LATEST IMPROVEMENTS OF THE SPring-8 LINAC FOR HIGH RELIABILITY

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Abstract

The 1-GeV SPring-8 linac is an injector for the SPring-8 synchrotron radiation storage ring (SR) with an 8-GeV booster synchrotron (Sy) and the 1.5 GeV NewSUBARU (NS) synchrotron radiation storage ring. In recent years, we modified the linac and NS timing system to change the beam routes every 0.5 seconds. The NS timing system was changed for synchronization with that of Sy, and the gun trigger signals were improved to be time-shared for Sy and NS. These modifications were completed successfully in 2013 and realized a no-wait injection of SR and NS. A pressurized SF_6 waveguide system was replaced with a vacuum waveguide system that included newly developed S-band vacuum circulators and isolators in FY 2013. In FY 2013, the total operation time of the SPring-8 injector linac was 4328.3 hours. The total downtime was 0.13% and as stable as the last few years ; the fault frequency was 0.22 times per day.

INTRODUCTION

The SPring-8 accelerator complex is composed of a 1-GeV electron linac, an 8-GeV booster synchrotron, and an 8-GeV storage ring. The linac injects electron beams into the booster synchrotron and the 1.5-GeV storage NewSUBARU ring of the University of Hyogo.

In the early stage of SPring-8 operation, the linac injected beams one or two times a day into each ring. In 2004, the top-up operation of the SR and the NewSUBARU ring (at 1 GeV) started to stabilize the stored currents and realized constant SR lights. At present, SR is being injected every time without depending on the filling pattern, and the stored current stability is 0.03% at 99.5 mA. The NewSUBARU ring performs the injection every six or seven seconds with a current stability of 0.01% at 300 mA.

To address the problem of aging equipment and improve the RF phase stability at the electron injector section of the SPring-8 linac, we replaced a pressurized SF_6 waveguide system with a vacuum waveguide system that included newly developed S-band vacuum circulators and isolators in FY 2013. As a result of RF conditioning and beam tuning, satisfactory beam performance was confirmed. Regular beam operation with this system started in April 2014 [1].

The data acquisition system, which was synchronized with the beam timing, has been adapted for BPM data collection. For other data, we performed conventional acquisition in 1-second cycles. However, if the beam synchronization of the monitored values of other apparatuses is carried out, we can easily investigate the cause of beam variation. Therefore, we added the data of klystron voltages, RF powers, RF phases, the magnet currents, and electron gun voltages etc. to our synchronized data acquisition system.

IMPROVEMENT OF RAPID CYCLE INJECTION SYSTEM

In the previous top-up operation, the beam direction from the linac was switched every fifteen or twenty seconds by sending command messages to network devices from the central control room. Because the commands are software-based and executed successively one by one, it took about ten seconds to complete them. To switch the beam injection routes every 0.5 seconds, we improved the timing systems of linac and NS. The NS timing system was improved to synchronize with that of Sy, and the gun trigger signals were improved to be time-shared for Sy and NS. The radiation safety system was also improved for faster alternate injection. The beam route's layout is shown in Figure 1. These improvements were successfully completed in June 2013 and realized no-wait injection of SR and NS.

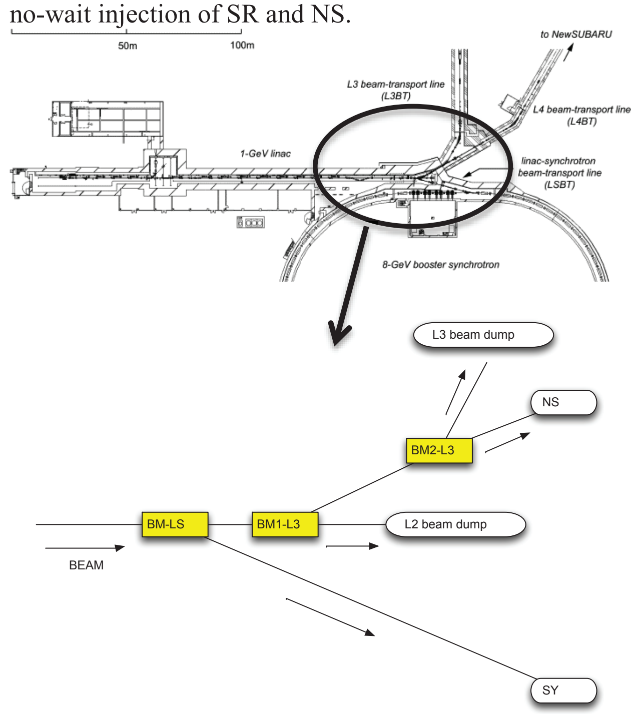

Figure 1 : Beam routes from SPring-8 linac.

