

A THIRD ACCELERATION UNIT FOR THE ESRF STORAGE RING

C. DAVID, J. JACOB, A. PANZARELLA, J.P. PERRINE AND J.L. REVOL

ESRF, MACHINE DIVISION

After only two years of design, construction and commissioning, a new acceleration unit is now in operation on the ESRF storage ring. It allows all klystrons and cavities to be run at moderate power even for high intensity operation at 200 mA, whilst still gaining in total accelerating voltage, from 8 to 12 MV. The third pair of cavities can also be used to modulate the radio-frequency voltage at the revolution frequency, thereby producing additional damping of longitudinal multibunch oscillations. The planning and commissioning constraints imposed by the installation of this equipment on a running machine was one of the challenging issues. The project was managed so as to minimize the inconvenience for ESRF users.

Four 352.2 MHz five-cell cavities and two 1.0 MW Radio Frequency (RF) transmitters (upgraded to 1.3 MW in January 94) were initially installed on the ESRF storage ring for an operation at the design current of 100 mA at 6 GeV. During the commissioning of the storage ring, it was already possible to store higher currents and 200 mA of beam current have been delivered to the users in multibunch operation since November 1995. This resulted in pushing the power through the cavity input couplers to very high values and required operating the storage ring with both RF transmitters, each feeding one pair of cavities with up to 750 kW. In early 1995 it was decided to construct a third RF transmitter (SRRF3) feeding a third pair of cavities [1]. Besides the reduced power load for the cavity couplers and a gain in redundancy, this third RF unit opens up other interesting new features.

DESIGN AND CONSTRUCTION

Based on experience gained from the existing RF units, it was decided to construct the third RF unit using similar hardware for the large components. This includes the klystrons, the high voltage power supply, the circulator, parts of the low level RF and the five-cell cavities [1, 2, 3, 4]. The 100 kV - 22 A DC power supply for the third klystron was ordered in September 95 from the constructor and mounted and cabled under our responsibility: it was a very successful

approach both in terms of cost savings and transfer of expertise to the RF crew. It also eased the implementation of an improved local control and of special measures against interference with the remaining RF equipment. The high-voltage power supply was ready as scheduled at the end of February 97. A new control system was developed for SRRF3 and commissioned in parallel with the hardware [5]:

- The object-oriented programming approach based on the separation between the transmitter and the cavities, which are themselves split into basic devices, proved to be very versatile for the development.
- The hardware protection is managed independently from the control software by a PLC for the slow interlocks and a hardwired system for the fast protections.
- The diagnostics tools included in the design are very useful for trip analysis and parameter follow up.
- The operator controls the RF system via an easy-to-use graphical user interface. Some sensitive parts of the RF system, such as the arc detection system, have been redesigned in order to reduce the rate of spurious triggering. Also the cavity vacuum equipment has been improved:
- The fast pressure interlock system, which is essential for the ceramics protection against glow discharges with subsequent sputter deposition of copper [3], has been doubled (two fast pressure detectors per cavity).
- The NEG pumps of the old design have been replaced by titanium sublimation pumps. This proved to be

very efficient during RF conditioning and commissioning with beam, as it was possible to activate these pumps regularly, so that the vacuum could recuperate quickly after a strong outgassing.

COMMISSIONING AND OPERATION

The new SRRF3 transmitter was ready for commissioning with beam on the scheduled date in August 97. After only four days, 160 mA could be stored and were then delivered for the first week of user service mode. The maximum ESRF current of 205 mA was reached one week later and served routinely in the 4th week of User Service Mode. The failure rate was higher during the commissioning period and the beam availability was reduced (90% instead of the usual 95%). After only three months of operation, the mean time between failures was recovered and is steadily increasing. During the three first months of operation, a lot of trips were caused by bursts of reflected power from the cavities, which were typically 50 μ s long and as high as 300 kW at the peak. These events were mostly associated with outgassing and were probably due to fast detuning provoked by multipactor in one of the five cells. Continuous operation of the cavities was the only cure for these trips which steadily became less and less frequent. In the early stage of commissioning, we were also confronted with high harmonic power generated by the

klystron. The harmonics are fed back to the klystron by the reflection from the circulator, which is only matched at the fundamental RF frequency. Careful adjustment and positioning of matching elements (iris, post) allowed the harmonic power to be brought to an acceptable level.

A part of the early failures were removed gradually during the first three months simply by debugging the system. The high voltage power supply proved to be very reliable.

NEW POSSIBILITIES

More flexibility and larger safety margin

The fact that the maximum ESRF beam current of 205 mA can be stored without SRRF2 represents a large gain in flexibility and security. Klystron acceptance tests, cavity coupler conditioning and extensive R&D work requiring RF power can now be performed without restriction for the ESRF users.

