Reliability of the Taiwan Photon Source

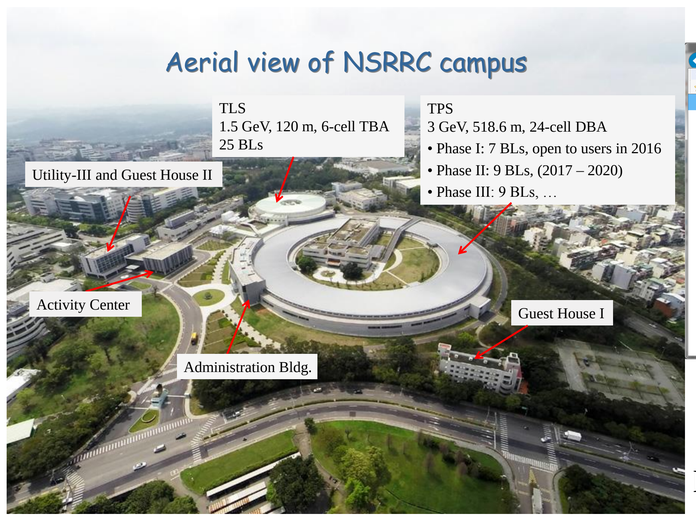
K. T. Hsu, Y. C. Liu, C. H. Kuo, C. Y. Liao, C. Y. Wu, Jenny Chen, P. C. Chiu, C. S. Huang, K. H. Hu, M. H. Yeh, M. C. Lin, Ch. Wang, K. B. Liu, C. S. Fang, K. R. Tsai, C. C. Kuo
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

ABSTRACT

The Taiwan photon Source (TPS) is a newly deployed 3 GeV synchrotron light source since 2016. Reliability design have been considered at design phase. Adopt right technology, adequate redundancy, enough safety margin are used to ensure acceptable reliability. However, some subsystems inherent operate in reliable way but some not due to various reasons. The light source was operate for dry run, beam-line commissioning, and to do pilot experiments during March-June, 2016. User service started from September 2016. Reliability is not good during early operation. Reliability improvement of subsystems and reduce troubleshooting efforts to minimize machine downtime were achieved after analysis causes of various unreliability events and to do adequate actions. Various diagnostics tools were employed to record related signals at the event happened. These diagnostic tools can capture beam trips, interlock signals, status of superconducting RF system, waveforms of the injection kickers, and instability signals of the stored beam for post-mortem analysis, especially for the non-trivial reliability related events. Lessons learned from these events teach us how to manage reliability of the accelerator system. After the efforts for last two years, reliability of the accelerator system improved drastically since operation of the TPS. Some unreliable scenarios, efforts to improve and plans for future will be summarized.

Operation Status

- 3GeV, 24 DBA lattices, emittance = 1.6 nm-rad.
- Deliver of 120 hours (5 days) per week for user operation.
- > 98% beam availability was achieved in Q2 2017.
- Top-up injection with high-low stored beam current limit.
  ~ 5 minutes decay beam for ~ 5 seconds injection
  ~ 300 mA +/- 0.3%
- 2/3 buckets filled.
- Stored beam current setting according to user's requirements
- Standard operation procedure setup for machine operations
- Single bunch mode is available for user. A better than 10^{-5} impurity achieved using the bunch cleaner (including camshaft mode).
- Low alpha mode tested ($\alpha \sim 2 \times 10^{-6}$, $\sigma_l \sim 2$ psec)



