

AUTOMATED STARTUP OF THE CEBAF 45 MEV INJECTOR

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Abstract

In order to improve the speed and reproducibility of restoring the beam in the Continuous Electron Beam Accelerator Facility (CEBAF) 45 MeV injector [1] after a full or partial shutdown of the accelerator, a program has been written using the Tcl/Tk [2] scripting language to automate most of the required steps. The procedure is separated into four main parts. The first part performs preliminary checks that verify that the hardware is set correctly and then turns on the main interlocked systems including high power magnets and RF. The second step turns on the gun high voltage. The final steps turn on the beam and verify that the beam quality is satisfactory by measuring the transmission, orbit, transverse beam size, and bunch length. Minor corrections for phasing are also performed in the program. In order to identify inefficiencies in the startup, each is timed and parameter changes are logged so that system drifts can be tracked. This paper describes the software implementation, the logic to achieve a successful startup, and efficiency results.

1 INTRODUCTION

A major goal of accelerator operations is the minimization of downtime. During a typical startup, there are several contributors to delays. First are component or system failures. Second are day to day drifts in the beam setup. Finally come distractions to the operations crews.

To alleviate these delays, a program has been developed that automates the startup of the CEBAF nuclear physics injector. The program is written in the object oriented language Tcl/Tk, which has been used successfully in several other high level applications at CEBAF [3]. As will be described later, full automation, though near, has not yet been achieved.

2 MOTIVATION AND PHILOSOPHY

Though the ultimate goal of the injector automatic startup program, AutoStart, has always been to achieve full automation, it was understood from the beginning that the program itself would be a tool used to identify obstacles impeding startup. Some of these obstacles include lack of repeatability, recurring hardware or software failures and, procedural errors. In view of this, a further set of goals was developed. These are:

- Rapid identification of component or system failures
- Standardization of startup sequence

- Verification of beam quality
- Automatic record keeping to identify points of recurring failure and areas that are delaying startup.

Personnel from the injector group and the operations group were chosen to develop the AutoStart program. This was done for several reasons. First, when the development of the AutoStart program began, the software group was overloaded with work on higher priority low and high level applications. Second, the startup documents were written by the members of the injector group. Having the document authors convert those procedures to programs allowed each step to be examined critically and changed if necessary. Finally, an automatic startup program follows the steps that a human operator follows and the insight of experienced operators was desired to aid in identifying some of the subtleties of actual startups.

3 EVOLUTION OF THE PROGRAM

3.1 Degree of Automation

The program began as a series of startup procedures in which each step provided instructions for the operator to carry out. The steps have been gradually automated and streamlined. After concern was expressed that operator skills would diminish if familiarity with the turn on procedure was reduced, easy access to an explanation of each step and instructions to perform each step manually, were provided. Priority for implementation has been based on ease of automation and degree of gain. In general, the program evolved so that those steps that were most time consuming or tedious for an operator to perform were automated first.

3.2 Structure

The program was initially designed to parallel the three states of the Personnel Safety System (PSS) of the accelerator. The Controlled Access PSS state, in which high power system operation is prohibited, allows personnel to enter the accelerator enclosure. The next higher state is Power Permit. In this state personnel are excluded from the accelerator enclosure and high power systems, with the exception of the electron gun, can be turned on. The highest state of the PSS is Beam Permit which allows gun high voltage turn on and beam operation. Since during machine access times operations crews are busy with other tasks, an early version of the program that was initiated while in Controlled Access was found to be ineffective. The program structure was

modified so that all functions occur after the PSS reaches Power Permit.

4 LAYOUT AND DESCRIPTION

The four main parts of the program are: system turn on, gun HV turn on, beam turn on, and beam check out.

