WATT TRANSFER STANDARD

John D. Ramboz
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA
James L. West
Rotek Instrument Corp., Waltham, MA 02154 USA

Abstract

The use of a time-division multiplier power meter as a watt transfer standard between the National Institute of Standards and Technology (NIST) and an industry standards laboratory is described. Measurements of power at 120 and 240 volts, 5 amperes, 50 and 62 Hz and at power factors of 1 and 0 lagging are described. After the unit of power was transferred to the industrial laboratory, a comparison of the laboratory and NIST calibrations indicated an agreement to within 14 parts per million (ppm).

Introduction

Consumers, suppliers, and government regulators of electrical energy are paying increasing attention to cost. One of the consequences of this attention is the development and testing of more accurate meters for alternating current power and energy measurements. Another is the development of more efficient distribution equipment including transformers and reactors. Commercial revenue meters having specified uncertainties of 0.1% are now being advertised. The gradual replacement of the 1 - 2% induction meter by its more accurate solid state counterpart is beginning. In order to evaluate the performance of these meters, transformers, and reactors, accurate power measurements are required. There is a growing need to establish the unit of power in industrial standards laboratories with an uncertainty suitable for measuring such performance, i.e., to better than 100 ppm.

An accurate method of measuring alternating current power uses a current comparator power bridge which relates the power to the units of voltage and resistance. The standardization may be accomplished with respect to the national standards by well known methods.[1] However, the use of such special power bridges requires skill, is time consuming, and is usually done only at national laboratories. A wattmeter, or watt converter (i.e. a device producing a dc voltage output proportional to the ac power input) calibration, which can be traced easily to national standards, greatly simplifies the testing of these new alternating current wattmeters and low-loss distribution components.

The design of such a wattmeter was undertaken at the Institut Mihailo Pupin, Belgrade, Yugoslavia, and was described at the Conference on Precision Electromagnetic Measurements in 1984.[2] This type of meter was used in 1987 for an international comparison of power standards. The meter was able to verify that the alternating current power standards of Canada, the Federal Republic of Germany, the Institut Mihailo Pupin, and the United State agreed within 25 ppm.[3]

A recently commercialized version of the above described watt converter [see the note following the references] has ac voltage and current input terminals and dc voltage output terminals. In its commercialized form, the wattmeter has two input ac voltage ranges, 120 and 240 volts and four ac current ranges, 1, 5, 10, and 50 amperes. Using the ac input ranges of 120 volts and 5 amperes, the conversion constant is 10 volts dc output per 600 watts ac input (active) power. An accurate 7½-digit voltmeter can be used to read the dc output voltage. Its small size and light weight makes it convenient to transport.

This paper describes an experiment demonstrating that this type wattmeter can be used to accurately transfer the unit of power from a national laboratory to an industrial standards laboratory without the need for specialized equipment or knowledge.

