ISBN: 978-3-95450-223-3 ISSN: 2673-7000 doi:10.18429/JACoW-NAPAC2019-TUPLE08

COMMISSIONING UPDATE ON RF STATION #5 OF AWA*

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Abstract

The RF system of Argonne Wakefield Accelerator (AWA) facility has grown over the years from one RF power station into 4 RF power stations. The demanding for RF power keeps growing as the capability of AWA continues to grow. Now the 5th RF station is needed to fulfill the RF power needs of AWA facility. Some details regarding the construction and commissioning of the 5th RF station of AWA facility are documented in this paper.

INTRODUCTION

Argonne wakefield accelerator facility is a small accelerator research facility setup in the 1980s to explore advanced accelerator concept. It started out with one RF station driving a photoelectron RF electron gun and a linac with few beam diagnostics. It has successfully demonstrated the electron beam driven wakefield acceleration with plasma, dielectric and metallic structures. As the scientific quest continues, AWA has grown. As shown in Fig. 1, AWA currently has 4 RF stations powering 4 beamlines: a 65MeV drive beamline, a 15MeV witness beamline, a cathode test stand and one L-band 20MW RF power station for testing novel RF cavity designs. The drive beam line itself has one 8MeV photoelectron RF electron gun, 6 linacs and a double emittance exchange beamline attached to it. There are 4 transverse deflecting cavities on this double emittance exchange beamline that need RF power. In order to power up all needed cavity for double emittance exchange beamline, the 5th RF power station is a must have.

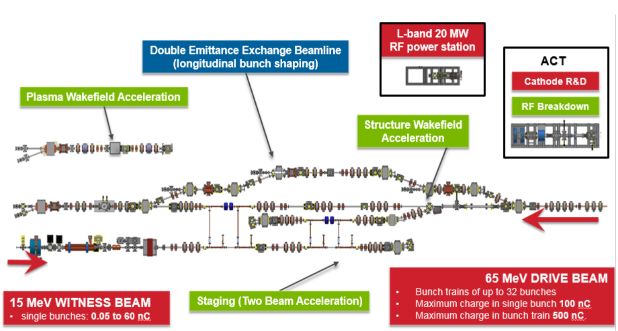

Figure 1: AWA facility beamline layout.

For cost efficiency reason, we decided to build the 5th RF station the same as our 3rd and 4th RF station. As showing in Fig. 2, the klystron we used is a TV2022F ordered from Thales Electronic Device [1]. The maximum power is 25MW with klystron voltage of 273kV and klystron current of 248A. The pulse length is 10us. The focusing solenoid and oil tank/high voltage pulse transformer assembly is ordered from Stangenes [2]. The high voltage pulse transformer turns ratio is 1:15.3 while the filament heater transformer turns ration is 120:28.

Due to some unexpected issues, the order for the transformer tank assembly was delayed and caused delays in the whole project. We are now expecting to power up this RF station in late October.

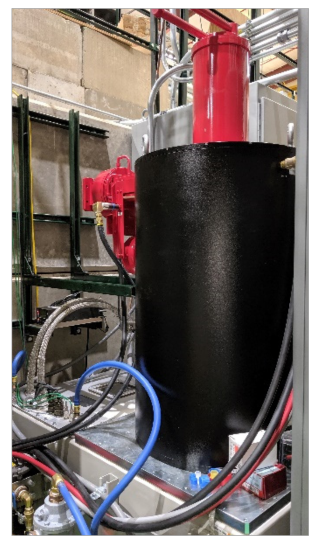

Figure 2: Picture of klystron, focusing solenoid & High voltage transformer tank assembly.

LLRF AND INTERLOCK CONSIDERATION FOR RF STATION 5

As showing in Fig. 3, except for RF Station #2, the LLRF for all AWA RF stations consist of one NI-PXI5404 to generate the 10MHz IF and a mixer to mix the 10MHz IF with 1.29GHz LO signal to generate the phase controlled 1.3GHz LLRF signal. This phase controlled LLRF signal will be gated and then amplified using a 500W pulsed amplifier before it is used to drive the klystron. We only need to add one NI-PXI5404, one mixer, one RF gate and a 500W RF amplifier to existing system for RF station 5. To feedback control the output of RF station 5, we will need another mixer to mix the signal picked up from RF cavities driven by RF station 5 with 1.29GHz LO to make the 10MHz IF signal. This 10MHz IF signal will be I/Q sampled using one of the 8 channels on NI-PXI5105 to obtain the phase and amplitude information.

