FERMILAB'S AUTOMATED ACCELERATOR START-UP PROGRAMS

G. Annala and B. Hendricks
Fermi National Accelerator Laboratory*
P.O. Box 500
Batavia, IL 60510

P. Emma
Stanford Linear Accelerator Center
Stanford University
Stanford, CA 94305

Sequencer type application programs are used to turn on several accelerator systems at Fermilab. One of the first systems to use such a program was the Tevatron main power supply system. The function of TARCAS (Tevatron Automated Ramp Check-out And Start-up) is discussed in this paper. There is also a brief summary of the operational experience with such sequencer programs.

INTRODUCTION

There are twelve main power supplies in the Tevatron which power nearly one thousand cryogenic dipoles and quadrupoles. This entire network is protected by a system of 68000 based Quench Protection Monitors. There are 24 such QPMs spaced around the ring each responsible for monitoring and controlling the proximate hardware. Additional magnet strings, such as low beta quadrupole insertions have their own quench protection systems as well. Before these systems are powered, operators must verify that all protection equipment is functioning normally. An extensive knowledge of a considerable amount of equipment is necessary for this verification. The single act of turning on the power supply system therefore requires an individual with a significant amount of experience and training. The goal of TARCAS is to allow a less experienced operator to perform that task efficiently and without error.

PROGRAM OPERATION

Initial powering of the Tevatron has always required a variety of tests of the protection equipment. Specific interactive application programs have existed for this purpose since the days of Tevatron commissioning. Even with these applications available, operators needed to make numerous judgements based on test results. TARCAS makes use of these existing applications to turn on the Tevatron in a more efficient and automated manner. Subjective interpretation of test results is largely eliminated.

Some of the tasks involved in a start-up are simple, such as verification of proper QPM parameter values. For these tasks, small blocks of code were merely duplicated in TARCAS. Other tasks are more complicated and require a substantial amount of code. Extensive code duplication presents a maintenance problem; therefore, TARCAS accomplishes most tasks by sequencing existing applications.

A TARCAS sequence begins with the operator selection of machine initial conditions. The initial conditions uniquely define a default set of events, the performance of which are necessary to establish an operational state. Figure 1 shows the layout of the sequence selection display. The sequence options are presented in a matrix configuration, where each column represents an individual event, and each row is a separate path (defined by the initial conditions) to the final operational state. Initial condition choices are shown in the left hand column of Figure 1. Entries within the sequence matrix are character encoded. An 'X' indicates that the event represented in that column is normally required and will be performed. A period ('.') means the event is not normally necessary and will be skipped. An 'R' marks the event as recommended. It will be performed if not specifically deselected. An 'S', 'H', or 'U' provides that only a sector (one of six), a house (one of four per sector), or unit (one of several per house), respectively, will be tested. The program will prompt the operator for the appropriate location. The '?' under "QBS TEST" indicates that the test will be done only if a QPM was replaced at a house with a QBS (Quench Bypass Switch) controller. The default selection of tests can be edited by the operator as the situation demands. Deselecting a field containing an 'X' is possible, but this first elicits a caution message since these operations are normally considered to be required.

T30 Tevatron Automated Ramp Check-out And Start-up ♦FTP♦ ♦COPIES♦

	QPM CHK	HWL TEST	ESS RST	HFU TEST	HIPOT	13.8 KV	VCB ON	QBS TEST	DMP TEST	RESET/ON	BO PS ON
M & D PERIOD	X	X	X	X	X	X	X	X	X	X	X
OPEN ACCESS	R	.	X	S	X	X	X	R	R	X	X
CNTRL ACCESS	.	.	X	S	X	X	X	S	.	X	X
QUENCH I>3KA	.	.	.	.	.	.	.	X	.	X	X
GROUND FAULT	.	.	.	.	X	.	.	.	.	X	X
HFU REPLACED	.	.	.	U	.	.	.	.	.	X	X
QPM REPLACED	H	X	.	H	.	.	.	?	.	X	X
QPM REBOOTED	H	.	.	.	.	.	.	.	.	X	X
P. S. WORK	.	.	.	.	R	.	X	.	X	X	X
OFF.........	.	.	.	.	.	.	.	.	.	X	X

