ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA097

EPICS BASED CONTROL SYSTEM FOR SPES TAPE STATION FOR BEAM CHARACTERIZATION: MOTION SYSTEM AND CONTROLS

M. Montis[1], M. Giacchini[1], T. Marchi[1], INFN-LNL, Legnaro, Italy
B. Genolini[2], L. Vatrinet[2], D. Verney[2], IPN, Orsay, France
J. Abraham[3], iThemba LABS, Somerset West, South Africa

Abstract

The SPES [1] [2] Tape Station (STS) for Radioactive Ion Beams (RIBs) characterization is under construction at LNL. This tool will be used to measure the actual composition of the radioactive ion beams extracted from the SPES-β ion source and to optimize the source's parameters. STS will provide beam diagnostic information by determining the beam composition and intensity. At the same time, it will be able to measure the target release curves needed for the source's characterization and development. The core part of the system, the related motor and controls are being designed and constructed in synergy with IPN Orsay (France), iThemba Laboratories (South Africa) and the Gamma collaboration (INFN-CSN3). In particular, the mechanical part is based on the existing BEDO [3] tape system operated in ALTO while the control system for motion is an EPICS [4] base application under implementation by iThemba and INFN, result of an upgrade operation required to substitute obsoleted hardware and update logic and algorithm.

INTRODUCTION

In order to characterize the radioactive ion beam provided by the SPES ion source, the STS uses particular techniques mainly based on γ-ray spectroscopy of the β-decaying radioactive nuclei.

The ions are implanted on an aluminated mylar moving tape and either measured in-situ or transported to a shielded decay location. The detection of single γ-ray spectra or β-γ coincidence spectra provides then the required information. The further movement of the tape allows removing any residual long-lived activity before a new measurement cycle is started (Figure 1).

The radioactive ions of interest are produced, extracted, ionized and pre-selected at the SPES target location. Two tape stations are foreseen in the present layout. A first Tape Station (STS1) is placed just out of the production and preselection bunkers and serves as the first feedback for the source operation. A second Tape Station (STS2) is installed after the High-Resolution Mass Spectrometer (HRMS) to operate as feedback for the HRMS itself. For non-reaccelerated beams (with and without the use of the HRMS), STS1 is used for beam composition determination before delivery to the experiments.

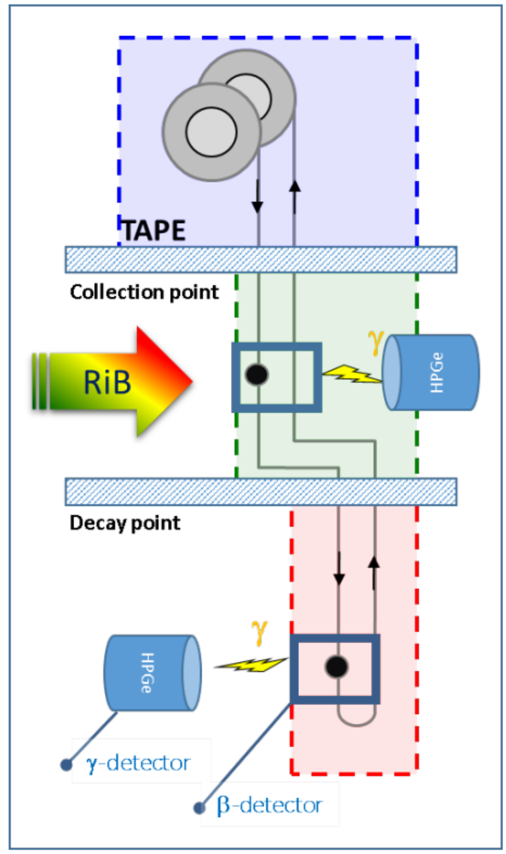

Figure 1: Schematic view of the Tape Station.

THE STS CONTROL SYSTEM

In Legnaro Laboratories a tape station was used to perform similar diagnostic analysis for dedicated experiments, but the status of mechanical, electronics and controls let us decide to invest in a new version: obsolete devices such as motors and electronics components not more available on the market is a crucial point for guarantee the maintenance of the system. At the same time, the old LabVIEW based control software must be updated in order to eventually manage new sensors and actuators.

With the focus to provide a solution fully integrated in the main SPES control system, a new EPICS control system has been chosen.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA097

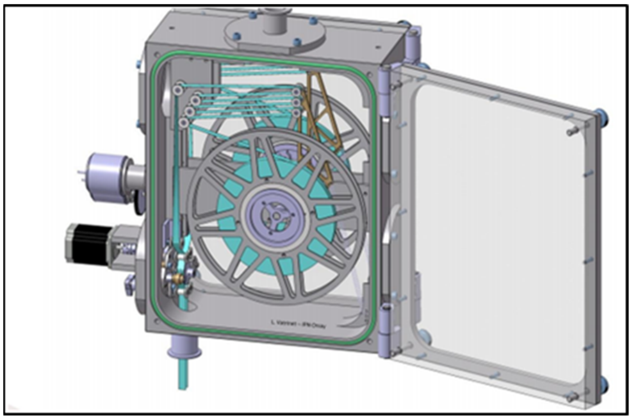

Figure 2: Tape Station layout provided by IPN Orsay.

