EPICS BASED HIGH POWER RF CONDITIONING CONTROL SYSTEM FOR THE SNS ACCELERATOR RF TEST FACILITY

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ABSTRACT

Charged particle accelerators use various vacuum windows on their accelerating RF cavities to pass very high RF power through. Before placing on the cavities the windows should be cleaned, baked and fully RF conditioned due to poor vacuum caused by outgassing and other contamination. The linear accelerator (linac) in the Spallation Neutron Source (SNS) in Oak Ridge National Laboratory (ORNL) contains various accelerating structures and the RF conditioning of their high power vacuum windows is necessary for present work as well as future upgrade and development. An example is the coaxial fundamental power coupler (FPC) with an annular alumina ceramic window for each of the 81 superconducting RF cavities in the SNS linac. The FPC's need to be tested up to 650 kW peak in travelling wave and 2.6 MW peak in standing wave in 1.3 microsecond 60 PPS RF. In this paper, an Experimental Physics and Industrial Control System (EPICS) based RF conditioning system for the SNS RF test facility (RFTF) has been presented [1].

INTRODUCTION

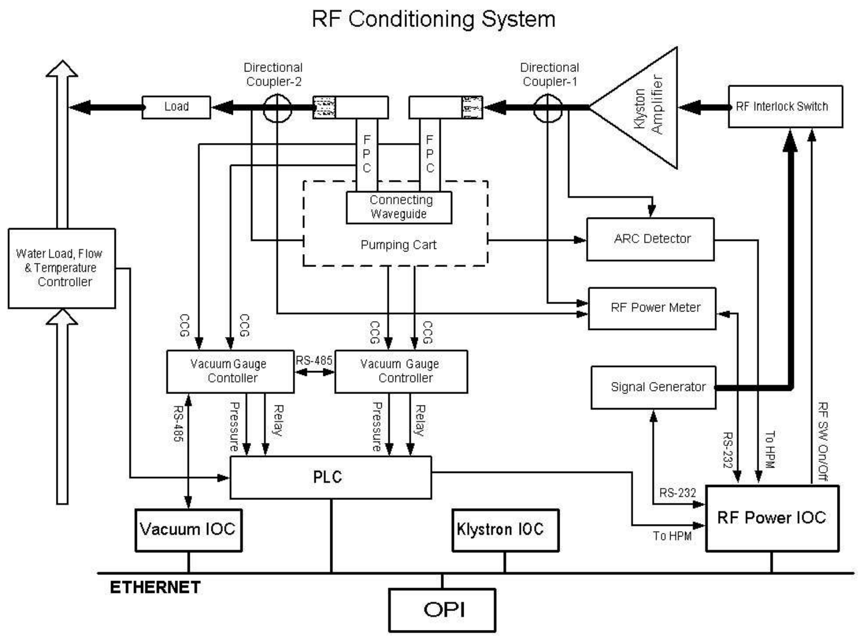
RF conditioning of the windows in couplers is one of the most important tasks to be done before placing them to the cavities. RF conditioning processes were developed and used in various accelerator projects including the SNS project [2]. Since the SNS accelerator is controlled by the EPICS based system, the proposed RF conditioning system has been designed by using EPICS to easily integrate it to the main control system of the SNS. The conditioning process has to be controlled very carefully not to damage the windows; with the high power RF the initial vacuum is unpredictable and any unsafe vacuum level can damage the high quality ceramic windows. Various RF and control instruments are integrated through the EPICS system on Linux platform to measure and to control the vacuum and the RF power while monitoring electron emission and unwanted arcing during the conditioning to interlock RF power. The interlock system has been designed by using the PLC and an RF switch with microseconds response time.

