STATUS AND UPGRADE PLAN OF HIGH POWER RF SYSTEM FOR THE PLS STORAGE RING*

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Abstract

The rf system for the Pohang Light Source (PLS) storage ring is operating at total maximum rf power of 300kW with four 75kW klystron amplifiers and four KEK PF-type normal conducting (NC) rf cavities for 190mA at 2.5GeV [1]. The PLS will be upgraded from 2.5GeV to 3.0GeV called the PLS-II [2]. Therefore the rf system should be greatly upgraded to supply total 670kW beam power. We are investigating the some upgrade ways with adding NC cavities or new super conducting (SC) rf cavities. According to the cavity type, the high power rf system will be adjusted the total rf power, and source type and quantity such as klystron or IOT. This paper describes the present operation status and several optional ways of high power rf system for the upgrade project of PLS storage ring.

INTRODUCTION OF PLS RF

The PLS is a 2.5GeV, third generation synchrotron radiation source, which has a full energy linac and a storage ring. The PLS rf system at the initial phase in 1994 consisted of three stations of total 180kW. Each station was consisted of the modified 60kW UHF TV transmitter as a power source, a circulator, a single-cell cavity with cooling system, all connected by 6-1/8" coaxial transmission lines and low level rf system. After one more station was added in 1996, then four 60kW klystrons were replaced with 75kW klystrons for increasing the storage currents so far. Therefore total rf power of 300kW can provide to store up to 190mA with 1.6MV gap voltage at 2.5GeV [3]. The NC cavities are well operated without any HOM instabilities by precise temperature controlled water cooling system [4].

Table 1 shows characteristics of the present status of major components of the PLS rf system.

Table 1: Characteristics of the PLS RF System

Klystron amplifier Klystron tubes	75kW (CW max.) modified E2V K3773BCD (4 EA)
Transmission line High power Circulator	6-1/8" Coaxial lines AFT 80kW, Coaxial
RF Cavities Shunt Impedance Unloaded Q Coupling Coefficient. Gap Voltage	Single-cell (PF-type) >8 MΩ >35,000 ~1.8 to 2.0 400kV/cavity (Pc=20kW)

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PRESENT OPERATION STATUS

In 2008, PLS rf system was operated 5,948 hours for the user services and machine studies. Four klystron amplifiers have been operated total 63,971 hours on average since 1994. And 75kW klystrons of K3773BCD made by E2V were operated 24,464 hours on average and the performance of micro-perveance was almost same in 2007. Also the performances of klystrons were confirmed, and the characteristics of klystrons were measured to adjust the tuning and linearity responses with a network analyzer. Although the aged klystron amplifiers were operated for 15 years, the total number of rf system faults in 2008 was greatly decreased to 12 times from 41 times in former year. The decreasing causes of rf faults are analyzed to stable operation of LLRF control, and proper maintenance of high voltage components and rf parts.

The faults were classified as 1 klystron amplifier fault, 2 high power rf faults, 4 low level rf control faults, 1 control system fault, and 5 unknown other faults that were suspected with rf system. It was difficult to define the unknown faults related to rf system although diagnosing with data acquisition system such as recorders, digital oscilloscopes, MMI controls and so on. We have been investigated the unknown faults related to rf system by more machine studies and other beam diagnostic system The four klystrons of 75kW have been operated at 65kW maximum level with a little lower bias for the 190mA of 2.5GeV storage ring to operate stably and to extend the lifetime of klystron tubes. In 2009 summer shot-down, the fifth rf cavity will be installed and operated to increase the storage ring current with more enough margin of rf power, and to maintain the rf system easily when one rf station is failed during user service operation.

Maintenance of RF System

Some maintenances were recently performed by replacement the failed components such as a high voltage transformer, some high voltage rectifier modules, an inductor, a temperature control unit of circulator, three dummy loads, and old parts such as high voltage capacitors, logic control boards, high voltage cables. Also output coupler of klystron was modified to add a directional coupler and an arc detector. The transmission lines of 6-1/8" EIA coaxial components were slightly aligned using two flexible coaxial lines and supporters because the transmission lines have been deformed by ground movement and rf building deformation. The low level rf controllers, rf linear detectors and the remote monitoring of low level rf system were improved for better stable operation

Table 2: Operation Data of Klystron Amplifiers

	KA#1	KA#2	KA#3	KA#4	remark(ave.)
Year 2008 Operation Hours	5,949	5,945	5,952	5,946	5,948
Klystron Operation Hours	12,137	31,498	25,693	28,527	24,464
Amplifier Operation Hours	66,375	77,200	77,461	78,848	68,023
Beam Voltage (kV)	26.9	27.3	25.7	26.5	26.6
Beam Current (A)	5.63	5.83	6.25	5.89	5.90
Anode Voltage (kV)	5.88	5.83	4.08	5.04	5.21
μP(micro-perveance)	1.85	1.85	1.95	1.97	1.89
Maximum RF Power(kW)	75	75	75	75	300(total)

Table 2 figures the operation data of four 75kW klystron amplifiers with K3773BCD klystrons in detail.

