COMPUTER CONTROLLED FORMATION OF THE 750-keV ACCELERATING COLUMN ON THE NEW CERN 50-MeV LINAC

H. Haseroth
CERN, Geneva, Switzerland

Summary

The advantages of the simple design and construction of the CERN high gradient double gap accelerating column are partially counter-balanced by a sometimes (depending on vacuum conditions) lengthy and manpower wasting formation procedure. After the introduction of a radiation measuring facility, rather than the usual cathode current monitoring, as criterion for increasing the HV, a strategy has been worked out for automatic formation. This strategy has been implemented in a computer program to run on the Linac Control Computer (PDP 11/45). The advantages are : faster formation, smaller number of breakdowns and no operator needed. This paper describes the hard and software necessary and the "teething problems".

Introduction

The 750-keV preinjector of the new 50-MeV CERN linac has a double gap short column (Fig. 1) based on the design of the 500-keV unit of the old CERN linac[1,2] The gap sizes are 61 and 68 mm, respectively, giving a total gap, excluding the thickness of the intermediate electrode, of 129 mm, which gives an average gradient of 58 kV/cm. The electrodes are made of titanium. The outside of the column, surrounded by normal air, consists of 19 sections of 65 mm thick porcelain rings interlaced with thin metal discs and bonded with epoxy (Araldite). This construction is fairly simple but requires very clean vacuum conditions, i.e., hydrocarbon partial pressure of $\leq 10^{-10}$ mbar, otherwise breakdown of the column occurs frequently and radiation levels can be extremely high.

Process of formation

The high sensitivity to pollution also makes the formation of the column up to 750 kV a lengthy and time consuming process. The total time needed to reach the operating voltage and the total number of breakdowns occurring during this process are very much dependent on the operator. There are several "theories" about formation. Some people believe that there is a minimum number of breakdowns which one cannot avoid, in order to reach, under given conditions, the operating voltage. Others believe the number of breakdowns to be inversely proportional to the formation time. Additionally there are several ways of increasing the HV when watching, for example the column cathode current ; namely :

- keeping the cathode current at a constant a) low level ; b) high level.
- increase the HV only when the cathode current has decayed to less than say 1μA.
- increasing the HV in large steps ;
- increasing the HV in small steps ;
- reduce the HV if the cathode current keeps increasing ;
- reduce the HV only if the cathode current jumps up ;
- never reduce the HV and tolerate the breakdown(s).

It is very difficult to decide which of these assumptions are correct, because the operator, as a human being, does not apply his ideas consistently over (sometimes) several hours. In addition, the ease of formation depends very much on different boundary conditions such as vacuum (total and partial pressures), previous treatment of the column, total amount of recent time during which no HV was applied, number of breakdowns and surface layers on the electrodes. It is clear that only control by a computer can guarantee the application of a certain strategy for a sufficiently large number of times, so that a conclusion as to which technique is the most successful can be drawn. An examination of old statistics (Fig. 2)[3] seems to confirm this.

Thus there is a certain academic reason to get the computer to do the formation. There are also three very practical reasons :

- the operator's time can be used for something else ;
- the computer is reacting faster than an operator, i.e.,
  - a) the formation time could be shortened;
  - b) possible breakdowns can be avoided by lowering the HV before a breakdown might occur.
- a reduced number of breakdowns (by applying the proper strategy) gives a longer life to the different HV components.

Hardware

There is a computer control (command) for the HV with acquisition of the HV the radiation level, the cathode current and the vacuum (total) pressure from a Penning gauge. The cathode current is read from a resistance connecting the cathode to ground using the appropriate protections against voltage transients in case of breakdown.

It should be mentioned here that the system is able to send out one set of command values, and to acquire one set of parameters, per machine cycle which is normally about 1 sec.[4] This implies that it is not necessary to make complicated calculations as to what moment to read or to set a parameter ; for example, if the program asks twice to read a parameter, the second reading will be taken automatically on the next linac pulse. This simplifies the programming but limits, on the other hand, the response time of the program if it decides, for example, to lower the HV after having looked at the radiation. Nevertheless experience has shown that the response time seems to be adequate, and is certainly much better than the response of an operator who has stood in front of the control panel for some hours.

