OVERVIEW OF THE NEW HIGH LEVEL SOFTWARE APPLICATIONS DEVELOPED FOR THE HIE-ISOLDE SUPERCONDUCTING LINAC

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Abstract

The High Intensity and Energy (HIE) ISOLDE project consists of an upgrade of the ISOLDE facility at CERN. With the installation of 32 independently-phased, superconducting (SC) quarter-wave resonator cavities the energy of post-accelerated radioactive beams (RIBs) will be increased from 3 MeV/u to over 10 MeV/u. The large number of cavities will increase the number of parameters to optimise. In order to ensure a fast set-up of the machine during operation and commissioning, new software applications have been specially developed for the SC linac. The first allows the conversion of optics settings into machine settings, and vice versa. The second will aid the phasing of the cavities using beam energy measurements. The last application will automatically generate the phase and the voltage settings for the cavities in the SC linac. In this contribution we will present the new application and how the HIE-ISOLDE controls are integrated with the CERN control system.

INTRODUCTION

The HIE-ISOLDE project represents a major upgrade of the ISOLDE facility at CERN. It focuses on the installation of a 40 MV superconducting linac, comprising 32 niobium sputter-coated copper cavities, operating at 101.28 MHz. The energy of the post-accelerated beam will increase to over 10 MeV/u, when the installation is completed. A layout of the HIE-ISOLDE installation, including the chopper line and the six cryomodules can be seen in Figure 1.

The new machine will be fully integrated in the CERN control system. An upgrade of the existing software is necessary, as well as the development of new dedicated applications related to the superconducting part. Three applications are now ready to be tested and, in addition to this, a fourth application, now under study, will provide a tool to help phase the cavities by means of time-of-flight (ToF). This work will mainly focus on the new applications developed for the SC part of the machine, after an introduction to the CERN control system and the tools that it contains.

The vacuum and cryogenics controls will not be discussed. Their development belongs to the Vacuum and Cryogenics groups respectively. Only monitoring will be allowed for the cryogenics, while for the vacuum an "operator mode" is foreseen, which will allow operators to accomplish small changes to the vacuum status of the machine.

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CERN TOOLS FOR HIE-ISOLDE

The accelerator complex at CERN includes several accelerators and hundreds of different devices, all remotely controlled. Therefore a strong and reliable control system is needed. The CERN control system is based on a so-called 3 tier architecture, see Figure 2.

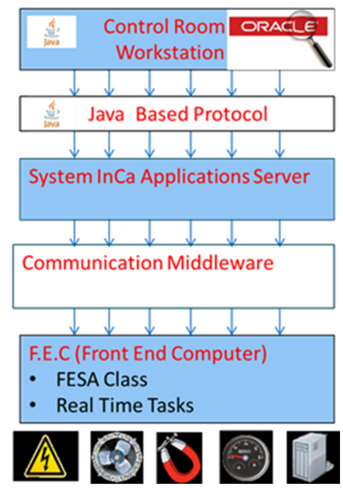

Figure 2: Three tier architecture

The first tier is the front end software application (FESA). FESA is a complete environment that provides JAVA based GUIs for the equipment specialist to design, test and develop their software [1]. A communication middleware developed in JAVA or C++ brings to the second level of the architecture: the InCA application server. InCA (Injection Control Architecture) aims at the homogenisation of the control system across the CERN complex [2]. In the top tier, running from the ISOLDE control room workstations one can find the GUIs made for generic applications, developed in JAVA by the Operation group, to control and observe the accelerator devices.

In order to support basic operation with the control system the CERN control group develops a handful of generic applications that allow runtime operation to be easily performed from any device. The ISOLDE facility mainly uses the following: Working Set (WS), Knobs, Timber, Inspector, Ramses.

The WS concept is a way to group devices together so that generic applications for display and acquisition can be viewed and controlled in a grouped way [3].

A knob can be seen as a set of properties that will be exposed via a generic viewer for a given device class/family name [4].

Timber is a tool that can extract time series data from multiple data sources simultaneously [5].

