STATUS OF THE AUSTRALIAN SYNCHROTRON TOP-UP OPERATIONS

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Abstract

In June 2012 the Australian Synchrotron commenced Top-Up Operations for User beamtime. The facility was designed for top-up from the start with a full energy 3 GeV injection system, however top-up only became a priority once the beamline user community had established itself at the new facility in operation since April 2007. New beam diagnostic and equipment protections systems were implemented as part of the move to top-up, including a new injection efficiency monitoring system. The effect of top-up on the beamline data was also tested with each beamline prior to engaging top-up during user runs. Top-up has now been running successfully for one year and the performance statistics from this period will be presented. Top-up operations is a very popular standard mode for user beam and falling into decay mode is now treated almost as a beam dump.

MOTIVATION

Top-up operations have been shown to improve the performance of beamline due to the stabilisation of heat load on the x-ray optics. Several test runs using top-up were performed to ensure there was unintended degradation of the machine or beamline performance [1]. The thermal shock on the beamline components have been shown to cause shifts in the calibration of the beamline, leading to requirement of time consuming re-tuning of the experiments. During the test runs the injection accelerators also showed an improvement in performance with systems being left in standby mode rather than off for 8 hours at a time.

EQUIPMENT PROTECTION AND BEAM DIAGNOSTICS

During the planning phase of the top-up operation mode (see also Ref. [2]), several equipment protection and beam diagnostic systems were identified as being necessary for the smooth running of top-up mode. The key conditions were;

- injection efficiency above 50%;
- energy defining slits in the booster-to-storage ring (BTS) transfer line;
- storage ring beam lifetime > 20%;
- storage ring beam current > 50 mA;
- storage ring magnets within acceptable range; and
- storage ring scrapers protecting IDs from beam losses.

Injection Efficiency

In order to safely perform top-up the injection efficiency has be be above 50%. The injection efficiency is defined as the ratio of the charge measured at the end of the BTS transfer line to the the charge increase measured in the storage ring after several damping times. The BTS measurement is made with a fast current transformer and the storage ring measurement is made with a DCCT. The system monitors the transmission efficiency of the beam all the way through the injection system and into the storage ring and is described in more detail elsewhere [3]. If the injection efficiency falls below the 50% level, top-up operations is suspended and the storage ring defaults back into decay mode. The injection system can then be tested up to the point of extraction from the booster in order to identify any faults and attempt to enter back in to top-up mode. If required the photon shutters can be closed and a fill-on-fill injection attempted to return to above 50% injection efficiency. The injection efficiency became more stabilised after a cycling routine for the BTS magnets was introduced prior to each top-up run.

Storage Magnet Settings

During the testing phase of top-up mode tolerances of the storage ring magnets were established to find a safe operating range for injecting. The operational settings were based on achieving the correct parameters in the storage rings such as the betatron tunes, orbit, energy acceptance, chromaticity and coupling. These tolerances were also used in the particle tracking procedure in the storage ring lattice model to ensure the beam trajectory during top-up was within specification. A dedicated magnet monitoring system (see Fig. 1) was designed and installed on each sector of the storage ring that would disable injection should the magnet settings fall out of tolerance.

Storage Ring Scrapers

In order to protect the IDs from lost electron radiation that damages the permanent magnet material, the vertical scrapers in the storage ring were set to be the smallest aperture in the ring. Concentrating the losses at this point where there is additional shielding installed absorbs both stray electrons that are not captured during injection and the beam tails that are lost from the stored beam.

