THE ELETTRA RADIOFREQUENCY SYSTEM STATUS AND DEVELOPMENTS

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Abstract

Full energy injection is now the standard procedure to refill the Elettra synchrotron radiation light source. The four RF storage ring plants have been benefited by this procedure in terms of reliability and stability of operation. The injector booster RF plant is running well. A new High Order Mode (HOM) diagnostic board has been tested using the radiofrequency (RF) cavity's signal to improve the HOM's detection. The performances of the new Inductive Output Tube (IOT) based RF power transmitter are presented.

NEW INJECTOR IMPROVEMENT

The Elettra full energy injector is made by a 100 MeV linac preinjector and a 3 Hz, 2.4 GeV booster [1]. It has been commissioned at the end of 2007 and it was routinely operating since March 2008. The booster 60 kW 500 MHz RF plant has proven its reliability and endurance. During the commissioning phase the arc detector mounted on the high power circulator was recording some false glows. They were due to the exposure of the detector electronic board to the ionizing radiation. In fact there is a unique hall that hosts the booster machine, the electronics devices and the power supplies. For that reason the electronic board was shielded using lead bricks and the alarms disappeared. The Booster RF effective voltage is ramped from 40 kV to 600 kV with a simple trapezoidal curve, total time of 160 msec. The highest voltage value does not depend from the extraction energy, which is selected by the extraction timing.

The distribution of the 499.654 MHz machine clock signal has been also redesigned. A signal master oscillator with ± 5 kHz adjustable frequency around the nominal value is also used to optimize the horizontal orbit of the storage ring as a function of the final energy, 2.0 or 2.4 GeV. Thus the whole system shifts accordingly and the 500 MHz phase relationship amongst the linac, the booster and the storage ring is established. Any uncertainty on the 500 MHz phase relationship has been definitively removed out, improving the storage ring refill procedure. For machine physics studies it is always possible to switch on separate signal generators and set the wanted frequency signal on each subsystem. The right phase amongst the subsystems is then settled back by the 500 degree mechanical phase shifters. These signal generators are, at the same time, spare devices of the main master oscillator.

HOM DETECTOR BOARD

The full energy injection has withdrawn the need to excite some longitudinal instability during injection and energy ramping that was the standard procedure at Elettra [2]. Now the storage ring accelerating cavities does not necessarily drive any longitudinal HOM. However this diagnostic tool is useful for the HOM final tuning.

The most effective CBM longitudinal instabilities have a frequency that ranges from 950 MHz, first longitudinal cavity's resonance, up to 2.1 GHz, the so called L9 mode. The minimum frequency gap between two longitudinal resonances is larger than 80 MHz.

The same longitudinal mode, or the same equivalent electromagnetic field, slightly shifts in frequency when measured in several cavities, mainly due to some small mechanical differences and temperature setting. But for each mode a span of 25 MHz around the nominal frequency value can take care of any differences and, at the same time, it is smaller than the minimum frequency separation between two longitudinal modes.

The HOM board samples the RF signal by means of a programmable Phase Locked Loop (PLL) device. The RF input signal passes through a high pass filter having f_c = 900 MHz. The longitudinal mode's frequency can be selected from a program developed with LabView tools.

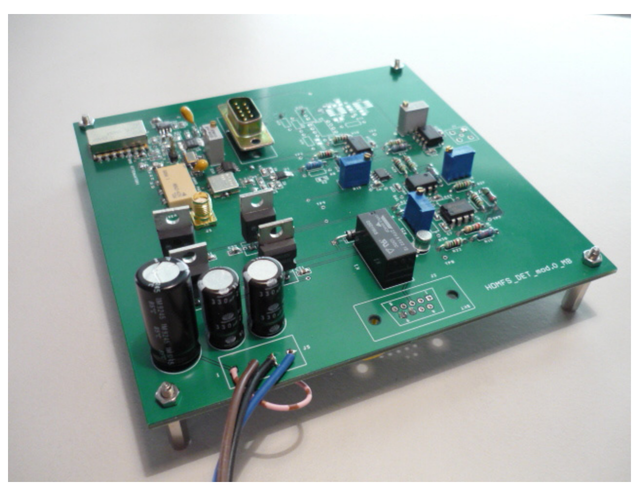

Figure 1: HOM detector board.

If the level of the RF signal at the wanted frequency is above a pre-selectable threshold the warning about the CBM excitation is given. The minimum detection threshold is around -25 dBm which corresponds to 3 degree of CBM excitation.

This board can be connected to one of the three RF pick ups available in the storage ring cavity in section #9. One is located near the coaxial input power coupler, on the RF line side. It rejects more than -80 dB the 500 MHz signal. It can detect any HOM frequency seen by the input coupler and somehow trapped in the coaxial line close to the input coupler. An interlock alarm will be set sampling this signal with the HOM detector board, to avoid dangerous rise of stationary electromagnetic fields close to the input coupler.

