CONTROLS FOR HIGH PRECISION BEAM ENERGY DETERMINATION AT CEBAF, HALL A : THE ARC PROJECT

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Abstract

ARC is an equipment of CEBAF (at Jefferson Lab) to measure the absolute energy of the electron beam. The determination of the CEBAF beam energy with a resolution of 10^{-4} requires a very accurate measurement of two quantities: the total bending of the beam and the field integral along the deviation. The bending measurement is done with a set of scanners which are also used for beam diagnostics. The control for the Magnetic Field Integral Measurement is a large application needing specific magnetic measurements routines. All the control software was written with EPICS. This paper describes the hardware choices and the two control systems which have the same conception and the same architecture. The experiment has been running since June 1998.

1 INTRODUCTION

The goal of the ARC Energy Measurement [1] is to measure with a very high accuracy ($\Delta E/E = 10^{-4}$) the energy in a bending section of the transport line located between the accelerator and the Hall A end station. The energy of the particles is given by $E = c * (\int B*dz)/\theta$ where c is the speed of light; $\int B *dz$ is the field integral of the dipoles and is measured by the magnetic field integral measurement part [2] [3] and the angle θ is the horizontal bending angle of the beam due to the dipole field and is measured by the angle measurement part (Fig. 1).

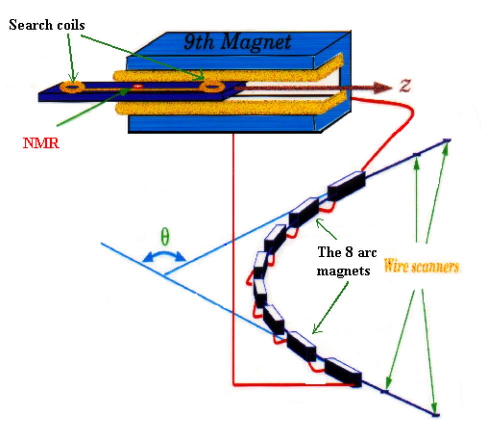

Figure 1 : Principle of the measurement

2 PRINCIPLE OF THE ANGLE MEASUREMENT

We use four scanners located on the Hall A arc : two just before the arc and two just after. Each scanner translates horizontally a set of three tungsten wires. Each time a wire crosses the beam a PMT located a few meters downstream records a signal due to the electromagnetic shower induced by the beam in the wire. One of the wire is vertical, producing a horizontal beam profile. It is the only wire used for the ARC angle measurement. The 2 other wires are at 45 degrees from the vertical and are used for beam diagnostics. Each scanner has a shaft encoder and a stepper motor. Recording, during the scan, the scanner position and the PMT output voltage allows us to determine the beam position at each scanner location. Both forward and backward passes are recorded. Then, thanks to calibration data, the users can deduce the beam bend angle through the arc.

3 HARDWARE FOR THE ANGLE MEASUREMENT

The controls are implemented on a VME. We chose the same boards as those previously used for Tesla Test Facility Injector Controls[4]. The CPU is a MOTOROLA MVME162 with 8 megabytes RAM, an ADAS scanning ADC ICV150 board to read the voltage, 2 ADAS ICV196 binary input/output boards to read the shaft encoder . A pulse generator is used to trigger the scanner acquisition at 1000 Hz. A terminal block ADAS STB24, now commercialized, was especially designed to be used with an ICV196 to interface and read the parallel output of the absolute shaft encoder. This STB24 terminal block is driven by the trigger input and stores encoder values.

A "sample and hold" board [5] driven by the same trigger signal was designed for ICV150. Its role is to precisely synchronize the shaft encoder position and the acquisition of the signal on each trigger.

An OMS 8-8 micro stepper motor board is used to move the scanners.

4 SOFTWARE FOR THE ANGLE MEASUREMENT

The software package is a set of 3 tasks : the main task to acquire beam profiles (Fig. 2), a task to set the scanners to their "home" position and an expert task for maintenance purpose.