HIGH POWER RF SYSTEM FOR PLS-II

Introduction

The PLS will be greatly upgraded from 2.5GeV to 3.0GeV of PLS-II to get better brightness with more insertion devices. Therefore, for the PLS-II of up to 400mA storage ring current at 3.0GeV energy, the high power rf system as well as rf cavities should be greatly upgraded and increased to supply maximum total 670kW beam power for the light radiation of bending magnets and all insertion devices.

The PLS-II rf system of the storage ring has an important role to compensate the energy loss by electrons due to synchrotron radiation from bending magnets and insertion devices, and to provide sufficient accelerating rf voltage for the good momentum acceptance and the proper lifetime of the stored beam even top-up operation.

Table 3 shows the parameters of PLS-II rf system compared to present rf system.

Table 3: Parameters of PLS & PLS-II RF System

Specification	PLS	PLS-II
Energy/Current	2.5GeV/200mA	3.0GeV/400mA
RF Frequency	500.082MHz	499.654MHz
Losses with IDs	620keV	1,658keV
Beam Power	124kW	670kW
rf Cavities(Q'ty)	NCx4(5)	NC(6) or SC(3)
rf Power Sources	75kW x4(5)	180~300kW
Total RF Power	300(375)kW	~900kW(SC)

The high power rf system can be designed and upgraded in some ways. According to design status of the rf cavity type such as NC or SC rf cavities, the high power rf system will be different because of total wall losses. To supply the 3.3MV rf voltage at 400mA, the SC rf cavities need 670kW rf power with about 0.12kW wall losses. But in case of NC rf cavities, the rf power need about 981kW with 311kW cavity wall losses.

High Power RF for NC Cavity

In case of NC rf cavity choice, HOM damped cavity developed at KEK-PF or BESSY-EC cavity is proper candidate. The high power rf system is needed to supply maximum 670kW beam power and 311kW cavity wall loss. Therefore, total rf source power should be more than 1200kW with proper operation margin of 20% and transmission loss for at least six cavities. The six new klystron amplifiers of 250kW is preferable option for reliable and stable operation. Alternative option with recycling four 75kW klystrons to save budget, and four new 300kW klystron amplifiers are needed for safe operation up to 400mA. Although the present NC cavities have some HOMs at higher current and power limitation by input coupler of 100kW, the performance will be improved adding HOM coupler, upgrading input coupler and cooling system. The present rf system can be operated with limited specification and lifetime because the 75kW klystron amplifiers are very old aging with 15 years operation. Another option of the 150kW combined amplifiers with two 75kW klystrons or a 300kW amplifier with splitter can be supplied to two NC cavities.

Figure 1 shows a block diagram of high power rf system for new HOM damped NC cavities with six 250kW klystron amplifiers. And figure 2 shows a block diagram of high power rf system for present two PLS cavities with two combined 150kW amplifiers and four new HOM damped NC cavities with four 300kW klystron amplifiers as another possible option.

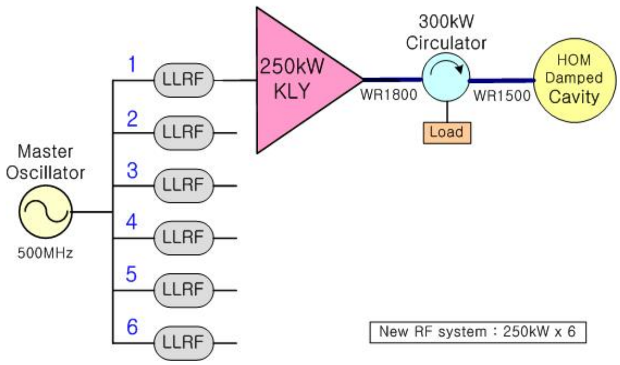

Figure 1: High power rf system for new damped NC cavities with six 250kW klystron amplifiers.

