# Comparison of LF Power

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***Abstract* — Electrical standards of low-frequency (53 Hz) power at three laboratories were compared to establish the relationship between the electrical units. The results of this comparison are described. The differences between each laboratory's values and the reference values were within the measurement expanded uncertainties at a coverage factor *k*=2.**

## I. Introduction

A limited number of laboratories in the Netherlands has the capability to calibrate LF Power following the ISO/IEC 17025 standard. Three of those laboratories organized this comparison to ensure their capability on LF Power. Yokogawa Europe Solution B.V. was selected as the *pilot laboratory*, which is responsible for providing the traveling standard, coordinating the schedule, collecting and analyzing the comparison data, and preparing the report.

## II. PARTICIPANTS

Three laboratories are participating in this comparison, all situated in the Netherlands.

**Table 1. List of Participants**

| Laboratory | Location | RvA Registration |
|---|---|---|
| Yokogawa Europe Solutions B.V. | Amersfoort | K164 |
| Centrale IJkinrichting Borculo B.V. | Borculo | K061 |
| KEMA B.V | Arnhem | K006 |

First measurements started at 15 June 2020 and comparison was completed at 27 July 2020.

## III. Traveling Standard

A transfer standard is needed with good stability for power during the comparison. The used standard is a Yokogawa WT5000T Precision Power Analyzer. This selected standard is owned by the European Standards Laboratory and used for comparisons and crosschecks exclusive. Hence, the behavior and stability are well known. On purpose, this transfer standard was given a deviation from nominal on power. This to avoid guessing the measurement results. During the comparison the stability of the transfer standard is essential. That is the basis of the comparison. Therefore, the pilot laboratory has measured the traveling standard by the start and the closure of the comparison. The average stability of the traveling standard was +16 ppm with a maximum of +24 ppm. The stability of the traveling standard was adequate for this comparison

## IV. Comparison

### *A. Testpoints*

After consultation with the other laboratories the pilot lab decided to perform the comparison at 100 V, 1 A, 53 Hz, at 1.0, 0.8, 0.5, and 0.0 power factors (pf) inductive. And 100 V, 5 A, 53 Hz, at 1.0, 0.8, 0.5, and 0.0 power factors (pf) capacitive. These test points are mostly within the scope of calibration for each participating laboratory.

*B. Reference value*

The reference value is based on the weighted average of the four measurement results. The start and closure measurements of the pilot laboratory, and the other two participants. This given by the next formula:

$$\bar{x} = \frac{\sum_{i=1}^{n} g_i x_i}{\sum_{i=1}^{n} g_i}$$

The weighing is based on the expanded measurement uncertainty, given by each laboratory.

*C. En factor*

From the results, for each laboratory the $|E_n|$ factor is calculated to the reference value by:

$$E_n = \left| \frac{x_i - X_{ref}}{\sqrt{U^2{}_{lab,i} + U^2{}_{ref}}} \right|$$

The qualification of the results is the following:

$|E_n| \leq 1$ Satisfactory result

$|E_n| > 1$ Unsatisfactory result

*D. Results*

For the results of the pilot laboratory the average is taken from the start and closure measurements.

**Table 2. Results 100 V, 1 A, 53 Hz pf = 1**

| 100V 1A PF 1 | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 100.043 | 0.007 | |
| CIJ Borculo | 100.036 | 0.037 | 0.20 |
| KEMA | 100.025 | 0.020 | 0.85 |
| Yokogawa | 100.047 | 0.004 | 0.39 |

