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새로운 저항 션트의 국제 비교

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Laboratory Intercomparison of AC-DC Current Shunts

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Abstract - An intercomparison of ac shunts between the National Research Council of Canada and Korea Research Institute of Standards and Science is presented. The comparison was performed for the recently develop 1 A and 5 A current shunts at KRISS. The results of the both phase angle and ratio error of the resistive shunts are agree within the level of ± 1.5 ppm and ± 5 ppm respectively at 50 Hz.

1. INTRODUCTION

KRISS Scientists have being involving on research project to develop ac/dc current shunt which are commonly used in ac power measurements in order to measure current very precisely at metrological level. However residual inductance and capacitance of resistive shunt produce phase difference between current and voltage and causes an error in ac power measurement. Therefore, most of the NMI's are conducting research to develop ac/dc current shunts having low phase angle difference to fulfill demand from industries for accurate power measurement.

AC/DC current transfer calibration can be performed using thermal voltage converter (TVC) at metrological level. However, the availability of TVC's is limited to low current ranges. The range extension of the ac/dc current transfer can be performed using step up procedure. In this procedure we need a set of standard shunts. Although the standard current shunts are commercially available their level of accuracy does not meet with metrological level. Therefore KRISS develop a set of current shunts to maintain accuracy of ac power measurement at metrological level.

The laboratory intercomparison is useful to check their accuracy level internationally and to obtain more reliable results in ac power measurement. Therefor, a laboratory intercomparison has been performed for recently develop 1 A and 5 A resistive shunts at KRISS with National Research Council (NRC) Canada and the results are presented in this paper.

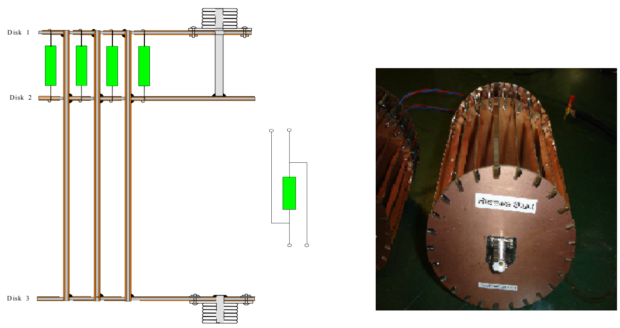
2. Theory

2.1 Structure of the Shunt

The designed current shunts are similar to the JEMIC design[1] and two shunts were developed with nominal current values of 1 A and 5 A having resistance 1 Ω and 0.2 Ω respectively. The output voltage for each shunt is 1 V. The 1 Ω ac/dc resistive shunt, rated 1 A, consist of twenty five 25 Ω Vishay type metal foil resistors connected in parallel while 0.2 Ω shunt having fifty 100 Ω resistors connected in parallel. The structure of the shunt includes three double sided printed circuit board plates connected by a number of ribs as shown in Figure 1. The input plate is separated by ribs from the output plates to minimize the inductive coupling between input and output of the circuit.

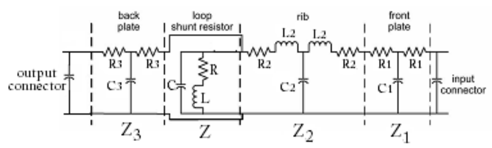
2.1 Theoretical Model

The model is consist of several identical component as shown in Figure 1a. The input current go one side of the rib through resistor and return other side of the rib. Therefore, each rib can consider as (R+L-C-R+L) network and the resistor as (R+L) with parallel C in series with the T network[2]. Both input and output plates can be considered as R-C-R network. Figure 2 shows that the simplified theoretical model for the shunt.



(a) (b)

<Fig 1> (a)Structure of the shunt and (b)Designed 1 A and 5 A resistive shunts



<Fig 2> Simplified equivalent circuit

The impedance of identical component can be written as follows.

Impedance of loop shunt resistor

$$Z = R[1+\omega^2 C(2L - CR^2)] + j\omega(L - CR^2) \quad (1)$$

front plate

$$Z_1 = 2R_1 + j\omega R_1^2 C_1 \quad (2)$$

each rib

$$Z_2 = 2R_2(1-\omega^2 L_2 C_2) + j\omega[2L_2 + C_2(R_2^2 - \omega^2 L_2^2) \quad (3)$$

