COMMISSION OF RF POWER SOURCES AND ITS AUXILIARY COMPONENTS FOR TPS IN NSRRC*

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Abstract

Since 2010, during the civil construction of Taiwan Photon Source (TPS) in NSRRC, the intensive testing activities for RF power facility have begun in RF lab. The RF facility includes 300kW klystron and its crowbar less power supply, 350kW ferrite loads, 350kW circulators and five-cell Petra cavity with the corresponding analogue LLRF systems. Some unexpected situations are happened, such as HV breakdown of HV transformers, arcing events of falling ferrite tiles inside ferrite load and Pr oscillation during the commission of the 350kW circulators. The high power circulators for safe klystron operation are also tested for various phases at cavity port. The temperature compensation unit plays key role in proper operation of circulator. The above situations are all encountered during long-term reliability test. For a high availability of electron beam in TPS, the highly reliable sub-systems are the basic requirement and hence, long-term reliability is so essential during commission period. Some noticeable test procedure and results are introduced as the present RF system progress of TPS plan in NSRRC.

INTRODUCTION

For the 3-GeV Taiwan Photon Source (TPS) at National Synchrotron Radiation Research Center (NSRRC), two sets of 300kW, 500MHz CW RF power source are planned to support two sets of KEKB type SRF cavity in storage ring [1]. The synchrotron system is scheduled for commission in 2014. During the civil construction period, the commission of RF sub-systems is also in progress in RF lab. Since the duration of accepting overall RF source system takes more than one year and many abnormal events were happened during commissioning, a brief experience sharing during those accepting tests is described here.

The turn-key RF transmitter system for NSRRC is finally bid by Thales Electronics in 2008. Thales (in France) provides 300kW klystrons and Thomson Broadcast AG in Switzerland provides high voltage power supply as well its auxiliary components. Besides the high voltage power supply and the klystron, the transmitter system also contains drive amplifier, focus magnet and its power supply, waveguides and 350kW ferrite loads. The control system of the transmitter is built by Siemens S7 PLC industrial controller. After the commission of transmitter system, the 350kW circulators and spare ferrite loads (by AFT microwave) also arrives for high power tests. During these commissioning, some delay events are encountered like HV breakdown of the missing insulation layer high voltage multi-taper transformer, many arcs caused by the falling of ferrite tiles inside the ferrite load and later the water leak and the reflection power oscillation caused by improper setting of temperature compensation unit (TCU) for the circulator.

The layout of the RF system for SRF cavity at RF lab in NSRRC is shown in Fig. 1. The schematic of the RF power system is also shown in Fig. 2. The overall 300kW, 500MHz RF power system has successfully finish its commission at the beginning of 2012 and used for RF conditioning of three room temperature copper five-cell Petra cavity and functional tests of the four sets analogue LLRF control system.

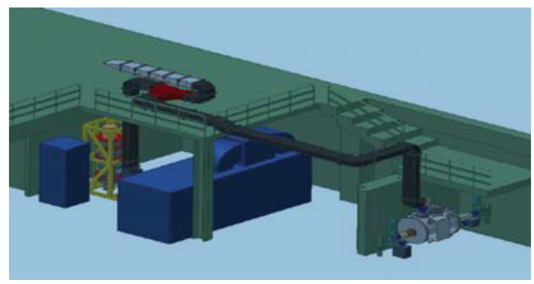

Figure:1 Layout of the 300kW RF power system for SRF cavity.

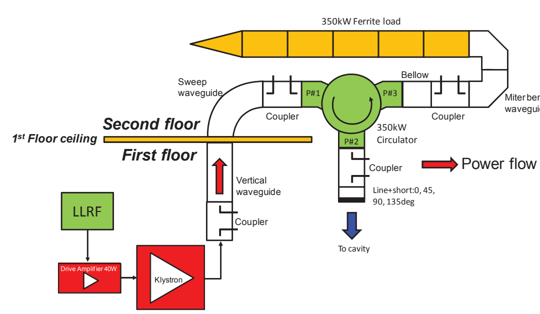

Figure 2: The schematic of high power RF system at RF lab in NSRRC.