It is planned to extend the waveguide network such that SRRF2 can replace either SRRF1 or even the booster RF system. By doing this, we will obtain a level of redundancy that will allow the operation of the storage ring to be safeguarded even in case of a major failure on any single transmitter.

Increase in cavity voltage

The third pair of cavities has allowed the cavity voltage to be raised from 8 to 12 MV with only a negligible increase in total power and still a reduction of the power per cavity coupler. However, it turned out that the associated gain in longitudinal acceptance did not show up on the lifetime which is presently limited by the transverse acceptance. Increasing the transverse acceptance of the storage ring is therefore one topic of machine physics studies to fully benefit from the enlarged longitudinal acceptance.

Since in single-bunch and 32-bunch operation the lifetime is also Touschek limited, the optimum voltage was found to be close to 8 MV, for which the bunches are longest and the energy acceptance is not yet limited by the RF.

Landau damping** of multibunch instabilities with cavities 5 & 6

For standard high intensity operation,

only 2/3 of the storage ring is filled to produce strong transient beam loading, which leads to a voltage modulation at the revolution frequency f_0 . The subsequent spread in synchrotron frequencies provides Landau damping of longitudinal multibunch instabilities which are driven by Higher Order Modes (HOM) developing in the cavities, a point of major importance for the ESRF [6]. An additional feature of the third RF system is the possibility to operate it at $f_{RF} + f_0$, such as to modulate the total RF voltage actively even for symmetrical fillings [7].

The detuned fundamental modes of cavities 5 & 6 can be used intentionally to launch an $n = 1$ multibunch instability. The threshold current is increased by a factor 4 when applying a modulation voltage of 1.5 MV. This scheme is employed for operation with 32 equally-spaced bunches in the storage ring. In this operation mode the optimum voltage of about 8 MV requires switching off cavities 5 & 6. As these are no longer temperature regulated, modulation is necessary to operate untroubled by multibunch instabilities at the nominal intensity of 90 mA.

Basis for an upgrade of the existing transmitters

After the successful commissioning of SRRF3, the new control system is now fully validated. From the high UNIX level down to the hardwired fast interlock system, it had been designed taking into account the necessity of upgrading the existing RF units. Thanks to the existence of SRRF3, this work is now possible in parallel to operating the storage ring at full intensity.

Based on the clear separation between cavity and transmitter control, we are able to proceed in two steps. We will first transfer the cavities 1 to 4 from the initial to the new control system. This will take place in the next October shutdown. The upgrade of the transmitters will then take place one by one.

CONCLUSION

The third RF acceleration unit was successfully built and put into operation. It was fully designed by ESRF staff in order to best match the operation constraints and specificities, and to fit into the ESRF environment, taking into account the experience

gained on the existing RF units. Performing such a design and construction work was very beneficial for broadening the knowledge and expertise of our RF group personnel. The project was completed within its budget and on schedule, and was managed so as to minimize the inconvenience for ESRF users. This was a challenging issue for a machine which delivers 5600 hours of x-ray beam per year. ■

ACKNOWLEDGEMENTS

The authors wish to thank the numerous colleagues from the Technical Services, the Computing Services, the Safety Group and the Machine Division for their contribution to the success of the SRRF3 project, and particularly: P. Barbier, D. Boilot, B. Boucif, M. De Donno, H. Delamare, M. Dubrulle, G. Gautier, P. Kernel, J.M. Mercier, J. Meyer, N. Michel, O. Naumann, J.L. Pons, E. Rabeuf, D. Vial.

REFERENCES

- [1] J. Jacob et al., «Construction of a Third RF Acceleration Unit for the ESRF Storage Ring», EPAC'96, Barcelona, June 1996.
- [2] J. Jacob et al., «Commissioning and Operation of one Booster and two Storage Ring RF Acceleration Units at the ESRF», EPAC'92, Berlin, March 1992.
- [3] J. Jacob et al., «RF System Development for High Current Accumulation in the ESRF Storage Ring», EPAC'94, London, June 1994.
- [4] J. Jacob et al., «Commissioning of the Third RF Acceleration Unit for the ESRF Storage Ring», EPAC'98, Stockholm, June 1998.
- [5] J.-L. Revol et al., «An Object Oriented Control System for the Third Storage Ring RF Unit at the ESRF», EPAC'98, Stockholm, June 1998.
- [6] O. Naumann and J. Jacob, «Fractional Filling Induced Landau Damping of Longitudinal Instabilities at the ESRF», PAC'97, Vancouver, May 1997.
- [7] O. Naumann and J. Jacob, «Landau Damping of Longitudinal Instabilities for the Operation of the ESRF Storage Ring», EPAC'98, Stockholm, June 1998.

** The Landau damping decreases the energy spread of the beam induced by coupled bunch oscillations and increases the bunch length (which also means the Touschek lifetime).