# COMMISSIONING OF THE ELECTROMAGNETIC INSERTION DEVICES AT SOLEIL

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*Abstract*

SOLEIL is the French 2.75 GeV third generation synchrotron radiation light source. Eleven undulators are installed yet in the storage ring and nineteen more Insertion Devices (ID) will be installed in the ring by January 2010. Among the installed IDs, there are four electromagnetic undulators of two different designs: one 640 mm period air coil undulator called HU640 [1] and three 256 mm period undulators called HU256 [2], made up of independent H yoke dipoles. The HU640 provides photons in any polarisation from linear to elliptical, in a range extending from 5 to 40 eV, thanks to three different groups of coils powered independently. The HU256, which are subject to hysteresis, provide horizontal and vertical, periodic or quasi-periodic linear polarisations, and also circular polarisation, covering a energy range from 10 eV to 1 keV.

The effects of each undulator on the closed orbit have been extensive studied, and compensated, using dedicated embedded steering coils. The correction method is explained and its results are shown. Finally, the first measurements of the radiation produced will be shown and compared to previsions.

## CORRECTION METHOD

The correction of the closed orbit distorsion (COD) resulting from magnetic defaults of the ID is realized for each undulator by a Feedforward system: the correction, based on e-beam measurements, is calculated in advance considering the state of the undulator, and applied using the own steerers of the ID, independently to the storage ring.

### *Correction for a Given Magnetic State*

For one configuration of the ID, the closed orbit is measured by the Beam Position Monitors (BPM) and compared to the undulator off-state. Knowing the efficiency of each of the four steering coils placed in both horizontal and vertical planes, at the entrance and the exit of the ID, the steering coils currents needed to correct the two orbits are calculated, checked and stored in tables. The difficulty lies in the fact that the orbit must be corrected for all configurations of the undulator. Both measurements of orbits and driving of the power supplies are performed using Matlab™ fully interfaced with the TANGO control system [3].

### *Basic Linear Cycle Correction*

Taking into account the hysteresis, the correction strategy consists in considering separately the different ways to supply the undulators according to the polarisation of the emitted radiation. The basic case is linear polarisation, for which magnetic field is produced in only one plane. In this mode, for example horizontal linear (LH) corresponding to vertical field, one needs to cover the whole hysteresis cycle always **by the same magnetic path** when changing the main supply current of the insertion, in order to achieve a good reproducibility of the magnetic state of the undulator, i.e. of both field peaks and integrals. As shown in figure 1, one can directly change the main current from point P to point M, but going from M to P makes it necessary to go through A and B. This is the only way to ensure precisely the effects of the undulator on both emitted radiation and electron beam versus main current. The off-state of the undulator is chosen as follow: main current to zero on the upeer branch of the hysteresis cycle. Although radiation is collected for experiments only when the magnetic state is on the falling side of the cycle (in order to achieve reproducibility of photon energy), it is needed to correct also for the COD among the lower branch, as the whole cycle will be covered. The result is a table of correction current values versus main current, different according to the branch of the cycle. After several cycles, a good stability on correction is achieved and both vertical and horizontal orbits are kept within 3 µm peak-to-peak. The same thing can be easily done for vertical linear polarisation (LV).

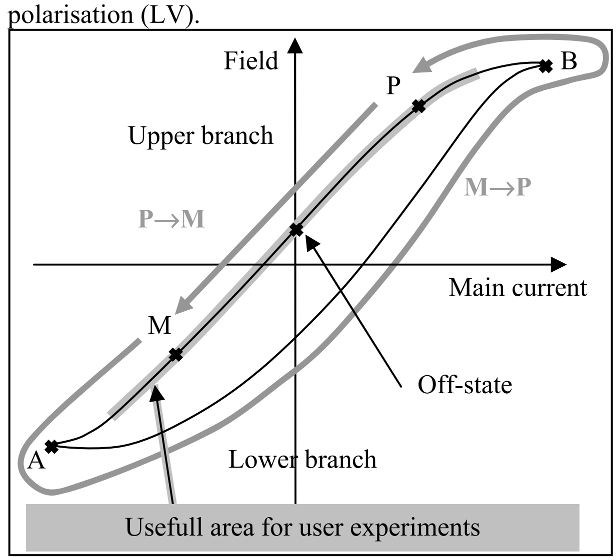


Figure 1: Sketch of main current driving method in linear mode.

For the HU256, it is also possible to correct the horizontal aperiodic (AH) and vertical aperiodic (AV) modes, which are special linear modes for which the peak field periodicity is voluntary degraded in order to reject emitted radiation harmonics [4]. The power which arrives on the first elements of the beamline optics is then smaller, whereas these harmonics are not used after the monochromator.