The radiation is measured with a conventional Geiger Muller tube (Philips ZP1220 for sensitivity reasons), which needs only one coaxial cable to feed power to its associated electronics and to transmit the signal. Thus it is possible to move the counter easily in order to find its optimum position.

The reason for measuring the radiation is partially the fact that it is easy to get a clean signal that does not carry any transients to sensitive equipment in case the column breaks down. In addition, the monitoring of the cathode current does not necessarily measure all the current that flows to ground, but only the current flowing via the cathode. However, if there is cathode current it will also produce radiation. So the radiation is the more complete measurement of what is going on inside the column.

Program

The program is written in FORTRAN to run on the PDP 11/45 Linac Control Computer. It would have been equally possible (and much easier for debugging and modifications) to have written it in BASIC, but then linking it to a touch panel to call the program would have been impossible. Therefore, FORTRAN was used, profiting from available subroutines for controlling and acquiring parameters. Provisions have been made to store all the relevant data of a formation on two files so that some statistical analysis can be made later on, or to produce plots of different formations.

General outline of the program

The first part of the program consists of the usual housekeeping, reading and preparing files for storing the data. It asks the user also for two radiation levels which will influence the speed of the formation.

The second part contains essentially all of the logic for running the formation except for that contained in three subroutines:

- WATCH (Fig. 3)

This subroutine is called everytime a change has been made to the level of the HV. It looks at the radiation level and compares it to the reference values given by the user. It sets the corresponding logical variables to "true" if the radiation exceeds those values and returns control to the main program. If the radiation exceeds only the lower level, there is no immediate action except for setting the first logical variable to "true". The radiation will then be read again and will be compared to the previous value. If the radiation is going down, the program will read again and again until the radiation is below the lower level. The low level variable will then be set to "false" and control is returned to the main program. If the radiation on the other hand is going up, control will be returned immediately with the corresponding variable set to "true".

This method had been adopted because low levels of radiation normally tend to drop down, whereas high levels of radiation or increasing low levels, will frequently be followed by a breakdown.

- BREAK (Fig. 4)

This subroutine is called to decide in case of doubt whether there was a breakdown on the column that could have falsified the command or the acquired values. As a result of values read incorrectly, the program may decide that the formation is finished, or increase the HV further, even if in reality the radiation is already too high, thus causing another breakdown, or simply stay in a loop. As the idea of feeding the output of a special breakdown detector in the form of a status signal to the computer has been abandoned, a signal that may itself suffer from the breakdown, this subroutine looks at the acquired values and checks if they seem reasonable.

After having read the parameters, the latest acquisition value of the HV is compared to the previous one, as well as to the command value. If either of those differences is too large, a breakdown is assumed and the logical variable (as well as the two variables assigned to the radiation) are set to "true". If the result of the comparisons is normal, the cycle is repeated five times to verify that there is a stable HV situation.

- FORMFI (Fig. 5)

This subroutine is used to check if a formation can be regarded as finished and that the situation is not degrading after the desired voltage level has been reached. To check this, the subroutine BREAK and WATCH are called successively, and the message of passing both successfully is handed back to the main program via a logical variable.

The formation is going on in a loop of the main program. According to the level of the HV, an increment is chosen for increasing (or decreasing) the HV. After the program has sent a command to change the HV value, the next request will be issued only if the previous increment was set to at least 80%. This is again done by going through a loop. After three unsuccessful iterations, the subroutine BREAK is called to check for breakdown. If there is breakdown, the program will reduce the HV command value by five times the incremental value and the cycle will start again. If there is no breakdown, there are two more trials to wait for the desired result. If even this is negative, the program will switch off the HV when the hardware for the status commands is installed. At present the program just ignores this instruction, but until now there was no formation where the program arrived at this situation.