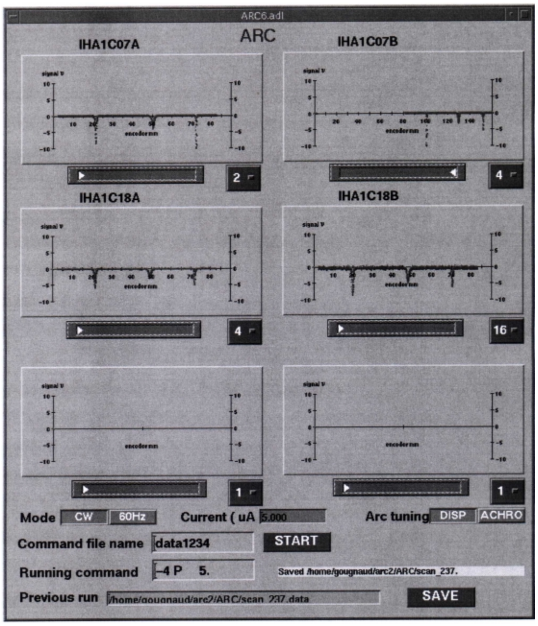

Figure 2 : Beam profiles

The beam profiles task is driven by a command file specifying the sequence of movements of scanners and setting the direction and the velocity of the displacement of each scanner. This application was easily carried out with EPICS and is a very good template model. The basic tools of EPICS, MEDM (editor display) and DCT (Database Configuration Tool) were sufficient, the State Notation Language SNL was very convenient to carry out this application (Fig. 3).

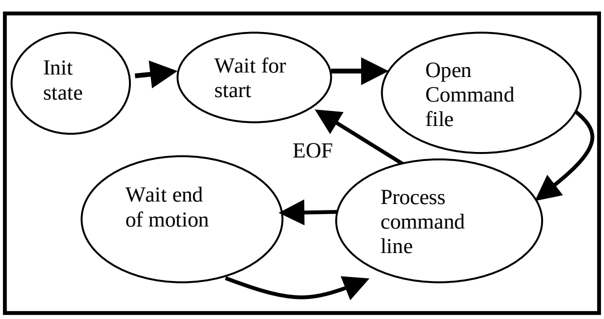

Figure 3: Diagram states for scanners

The dynamic assignment provided by SNL is easily applicable in the case of scanners. It gives the possibility to assign and "deassign" in the same SNL program the same variable to different process variables of the database. It permits us to assign the same variables successively to the different scanners.
Therefore, the same sequences of code are valid for the different scanners.

The data are saved on a file for off-line angle computation.

We chose also to describe scanners in descriptor files : device name, encoder home position, encoder sign, number of units per turn for the encoder, number of microsteps per step for the motor, number of steps per turn, polarity of the motor, screw pitch… The SNL programs read the descriptor file for each scanner. Consequently, if the user needs to change the mechanics of the scanners, the software stays valid.

There is also a task checking if each scanner is in the "home position". It is mandatory when the beam is present and the scanners are not in use. Otherwise, the beam could melt the scanner wire. We added an expert task to allow easy maintenance of the system using user defined displacements.

5 PRINCIPLE OF THE MAGNETIC FIELD INTEGRAL MEASUREMENT

A 9^{th} dipole , identical to the 8 arc dipoles, called the reference dipole, was installed in a specific building, out of the beam line; it is powered in series with the arc magnets and equipped with a device measuring its field integral with a 10^{-5} accuracy. As each of the arc dipole has been previously calibrated relatively to the reference dipole, this relative calibration, done once and for all, and the absolute reference magnet measurement, done at each energy change, provide the required arc field integral.

6 DESCRIPTION OF THE FIELD INTEGRAL MEASUREMENT SYSTEM

The system consists of four NMR probes and of two search coils, mounted on a common support moving inside the gap of the magnet. The distance L between the coils is close to the magnetic length of the magnet. The NMR probes and both search coils are located on the beam axis and can move along this axis over a distance of about 3 m. The measurement is done by moving the coils in such a way that at the beginning of the measurement the first coil is close to the center of the magnet and the second one is about 1.5 m outside the entrance; at the end of the movement, the second one is close to the center and the first one 1,5 m outside the exit. Assuming that the first coil's final position is the same as the second coil's initial position , one can show that:

$\int dx \int V(t')\, dt' = -(\int B dz - B0*L)*S$

where A and B are the departure and arrival points of the first moving coil, V is the output voltage of the two coils in series, B0 is the central field, L is the distance between the axis of 2 coils, S is the average magnetic area of the two coils.