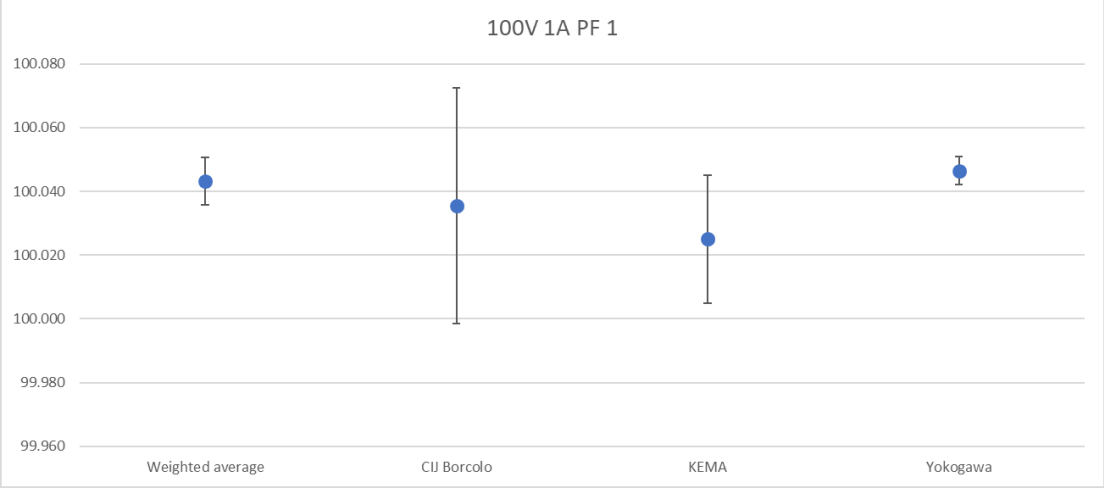


**Table 3. Results 100 V, 1 A, 53 Hz pf = 0.8 Inductive**

| 100V 1A PF 0.8 Ind | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 80.034 | 0.017 | |
| CIJ Borculo | 80.029 | 0.037 | 0.13 |
| KEMA | 80.030 | 0.020 | 0.15 |
| Yokogawa | 80.037 | 0.013 | 0.15 |

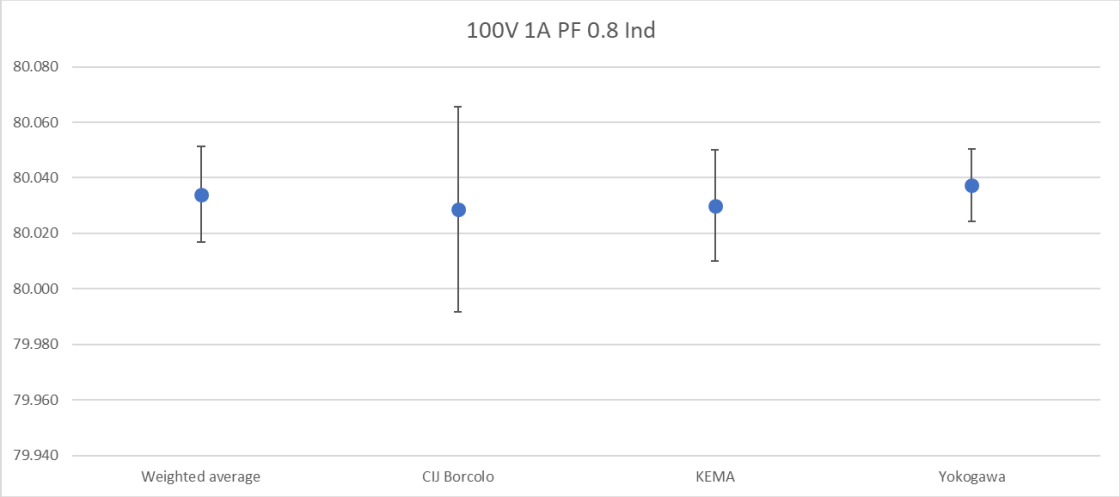



**Table 4. Results 100 V, 1 A, 53 Hz pf = 0.5 Inductive**

| 100V 1A PF 0.5 Ind | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 50.021 | 0.021 | |
| CIJ Borculo | 50.019 | 0.037 | 0.05 |
| KEMA | 50.020 | 0.020 | 0.05 |
| Yokogawa | 50.023 | 0.018 | 0.06 |

