AUTOMATING THE TUNE MEASUREMENT IN THE LNLS CONTROL SYSTEM

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Abstract

As part of our efforts to improve beam stability and reliability at LNLS, we have developed a system for automating tune measurements. This system is based on a commercial GPIB-controlled spectrum analyzer and fed by a difference signal from a stripline pickup. Following a tandem-like approach the software is composed by two layers. The top one, which includes the end-user interface, sends task commands to the bottom layer which suitably manages the analyser. The system is capable of setting the instrument for optimal measurements in a variety of operational conditions through feedback algorithms and triggered events, allowing tune tracking during particular cases, such as IDs (Insertion Devices) movements and energy ramps.

INTRODUCTION

The Brazilian Synchrotron Light Laboratory (LNLS) storage ring is a 1.37 GeV machine where injections occur in low energy top-up mode [1] twice a day. The control system synchronizes the magnet power supplies during the ramps, however, the long term repeatability of the betatron tunes is affected by several operational conditions, such as electrical blackouts and machine physics shifts, when the magnets are restarted in order to bring the accelerator closer to its nominal characteristics.

Besides the long term tracking of the tunes, another important reason for developing the "TuneLogger" system is the upcoming high-resolution Plane Grating Monochromator (PGM) beamline based on an elliptically polarizing undulator (EPU) [2]. Even with a feedforward control system running to minimize the position changes in the storage ring due to the undulator movements, energy and polarization scans certainly will impact betatron tunes, which will need fast monitoring.

The tune logs had been done manually until recently just in few specific situations as before and after the energy ramps. The logging of these values during user shits, or even during accelerator experiments, is one of several monitoring systems needed to keep and improve the high reliability levels in the accelerator operation.

SYSTEM DESCRIPTION

The measurement system, divided between hardware and software levels, is detailed bellow in Fig. 1 and 2. The challenge in this project was to integrate consistently the tune measurements with the control system database.

Hardware

The hardware level, depicted in Fig. 1, is composed by a HP8594E spectrum analyzer that delivers a maximum sweep signal of +2 dBm, being amplified up to +26 dBm and applied to a set of 2 pairs of non-rotated 155 mm stripline kicker. The beam performs small oscillations at the betatron frequency which are measured by 155 mm stripline pick-up rotated by a 45º with respect to the reference orbit plane, connected to a subtracting hybrid. The -60 to -70 dBm difference signal from two opposite antennas gives the oscillations in both transverse planes. Two Macom H-9 hybrids generate the 180º out of phase signals. Low performance cellular RG-58 cables are used at the present moment. The measurement is performed at 115 MHz, around the 36th revolution harmonic. This frequency represents a good compromise between cable attenuation and the pick-up frequency response.

Software

TuneLogger was written in Delphi language to automatically control the spectrum analyzer and perform tune measurements on several situations. In order to achieve these requirements, a number of routines were implemented to properly set the instrument according to the chosen monitoring option, so that any desirable adjustment capable of improving the measurement could be done on-the-fly.

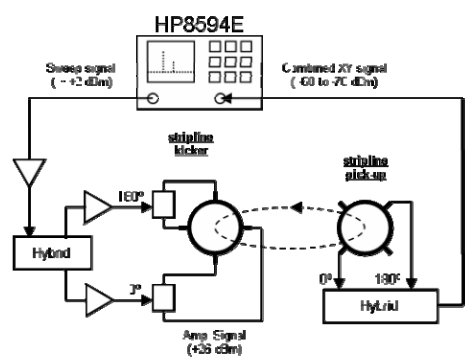

Figure 1: Tune measurement system.

Once started, TuneLogger's bottom layer application (middleware) connects to the spectrum analyzer via GPIB and waits for a TCP/IP connection from the upper layer (end-application). At the instrument connection, the default manufacturer setup is set on the analyzer to ensure a well-known start-up state, which prevents configuration problems. Thus at the end-application, the user is requested to choose the operation mode in order to unlock the interface and effectively start the measurements. Figure 2 presents the TuneLogger user interface, showing tune values, the analyzer parameters, exchanged information between the control system and instrument, and operation logs (that can be recorded).

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The end-user software possesses two operation modes: one only for betatron tune measurement (B mode), and another one for betatron and synchrotron tunes measurement (BS mode). These different modes were necessary due to the restrictions imposed by spectrum analyzer performance, which imply an compromise between speed and resolution. In both modes, autoset routines are emulated through dedicated pieces of code. These autoset routines find the tune signals around the chosen revolution frequency harmonic in the spectrum and adjust the device for optimal measurements.

