INDUCTANCE VALIDATION OF LCR METER AFTER RECALIBRATION

VALIDASI INDUKTANSI LCR METER SESUDAH REKALIBRASI

Lukluk Khairiyati, Muhammad Azzumar, Miftahul Munir, Mohamad Syahadi
Pusat Riset dan Pengembangan Sumber Daya Manuasia – Badan Standardisasi Nasional,
Kawasan Puspiptek Serpong, Gedung 420, Setu, Tangerang Selatan, Banten, Indonesia.
Email: lukluk@bsn.go.id

ABSTRACT

Laboratory of National Measurement Standard for Electricity and Time (NMS ET Lab) has validated the measurement results pre and post 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 pre and post the LCR meter recalibration process at SCL - Hong Kong. Based on the E_n number analysis, the values between -0.21 to 0.44 were obtained for 5 measurement points, therefore the calibration system and method used by NMS ET Lab are valid and have measurement results that are equivalent to other countries.

Keywords: LCR meter, inductance, standard inductor, *En* number

ABSTRAK

Laboratorium Standar Nasional Satuan Ukuran Kelistrikan dan Waktu (Lab SNSU KW) telah melakukan validasi hasil pengukuran sebelum dan sesudah proses rekalibrasi LCR Meter pada parameter induktansi. Proses validasi dilakukan pada nominal 100 µH, 1 mH, 10 mH, 100 mH dan 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 sebelum dan sesudah proses rekalibrasi di SCL – Hongkong. Berdasarkan analisis E_n number, diperoleh nilai antara 0,44 sampai -0,21 untuk semua titik pengukuran, sehingga dapat disimpulkan bahwa sistem dan metode yang digunakan Lab SNSU KW untuk mengalibrasi LCR Meter telah valid dan setara dengan negara lain.

***Kata kunci**:, LCR meter, induktansi, 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).

Laboratory of National Measurement Standard for Electricity and Time (NMS ET Lab) 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.

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 was conducted to validate the calibration system for LCR meter on inductance parameter by comparing the measurement results pre and post the LCR meter recalibration process at SCL - Hongkong. Validation was implemented for inductance parameter considering the availability of standard inductor which is traceable to KRISS-Korea and performed using direct method which has several advantages: timesaving, needs fewer instruments for monitoring, and requires less parameter for computation.

The validation was based on E_n number from the comparison between measurement result by NMS ET Lab and calibration result by SCL Hongkong which should be within the value of -1 and 1 (Sutanto et al., 2016). In accordance with SNI/ISO 17025:2017, validation was carried out to guarantee the quality of the NMS ET Lab in inductance measurement.

2. 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.

$$C_{LX} = (L_S + \delta L_D + \delta L_{TS} + \delta L_F) - (L_{iX} + \delta L_R) \quad (1)$$

where :

C_{LX} : correction of LCR Meter indication.

L_S : corrected inductance value of standard inductor.

δL_D : drift of standard inductor.

δL_{TS} : temperature coefficient of standard inductor.

δL_F : frequency coefficient of standard inductor.

L_{iX} : average value of LCR meter reading.

δL_R : 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 pre and post recalibration with consideration to the measurement date. Expresion of the reference value and uncertainty are shown in Equation 2 and Equation 3 respectively (Blanc, 2014).

$$CL_{ref} = \frac{CL(t_2) - CL(t_1)}{t_2 - t_1} \cdot (t - t_2) + CL(t_2) \quad (2)$$

where:

CL_{ref} : reference value of LCR Meter.

$CL(t_1)$: correction value of LCR Meter pre recalibration.

$CL(t_2)$: correction value of LCR Meter post recalibration.

t : recalibration date at SCL – Hongkong.

t_1 : measurement date pre recalibration.

t_2 : measurement date post recalibration

$$u[CL_{ref}] = \frac{1}{t_2 - t_1}.\{(t_2 - t)^2.u^2[CL(t_1)] + (t - t_1)^2.u^2[CL(t_2)] + 2.(t_2 - t).(t - t_1).r[CL(t_1), CL(t_2)].uCL(t_1).uCL(t_2)\}^{1/2} \quad (3)$$

where :

$u[CL_{ref}]$: uncertainty of reference value of LCR Meter.

$u[CL(t_1)]$: uncertainty LCR meter pre recalibration.

$u[CL(t_2)]$: uncertainty of LCR meter post recalibration.

