HIGH VOLTAGE STABILIZATION SYSTEM OF CARIBU/ECR FOR ATLAS

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Abstract

With the increased radioactive beam capabilities brought by new CARIBU (Californium Rare Isotope Breeder Upgrade) in ATLAS facility, highest charge breeder efficiency of ECR is desired. Experimental study shows that the best efficiency could be achieved when high voltages (up to 50 kV) of two platforms (CARIBU and ECR) are only different within less than 1V [1]. We have developed a system with some innovative ideas implemented to measure the required tiny voltage difference ratio (~0.002%) precisely and to protect the system too. High voltage (HV) filter is designed to protect it from severe HV sparks and multiple level of relays with high precision medium HV divider are used to protect it from possible power supply failure. Homemade HV divider is used for rough measurement and control. Measurement results are converted to optical signals and then used to control power supplies to achieve the desired platform voltages. The system has been partially tested and will be used in the future.

INTRODUCTION

When developing such a system with very high sensitivity and accuracy as mentioned above, at first we need to consider how to prevent damage from HV shock and power supply failure. We also need to think about how to measure the voltage difference precisely.

In ATLAS facility, both CARIBU and ECR1 are on a common HV platform of 350 kV. Then the 50 kV bias is applied to them on top of the 350 kV with separate power supplies. There are numerous instruments which are biased with different HV or high current power supplies on both platforms. Occasionally, HV sparks may occur. Those HV sparks are fatal to electronic measurement systems if they are not protected. Possible power supply failure is another threat we need to deal with. We cannot eliminate power supply failure, but we can protect the system with an appropriate design.

Using high voltage divider to measure the voltage difference is a simple and tempting idea. But careful study indicates that this approach has un-surmountable problem. Due to variation in resistor resistance caused by temperature and voltage bias variation, typical HV divider may only provide about 1% accuracy. Even for very expensive custom made high voltage divider with 0.1% tolerance, it still cannot provide the accuracy we need here. The high common mode noise also introduces more measurement error.

SOLUTION

Multiple levels of filter circuit are used to protect the system from HV, high current sparks in electrometer [2]. This kind of sixth-order low pass filter can achieve high-frequency attenuation exceeding 10^{+5}. So we adopted this approach for our HV spark protection.

Multiple levels of relay can be used to protect the system from power supply (PS) failure. Details will be explained in design and test section. Relays are turned off when PS fails. Homemade HV divider is used for coarse control and monitoring.

CARIBU side high voltage is used as floating GND for our measurement system. So when the tow platform HVs are very close, accurate measurement can be achieved without introducing big noise.

SIMULATION

Spice simulation is performed on a simplified low pass filter as shown in Fig. 1. In this simulation, a hypothetical high voltage spark source (I1, 20 kA, ~1ns rise time) shown in Fig. 1 is used.

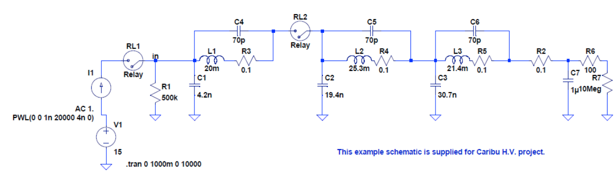

Figure 1: A simplified low pass filter with two relays.

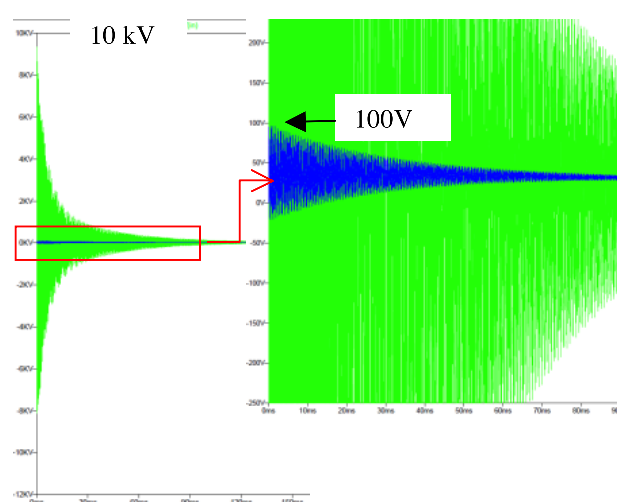

Figure 2: Simulation results of the filter shows the attenuation of HV shock

The filter is similar as that which can be found in [2]. The simulation result is shown in Fig. 2. The plot at left shows the voltage waveform (green colour) at R1. It is about 10 kV peak. After filter, the peak voltage (peak of blue waveform) level drops to about 100V peak at C7/R6. The peak voltage attenuation is about 100 which is 40dB. The inset shows the zoomed view of area inside the red rectangle. Some components such as capacitors and resistors in the low pass filter are HV components.