Through the agreement among LNL, IPN-Orsay and iThemba Labs a brand-new diagnostic station for the SPES project in under development and production: based on the tape station design (mechanical and algorithms) used in IPN, the mechanical upgrade was in charge of LNL while the new control design was provided by LNL and iThemba.

Figure 2 shows a 3D sketch of the core part of the system, namely the tape cassette. The box contains two disks which host the mylar tape and allow to roll it in either direction, just like a movie tape. To do so, three motors and a feedback system are employed. One stepper motor defines the velocity and rotation direction of the tape, while two DC motors controlled by the feedback system roll the tape around the disks, keeping the proper tension. In addition to the cassette, the main components of the tape station system are (Figure 3):

- The vacuum system
- The detection system (data acquisition and detector's power supply)
- The electrostatic beam deflector

The control system to be implemented has three main tasks:

1. It has to drive the motion of the tape cassette according to user-programmable parameters like tape speed, number of steps, number of cycles.

2. It has to coordinate the movement with the other subsystems, acting as master handler.

3. It has to provide a global user capable of dealing with all the aforementioned subsystems and to allow the user setting all the experiment parameters.

The approach chosen is to implement the master functions on the same EPICS server that is controlling the motion of the cassette and to dialogue with the other subsystems using either EPICS variables (slow controls) or digital signals (real-time controls). Doing so, the control servers

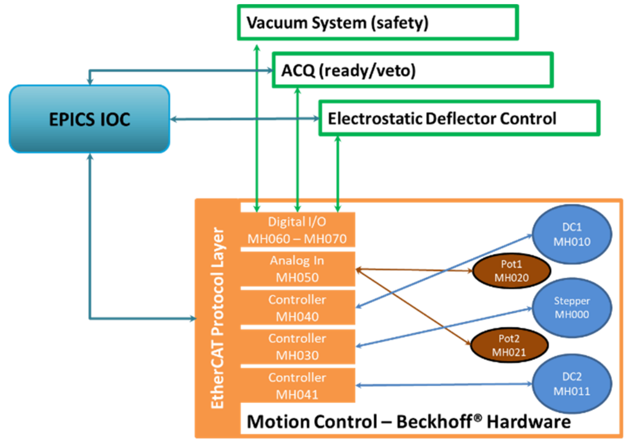

Figure 3: Global scheme of a single STS.

of the other subsystems are kept independent and there is no need for real-time software communication.

The logic already developed and used in IPN (Figure 4) is used as starting point for the new algorithms required to integrate and control all these sub-systems; the schema defines different parallel processes provided by the application, where the user can configure the setup according to the experiment's requirements. For example, the system can be set in order to automatically or manually change the rotation direction of the tape, using different velocity profiles according to the initial configuration.

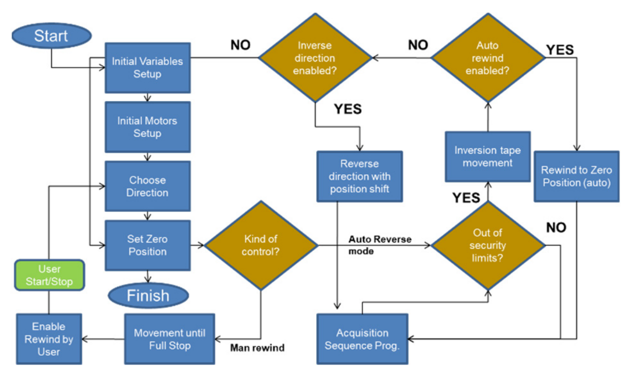

Figure 4: Logic designed to control the motor system for the actual STS.

For the human-machine interface, Control System Studio (CSS) application is chosen because it is the standard tool used to realize all the control system interfaces for all the systems and apparatus controlled in EPICS in the SPES project.

MOTION CONTROL PRELIMINARY DESIGN AND TEST BENCH

The motion system is a crucial part of the entire STS control apparatus because it has to guarantee specific characteristics and features in terms of tape velocity and position precision. As consequence, the campaign of hardware and software upgrade must be verified and the solutions adopted validated.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA097

For this reason, a preliminary test bench (Figure 5) has been realized with the double objective of:

- Verify the set of hardware chosen by LNL and iThemba accordingly to the specification provided by IPN.
- Verify the low-level EPICS software required to communicate and control the hardware chosen for implement the tape station.

Under software aspect, the solution designed for the motor control is based on EtherCAT bus: initially developed by Beckhoff® [5], this protocol is an Ethernet-based fieldbus system and is suitable for both hard and soft real-time computing requirements in automation technology reducing hardware costs. At the same time, the EPICS layer has been built from Etherlab [6] device driver and Diamond Light EPICS EtherCAT master support [7].

The test bench is a single EtherCAT slave I/O system populated with all the modules required to:

- Communicate to the EtherCAT master (the main server where the EPICS applications run)
- Control the stepper motor and the two DC motors
- Read the potentiometers' position used to verify the tape tension

More than that, different basic modules devoted to provide Digital I/O have been selected in order to guarantee an additional degree of freedom to the system (in case additional signal must be interfaced).