At the next step, after having asked for an incremental change in the HV, the subroutine WATCH will be called to check that the radiation is sufficiently low before the next increase of the HV level. Otherwise the HV will be slightly or drastically reduced, depending on the level of radiation.

Before every increase of the HV, the acquisition is compared with the nominal formation voltage. If this is reached or exceeded, subroutine FORMFI will be called and the validity of the formation will be checked. If the result is positive, a small correction will be calculated and the HV set exactly to the nominal value. After this, the last data are written onto the data files, some messages are displayed on the terminal and the program finishes.

Operational Experience with the Program

The first tests with the program were done by increasing the voltage only, because it was believed that with sufficiently small incremental values it would just be necessary to watch the radiation, and perhaps to stop increasing the HV, in order to avoid breakdown. It turned out that frequently it seemed much better to actually reduce the HV in order to avoid a subsequent breakdown. Another simple fault was that originally the program finished when one had reached the operating voltage. Sometimes only a few seconds later there were successive breakdowns and a drastic increase in radiation. This was the reason for introducing the subroutine FORMFI.

Less trivial problems occurred when having breakdowns in the course of formation. Sometimes the program would stop and claim that the formation was finished, sometimes it would simply stop. In order to discover the cause of this problem, command and acquired values were frequently displayed on the terminal together with information as to what point the program was at. It turned out that in the case of a breakdown there is not only "noise" coming to the computer, but more specifically the acquired values may be wrong. This was one reason for introducing the subroutine BREAK, and also to check in the main program if the previous command sent out was already successfully executed. In critical parts of the program values are read several times, to make certain that the situation was stable before drawing conclusions on how to continue.

Conclusions

With the computer controlled formation program, there is now a very quick and reproducible method of forming the accelerating column. A considerable amount of manpower has been gained and the formation is done without stressing unnecessarily the HV components. It is interesting to note that a typical formation after an ion source change used to take about three hours and cause about 20 HV breakdowns. With the help of the computer, the formation takes about one hour and causes only about ten breakdowns. By building up the statistics it is now possible to decide which are the best parameter settings for an optimum formation.

Acknowledgements

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References

1) E. Boltezar, H. Haseroth, W. Pirkl, G. Plass, T.R. Sherwood, U. Tallgren, P. Têtu, D. Warner and M. Weiss, The New 50-MeV Linac, this conference.

2) M. Hone, The Accelerating Column for the Pre-injector of the New Linac, CERN Internal Report, in preparation.

3) F. Chiari and J. Knott, Le Fonctionnement du pre-injecteur du Linac en 1970, MPS/LIN/Note 71-4.

4) A. Cheretakis, J. Knott, P. Mead, A. v.d. Schueren and U. Tallgren, The Control System of the CERN New Linac, PS/LIN/Note 76-20.

Discussion

Bentley, NEN: Can you give an equivalent radiation level for your upper and lower thresholds?

Weiss: These lower and upper radiation levels depend on where you place your counter. I have shown that the counter has been placed a few meters away from the Faraday cage or the column. Placing it closer or further away would change the signal, so absolute radiation thresholds are meaningless. However, as I remember, the lower level is 0.2 rem and the higher is 1.4 rem.

Bentley: But that is not calibrated in terms of a radiation level at the column or at any particular distance?

Weiss: No, this is just something which has been found from experience.

Bentley: What is the time scale of your command steps?

Weiss: All the commands which are sent to our linac are synchronized to the linac pulse which is about once per second. So nothing will happen until the next linac pulse. Then, we first perform the data acquisition to see how the command has been executed and if the conditions for another command are satisfied. After that we can send out the next command. We have found this procedure to be extremely useful because one has just to press a button and go out of the room and come back in an hour and the column is formed.

Curtis, FNAL: When sparks or breakdowns occur during voltage conditioning of the column, is the high voltage power supply turned off or left on and just turned down in voltage?

