# EFFECTIVE CYCLING AND RAMPING

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*Abstract*

The National Synchrotron Radiation Centre Solaris, Krakow, Poland has been successfully built in collaboration with several institutes and organizations. The MAX IV Laboratory, Lund, Sweden and Elettra-Sincrotrone, Trieste, Italy, are the most important synchrotron partners. Solaris has built, as an adaptation of MAX IV, 1.5 GeV storage ring and linear accelerator based on the same components, therefore the device server for the magnet circuit has been developed by MAX IV. Ramping was included in expert consultancy services contract won by Elettra-Sincrotrone. Solving problem with the power supplies stability and thanks to snapshots usage as steps for the ramping it was possible to ramp the beam without losing current linearly.

## INTRODUCTION

The Solaris synchrotron is an adaptation of the 1.5 GeV synchrotron ring of MAX IV (Fig. 1), the new synchrotron facility in Lund, Sweden, and a result of the collaboration between Jagiellonian and Lund Universities. The facility is constructed with a linear accelerator injector and a 96m storage ring with 12 identical Double-Bend Achromat (DBA) cells (Fig.2) and 12 straight sections, where the future beamlines will be installed.

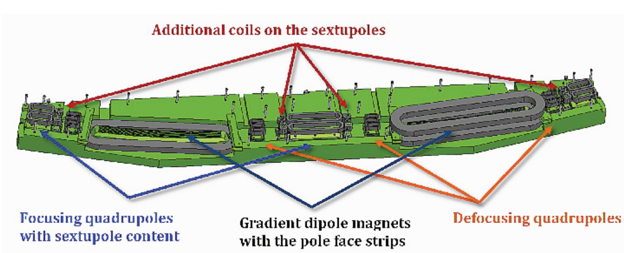


Figure 2: The lower part of the SOLARIS storage ring magnet, length: 4.5 m, weight: 4t.

In this unique and novel design, all of the magnetic functions of one cell are combined in one monolithic iron block. The integrated design enables a much more compact beam, which again enables smaller magnets, smaller power supplies and a smaller facility.

Solaris is currently commissioning the UARPES beamline that will deliver the synchrotron radiation from undulator in the range from 8-100 eV to the research instruments of the first scientific users [1-3].

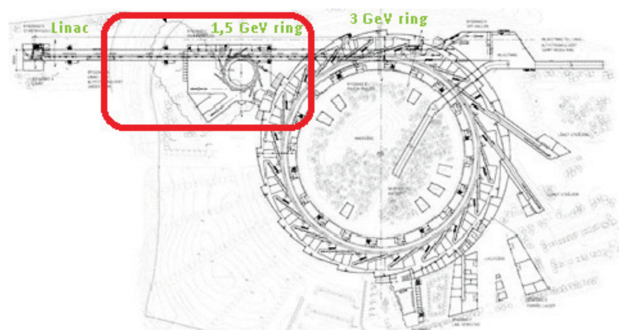


Figure 1: Sister project of MAX IV

## CYCLING

### *Magnet Cycling*

A single power supply drives one or more magnets. A magnet circuit device exists to make the association between magnets and power supplies, even if in many cases there is a one-to-one correspondence (such as for the corrector magnets).

The magnet Tango devices are read-only devices. The control of the field is via the circuit device. The steering parameter depends on the type of magnets on the circuit; for example, for a circuit of quadrupoles it is k_1. When the user requests some k_1 value, the circuit device computes the necessary current and writes this to the power supply Tango device. The magnet devices then show their individual fields based on the current from the power supply they are associated with.

In Max IV 3 GeV ring, some magnets have trim circuits, which means that one physical magnet may have both a main coil circuit and power supply and a trim coil circuit and power supply associated with it. The trim coil circuit can operate in different modes, selected via the switch board device. A magnet with a trim circuit will show the vector sum of the main coil and trim coil fields.