7 HARDWARE AND SOFTWARE FOR THE FIELD INTEGRAL SYSTEM

Identical VME and CPU that were used for the Angle Measurement system were purchased.

∫V(t') dt' is performed by a Precision Voltage Integrator PDI 5035 VME board from METROLAB company. The device driver software for EPICS was the only one developed at Saclay [6] for this project. B0 is measured by a NMR teslameter from METROLAB through an interface RS232. The driver for RS232 was available in the EPICS community. The moving support of NMR probes and coils is driven by a brushless motor which is controlled by the VME PMAC board from Delta Tau used in different sites of the EPICS community [7]. For initialization and motions of the motor, configuration files are used. Therefore, the setup and tuning for motorization are done independently. Temperatures and current in the dipole are digitized by an ADAS scanning ADC ICV150 board. An ADAS binary input/output ICV196 board is used to read the limit switches.

The integral consists of successive measurements, firstly a movement and a measurement of the central field B0 by NMR, then the measurement of a forward pass flux integral given by the voltage integrator, then the measurement of a backward pass flux integral and again finally a movement and a measurement of the central field B0. The above sequence of integral is fully automatic thanks to a set of routines in C language that permits to select the gain of the voltage integrator PDI and to select the appropriate NMR probe.

A large SNL program was designed to manage this application. Three people collaborated to write this SNL program which includes three main parts. Each part is made of several states. A part is dedicated to motorization, another part to the NMR reading and another part to the integral. The communication through the database permitted us to do independently the developments and the tests.

Therefore, EPICS and the SNL language were also convenient for this application which was more demanding than that with the scanners.

Mechanisms of synchronization between different set of states were also useful to synchronize the different movements. But a tool to debug SNL would have been appreciated.

Several MEDM displays were developed. The main display is the control of the integral measurement (Fig.5). The other displays can be used to control short displacements for tests, to select the NMR probe, to control the gain of the voltage integrator.

8 CONCLUSION

Using this command control system we could reach an accuracy better than 10^{-4} in the measurement of beam energy for Hall A. The experiment has been running since June 1998. This very exciting work ended for the French team in June 1999 and the two systems were delivered to Jefferson Lab teams.

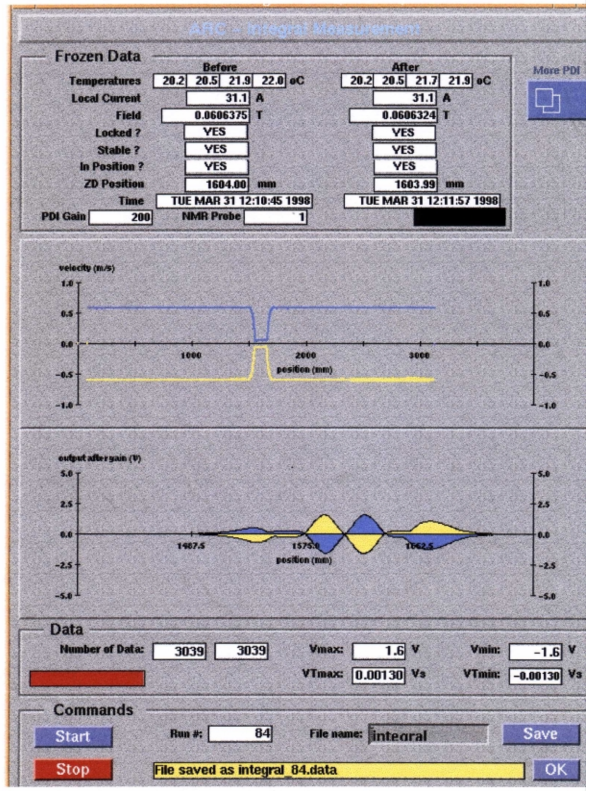

Figure 5 : the Integral

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