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AN EVALUATION OF THE INTEGRITY OF THE SHUNT AND I SIGNALS AT THE LAB2 TEST STAND

J. Ozelis
B. Kinney
D. Lewis

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I.) Introduction

In an effort to understand possible sources of signal degradation which lead to poor reproducibility of EI/EO measurements taken using DVM's without direct analog integration or magnet voltage bucking, it was decided to analyze the signal paths of the I-dot coil voltage and the shunt voltage. This analysis encompassed the visual inspection of the signal cables, signal routing and shielding concerns, and measurement of the noise voltages at various positions along the respective signal paths. In addition, the overall grounding strategy of the power supplies and test stand was breifly observed.

II.) Visual Inspection

The signal cable from the main current shunt is a twisted pair enclosed by a braided shield, leading from the shunt to an HP 3457A DVM via a cable tray suspended above the magnet. This braided shield is terminated at the DVM end by being connected to the current input of the DVM. However, this current input may NOT be at ground potential, and therefore may not provide effective shielding of the conductors. This situation can be inproved by grounding the shield to the rack housing the DVM, by simply installing a spade lug on the braid and fastening it to the rack mounting flange with the appropriate screw. The shunt signal is also fed to a second DVM (Racal/Dana) via a banana-plug terminated coaxial cable. For EI/EO measurements, the shunt signal is tapped from the point where the main shunt signal cable is connected to the HP DVM.

The signal cable from the I-dot coil is likewise a twisted pair shielded by a braided jacket. This cable runs from the I-dot coil, which is mounted on one of the current lead flags with its axis parallel to the flag's long dimension, along a cable tray into the endrack on the floor. At the endrack, the I-dot signal is fed to two isolation amplifiers whose outputs are fed to the magnet safety circuit and LeCroy module. Signal routing in the endrack itself is usually accomplished through the use of twisted pairs.

The grounding system of the power supplies and measurement components was inspected. The Transrex power supplies are all tied together with the instrumentaion racks via braided cable, while the Transrex's themselves are tied to the system ground (a 3' section of rod inserted into the ground outside the laboratory building) via a thick copper multistrand cable. The ground side of the shunt is also tied to the system using this same cabling. The various A.C. powered instruments are grounded via their

3-prong line cords, which are connected to the A.C. bus of the racks. The racks' A.C. bus is connected to the A.C. line transformer of the lab.

III.) Noise Measurements

Measurements of the voltages present on the circuit elements described above were made using a Tektronix Model 5116 oscilloscope with a Model 5A26 dual differential input amplifier. These measurements are for various configurations as decribed below.

A. Shunt Signal

The shunt signal was measured directly at the shunt with no current flowing in the system and the power supplies turned off. A high frequency noise component was observed, superimposed upon a 60 Hz component. The amplitude of the high frequency component was 120 uV(p-p), while the 60 Hz component showed an amplitude of 45 uV(p-p). The shunt signal at the end of the cable where it is connected to the HP DVM showed the same basic structure, but the amplitude of the high frequency componenet had increased to 360 uV(p-p). This measurement was made with the cable disonnected from the DVM. Connecting the cable to the DVM's introduces substantial additional noise to the system - the high frequency component has an amplitude of 10.3 mV(p-p) with the HP DVM in place, and rises slightly more (11.4 mV(p-p)) with the Racal/Dana DVM added in. By grounding the shield of the twisted pair to the electronics rack itself, rather than attaching it to the DVM current input, the situation improves somewhat. In so doing, the noise is reduced to 1.1mV(p-p) with one DVM in place, and 5.4 mV(p-p) with both DVM's in place.

B. I-dot Coil Signal

The I-dot coil signal was first measured without any current applied to the system, and with the power supply off. The signal was first measured with the secondary coil in its normal position, and the signal was extracted directly from the coils, with the coils disconnected from the endrack and isolation amplifiers. This measurement yielded a value of 5.4 mV(p-p) for the high frequency component (the nature of the noise waveform was similar to that of the shunt signal). With the secondary coil removed from the bore of the primary and placed vertically on the floor, the signal dropped to 2.4 mV(p-p). When the secondary coil was placed parallel to and on top of the primary coil, the signal was essentially unchanged (2.1 mV(p-p)). The signal measured directly from the primary was 2.2 mV(p-p), indicating that the voltage noise across both coils was essentially equivalent. However, the signal from the primary with the secondary in place was higher at 5.4 mV(p-p). Therefore, it appears that the voltage noise across either component is higher when the components are in their operating configuration, than when they are separated (de-coupled), and only sensitive to changing fields in the environment.

The I-dot coil signal was also studied at the endrack where the signal is fed to the two isolation amplifiers after travelling through about 30 feet of shielded twisted pair conductor. At this location, with the amplifiers still disconnected, the voltage noise across the secondary when inserted into the primary was observed to be about 0.3 mV(rms). This is about a factor of 10 smaller than the equivalent noise voltage at the coil itself. This may be attributable to attenuation of the high frequency component of the noise. With the amplifiers inserted into the circuit, the signal degradation is increased, and a measurement of the voltage noise yields a value of about 3 mV(rms). This is comparable to the noise measured directly at the secondary coil, and is about a factor of 10 worse than without the amplifiers in the circuit. The noise measured at the output of the isolation amplifiers has an observed amplitude of about 10 mV(rms), and consists almost entirely of the 60 Hz component, the high frequency noise having been essentially filtered out by the amplifier.

The I-dot coil signal was then studied (at the endrack location) with the power supply on. Without any current flowing, the noise was observed to be 0.8 mV(rms). With the isolation amplifier in the circuit, the noise increased to about 7.5 mV(rms). With a current of 100 A (D.C.) flowing in the circuit, the noise was observed to be 32 V(p-p), and at a current of 3 A (D.C.), the noise was found to be 18 V(p-p). This noise (with I=0) is comppletely dominated by the 720 Hz noise from the SCR firing pattern. At I=2000 A, the noise across the I-dot coil secondary exceeds 50 V(p-p). Even with the secondary coils removed from the primary, a noise voltage af about 2 V(p-p) can be observed across the secondary coil, due to pickup from variations in the external(stray) field present around the magnet test area caused by the 720 Hz fluctuations in the supply current.

IV.) Conclusions/Remarks

To improve the signal integrity of the shunt signal, the braided shield of the shunt signal cable should be properly grounded to the rack. The cable itself appears to be of adequate type for the needs of the measurement. The I-dot coil signal is (of course) very strongly affected by changes in local magnetic fields, and some effort should perhaps be made to evaluate the electromagnetic environment of the magnet test area, with a view toward determining a location for the I-dot coil in a suitably field free region. The major contribution to noise in the I-dot coil signal is primarily the 720 Hz noise of the power supply, and less conspicuously, the noise introduced by the isolation amplifiers. Neither of these two sources of signal degradation appear to be able to be easily eliminated.

In principle, the noise induced by the 720 Hz SCR firing pattern would not affect an EI/EO measurement if the inductances of the magnet and I-dot coil could be matched exactly across the frequency range of interest. They could then be subtracted from each other, and all effects of noise induced inductive voltages would cancel. In practice, however, the inductances are not matched, and the subtraction of the inductive voltages is effected by a voltage divider circuit on the I-dot coil signal. This allows for the possibility of an inexact cancellation due to differences in the ratio of Lmag/Lcoil as a function of frequency. Differences in phase may also lead to errors in the voltage cancellation, since the reactance and inductance will change (and perhaps differently) with frequency.