Parametrization of AmPS magnets for the control system

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Abstract

Parametrization of the AmPS magnets (dipoles, quadrupoles, sextuples and steering coils) has been performed by precisely measuring the field integrals of each magnet type as function of the excitation current. In order to guarantee a good accuracy of the measurements the used Hall probe was carefully calibrated. These magnet data have been imported into the machine-simulation program DIMAD and a complete refit has been made for various machine properties like the achromatic curved section, the tune, the chromaticity, etc. The algorithms have been implemented in the control system and were calibrated against the beam energy. From the start of the commissioning (spring 1992) the calculated settings and the measurement results proved to be in good agreement: guiding the first beam through the ring took only a few minutes. Also the first measurements of the betatron tune are in agreement with the calculated value using the parametrization of the ring magnets. Furthermore local closed orbit bumps can be generated in the following regions: the injection area, the extraction area, the r.f. cavity area and the internal target area. The performance of this program also indicates the magnet settings are correct.

I. INTRODUCTION

The first commissioning of AmPS (Amsterdam Pulse Stretcher) ring at NIKHEF has been performed in spring 1992 and recently AmPS delivered a 1.5 μA beam with a duty factor of ~30% for nuclear physics experiments. The evolution of its performance is described in [1][2]. The construction of AmPS has been described elsewhere[3]. There are 32 dipoles, 68 quadrupoles and 32 sextupoles, as well as 4 extraction sextupoles and 32 combined steering magnets installed in AmPS. It is built for improving the duty factor of 0.1% from linac to ~100% from the pulse stretcher ring. For proper computer control of the power supplies, the parametrization of the magnets is necessary. The main parameters of those magnets and the measurement results of these magnets have been shown in[4]. However, the integral field of the quadrupoles and sextupoles, and the magnetic field as function of the excitation current were not known. A few of each type of magnets, such as ring dipoles, the quadrupoles, the sextupoles, and the steering magnets, therefore, have been measured thoroughly. The final measurement result has been implemented to the program DIMAD[5] to refit the parameters of the machine properties such as tune, chromaticity, etc. Parametrization, which was based on the measurement results from those magnets, was calculated in order to provide enough information for a central computer control of AmPS. The successful start of the commissioning proved that a good parametrization steered the beam through the ring with some ease.

II. MEASUREMENT PREPARATION.

The tools which were available for measurement were a DTM-141 Hall probe (Group 3 Technology) and a precise position x-y-z measurement setup. In order to obtain a high accuracy, the following calibration were made.

The accuracy of the Hall probe for the magnetic field was calibrated by an NMR in the magnetic field region of 0.3 – 1.0 T.

The temperature dependence of the Hall probe has been measured with a Tektronix-thermometer. The temperature-dependent coefficient is $1.77*10^{-5}$ T /°C.

This Hall probe was used to measure the quadrupole field along the axial direction in order to obtain its integral field. The position of the Hall probe was read out within an accuracy of 0.01 mm with the x-y-z measurement setup. In order to improve the accuracy of the integral field of the multipoles the sensitive center of the Hall probe was calibrated with the x-y-z setup. By rotating the Hall probe 180° in the center of the quadrupole it turned out that the sensitive center of the Hall probe had a 0.4 mm offset with its mechanical center. With the correction of this offset the measurement result gave a better result for the quadrupole and the sextupole.

III. PARAMETRIZATION OF THE MAGNETS.

Measurement results for the ring dipoles[4] indicated that there is deviation of the integral field ∫Bdl between the 32 dipoles (which is about ±0.3%). Since they will be connected to one power supply, the paranmetrization has to take into account of this fact. A few dipoles were measured and a mean value of their integral field has been taken for the parametrization. In the mean time an NMR probe was used to calibrate the central magnetic field. The integral field is not the linear function of the excitation current and a slight saturation occurs when a high excitation current is applied were observed for ring dipoles. Therefore, a polynomial fitting program was used to obtain the coefficients of the dipole integral field. The dipole field as function of the excitation current as well as the beam energy is implemented in the control system. There is an additional dipole located outside the ring and an NMR probe is installed in the gap of the dipole to track the performance of the 32 ring dipoles.

