IS A FRONT PORCH REQUIRED FOR ISY?

Y. Baconnier

Injection in the injector synchrotron ISY from the ACR uses four successive firings of the kickers in the two machines in order to distribute the four bunches evenly along the circumference of ISY. Even equipped with fast resonant charging power supplies, the kickers require 5 ms dead time between firings. The complete injection process therefore takes at least 15 ms. During this time the field in ISY cannot be ramped with the nominal rate of rise (0.45 T s\(^{-1}\)) because the injection field (131 10\(^{-4}\) T) would change by about 70 10\(^{-4}\) T from the first bunch to the last. Injection in ISY must therefore be done at constant field. This part of the cycle is usually called the "flat bottom", the part with the nominal rate of rise being the "ramp".

The transition between the flat bottom and the ramp is limited by power supplies characteristics and cannot be less than a few times 20 ms, in which case we call it a knee, or it can be determined by beam dynamics requirements, in which case it is usually longer (a few times 100 ms) and it is called a front porch. So the question really is: a knee or a front porch?

Machines which have only one power supply for their main magnet do not have problems of tracking during the knee. In ISY the tracking of 18 main magnet power supplies imposes an accurate current programme during the knee.

Moreover the dipole fields induced by the eddy current in the vacuum chamber would represent 1.4% of the main field if the full rate of rise (\(\dot{B} = 0.45\) T s\(^{-1}\)) was already present at low fields. The eddy current effects have been described and a compensation proposed using the ISR poleface windings (PFW)\(^1\)). The compensating current required in the PFW is null on the flat bottom (\(\dot{B} = 0\)) and constant and maximum on the ramp. If the change in \(B\) is too fast the inductive part of the impedance seen by the eddy currents induced in the vacuum chamber cannot be neglected\(^2\)). The corresponding time delay between \(B(t)\) and the required current in the poleface windings is difficult to predict and must be adjusted experimentally.
Another important effect is the distortion of the closed orbit due to the variations from magnet to magnet of eddy current induced fields. These variations are the consequence of the fluctuations of vacuum chamber thickness and resistivity.

Let \( \sigma_t / \epsilon \) and \( \sigma_f / \rho \) be the relative standard deviations of thickness and resistivity of the vacuum chamber in the 384 ISR magnet blocks. The corresponding relative variation of induced field \( B_1 \) is:

\[
\frac{\sigma_{B_1}}{B_1} = \left[ \left( \frac{\sigma_t}{\epsilon} \right)^2 + \left( \frac{\sigma_f}{\rho} \right)^2 \right]^{1/2}
\]  

(1)

The tolerance on the vacuum chamber thickness of the ISR is \( \pm 0.1 \) mm (O. Gröbner, private communication). Assuming this value to be the 95% confidence level then

\[
\sigma_t = 6.7 \times 10^{-2} \text{ mm}
\]

\[
\sigma_f / \rho = 2.9 \times 10^{-2}
\]

The tolerance on the ISR vacuum chamber resistivity is not known. We can use instead the results of measurements made in the SPS on the same type of steel (B. Angerth, private communication). Two sets of measurements made on two batches of about 20 tons of sheets gave

\[79.5 < \rho < 82.0 \ \mu \Omega \text{ m}\]

Assuming that this dispersion corresponds approximately to two standard deviations,

\[
\frac{\sigma_f}{\rho} = 1.6 \times 10^{-2}
\]

The induced dipole field \( B_1 \) is calculated in LEP note 163; for \( B = 0.45 \) T s\(^{-1}\) it is

\[B_1 = 1.8 \times 10^{-4} \text{ T}\]
The insertion of these values in (1) gives

\[ \sigma_{B_1} = 6 \times 10^{-6} \text{ T} \] .

The corresponding closed orbit amplitude \( x_{co} \) can be estimated in assuming a random contribution of the \( N = 384 \) ISR blocks so that using two standard deviations of the distribution in order to obtain the 98% confidence level,

\[ x_{co} = \pm \frac{1}{2 \sin(nQ)} \cdot 2 \sqrt{N} \cdot \sqrt{\bar{p}} \cdot \beta_{\text{max}} \cdot \frac{\sigma_{p} \cdot \ell}{B \cdot \gamma} \]  

(2)

where

- \( Q = 17.2 \)  Horizontal value of ISY
- \( \bar{B} = 16 \text{ m} \)  Average value of \( B_1 \) in ISY
- \( \beta_{\text{max}} = 80 \text{ m} \)  Maximum value of \( B_1 \)
- \( \ell = 2.5 \text{ m} \)  Length of a magnet block
- \( B \cdot \gamma = 2 \text{ T}\cdot\text{m} \)  Magnetic rigidity at 600 MeV

The resulting prediction is

\[ x_{co} = \pm 9 \text{ mm} \]

The correction of this contribution to the closed orbit must be programmed to follow \( B \) during the cycle. A similar effect exists for the sextupolar component of the eddy current induced field. No estimation has been made of the corresponding enlargement of the third order stop band.

The perturbations to the beam are proportional to the ratio

\[ \frac{\dot{B}}{B} \]

The previous calculations assume full rate of rise \( \dot{B} = 0.45 \text{ T s}^{-1} \) at the field level of injection \( B = 131 \times 10^{-4} \text{ T} \), that is
The cycle proposed for ISY in the LEP report is calculated assuming a constant \( \frac{B}{B} = 4.5 \text{ s}^{-1} \) during the front porch. The perturbations to the beam are therefore reduced by a factor 7.5 so that for example the closed orbit distortion \( x_{\text{CO}} \) becomes negligible. The front porch duration is about 0.45 s which provides ample time to ensure proper tracking of the various power supplies.

References

1) LEP note 163, Influence des courants de Foucault dans la chambre à vide de l'injecteur du LEP, C. Roy.

2) LEP note 39, Eddy currents in the vacuum chamber during acceleration in the LEP-70 magnets, J.-P. Gourber and C. Wyss.