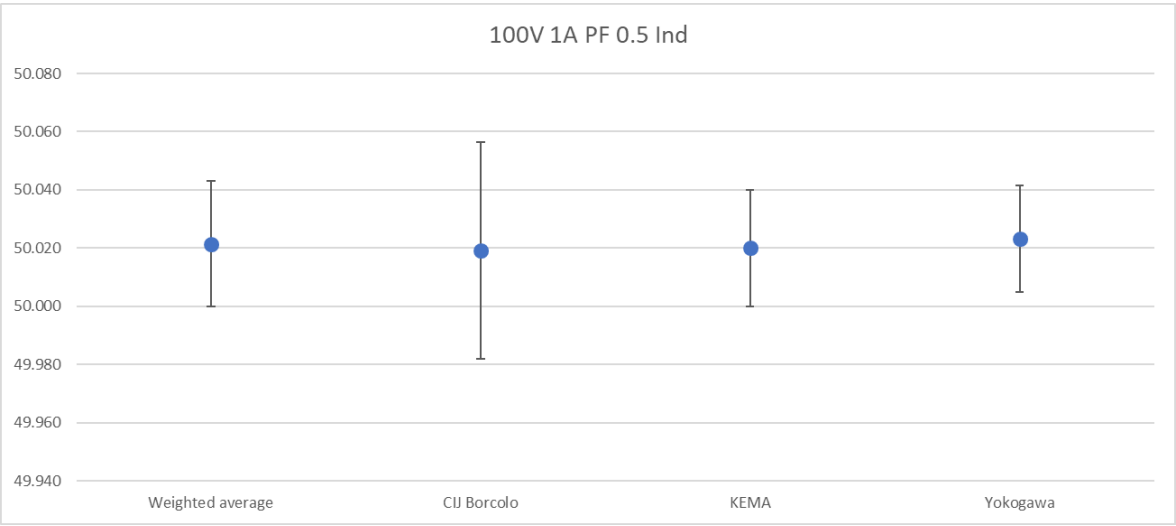


**Table 5. Results 100 V, 1 A, 53 Hz pf = 0.0 Inductive**

| 100V 1A PF 0.0 Ind | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 0.000 | 0.023 | |
| CIJ Borculo | -0.001 | 0.038 | 0.02 |
| KEMA | 0.002 | 0.020 | 0.05 |
| Yokogawa | 0.000 | 0.021 | 0.01 |

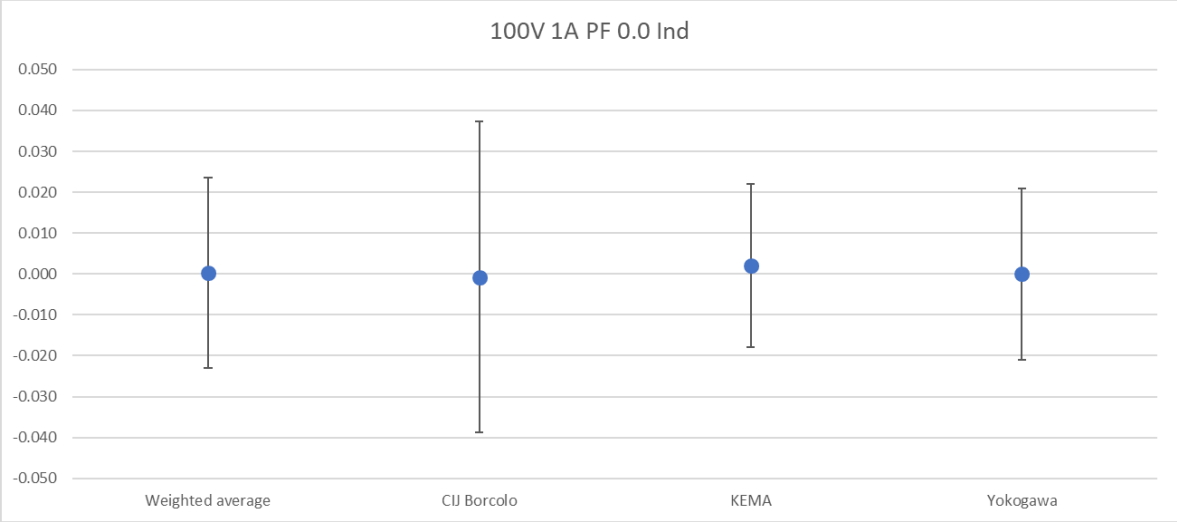



**Table 6. Results 100 V, 5 A, 53 Hz pf = 1.0**

| 100V 5A PF 1 | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 500.138 | 0.037 | |
| CIJ Borculo | 500.10 | 0.18 | 0.20 |
| KEMA | 500.15 | 0.10 | 0.12 |
| Yokogawa | 500.141 | 0.022 | 0.09 |