OVERALL SYSTEM DIAGRAM

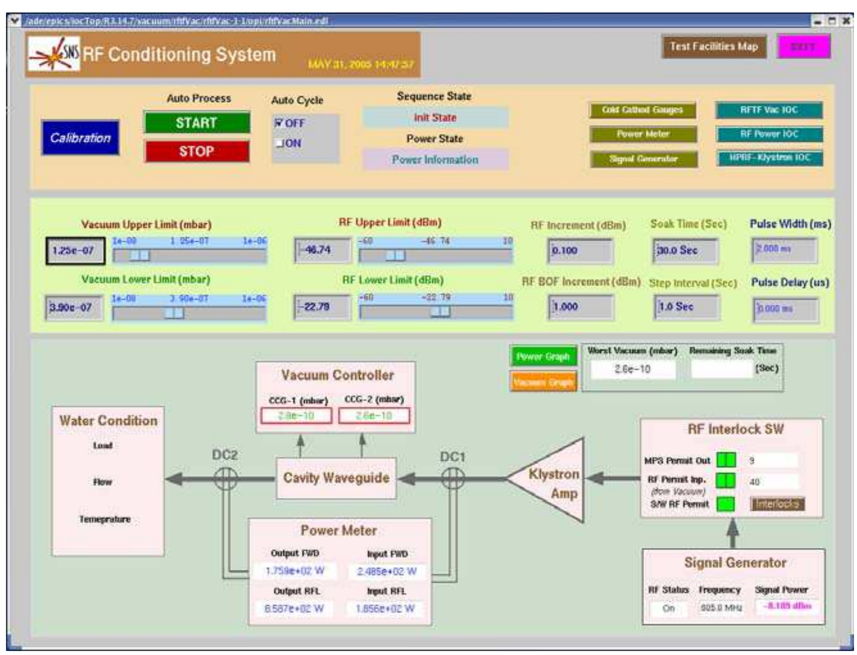
The overall block diagram and the screen shot of the main Operator Interface (OPI) of the RF conditioning system are shown in the Figure 1. The amplified RF from the klystron amplifier will be transmitted to the devices under processing through the waveguide transmission line. Between the klystron and a power coupler there are directional couplers to monitor the power signal. The RF power will be transmitted to another power coupler through a connecting waveguide and finally reach the termination that is a water load for travelling wave processing or an adjustable short for standing wave processing. Two RF power meters each with two channels are connected to the RF power IOC through RS-232 to measure the forward and reflected power levels at the input and the output ports of the couplers. Four cold cathode gauges (CCG) are used to monitor the vacuum inside each coupler and the pumping cart and these gauges are connected to two MKS vacuum gauge controllers (VGC). Analog modules and relay modules of VGC are directly connected to the PLC to supply the pressure and relay status information, respectively. If vacuum pressure crosses the predefined upper limit then the PLC will send a RF off request signal to the high power module (HPM) of RF power IOC. The IOC will shut down the RF Interlock switch within a few microseconds during any kind of abnormal situation. So, PLC is used for continuously monitoring the vacuum level and other auxiliary systems like water load, flow and temperature conditions. Communication modules of VGC are also connected with the vacuum IOC through RS-485 for controlling the VGC's remotely.

Signal generator is connected to the RF power IOC through RS-232 connection. The output of this signal generator goes to the RF interlock switch and delivered to the driver amplifier. If the IOC gives the permission to pass the signal then the switch passes the signal to the driver for klystron amplifier.

An arc detector is used on each coupler to detect the arc during the RF conditioning process and it is connected to the HPM of the RF power IOC. RF power IOC shuts down the switch to interlock as soon as any arc occurs.



(a) Overall block diagram



(b) Main OPI screen

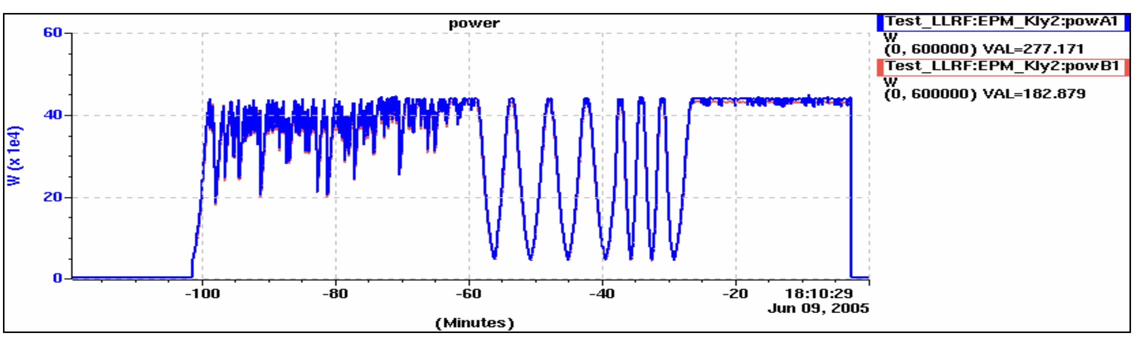
Figure 1: The overall block diagram and main OPI of the RF conditioning system

DEVELOPMENT OF THE CONTROL SYSTEM SOFTWARE

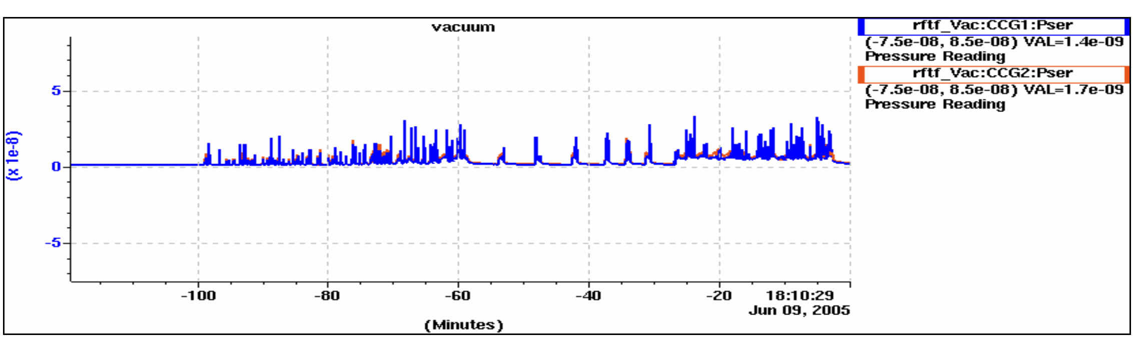
RF conditioning process constitutes several states with some predefined conditions and instructions. The process continues by following the conditions and instructions written in each state depending on the real time values of EPICS Process Variables (PVs) from the various instruments. The possible states during the RF conditioning process are given follows- Initialize: starts the control program, initializes and calibrates instruments; Increase: increases the RF power; Decrease: decreases the RF power; Hold: hold on the current RF power; Vacuum upper limit: takes necessary actions when vacuum crosses the upper limit; Fault Detection: this state starts in any kind of abnormal situation; Ramp after fault detection: starts the conditioning again after the fault diminishes; End: finishes the conditioning process. EPICS sequence programming has been used to control and define these states. The detail description of these states can be found in [3].

