# ISHN ION SOURCE CONTROL SYSTEM OVERVIEW

M. Eguiraun*, I. Arredondo, M. Campo, J. Feuchtwanger, G. Harper, S. Varnasseri,
ESS Bilbao Consortium, Spain
J. Jugo
University of Basque Country, Spain

*Abstract*

ISHN project consists on a Penning ion source, which will deliver up to 65 mA of H- beam pulsed at 50 Hz, with a diagnostics vessel for beam testing purposes. The present work summarizes the control system of this research facility. ISHN consists of several power supplies for plasma generation and beam extraction, including auxiliary equipment and several diagnostics elements. The control system implemented with LabVIEW is based on PXI systems from National Instruments, using two chassis connected through a dedicated fiber optic link between the HV platform and ground. Source operation is managed by a real time processor, while additional tasks are performed by means of an FPGA. In addition, the control system uses EPICS Archiver and Hypertable database for data logging. The integration of EPICS into the control system is done by deploying a Channel Access Server in the PXI Controller,.

## INTRODUCTION

The ESS-Bilbao (ESSB) light ion linear accelerator has been conceived as a multi-purpose machine, useful as the core of a new standalone accelerator facility in southern Europe [1]. The project aims to develop significant capabilities needed to support the country participation in a good number of accelerator projects worldwide. In this context, the designed accelerator should serve as a benchmark for components and subsystems relevant for the ESS project as well as to provide experience on power accelerators science and technology.

In this context, the development of a front-end test stand for ion sources will allow ESSB to test, develop and optimize ion sources and their working parameters. Currently, a modified penning ion source on loan from ISIS is being tested [2]. This project serves several goals. It generates experimental data that can be contrasted with simulations and it serves as test stand for control systems and hardware (data acquisition, diagnostics, etc.).

A penning type ion source is operated applying a pulsed discharge periodically ($800\mu sec.$, $30A$) to source's cathode, generating a mixed plasma of Hydrogen gas and Caesium vapor. Hydrogen is delivered applying a pulsed voltage to a piezovalve for $250\mu sec.$, and its voltage is automatically controlled for maintaining a constant pressure in the plasma chamber. Once the plasma is stabilized ($\sim 500\mu sec$ later), a pulsed extraction voltage is applied ($300\mu sec.$, $12kVolt$) generating an $H^-$ beam. This pulse diagram is repeated at $50Hz$, see Figure 1. In order to accelerate the beam, the platform high voltage power supply usually runs at $35kVolt$. In addition, a continuos power supply ($600V$ and $2A$) is needed for conditioning ion source's electrodes. This power supply is only used in the beginning of the operation. The main devices required for source operation are listed in Table 1

* $meguiraun@essbilbao.org$

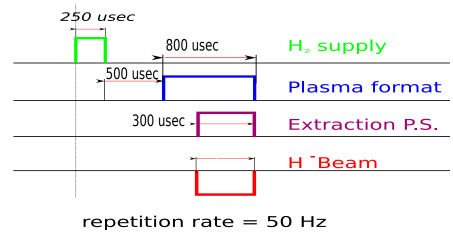


Figure 1: Pulse diagram for beam generation.

Table 1: Main Devices for Ion Source Operation.

| *Utilities* | *Plasma creation* |
|---|---|
| $Cs$ Heaters | DC Power Supply |
| $H_2O$ Refrigeration | Pulsed Power Supply |
| Air Refrigeration | $H_2$ Piezovalve |
| Vacuum pumps and sensors | |
| *Beam Extraction* | |
| Extraction Power Supply | |
| High Voltage Platform Power Supply | |

Once the beam is extracted, it goes through the so called diagnostics vessel, Figure 2 picture. The first diagnostics are the current transformers (ACCT and DCCT). Then, a quadrupole focuses the beam and a dipole is used for obtaining information about the degree of stripping and beam species components. The least beam diagnostics are a Faraday Cup for measurement of beam current, a Retarding Energy Analyzer for energy spread analysis, and, finally, a pepperpot device for obtaining emittance values. These devices, cannot be activated simultaneously and are also used as beam stoppers.

The control system is in charge of all of these elements, ensuring its correct operation and granting safety for both personnel and machine. In the following section, the architecture of the system will be explained, extending the information of [3].