4.1 Startup Screen

The main AutoStart screen is shown in Fig. 1. The buttons to activate each of the four subprograms are positioned horizontally to minimize screen space. While the program is running, a log file is kept, detailing the progress of the startup, including any faults that may occur. When the System Turn On subprogram is activated, a timer is started that records the overall length of time that the startup takes. Each subprogram is timed as well. Options to enter comments concerning the program, view the log file, and initiate detailed checkout programs are provided under the menu.

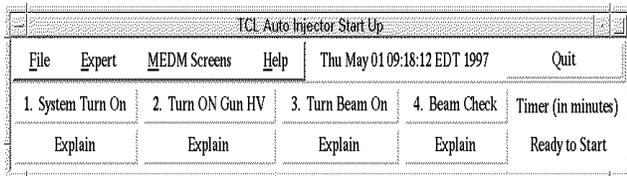


Fig. 1. The main injector AutoStart screen shows the buttons that activate the four main parts of the program.

4.2 System Turn On

The System Turn On portion of the program performs the following functions:

- Turn on of all injector RF cavities
- Turn on and hysteresis cycling of the arc dipole magnets
- Opening of all accelerator valves
- Hysteresis cycling of injector solenoids and quadrupoles.

The System Turn On screen is shown in Fig. 2. Flag indicators along the top of the screen are yellow during execution and turn green or red indicating either success or failure. Status of the program is provided in text boxes below the status indicators. Each function can be activated individually by the operator or automatically. Since the turn on of the rf cavities and dipoles can take up to 10-20 minutes each, an independent process is launched to allow parallel turn on. Stray fields generated by the accelerator arc dipoles are the reason that these must be on for successful injector startup. Due to inconsistent response times, the arc dipole routines have caused the most difficulties, even causing crashes of the control system. This problem is being currently addressed.

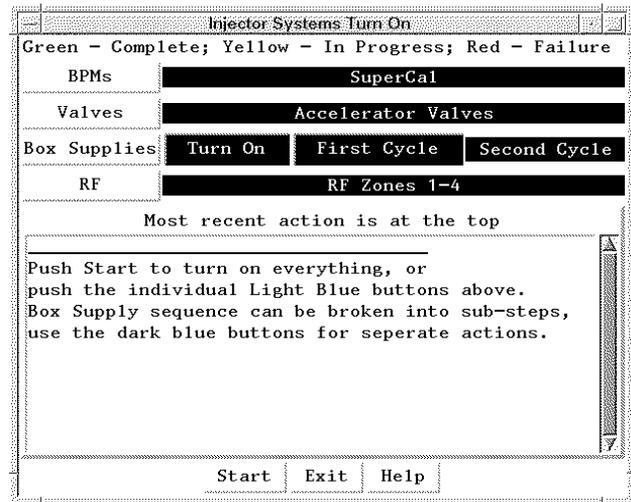


Fig. 2. The System Turn On control screen is shown.

4.2 Gun HV Turn On

When the system turn on section is complete, the program waits for acknowledgement from the operator that the PSS state has changed to beam permit. At this point, the control electrode is set to suppress electron emission and the gun high voltage is automatically turned on. In addition, all interlocks preventing beam turn on are verified to be clear. The gun high voltage turn on screen is similar to the System Turn On screen with indications given for success or failure.

4.3 Beam Turn On

Beam turn on requires only one action: change of the gun control electrode to allow electron emission. The program requests via a textbox that the operator do this manually. This is the only true administrative break point in the program that prevents “one button” startup.

4.4 Beam Check Out

To verify that the injected beam properties are satisfactory, a minimum set of checks is done automatically. Determining a minimum set has been more challenging than was first thought. More checks were added as errors were found over the span of months. Out of this emerged a nearly complete and detailed set of automated checks that were slowing down the startup. This complete set was then reduced to four diagnostic checks. The beam current is checked automatically by inserting a Faraday cup and comparing the signal with the standard. Orbit is checked for perturbations outside a range of +/- 2 mm for all beam position stripline monitors. Several critical locations have allowable errors of +/- 0.25 mm. The transverse profile is checked by automatically triggering a wire scan at a high dispersion point. This verifies proper phasing of the acceleration cavities and transverse matching of the injector to the accelerator. The final step activates a program to measure the phase transfer function in the low energy end of the injector.