*LOG
*EDIT
LOWBETA ON
HIGH LEAD FLOWS
*OFF/*ON

Select ↑ initial conditions

FIGURE 1

When an event requires execution of another application program, TARCAS saves the position of its present progress and loads relevant data for passage to the new application into an 80 byte command buffer. TARCAS then terminates and the execution of the new application begins. The new application is now completely driven by parameters in the command buffer. The command buffer also contains information about the next application(s) to execute. Up to three foreign applications may be consecutively sequenced, with test results being written to the command buffer, before TARCAS executes again. When the final foreign application completes its task, it returns control to TARCAS. The command buffer is decoded to determine

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results of the tests performed. TARCAS then continues execution of the sequence.

This scheme requires that the foreign applications called by a sequencer be able to discriminate an interactive run from a sequencer run. The application must perform the same function whether driven by a command buffer, or interactively by an operator. In the case of TARCAS, this required modification of existing applications. An explanation of the "QBS test" will illustrate not only the mechanics of TARCAS, but the advantages of doing such a test with a sequencer program.

When a quench occurs, the QBSs conduct and provide a current path around the quenching magnet(s). Testing the QBS system is done by the following procedure. The Tevatron is energized to a DC level of 90 Gev. Every 30 seconds the current is ramped up to the 120 Gev level and then ramped back down to the 90 Gev level. During the period of positive dI/dt, the voltage across each cell is measured (a cell is made up of 10 magnets). Each cell has a known inductance, so the expected inductive voltage is easily calculated. For the test, the QBSs in one sector are turned on. The voltage across each cell in the tested sector should be lower than those in the rest of the ring. For an operator to do the test manually, the cell voltages must be read during the correct portion of the ramp. This portion of the ramp is about three seconds in duration. Then the operator must verify that the cell voltages are correct throughout the ring. (There are over 200 readings to consider.) Then the operator must disable testing of the QBSs in one sector and enable testing in the next sector. This procedure is awkward and slow, and the likelihood of human error is high. The procedure is well suited to computer automation, however.

This test has been made easier and more efficient with the use of TARCAS. The existing QBS test program was modified such that, when run by TARCAS, it enables the proper sector of QBSs. It also reads cell voltages at the proper time and compares the voltages to expected values. There is ample time for the computer to do all this between rising portions of successive ramps. Results of the test are written into the command buffer. If the test was successful, control of the console is returned to TARCAS and the sequence continues. Otherwise, the sequence stops at this point. The operator must decide whether to return to TARCAS to attempt the test again, or to repair the appropriate QBS hardware.

TARCAS also must do some bookkeeping as it runs. Results of the various events must be logged so that subsequent tests may be scheduled properly. If an event fails, the sequence is halted but the progress of the sequence is saved. TARCAS then gives the option of continuing the sequence from that point, advancing to the next event without redoing the failed test, or starting a new sequence from the beginning. The progress and results of each sequence are also written into a circular log file so that interested individuals may review recent start-ups when time permits. An example of a log file is shown in figure 2. Comments can be entered by the operator for each log entry to explain a failure or a nonstandard test situation. In this example, a Tevatron refrigerator was not ready which inhibited the QPM permit to energize.

