Radiation dose due to accidental beam loss of stored beam in Indus-2 Storage Ring

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Abstract

Indus-2 is a 2.5 GeV electron storage ring commissioned at Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, India. The storage ring is housed in a circular shielded tunnel of width 4.8 m. External and internal shield walls of the tunnel are made of ordinary concrete of thickness 1.5 m and 0.6 m respectively. Shielding design of the storage ring was carried out based on assumed beam loss scenario, in which normal and accidental beam loss was considered. During the commissioning period, accidental beam loss occurring in the ring was studied. From the study, various reasons for the loss and average number of accidental beam losses per day are found out. Against the assumed accidental beam loss of 6.0 per day, an average 2.08 per day is obtained from the present study. The radiological consequence of the accidental beam loss is evaluated. The details of the study with results and conclusion are presented in the paper.

1. Introduction

Indus-2 synchrotron radiation source (SRS) is a booster cum storage ring at Raja Ramanna Centre for Advanced Technology, Indore, India [1]. The storage ring is commissioned up to 200 mA at the design energy of 2.5 GeV. The facility is comprises a pre injector (20 MeV microtron) and a booster synchrotron (450 MeV/550 MeV). Electron beam is accelerated up to 20 MeV in microtron and injected into booster ring. Accelerated electrons at 550 MeV from the booster synchrotron are injected into Indus-2 storage ring. After accumulating the desired beam current, the energy is ramped up to 2.5 GeV and allowed to decay in the storage mode. There is provision for accommodating 26 beam lines on Indus-2. Presently 13 beam lines are operated and are used for various research applications [2]. The schematic view of Indus -2 SRS is shown in the Fig. 1.

Indus-2 storage ring is housed in shielded circular tunnel made of ordinary concrete (2.35 g /cc). Radiation environment during operation of the electron storage ring comprises bremsstrahlung x-rays followed by photo-neutrons [3, 4]. Radiation shielding of the ring tunnel was designed and constructed based on the radiation source terms obtained from the design beam loss scenario [5]. Normal losses and accidental losses are considered while estimating the source term. During operation, the stored beam may get accidentally lost or sometimes intentionally killed. The accidental beam loss occurs due to many reasons like actuation of various interlocks and faults or trips in various sub-systems. The beam is intentionally killed by the operator for fresh filling or for shut down. For shielding evaluation of Indus-2, 6 accidental beam losses per day were assumed. In the present work, actual data on the accidental beam loss scenario was studied on daily basis for two years. It is found from the study that on an average 2.08 beam losses per day are occurring. Various reasons for the accidental loss are analyzed and the radiological consequences of such accidental beam loss are also assessed.

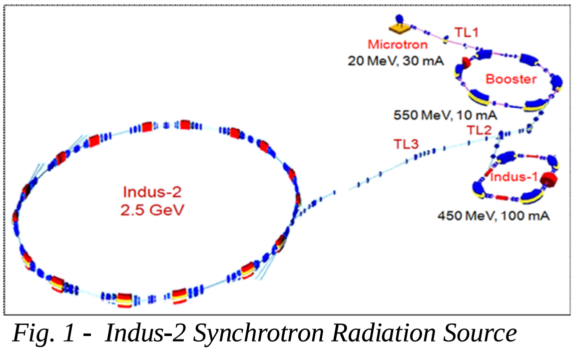

Fig. 1 - Indus-2 Synchrotron Radiation Source

2. Methodology

For the operation of the storage ring, various sub-systems like radio-frequency (RF) system, magnet systems (magnet and its power supplies), vacuum system, low conductivity water (LCW) system, radiation safety systems (RSS), safety interlock system, beam diagnostics system etc. are deployed. During the routine operation of Indus-2 storage ring, accidental beam loss occurs due to may reasons. Some of the reasons we identified are RF trip, magnet power supply trip, actuation of interlocks in front-end of beam lines, loss of low conductivity water and safety interlock actuation. Data on accidental beam losses is collected from the daily operational details of the storage ring. In addition to accidental beam loss, the data of intentional beam killings are also collected for the analysis. In some cases, the reason for accidental beam loss was not known, which was also accounted. This study was continued for 2 years and the data is analyzed.

3. Results and discussion

The accidental beam loss (including the intentional beam killing) data obtained from study is presented in Fig. 2 and Fig. 3. The figures indicate the results obtained during the year 2012 and 2013. The data shows that 390 accidental beam loss occurred during 2012 whereas 455 in the year 2013. In the year 2013, higher accidental loss is observed in comparison with 2012, and is attributed to more intentional beam killing for experimental purpose or for fresh filling. Besides, commissioning activities of front-end of new beam lines were taken up during 2013, during which conditioning of the front-ends led to increase of pressure in the front-end, sometimes. This also contributed to accidental beam loss on actuation of pre-set vacuum interlocks. In the facility, the mode of killing the stored beam, on actuation of any safety interlock, is through tripping of the RF system. From the data collected, the average accidental beam loss occurring per day is calculated and found to be 2.08 against the assumed accidental beam loss of 6. The cause analysis shows that intentional beam killing followed by RF and magnet power supply trip contributes to the the accidental beam loss of the stored beam.