This verifies that the bunching is correct. This program has been automated to a large degree. However, since the output of the diagnostic is a complex plot of the phase transfer function, optimization of the phases still relies on operator feedback. The complete diagnostic list is now offered as a menu option. Options for running the complete injector diagnostic checkout, opening useful control screens and the standard options described earlier are accessible via a menu.

4.4 Efficiency Tracking

Since one goal of the AutoStart program is to reduce the startup time of the injector and accelerator, a plotting routine [4] is accessible from the menus that gives a plot of run times for each section of the program as well as the overall run time. Such a plot is shown in Fig. 3 with actual data of the time taken to measure the phase transfer function described in the preceding section. Sufficient data has not yet been collected on all portions of the startup but general observation has produced the following results. In the absence of faults, system turn on takes 10 minutes, gun HV and beam turn on takes 2 minutes, and beam checkout takes 5 minutes for a total of about 20 minutes. However, for typical startups, system turn on takes 20 minutes, Gun HV and beam turn on still take 2 minutes (few failures in these steps), and beam checkout requires 20 minutes, including adjustments of the injector rf phasing. This produces a time for typical injector turn on of 45 minutes from a state of controlled access to beam delivery to the linac. The major time consuming portions of the startup are turn on and cycling of the dipoles, and measurement and adjustment of the phase compression. Improvement of the efficiency of the latter could reduce the startup time by up to 15 minutes.

5 PLANNED IMPROVEMENTS

The first and obvious goal, to be implemented within the next three months, is the interfacing of the PSS with the accelerator control system EPICS. This will allow nearly full automation of the startup. In fact, the necessary modifications have been made and await the hardware implementation. Full automation of the bunching setup is also in progress. This would include automatic adjustment of the rf phases to optimize phase compression. Next, a quick method of analyzing past data for fault occurrence is necessary to make the program useful as an error tracking tool. Finally, extension of the automatic startup to the entire accelerator is planned. In view of the fact that the dipole turn on routine is complete, the most difficult portion to be

written is the beam verification sequence for the entire accelerator.

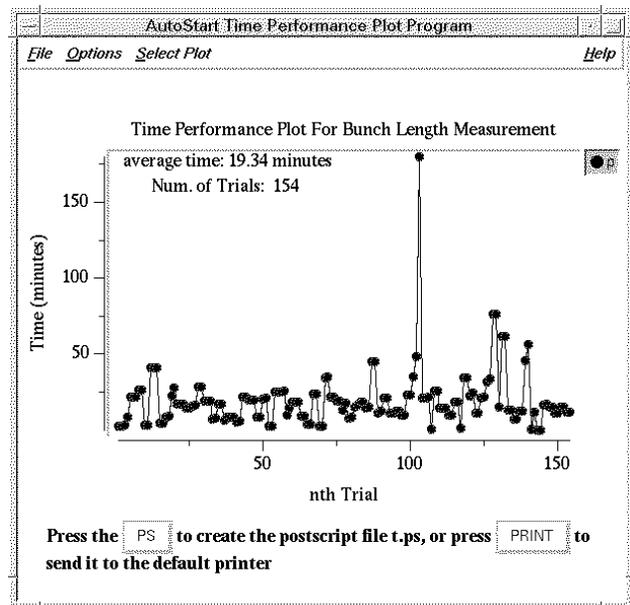


Fig. 3. Performance plots such as shown here can be accessed from the menu in the AutoStart main screen.

6 CONCLUSION

A partially automated injector startup program has been written for the CEBAF nuclear physics injector by members of the Injector and Operations Groups. Currently, hardware obstacles prevent full automation but these are being removed.

7 ACKNOWLEDGEMENTS

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