**PERFORMANCE VALIDATION OF LCR METER CALIBRATION: INDUCTANCE PARAMETERS BEFORE AND AFTER RECALIBRATION**

***Validasi Unjuk Kerja Kalibrasi Lcr Meter : Parameter Induktansi Sebelum Dan Sesudah Rekalibrasi***

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**ABSTRACT**

Electrical Laboratory of National Measurement Standards – National Standardization Agency of Indonesia (Lab SNSU – BSN) has validated the measurement results before and after the LCR meter recalibration process on inductance parameters. The validation process was carried out at nominal values of 100 μH, 1 mH, 10 mH, 100 mH and 1 H in accordance to the reference standards. The direct measurement method was used to measure the inductance parameter of LCR meter with standard inductor. Validation is carried out by comparing the measurement results before and after the LCR meter recalibration process at SCL - Hong Kong. Based on the *En* number analysis, the values between -0.21 to 0.44 were obtained for all measurement points, therefore the calibration system and method used by the Lab SNSU – BSN are valid and have measurement results that are equivalent to other countries.

**Keywords:** Lab SNSU – BSN,LCR meter, inductance, validation, standard inductor, *En* number

**ABSTRAK**

Laboratorium Kelistrikan dan Waktu SNSU - BSN (Lab SNSU-BSN) telah melakukan validasi hasil pengukuran sebelum dan sesudah proses rekalibrasi LCR Meter pada parameter induktansi. Proses validasi dilakukan pada nominal 100 μH hingga 1 H sesuai dengan standar acuan yang dimiliki. Metode pengukuran yang digunakan metode pengukuran langsung dimana LCR Meter parameter induktasi diukur dengan menggunakan standar induktor. Validasi dilakukan dengan membandingkan hasil pengukuran yang dilakukan di Lab SNSU – BSN dan hasil rekalibrasi dari SCL – Hongkong. Berdasarkan analisis En number, diperoleh nilai antara 0,44 sampai -0,21 untuk semua titik pengukuran, sehingga dapat disimpulkan bahwa sistem dan metode yang digunakan Lab SNSU–BSN untuk mengalibrasi LCR Meter telah valid dan setara dengan negara lain.

**Kata kunci**: Lab SNSU – BSN,LCR meter, Induktansi, Validasi, Induktor standar, *En* number

1. **INTRODUCTION**

LCR meter is an electronic device that can be used to characterize the material properties or passive component with wide frequency range using certain voltage signal or test current. LCR meter is available on analog or digital (Khoza, 2015).

Electrical Laboratory of National Measurement Standards – National Standardization Agency of Indonesia (Lab SNSU – BSN) has developed calibration system for LCR meter on inductance, capacitance and resistance parameters. The Calibration and Measurement Capability (CMC) at the frequency of 1 kHz for inductance parameter is within the range from 100 μH to 10 H, for capacitance parameter is within the range from 1 pF to 1 μF and for resistance parameter is within the range from 1 Ω to 10 kΩ.

LCR meter is recalibrated periodically every 5 year to other NMI (National Metrology Institute) to maintain the performance and traceability. The calibration process involved high accuracy impedance standards which are connected directly to LCR meter then the error of LCR meter is calculated from the deviation between measured value and reference value (Overney, 2017).

This research is conducted to validate the calibration system for LCR meter on inductance parameter using direct method by comparing the measurement results before and after the LCR meter recalibration process at SCL - Hong Kong. The validation is based on *En* number from the comparison between measurement result by Lab SNSU – BSN and calibration result by SCL Hongkong which should be within the value of -1 and 1 (Sutanto et al., 2016).

1. **LITERATURE REVIEW**

**2.1 LCR meter**

LCR meter is an instrument used for measuring impedance parameters (inductance, capacitance and resistance) of a component. It is appropriate as a transfer standard since its linearity attribute (Waltrip et al., 2005).

**2.2 Standard Inductor**

Standard inductor used as a reference for inductance parameter is General Radio GR-1482, which has toroidal winding on a ceramic core, submerged in combined ground cork and silica gel inside an aluminum shell. It has high stability (±100 ppm/year) and low thermal coefficient (30 ppm/°C) features. (Callegaro et al., 2006 and IET Lab Inc., 2018).

