HIGH POWER RF SYSTEM AND ITS UPGRADE PLAN FOR THE PLS STORAGE RING

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Abstract

The high power RF system for the PLS storage ring consists of four 60 kW klystron amplifiers feeding four RF cavities independently. Total klystron amplifier power of 240 kW can support the stored currents of about 400 mA at 2.0 GeV and 200 mA at 2.5 GeV. However, several insertion devices such as undulators and multi-pole wigglers will be installed in the near future so that more RF power is required. Therefore, we are going to increase the RF power by replacing 60 kW klystrons with 75 kW klystrons and adding one more RF station. This paper describes the plan to increase the RF power with 75 kW klystrons, and other necessary modifications to the present high power RF system.

1 INTRODUCTION

The Pohang Light Source (PLS) is a 2.0 to 2.5 GeV, third generation synchrotron radiation source, which has a full energy linac and a storage ring. The storage ring RF system should provide enough energy for compensating synchrotron radiation loss and the beam loading.

The PLS RF system at the initial phase consisted of three stations, in which each station has a 60 kW CW klystron amplifier as a power source, a circulator and a single-cell cavity, all connected by 6-1/8” coaxial transmission lines. The total RF capacity could afford to store the beam current up to 300 mA with 1.2 MV of the accelerating voltage at 2.0 GeV. In 1996, one more station was added. Therefore, total RF power of 240 kW can provide enough power to store up to 400 mA with 1.6 MV of the accelerating voltage at 2.0 GeV and 200 mA at 2.5 GeV, which was beneficial to the lifetime to increase over 40%. Table 1 shows characteristics of the RF system components[1].

Table 1. Characteristics of the PLS RF System

Klystron amplifier Klystron tubes	60 kW (CW) Philips YK1265 Marconi EEV K3672
Transmission line High power Circulator	6-1/8” Coaxial line 80 kW, Coaxial
Cavities Shunt Impedance Unloaded Q Coupling Coeff. Gap Voltage	Single-cell (PF-type) >8 MΩ >35,000 ~1.8 400 kV/cell

In 2001, the PLS goes into the seventh year of the user operation. One of the operational targets of this year is to provide 170 mA at 2.5 GeV to users regularly.

Optimizing the cavity temperature control has been performed to cure beam instabilities[2]. The upgrade of the low level RF feedback system is now in progress, which will be finished by 2001[3].

2 PRESENT OPERATION STATUS

By the end of July 2001, RF system of the storage ring have operated for 2,800 hours, and the accumulated average operation time for klystron amplifiers amounts about 32,000 hours. Four klystron amplifiers were operated between 20 kW and 45 kW level during normal operation at 2.5 GeV of 170 mA. So far, three 60 kW Philips YK1265 klystron tube are replaced after about 30,000 hours lifetime for the high power rf system. Klystron performances have been gradually decreasing after about 10,000 hours operation. Therefore the micro-perveance was decreased from 2.0 to 1.3 that means the available maximum rf power was decreased from 60 kW to about 45 kW.

In 2000, the RF system was operated about 5,300 hours for the user services and machine studies. Four klystron amplifiers were operated for 20,801 hours in total. Sometimes three klystron amplifiers were operated because of beam instabilities, low level RF phase unlocking and maintenance. The 2.5 GeV operations were carried out up to 170 mA storage current, and some machine studies about beam instabilities and optimization of the operation parameters were examined with rf system. The total number of rf system faults was 190 including faults with vacuum trips; 59 of the circulator arc trips in 1999 decreased to 15 in 2000. Almost circulator arc trips happened at No.1 circulator so that circulator arc detector was exchanged.

The stabilization of the low level rf system such as adding mechanical phase shifters has been performed. Also a new low level rf system is fabricated, installed, and testing for more stable rf operation. The upgrade of the low level RF system will be finished by the end of 2001. The new low level rf system incorporates NIM type modules, which enable the easy maintenance of each module, and provide a lot of diagnostic points for the RF and control signal monitoring[4].

Using a spare cavity and a newly assembled klystron amplifier, the high power rf test station has been operated. New component tests, control electronics test and other high power test of the prototype components have been performed in this high power rf facility.