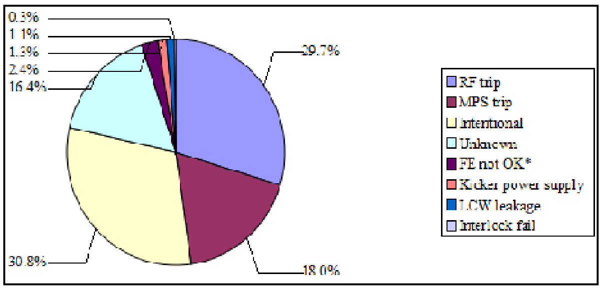

Fig. 2 - Reasons attributed to accidental beam loss (2012)

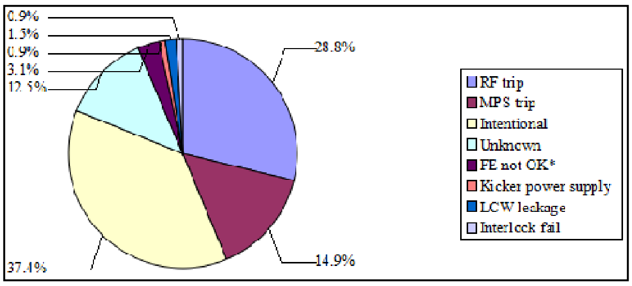

Fig. 3 - Reasons attributed to accidental beam loss(2013)

The radiological consequence of the accidental beam loss has been evaluated. It has been noticed that in the event of an accidental beam loss, ion chamber based radiation monitor installed within the ring tunnel shows a sudden rise in the radiation level. A plot showing a typical beam loss and the sudden rise in radiation level is given in Fig. 4. As the dose rate shown by the ion chamber monitor does not give the true dose per event, the conservative dose value per event is calculated assuming a point loss of 200 mA circulating current at 2.5 GeV, using the empirical relations suggested by W.P.Swanson [6]. The bremsstrahlung dose per event obtained within the tunnel is 59 Sv at 1 m from storage ring. The dose per event due to medium energy and high energy neutrons is also calculated from the source term used for the design calculations [5]. The neutron dose obtained is 1.95 mSv at 1 m from storage ring. Assuming 2.08 beam loss per day, the total dose per day within the tunnel works out to be 125 Sv at 1 m from the loss point in the ring.

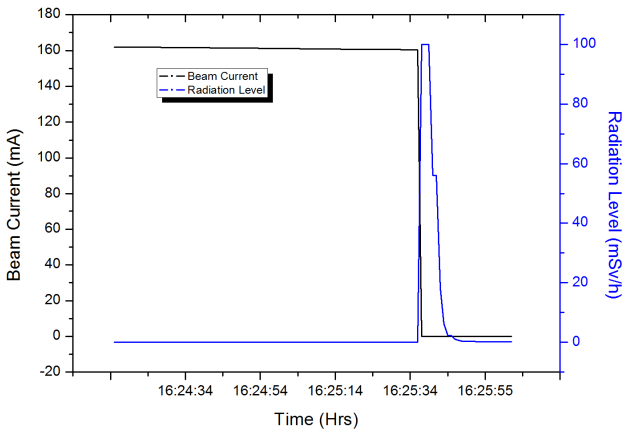

Fig. 4 - Radiation level indicated by a ion chamber monitor during an accidental beam loss (160 mA at 2.5 GeV to 0 mA)

Expected dose outside the shield is also evaluated. As the experimental hall is shielded from the ring by a 1.5 m thick ordinary concrete wall, dose per event in the lateral direction during accidental loss outside the shield is calculated taking the shielding thickness of 1.5 m. In the forward direction a slant thickness of 3.14 m ordinary concrete shield is taken for the calculation. The bremsstrahlung photon dose per event (for 200 mA at 2.5 GeV) is worked out to be 0.70 μSv in the forward direction whereas the neutron dose is 2.34×10^{-3} μSv. Assuming 2.08 losses per day, the total dose expected in the forward direction is 1.42 μSv/day, and in the lateral direction, it is 4.62 μSv / day. From the dose assessment, the dose per day outside the shield due to an accidental loss of stored beam is found to be well within limits. In the case of a distributed loss, the dose will be less than the values obtained for a single point loss.

4. Conclusion

A study was undertaken to monitor the accidental beam loss occurring during the operation of Indus-2 storage ring, at 2.5 GeV. This study helped in evaluating the number of sudden beam loss events occurring during operation, against the assumed beam loss, and the radiological consequences. From the study carried out for 2 years, it was observed that on an average 2.08 beam killings per day is occurring during the operation of the storage ring against the assumed value of 6.0 for shield evaluation. Corresponding to the operating parameters of 200 mA at 2.5 GeV, the radiological consequence outside the shield is evaluated and found to be well within limits.

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