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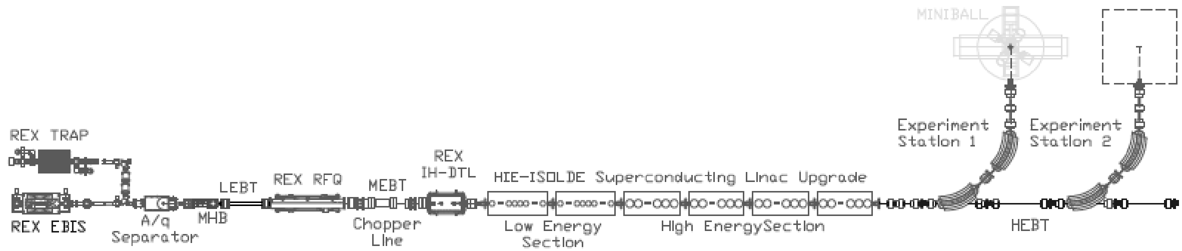

Figure 1: Schematic layout of the HIE-ISOLDE installation

The Inspector allows operators to build a sequence of devices they would like to control. It provides data logging, data history, and alarms [6].

Ramses (Radiation Monitoring System for Environment and Safety) represents the state of the art in radiation protection, according to the international standard IEC 61508 [7].

LOW ENERGY AND NC LINAC APPLICATIONS

This section describes the main applications used in the REX-ISOLDE charge-breeder and normal conducting (NC) linac [8].

- Control application of the REX-TRAP device, a gas filled Penning trap used for accumulation, bunching and cooling of the ion beam.
- Control application of REX-EBIS device, an electron beam ion source (EBIS) used to charge breed the isotopes produced at ISOLDE.
- Mass-Scan: creates a mass-scan of the EBIS extracted beam using the REX-ISOLDE separators magnets. Utility to identify the mass-to-charge ratio (A/q) before the injection into the NC-linac.

The HIE-ISOLDE machine will be installed downstream the REX-ISOLDE linac. Some applications already developed for REX-ISOLDE will also be used at HIE-ISOLDE, after the necessary software modifications. Those applications are:

- Equipment Array: allows the operators to visualise, change, recover and save settings from a list of devices. It also implements the possibility of scaling the settings according to the A/q ratio.
- Energy Scan: uses the dipole magnet after REX-ISOLDE linac as spectrometer to determine the beam energy. The magnet is calibrated with the RFQ beam at a fixed energy of 0.3 MeV/u. In the future time a time of flight system will be used for accurate calibration.

APPICATIONS DEVELOPED FOR HIE-ISOLDE

The large number of cavities envisaged for HIE-ISOLDE will ensure a high flexibility in terms of beam acceleration. On the other hand it will increase the complexity of the machine. Particularly the SC linac must be re-phased for each accelerated beam. In order to ensure a fast beam set up three applications and a new diagnostic has been developed. The following paragraphs introduce the new software tools.

HIE-ISOLDE Diagnostics

New beam diagnostic devices will be installed at HIE-ISOLDE. For beam current measurements the main device will be a Faraday cup, while a scanning slit and Faraday cup in combination will take the beam profile measurements. The possible use a silicon detector for energy measurement and for time-of-flight is also taken into account. A similar procedure is followed at TRIUMF for the ISAC II supercondcting linac. A high level Matlab application has been developed and tested over there [9]. A similar routine can be developed for HIE-ISODLE. The full specification of the diagnostics system can be found in [10]. The GUI of the new application has been developed following the skeleton of the REX-ISOLDE diagnostic application. Major operational tests will be conducted once the devices are installed.

HIE-ISOLDE Converter

The aim of the HIE-ISODLE Converter application is to allow the operators to convert machine settings to optics files, in order to visualise the beam envelope, and vice-versa. It will allow the operators to quickly evaluate a setting and check online where the beam might be mismatched. The optics program used to simulate the beam is TRACE 3-D [11], but it might convert also other beam simulation input file format in a future version. The machine settings are text file formatted according to the equipment array application file format. A full description of the algorithm can be found in [12]. First tests on this application have been performed with the REX-ISOLDE accelerator. Loading the theoretical setting and slight modifying them the transmission achieved was close to 80%.

From TRACE3D to Equipment Array File

This section shows the procedure used to convert TRACE 3-D files into machine settings. For brevity reason only the main elements type conversion is discussed here.

