IMPROVEMENTS OF SPRING-8 LINAC TOWARDS TOP-UP OPERATION

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Abstract

The top-up operation of the SPring-8 storage ring has been started since May 2004. In order to realize alternative injection into the booster synchrotron in the top-up operation and the NewSUBARU, a fast response bending magnet was replaced the DC bending magnet in the beam transport line to the booster synchrotron. In order to obtain the higher reliability of the linac for the top-up operation, reinforcement of the beam monitor systems, further improvement of RF phase stability and upgrade of the control system were required. BPMs have been additionaly installed in energy dispersion sections. The phase variation in the RF system was reduced by the thermal control in the waveguide of the klystrons drive system. We re-engineered the VME systems to improve availability of the linac operation considering its reliability and flexibility.

INTRODUCTION

The SPring-8 storage ring has maintained a top-up operation since May 2004. In the top-up operation, frequent beam injections at short intervals keep the stored current approximately constant. Fig. 1 demonstrates the obtained current variations for two days; the constancy of the stored current was less than 0.1%.

The synchrotron radiation (SR) lights of constant intensity give users the following great benefits: The unstable thermal deformation of X ray optics caused by the decay of the SR light intensity was completely stabilized. This optical stability maximizes performance of high precision experimental devices. The top-up operation also enables some filling patterns which have the short Touschek lifetimes, such as the several bunch operation. The top-up operation thus promises wide range of users to provide the expanded experimental environment.

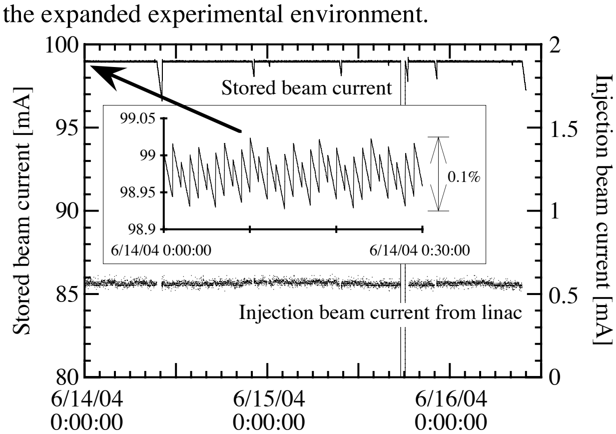

Fig.1 Stored beam current in the top-up operation, and injecting current to the synchrotron from the linac.

Aiming at an ideal top-up operation, which is almost realized, the SPring-8 accelerator division has performed various R&Ds: The ring accelerator team succeeded in stabilizing the stored beam even at the moment of the beam injection [1]. A linac has been improved in order to provide beams with the stable energy and current at any time.

The linac has to inject beams into a 1.5 GeV storage ring New SUBARU located in the SPring-8 site [2]. In order to perform the simultaneous top-up operation of the two rings, we installed at the end of the linac the new bending magnet which can be momentary excited at a short interval.

We explain the linac improvement towards the top-up operation according to the following classification:

- Enhancement of beam stability.
- Enhancement of reliability.
- Fast beam distribution.

ENHANCEMENT OF BEAM STABILITY

Improvements

The beam stability of the SPring-8 linac has been improved by means of reducing RF variations, providing beam energy compensation, and reinforcement of monitor systems as follows [3].

Variations in the RF power and phase have been reduced by improving the voltage regulation system for the klystron modulator, and by stabilizing the temperature drift of the atmosphere and cooling water in order to reduce the phase variation. These improvements realized a greatly reduced energy fluctuation of 0.03% rms. We recently observed that the temperature variation has increased to 5˚C and a nonnegligible phase fluctuation has reappeared. This problem is discussed in the next section.

A new synchronous oscillator synchronizes a beam trigger pulse and a 2856 MHz reference signal. Variation in the beam charge was reduced by this synchronizing technique; the stabilized beam loading consequently resulted in the beam energy fluctuation of 0.01% rms.

A beam energy compression system (ECS) was installed to compensate for accidental energy variation and reduce the energy spread due to beam loading. The reduced energy spread enabled the high-current injection without increasing beam loss.

A BPM system employing shared memories for synchronized fast data acquisition has been constructed. And 13 sets of BPM were added in last year. A quasi nondistractive profile monitor using thin foil OTR was installed in a chicane section of the ECS to observe the beam energy and energy spread during the beam injection.

These monitors greatly aid in both beam diagnosis and beam adjustment.