TRANSMITTER SYSTEM AND ITS TEST PROCEDURE

The purchasing of the two sets 300kW RF amplifier system from Thales Electron is due to its highly reliability of the crowbar less high voltage power supply (HVPS) (made by Thomson) demonstrated by many light sources like SLS, CLS, DLS, SSRF [2-4]. The specification of the RF amplifier system is listed in Table I.

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Table I: the technical specification of HVPS and klystron

HVPS	Thomson AG
Peak voltage	5-55kV
Output current	0..12A
Continuous output power	520 kW
Number of modules	86
Efficiency	96 %
Regulation accuracy	<1%
Short circuit energy	<15J
Klystron	Thales Electron Devices
Frequency [MHz]	499.65 MHz
VSWR	<1.1
Beam voltage	54 kV
Beam current	9 A
Anode voltage	32 kV
RF average output power	310kW
Efficiency	65%
Heater current	28A

The control system of the HVPS is achieved by PLC Siemens S7 with easy operation touch panel using Ethernet protocol for command communication and EPICS data acquisition. Since the reliability of synchrotron facility is the key issue, long-term reliability test run is therefore performed during the commission of the RF amplifier system. For klystron, HVPS and the ferrite loads, full 300kW power are tested for 50hr then 8hr off and continued with full power 24hr without any fault. Thanks to such test procedure, the malfunction of HV transformer, the ferrite load and not properly set parameters TCU for circulators RF feedback control can be identified and will be described below. The event history of the RF power system is briefly summarized in Table II. Identify these problems during accepting would be helpful in formal synchrotron system operation.

Table II: the brief history log of RF power amplifier system commission in NSRRC

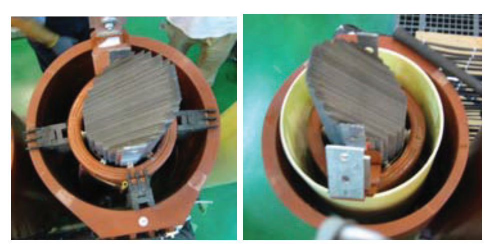
Date	Event
2010.4.30	The arriving of HVPS and klystrons
2010.7.23-24	1st set 50hr reliability test and found transformer HV weak breakdown
2010.8.23-9.3	Repair HV transformers
2010.9.3-9.10	One Ferrite load arcing and use the other one
2010.9.23	1st set RF amplifier site 50+8+24hr reliability test success
2010.9.28-10.29	Exchange of two sets of HVPSs and klystrons
2010.11.30	The tile falling ferrite is repaired
2010.11.24-12.13	2nd set RF amplifier 50+8+24hr reliability test success
2010.12.27-2011.01.05	Do high power reliability of two spare klystrons
2011.08.02	Circulators and spare ferrite loads arrive NSRRC
2011.10.17-11.30	Three sets circulator high power test and found unstable problem of TCU RF feedback control
2012.4.2-4.4	AFT send engineer to NSRRC for TCU modification
2012.4.5	Finish high power test of overall new RF power system for TPS

SUBSYSTEM EVENT-- HVPS

After 1st set 300kW transmitter was readily set for continuous test run in July, 2010, the first unexpected arcing was happened to cause the damage of fiber control board and PSM modules. After fixing and replacing the damaged components, the second HV breakdown happened again to cause the malfunction of filament power supply. Then, one abnormal arcing trace was found on the last tap (86th) of the delta-Y HV transformer as shown in Fig. 3 (a) and the cast resin glue repair of the HV weak part is shown in Fig. 3(b). Besides, the missing fiber glass insulation layers are simultaneous added to the total four transformers for proper HV protection as shown in Fig. 4. After such modification, the high voltage tests of the HV multi-tap transformers are performed as the second taps are all shorted together. Test voltage up to 100kV between primary and secondary coil with lower than 1mA leakage current of four transformers had all successfully passed.

(a) (b)

Figure 3: (a) The arcing trace on the HV weak transformer and (b) its repair



(a) (b)

Figure 4: The procedure to install fiber insulation layer inside multi-tap HV transformer (a) before and (b) after.

