NEUTRINO HORN POWER SUPPLY OPERATIONAL EXPERIENCE*

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Abstract

The operational experiences required to run the 300 kA pulsed power supply at Brookhaven National Laboratory are given. Various interlocks and monitoring circuits are described and the impact on system reliability are discussed. The initial conditioning process of the power supply during startup is described.

Introduction

Normal neutrino horn operation is controlled by the AGS main operations control room via a computer link. The majority of the horn instrumentation and control equipment necessary for horn operations is located in the neutrino horn control trailer which is situated in the Northwest experimental area of the AGS. Analog, digital and video information about the horn and power supply performance is displayed in the trailer for both local control and trouble-shooting assistance. Most of the analog signals are multiplexed and distributed to the main control room and/or experimental areas. Most of the video signals are for local monitoring only except in some instances where main control must monitor a particular test of a horn component.

When the neutrino program is in progress, important horn operating parameters are monitored by the main control either by analog scope displays or computer terminals. Also, the experimenters use some of the horn power supply signals to complement there experimental data. As a result of the continual updating and instrumentation improvement over the last three years, horn operational efficency has improved significantly.

A major improvement was in current monitoring for the discharge pulse. In the past only one discharge module was monitored with its current value multiplied by the number of modules on line. While this was an acceptable method for monitoring total horn current for broad band experiments, narrow band experiments demanded a closer tolerance on horn current values. Individual current transformers were installed for each module. Total horn current is now measured by a summing network of each current transformer and subsequently used for experimental data, as well as, an important monitoring signal.

Power Supply Instrumentation

Interlocks

The power supply control and monitoring instrumentation resides in the local control trailer. This equipment is operated locally by assigned technicians or can be remotely controlled by the AGS control room operations personnel. Basically, local operation is in effect only during critical start-up periods or during special testing programs. As a result of the dependency of the remote operation approximately 65 interlocks are in the operating system. Some of these interlocks are directly associated with the power supply components while others are concerned with system support items.

Some of the system interlocks are for personnel saftey and are either related to power supply security or secondary beam security. In both cases the high voltage output circuit will be clamped to ground via a relay. Usually the system security interlocks are microswitches or equivalent and are double pole for annunciation as well as interlock functions.

Most of the interlocks serve to protect the various power supply assemblies and horn components from damage or unusual operating parameters. Examples of the types of interlocks are as follows: air and water flow sensors; pressure transducers; thermocouples; acoustic pick-up devices; current coils; and overvoltage or overcurrent sensors.

All interlocks are easily identified at a local annunciator panel located in the power supply house. In the case of horn water cooling and horn gas, an annunciator panel resides in the horn pump house. In addition, an interlock alarm computer program is available on demand.

During the initial running period of the new horn there were several failures of the coaxial power feeds used to connect the horn to its power supply. In general, these failures were caused by a short between the inner and outer conductor of the coaxial line. This type of failure would ccause a blow out of material from the power feed accompanied by very loud explosions, but would not trip the system off. Although the noise was very impressive there was little other indication that a destructive process was taking place, since the horn itself is almost a short circuit. Because the horn is run unmanned and is located in a very remote area, this type of failure could go unnoticed for many hundreds of pulses. This, in fact, did happend and additional damage to adjacent conductors and equipment did occur. To solve this problem an audio interlock was added that shut the power supply off if a set noise level was exceeded. After the addition of this interlock all other failures of this type were indicated immediately and damage was kept to a minimum.

Power Supply Control Instrumentation

a. The power supply control bucket consists of voltage ramping circuitry, local computer contol, voltmeters, charge time scaler, and interlock annunciation. The voltage ramping circuit is dependent upon a voltage divider signal that looks directly at the capacitor bank voltage. The output ot this divider ramps up with the dividers on each of the horn system power supplies but holds its voltage until the series ignitrons in the discharge modules are triggered. Individual power supply voltage dividers also give indication of power supply ramping voltages. The output of these dividers show the supply ramping voltages at there final value and then quickly dropping to several hundred volts when the current diverter is fired.

