A METHOD FOR DETECTING CORONA WITHIN RING MAGNET COILS OF THE ZERO GRADIENT SYNCHROTRON*

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Abstract

During recent years interest has developed in monitoring corona in the ring magnet coils of the Zero Gradient Synchrotron (ZGS). The threshold of corona in the magnet coils is thought to impose a limit on the amplitude of voltage which may be supplied by the RMPS for reliable operation. Accordingly, a method was devised to detect corona originating in the magnet coils. This technique was implemented on the ZGS test fixture (a half octant) and studies indicated that single corona pulses could be reliably detected when transmitted on the test fixture coils or when buried within the test fixture. This corona monitoring method utilizes a high quality communications receiver to provide 5 μV sensitivity, which is adequate for the detection of single corona pulses of approximately 10^{-11} coulombs per pulse. With some modification, the method could be implemented to provide on-line continual corona monitoring of magnet coils during acceleration.

Introduction

In the past few years, two main ring octants at the ZGS have suffered catastrophic turn-to-turn faults. To avoid such occurrences or at least predict their imminence, it was desirable to determine the onset voltage of turn-to-turn corona. A number of investigations had yielded virtually nothing as far as a technique for detecting turn-to-turn corona, although coil-to-ground corona is easily seen.

Experimental Procedure

Initially a corona generator was set up and corona pulses were photographed. A good photograph of the corona pulse was selected and the waveform carefully measured. This waveform was approximated by a sum of exponentials to give an approximate function of time. The absolute magnitude of the Fourier transform of this approximate function was determined to provide the amplitude density spectrum. It was apparent that frequencies of interest were in the range of 1 - 10 Mc.

Next the ZGS test fixture was excited from a variable frequency current source connected between turns 8 and 16 on one end. The ZGS test fixture is a magnet physically and electrically equivalent to one-half of a main ring octant. The response was measured between turns 8 and 16 on the other end. It was apparent that there was a peak in transmission at approximately 6 Mc, and several other well-known resonances were evident.

From the results of these tests the decision was made to look for noise generated by corona pulses by using a sensitive detector at 6 Mc. For a detector a Collins Communication Receiver was selected which had a sensitivity of approximately 5 μV. The signal between turns 8 and 16 on one end of the test fixture was the input to a high pass filter and the output of the high pass filter was connected to the antenna input of the Collins. The 500 kc IF output of the Collins was detected, filtered, and connected to the input of a counter. On the other end of the test fixture turns 8 and 16 were ac coupled to a 3.9 kΩ resistor in series with a pair of corona electrodes. These electrodes were excited from 60 cycles. The corona pulses were easily detected and a considerable amount of time was spent investigating corona pulse rate as a function of exciting voltage, receiver frequency, rf gain, etc. A curve of corona pulse rate versus exciting voltage is shown in Fig. 1.

A 15 kVA audio power amplifier was connected to the terminals of the test fixture coil, and the center tap ground strap was lifted. Test fixture coil impedance was measured as a function of frequency at low voltage (~ 100 V). It was found that |Z| rose from 38 Ω at 200 cycles to 175 Ω at 7.5 kc and then fell off. The impedance was always reactive - no shunt resonance was observed under 10 kc.

The voltage applied to the test fixture terminals was raised while observing the count rate of the corona detector which was still connected

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between turns 8 and 16. With approximately 650 V at 7.5 kc, a noise threshold was encountered similar to the effect in Fig. 1. This threshold was abrupt and repeatable, and resembled corona noise as generated by the corona electrodes except that it was stronger. Considerable time was spent examining this noise threshold which seemed relatively independent of exciting frequency down to 2 kc. Curves of noise rate versus voltage were run resembling Fig. 1.

In an effort to isolate the source of corona noise, the leads from the output transformer of the power amplifier were removed and the corona detector system was connected directly to the transformer with an attenuator. No corona noise was seen up to 1000 V. Some uncertainty remains, however, as to whether or not the output transformer is corona free, and further investigation is warranted.

The power amplifier was reconnected to the test fixture and the detector was ac coupled to turns 8 and 16. With the entire coil-output transformer combination floating, a ground strap was tied to various turns and the corona threshold examined. It appears that the corona threshold varies with ground strap connection. The implication is that some or all of the corona was from coil to ground rather than across a layer.

Conclusions

1) Individual corona pulses can be detected when transmitted through the test fixture by using a communications receiver or instrument of comparable sensitivity tuned to an appropriate frequency.

2) The power amplifier itself and output transformer are corona free up to 1000 V. Some small doubt exists here and further investigation is warranted.

3) There is apparently corona in the test fixture at approximately 600 V. The threshold voltage appears to be frequency independent. Some or all appears to be from coil to magnet iron.

4) In order to extend this corona detection technique to the main ring octants, a floating octant could be excited from a current source and transmission measured as a function of frequency. The corona detector consisting of high pass filter, Collins, detector, filter, and counter could then be connected across a layer and tuned to an appropriate frequency.

5) There is no reason why an octant cannot be examined for corona while being ramped by the RMPS. If a corona threshold exists at a voltage less than the exciting voltage from the RMPS this should be readily visible. If the detector were connected across a layer, corona pulses should be detectable anywhere within the octant. One could envision an on-line system to watch for corona during routine operation, perhaps involving one or two communications receivers adjacent to the ring with the detector output brought to the control room.

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