Results coming from the tests performed using the test bench let us to validate the proof of concept (hardware selection and software design): the entire set of Beckhoff® modules chosen for the tape station was fully controlled under EPICS and, as consequence, every single device (stepper and servo motors, potentiometers, encoder, etc.) is completely interfaced into the EPICS framework.

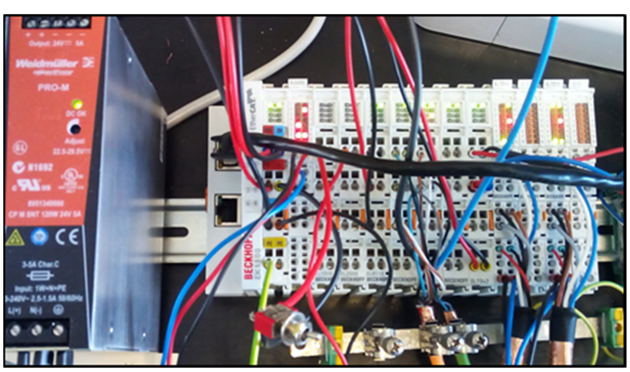

Figure 5: Test bench actually available in LNL for testing the EPICS low lover software layer.

CONTROL SYSTEM TESTS PERFORMED

In collaboration with iThemba LABS, we were able to perform a set of tests directly connecting the control system hardware to a prototype of the Tape Station and control is through a dedicated Graphical User Interface (GUI) (Figure 6). This kind of tests were very important in order to verify and guarantee the minimum performances required by the scientists. Devices used and tested in this test bench were the ones which will be used in the final stage.

Figure 6: Tape Station setup for tests performed.

As previously mentioned, the tape system is based on the device used in IPNO-Orsay and it has been built by LNL workshop using the original draws provided by the French Laboratory. During the reverse engineering, some minor modifications have been done. As consequence, these tests were also important to verify the mechanical part.

The set of tests performed covers different aspects: basic EtherCAT communication, hardware performances, software functionalities and system performances. In particular:

- <u>Test on package lost:</u> EtherCAT packet loss can occur when multiple processes is processed by the CPU. In the original design, the EPICS application should run into the same machine providing control panels. Because of the usage of multiple applications, we discovered packet loss. The situation required a different dedicated server for the controller. After the software migration (checking the functionality was maintained), we observed the absence of packet loss into the EtherCAT communication;
- <u>Test on a dedicated test bench for required max speed:</u> we ran the stepper motor and the 2 servo motors at the maximum speed according of 3m/s to the requirements received from the mechanical experts. Tests performed let us achieve the nominal specifications and during these tests we observed no package loss;
- <u>Test on assembled tape station for achievable max speed:</u> we started by moving each motor independently at slow speed to ensure the direction of rotation and the readback from potentiometers were correct. Then we ramped up the motor speed at increment of 0.1 m/s while continuously optimizing the PID parameters. Dur-

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA097

ing this process, instability occurred as a natural consequence of the tuning. At the same time, mechanical tuning was required due to misalignment and parts not perfectly tightly. Once all the mechanical issues were resolved, we were able to reach the maximum specification speed required by design; more than that, we pushed the system to 4.5m/s;

- Test for positional precision and travel time in a typical experimental setup (implantation to detection): once the maximum speed was reached, we focused on optimizing the travel time and the relative speed profile taking into account a travel distance of 555mm, (distance between implantation and detection points, according to the mechanical draws). The optimization process required a fine tune of the PID and acceleration related to the stepper motor. According to the results obtained, the tape station can move required experimental distance in an average of 0.75s reaching a top speed of 2.1m/s and with a precision of 2mm;
- Test for positional precision for long tapes runs: we performed a long run of about forward and 25m back to 0. In this situation we found a position error of +20mm; this suggests the tape slip somewhere along the path so long run are not repeatable. With the actual setup, this is a limitation on the performance of the system and the relative implantation and detection.

CONCLUSION

The tape station is the first diagnostic system completely designed and realized from the scratch in EPICS for the entire SPES project. One of the most challenging point is the substitution of the actual hardware in use on a similar apparatus with a brand new one and, as consequence, providing the software required to control it. Results coming from the tests performed are promising, in particular for the debug made under software and electrical parts which let us achieve the project requirements, keeping in mind the necessity of partially modify the mechanics part.

The great collaboration among the Laboratories involved in this project has given the boost required to reach the preliminary goals in a very short time, and the actual results can confirm it.

REFERENCES

[1] SPES, https://web.infn.it/spes
[2] SPES EPICS, https://web.infn.it/epics
[3] Etilé *et al.*, *Phys. Rev. C,* vol. 91, no. 9, p. 064317, Jun. 2015, doi:10.1103/PhysRevC.91.064317
[4] EPICS, https://epics-controls.org
[5] Beckhoff®, https:/beckhoff.com
[6] Etherlab, https://etherlab.org/en/index.php
[7] Diamond Light Source EtherCAT, http://controls.diamond.ac.uk/downloads/support/ethercat/