In addition to the voltage monitoring, the total charge time of the capacitor bank is displayed and can be used to interlock the power supplies if this parameter falls outside of a prescribed window.

b. A datacon bucket contains a power supply controller, timing autodets, scalers, and an analog multiplexer. This bucket serves for the remote operation of the power supply and pertinent signals read-back.

c. One of the most significant improvements to the system was to add current transformers to each of the discharge modules. With this instrumentation it became possible, with experience, to determine weak or malfunctioning modules before they completely stopped working. This allowed a degree of preventive maintenance which did not exist in the past and greatly reduced system downtime. Each of the current transformer output signals, which were on the order of 100 volts, where fed to precision voltage dividers. The output of each of these dividers were digitized and sent to the main control room and the experimenters trailer. The output of each module could then be monitored and modules, which occasionally misfired, could be replaced before they eventually failed. The

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output of each voltage divider was also summed through an amplifier, the output of which was an accurate indication of the total power supply current. This signal, along with a signal which indicated beam on target, was used to set the horn timing predets.

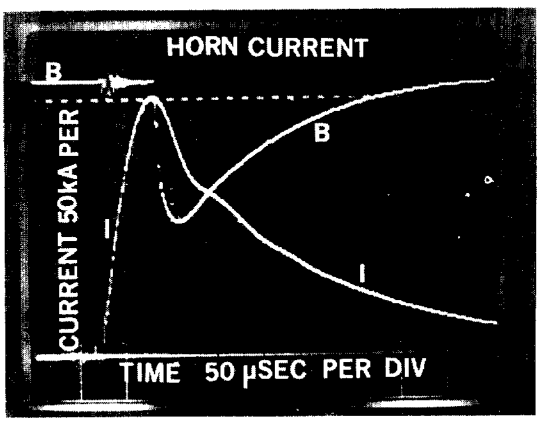
d. Timing signals for the horn power supply are generated locally by a predet sychronized with the AGS machine cycle.

d.1. Start Charge......70 to 100 ms after the horn trigger

d.2. Stop Charge.......50 ms before beam time (only used if ramp circuit fails)

d.3. Back-up Trigger...50 ms after beam generated trigger (EXAU3)

e. The horn power supply begins its current discharge 56 µs before beam time. A trigger pulse sychronized with RF/12 AGS machine time is generated by a datacon autodet and in turn triggers the power supply so the horn current peak is right at beam time. The current pulse is displayed on an oscilloscope with the beam pulse signal superimposed. Any variation in timing is easily observed as can be seen in fig. 1.



Relative timing of horn current pulse and proton beam on target.
I = horn current; B = beam on target

Figure 1

f. The power supply control bucket contains all the functions for manual control with essential metering. A charge time scaler indicates the total charge time for the capacitor bank modules. This particular read-out gives a quick indication if any modules are malfunctioning. At operating voltage of 12 kV, a change of approximately 50 ms will occur if a module does't discharge the capacitors.

g. The local control trailer contains several TV monitors. The two TV cameras in the horn power supply house are for both instrument monitoring and remote visual inspection. Each capacitor module has an associated voltmeter that can be viewed by the TV monitor. This enables an operator to make a quick inspection of module charging performance in case of lower discharge current values. The other camera can scan the entire capacitor bank area to help locate arcing problems that can occur at high operating parameters.

During testing of the horn or associated components a TV camera will be placed in the tunnel enclosure to view possibe failures in the horn or hard coax feeders. In some cases a video taping recorder has been placed on line for future analysis of failed components. This camera can only be useful during initial testing conditions for secondary beam during operating periods quickly damages TV camera.

Initial Horn Testing

Final Inspection

a. First there is a final Inspection of all horn components, tunnel, and power supply systems. This includes the clearing out of all unused equipment and tools. An inspection of all signal cables must be made to insure there are none laying across the high voltage transmission lines.

b. Set up TV cameras at all critical locations as determined by previous experience or new designs.

c. Secure all radiation and personnel gates.