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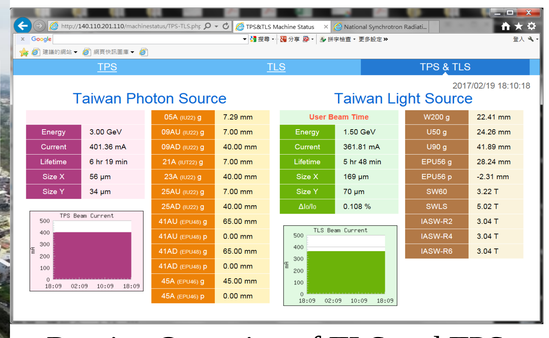
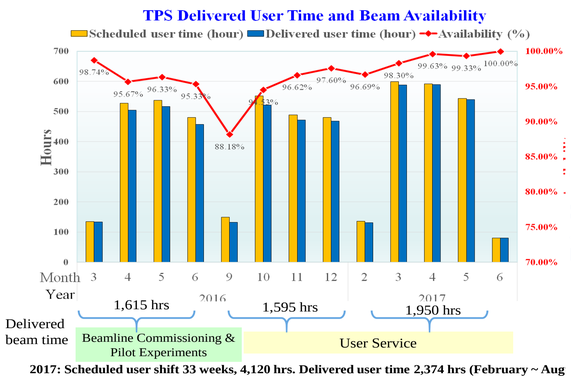
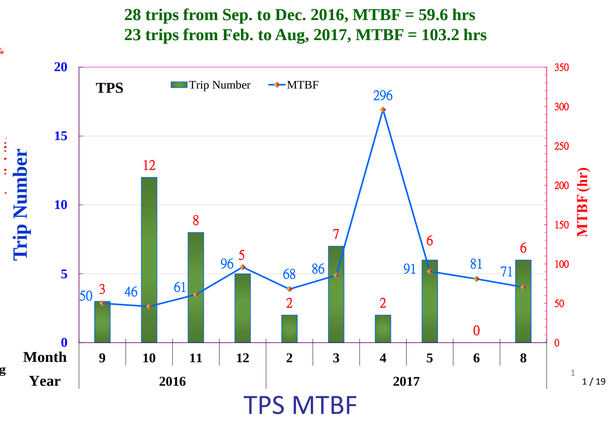


Routine Operation of TLS and TPS



TPS Operation Statistics



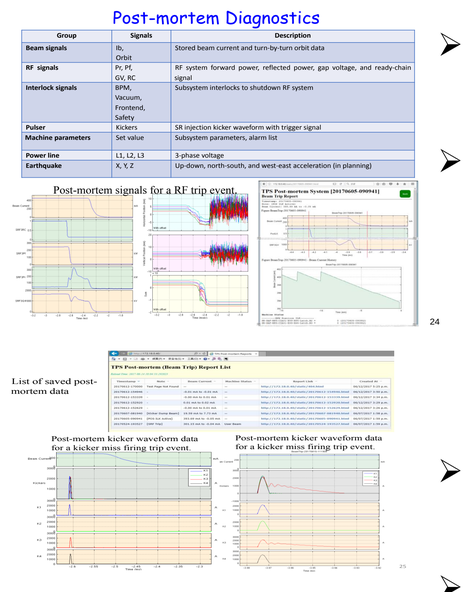
TPS MTBF

Some Events which Deteriorate Reliability and Its Remedy

Events	Cures
BPM platform: IOC crash, BPM process kill	Upgrade OS, increase memory size
250 Amp/30 V power supplies AC fault occasionally	Replace all AC modules
RF vacuum degrade of CPL	Regular RF coupler conditioning
Circumference change caused saturate of the FOFB loop due to ambient temperature effects combine with tidal effects	Add RF DC compensation
Beamline hutch/front-end/accelerator unreliable, front-end interlock controller crash due to software bugs	Add extra hard-wired interlock to parallel run with front-end NI-RIO based interface environment
CPSC memory exhausted due to software device driver to monitor SFP status	Fixed device driver bug
Klystron modulator trip	Reconditioning of the linac RF system
Kicker misfired	Coaxial cable trigger links=> fiber trigger links
…	…

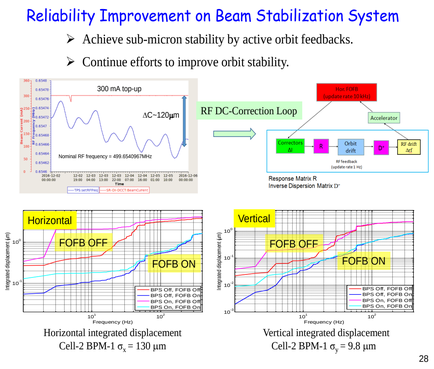
Remark: ~70% events never happened after cured

