

SIX MONTHS OF OPERATION OF THE NEW RF CAVITY SYSTEM OF SLRI

N. Juntong[†], Ch. Dhammatong, P. Sudmuang, N. Suradet
Synchrotron Light Research Institute, Nakhon Ratchasima, Thailand

Abstract

The new RF cavity system has been installed in the storage ring of SIAM Photon Source (SPS) since August 2016. The RF cavity was designed base on the MAX-IV laboratory capacitive loaded type cavity. The solid-state technology was implemented in the RF high power transmitter. The low-level RF system utilized the digital technology. The system has been successfully commissioned and run with a capability to compensate an energy lost from a full capacity run of insertion devices since August 2016. This paper summarizes the problems and actions of new RF system and presents an overview of six months of operation of the new RF system in the storage ring of SPS.

INTRODUCTION

The SPS has serviced with the bending magnet beamline to user since 2003. The U60 undulator was later installed in the storage ring in 2007. New insertion devices (ID), the 2.4 T multipole wiggler and the 6.5 T wavelength shifter, was installed in SPS ring during June to August 2013 [1]. With a full operation of these magnets, it is beyond a compensation capability of the existing RF system. The second RF system was installed to strengthen the compensation limit in August 2016 [2-3]. The SPS ring was reopened for user service after a complete beam commissioning in September 2016.

The SPS services beam is in a decay mode with a maximum 150 mA electron beam at 1.2 GeV. Electron is first injected with the beam energy of 1.0 GeV from the booster ring and later ramped up to 1.2 GeV. The service is 11.5 hours per shift with 1 hour reserved for injections. The 24 hours beam current is illustrated in Fig. 1 and can be seen real-time online at the machine status webpage [4].

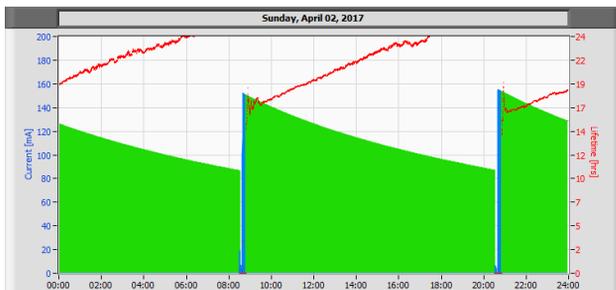


Figure 1: Beam current during the 24 hours beam service period of SLRI.

The beam service mode is classified in to 5 modes according to the operation of the IDs: mode 1-Bare Ring (U60), mode 2-MPW (U60 with 2.2 T wiggler), mode 3-

SWLS (U60 with 6.5 T wavelength shifter), mode 4-Full IDs (U60 with 2.2 T wiggler and 6.5 T wavelength shifter), and mode 5-IDs (U60 with 2.2 T wiggler and 4.0 T wavelength shifter). The SPS ring services in mode 5 after a shutdown, which is same as before a shutdown. There is a radiation, which limits the operation of the full capability of the IDs in mode 4. The radiation also limits the operation of the new RF system. These issues are being investigated and treated.

INCIDENTS DURING COMMISSIONING

The new RF cavity was conditioned after it has been installed in the storage ring. The SPS storage ring has no shielding roof. A radiation has been detected higher than a safety standard in the experimental hall during a conditioning process. Unauthorised person was not allowed entering an experimental hall during the conditioning. The cavity was later shielded locally as shown in Fig. 2 and the operation with electron beam has been monitored within a safety radiation level.



Figure 2: The RF cavity in the local shielding.

The RF cavity was diagnosed with a minor leak after the acceptance test process, running at 30 kW RF power for 12 hours. The leak was observed after changing the beta coupling from 1 to 2 as the base pressure of the section could not reach 10^{-10} Torr after the vacuum baking process. The leak position was found at one of the pickup probe ceramic window as shown in Fig. 3. The leakage might caused by either a fast RF conditioning process or the impurity in the ceramic window during a manufacturing. There might be a tiny spark on the ceramic surface when electric field was concentrated on that surface. The leaked window was replaced by a blind flange as there was no spare window. The other pickup probe was used for monitoring the RF accelerating voltage and phase.

The cavity was later conditioned up to only 190 kV as the schedule time was delayed by the leak issue. The beam commissioning was done in mode 4 and mode 5. High radiation was detected when operated in that modes with a

[†] nawin@slri.or.th

high cavity voltage. The beam service is decided to be only in mode 5 with the cavity voltage of 185 kV while the radiation issues are being solved.