Weiss: This program contains a subroutine which checks for breakdowns. If something unusual has been observed, for example, the command of the high voltage and the required valves are too far apart, the program checks to see if a breakdown has occurred. If so, it drastically drops the high voltage (I think it drops it 5 steps) and continues in the loop to check if it is enough or must go further.

Curtis: The power supply is not turned off then?

Weiss: No, it is not turned off.

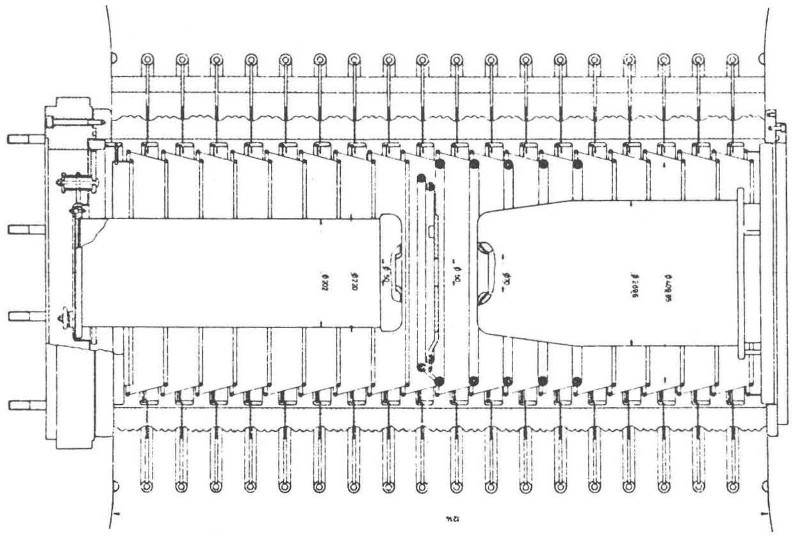

Fig. 1 Accelerating column

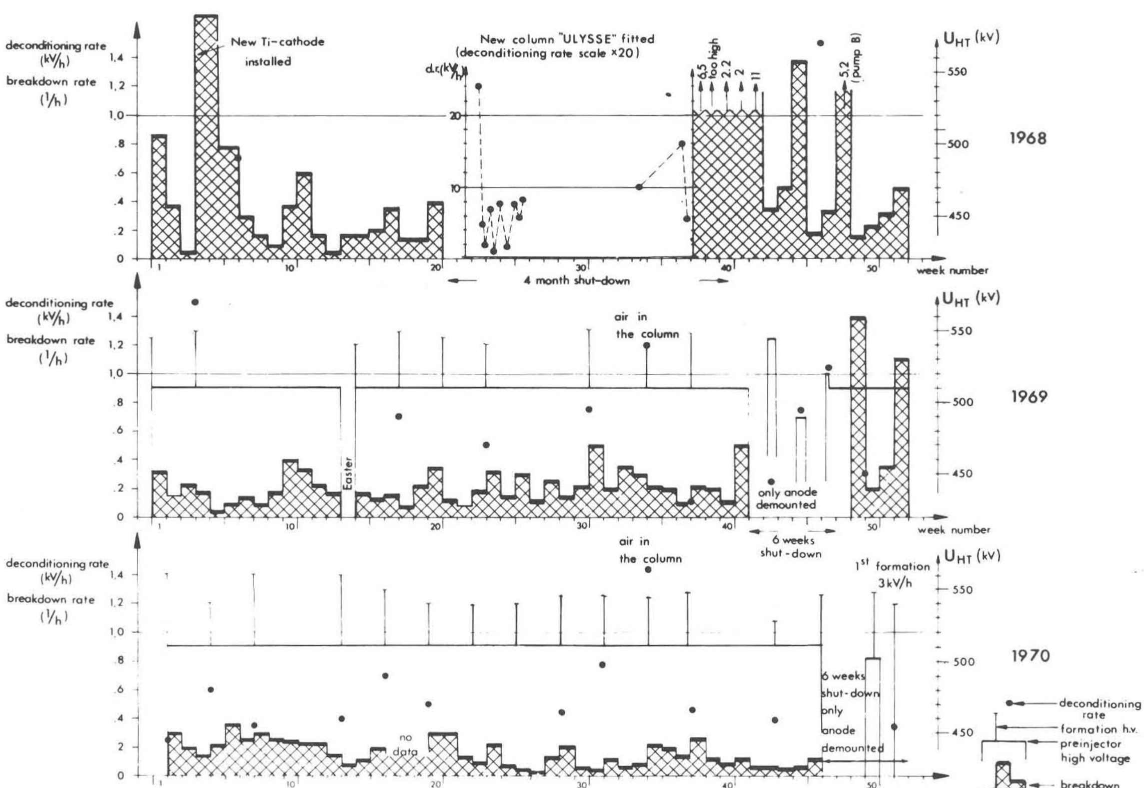

Fig. 2 CERN-PS-PREINJECTOR STATISTICS 1968/69/70 MPS 4158 105-2383-3 1-648

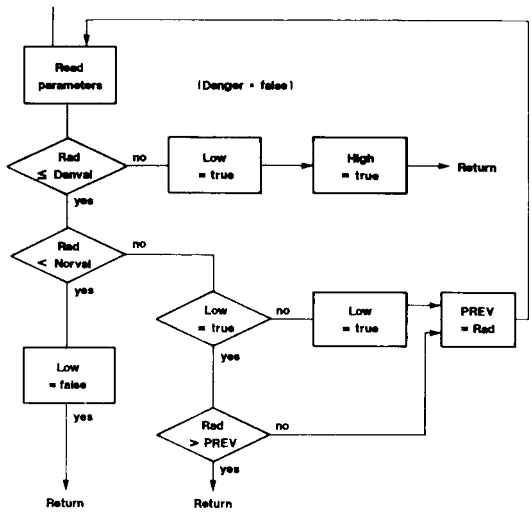

Fig. 3 Flow diagram for subroutine WATCH

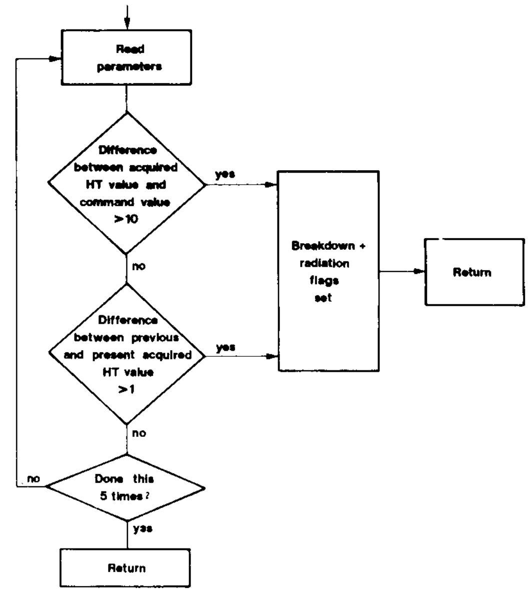

Fig. 4 Flow diagram for subroutine BREAK

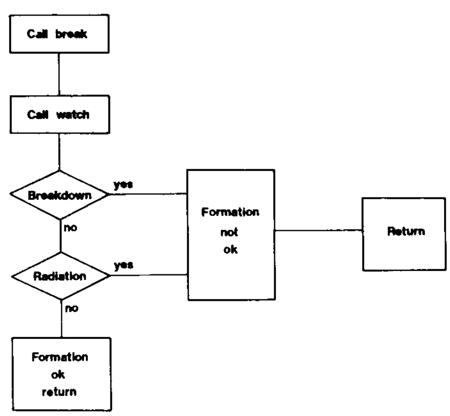

Fig. 5 Flow diagram for subroutine FORMFI