DESIGN AND TEST

The system has been built by following the block diagram shown in Fig. 3. The voltage difference is measured by Delta V board and then converted to frequency. The frequency is then converted to optical signal and communicated to F-V converter. The signal is converted back to voltage before sampled by ADC. The computer checks the data and then goes back to control power supplies and control the system based on the data and control setting. A typical voltage to frequency converter used is shown in Fig. 4. It can be modified to use as frequency to voltage converter. The voltage after F-V converter can be used to control power supplies directly in case we need it.

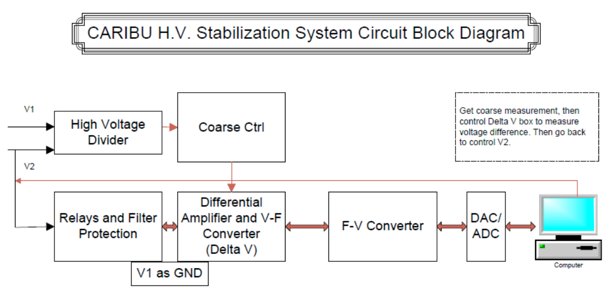

Figure 3: Block diagram of the HV stabilization system.

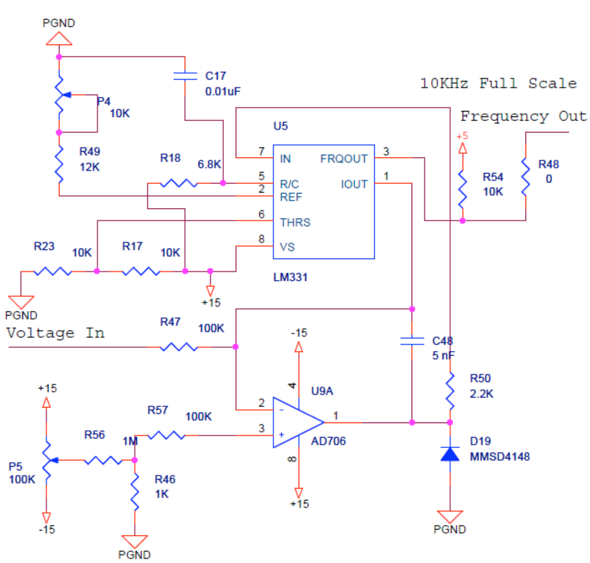

Figure 4: A typical voltage to frequency converter.

A FUG power supply with very high stability (10^{-5}/8h, ^{o}C) is used at CARIBU side platform voltage. This HV is used as the floating ground for the HV stabilization system. Power supply for Delta V board is referenced to CARIBU platform voltage.

A ultra precision medium high voltage divider (0.01% tolerance) with very low temperature coefficient is put on the Delta V board. It makes the accurate measurement feasible while also protecting this board from potential damage caused by medium high voltage up to 1500V after the low pass filter. A precision instrumentation amplifier AD8221 with high common-mode rejection ratio (CMRR) is used after the on-board divider. There is one relay on the Delta V board with release time ~1 ms. The 15 kV and 75 kV relay have release time ~2 ms and 15 ms respectively. Those two relays are RL2 and RL1 in Fig. 1. When there is a power supply failure, the one side voltage drop or increase due to the failure is estimated as 50V/ms, the relays in series are turned off by on-board monitoring circuitry to protect the system. Relays in series here are not for the purpose of protection from HV sparks. They are too slow for this but good for power supply failure protection.

A homemade HV divider provides ~1% accuracy and is used for coarse measurement and control in the system. Coarse control board is on 350 kV common HV platform and communicates with Delta V board through optical fiber cables.

The built system is show below in Fig. 5. The zoomed view of the low pass filter board and Delta V board is shown at right with the shield removed.

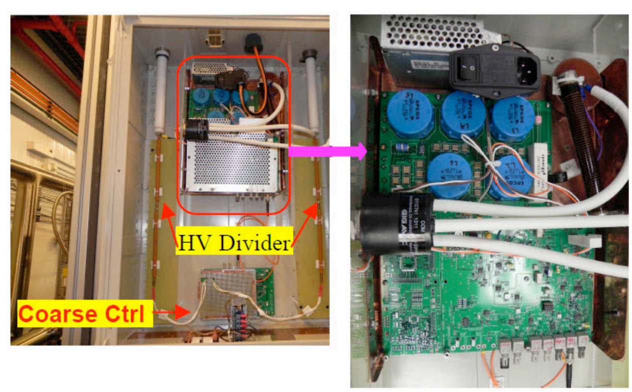

Figure 5: A simplified low pass filter with two relays.

Figure 6: F-V converter and control unit.

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Figure 6 shows the front and back panels of the F-V converter and control unit. This chassis can be placed on any platform close to ADC/DAC and it connects with Delta V board through optical fiber cables.

The whole system has been tested on bench and had some field tests too. Field test verified that it can stand at least 50 kV isolation which is one of the design goals. The voltage difference can be measured precisely to ~100 mV or less which exceeds another design goal of 1V. Final user interface software is in progress and the unit will be used in future in our facility.

ACKNOWLEDGMENT

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