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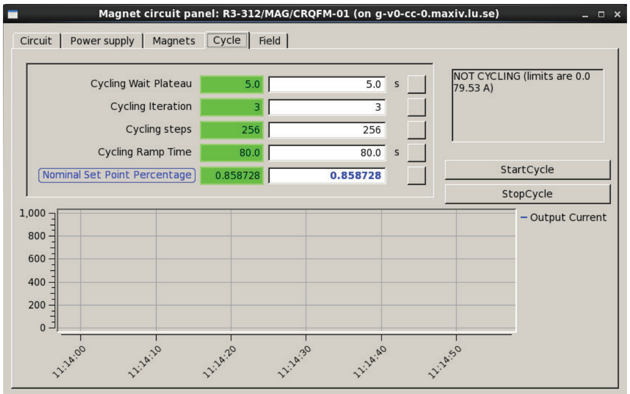


Figure 3: The cycling tab of magnet circuit panel

The cycling procedure is as follows:

1. Set current to 0 using ramp.
2. Once current read-back reaches 0, wait 5 seconds.
3. Set current to maximum allowed by the power supply (PS) device using ramp (i.e. 110% of nominal, or max that the PS can give).
4. Once current read-back reaches max, wait 5 seconds.
5. Repeat *n* times.

The cycling is implemented as a state machine in the magnet circuit device. The current limits are taken from the power supply devices which are configured with limits beyond which the PS should not go, corresponding either to 110% of the nominal field or to the maximum of the power supply, whichever is lower.

Current increase/decrease value at each ramp steps, and waiting time between them (Fig.3), are defined using read/write device tango attributes. Attributes values cannot be set when cycling is *On*.

Number of iterations and nominal current (as percentage of max current) can also be configured as tango attribute.

The operator can customize value that cycling device sever will set on power supplies.

### *Magnets, Magnet Circuits and Power Supplies*

In some sections of the Linac one magnet is driven by one power supply but in others several magnets are on the same circuit driven by a single power supply (Fig.4). For this reason, the magnet circuit devices are introduced, and these are used everywhere even if there is a 1 to 1 mapping between magnet and power supply. In the Linac there may be a few magnets on the same circuit but for the rings it can be in the order of hundreds. The circuit devices are used to control the fields by changing the current on the appropriate power supply and the magnet devices themselves provide read-only information on the fields.

The properties of the magnet circuit devices specify the "parent" power supply device and the "child" magnet devices. The magnet devices have properties that give the parent magnet circuit device. These mappings are used in the synoptic panel to bring up the appropriate circuit or power supply graphical user interface (GUI) when the user selects a certain magnet. e.g. if you select any of n magnets on one circuit, you will get the GUI for that circuit and corresponding power supply; changing the current will affect all magnets on that circuit [4-5].

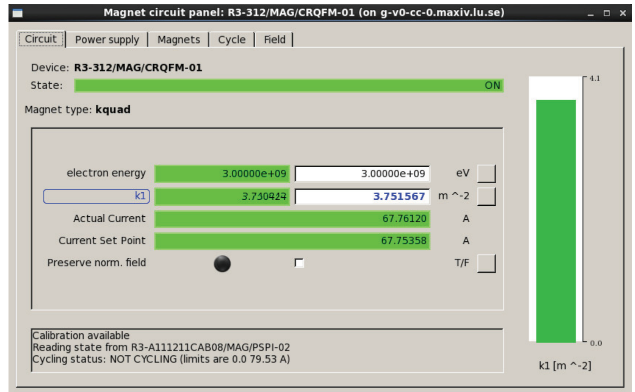


Figure 4: Circuit tab of magnet circuit panel

## RAMPING

### *Ramping Device Server*

The ramping Device Sever (DS) is a tango device server which is able to perform synchronized ramps of configured r/w attribute values. The DS is a multiclass server (Fig.5):

1. RampingClass: this class implements all attributes/commands related to the ramping master process. The ramping master process is in charge of calculating, synchronizing and eventually manipulating (linearization, speed modulation) of the ramping values. The ramping master server provides the time base (master tick) to the ramping system. An internal omnithread, which run at a programmable frequency, unlock/lock the execution of hardware (HV, i.e. power supply) setting by means of two different mechanisms: the omni condition variable or a simpler but less efficient busy loop.
2. RampingDeviceClass: this class implements a sort of virtual device, which stays between the ramping master device and the HV tango device (i.e. power supply tango device). These devices are in charge of connecting/monitoring/logging the communication with the tango devices that have to be ramped. At every ramping calculation, the master device transfers a table of two columns to each ramping device; the first one contains the master tick values at which the HV tango device has to be set, the second column contains the corresponding setting values. Each ramping device implements a thread which is unlocked at every ramping master tick: if the master tick corresponds to a tick in the table then the ramping device set the HV tango device attribute.

