HIGH POWER WAVEGUIDE SWITCHING SYSTEM FOR SPring-8 LINAC

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Abstract

To realize the high availability and reliability of SPring-8 linac, a vacuum type waveguide switch has been developed to establish a backup system of the first klystron for the electron injector system and the klystron drive line. The waveguide switch was installed between the high power RF circuits for the first and second klystrons in February 2006. After RF conditioning, maximum RF power of 74 MW at peak, 2.5 μs in pulse length, and 60 pps in repetition rate were achieved without serious problems for the RF and vacuum characteristics. A switching test of this backup system was carried out, and beam condition was maintained after switching.

INTRODUCTION

The SPring-8 and NewSUBARU storage rings have maintained top-up operations since May 2004 and June 2003, respectively. The SPring-8 linac is now performing frequent beam injections into the two synchrotrons at short intervals to keep the stored current approximately constant [1]. The present minimum injection interval is about five seconds for parallel top-up operations, and the constancy of the stored current is less than 0.1% for the SPring-8 storage ring and less than 0.2% for NewSUBARU.

The SPring-8 linac has supported stable top-up operations with energy-stabilized beam injections; energy instability has been improved to 0.02% rms in the long term with the operation of an energy compression system (ECS). In addition, reducing the frequencies of failures or linac downtime is indispensable to prevent the degradation of the stored current constancy in the top-up operation. The most frequent failure category in the linac is RF failure in which the faults of the klystrons and modulators are classified.

The linac is equipped with thirteen 80 MW pulse klystrons (Toshiba E3712). All the klystrons are feeding RF power (10 Hz) to the accelerating structures, and two are intermittently disabled by the trigger system in synchronization with the beam trigger signals (1 Hz) to avoid beam accelerations. That is, eleven of the klystrons have usually been used to accelerate electron beams to 1 GeV, and the other two have been kept for hot spares on line.

Except for the first and ECS's klystrons, when one of the eleven working klystrons faults and it cannot be recovered within a few minutes, a standby klystron is activated to accelerate beams instead of the failed one. Serious failure of the first klystron, however, completely stops linac operation for a long time because it feeds RF power to the injector section of the linac and the long drive line for the other eleven klystrons.

We therefore constructed a backup system for the first klystron to feed RF power from the second klystron to the injector. The backup system is composed of waveguide circuits, a high power waveguide switch, and its control system. The waveguide switch, the key component of this system, was developed based on the design of a commercial waveguide switch manufactured by Nihon Koshuha Co., Ltd.

In this paper, we describe the concept of the backup system, the vacuum type waveguide switch newly fabricated, the installation and conditioning of the system.

HIGH POWER RF BACKUP SYSTEM

Fig. 1 shows the original waveguide circuit and the new backup system for a high power RF source installed in the SPring-8 linac.

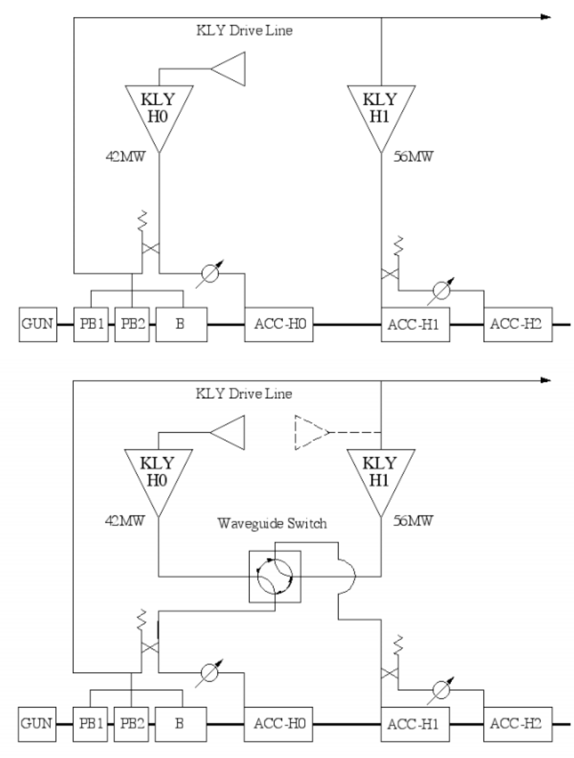

Figure 1: Original waveguide system (top) and new backup system (bottom) of high power RF source for electron injector and klystron drive line in the SPring-8 linac.