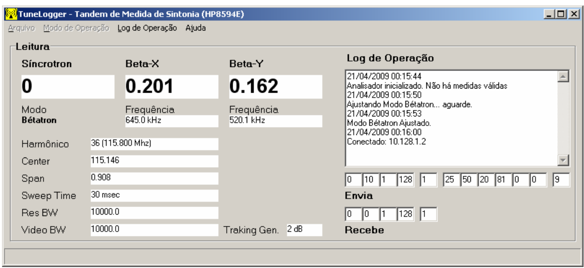

Figure 2: TuneLogger's user interface.

The B mode is designed for fast data acquisition of betatron tunes, commonly used during energy ramps or IDs movement. In this mode, the synchrotron tune is not measured and the whole screen of the analyzer is used for a single spectrum. In BS mode, the acquisition rate is lower due to the higher number of commands exchanged with the analyzer, and all tunes are measured in a split mode screen, one screen for betatron tunes and another one for synchrotron tune. Table 1 summarizes the system performance parameters.

Besides autoset routines, additional features contribute to an effective performance. High communication rates via GPIB and TCP/IP allowed threads were used to manage the many features of the software: user interface, adjustments from the control system, acquisitions from the analyzer and calculations, all 'at the same time'.

Due to low signal power, some control loops and filters were implemented to assure the proper working of the system in a broader range of cases. These features can act even under beam losses or analyzer problems. For example, if the signal power reaches a value lower than 80% of the screen limit, TuneLogger recalculates the screen scale; if the loss is big and the value reaches less than 20% of the screen, the *autoset* routine is called; and if no beam is stored the software waits for a betatron peak. The system can properly measure betatron tunes with just a few mA stored. On the other hand, the synchrotron threshold reached 10 mA. For lower currents, manual measurements are still necessary.

A similar approach is applied to detecting and averaging peak thresholds. For the first, the parameter is always increased until failure and then decreased until it succeeds, then defining an adequate operation range. For averaging, the standard deviation of the peak power is evaluated and the average is increased whereas the standard deviation increases. The inverse is also true.

Table 1: Performance Parameters

Mode	B	BS
Rate	3 Hz	0.3 Hz
Resolution	3 kHz (0.001)	3 kHz
Current threshold	2 mA	10 mA
Autoset time	7 sec.	12 sec.

FIRST RESULTS

Improvements that resulted from using TuneLogger include tune recordings at 1 SPS, limited by the control system data logging rate. Due to database integration several experiments can now be cross-checked with the tunes and further measurements can also be performed much faster. Figure 3 shows a beta function measurement performed by a specific control system software tool using the TuneLogger data. This experiment used to take hours to be completed, but now it takes few minutes due to TuneLogger and also to automated shunt power supplies installed in all individual quadrupoles [3].

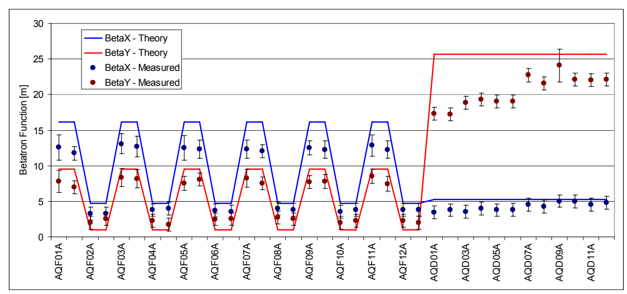

Figure 3: TuneLogger's betatron function measurement.

Another experiment made possible by TuneLogger is the betatron coupling measurement shown in Figure 4. The horizontal-vertical linear coupling in the lattice can be measured by the closest tune approach. In this method the separation between horizontal and vertical tunes is measured as a function of the strength of a quadrupole family.

As a monitoring example, the Fig. 5 shows the betatron tunes along the wiggler gap opening during an energy ramp from 1370 MeV to 500 MeV, performed at 180 mA.

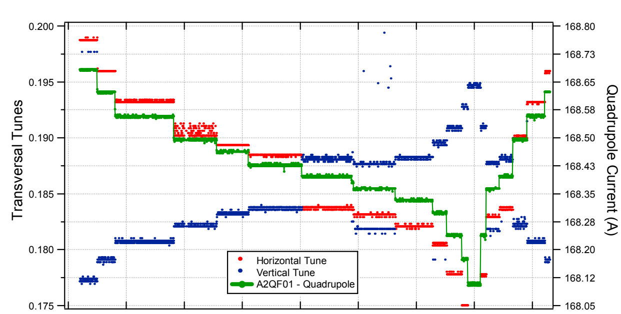

Figure 4: Betatron tune coupling.