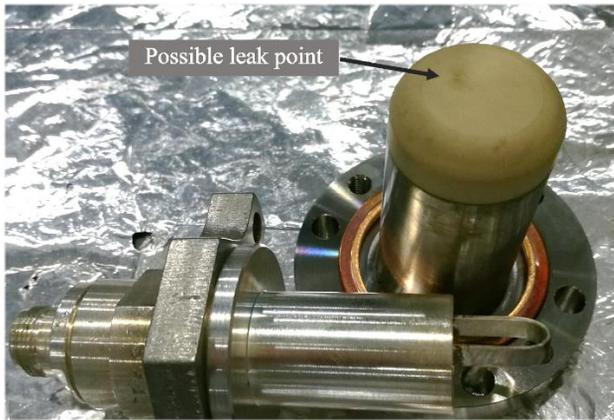


Figure 3: The possible leak point of the pickup probe ceramic window.

RF CONDITIONING

The new RF cavity was conditioned up to only 190 kV accelerating voltage after recovering from the leakage at the pickup probe window. Other RF conditioning was performed two time during the six-month operation. It was scheduled during a machine study period in December 2016 and February 2017. The conditioning was scheduled on the night shift to avoid generating radiation to daytime researchers. The purpose of the conditioning is to recover the cavity back at the capability of handling a 30 kW RF power in order to generate a 300 kV accelerating voltage. Other purpose is to cure a multipacting.

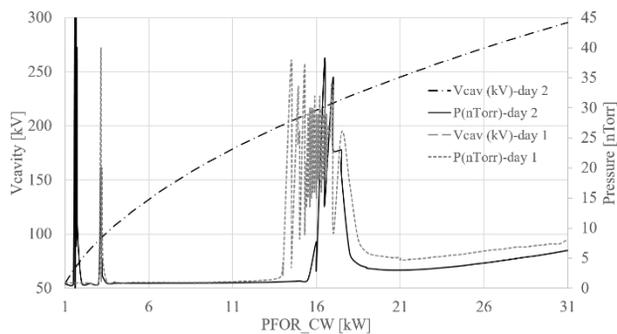


Figure 4: Results of the December conditioning.

The December conditioning was scheduled for two nights. Main activity was to push the cavity to its limit at 30 kW power. The vacuum pressure and the cavity voltage with various RF power during the conditioning is shown in Fig. 4. The cavity voltage increased with respect to the input power, but it was not 300 kV at 30 kW power. It was 295 kV. The voltage will reach 300kV when a good vacuum has been obtained inside a cavity. The multipacting was observed from an unexpected increasing of the vacuum. They were at 3.1-3.2 kW and 13.9-18.0 kW. The range at a higher power was narrowed down to 16-17.5 kW

after the first night of treatment. The amplitude of multipacting at 3.2 kW was decreased, but there was a high multipacting at 1.7 kW as can be seen in Fig. 4. The low power multipacting can be allowed as the operational point is not at a low power, but the high power multipacting shouldn't be avoided. It will limit the smooth variation of the cavity voltage. The treatment of these high power multipacting was resumed in the February conditioning.

The February conditioning was also scheduled for two nights. Main activity is to cure a high power multipacting. The pressure and the cavity voltage resulting from this conditioning is shown in Fig. 5. Comparing with the December conditioning, the multipacting magnitude is much lower. The multipacting was at 16-18kW and at the low power of 1.7kW and 3.3kW. The amplitude of pressure was decreased after the treatment especially for the high-power points. The conditioning will resume in the next scheduled slot.

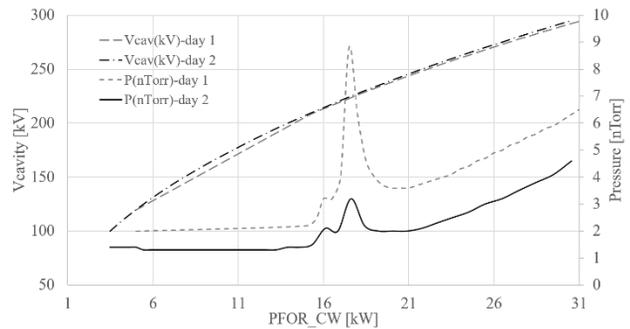


Figure 5: Results of the February conditioning.