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If a serious failure occurs in the first klystron (KLY-H0) or its modulator (MOD-H0), the waveguide switch is rotated to change the power direction of H0 and H1, and the drive amplifier for the H0 klystron is connected to the H1 klystron. Then the second klystron (H1) can provide RF power to the electron injector and the klystron drive line to avoid a long-time shutdown of the linac. Since the relative RF phases between the master klystron (H0/H1) and the others do not change after switching, machine tuning is very simplified in this backup system if H1 klystron is operated in a standby mode.

The requested specifications for the waveguide switch in this backup system are summarized in Table 1. Nominal values are required for injection to the booster synchrotron and NewSUBARU (1 GeV), and the maximum values for the solo operation of linac (max. 1.2 GeV).

Table 1: Specifications requested for waveguide switch.

	Nominal	Maximum
Peak RF power	60MW	80 MW
Pulse length	2.5 μs	2.5 μs
Repetition rate	10 pps	60 pps

VACUUM WAVEGUIDE SWITCH

High power waveguide switches (rotary E-bend) are widely used in accelerators but most are used in SF_6 gas. In the SPring-8 linac, high power waveguides are used in a vacuum except for the bunching section. Therefore, a vacuum type waveguide switch is preferred for this backup system. A 10 MW waveguide switch used in a vacuum has been developed by Nihon Koshuha Co., Ltd. We improved this waveguide switch to adopt higher peak and average RF power. Relevant improvements are listed below:

- The bonding method for the rotor (OFC: Hitachi Cable, Ltd. C1011), fabricated in halves, was changed from bolt connection to diffusion bonding. This prevents air void between bonding surfaces and contributes to UHV stability.
- The surface of the rotor was processed by an electropolishing method to remove micro structures and minimize the possibility of vacuum RF discharges in the waveguide switch.
- A rotor cooling system was fabricated. A copper rod is firmly contacted to the rotor to conduct the heat due to RF power loss. The rod is detached from the rotor during rotation.
- A vacuum evacuation port was added to enhance pumping speed in the choke groove and in the thermal conductor chamber.

The remote controller has been newly manufactured, and the rotor can be rotated remotely with a reversible motor. Moving time is about five seconds.

Pictures of the rotor in fabrication (before diffusion bonding and electropolishing) and a drawing of the waveguide switch are shown in Fig. 2. The gap between the rotor and housing was precisely manufactured within 0.2 mm to minimize the power penetrates in the choke.

The final RF performance is listed in Table 2.

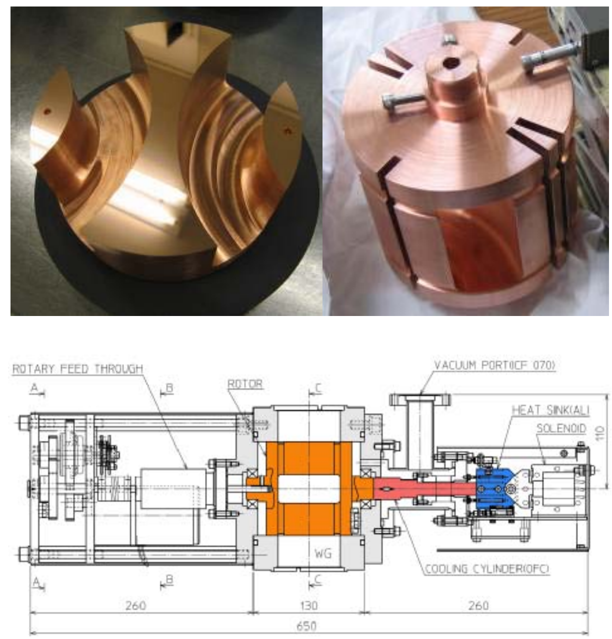

Figure 2: Rotor of waveguide switch before diffusion bonding (top-left) and electropolishing (top-right). Bottom is a drawing of the waveguide switch.