Room temperature issue

The linac holds thirteen 80-MW S-band klystrons to feed RF powers to accelerating structures. The first klystron drives the rest twelve klystrons via a 90-m long waveguide drive line. This RF system is shown in Fig. 2. The temperature variations in the klystron gallery caused the RF phase fluctuation at the output ports of the drive line because the waveguide was not temperature stabilized. The phase at the end of the drive line has the temperature coefficient of about 3 deg./˚C.

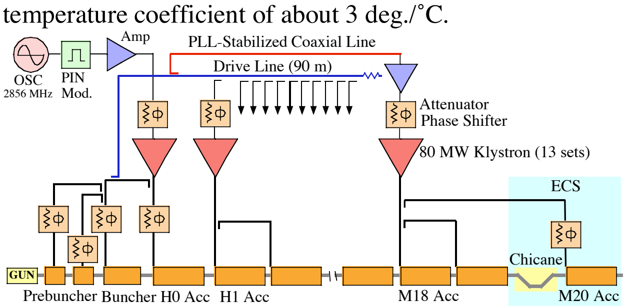

Fig. 2 RF system of SPring-8 linac

We reduced the RF repetition rate from 60 Hz to 10 Hz for electric power saving in 2002, we accordingly saw remarkable room temperature drifts when the outdoor air had low temperature in winter. The reason was as follows: This power saving greatly reduced heating up of the gallery air. An air conditioner system can only cool down the ventilated air and it also took the cold outdoor air into the gallery. The gallery temperature consequently could not be controlled and fell down below a set value in winter. In order to reduce the temperature drift of the waveguide, we took the following measures: We covered the 90 m long waveguide with thermal insulation and circulated 28 ˚C waters in the insulation. The temperature variation of the waveguide was consequently reduced to one third of that of the gallery. Intakes of outdoor air were closed in order to minimize the influence of the outdoor air.

Long-term stability

The long-term energy stability was measured by the BPM and OTR monitor mentioned above. Fig. 3 presents the beam energy variations before and after the ECS during two days. The plotted energies before the ECS shows the accidental reduction, the compensated energies, however, kept its stability of 0.14% (p-p) through the measurement. Thus the ECS is effective in maintaining both shot-by-shot and long-period beam energy stability.

ENHANCEMENT OF RELIABILITY

Diagnosis of klystron modulator

The top-up operation of the SR keeps the constant stored current with variations less than 0.1% over several weeks. In order to maintain this current stability, it is indispensable to reduce frequencies of the modulator's faults. Most of the faults are caused by prefires (spontaneous turnon) of thyratrons. A prefire occurs when the thyratron's reservoir voltage is not adjusted at an optimum voltage. In order to expect or prevent the thyratron prefire, the reservoir heater voltages and prefire counts of thyratrons are automatically acquired in a database. And turn-on time jitters is measured every week. The acquired data will be used for diagnosis of the thyratrons.

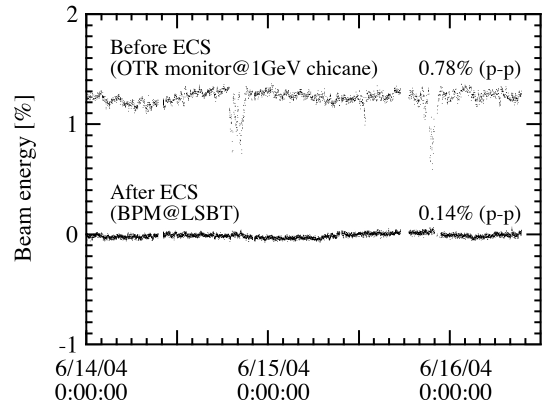

Fig.3 Variations of the beam energy before/after ECS

Preparation of standby klystrons

Eleven of the klystrons have been used to accelerate electron beams up to 1 GeV and the other two have been kept for spares on line. The two spares were not powered, hence it would take more than few hours for RF conditioning of the two klystrons and their accelerating structures when they had to work instead of a failed klystron. This conditioning time, which might suspend the top-up operation, could be zero if the two klystrons had been powered and fed RF powers to the accelerating structures without accelerating beams.

The RF system works at 10 Hz, the beam, however, is ejected at 1 Hz. We thus introduced a trigger mask circuit which momentary disable any working klystrons not to accelerate beams. Now all the klystrons are feeding RF powers to the accelerating structures and two of them are on standby and ready for beam acceleration. Thus we will greatly reduce the linac down time in case that one klystron or modulator of normal section fails.

Upgrade of linac control system

The upgrade was divided into two phases. In the first phase on 2000, we mainly replaced software part with SPring-8 standard framework. In the second phase on 2003, we reengineered the VME systems to maximize availability of the linac operation considering reliability, usability, expandability and flexibility. We newly developed an optically linked remote I/O system and intelligent motor control units. By adopting these systems, the number of the controllers were reduced. All interface connector boxes were re-designed and replaced to achieve easy maintenance and expandability [4].