Two RF pick up are displaced along the cavity equator. Having a capacitive and inductive coupling respectively, they can detect odd and even HOMs. Connected to these signals, the HOM board will monitor the beam's excitation, giving a fast response on its intensity and identifying the cavity number.

DIGITAL LOW LEVEL RF

The feasibility study on a digital low level RF (DLLRF) is completed. The main purpose of a general LLRF system for storage rings is to stabilize the amplitude and the phase of the accelerating cavity field, mostly against beam loading effects, temperature variations and stability issues of the amplification stages. Furthermore the cavity must be kept always near the resonance (an off-set is needed for the Robinson's principle).

The main specifications and improvements that are going to be pursued with the design of regulation loops based on digital technique are listed in table 1.

Table 1: DLLRF Specifications

Loops	Amplitude	Phase	Frequency
Frequency	499.654 MHz ± 10 kHz		
Dynamic Range	27÷30 dB	27÷30 dB	20 dB
Regulation Range	~1÷650 kV	±30 deg	±200 kHz
Accuracy	±0.1 %	±0.1 deg	100, 500, 1000 Hz
Closed Loop Bandwidth	20 kHz	20 kHz	>0.2 kHz <1.0 kHz

The approved DLLRF layout is shown in figure 2. The system is composed by three main parts: a first down-conversion stage that translates the cavity signal to the intermediate frequency (IF), the digital control, which is responsible for the sampling and regulation, and the up-conversion stage, that drives the high power RF chain with the corrected signal.

The first efforts have been spent in the digital part. An evaluation board for ALTERA FPGA, that was developed by the Instrumentation group from Sincrotrone Trieste, is exploited to characterize the ADC (Analogue to Digital Converter) that is going to be used, the LTC2008 by Linear Technology. The sampled signal by the ADC is acquired in a PC through the FPGA by a LabView VI tool, so that several analysis and comparisons on the acquired signal spectrum can be performed for the proper characterization of the device.

The sampling techniques IQ, NON-IQ and DDC (Digital Down Conversion) are being analyzing by Matlab and Simulink simulations, in order to evaluate and compare accuracy and time cost of each technique.

Numerical models on the longitudinal dynamic of the beam loaded cavity system and the phase and amplitude loop feedback are under development to set the main loop's parameters.

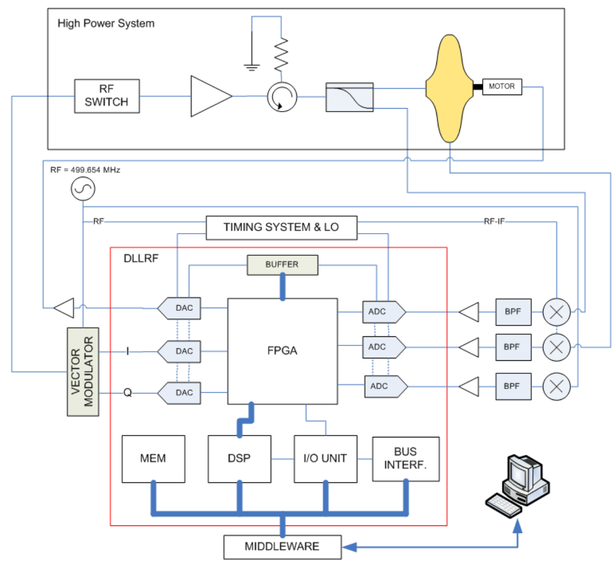

Figure 2: DLLRF block diagram.

THE RF UPGRADE PROJECT

The RF upgrade project started in 2006. The first milestone was to install, commissioning and operating a 150 KW CW transmitter on one RF plant to improve the storage electron beam lifetime and recover the safety margin of the available RF power [3]. The total output power was obtained by combining two 80 kW transmitter equipped with the IOT tube TH 793, working in CW mode, from Thales. The transmitter was definitively operating beginning 2007. The Transmitter, "B652 KA 150kW" from Electrosys and the associated equipment is performing well. The Elettra cavity has been successfully conditioned up to 60 kW CW, the maximum input power the cavity can dissipate without beam. It corresponds to an effective accelerating voltage of 610 kV. The water cooled door knob transition from the waveguide to 6 1/8" line is performing well too. Nevertheless, it has not been possible to take advantage of all the promised features of the new 150 kW power plant yet.