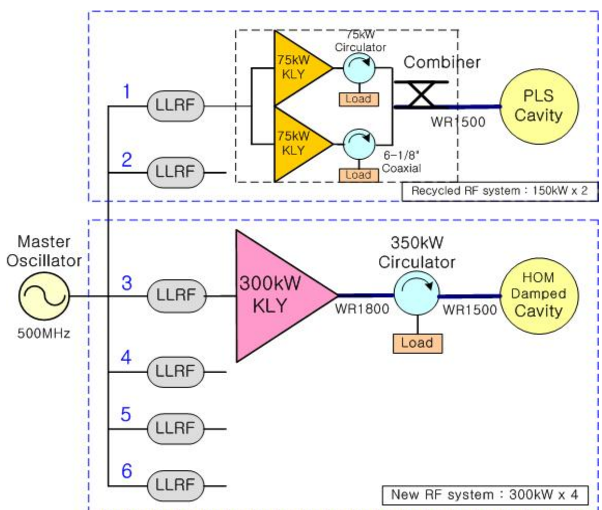

Figure 2: High power rf system for present and new damped NC cavities.

High Power RF for SC Cavity

In case of SC option, the SRF module of CESR-III or KEKB type is a proper candidate. Three cavities are needed to supply maximum total 670kW beam power. The wall losses of three SC cavities are less than 0.12kW which can be neglected for design of the high power rf system. Therefore each high power rf station should be supplied about up to 300kW according to the maximum availability of input coupler and operation parameters.

Figure 3 and 4 shows a simple block diagram of the high power rf system for three SC cavities with 300kW class klystrons and three combined IOT amplifiers.

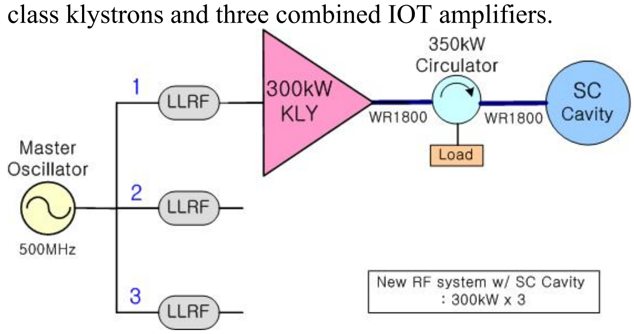

Figure 3: High power rf system for new SC cavities with three 300kW klystron amplifiers.

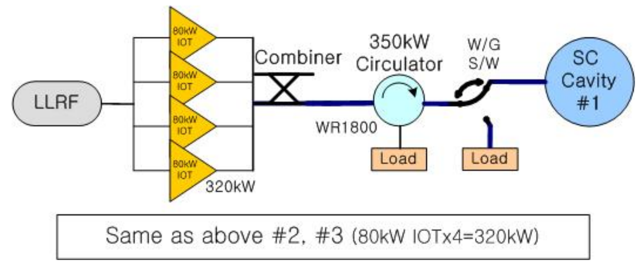

Figure 4: High power rf system for new SC cavities with three combined 320kW IOT amplifiers.

TRANSMISSION LINES

The high power rf generated by a klystron should be delivered to a rf cavity with few losses by coaxial lines or waveguides. The coaxial lines have not limited the cut-off frequency and saved installation spaces, but the maximum transmission rf power is limited by outer diameter. The maximum transmission rf power of 6-1/8" EIA coaxial of PLS transmission lines is limited up to 80kW at 500MHz. To transmit the rf power safely for PLS-II, some WR1500 and WR1800 waveguide components should be used according to match the output flange of klystron and input coupler flange of rf cavity. There are many kinds of waveguide components such as circulators, water loads, directional couplers, power combiner and splitter, elbows, flexible sections and so on. The high power circulator is needed to isolate and protect the klystron from the reflected power of the cavity. In addition, rf loads are required to absorb the reflected rf power and to test the klystron amplifier independently.

SUMMARY

Present status of PLS and upgrade options of PLS-II for high power rf system are introduced. The high power rf system for PLS-II is usually depended on the rf cavity type and beam currents with beam energy. Therefore after review and decision of cavity type of SC or NC, the detail design will be investigated and modified the specification soon. Anyway the higher rf power sources more than 180kW will be needed for PLS-II. In case of SC cavity, three 300kW class klystron or IOT combined amplifiers are preferable option for PLS-II high power rf system.

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