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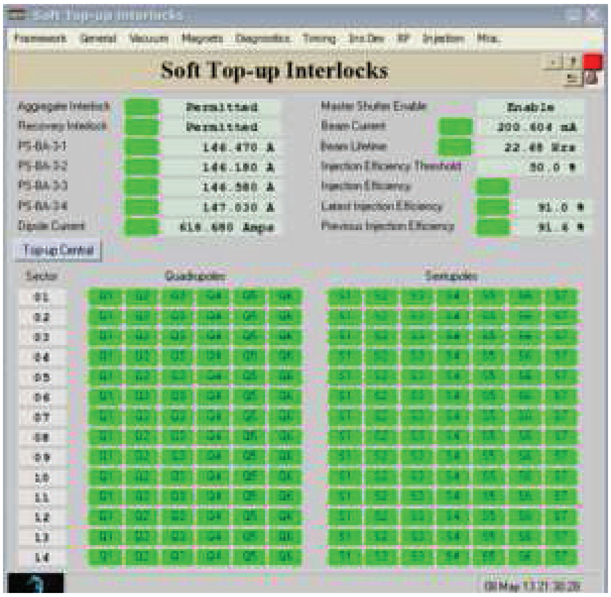

Figure 1: GUI for the top-up interlock and magnet monitoring system.

TOP-UP PROCEDURE

Beamline Notification Events

Using the event driven timing system [4, 5] Top-Up events are created for the injection system and for the beamlines. The beamlines event is a pre-trigger for the top-up event that can be used by experiments to inhibit a measurement during the few milliseconds of beam motion induced by the storage ring injection kickers and the during the damping time for the injected shot.

Lifetime and Top-Up Frequency

The lifetime of the beam in user mode with 1% emittance coupling into the vertical plane and IDs inserted is 23.5 hours at 200 mA. Combined with the injection system average current output of around 0.7-1 mA per shot and the condition that the stored beam should not drop below 200 mA results in one top-up injection shot every five minutes. If a shot is missed due to any reason on one top-up cycle, the next cycle will allow for multiple recovery shots to push the current back up to 200 mA. The threshold on the lifetime is set at 20 hours to ensure that the time between injections is kept above four minutes.

Fill Pattern

Presently there is only one filling pattern used during user beam; 330 bunches filled and a 30 bunch ion clearing gap. This fill is obtained by injecting a 75 bunch train with a stepped injection delay relative to the storage ring orbit clock. The resultant fill pattern in the storage ring is shown in Fig. 2.

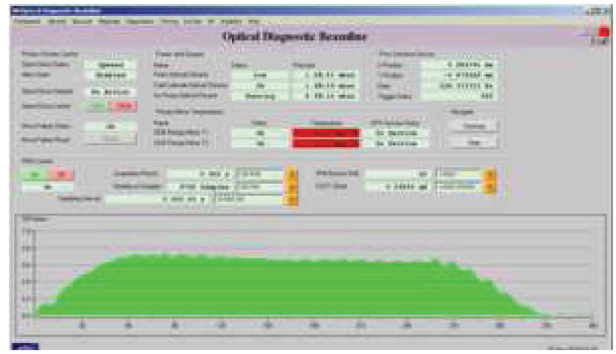

Figure 2: Typical user mode fill pattern.

Decay Mode and Top-Up Recovery

If the system drops out of top-up mode it defaults to decay mode, an announcement is made, the photon shutters stay open and the control room attempts to restore top-up. If one shot is missed while in top-up mode, the next scheduled shot can include a recovery shot once every 8 seconds to attempt to stay above 200 mA and not fall out of top-up mode. The injection rate is not at the maximum 1 Hz since the pulse magnets start to drift due to heating effects. Figure 3 shows a typical top-up run where on shot was missed on one occasion in an 8 hour period, the statistics of top-up availability are discussed in Sec. .

Figure 3: Typical facility status monitor during a top-up run.

BEAM AVAILABILITY

The beam availability statistics are now being kept to monitor not just beam availability but also top-up availability. The statistics are generated through a web server using PHP scripting and a MySQL database to query the EPICS archiver. Fig. 4 shows the weekly dropout, availability and downtime since top-up was introduced in June 2012.