$r[CL(t_1), CL(t_2)].u[CL(t_1).uCL(t_2)]$: coefficient of correlation between $CL(t_1)$ and $CL(t_2)$ 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 E_n calculation (Yayienda et al., 2017). The formula of E_n number calculation is shown in Equation 4.

$$E_n = \frac{CL_{rec} - CL_{ref}}{\sqrt{u^2[CL_{rec}] + u^2[CL_{ref}]}} \quad (4)$$

where :

CL_{rec} : correction value obtained from recalibration result at SCL - Hongkong.

CL_{ref} : correction value obtained from measurement conducted by Lab NMS ET.

$u[CL_{rec}]$: uncertainty value obtained from recalibration result at SCL - Hongkong.

$u[CL_{ref}]$: uncertainty value obtained from measurement conducted by Lab NMS ET.

3. 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.

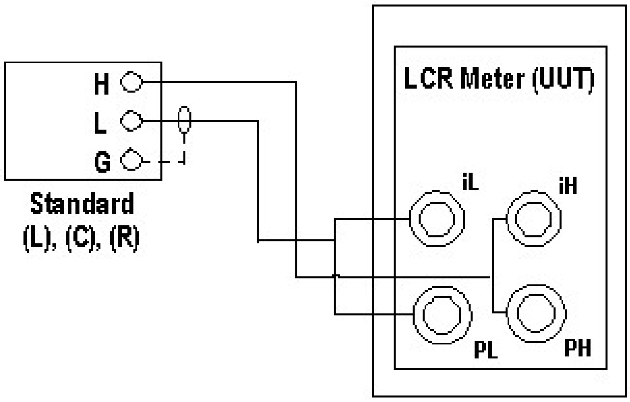

Figure 1. Inductance Measurement of LCR Meter

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. Figure 2. The Connection for inductor measurement configuration using direct method.

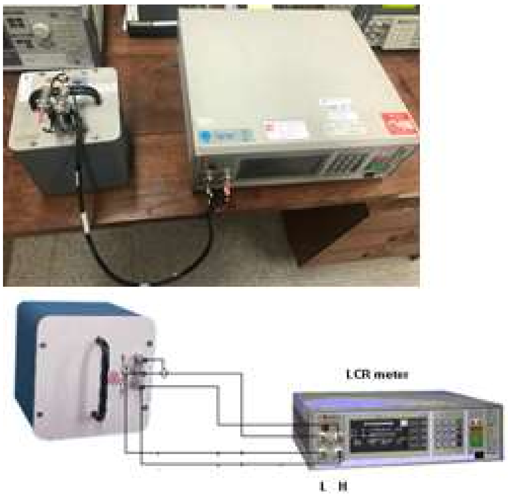

Figure 2. The conection for Inductance Measurement using LCR meter

The performance evaluation for inductance measurement can be observed through the En number based on guidance of SNI/ISO 13528: 2016 which is frequently presented for calibration and measurement in metrology. 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. The measurement setting and the nominal inductor are based on calibration certificate of LCR meter at SCL-Hongkong.

4. RESULT AND DISCUSSION

The recalibration at SCL - Hongkong was performed on September 2020. Measurement at Lab NMS ET was conducted pre recalibration on June 2020 and post 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 pre and post 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 pre recalibration

LCR Meter			Measured Correction				
				Measurement Uncertainty			
Measurement Mode	Meter Reading		Value y		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 post recalibration

LCR Meter			Measured Correction				
				Measurement Uncertainty			
Measurement Mode	Meter Reading		Value y		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 Uncertainty			
Measurement Mode	Meter Reading		Value y		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 3, Figure 4, Figure 5, Figure 6 and Figure 7.