3 RF POWER BUDGET

3-1 Radiation Loss for Insertion Devices

The necessity of upgrade plan of the rf power budget for radiation loss compensation at 2.5 GeV/250 mA operation and lifetime improvement are analyzed. We estimated the rf power budget required to compensate the radiation loss by bending magnetes and various insertion devices. Table 2 lists the radiation loss in the bending magnets and the insertion devices at 2.5 GeV. The radiation loss by ten insertion devices is expected to be 266 keV, and the total radiation loss is approximately 815 keV.

Table 2. Radiation Loss at 2.5 GeV

	IDs	Operational year	Radiation loss [keV]
Bending magnet			**548.4**
Insertion device	ID1: U7	2000	17
	ID2: EPU6	2001	6
	ID3: U10	2002	20.8
	ID4: MPW0	2003	53.2
	ID5: IVU1	2004	3.3
	ID6: IVU2	2005	3.3
	ID7: IVU3	2005	3.3
	ID8: MPW1	2005	53.2
	ID9: MPW2	2006	53.2
	ID10: MPW3	2006	53.2
	Total ID loss		**266.5**
Total loss			**814.9**

Parasitic mode loss is not included.

The U7 undulator has been operating since last year. In the near furture, EPU6 and U10 undulators will be serve for the users. A Mutipole wiggler(MPW) and an in-vacuum undulator(IVU) have been proposed.

3-2 RF Power and Beam Current Limitation

The energy loss of the electron beam due to synchrotron radiation is compensated by the electromagnetic wave energy suplied by the rf high power system. It is essential to have enough power from the klystron amplifiers to compensate the energy loss. The energy loss due to synchrotron radiation in the bending magnets by one electron is given by

$$\Delta E / turn[keV] = 88.5E^4[GeV] / R[m], \tag{1}$$

where E is the electron energy in GeV, and R is the radius of curvature in meters of the orbit in the bending magnets (R=6.3012 m). The energy loss in a wiggler or undulator insertion device is given by

$$\Delta E[keV] = 1.27E^2[GeV] < B^2[T] > L[m], \tag{2}$$

where $< B^2 >$ is the average value of the square of the magnetic field in tesla over the length of L of the insertion devices in meters. Therefore, it has more than 2 times increase of rf power as electron energy increases from 2.0 to 2.5 GeV. Table 3 shows RF Parameters for 2.5 GeV operation using 75 kW klystrons.

Table 3. RF Parameters for 2.5GeV operation

	Without ID	With Ten IDs	
Radiation loss, keV	548.4	814.9	
RF voltage, MV	**1.6**	**1.6**	**2.0**
Number of cavities	4	4	5
Over voltage factor	2.92	1.96	2.45
Synchronous phase, deg	160	149.4	150
RF bucket height, %	1.58	1.27	1.63
V_{br}/V_c (Robinson Stability) @ 250mA	1.9	1.9	1.9
Frequency Detuning @250 mA, deg.	-33	-44	-37.7
Wall Dissipation Power per cavity, kW	18.8	18.8	18.8
Required total RF power @ 250 mA, kW	**212**	**279**	**298**
Touschek life time[1] @ 250 mA, hr	**38.1**	**22.6**	**37.6**
Available total klystron RF Power, kW (using 75 kW klystrons)	300	300	375
Max. Stored Beam Current, mA [2]	**355**	**240**	**300**

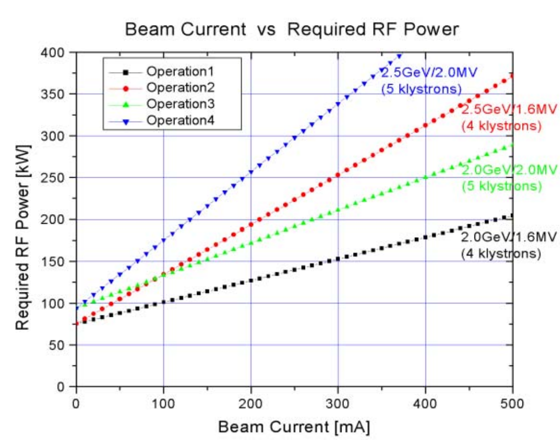

Figure 1: Beam Current vs Required RF Power

Figure 1 shows the RF power budget graph as increasing the beam current at 2.0 and 2.5 GeV operation with 1.6 MV of four klystrons and 2.0 MV of five klystrons.