* Work supported by DOE Office of HEP and Office of BES under Contract No. DE-AC02-06CH11357.
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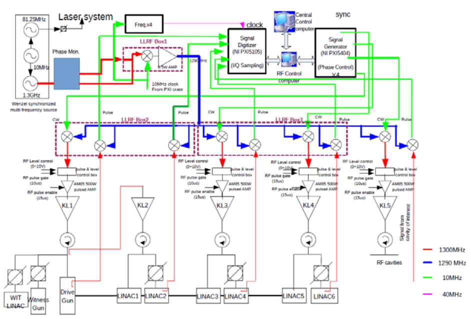

Figure 3: AWA low level RF system layouts.

Showing in Fig. 4 is the interlock logic of RF station 5. The high voltage power supply (HVPS) enable signal will only be passed through to HVPS when the local interlock chain of RF station 5 is complete and RF station 5 is not disabled/bypassed. The interlock input for HVPS will only be true if the RF station is not disabled/bypassed and all local interlock signals are OK. The interlock chain complete signal to top level interlock chain can be true either when the local interlock chain is complete physically or this RF station is disabled/bypassed.

As showing in Fig. 5, the interlock chain of AWA facility will not complete unless the local interlock chain complete

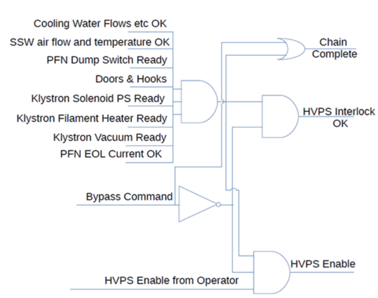

Figure 4: Interlock logic of RF station 5.

signals are received from all modulators. The Bypass Command was introduced to the local interlock of all RF stations to allow the chain complete signal being generated without the actual interlock chain being complete. This arrangement gives us the flexibility to power up only the needed RF stations without rewiring the interlock circuits.

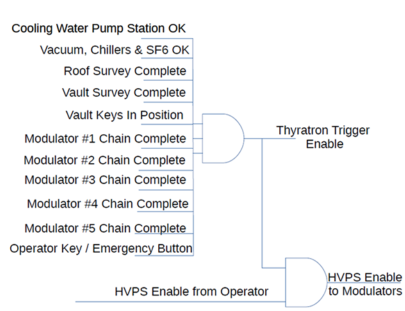

Figure 5: Interlock logic of AWA facility.

THE PULSE FORMING NETWORK (PFN)

As showing in Fig. 6, the PFN of AWA Modulators are consisted of two parallel lines with 12 L/C pairs each. The capacitance of each capacitor is 0.05uF +/- 5%. The voltage rating is 50kV.

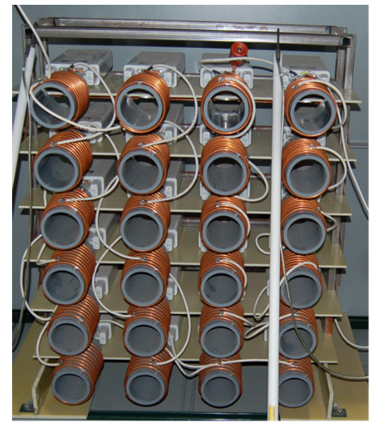

Figure 6: Picture of the PFN.

The inductors are made of ¼" copper pipe winding on a 5" PVC pipe. The inductance can be adjusted continuously by changing the connection point on the winding.

The pulse shape and characteristic impedance can be tuned by adjusting the inductance of each individual inductor.

An end of line (EOL) clipper diode stack and resistor assembly is connected at the end of PFN line to absorb reflection power. EOL current monitor is installed to monitor the EOL clipper current for abnormalities and provide the PFN EOL Current OK interlock signal.

A TDK-lambda 303L-40KV-POS constant current high voltage charging power supply [3] is used to power the PFN.

A solid state switch assembly, S56-10-N40kV Solid State Thyratron Replacement from Applied Pulsed Power [4], is used in the place of thyratron. The using of solid state thyratron replacement have successfully eliminated several performance issues we had with our modulators [5]. The cooling air flow and the temperature of switch body are monitored and interlocked. A dump switch is installed and interlocked for safety. Once the cabinet door is opened or the hook is not in position, the PFN dump switch will be closed to discharge the PFN and trip the interlock to prevent HVPS to charge the PFN.