SUBSYSTEM EVENT--FERRITE LOADS

After solving the HV weak problem of HV transformers, full power test of 1st RF amplifier system was then continued. However, 50 hr faulty-less test was always interrupted by the arcing event of the 350kW ferrite load. After several times of such trips, the ferrite load was opened and many ferrite tiles cracks were swept out as shown in Fig. 5. Since the quality of these non-properly glued tiles of the first two segments of the ferrite load was not acceptable anymore, the transmitter high power test would then be continued by using the load of the other set transmitter. After receiving the new first two segment of the bad ferrite load, the both 300kW transmitter systems are finally accepted at NSRRC RF lab in the end of 2010.

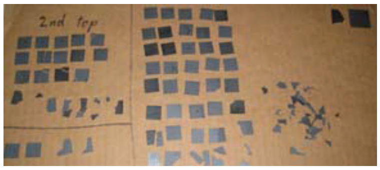


Figure 5: The falling cracks of the poorly glued ferrite tiles.

SUBSYSTEM COMMISSION—350KW CIRCULATORS AND ITS TCU

Due to yearly budget limitation, the high power circulators and spare ferrite dummy loads were purchased later than the RF amplifier system. Two of the circulators will be joined as complete RF power system in synchrotron operation and the third is planned to be a spare part and experimental purpose in SRF lab. For normal operation of circulator, there shall be a matched temperature compensation unit (TCU) for compensating the temperature variation of the internal magnet. Besides the simply temperature compensation, we also purchase the RF feedback option for fast reflection power control. However, after the successful test of the first circulator, the left two circulators all have water leak problem under lower than 6 bar inlet pressure operation. The water leak is very dangerous situation in our RF lab due to that the dropping water on 1st floor would fall to the HV cabinet of transmitter in basement as shown in Fig. 1. In order to prevent such trouble happens again, the over-spec. static water pressure was kept up to 9kgf/cm^2 for 24hr to ensure the water pipes on the circulators are fully fixed as shown in Fig. 6.

Figure 6: The water pressure persistent test stand for the repaired water leak 350kW circulators.

Misfortunes never come singly. During the tests of the left two circulators, the reflection power high trips during long-term high power test at certain phase and oscillating reflection power when activating RF feedback function at low forward power level are observed as shown in Fig. 7. Since there are many parameters within the TCU module, AFT only allowed their customer to adjust the permitted variable for optimizing the behaviour the TCU. The e-mail communication between NSRRC and AFT had improved the temperature compensation function of TCU. However, the performance test with simply temperature compensation cannot be passed at four phases (0, 45, 90 and 135deg phase extension) variation at cavity port. The trustworthy AFT finally sends their engineering expert for the fine adjustment the TCU of these two circulators. Till this moment, the complete RF power systems are finally and fully accepted by NSRRC.

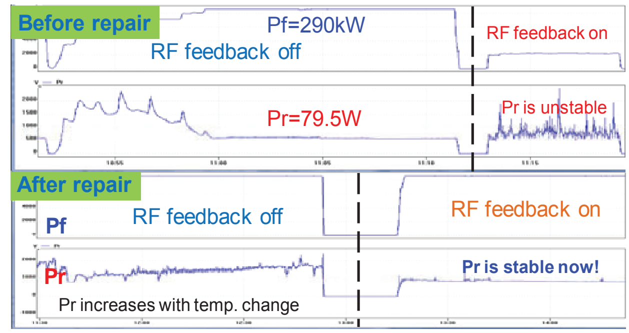


Figure 7: The TCU for 350kW circulator with good temperature compensation function and unstable RF feedback control function before repair.

DISCUSSION

The high power RF components need special attention during acceptance test. The reason for this is that the vendors, such as AFT and Thomson, usually do not have such high power test facility in their factory. Hence, only function and small power tests are performed before shipping out. To ensure the proper operation of these high power components such as HVPS, ferrite loads and circulators, long-term full power run tests are very important for customers to have a faulty-less high power RF system. From our precious suffering experience, the inevitable time wasting and costly tests would demonstrate the essentiality of long-term reliability acceptance test. Without these tests, once these fatal accidents are happened during synchrotron system commission, the resulting delay time, idle manpower and many other costs would be inestimable.

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