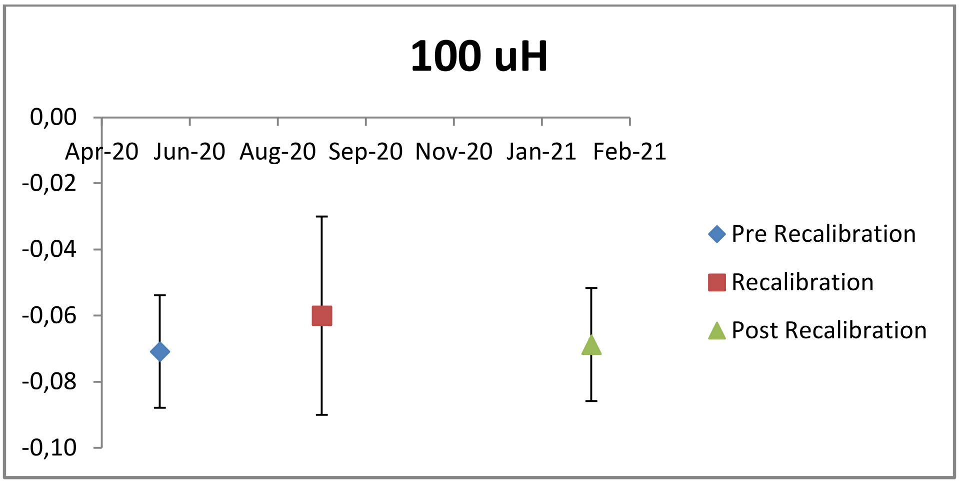

Figure 3. Measurement and recalibration results of LCR meter at nominal of 100 µH