If a particular event fails during a sequence, a message is displayed describing the failure. Suggested remedies to the failure are also displayed. This feature is important for allowing the less experienced operator to take a greater role in turning on the accelerator.

```
T30   Tevatron Automated Ramp Check-out And Start-up ♦FTP♦  ♦COPIES♦
*MAIN PAGE ———————— TARCAS LOG ———————————— *DIRECTORY
FILE  NO. : -<23>+
DATE/TIME : 02/01/89  1810 complete                    LOBETA:  ON
CONDITION : QUENCH I>3KA
♦house-selection♦         ♦event-selection♦
↓↑—— STEP TITLE ———————— STATUS ———— COMMENTS ————
 1 MR ESS extrct PS permit  complete
 2 Load QBS ramp: T49       complete
 3 Wait for clock event $41 complete
 4 PS-QPM rst, HWL, ramp-on failure   frig not ready/no QPM
 5 PS-QPM rst, HWL, ramp-on complete                  reset
 6 QBS test: T29            complete
 7 Load HEP ramp: T49       complete
 8 B0 PS reset and ON       complete
 9 Check-out complete !     complete
10
11
12
13
14
15
```

FIGURE 2

Test threshold parameters are stored in a convenient control file (figure 3). This file can be accessed and easily modified from TARCAS allowing system experts to vary constraints on their equipment in a way that is transparent to operations.

```
T30   Tevatron Automated Ramp Check-out And Start-up ♦FTP♦  ♦COPIES♦
*RETURN ——————————————————————♦QBS Plot♦—♦Ram ——— PAGES ———
QPM CHK :  | smpl time: < 30> sec.                    | TARCAS:<T30 >
           | excit lim: <-100 > min, < 4107> ma       | PAT32: <T32 >
           | V2G limit: <-800 > min, < 800 > ma       | PAT31: <T31 >
           | ♦B0 V2G limits♦                          | PAT27: <Z1  >
                                                      | PAT33: <T33 >
HFU TEST:  | time-out : <  3> min.                    | PAT22: <T22 >
                                                      | PAT49: <T49 >
HIPOT   :  | bus 2 gnd: <  9> Imin,  < 40> Imax       | PAT29: <T29 >
           | bus 2 bus: <  0> Imin,  < 28> Imax
           | cell vlim: < .1  > V (@ 1KV)
           | lead vlim: <  2>  mV (@ 1KV)
           | V2G % tol: <100> % of average

QBS TEST:  | QBS fired: <-2.2 >Vmin, <-.5  >Vmax, V.
           | QBS reset: <-7.5 >Vmin, <-2.25>Vmax, V.
           | Plot min : < 460> Amps, <  20> Idot, A/s
           | Reset lvl: < 405> Amps, <   4> Idot, A/s

DMP TEST:  | Vdrp %tol: < 75> % of IRING*(1/4 Ω)

RMP FILE:  | TECAR rmp: <16>QBS-file < 7>HEP-file
```

FIGURE 3

Pointers to the foreign applications used by TARCAS are kept as logical names in a control file. Access to these names is provided by the window shown at the upper right of figure 3. This feature aids in software development. The entries, such as T32 are logical names of programs that TARCAS accesses. If one of these programs is modified, the new version can be easily tested by entering its name in the right hand column of the window. In the above example, a test version of program T27 will be used. The name of the test program is Z1.

OPERATIONAL EXPERIENCE

Since the advent of TARCAS, operators have been able to turn on the Tevatron without going through extensive training on the various application programs devoted to the Tevatron power supply systems. The advantage is that the operators with limited experience can contribute significantly with less supervision. This frees up other members of the operations staff, and more tasks can be done in parallel.

Another benefit is that the chances of a procedural error occurring during start-up is reduced. Also, although there are no statistics available at present, TARCAS has served to streamline the start-up process. Time savings increase with the more complicated turn on sequences.

The success of TARCAS has spawned similar programs to turn on the Main Ring power supply system, and the cryogenic magnet strings in the Switchyard. Calculating and loading RF curves for antiproton extraction is also done via a sequencer program. The Colliding Beam Sequencer[1] is another example of a time saving sequencing program which automates an otherwise complicated task.

[1] D. E. Johnson and R. P. Johnson, "The Fermilab Colliding Beams Sequencer," presented at the IEEE Conference on Particle Accelerators, Chicago, IL, March 22, 1989.