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Modulator Trigger System

The modulator's PFN circuit is charged by the high voltage DC circuit just after the complete discharge of the PFN, and the charging time is sufficiently short for 60-Hz operation. If the interval of the thyratron ignition is prolonged for low repetition operation, the PFN voltage's droop becomes significant and may not be negligible. To prevent large droop, a klystron modulator is ignited by a pre trigger that is driven at irregular 4 Hz as shown in Figure 2. As a result, we are operating low 2 kV on PFN voltage to 10 Hz operation (max voltage 50 kV).

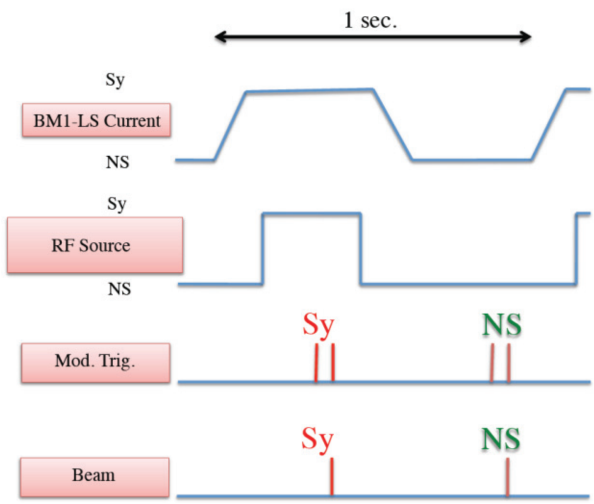

Figure 2 : Timing chart for triggers and magnetic status of BM1-LS.

Switching Magnet and Interlock System

The electron beam route of the linac is switched to the Sy or NS directions by the pattern excitation of the BM-LS bending magnet, as shown in Figure 1. The BM1-L3 is excited (but not the BM2-L3) for the NS injection. BM-LS is an electromagnet made of lamination steel plates, which make rapid cycle excitation possible.

An excitation pattern is generated only once by the TTL trigger from the outside. By carrying out 1-Hz pattern excitation of BM-LS, electron beams can be injected into Sy at 1 Hz. When the timing is not excited, they can be injected into NS at 1 Hz. An aluminum chamber was used for the vacuum chamber of the BM-LS before the rapid cycle distribution. However, since the temperature of the chamber rose to about 80º by the eddy current as a result of the pattern excitation examination, we replaced it with a stainless steel chamber.

A programmable logic controller (PLC) with comparatively low speed processing circuits and network communication was used as an accelerator safety system for stable and reliable safe interlock operation. In conventional systems, it cannot respond to a rapid cycle distribution. We manufactured a Sy/NS beam-route-switching module, and quick judgments were transmitted with hard wire for rapid cycle status switching.

The variation of the stored current of the NS in the top-up operation is shown in Figure 3. Compared with before the introduction, the current stability after introduction improved to about 60%. Since the injection interval became shorter with rapid cycle distribution before, the range of the fluctuation of the SPring-8 storage ring stored current became about 50%.

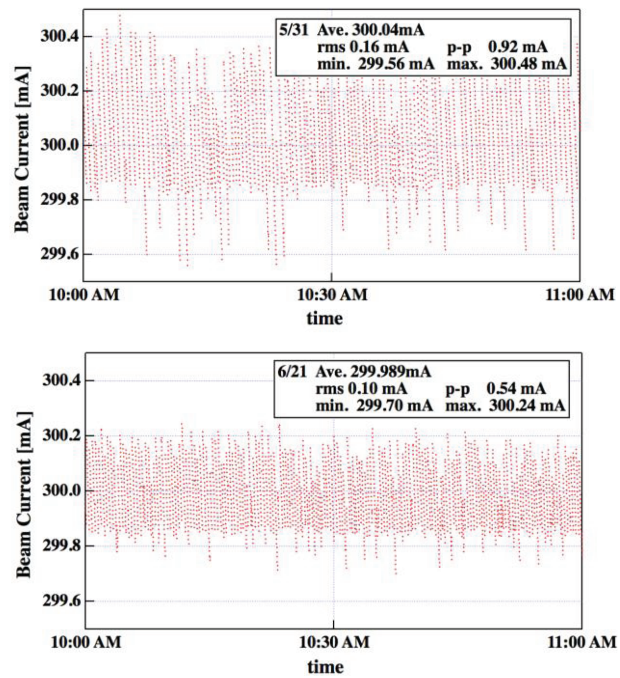

Figure 3 : NS stored current stability before and after rapid cycle beam route switching. Up: before installation, Down: after installation.

VACUUM WAVEGUIDE SYSTEM FOR INJECTOR SECTION

Recently, some linac equipment must be replaced due to aging. For example, trouble with an old motor-driven system in a waveguide phase shifter and an attenuator had increased in recent years. These problems were significant in the waveguide system's electron injector section. Waveguides were filled with pressurized sulfur hexafluoride (SF_6) gas, and the pressure was controlled to maintain 112±1 kPa for RF phase stability. However, the situation worsened to more than 114 kPa during a rapid atmospheric depression when a typhoon passed and caused a phase shift. Therefore, we replaced this system with a vacuum-type waveguide system. However, since no vacuum-type RF circulator was commercially available at that time, we started R&D in 2010.

