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R. Carranza[1], S. Campos[1], A. Castruita[1], T. Nelson[2], A. Ribeiro[3], E. So[4], L. Di Lillo[5], A. Spaggiari[6], H. Postigo[7], H. Sanchez[8], J. Gonzalez[9] and G. Porras[10]

[1]Centro Nacional de Metrología México, rene.carranza@cenam.mx; [2]National Institute of Standards and Technology, USA; [3]Instituto Nacional de Metrologia, Qualidade e Tecnologia, Brazil; [4]National Research Council of Canada; [5]Instituto Nacional de Tecnología Industrial, Argentina; [6]Administración Nacional de Usinas y Transmisiones Eléctricas, Uruguay; [7]Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual, Perú; [8]Instituto Costarricense de Electricidad, Costa Rica; [9]Centro Nacional de Metrología de Panamá, Panamá; [10]Instituto Nacional de Metrología de Colombia, Colombia

Abstract — **From years 2010 to 2012, a key comparison of power standards at 50/60 Hz was conducted in the SIM region. The comparison included measurements of active and reactive power at three frequencies, aiming at providing support to high accuracy measurement needs of reactive power. This paper presents the results of the SIM.EM-K5 comparison and the assessment of the link between this comparison and the CCEM-K5 key comparison on 50/60 Hz power completed in 2001.**

Index Terms — **Key comparison, power measurement standards, linear regression fitting, reproducibility, uncertainty.**

I. Introduction

Under the auspices of the Committee Consultative of Electromagnetism, CCEM, the SIM Electromagnetic Working Group carried out a key comparison of power standards at 50/60 Hz. CENAM participated as the pilot laboratory. The SIM.EM-K5 comparison aimed at providing a link to various NMIs in the SIM region to the CCEM-K5 key comparison on 50/60 Hz power conducted by NIST and completed in year 2001[1].

The comparison was organized according to the Guidelines of the CCEM [2]. Testing points included measurements of active and reactive power at frequencies of 50 Hz, 53 Hz and 60 Hz. Measurements of reactive power in this comparison are a meaningful tie for the SIM participating laboratories to the key comparison data base of the CIPM, besides providing support to high accuracy reactive power meters already available everywhere.

A link between the results of the SIM.EM-K5 and the CCEM-K5 key comparisons was carried out by CENAM [3]. It is based on the work of F. Delahaye and T. Witt [4]. The link laboratories participating in both comparisons accepted that their measurement results were used to estimate the link between the two comparisons, which consists of a correction to be added to the results of the SIM.EM-K5 comparison so that the transformed results can be directly compared with the CCEM-K5 comparison results. The analysis confirms that the link between the two comparisons is reliable.

II. Overview of the SIM.EM-K5 Key Comparison

In order to meet the schedule time the comparison was organized in two loops, $j = 1, 2$. A Radian RD-22-311 and a RD-23-432 were used as traveling reference standards for loops $j = 1$ and 2, respectively. Traveling measurement standards for the SIM.EM-K5 key comparison were provided by Radian Research Inc[1].

The testing points in the comparison were 120 V, 5 A at power factors of 1.0 and 0.5 lead-lag for active power, and 30° and 90° lead-lag for reactive power measurements. Tests were conducted at three frequencies: 50 Hz, 53 Hz and 60 Hz. The total number of testing points was 21. Aiming to establish a link between this SIM.EM-K5 key comparison and the last key comparison CCEM-K conducted by NIST [1], the SIM comparison included the testing points of active power at 120 V, 5 A at power factors of 1 and 0.5 lead-lag and a frequency of 53 Hz.

Eleven national metrology institutes from the SIM region were originally included in the comparison. The Laboratorio Custodio del Patrón Nacional de Magnitudes Eléctricas, LCPN from Chile did not submit its measurement results for this comparison, thus this NMI was not considered in estimating the key comparison reference value.

The comparison was arranged in two independent loops in a daisy pattern. Measurements of the participating laboratories started in June 2010 and ended in April 2011. The performance of the reference standards for loops $j = 1$ and 2 was determined by applying a lineal regression model to measurements carried out by CENAM from December 2009 up to April 2012.

III. Main Results from the Comparison

The work of N. Oldham *et al* [1] was followed in order to estimate the key comparison reference value (KCRV), the formula to obtain the degrees of equivalence and the uncertainty associated to them. The linear regression fitting on the measurements carried out by CENAM as the pilot laboratory provides a robust estimate of the key comparison reference value. The fitting also allows estimating the predicted values of measurement results of the participating laboratories. The main contribution to the uncertainty of the

[1] Reference is made throughout this abstract to different trademarks, without implying that the authors recommend them.

KCRV comes from the residuals of the approximated linear regression curve and the correlation between the predictions of the measurement results of the participating laboratories with respect of the estimated KCRV.

A link between the results of the SIM.EM-K5 and the CCEM-K5 key comparisons of power was carried out. The following laboratories were the link between the SIM.EM-K5 and the CCEM-K5 comparisons: NIST, NRC, INTI, INMETRO, UTE and CENAM. The link basically consists of an additive correction to the results of the SIM.EM-K5 comparison so that the transformed results can be directly compared with the results of the CCEM.K5 comparison, where the additive correction is determined by a weighted mean of the corresponding differences of the linking laboratories. This criterion is applicable since the CCEM-K5 and SIM.EM-K5 are of the same quantity of active power at 120 V, 5 A, 53 Hz and power factors equal to 1 and 0.5 lead-lag. This procedure does not change the CCEM-K5 key comparison reference value. From this link the degrees of equivalence DOEs are calculated and reported in [3]. A test of internal and external consistency [5] was applied to the link measurement results, where the main concern was the "reproducibility" of the measurement results over the time span between the two comparisons. The consistency tests yielded a Birge ratio lower than one in the three power factors where the link of the two comparisons is applicable, thus confirming the reliability of the link.

The measurement results of the SIM.EM-K5 key comparison will be presented at the CPEM 2014.

IV. Conclusion

A key comparison of 50 Hz to 60 Hz was carried out in the SIM region within years 2010 and 2012. The comparison included measurements of active power, thus it may be linked to the last CCEM-K5 key comparison of 50/60 Hz power conducted by NIST and ended in year 2001. The SIM.EM-K5 comparison also included measurements of reactive power, as a meaningful support for providing traceability to low uncertainty reactive power standards.

From the measurement results of some of the participating laboratories of the SIM.EM-K5 comparison a link with the previous CCEM-K5 was determined. From the assessment of the link it may be said that the measurement results of the SIM.EM-K5 and the CCEM-K5 key comparisons of power are properly linked.

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