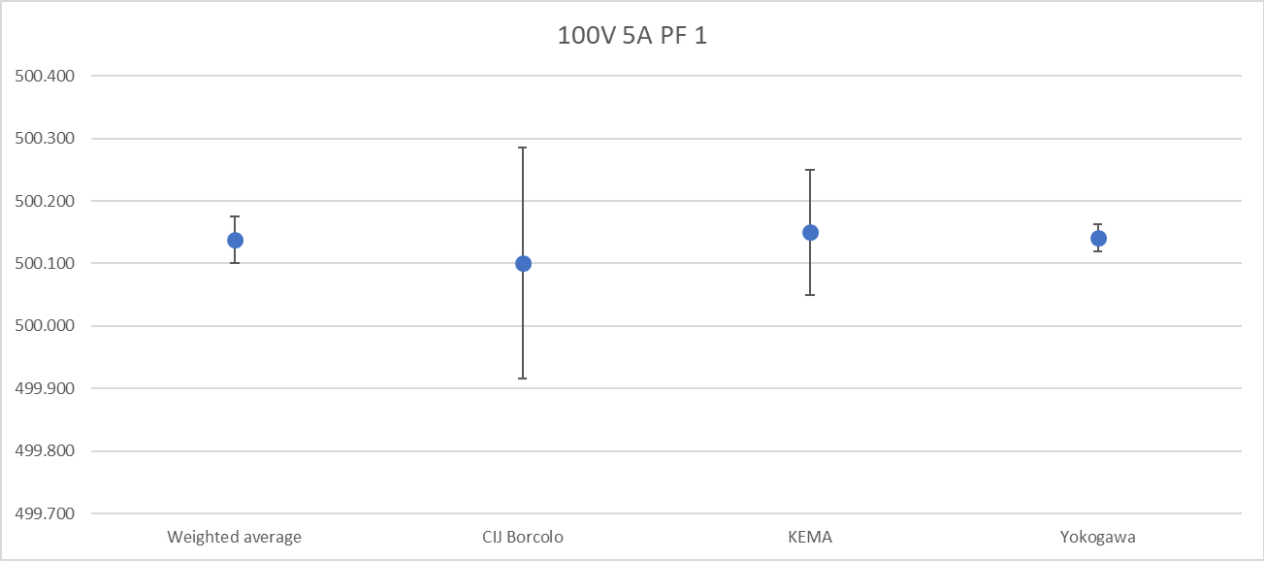


**Table 6. Results 100 V, 5 A, 53 Hz pf = 0.8 Capacitive**

| 100V 5A PF 0.8 cap | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 400.108 | 0.034 | |
| CIJ Borculo | 400.04 | 0.18 | 0.35 |
| KEMA | 400.13 | 0.10 | 0.21 |
| Yokogawa | 400.111 | 0.019 | 0.09 |

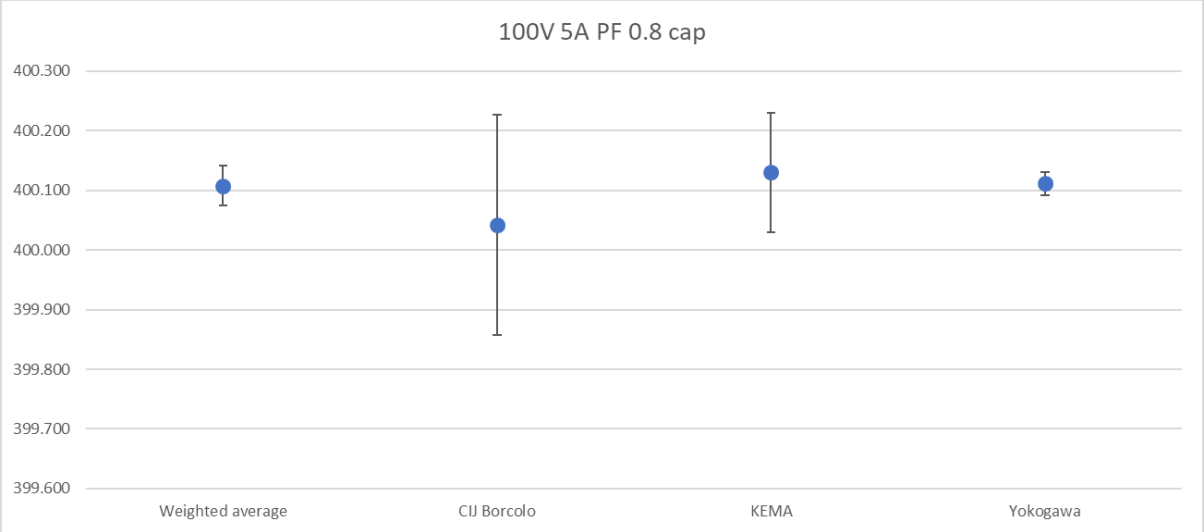



**Table 7. Results 100 V, 5 A, 53 Hz pf = 0.5 Capacitive**

| 100V 5A PF 0.5 cap | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | 250.068 | 0.029 | |
| CIJ Borculo | 250.05 | 0.19 | 0.09 |
| KEMA | 250.09 | 0.10 | 0.22 |
| Yokogawa | 250.068 | 0.016 | 0.01 |