### *Transitions*

When switching from LH to LV polarisation, two cycles are needed to obtain an equivalent correction as previously.. This is due to residual vertical field not immediately cancelled out despite reaching saturation for horizontal field. To avoid this, some specific tables called transition tables are calculated in order to maintain orbit stability while switching between modes.

### *Elliptical/Circular Mode*

Finally, the most difficult configuration is for elliptical modes (E): in this case, both components of field are present. While this situation is solved by 2D tables for hysteresis-less devices, it can not be done here. The chosen method is not the same for HU256 and HU640 undulators.

For the first ones, the idea is to drive the two main power supplies one after the other, in order to make their effects independent from each other. First, a cycle of horizontal field is covered until reaching the target value, corresponding to current#1. Then, while holding current#1, a cycle of vertical field is made until reaching the right couple of currents: current#1 and current#2). Thus, after reproducing this for different values of horizontal field, one obtains 1D tables versus current #2 for several values of current #1.The advantage of this method is the possibility to change quickly the polarity of vertical field while holding horizontal field. Thus it is possible to switch from right circular (CR) to left circular (CL) polarisations easily, as shown in figure 2.

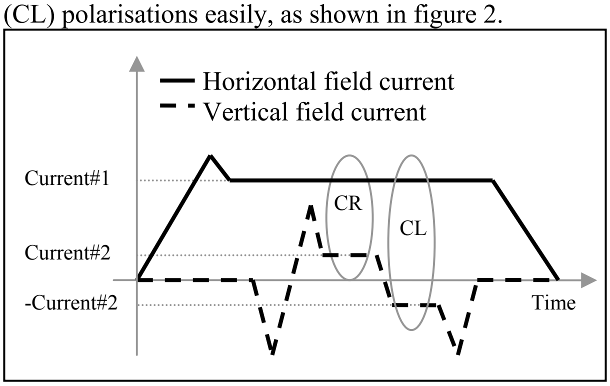


Figure 2: Scheme of a full elliptical cycle for HU256.

The HU640 is subject to hysteresis too, which is not consistent with its iron-free design. This point is not understood yet. The aim is for the moment to drive the undulator in circular polarisation only and not necessarily any elliptical one. To achieve this, the values of currents for the three main power supplies (PS1, PS2 and PS3) leading to pure circular polarisation are firstly computed by beamline scientists at different radiation energies.. Then, as represented in figure 3, the undulator is driven in energy, as each main current is a bijection versus energy.

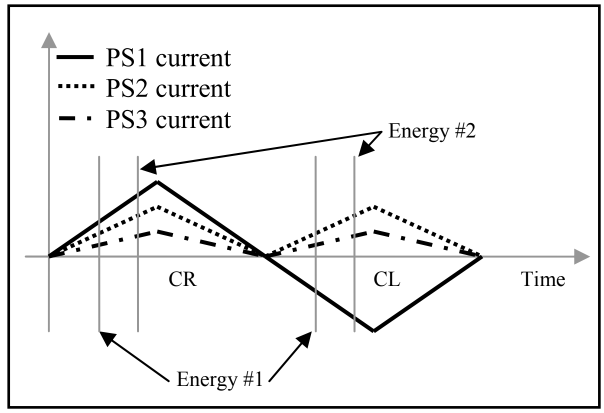


Figure 3: Scheme of a CR and a CL cycle for HU640.

### *COD Correction Method Conclusion*

This way to drive undulators is not perfect for three reasons. First, the COD is well corrected in periodic linear modes but results are worst for aperiodic modes in the case of HU256, and insufficient for elliptic mode. The second point is that it takes a lot of time to cover the cycles (about 3 minutes for each linear cycle). This problem is much more present for elliptic mode, for which one needs to cover two cycles one behind the other in order to obtain a couple of main currents values, which takes up to 15 minutes. Finally, the time taken to reach the right configuration and the large number of tables needed (more than twenty tables for one HU256 undulator) make the commissioning of these insertions very heavy. The different modes for each ID are summarized in Figure 4.

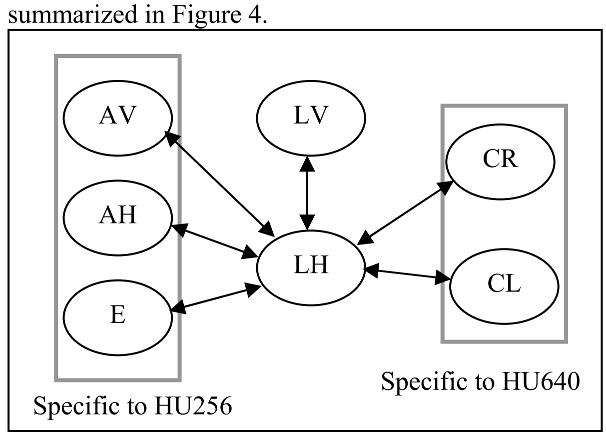


Figure 4: Summary of the different modes and transitions.