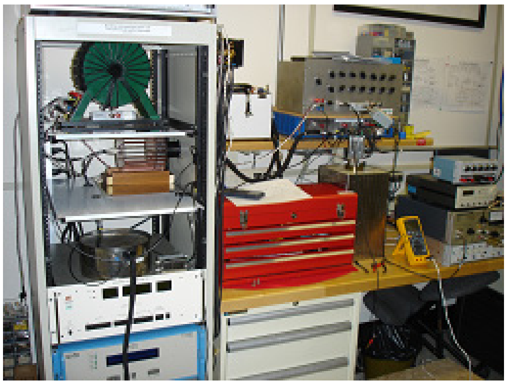
and back plates

$$Z_3 = 2R_3 + j\omega R_3^2 C_3 \quad (4)$$

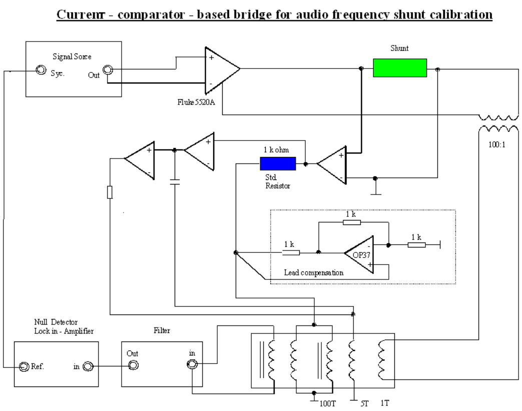
The equivalent circuit and total impedance of each component mentioned above are very useful to select mechanical dimensions of the resistive shunt. Although longer ribs reduce the coupling effect between input and output, it will increase the capacitance and inductance of the shunt. Therefore optimum length of ribs compensate both effect. Since the power rating of the film type resistors are very small, number of resistors are connected in parallel increasing number of ribs, thus increasing the internal capacitance of the shunt. Therefore two or four resistors can be connected together in small plate to reduce the number of ribs and impedance Z_2 as well. However smaller dimension increases the working temperature of the shunt. In fact we need optimum dimension to design the resistive shunt. A comparison results[2] revealed that the ac/dc difference of a design with shorter ribs is less depend of the frequency than a design with longer ribs.

3. Experimental work and Results

The shunt calibration system and circuit diagram used for laboratory comparison between KRISS and NRC Canada are shown in Figure 3. The system is based on current comparator including amplitude and phase control amplifiers, signal source, current transconductance amplifier and lead compensation circuit.



(a)



<Fig 2> (a) Shunt calibration system and (b) Circuit diagram

In this shunt calibration system the transconductance amplifier supplies the relevant (1 A or 5 A) current signal to the test shunt and voltage across the shunt compare with the voltage at the 1 kΩ standard resistor through the buffer. The calibration results from both KRISS and NRC are presented in Table 1.

<Table 1> Comparison results

Shunt	KRISS results (ppm)		NRC results(ppm)	
	50 Hz	400 Hz	50 Hz	400 Hz
A: 1 ohm (1 A)	5 + j2.5	-	1 + j4	1+ j10
B: 0.2 ohm(5 A)	6 + j3.3	-	1 + j5	1 +j12

The test at KRISS was performed at the frequency 50 Hz only and higher frequency test system has to be developed. The inter laboratory results revealed that the phase angle error of both shunt agreed within ± 1.5 ppm. Although shunt inductance and capacitance produce the phase difference, phase difference can be introduced by circuit reactance component. Usually inductance of the parallel wires is in the order of 1x 10^{-8} henry. However such type of small inductance make big difference to the time constant of the shunt in theoretically even in 50 Hz ($\omega = 10^2$). Therefore phase different within ± 1.5 ppm in two laboratory system is acceptable. The comparison results shows that ac/dc ratio error of the shunts do not agree at the level of 1 or 2 ppm. One possible reason is uncertainty level of the two measuring system. A theoretical evaluation is useful to find the clarification for two different results. The real parts of the each impedance component, ribs, loop resistance and PCB plates, represent the amplitude of the total impedance of the shunt. Moreover equations (1) and (3) shows that their real part is frequency dependant. Both equations the term of $\omega^2 LC$ is contributing the ratio error of the shunt. Theoretically those reactance (L and C) are very small and the oder of values are 10^{-7} and 10^{-11} respectively. Therefore the term $\omega^2 LC$ is less than 1 ppm the angular frequency value is up to 10^4 and it means that the ratio error should be aground 1 ppm theoretically. However the system uncertainty increases experimental value than expected theoretical value.

Conclusion

Laboratory comparison revealed that the newly design resistive shunts can be used in ac power measurements with the uncertainty level of ±5 ppm at 50 Hz.

Reference

1. Takuhiro Tsuchiyama and Takuya Tadokoro, Development of a high precision AC standard shunt for AC power measurement. *Conference on Precision Electromagnetic Measurements ,Canada, 2002.*

2. Piotr S. Filipski, AC-DC current shunts and system for extended current and frequency ranges. *IEEE Transactions on Instrumentation and Measurement. Vol., 55, No. 4, 2006.*