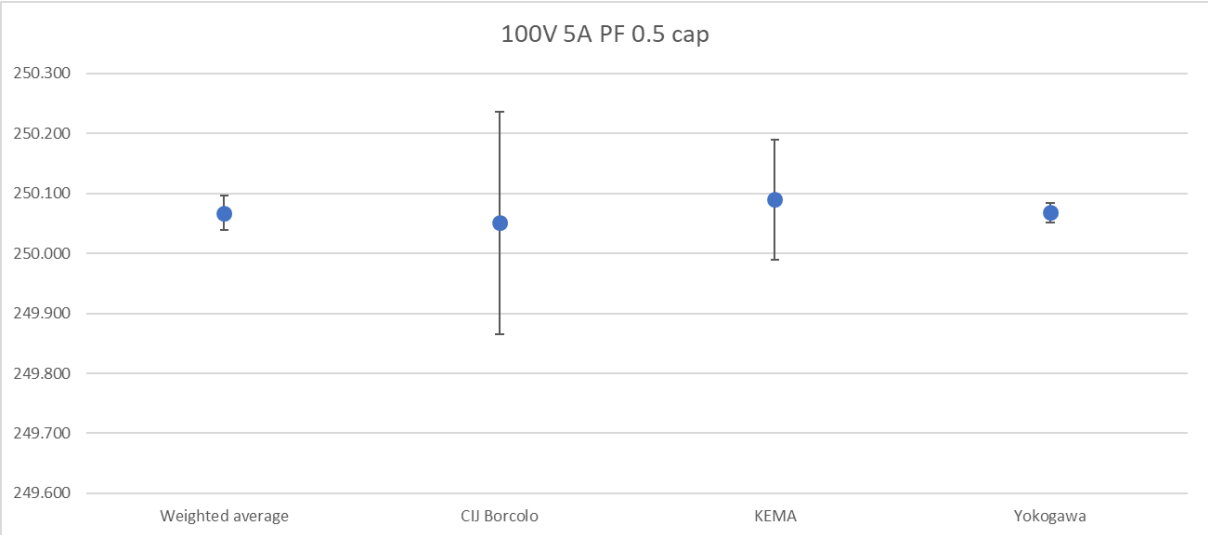
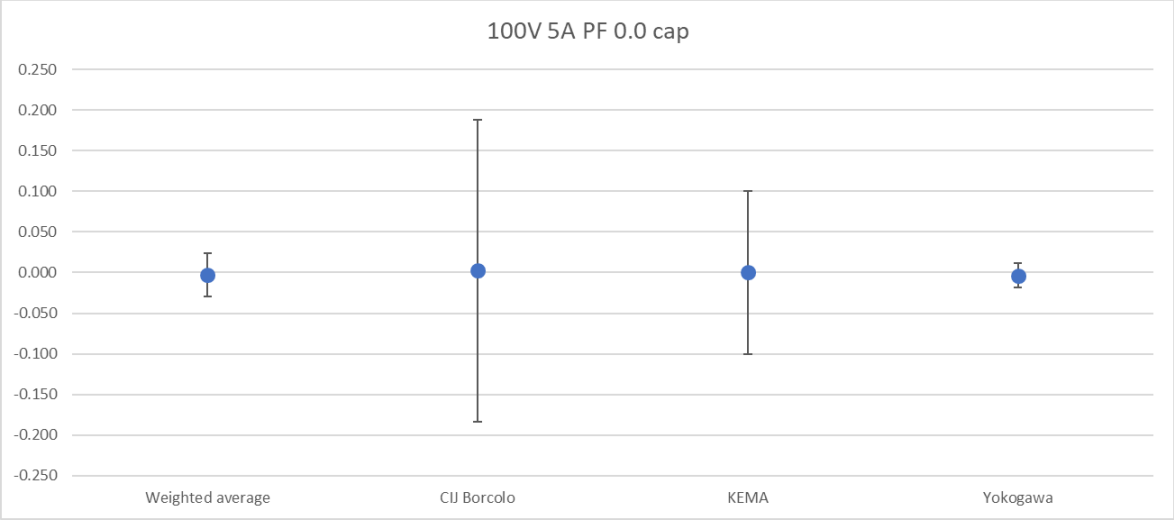


**Table 7. Results 100 V, 5 A, 53 Hz pf = 0.0 Capacitive**

| 100V 5A PF 0.0 cap | Measured value [W] | unc k=2 [W] | ABS En |
|---|---|---|---|
| Weighted average | -0.003 | 0.027 | |
| CIJ Borculo | 0.00 | 0.19 | 0.03 |
| KEMA | 0.00 | 0.10 | 0.03 |
| Yokogawa | -0.004 | 0.015 | 0.02 |




## V. Conclusion

All measurement agrees with the reference value for the expanded measurement uncertainty. The stability of the traveling standard was adequate for this comparison. The comparison is a success and can be used to for fill
EN-ISO/IEC 17025:2017 § 7.2.2.1e, § 7.7.2