Figure 6 shows the vertical betatron tune registered in two different situations: during a ramp performed at normal speed and another one performed at slower speed. It is easy to see the similarity between both curves. Even with a ten times faster acquisition rate, one can see almost the same features in both graphs. Figure 7 shows the tune logs during an energy ramp where a beam loss occurred.

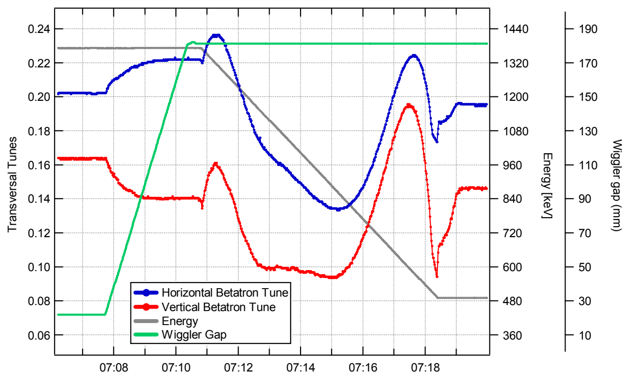

Figure 5: Betatron tune log during a wiggler movement.

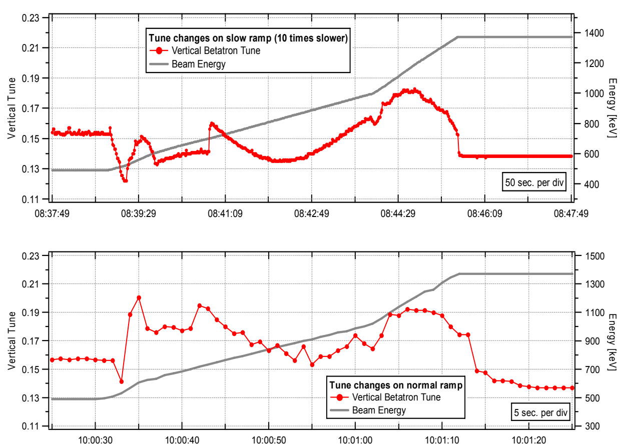

Figure 6: Vertical betatron tune along slow (up) and normal (down) ramps.

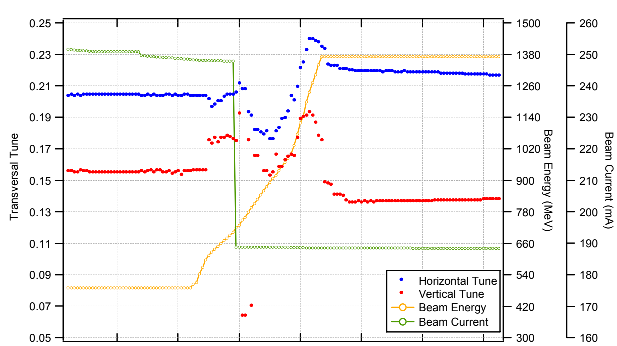

Figure 7: Betatron tune along slow (up) and normal. (down) ramps.

DISCUSSION AND FUTURE PLANS

Based on presented results, the system is clearly limited by analyzer performance or, specifically, by the sweep time and resolution of the device, even operating with the best combination of speed and resolution, which could be surpassed by replacing the employed analyser with another with better specifications. A Real Time Spectrum Analyzer (RTSA) can give data in rates several orders of magnitude higher with similar resolution. Some tests with Libera Brilliance [4] showed that complementary tune measurements can be performed with higher resolution, but smaller effective measurement rates. An alternative option is a RF PXI device installed in a PC, that can give both resolution and higher rates.

Another source of difficulties to measure tunes is the absolute amplitude of the peaks. The signal to noise ratio is sometimes just few dB above the instrument noise floor. As mentioned, the order of magnitude of signal amplitudes is about -60 and -70 dBm (horizontal and vertical spectral lines, respectively). We believe that this situation is caused by non-optimal pick-up placement and high cable attenuation. Increasing the antennas area and length, positioning the pick-up in a high beta function sector, preferentially with low dispersion function, or replacing the cables with a better type, could increase the signal power and maybe decrease another symptom: the betatron tunes contamination by synchrotron tunes. In addition, a hardware improvement will be studied to reject this contamination.

CONCLUSIONS

With TuneLogger we achieved the proposal of integrating continuous tune measurements to the control system. Some experiments became faster and more accurate, and tune tracking is now possible with data recorded along user shifts and injection periods. Some refinements are in due course such as the improvement of the power levels, implementation of more efficient filter for synchrotron tune measurement and reduction of the contamination level associated to inter-modulation between betatron and synchrotron peaks.

REFERENCES

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