**2.3 Direct Method**

Direct method is used for inductance measurement of LCR meter by comparing with standard inductor as reference. This method is implemented when a measurement system consist of two instruments (source and meter) is connected directly (Khairiyati et al., 2017). Mathematical model of LCR meter measurement for inductance parameter is shown in Equation 1.

where :

: correction of LCR Meter indication.

: inductance value of standard inductor.

: drift of standard inductor.

: temperature coefficient of standard inductor.

: frequency coefficient of standard inductor.

: average value of LCR meter reading.

: resolution of LCR meter.

Contribution to uncertainty budget of inductance measurement was coming from standard inductor, LCR meter and environmental condition.

**2.4 Validation**

Validation process is performed by calculating reference value as linear interpolation between first measurement (before recalibration) and second measurement (after recalibration) with consideration to the measurement date. Expresion of the reference value and uncertainty are shown in Equation 2 and Equation 3 respectively.

where:

: reference value of LCR Meter.

: correction value of LCR Meter before recalibration.

: correction value of LCR Meter after recalibration.

: recalibration date at SCL – Hongkong.

: measurement date before recalibration.

: measurement date after recalibration

where :

: uncertainty of reference value of LCR Meter.

: uncertainty LCR meter before recalibration.

: uncertainty of LCR meter after recalibration.

. : coefficient of correlation between and determined as 1 (Blanc, 2014).

Equation 3 is used to analyze reference value which later be used as validation to recalibration value. Evaluation of measurement result and validation of LCR meter calibration system were analyzed using En calculation (Yayienda et al., 2017). The formula of En number calculation is shown in Equation 4.

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where :

: correction value obtained from recalibration result at SCL - Hongkong.

: correction value obtained from measurement conducted by Lab SNSU – BSN.

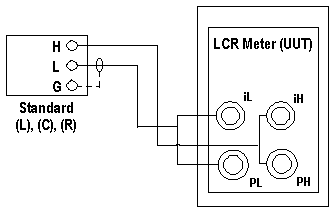
: uncertainty value obtained from recalibration result at SCL - Hongkong.

: uncertainty value obtained from measurement

conducted by Lab SNSU – BSN.

1. **METHOD**

Method used for validation of inductance measurement of LCR meter was direct method using standard inductor as reference. Standard inductor was traceable to KRISS – Korea on 2015. The schematic diagram of inductance measurement is shown in Figure 1.



**Figure 1. Inductance Measurement of LCR Meter**

Inductance parameter of LCR Meter was calibrated using standard inductor with 3-wire connection. Considering the measurement range, this connection was effective to acquire precision result.

The room temperature and humidity was conditioned about (23 ± 3)°C and <75%RH, then LCR Meter was powered on about 30 minutes to stabilize. After that, zeroing process executed using open and short procedure to eliminate the error from the cable and device. During zeroing, correction was calculated and saved in memory and then applied on measurement (IET Lab Inc., 2014).

The measurement settings of LCR Meter were frequency at 1 kHz, voltage at 1 V, slow accuracy and zero DC bias voltage off. Measurement was taken five times for each nominal of 100 μH, 1 mH, 10 mH, 100 mH and 1 H.

1. **RESULT AND DISCUSSION**

The recalibration at SCL - Hongkong was performed on September 2020. Measurement at Lab SNSU - BSN was conducted before recalibration on June 2020 and after recalibration on February 2021 with similar environtmental condition to obtain consistency and quality of the result.

The correction and uncertainty measurement of LCR meter was calculated using Equation 1. The measurement result before and after recalibration is shown in Table 1 and Table 2, respectively. Table 3 shown the recalibration result at SCL – Hongkong obtained from the calibration certificate.