## CONTROL SYSTEM OVERVIEW

The control system architecture can be observed in Figure 3. Due to the high voltage in the platform, the main

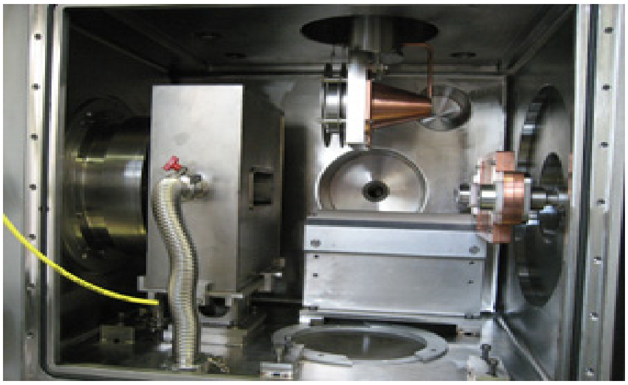

Figure 2: Diagnostic devices: from left to right, ACCT and DCCT (not visible), Quadrupole, Dipole, Faraday Cup, RPA (behind) and Pepperpot grid.

system is divided into two control subsystems, located at ground and at the platform, respectively. Each area has its own operator panel, allowing the operation of the ion source from both control desks, but not simultaneously. However, continuos monitorization and data logging of the status of the system is always active in the both panels.

The control system architecture for source operation and data acquisition is mainly based on hardware from National Instruments. Two PXI (PXI-1042Q and PXIe-1065) chassis are used, one at ground and other at platform. They are linked with a dedicated MXI fiber optic card from same vendor, and therefore, the two-chassis system can be treated as a single element from the point of view of the control designer.

The chassis located at ground contains a Real Time controller programmed in LabVIEW. It manages Cesium boilers' and pressure's control loops, some data acquisition through other PXI cards and the FPGA and communication with the operator's control desk using shared variables. It also communicates with some power supplies by Modbus/TCP and GPIB and pressure sensor by serial protocol link. In addition, the EPICS server is deployed in this device.

On the other hand, the FPGA located on the HV platform controls diverse elements. It manages the pulse signals for plasma power supplies and $H_2$ supply, generating the pulse diagram of Figure 1. In addition, it manages some safety signals from and to plasma power supplies and controls several electrovalves for gas supply and refrigeration of the ion source. Being the only card with signal acquisition capabilities in platform, it is in charge of acquiring voltage and current waveforms from plasma generation power supplies. Furthermore, it also measures gas flow rate, temperatures of the ion source and some other standard parameters.

As there are two operator panels, the code should avoid data overwriting between both monitorization applications. Therefore, two mode of operation are defined: local and remote.

All the code has been programmed in LabVIEW: the Real Time application, the FPGA and both monitorization programs.The main operator panel runs in a Linux environment. This is recommendable since the necessity of the EPICS archive engine.

In addition to the main controllers, a Twido PLC manages the operation of the vacuum system, which consists of two mechanical and two turbomolecular pumps. The advantage of this modular solution is to have the ability of performing stops and upgrades of the main control system without disturbing vacuum operation. This is very important in the commissioning phase, where adjustments of diverse elements and minor changes of the control system are usual. Moreover, a modular control approach leads to the possibility of reuse code and proposed control solution in other projects.

Two safety PLCs from PILZ located in both cabinets ensures safety during operation. The one located at ground handles several safety sensors (doors, grounding arm status, ...) and ensures that power supplies only receive electrical supply if safety environment is guaranteed. The safety PLC located in the platform handles the signals related to the $H_2$ supply and the electrical power supply of the $Cs$ heaters. If any problem is detected or if the emergency stop is pressed, safety system shutdowns high voltage power supplies.

The fiber optic link is used for ethernet communication, and the real time controller, both monitor panels, plasma power supplies, PLCs and some other noncritical devices are attached to this network.

The following sections will briefly explain the main changes that have been implemented in the last upgrade. The most important one is the addition of an EPICS server to system, along with a new data logging system, based also in EPICS. Finally, the timing system is explained.

### *EPICS Integration*

With additional minor improvements and modifications in current control system, an EPICS server has been implemented. It is based on the implementation by National Instruments (LabVIEW DSC module), and runs on the real time system in the PXI controller. As the first version of the program was a pure Labview implementation, some parameters of the control system are left out from EPICS server, for example some PID gains. The parameters that are published via EPICS are mainly for system configuration and machine operation, along with data acquisition variables, resulting in 65 Process Variables. The current implementation lacks of several critical capabilities of PVs such as alarm handling and extended field support. For that reason, EPICS server is used just to communication, without the full functionality that an IOC provides.