Table 2: RF performance of fabricated waveguide switch.

	Port 1 to 2	Port 3 to 4
VSWR	1.03	1.04
Insertion loss	0.040 dB	0.048 dB
Isolation	less than -87 dB	

INSTALLATION AND CONDITIONING

Before installation into the SPring-8 linac, a high power test of the waveguide switch was performed in May 2005 at the RF gun test stand. Without any serious problems, peak RF power of 62 MW was achieved with a pulse length of 2 μs and a repetition rate of 10 pps. This condition approximately satisfies the nominal parameters of linac operation.

After passing the high power test, in February 2006 the waveguide switch was installed between the high power waveguide circuits of the first (H0) and second

(H1) klystrons to establish the backup system. The waveguides were extended to the waveguide switch, and pumping ports for sputtering ion pumps (SIP) were added near the waveguide switch, which is pumped by using SIP's with a pumping speed of 45 L/s at waveguides of H0 and H1. It was also pumped from an evacuation port at a thermal conductor chamber by using a SIP with a pumping speed of 30 L/s. For this SIP, a meshed copper gasket (ICF70) was used to prevent penetration of higher harmonics power from the klystron into the SIP.

RF conditioning was performed for seven days in the daytime with a repetition rate of 60 pps. Conditioning history is shown in Fig. 3.

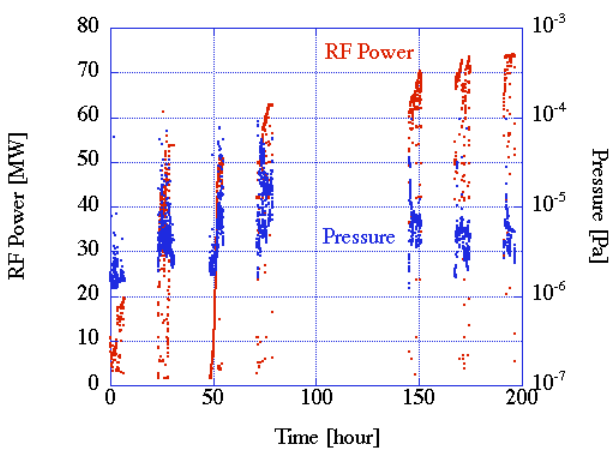

Figure 3: RF power from klystron (H1) and pressure in waveguide switch during RF conditioning with a pulse length of 2.5 μs and a repetition rate of 60 pps. Conditioning was performed intermittently.

After conditioning for 24 hours, the peak power of the H0 klystron reached a normal level (50 MW), and the drive power for the other klystrons became sufficient. The RF power of the second klystron achieved maximum power of 74 MW after conditioning for 56 hours. In this condition, power loss in the rotor of the waveguide switch was estimated at 10 W, and the temperature on the heat-sink at the outer end of the thermal conductor of the waveguide switch became 42 C. in an actual measurement.

After RF conditioning, the repetition rate was changed to 10 pps for top-up injection into the rings, and vacuum pressure near the waveguide switch became lower and more stable.

CONCLUSION

We constructed a backup system for the first klystron that drives other klystrons and the electron injector in the SPring-8 linac. A vacuum type waveguide switch, the key component of this system, was developed. After RF conditioning, maximum RF power of 74 MW was obtained with a pulse length of 2.5 μs and a repetition rate of 60 pps. This performance successfully satisfies the normal operation parameters of the SPring-8 linac.

A switching test of the first and second klystron with a beam operation was successful, and after switching, such beam conditions as position, injection current, and so on, were retained.

The availability and reliability of the high power RF system in the SPring-8 linac have been enhanced with the construction of this backup system. We are also planning to install a backup gun to increase total reliability. Furthermore, we are studying automatic parameter tuning after the exchange the failed klystron or modulator and the standby one to minimize the discontinuance of beam injection.

REFERENCES

[1] H. Hanaki, et al., "Enhancements of Machine Reliability and Beam Quality in SPring-8 Linac for Top-up Injection into Two Storage Rings", PAC'05, Knoxville, p. 3585.