There are three types of quadrupoles, which have aperture diameters of 71mm, 95mm and 144 mm respectively.

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There is one type of sextupole installed in the ring and its aperture diameter is 80 mm. One of each magnet type has been measured for the integral field. Every quadrupole and sextupole has been measured by rotating coils and the results indicated that the higher-order components in the quadrupole are less than 0.1% for radii up to 0.8r and 1% for sextupoles[4]. The integral field was therefore measured in the 0.6r region in order to obtain the relative high accuracy. The optical strengths ($K_{q/s}$) of the quadrupoles and sextupoles are converted to the excitation current as function of the beam energy.

The measurement results of the multipoles show that the effective length of the magnets with respect to their design value is somewhat different, see table1:

Table 1: *The effective length of the magnets, where Q is quadrupole and S is sextupole. The number is the diameter. First column is the design value and the second column is the measurement result.*

	L_{de}.[mm]	L_{mea}.[mm]
Q71	210	213
Q95	290	296
Q144	290	323
S80	150	142

The beam energy was calibrated by an analytic bending magnet with the aid of a secondary emission monitor in the tune-up line at the end of the linac, which gives an accuracy of the beam energy of 0.1%.

The measurement results were imported into the program DIMAD[5] to refit the required optical properties of AmPS, such as achromatic transform in the curved section, tune and chromaticity. The new parameters of the magnets are used as the input for the control system.

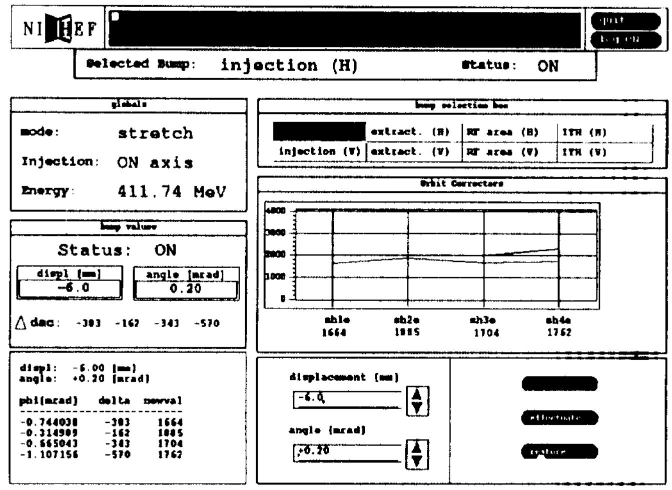
With this effort when the commissioning started at spring of 1992, it only took a few minutes to guide the first beam through the ring. Measurement of the machine betatron tune yields v_x = n.38 and v_y = n.21 which is in a good agreement with the design value.

There are 32 pairs of steering magnets in AmPS for orbit correction purpose. Their integral field has also been measured in both the vertical and the horizontal direction. The excitation current is as function of both the bending angle and the beam energy. This is implemented in the control system as well.

IV. PARAMETRIZATION OF MACHINE PROPERTIES.

In order to be able to adjust the machine parameters promptly, chromaticity adjustment and tune adjustment are also implemented in the control system. Two quadrupole families are chosen for the tune adjustment, and two sextupole families are chosen for the chromaticity adjustment. A precalculated table is implemented in a graphic setup to make it user friendly. An example of this setup is shown below.

Besides the program for tune and chromaticity control, local bump programs for the injection area, the extraction area, RF cavity area and the internal target area are implemented also. There are four pairs of steering magnets chosen in each concerned region. According to the request from the user, such as an angle or a displacement in the local area, the program will calculate the required current for each steering magnets as function of the beam energy, and then it will be executed. With this facility one can easily adjust the closed orbit at the injection or extraction area with one's interest or fit the request from the ring condition.



V. CONCLUSION.

The commissioning experience in the past period proved that the careful parametrization of the ring magnets and the machine properties are worth to do and it provides convenient tools for adjusting ring parameters as well as helping to understand the performance of the operation during the commissioning period.

VI. REFERENCES.

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