The field and gradient of the magnetic elements (quadrupoles, solenoids, and dipoles) are converted to the current control value (CCV) by means of calibration curves from magnetic measurements.

Three fields describe the normal and super conducting RF in the equipment array file: CCV amplitude (pick-up voltage), CCV phase (desired phase value) and synchronous phase.

To set those parameters for the SC RF the phase and the effective voltage of both gaps are taken (φ_1 , V_{eff1}) and (φ_2, V_{eff2}) from the TRACE 3-D file. The transit time factor (TTF) is calculated from the input energy in the first gap. The total voltage is calculated as follow:

$$\mathrm{V_{1,i}} = \frac{\mathrm{V_{1eff,i}}}{\mathrm{TTF_{gap1,i}}} \text{ and } \mathrm{V_{2,i}} = \frac{\mathrm{V_{2eff,i}}}{\mathrm{TTF_{gap2,i}}} \qquad (1)$$

Where i represents the cavity number. The total voltage is the sum of the two voltages (V_1 *and* V_2) for each cavity. The pick-up voltage that should be measured on the cavity is converted from the total voltage using a calibration implemented in the FESA class. The synchronous phase for each cavity is given by the average of the phase in the two gaps. The CCV phase is set to zero because it cannot be calculated from the Trace3D file.

From Equipment Array to TRACE3D File

The application can discriminate if the selected file belongs to a transfer line or to the linac. The energy at the beginning of the transfer line or the energy at the entrance of the SC linac will be input accordingly.

From the equipment array file the total voltage measured on the pick-up, expressed in MV, the synchronous phase and the CCV phase are given as input parameters.

The routine finds for each gap the phase that guarantees the maximum energy gain after each cavity. It will then use this phase in the first gap, after subtracting 20 degree, set this phase to calculate the voltage and phase in the second gap. This set of operations is then iterated for each cavity. The calculation of the effective voltage takes into account the TTF of each gap.

HIE-ISOLDE Phase Up

This application will allow the operators to manually phase up each cavity, by finding the maximum energy gain as a function of the cavity phase. It is also a tool to build a calibration curve between the accelerating voltages on the cavity measured with the beam, and the voltage measured on the cavity pickup.

The energy gain that the beam experiences in each cavity is assumed to be sinusoidal. At the end of the linac a calibrated bending magnet is used as a spectrometer. It is therefore possible to relate the phase in each cavity to the energy gain in terms of the measured magnetic field. Pairs of points of phase, magnetic field (φ, B) are fitted with a cosine function with three fitting parameters. From the fit the application will calculate the maximum energy gain, the phase of the maximum energy gain and the cavity gradient.

To build a calibration the phasing procedure should be repeated for different values of the field amplitude in the cavity. The energy gain is given by:

$$\Delta E = \frac{q}{A} V_0 T(\beta_i) \cos\varphi \qquad (2)$$

where $V_0\, T\, (\beta_i)$ is the effective voltage. From this information it is possible to calculate the total accelerating voltage as seen by the beam for each cavity and plot it as a function of the pick-up voltage, in case of the NC RF or total accelerating voltage calculated from the pick-up voltage fir the SC RF. The full algorithm can be found in [13].

HIE-ISOLDE Generator

The aim of the HIE-ISOLDE Generator application is to provide a tool that, given a few input parameters, will calculate the voltage and phases necessary on the superconducting cavities to meet the desired energy. The routine can be executed on line during set up and will allow the operators to quickly switch between beam and machine configurations. The following parameters, inserted by the user, are taken as an input: mass to charge ratio (A/q), input energy in the SC linac [MeV/u], desired output energy [MeV/u], voltage distribution among the cavities, and linac lattice. In order to perform the calculation some information like the transit time function as a function of beta or the field distribution in the cavities will also be taken from configuration files.

The application uses the information on the energy gain to update the energy value in a loop until the desired energy is reached. If the desired energy cannot be reached an error message will appear and the application will stop.

More information about the application can be found in [14]. Error tolerance required to automatically phase the HIE-ISOLDE linac are studied in [15]

CONCLUSION

Several tools have been developed and a general upgrade of the existing software has been carried out. The software needed for the commissioning has been identified and most of the codes' debugging has been done off-line. The applications are ready but the final commissioning will take place during dry-runs when the hardware becomes available and during beam commissioning.

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