4 UPGRADE PLANS

4-1 Replacing 60 kW klystrons with 75 kW

We have a plan to install the fifth RF station to the storage ring after replacing four 60 kW klystrons with 75 kW klystrons for increasing the stoage. The high power rf system with four klystron amplifier power of 240 kW can support the stored currents of about 400mA at 2.0 GeV and 200 mA at 2.5 GeV. According to the installation plan of the insertion devices such as wiggler and undulator in the near future, more rf power will be required to support the present current storage capability. Therefore, a plan to increase the rf power by replacing 60 kW klystrons with 75 kW klystrons and adding one more rf station in the storage ring are examined. Replacing a 60 kW klystrons with 75 kW klystrons is a resonable option because the rf system is composed with a 80kW coaxial type circulator and 6-1/8" coaxial transmission lines. Also 75 kW klystrons of maximum rf power with 6-1/8" coaxial transmission lines are maufactured by the Marconi and the Thomson. Three type 75 kW klystrons have been developed and used. One is the 4 external cavity type of the Marconi EEV K3773, the other is the 5 external cavity type of the EEV K3755. And last one is the 5 internal cavity type of the Thomson TH2133. There are some advantages and disadvantages of the mechanical and eletrical specifications, but the EEV K3773 is more easy to modify the current klystron amplifier at PLS rf system. Therefore, at first, we purchased one 75 kW klystron from the Marconi and tested sucessfully at the factory acceptance test . Table 4 shows the test results of the 75 kW klystron.

Table 4. Test results of the 75kW klystron

Model	EEV K3773BCD
Maximum rf power	76 kW(CW)
Gain	40 dB
Saturated efficiency	45.3 %
Beam voltage	27.5 kV
Beam current	6.1 A
Drive power	7.5 W
Micro-perveance	~1.95

After testing the 75 kW klystron at the rf test lab with mechanical modification such as additional cooling, coaxial lines, and adjusting of the electrical specification, we will replace the 60 kW klystron at storage ring rf system. When replacing four 60 kW klystron with 75 kW klystron, we can get more 60 kW rf power with total 300 kW that means the storage ring beam current will be increased more 100 mA, up to 300 mA of 2.5 GeV at present operation condition with three insertion devices.

4-2 Addition of the fifth rf station

We have a plan to install the fifth rf station to the storage ring after replacing four 60 kW klystrons with 75 kW klystrons for increasing the stoage current at 2.5 GeV with ten insertion devices. For this station, an in-house assembled klystron amplifier will be placed and a newly upgraded low level system will be prepared with a minimum budget. The in-house assembled klystron amplifier will be used the 75kW klystron tube, while other subsidiary components will be manufactured in domestic companies and it will finally be assembled in the laboratory. Another option of the 75 kW solid state rf amplifier will be examined, because the high power rf amplifiers for commercial digital television applications have been developed with economic prices. So far, 30 kW solid state rf amplifiers have been developed and used for broadcasting transmitters instead of the klystron transmitters. After several years, the 75 kW solid state rf amplifier will be competed as developing more high power transistors with more cheaper price. Therefore high power solid state rf amplifier will be competed with klystron amplifier due to economic and operational reason.

When installing the fifth 75kW rf station, we will have a 375 kW total rf power. Even though ten insertion devices will be operated, the rf power budget for radiation loss can compensate up to 300mA at 2.5 GeV operation.

5 SUMMARY

The high power RF system with four 60 kW klystron is introduced with present operation status. The necessity of upgrade plans of the rf power budget as installing the insertion devices at 2.5 GeV/250 mA are analyzed. We estimated the rf power budget required to compensate the radiation loss by bending magnetes and various ten insertion devices. We are going to increase the RF power by replacing a 60 kW klystron with a 75 kW klystron and have the upgrade plan of adding one more RF station according to installing insertion devices and increasing the storage current.

6 REFERENCES

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