**Table 1. Measurement result of LCR meter before recalibration**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| LCR Meter | | | Measured Correction | | | | |
| Measurement Mode | Meter Reading | | Value y | | Measurement Uncertainty | | |
| Expanded Measurement Uncertainty | | Coverage Factor |
| Ls | 100.0388 | μH | -0.070 | μH | 0.017 | μH | 2 |
| 0.99934 | mH | 0.00030 | mH | 0.00013 | mH | 2 |
| 9.9916 | mH | 0.0050 | mH | 0.0013 | mH | 2 |
| 99.999 | mH | 0.015 | mH | 0.013 | mH | 2 |
| 1.002673 | H | -0.000003 | H | 0.00013 | H | 2 |

**Table 2. Measurement result of LCR meter after recalibration**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| LCR Meter | | | Measured Correction | | | | |
| Measurement Mode | Meter Reading | | Value y | | Measurement Uncertainty | | |
| Expanded Measurement Uncertainty | | Coverage Factor |
| Ls | 100.039 | μH | -0.0708 | μH | 0.017 | μH | 2 |
| 0,99934 | mH | 0.00030 | mH | 0.00013 | mH | 2 |
| 9,99161 | mH | 0,0050 | mH | 0.0013 | mH | 2 |
| 99,9985 | mH | 0.015 | mH | 0.013 | mH | 2 |
| 1.00267 | H | -0.00002 | H | 0.00013 | H | 2 |

**Table 3. Recalibration result of LCR meter**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| LCR Meter | | | Measured Correction | | | | |
| Measurement Mode | Meter Reading | | Value y | | Measurement Uncertainty | | |
| Expanded Measurement Uncertainty | | Coverage Factor |
| Ls | 100.14 | μH | -0.06 | μH | 0.03 | μH | 2 |
| 1.00104 | mH | 0.00029 | mH | 0.00016 | mH | 2 |
| 10.0002 | mH | 0.0049 | mH | 0.0010 | mH | 2 |
| 100.040 | mH | 0.012 | mH | 0.010 | mH | 2 |
| 1.00074 | H | -0.00003 | H | 0.00011 | H | 2 |

The correction and uncertainty values of each nominal then plotted to show the correlation of these three data, as shown in Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6.

**Figure 2. Measurement and recalibration results of LCR meter at nominal of 100 μH**

**Figure 3. Measurement and recalibration results of LCR meter at nominal of 1 mH**

**Figure 4. Measurement and recalibration results of LCR meter at nominal of 10 mH**

**Figure 5. Measurement and recalibration results of LCR meter at nominal of 100 mH**

**Figure 6. Measurement and recalibration results of LCR meter at nominal of 1 H**

Based on Figure 2 – 6, the measurement results before and after recalibration were consistent with recalibration result. The reference value, its uncertainty value and En number were calculated using Equation 2, Equation 3 and Equation 4, respectively and shown in Table 4.

**Table 4. Comparison between measurement result at Lab SNSU BSN and recalibration result at SCL - Hongkong**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Nominal | Lab SNSU – BSN | | SCL - Hongkong | | Satuan | *Normalized error*  En |
| Koreksi | Ketidakpastian | Koreksi | Ketidakpastian |
| 100 | -0,070 | 0,023 | -0,060 | 0,030 | µH | 0,44 |
| 1 | 0,00025 | 0,00014 | 0,00029 | 0,00016 | mH | 0,17 |
| 10 | 0,0050 | 0,0012 | 0,0049 | 0,0010 | mH | -0,065 |
| 100 | 0,015 | 0,013 | 0,012 | 0,010 | mH | -0,21 |
| 1 | -0,00001 | 0,00013 | -0,000030 | 0,00011 | H | -0,12 |

The En numbers for all inductance nominal were ranged within -0.21 to 0.44 which can be concluded that measurement performed by Lab SNSU – BSN were valid and equivalent to recalibration performed by SCL – Hongkong.

1. **CONCLUSION**

Validation process of direct measurement method for inductance parameter of LCR Meter has been realized. The measurement results before and after recalibration conducted by Lab SNSU - BSN were equal to recalibration process at SCL – Hongkong based on En number calculation. The system and method for LCR Meter calibration are valid and in good agreement to other countries.

1. **ACKNOWLEDGEMENT**

All authors are the main contributor for this article. The authors would like to thank Deputy for National Measurement Standards – National Standardization Agency of Indonesia which has facilitated this research and recalibration process of LCR Meter.

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