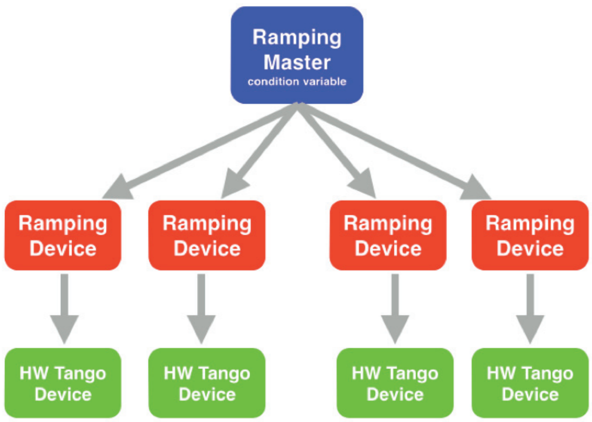


Figure 5: Ramping architecture

### *Ramping Calculation*

The ramping calculation process is split in 4 phases. The first two phases are mandatory, whereas the last two are optional:

1. The ramp values of each device between two SNAP records are calculated in order to have the maximum speed (according to max slope, max step, min set time). Depending on the SNAP record values some ramps could finish earlier than others, which is unwanted. Therefore the phase 2 is mandatory.
2. The device which takes more time than the others between two SNAP records is identified. The ramps (between the two SNAP records) of all the devices are "stretched" in time to last as the slowest one. This operation is done for each ramping segment (ramping segment = ramping values between two SNAP records).
3. It is possible to define a device (among the ones defined in the ramping system, (i.e.: the bending magnet) which requires a constant slope through all the SNAP records. The ramping segment (of the selected device) with the lowest slope is identified. To have the same slope as the slowest one the remaining segments are "stretched" in time to have the same slope. In this way a constant slope is guaranteed all along the whole ramping. At the same time the segments of the other devices are stretched in the same manner to guarantee the same execution time of all the ramps. Before linearizing the ramp of the selected device, the user must be sure that the slope between all SNAP records is all positive or negative otherwise the linearization process will return an error.
4. It is possible to arbitrarily modulate the ramping speed by dividing in periods the total time required by the ramping process, and defining the speed of each of them. For each period the ramping speed is adjusted using a multiplicative factor [6].

## CONCLUSIONS

There are still some issues to consider in MagnetCircuit device server regarding the cycling. For example, dipoles, the bending angle theta does not correspond to the first element in B. The bending redefines the coordinate system therefore Bi is actually zero. However, there is a non-zero quadrupole component. For the time being, theta may appear (incorrectly, not least in terms of units) in the field vector. Next, if the power supply has no range set on the current, the magnet circuit device will not start. This may in fact be useful, since the range of k1, etc., and the ability to do cycling depends on the current limits being set. Furthermore, interplay between setting device status (from the power supply status) and the cycling status (from the cycling state machine) should be refactored [7].

At the start of the commissioning, during first tests of ramping there were some problems with the power supplies stability and problems with accumulation. After resolving those problems, it was possible to ramp the beam making some snapshots in between. Snapshots were regularly improved and after a set of tests there was around 8 intermediate steps included in ramping procedure. Unfortunately, at high beam current there was some beam current losses. After precise investigation of the topic, the nonlinear optics at 500 MeV was not the right one with the ramping running close to the unstable solution with chromaticity close to 0 and – 1. Once the optics was changed to have higher chromaticity the ramping from 517MeV to 1.5 GeV was possible with only one snapshot. Finally, it was possible to ramp the beam without losing current linearly.

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