DETERMINATION OF FREQUENCY COEFFICIENTS FOR THERMAL VOLTAGE CONVERTERS AND DIGITAL VOLTMETERS BY COMPARISON TO INDUCTIVE VOLTAGE DIVIDERS

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Abstract

The Ac-dc Transfer Project at NIST is expanding the use of inductive voltage dividers (IVDs) for the calibration of high-voltage ranges of thermal voltage converters (TVCs) and digital voltmeters (DVMs). We report on a system to facilitate the comparison of the frequency coefficients between two ranges of TVCs or DVMs to the frequency coefficient of an IVD ratio.

Introduction

The higher voltage ranges of thermal voltage converters (TVCs) are commonly characterized by a range-to-range build-up technique. Our project is working on the expanded use of inductive voltage dividers (IVDs) for the calibration of high-voltage ranges of TVCs and digital voltmeters (DVMs).

Inductive dividers have very accurate ratios, but comparison of dividers to TVCs is a difficult task. We have previously made comparisons between the ratios of a binary inductive voltage divider and thermal voltage converters using the system we reported in [1]. Although the uncertainties obtained from that work were comparable to those from TVC build-ups, the system required to compare such a transformer device to an ac-dc transfer instrument was very complex and difficult to operate. In this paper, we describe a much simpler system to facilitate the comparison of the frequency coefficients of two ranges of TVCs, or DVMs, to the frequency coefficient of an IVD ratio.

Comparator System Design

The circuit for the Comparator System is shown in Figure 1. The voltage V_s is applied to the IVD so the voltage on the high potential terminal is V_{in}. The plane of reference for the high-voltage

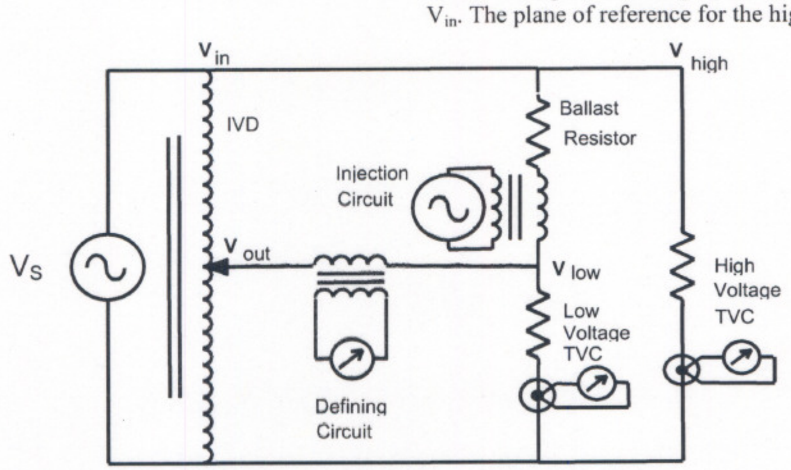

Figure 1. Diagram of comparator system.
The detectors on the outputs of the TVCs are digital nanovoltmeters.
The detector on the defining circuit is a lock-in amplifier.

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TVC is connected to the high potential terminal of the IVD. The voltage applied to the low-voltage TVC is matched to that at the IVD tap. Since the plane of reference for the high-voltage TVC is connected to the top of the inductive divider, we have $V_{high} = V_{in}$. The ballast resistor is chosen to bring V_{low} close to the low-voltage TVC operating voltage. Because it is difficult to provide a ballast resistor that matches the low-voltage TVC closely enough, fine adjustment to V_{low} is made by adjusting, in magnitude and phase, the voltage applied to the injection circuit [2,3]. The injection circuit and defining circuit are of similar construction with windings around a magnetic core that is itself linked by the inner conductor of the coaxial lead. A magnetic shield surrounds the core and winding. At higher voltages, the defining circuit can be made with a driven internal shield. The ac source for the injection circuit is phase locked to V_s. The detector for the defining circuit is a lock-in amplifier, also phase locked to the primary signal source. The sensitivity in the null detection at the defining circuit is better than 1×10^6.

A null in the defining circuit indicates that no current flows between V_{out} and V_{low}, so $V_{out} = V_{low}$. If the ratio of the divider at frequency i given as k_i, then $V_{out} = k_i V_{in}$, and therefore:

$$V_{low} = k_i \, V_{high}. \qquad (1)$$

The output emfs of the TVCs, and likewise the readings for DVMs under test, are monitored in the same manner as for ac-dc transfer difference calibrations. A relationship similar to equation (1) exists for each frequency tested. The frequency coefficients of the high-voltage TVC or DVM are determined in terms of those for the low-voltage unit by an ac-to-ac transfer. For example, 1 kHz and 100 kHz are applied in a timed sequence to determine the variation between those frequencies.

Comparator System Components

Previous work has concentrated on the use of binary inductive voltage dividers (BIVDs) with $k = 0.5$ due to the ability to accurately determine their ratio and to their broad bandwidth [4]. While this new system has been tested with such a 1000 V BIVD, it also is usable with dividers having arbitrary ratios making it possible to compare ranges of TVCs and DVMs over wide voltage ratios.

One reason IVDs have seen limited use at higher voltages is the lack of suitable signal sources with the right characteristics and sufficient power to supply these low-resistance, inductive loads. For this work a new, custom designed power amplifier has been built specifically to supply IVDs up to 1000 V and 100 kHz.

Data collection, frequency switching, and adjustment of amplitude and phase are automated. Measurements between test frequencies are taken in a timed sequence with the reference frequency interleaved with the higher frequency points. Preliminary measurements using this automated system indicate satisfactory performance.

References

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