ALIGNMENT FOR THE LNLS SYNCHROTRON LIGHT SOURCE

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Abstract

The Brazilian Synchrotron Light Source is composed by a 15 meter long underground Linac (120 MeV), a 20 meter transport line with horizontal and vertical deflexions and a 30 meter diameter storage ring. In this report we describe the alignment method employed at LNLS, which is based on scaling bars and angle measurements; and in-house specially developed equipment and software. We present the obtained results, which directly affect the beam performance, particularly at commissioning phase.

1. INTRODUCTION

Four reference marks were installed during the construction of the LNLS main building on the main columns of the metallic structure, based on the coordinates of the five site topographical monuments. These four reference marks were used to install all the concrete girders of the magnets, the pipe rack pillars and other structures inside the building. The repeatability in theodolite positioning and coordinate measurements was so high that it was decided to install all the 70 floor reference sockets with the same procedure and use these sockets for the fine alignment of all magnets. The home made scale bar was used as a standard length to check every alignment operation.

2. ALIGNMENT HARDWARE AND PROCEDURE

Angle measurements are performed with two T3000 Leica Electronic Theodolites which are connected on line to a laptop computer. Component leveling is accomplished through a NA2 Leica level. The reference sockets and the fiducial marks on the dipoles were designed to hold a Taylor-Hobson sphere. To align the magnets with some specific offset from the line of sight, individual offset bars with different shapes are used. The shapes depend on each specific application. These offset bars are produced with the laser cutting machine, using different materials (Stainless steel, acrylic, etc.), depending on the application. The accuracy on the dimensions of the bar is 0.05 mm, determined by the laser cutting machine. A parallel plate translator, adaptable to a T3000 telescope was developed to facilitate the positioning of the theodolites in front of a line of view passing through two specific points.

The transfer of coordinates from the storage ring level to the Linac underground tunnel was done using a 0.2 mm diameter nylon plumb line, with a 1 kg load immersed in oil for oscillation dumping. The nylon spring is put in the correct position with an XY translator, monitored by 2 theodolites in the floor level. When the pendulum get to rest, the theodolites are transferred to the tunnel and positioned at 90 degrees around the nylon wire. The vertical movement of the telescope allows, then, to find the desired position where a floor socket is to be grounded. With this procedure we have installed 2 floor reference sockets, parallel to the Linac theoretic position.

2.1 Floor reference sockets

The first model, a 50 mm diameter cylinder that directly hold the Taylor-Hobson sphere, proved to be inadequate due to the need for large holes on the floor. The final model, limited to 15 mm diameter, allows the use of normal drilling machines equipped with a 18 mm concrete drill. An adapter is machined to hold the sphere. The top border of the cylinder is designed to protect the reference surface and the internal diameter. The cylinder is installed 1,5 mm bellow the floor level (for safety reasons), with a leveling plate.

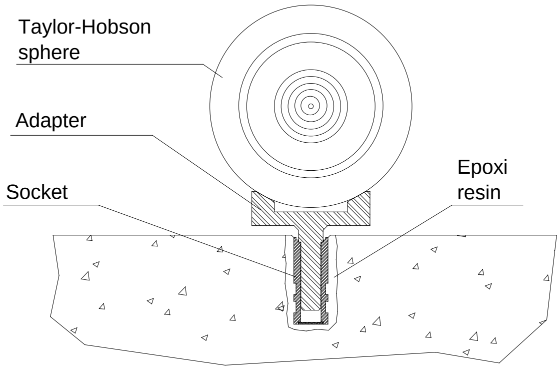

Fig. 1: Floor reference socket holding a Taylor-Hobson sphere. When the adapter is removed, a small cap protects the socket reference surfaces.

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2.2 Glass Scale

A reference length scale was designed to be used as a verification to the alignment procedure. As such, it is designed to be portable, resistant and stable. The present model is made with a 2700 mm long, 40mm wide and 4 mm thick glass strip, which is enclosed in a rectangular aluminum tube. The glass strip is glued on the tube with flexible silicon adhesive to minimize tension on the glass due to the thermal expansion of different materials. There are two apertures near the extremities of the aluminum tube to provide visual access to the targets glued on the glass. The targets are plotted on a plastic film (in the next version they will be plotted directly on the glass), with a 2000 dpi resolution photo plotter, which allows drawing 0.1 or 0.2 mm diameter target points, resulting in very nice visualization with the theodolites for distances between 3 and 10 meters.