Fig. 6 helps to identify where to put the effort to improve the performance of top-up mode. As seen in Table 1 the linac is the largest single cause for a top-up dropout several upgrades are being performed on the linac (see Sec.).

Since the fly wheel UPS was installed in January 2012 and top-up mode commenced in June 2012, the 16 week

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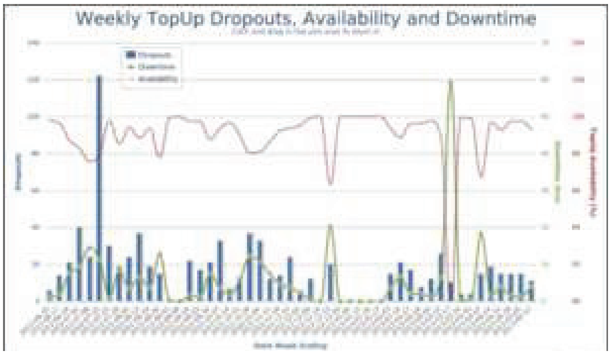

Figure 4: Dropouts and downtime since the start of top-up operations in June 2012.

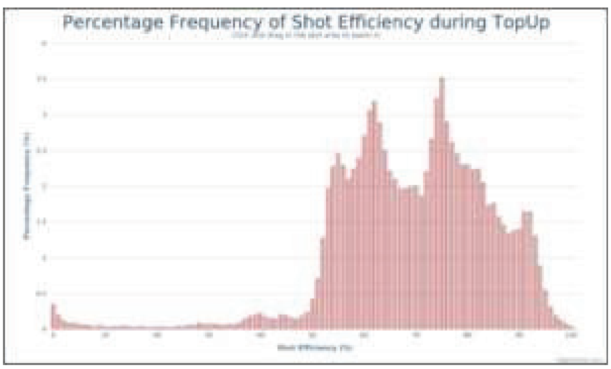

Figure 5: Histogram of beam injection during top-up.

averaged availability has not dropped below 98.4% (see Fig. 7).

FUTURE IMPROVEMENTS

Since linac is the biggest cause of top-up dropouts a phase monitoring system is being installed to help tune the RF and hopefully reduce the number of reverse power trips. New ion pumps are also being installed in the linac since

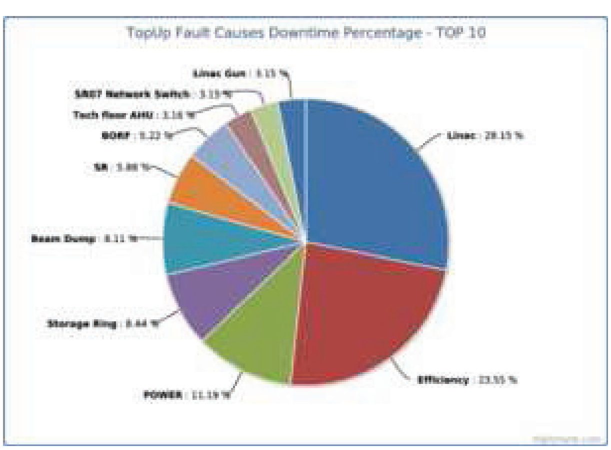

Figure 6: Breakdown of the faults that cause a top-up dropout.

Table 1: Fault Counts Causing Top-Up Dropout

System	Dropouts	Downtime
Linac	321	38:39:29
Efficiency	161	32:11:56
Lifetime	44	04:15:16
Tech floor Air Handling Unit	22	04:31:24
Booster Ring RF	20	07:12:07
Computer Controller (IOC)	19	03:38:53
Testing	16	00:03:12
Human	15	01:16:02
Power	13	15:26:22
Beam Dump	13	11:06:11
Booster Ring	12	02:00:05
Storage Ring	9	11:51:40

Figure 7: Beam availability as a 16 week running average since the start of user operations in April 2007.

they are suspected of causing arcs in the accelerating structures.

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