The IOT Tube and Elettra Procedures

Due to the switchless combiner, it is really easy to merge the two transmitters power's on the Elettra cavity as well as to separate them. One transmitter can work standalone on the unbalanced load, while the second one is feeding the Elettra cavity. This feature has been greatly used during last year. In fact, after the initial success of first months of operation, the reliability of the TH 793 tube was not as expected: this tube has shown a sort of early aging with an increasing number and frequency of tube's faults: three tubes TH 793, the two installed since the beginning and the last the spare one, have worked for a total of 25000 hours. This had a great impact on the reliability of the photon beam light delivered to the user's community and it has forced us to run only one transmitter/time on the Elettra cavity and to perform some parallel checks on the second one, or even to use the second one as a recovery transmitter in case of failure. This sort of weakness suffered by these tubes can not be easily explained. The tubes never lost their characteristics and efficiency. But, at the same time they have not been always driven at the maximum output power. One possible reason of this unreliability could be explained looking how these tubes are used at Elettra. The storage ring machine requires an output power level that follows the accumulated beam. Therefore the IOT tube forward power is accumulated beam current dependent.

Moreover, Elettra has implemented a safety interlock system based on a brief interruption of RF power to the cavities. Any orbit offset and/or any attempt to access the Elettra tunnel causes a "beam dump". This stops the RF signal that drives the four storage ring plants for 4.2 msec. During this time interval there is no RF power in the accelerating cavities. The accumulated beam is not accelerated anymore and decays naturally in 1.2 msec. But this time interval is short enough to allow the sudden restore of the full RF power to the cavities. Rising and falling time of the "beam dump" interlock signal is about 300 µsec.

The cavity amplitude loop follows the sudden beam dump, counteracting to restore the accelerating voltage and opening the error control signal at the maximum value. Then, when the RF power is applied back to the cavity, the system moves backwards the resonance according to the feedbacks loop band width, but it starts from this high power level. This procedure results in a huge and sudden output power request from the IOT tube. After any beam dump, the IOT tube is driven from the minimum to the maximum level in 300 µsec. It is not yet clear if this procedure was contributing to degrade the IOT tube reliability. Klystron tube based transmitters never had this problem. Anyway the maximum output IOT power was limited to 65 kW. Moreover last October one transmitter was upgraded with the TH 793-1. This tube has been specially designed for the ALBA synchrotron light source.

The installation was successful. However the tube's performances were really up to the expectations and the tube was de-installed. A bad insulation of the grid cable in the input circuit was causing a false contact, spoiling the tube behaviour. Due to this hardware problem, the real TH 793-1 performances could not be tested.

A further step to get rid of the IOT tube sudden overdrive caused by the "beam dump" procedure has been completed these days. Any beam dump or an excessive reflected power, that means an accumulated beam loss, freezes the amplitude loop's counteraction, leading smoothly to the nominal value of the cavity input power.

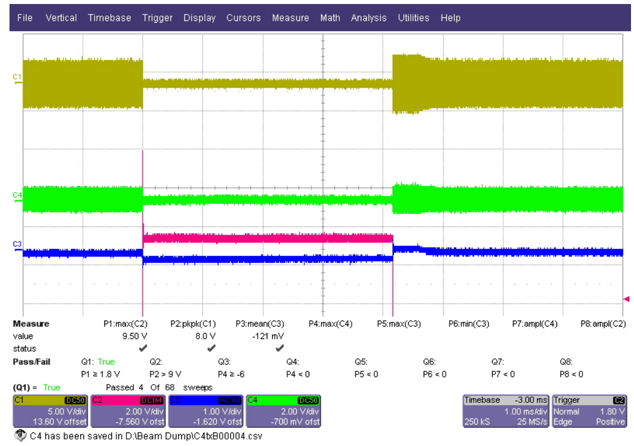

Figure 3: Beam dump procedure without amplitude loop constraint. The IOT forward power (dark green trace) is larger after the beam dump due to the cavity mismatch and loop counteraction. Light green trace is the reflected power, blue trace is the IOT collector current.

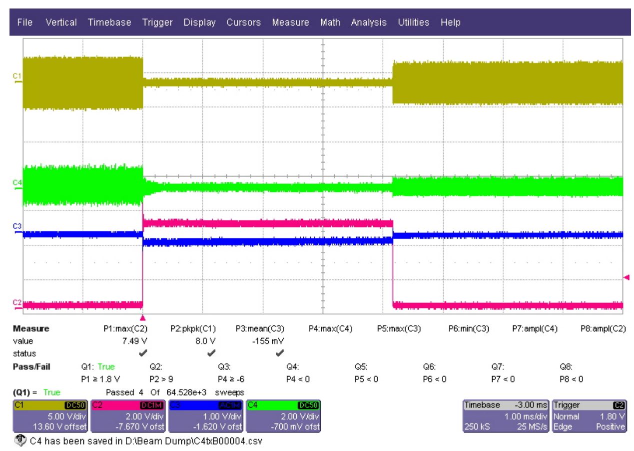

Figure 4: Beam dump procedure with amplitude loop constraint. Before the dump, the forward power is around 55 kW (accumulated current 330 mA). It backs to 28 kW, when the input power is applied to the cavity.

Relevant efforts have been made to assess and improve the TH 793-1 IOT tube working conditions. Having tested only one tube which had undergone a false contact cable trouble, no final conclusion can be drawn about its use in the storage ring application.

REFERENCES

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