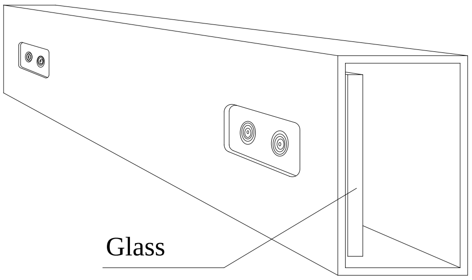

Fig. 2: Schematic view of the glass scale showing the glass, the aluminum rectangular-shaped tube and the targets.

The calibration of this first prototipe was done using two theodolites and a cristal scale of a CNC machine (±20 µm), in a temperature controlled room. The next prototipe will be calibrated with a laser interferometer.

2.3 Offset bars

To align the Linac it was used two floor reference sockets installed in the tunnel, with the coordinates transferred from the storage ring level with special plumb lines. These two points were positioned around 600 mm parallel to the Linac center line. The theodolite, equipped with the parallel plate translator, was put collinear with the two points. To align each component of the Linac, offset bars are used, manufactured using a 5 mm thick acrylic, with a target point of 0.3 mm diameter. As these bars were produced very quickly with the laser machine, each different component used its own offset bar. In this way, the theodolite was positioned only once for the alignment of the whole Linac. The NA2 level was installed in the same special tripod, together with the theodolite, to guarantee the leveling of the components.

This same procedure was used to align the quadrupole and sextupole girder in the storage ring. Each girder was checked for non linearity or twist before the installation of the magnets. The repeatability of the installation of any magnet in this girder was checked during the magnet measurement and demonstrated enough confiability, i.e., differences in magnetic center position less than 0.1 mm. The dipoles central reference mark are installed at the intersection of the straight electrons trajectories, based on the magnetic field measurements. The theodolites were installed in such way that the line of sight passes around 350 mm parallel to the line joining the central marks of two adjacent dipoles. This is done with two special masks that fit in two reference marks on the top of the dipoles (Fig 3). To align the girder,

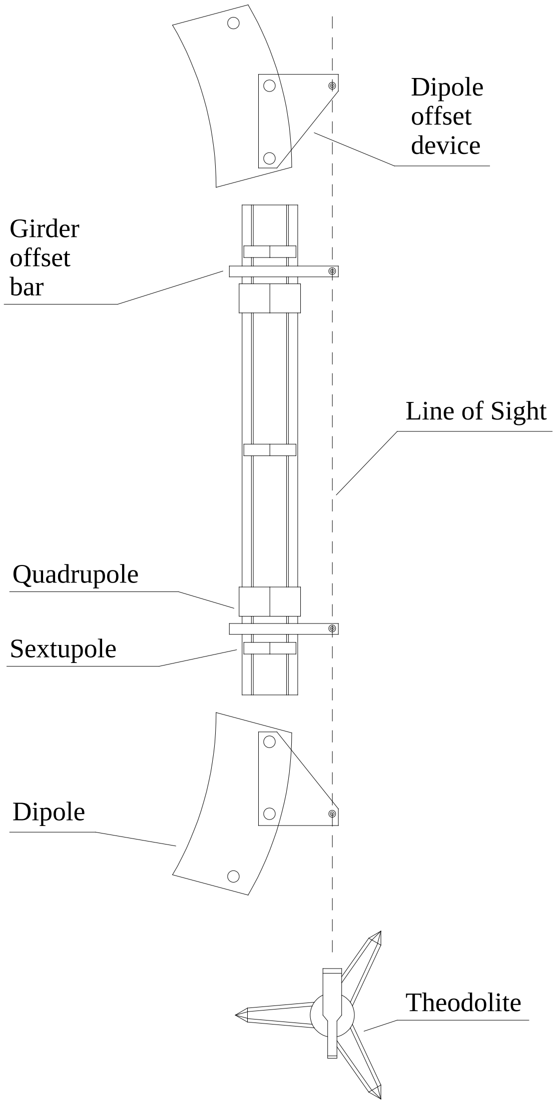

Fig. 3: General lay-out of the storage ring alignment procedure, based on offset bars.

two offset bars are installed near its extremities. To level the girder, the NA2 level is used. To align each magnet longitudinally on the girder, a simple measuring tape was used , with tolerances of ±1.5 mm.

