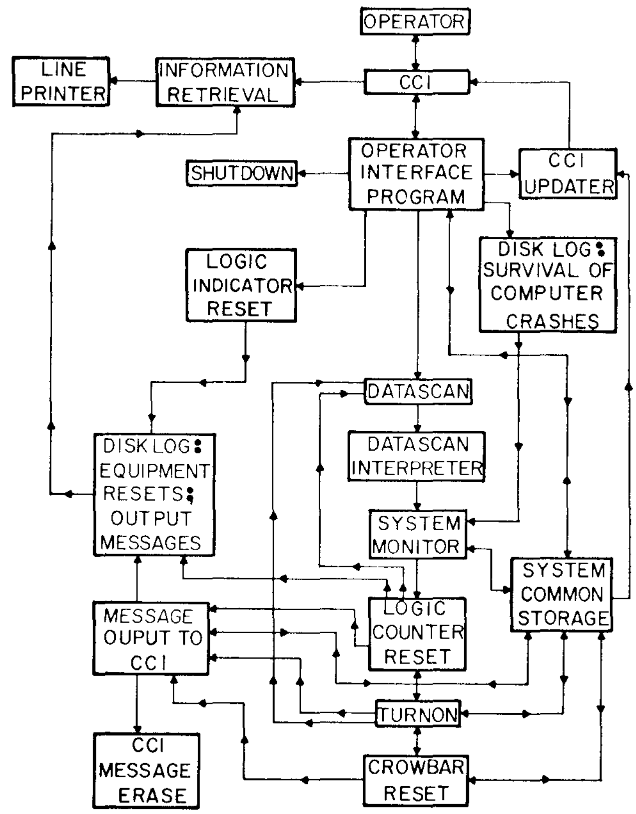

Fig. 1 System Organization