When the program starts then it sets the RF power amplitude in the signal generator to the predefined RF lower limit. Then the sequencer monitors the RF permit signal from the RF power IOC, which controls the RF interlock switch. If the RF permit is ON then the sequencer jumps to the 'Increase' state otherwise it goes to the 'Fault Detection' state. The main task of the 'Increase' state is to increase the RF power and the step of the increment can be defined by the variable 'RF Increment'. This state also monitors the vacuum limit, if it is within the limit then the sequencer jumps to the 'Hold' state to hold on the current RF power, but it jumps to the 'Vacuum Upper Limit' state if the vacuum crosses the upper limit. When the vacuum reaches below the lower limit then the state checks the variable 'Auto Cycle' and if the 'Auto Cycle' is ON and RF power is greater than or equal to upper limit then the state will hold on the current RF power until the 'Soak Time' has been elapsed and jumps to the 'Decrease' state but if the 'Auto Cycle' is OFF for the same RF power then it simply jumps to the 'Hold' state for holding on the current RF power. 'Hold' state is mainly used for holding on the current RF power input to the klystron amplifier from the signal generator. When the vacuum is within the limit and RF amplitude just crossed the upper limit then the sequencer is being looped around this 'Hold' state. Moreover, it jumps to the 'Vacuum Upper Limit' state if the vacuum crosses the predefined upper limit. The main difference between the 'Vacuum Upper Limit' state and the 'Decrease' state is – here the decreasing step defined by the variable 'RF BO Increment' is much bigger than the step in 'Decrease' state. Because if the vacuum crosses the upper limit then the RF power should be backed off by a significant amount and it should be looped around this state until the vacuum reached below the upper limit.

In any kind of unwanted situation the program immediately jumps to the 'Fault Detection' state and shuts down the RF output from the signal generator and looping around this state until the fault clears. When the RF permit is ON then the sequencer moves to the 'Ramp after Fault' state and increased the power by 1 dB until the power crosses the lower limit. When the RF conditioning process has been finished, then the 'End' state turned OFF the RF power output from the signal generator and jumps to the 'Initialize' state to start another conditioning process.



(a) RF power



(b) Vacuum

Figure 2: Conditioning results in travelling wave mode.

RESULTS AND ANAYLYSIS

The RF test facility in the SNS was constructed in 2004 and has been being used for various high power RF tests. Upgrades and additions have been made lately to improve the performance of the overall system. The developed control system software and hardware described in this paper have been integrated to the high power RF system successfully. The whole system was checked carefully to verify the reliable and safe testing.

Several experiments were performed at RF test facility to determine the validity and performance of the proposed RF conditioning system and software implementation. Tests were made in both travelling wave and standing wave modes. Figure 2 shows the conditioning results during the travelling wave mode. In the power graphs the input and output forward power has been represented by blue and red colours respectively, while in the vacuum graphs these colours represented the vacuum pressure in the first and second couplers respectively. The auto cycle conditioning and the constant power conditioning has been shown in the figure. It also shows the smooth starting of the conditioning process with the gradual increase of power. It is clear from this figure that how RF power is backed off and increased again when the vacuum has been crossed the predefined upper limit. Interlock functions of the control system and the control software have been tested and checked to ensure reliable and safe operation of the high power RF test setup.

CONCLUSION

With the addition of improved software and hardware, the RF test facility at the SNS is becoming a full featured high power RF Test facility that is capable of supporting the conditioning work of various high power RF components that is needed to be done for the SNS and for possibly other scientific projects in the community.

The research described in this paper has been performed by focusing on implementing such conditioning system integrated into EPICS environment that is the common control platform of large-scale scientific instrumentation. Although the proposed RF conditioning system has been designed for conditioning the RF windows used in the accelerators, this system can be applied to condition various RF materials, structures, and windows used in any field or applications.

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REFERENCES

[1] Y. Kang et al, “High Power RF Test Facility at the SNS”, PAC 2005, Knoxville, TN, May 2005

[2] M. Stirbet et al, “RF Conditioning and Testing of Fundamental Power Couplers for SNS Superconducting Cavity Production,” PAC 2005, Knoxville, TN, May 2005

[3] S.M. Hasan, “Design and Development of EPICS based RF Conditioning System for the High Power RF Components of Charged Particle Accelerators”, Masters Thesis, University of Tennessee.