Figure 6: The new RF system control panel.

OPERATIONAL PERFORMANCE

The new RF system is running as the main system while the existing system is kept as the backup. The cavity was operated at 185 kV for storing electron beam 150 mA at 1.2 GeV. This operating parameter is sufficiency for a beam lifetime and the radiation is within the safety limit. The control panel of the RF system is shown in Fig. 6. This control screen can be accessed either from a control room or at the LLRF control rack. The cavity voltage and phase

is well controlled within ± 500 V and ± 0.1 degree, respectively. There was a reflection when changing the master oscillator frequency during a machine parameters measurement as shown in Fig. 7. The reflection is caused by the frequency mismatch between cavity and amplifier, but this mismatch can be solved by the tuner mechanism of the cavity.

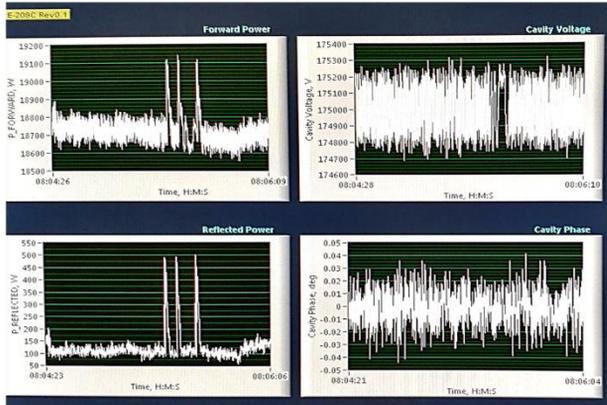


Figure 7: The reflection during a frequency adjusting.

There were no serious failure effects to user beam time from the new RF system during a six-months operation. The beam lifetime in mode 4 and mode 5 at 185 kV cavity voltage is greater than 20 hours. The machine status and important parameters as shown in Fig. 8 can be seen online via the machine status website. The operational history and the electronic logbook can also be accessed online.



Figure 8: Operational status of the SPS storage ring.

Operational Issues

The downtime of the new RF system during the six-months period can be categorised by a sub-system failure as illustrated in Fig. 9. The high downtime during this period was from a learning curved of the maintenance. The failure in the high-power RF amplifier (HPA) system was the major downtime of the RF system followed by the failure in water cooling system. The HPA system failure was mainly from the controller communication fault. The communication problem was solved by replacing a flash card of the PLC, which contain a new programming algorithm.

The cooling system problem was mainly from the cavity cooling flow rate dropped. This was caused by the heat accumulated in the cooling unit and degraded the compressor

performance. After the heat issue has been rectified, the problem was solved. The HPA cooling system had one of three compressors overloaded. This problem is being investigated with a manufacturer.

There were a vacuum incidents from the cavity section. This is the usual phenomenon of the new RF cavity. After the base pressure inside the cavity is getting better, the residual gas captured beneath the cavity inner surface will burst out and this make a pressure inside the cavity increase suddenly. The problem will disappear after a long operation of the cavity. The LLRF system problem was mainly from an error of the controlling program. This was actioned by restarting the system.

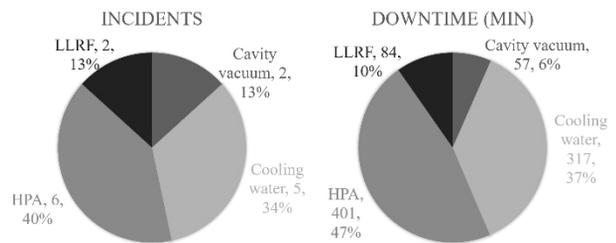


Figure 9: The new RF system breakdown issues.

CONCLUSION

The new RF cavity system was successful commissioned in August 2016. The radiation was observed higher than a safety standard during the commissioning process. The local shielding was installed at the cavity. The cavity was operated at 185kV for a user beam service. The cavity voltage and phase is controlled by a digital LLRF system within ± 500 V and ± 0.1 degree, respectively. There was no serious downtime from the new RF system. The major downtime of the system was caused by the failure in the RF amplifier system and the water cooling system. The new RF cavity is being conditioned to recover the capability of handling 30kW after solving the leakage at the pickup probe window. The multipacting is also being treated to avoid a high-pressure effect while operating at a high cavity voltage. Two RF systems will be run in combination to increase an energy compensation of the SPS storage ring.

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