3. ALIGNMENT SOFTWARE

A software package has been developed in-house to perform geodesic tasks. In order to establish a practical and reliable alignment procedure, an effort has been put to automate data acquisition and produce a user friendly interface with on-line error checking routines. The software has been implemented in QuickBasic in a PC laptop.

The program consists of many interconnected modules which handle the data files. The basic structure is illustrated in figure 1. We call target point an arbitrary point whose coordinates are to be determined and a goal point an arbitrary point whose theoretical coordinates are known. In this last case, we want to determine the theodolite sightings which pass through the point.

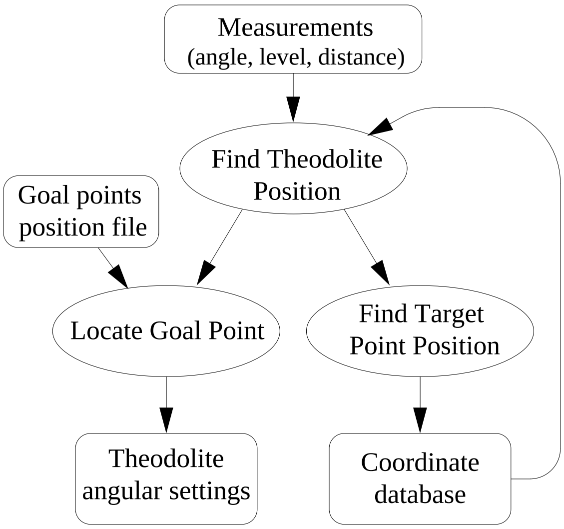

Fig. 4: Basic structure of the LNLS alignment software.

The data processing modules currently available are:

a) Theodolite coordinate determination. Two algorithms are implemented:

a.1) The position of the theodolites are determined analytically by a geometrical approach[1], given the coordinates of 3 reference monuments and respective theodolite sightings. The measurement accuracy can be improved by increasing the number of considered monuments, in which case a statistical analysis is performed for the combination of points.

a.2) The coordinates of two theodolites are determined in the autocollimation frame using sightings to a standard ruler of known length at several different positions. The coordinates of a reference monument is needed if one wishes to transform to the laboratory frame. The autocollimation frame is determined by zeroing the azimuths while sighting each theodolite with the other one.

b) Target point coordinate determination. The implemented algorithms are:

b.1) The target point planimetric coordinates and height are derived independently by using plane trigonometry.

b.2) The three dimensional coordinates are taken as those of the point closest to the lines-of-sight from the two theodolites. The computation uses a vector calculus approach.

c) Goal point coordinate determination. This module uses a trivial plane trigonometry approach.

The on-line error checking routines include displaying statistical analysis and error propagation results for theodolite and points coordinate at each calculation step and checking the consistency of the several redundant data using F test.

4. CONCLUSIONS

The alignment procedure adopted at LNLS seems to be a little bit unusual, or less precise since we did not use network optimization softwares or high precision distance meters, but it seems to be perfectly adequate for this kind of machine, where small errors in the scale factor can be compensated by adjusting the RF frequency. The machine geometric accuracy, except for the scale factor, is determined mainly by the theodolites, and the present commissiong results demonstrate that we have achieved the required tolerances since we got our 1000th turn (at low energy)[2] with all 30 correctors off.

REFERENCES

[1] ‘Euclid’s Elements’, translated by Sir Thomas L.Heath, Dover. Proposition 21, Book 3.

[2] A.R.D.Rodrigues et al, ‘LNLS Commissioning and Operation’, these proceedings.