Interlock Clearance

1. Clear horn power supply interlocks (for P.S. 1 and 2)

	INTERLOCK NAME	SOURCE
1	440 ac Phase A	Current Coils
2	440 ac Phase B	Current Coils
3	440 ac Phase C	Current Coils
4	Overcurrent	Circuit in P.S. cabinet
5	Overvoltage	Meters in control room
6	Cabinet Doors	Microswitches
7	Tetrode Filament	Circuit in P.S. cabinet
8	Tetrode Temp.	Sensor in tube enclosure

2. Clear system interlocks

	INTERLOCK NAME	SOURCE
1	Pump House	Pump house control panel
2	Coax Fan	Tunnel fan vane switch
3	Horn Audio	Microphone in tunnel
	Current Spike	Control Room circuit
4	Target Pressure (Hi)	Target block transducer
5	Target Pressure (Lo)	Target block transducer
6	Tunnel Gates	Tunnel interlock system
7	Screen Door	Microswitch
8	P.S.H. Door	Microswitch
9	250R Filament	Sensor in Diode Box
10	250R Cooling	Sensor in Diode Box
11	Trigger Rack Air	Vane switch in trigger rack
12	Ignitron Water (East)	Pump flow switch
13	Ignitron Water (West)	Pump flow switch
14	Resistor Water (East)	Pump flow switch
15	Resistor Water (West)	Pump flow switch

Set-up Horn Power Supply Operating Signals

1. Set high voltage interlocks to 4 kV
2. Set-up timing signals as follows:
   Charge Start ------ 0.0 ms
   Charge Stop ------- 50 ms to 100 ms before horn trigger
   Horn Trigger ------ 1200 ms
   Scope Trigger 1 --- 0.0 ms
   Scope Trigger 2 --- 1200 ms
3. Display horn current ramping signal and current pulse on scope
4. Set up the TV monitors on the various horn components that are of immediate concern and on the capacitor bank voltage meters.

Commence Initial Horn Pulsing

1. Turn on horn power supply to a 2 kV level using the manual control mode.
2. Check all TV monitors for signs of arcing.
3. Check all operating signal read-outs.

   1 Voltage meters in control module
   2 Charging ramp trace
   3 Charging time on control module scaler
   4 Discharge current pulse
   5 P.S. control voltage on DVM

4. Over a period of 2 hours of continuous running, slowly ramp up the power supply voltage, stopping at 2 kV increments until the preestablished operating parameters are reached. Continue to check all TV monitors and instrumentation as outlined in Section d.3). Log in all read-outs at each step. Take polaroid pictures at each step.
5. When having reached maximum test levels, continue pulsing for 1 hour. After 1 hour of testing, turn off charging system and proceed to inspect all horn connections, coax flexures, header assemblies, and soft coax connections.
6. If satisfied that no apparent problems have surfaced, continue testing for 4 hours continuously. Along with the visual inspection as described, temperature measurements at critical locations can be logged.
7. After the first 24 hours of running, inspection intervals can be lengthened to 8 hours for the next 24 hour period.
8. The next plateau of testing is essentially a nonstop test for 10 to 14 days to accumulate several hundred thousand operating current pulses.

Conclusion

This report has touched on an overview of the neutrino horn power supply instrumentation and operation during initial testing. The actual on-line operation of this power supply varies little from the testing considerations. When experiments are on-line the timing of the horn pulsing in relation to the beam is the only other parameter that comes in to effect after initial horn testing.

Usually, the various experimenters keep close tabs on this parameter,as well as, the total horn current value. It is interesting to note that with all the various instrumentation the most significant in detecting problems associated with horn components is an audio intercom that picks up arcing sounds in rather resounding fashion. Both the local control room and the AGS main control pick up this audio signal. When the horn is pulsing one can easily hear any change in pulsing repetition caused by faulty capacitor discharge modules or change in timing signals. Over the years this simplest of instruments has probably been the most effective.

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