## CORRECTION RESULTS

The main results on COD correction are shown in table 1. The chosen figure of merit is the peak-to-peak orbit, i.e. the difference between the largest and the smallest orbit values measured over all the BPMs. The values represent the maximum variation of the horizontal orbit (H) and vertical orbit (V), among one whole cycle for linear polarisations, or among several chosen cycles for elliptic mode, since it is very laborious to check all the cycles corresponding to the tables.

Table 1: Summary of COD correction performance for the four undulators. Optimal values are 10 µm for H and 1 µm for V. Transition results are not shown here.

| Undulator | Mode | H (µm) | V (µm) |
|---|---|---|---|
| HU256 CASSIOPEE | AH | 2 | 2 |
| | LH | 3 | 2 |
| | AV | 2 | 2 |
| | LV | 2 | 2 |
| | E | 8 | 10 |
| HU256 PLEIADES | AH | 5 | 5 |
| | LH | 3 | 5 |
| | AV | 5 | 7 |
| | LV | 2 | 4 |
| | E | 5 | 10 |
| HU256 ANTARES | AH | 2 | 10 |
| | LH | 5 | 5 |
| | AV | 3 | 10 |
| | LV | 5 | 5 |
| | E | In progress | In progress |
| HU640 DESIRS | LH | 5 | 5 |
| | LV | 5 | 5 |
| | CL | 12 | 12 |
| | CR | 13 | 15 |

## IMPROVEMENTS

The values shown in Table 1 are average values of orbit variation, not taking into account transient spikes visible in Figure 5.

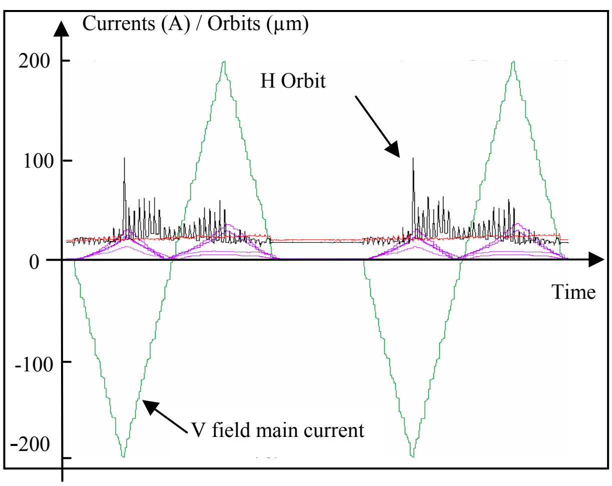


Figure 5: Measurement of two LH cycles made on HU256 CASSIOPEE using analog driving. One can notice the good reproducibility of the orbit variations, but also the high values of the spikes.

While the correction method, the accuracy of the Feedforward tables and of the power supplies have an influence on average orbit variations, it is not the case for these spikes, which are caused by a transitory bad agreement between currents delivered by main and correction power supplies. This nasty effects results from a bad synchronisation between the power supplies, or a big difference of slew rates. As these spikes can reach very high values (up to 100µm), some studies are in progress to reduce them. The principal lead is to drive the power supplies with analog tensions instead of using Profibus, in order to take off delays related to the internal bus of the power supplies. A second lead would be to reduce the step of currents in the tables, but it would result in a longer cycle time. The right balance needs to be found for each type of undulator.

## RADIATION MEASUREMENTS

For all these undulators, the associated beamlines are equipped with in-house diagnostics called DiagOn [5] in order to check alignment of the undulator with the beamline optics, and based on the radiation produced by the undulator. Thus, these DiagOns make it possible to get pictures of radiation rings, to check the alignment of the ID, the efficiency of the undulator corrections, and to quantify the emitted energy versus the undulator configuration. Figure 6 shows an example of these measurements.

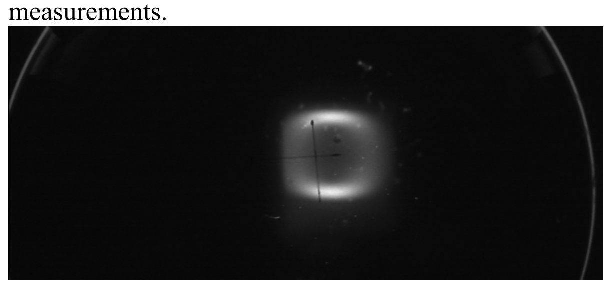

Figure 6: Radiation rings emitted by HU256 CASSIOPEE and seen by the corresponding DiagOn. The radiation is produced in LH mode with a 19 A vertical field main current, corresponding to 120 eV. The cross symbolises the expected ring centre position.

## REFERENCES

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