Figure 4 shows the new configuration of the vacuum waveguide system for the electron injector section. An 80 MW klystron (Toshiba E3721), called KLY-H0 provides RF power to the electron injector section, a klystron drive-line, and a 3 m-long traveling-wave accelerator structure, called ACC-H0. RF circulators are installed to absorb the reflected powers from the buncher accelerator structure and a reflection-type high power attenuator. In

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two pre-buncher lines, isolators, where the reflected RF power is absorbed in a ferrite array, are installed between pre-buncher cavities and a phase shifter and attenuator (ϕA in Figure 4).

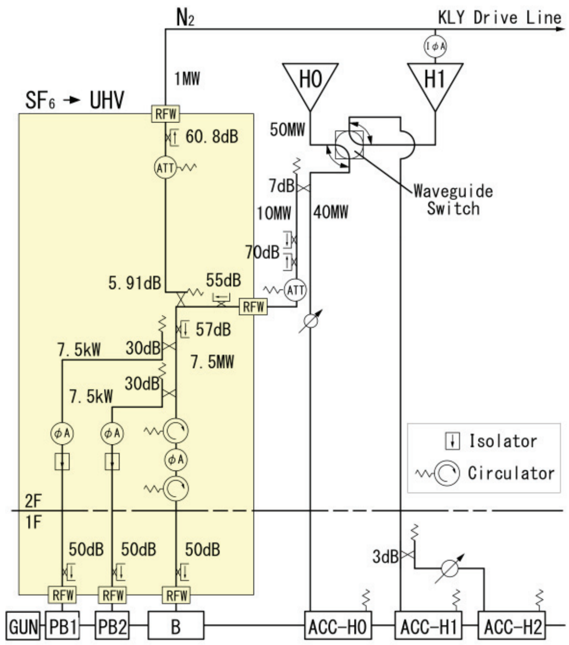

Figure 4 : Layout of new vacuum waveguide system for electron injector section of SPring-8 linac.

After confirming the long-term stability of the circulators and isolators, we installed these components in the waveguide system for the injector section of the SPring-8 linac during the January-March maintenance period in FY 2013. High power phase shifters and attenuators were installed in the klystron gallery (upper floor) for easy handling of trouble under beam operation, although they were placed in the accelerator room (lower floor) for a previous SF_6 system.

EXPANSION OF SYNCHRONIZED DATA ACQUISITION SYSTEM

Data acquisition of the non-distractive type beam position monitor (BPM) of the linac was carried out on the synchronized data acquisition system with beam timing [2]. The data from this acquisition system are very useful for beam tuning. However, because of the limitation of the database function, it has been impossible to directly compare the beam-synchronized BPM data and the conventional asynchronous data, such as the PFN voltages in the database browser screen. We need to download them individually from the two databases and analyze them off-line to learn their correlations. We therefore extended the synchronized data acquisition to collect conventional physical values.

The klystron modulator PFN voltages, the electromagnet currents of the beam transport lines, and the injection section were included in the synchronized acquisition in FY 2013. Extension of the remaining electromagnet current and the RF power will be performed in FY 2014.

OPERATION STATUS

Figure 5 shows the operation statistics from 2005 to 2013. The fault rates gradually reduced after we improved the components. Although in 2008 we recognized that the long downtime was caused by the trouble with the gun bias circuit, introducing the twin gun and backup systems for the failed klystrons considerably suppressed the interruption of the top-up operation caused by linac's failures. Linac's downtime was 0.59% in FY 2005: it decreased to 0.13% in FY 2013.

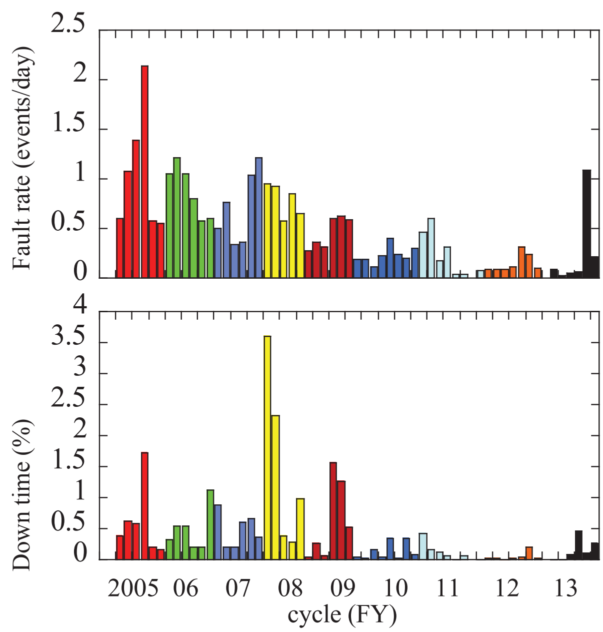

Figure 5: History of the faults in FYs 2005 to 2013

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