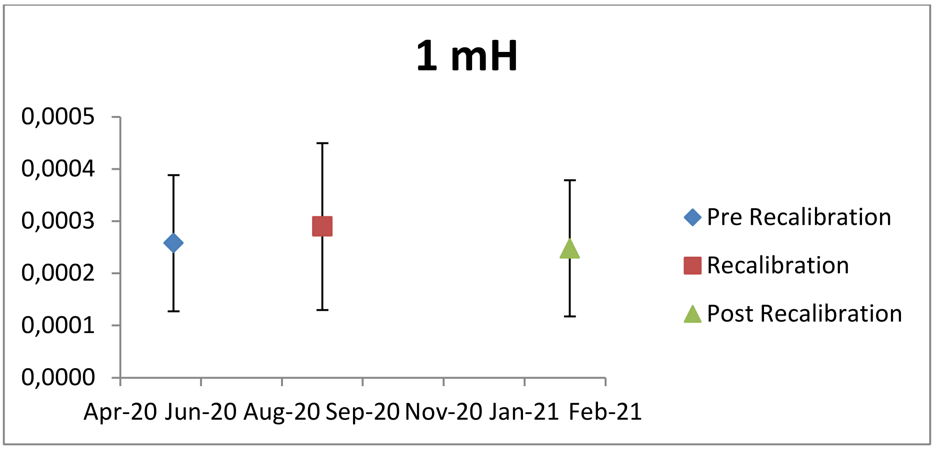

Figure 4. Measurement and recalibration results of LCR meter at nominal of 1 mH

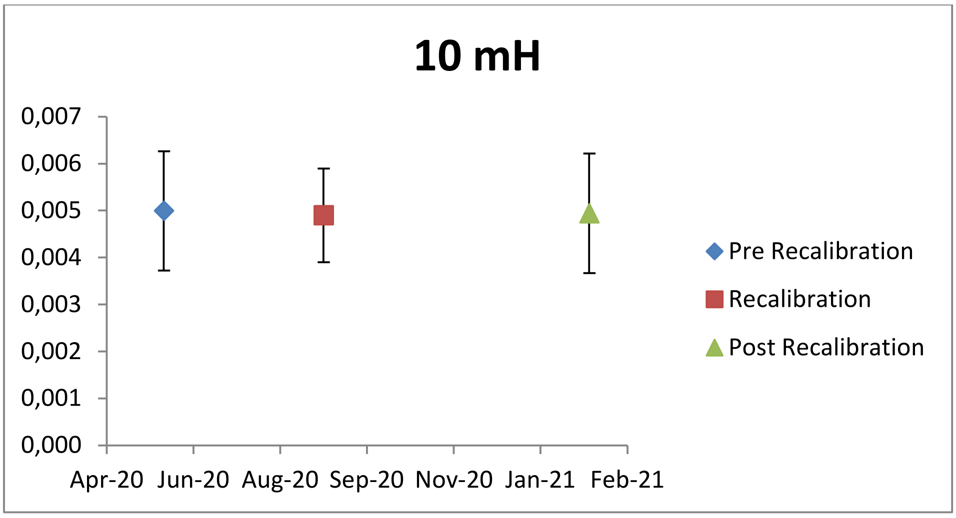

Figure 5. Measurement and recalibration results of LCR meter at nominal of 10 mH

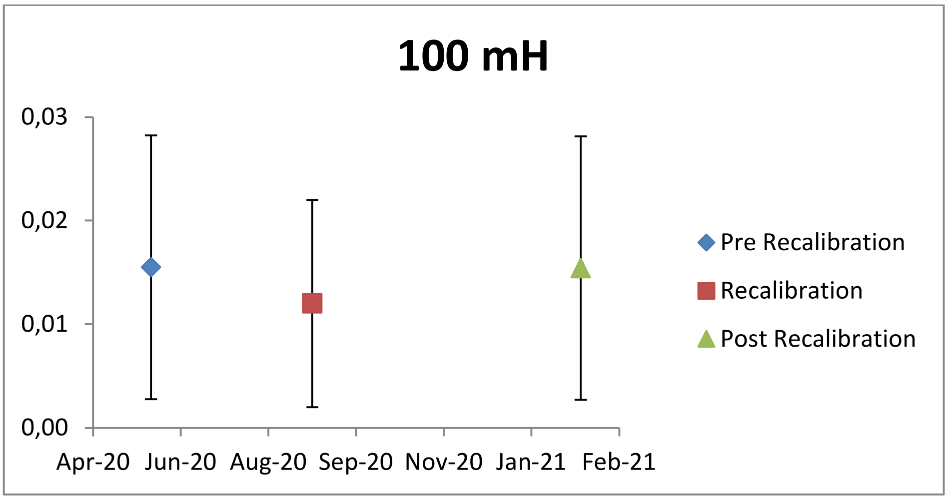

Figure 6. Measurement and recalibration results of LCR meter at nominal of 100 mH

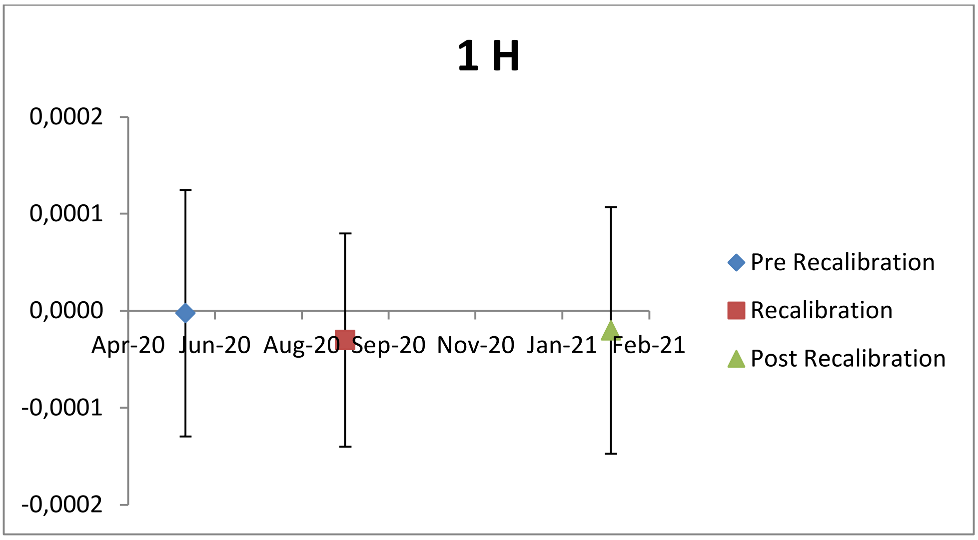

Figure 7. Measurement and recalibration results of LCR meter at nominal of 1 H

Based on Figure 3 – 7, the measurement results pre and post recalibration were consistent with recalibration result. The reference value, its uncertainty value and E_n number were calculated using Equation 2, Equation 3 and Equation 4, respectively and shown in Table 4. The En numbers for all inductance nominal were ranged within -0.21 to 0.44 which can be concluded that measurement performed by Lab NMS ET were valid and equivalent to recalibration performed by SCL – Hongkong.

Table 4. Comparison between measurement result at Lab NMS ET and recalibration result at SCL - Hongkong

Nominal	Lab NMS ET		SCL - Hongkong		Unit	*Normalized error*
	Correction CL_{ref}	Uncertainty $u[CL_{ref}]$	Correction $CL_{SCL-Hongkong}$	Uncertainty $u[CL_{SCL-Hongkong}]$		En
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

5. CONCLUSION

Validation process of direct measurement method for inductance parameter of LCR Meter has been realized. The measurement results pre and post recalibration conducted by Lab NMS ET were equal to recalibration process at SCL – Hongkong based on E_n number calculation. The system and method for LCR Meter calibration especially for inductance are valid and in good agreement to other countries.

6. 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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