Tuning PFN at Low Voltage

It is not desirable to tune PFN at its working voltage due to safety reasons. A simple switching circuit using an array of 2n2222 transistors was made for the purpose of tuning PFN safely at low voltage. The schematic of the switching circuit is given in Fig. 7.

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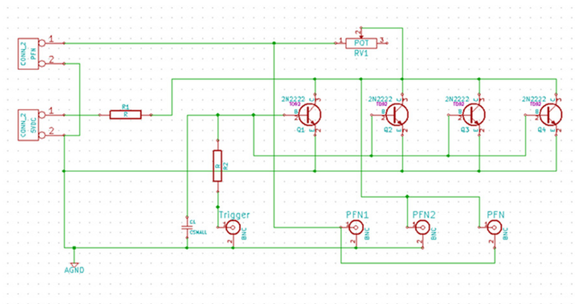

Figure 7: Schematic of switching circuit for tuning PFN at low voltage.

As showing in Fig. 8, the non-negligible ON resistance of 2n2222 array will cause non-negligible voltage drop across the switch circuit which will affect the precision of tuning results.

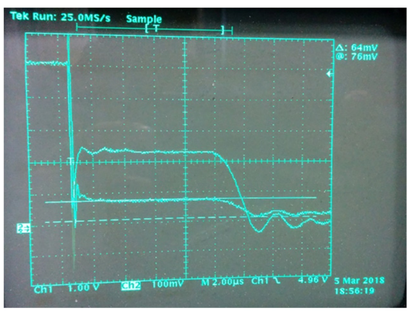

Figure 8: Scope trace showing the effect of non-negligible “ON” resistance.

In order to minimize the effect from transistor ON resistance, we expanded the array to 7 transistors in our final circuit. With the expanded transistor array, the voltage drop across the switch becomes negligible as showing in the Fig. 9.

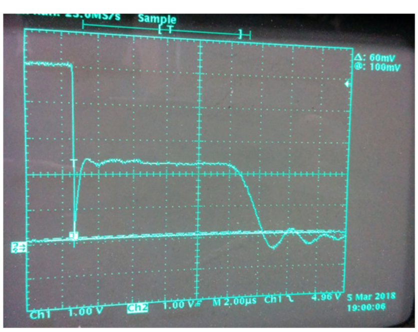

Figure 9: Scope trace showing the results from the expanded transistor array.

Due to the fact that the characteristic impedance of our PFNs are about 4ohms, there will be less errors in the dummy load resistance if we tune the two parallel PFN line separately. Also it is much easier to tune the two parallel line separately. After the first line is tuned, the 2nd line can be configured similar to the 1st line and will be tuned with a few small adjustments. The final tuning will be done with a few touches after joining the two parallel lines together.

UPCOMMING HIGH VOLTAGE TEST AND COMMISSIONING

Once the construction is completed, high voltage tests will be conducted to verify all the settings and interlock signal wiring.

At the beginning of high voltage test, we need to check the pulse shape. If the klystron voltage pulse shape was too far off from the pulse shape during low voltage PFN tuning, it is an indication of failing component or some other connection issues.

The 2nd thing we will check is the ratio between PFN voltage and HVPS voltage setting. This ratio should be about 1:2 otherwise the PFN characteristic impedance is not matched with the load. The tuning circuit dummy load need to be verified and wirings need to be checked for perfection. PFN retuning at low voltage might also needed if dummy load resistance wasn’t correct.

Another voltage ratio we should checked is the ratio between PFN voltage and klystron voltage which should be about 1:15.3. If it is not, then there must be some wiring problems.

As HVPS setting increases, we also need to pay attention to the klystron reverse voltage or backswing. This voltage should be kept <60kV.

All signals must be monitored closely for abnormalities. Stop pulsing the machine immediately if there is any sign of arcing or breakdown.

Always following the lock out tag out (LOTO) procedures and Zero Voltage Verification (ZVV) procedures to put the modulator under electrical safe working condition before doing any change to the modulator.

CONCLUSION

As a result of the growing capability of AWA facility, the demanding for RF power is also growing. Now the 5th RF station is under construction to fulfill the RF power needs of AWA facility. Due to unexpected delay in the order of few key items, the construction is behind schedule. Once RF station 5 is commissioned, it will enable AWA facility to realize all its potential capabilities.

AKNOWLEDGEMENT

This work is sup-ported by the Department of Energy, Offices of HEP and BES, under Contract No. DE-AC02-06CH11357.

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