

MAX IV ONLINE LINAC MODEL

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Abstract

An online linac model has been developed at MAX IV in order to enable a calculation of the properties of the linac beam based on the actual settings of the magnetic elements. The model is based on the Elegant simulation code and uses the design linac lattice file. A set of Matlab scripts fetch the actual settings of all elements via the Tango control system, pass these values on to Elegant and run the simulation. The model includes an optimization option for yielding desired beta- and alpha-function values at various points along the linac by calculating optimal settings for chosen elements.

INTRODUCTION

The MAX IV accelerator is a Swedish national light source presently under commissioning. The main components of the facility are a 3 GeV linac, a 1.5 GeV storage ring and a 3 GeV storage ring [1]. The linac is used both as an injector for the two storage rings and as a source of short electron pulses for the Short Pulse Facility. The linac design also includes the potential to function as a driver for a FEL and this option is presently being investigated in detail [2].

The linac consists of 39 warm S-band linac sections and 18 RF stations, each consisting of a 35 MW klystron and a solid state modulator. There is choice of two electron guns: one thermionic RF gun which is used for ring injections, and one photocathode RF gun which is used for the Short Pulse Facility operation. A schematic view of the linac is shown in Fig. 1.

The control system is based on Tango [3]. A large number of scripts, written both in Python and Matlab, have been developed for communicating with Tango and controlling various aspects of the machine.

In the control system, each magnetic element is represented as a unique Tango device. The magnet calibrations are incorporated directly in the respective Tango device, hence magnet settings can be specified either as power supply currents or in terms of the main magnetic field component (e.g. bending angle for dipoles, k-value for quadrupoles, etc.). The main magnetic field

component depends of course also on the beam energy at the particular element, hence the Tango device also includes an energy attribute. An example of a synoptic magnet panel is shown in Fig. 2.

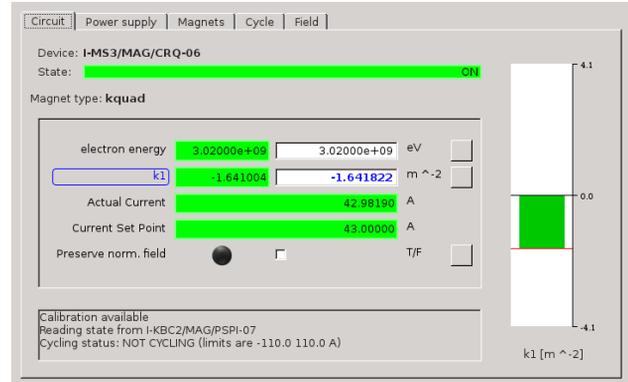


Figure 2: Example of a synoptic magnet panel showing the tab for input in terms of physics quantities (k-value and energy).

In order for the devices to report a valid main component, the beam energy must be well-known at each point in the linac. For this purpose a script has been developed which calculates the beam energy at each magnetic element. The script is based on the energies determined by the large bending magnets in BC1 and BC2. The energy difference between BC1 and BC2 is divided between the linac sections and weighted by the voltage squared of each modulator (this is a simplified model which, however, works reasonably well). In case the linac is run off-crest, the phase of each modulator is also taken into account.

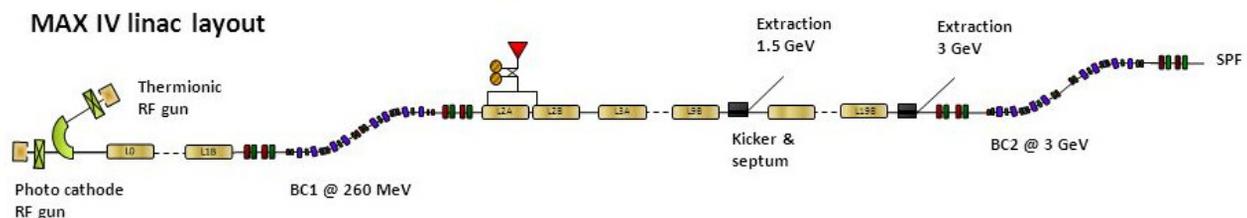


Figure 1: The MAX IV Linac.

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The linac was designed using the Elegant simulation code [4]. In order to be able to efficiently adapt the beam to different requirements, it is a big advantage to also be able to quickly obtain an Elegant calculation for the actual settings of the machine, and be able to get an Elegant prediction of the optimal settings of the linac elements for obtaining certain desired beam parameters. For this purpose, an online linac model has been developed.

The online model is implemented as a set of Matlab scripts through which the communication between the machine and Elegant passes and is controlled.

The communication between the machine and Elegant is simplified by the fact that the physics quantities needed for Elegant input are directly obtainable from the Tango devices. Hence there is no need for any further conversion between machine quantities (such as power supply currents) and physics quantities (such as k-values). Access to the machine parameters from Matlab is very straightforward using the Matlab/Tango bindings.