The Real Time controller publishes those PVs taking data from LabVIEW's Shared Variables, but since the main operator panel runs on Linux (there is not support for SV on Linux), this program must read and write data directly

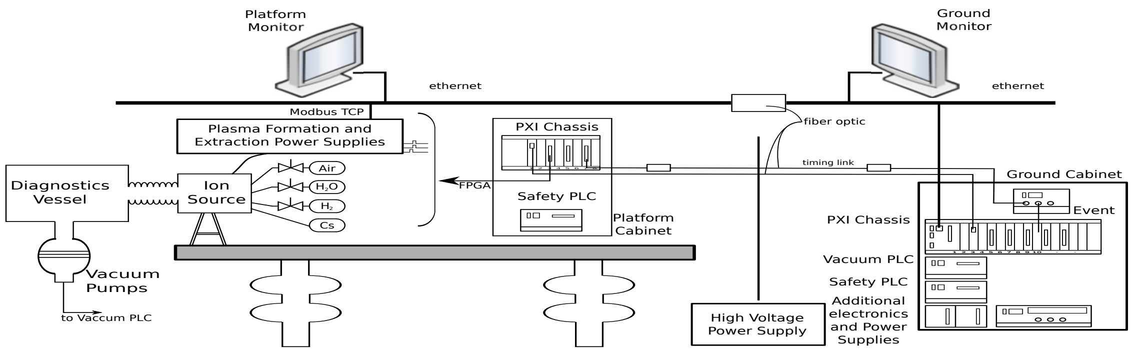


Figure 3: Control System Architecture.

from and to EPICS PVs. For that purpose CA Lab LabVIEW library is used [4]. It provides some vi-s for interfacing EPICS and LabVIEW and can be compiled for a Linux environment.

An alternative to NI approach is the one presented in [5], a pure CA server implementation in LabVIEW. It is under development but once released it will be tested to check if it fulfills the control requirements as presented in this work.

### *Data Archiving*

As far as the database architecture is concerned, it was decided to keep the MySQL schema provided by the ArchiveEngine utility [6], an EPICS ChannelAccess client. Using this client, any channel served by any ChannelAccess server can automatically saved to a relational database, like MySQL or Oracle. In present case, Hyperachiver, a customized version of the RDB Archiver, and HyperTable, as an alternative database to MySQL or Oracle, are used. This has been developed at INFN laboratories at Legnaro (Italy) and modified in ESSB to fulfills ISHN project requirements. Since this database choice requires a linux environment, the current implementations is running on Fedora14.

PVs of array type are stored every $5sec$, the rest of the variables at $1sec$ except the ones that are recorded only on changes. This gives a total amount of data around $100MB/hour$. A graphical user interface was developed in python at ESS-Bilbao in order to have at disposal a simple data visualization tool, lighter than CSS and, as it was proved by the tests' results, faster than CSS Data Browser, which had already been used by people at INFN/LNL.

### *Timing System*

An independent high resolution synchronization system has been designed to generate timing for triggers of plasma generation and extraction as well as data acquisition for beam diagnostics. The current design is based on commercial devices. A master event generator located at ground cabinet produces two event signals at $50Hz$. One needed in ground PXI to trigger data acquisition for beam current transformers and Faraday Cup, and the other one to trigger the generation of pulses for the plasma formation power supplies, passing through electrical-optical converters. On each chassis there is a stable and precise dedicated timing card (PXIe-6672 and PXI-6651) which receives the event signal and routes it to a PXI Trigger line. Then, a DAQ card at ground and the FPGA inside the chassis of platform starts data acquisition and pulse generation, respectively. The approximate delay of the signal due to the optical-electrical converters and the difference in cable length is around $100nsec.$, which is compensated in the event generator configuration.

## FUTURE WORK

The ISNH control system is under development in various aspects, as for example the timing system. Some delay cards (Green Field technology GFT-9404) are being tested in the laboratory, but the lack of LabVEW Real Time support prevents for its usage in the facility.

In addition, full features of EPICS will be implemented, by means of a different implementation, or by deploying an extra IOC in the host computer. The most interesting features are first, the alarm handling through the so called alarm server and its operation in Control System Studio. Even if it is not required at this development stage, the EPICS gateway and nameserver are also interesting features to be implemented.

## REFERENCES

[1] ESS-Bilbao home page, http://essbilbao.org

[2] D. C. Faircloth et al., "The Front End Test Stand High Performance H- Ion Source at RAL", Review of Scientific Instruments, Volume 81, Issue 2, 2010.

[3] M. Eguiraun et al., "ISHN Ion Source Control System Overview and Future Developments", Proceedings of IPAC' 11, San Sebastian, Spain Sep. 4-9, 2011.

[4] CA Lab, http://www-csr.bessy.de/control/SoftDist/CA_Lab/

[5] A. Zhukov et al, "EPICS Channel Access Implementation in LabVIEW", Proceedings of ICALEPS'11, Kobe, Japan, octuber 12-16 2009.

[6] M. del Campo et al., "EPICS HyperArchiver: Initial Tests at ESSBilbao", Proceedings of IPAC' 11, San Sebastian, Spain Sep. 4-9, 2011.