Practice of Reliability Improvement for TPS



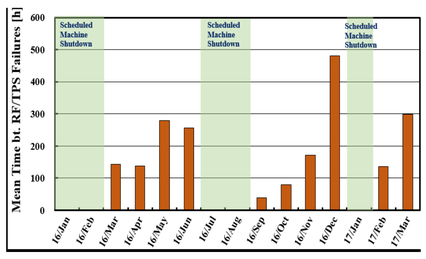
Post-mortem data capture and analysis

- TPS facility wide data acquisition system to capture necessary data for post-mortem data for further analysis.
- Data acquisition to support various data rate, sampling rate from kHz/sec to bunch-by-bunch. ~1 kHz/sec for mains voltage monitoring. ~ 50 Ms/sec for kicker waveform monitoring, Turn-by-tune beam data for beam position monitoring, bunch-by-bunch for instability observation. All of these data acquisition can trigger by post-mortem event synchronized.
- Some kickers were fired unexpectedly without trigger signal, problem solved after replace the coaxial cable trigger links by fiber trigger links.
- Analysis tools can identify source of the event with high confidence level. More sophisticated analysis tools is in developing.



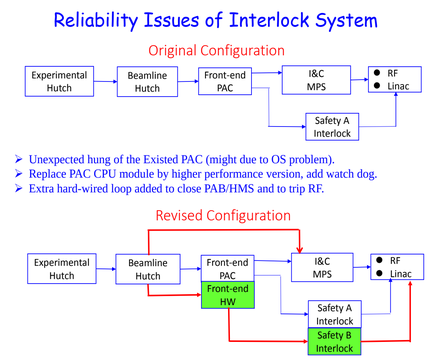
Fast Orbit feedback System

- Fast corrector DC removing scheme to move DC value to slow corrector.
- RF DC correction to cope with thermal and tidal effects for slow circumference change.
- Many diagnostics parameters monitoring: Beam position rms value, BPM healthy, IOC status, … etc.



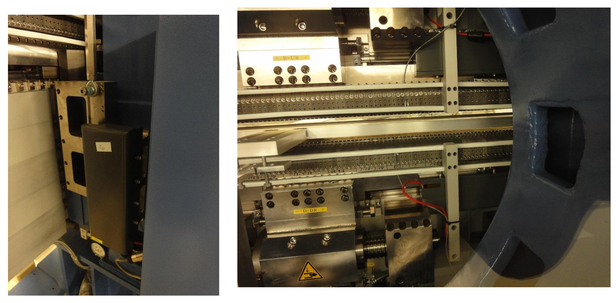
Operation statistics for the storage ring SRF modules at the TPS

- Regular SRF coupler conditioning and beam processing (current weekly base, two weeks based will try later).



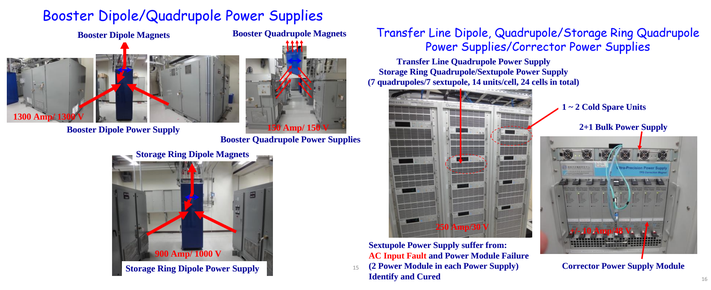
Beamline hutch/Front-end-Accelerator unreliable

- Due to CPU crash of the NI-RIO module after remote login which caused interlock failured.
- Add another hard-wired logic to parallel run with the existed NI-RIO based front-end interlock system.
- Replace new generator NI-RIO CPU module with the same weakness are ongoing.
- Pay more attention on the heterogeneous interlock environment of beamline/front-end/safety loop/accelerator.



Soft error due to radiation of optical encoder in EPUs

- No shield of optical encoder during commissioning stage. Radiation induced soft-error happened occasionally.
- After shield the optical encoder by 10 mm thick lad cover, the software-error almost eliminate.



Power supply system

- Large power supply spare unit with manual switch for fast switch out fault unit.
- Sextupole power supply suffer from: AC input fault and power module failure.
  Identify and cured.

… and many other efforts

Summary

- The TPS provide user service for last passing years. Reliability was improved gradually after learns from failed events and cure by apply adequate measures.
- Regular staffs training are necessary.
- Apply preventive maintenance and preventive refurbishment to avoid unnecessary downtime.
- Apply reliability engineering, human performance training to ensure reliability of future development.
- Data logging, analysis tools, correlation analysis, software tools, and apply machine learning techniques for further enhance reliability.

*E-mail: kuotung@nsrrc.org.tw

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