FAST BEAM DISTRIBUTION

Installation of fast response bending magent

The linac is equipped with a bending magnet which switches a beam from the transport line for the NewSUBARU storage ring to one for the booster synchrotron. In order to realize simultaneous top-up operation of the two rings, the bending magnet has to repeat turnon and turnoff at a short interval. Thus a previous block-type bending magnet was replaced with a fast response bending magnet.

In order to achieve fast response and a small residual field, a material of 50A400 silicon steel plate 0.5 mm thick was chosen for the lamination-type yoke of the new magnet. The measured residual field was about 10 gauss, one third of the previous field.

A fast response power supply was also fabricated for the new bending magnet. This power supply can excite the new magnet at 0.9 T with the rise/fall time of 200 ms.

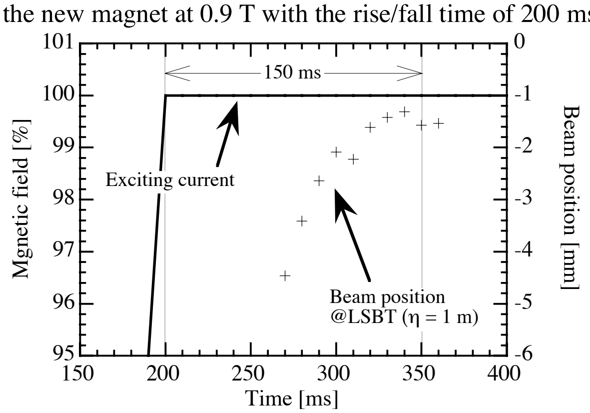

Fig.4 Influence of eddy current on the vacuum chamber

Excitation of the bending magnet induces an eddy current in a wall of a vacuum chamber. The eddy current may decay slower than the rise time. We therefore investigated the influence of the eddy current on the beam orbit as a function of time. The beam position was measured by a BPM downstream. The experimental results shown in Fig. 4 concludes that the influence of the eddy current remains for about 150 ms after the excitation current reaching a set value.

Linac operation parameter

Before beginning the top-up operation of the SR, the injection current and the linac RF frequency had been different values for the synchrotron and NewSUBARU, respectively. The reason why we had the slightly different frequencies is that the linac RF frequencies were made from the two ring's frequencies of 508.58 MHz and 500 MHz [5]. We therefore had to prepare two operation parameter sets for the two rings. The frequent switching will damage the linac's mechanical devices such as mechanical phase shifters.

In order to realize the frequent alternative top-up injecton into the two rings, we had to keep one operation parameter set for injection into the two rings except for the bending magnets and the beam transport lines.

New RF frequencies were surveyed again to minimize the frequency difference. The discrepancy in the new frequencies is only 16 kHz; the beam energy difference was expected to be negligibly small. Fig. 5 shows the measured beam energies for the injection into the two rings keeping one parameter set. The obtained final energy difference of 0.03% (after ECS) is small enough comparing to the energy acceptance of the two rings.

The new common beam parameters are the beam pulse width of 1 ns and the beam charge of 0.6 nC.

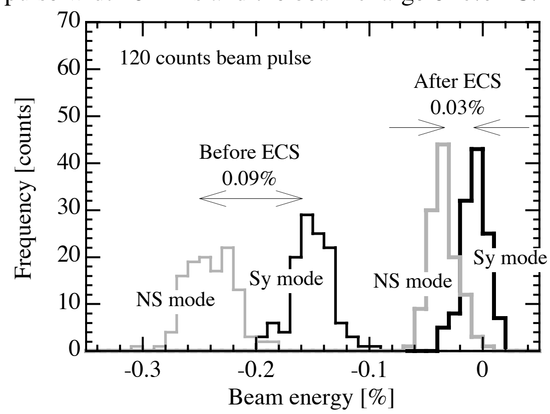

Fig.5 Energy fluctuation at the top-up operation

NEXT STEP

The top-up operation of both the rings will begin since September 2004.

The stored current in the SR is now maintained with the variation less than 0.1%. The constancy of 0.01% or less is planned as the goal of the current stability. The uniformity of the stored charges is also requested. In order to reach these goals, it is necessary to precisely control and monitor the beam at low current.

Klystrons and thyratrons have their operation lives. Klystron modulators generating the high power and high voltage pulses may be the most liable to fail. We are aiming at quick setting of the new operation parameters without disturbing the top-up operation when replacing a failed modulator with the standby one.

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