Starting Values

Space-charge effects are not included in Elegant which restricts its range of applicability to energies above ~100 MeV. For the MAX IV linac model, this implies that the linac components up to and including the first linac section can not be included in the model. The model therefore has to be supplemented with a measurement of beta- and alpha-values at some point along the linac, to be used as starting values. These parameters can be measured at four points along the linac: at the three matching sections and at the beginning of the SPF section. A GUI, shown in Fig. 3, has been developed for performing the measurement of the Twiss parameters using the conventional quad-scan method [5]. In addition to the Twiss parameters, the quad-scan also yields the beam emittance.

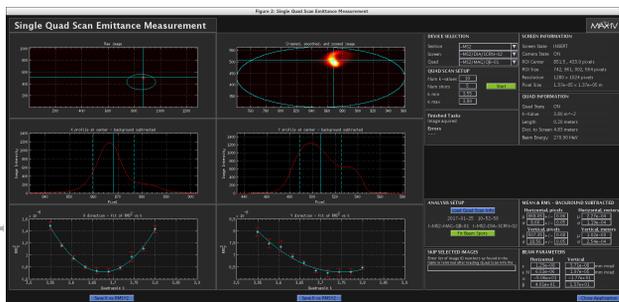


Figure 3: GUI for measurement of Twiss parameters using the quad-scan method.

The Elegant calculation can be performed equally well in the backward direction as in the forward direction. Hence, the measured starting values for beta and alpha at any point in the linac will yield the beam parameters along the entire linac.

Running the Script

The user interface for the online linac model is shown in Fig. 4.

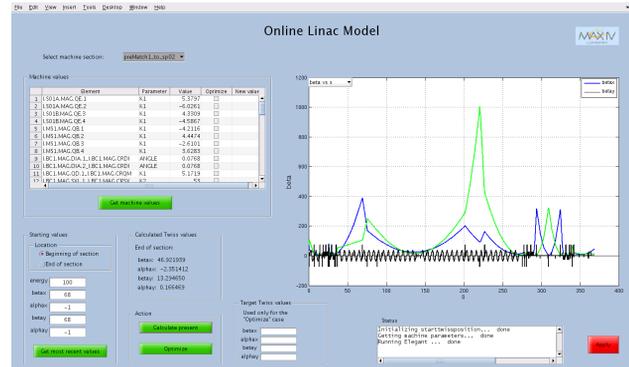


Figure 4: Online linac model GUI.

After selecting the desired part of the linac for which to perform the calculation, the actual settings of the relevant elements are fetched from Tango using the command *tango_read_attribute* from the Matlab/Tango bindings. A new Elegant command file is then created and the actual element settings are specified using the *alter_elements* command for each element. Elegant is subsequently invoked through a system command and is run using the newly created command file and the design linac lattice file.

The result of the simulation is saved in the form of SDDS-files from which the desired parameters (e.g. beta- and alpha-values) can be easily extracted. A simple Matlab script has been written for extracting the beta-function and the dispersion along the linac and displaying these functions for the chosen part of the linac.

The fetched machine values are displayed in a table in the online linac model GUI. This table is editable, which means that values can be modified before invoking Elegant for the calculation. Hence, the effect on the beam from modifications of element settings can easily be tested before applying the changes to the real machine.

Optimization

The model includes the option of letting Elegant calculate optimal settings for a chosen set of elements in order to achieve desired values of beta and alpha at any of the three matching sections or at the beginning of the SPF section. Elements to be optimized are selected in the element table in the GUI, and the desired beta- and alpha-values are specified. Choosing the optimization option then adds the Elegant *optimize* command to the command file before invoking Elegant. The optimized element values are then shown in a new column in the element table, and the new beta-function is displayed in the graph in the GUI together with the old function.

A common situation is that the beam parameters desired to be adjusted are the same as the parameters providing the starting values. In this case a backward calculation extending to the beginning of the particular linac part is first performed. The calculated values at the beginning of

the part are then used as starting values for a forward optimization calculation.

STATUS AND OUTLOOK

The online linac model is presently in a testing phase and has not yet been used in routine operation. Preliminary tests show quite reasonable results, however, and indicate the usefulness of the approach. In the near future the model will be extended with further features, e.g. the possibility to specify desired beta- and alpha-values at any point in the linac (not only at the three matching sections or the beginning of the SPF section). The possibility to specify a desired dispersion will also be added.

Another feature to be added is the calculation of response matrices for chosen corrector/BPM sets. Response matrices are used by the linac trajectory-

correction script which is running in routine operation to keep the beam trajectory stable. At present, the response matrices are measured, which means that a certain amount of noise is inevitable. It is possible that calculated response matrices may yield an enhanced performance of the trajectory correction.

REFERENCES

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