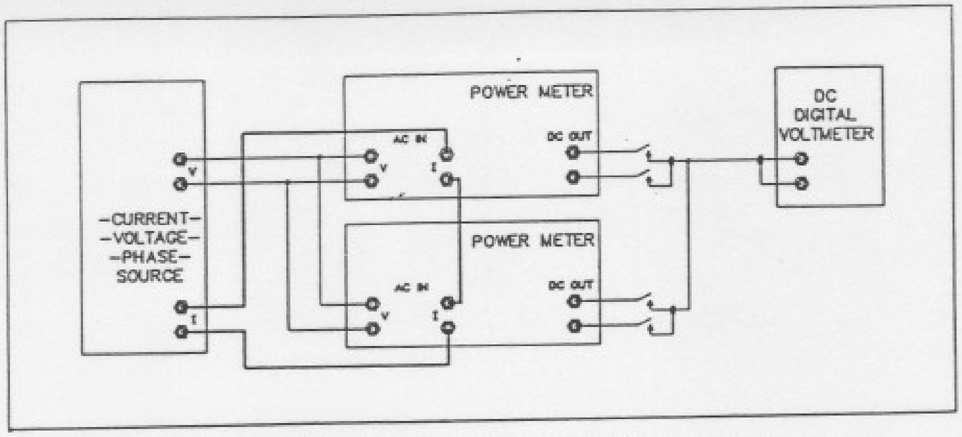
Procedure

In this experiment two wattmeters were used. The object of the experiment was not only to show that the meter is stable but also that the calibration can be transferred from one meter to another meter with ease. The first meter was sent to NIST for testing in September 1988. NIST reported corrections to the conversion constant at 120 volts, 5 amperes, 240 volts, 5 amperes, 50 and 62 hertz and 1 and 0 power factor lagging. This meter was used in January 1989 with its corrections in an industrial standards laboratory to determine corrections to the conversion constant of the second wattmeter. The second wattmeter was then sent to NIST for determination of the corrections to its conversion constant with respect to the national standards. The difference between the conversion constant as determined at the industrial standards laboratory and at NIST is a measure of the stability of the wattmeter and of its ability to be used as a transport standard. The elapsed time from the initial test of the first meter to the last test of the second meter was nine months.

The procedures for transferring the calibration from a reference wattmeter to a second uncalibrated wattmeter are simple. A stable source of ac voltage and current with adjustable power factor was applied simultaneously to the voltage and current inputs of the two watt converters. A digital voltmeter was used to measure the two wattmeter dc voltage outputs. The arrangement is shown in Figure 1. The difference between the two dc output voltages is corrected for the calibration of the standardized meter and the result is the correction to the conversion factor of the second meter.

Using the source referred to above, the measurement of the output of the wattmeters have a short term stability of a few parts per million over a 20 minute interval. The digital voltmeter averaging feature was used so that each measurement was the average of 10 readings at 3.2 second intervals. Further, the measurements were repeated on four successive days and the average of the four measurements was used as the correction for the wattmeter. The temperature of the standards laboratory was maintained within ±0.5°C during the tests. Since the measured temperature coefficient of the power meters is less than 2 ppm of apparent input power per degree Celsius, temperature variation in the laboratory had only a minor influence on the measurements.

For the procedures used by NIST to calibrate watt converters, the reader is referred to Reference [3] which has a description of the equipment used by the standards laboratories of Canada, the Federal Republic of Germany, the Institut Mihailo Pupin, and the United States for wattmeter testing.



Arrangement for comparing the calibrations of two alternating current power meters

Figure 1

Results

Table 1 compares the corrections in parts per million to the conversion constant at 5 different test points as determined in the industrial standards laboratory in January 1989 and as determined at NIST in June 1989. It can be seen that the maximum difference in the corrections for this nine month period to the conversion constant occurred for an input of 120 volts, 5 amperes, unity power factor and at 62 hertz, and was 14 ppm.

It should be again noted that these results are measures of the stability of the two meters used over the period of the tests as well as of the random errors of the measurements at NIST and the industrial laboratory. In a transfer standard, one looks for good long-term stability. These data do not include the systematic uncertainty of the NIST calibrations since it is the same in both sets of measurements at NIST and hence does not affect the 'difference in calibration corrections' shown in Table 1.

Test Conditions	Industrial Standards Laboratory Calibration Corrections (ppm)	NIST Calibration Corrections (ppm)	Difference in Calib. Corrections (ppm)
50 Hz 120 V 5 A 1 PF	-14	-8	-6
62 Hz 120 V 5 A 1 PF	-24	-10	-14
62 Hz 120 V 5 A 0 PF Lag	-1	-10	+9
62 Hz 240 V 5 A 1 PF	-42	-42	0
62 Hz 240 V 5 A 0 PF Lag	-6	-7	+1

TABLE 1

Comparison between the calibration correction in parts per million of watt converter conversion constant as determined at an industrial standards laboratory and at the National Institute of Standards and Technology.

References

[1] N. M. Oldham, O. Petersons, B. C. Waltrip, "Audio-Frequency Current Comparator Power Bridge: Development and Design Considerations", IEEE Trans. Instr. and Meas., Vol.38, No. 2, pp. 390-394, April 1989.

[2] P. Miljanic, B. Stojanovic and P. Bosnjakovic, "The Development of a High Precision Time-Division Power Meter", in Proc. Conf. Prec. Electromagn. Meas., pp. 67-68, Aug. 1984.

[3] W.J.M. Moore, E. So, N. M. Oldham, P. N. Miljanic, and R. Bergeest, "An International Comparison of Power Meter Calibrations Conducted in 1987", IEEE Trans. Instr. and Meas., Vol. 38, No. 2, pp. 395-401, April 1989.