A Study of Accuracy of Projection Method to Determine Low Resistance Using Wheatstone Bridge

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ABSTRACT

Resistors are a very important part of any electrical circuit and hence its accurate measurement is of great importance. Resistors can be broadly classified as Low, Medium and High resistors. Wheatstone Bridge provides the most accurate way to measure medium resistances but to measure low resistance it gives significant error. Projection Method is a modification of Wheatstone Bridge wherein the four terminal of the Wheatstone Bridge are projected and connected to a four way key. In this paper we have measured low resistances from 0.1 Ω to 10 Ω and tried to find the accuracy in measurement by finding the standard deviation. The standard error has been calculated and using it the confidence limit of the measured data has been obtained. It is found that Projection Method gives very accurate measurement of standard resistances having low values of 01 Ω to 0.9 Ω but when the value of standard resistor becomes higher than 1 Ω, there is a significant standard deviation and mean value obtained also has a high value of error. Resistances of the value of 8 Ω and higher cannot be measured by Projection Method as deflection on both sides of the Bridge is not obtained. Thus Wheatstone Bridge can be effectively used to measure low resistance by using Projection Method technique.

INTRODUCTION:

Resistors are a very important part of any electrical circuit and hence its accurate measurement is of great importance. Resistors can be broadly classified as Low, Medium and High resistors. All resistances of the order of 1 Ω and under may be classified as low resistances while resistances from 1 Ω upwards to about 0.1 MΩ may be referred as medium resistances. The different methods to measure low resistances include Ammeter Voltmeter method, Kelvin Double Bridge method and Potentiometer method. Wheatstone bridge can measure the resistance from few ohm to several mega ohm but to measure low resistance it gives significant error. So, we need some modification in Wheatstone bridge to make it suitable for low resistance measurements. Kelvin Double Bridge method is one such modification of Wheatstone Bridge to measure low resistance but it requires four terminal resistors and uses 2nd set of ratio arms for calculation. The simplest modification of Wheatstone Bridge to make it suitable for low resistance measurement is the Projection Method in which the four terminals of the bridge are projected out and connected to a four way key.

THEORY:

A Wheatstone Bridge provides a very precise means of measuring a unknown medium resistance by comparing it with a known one. It is a simple bridge circuit consisting of a source of emf, a galvanometer and a network of four resistors as shown in figure-1
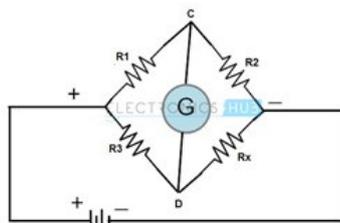

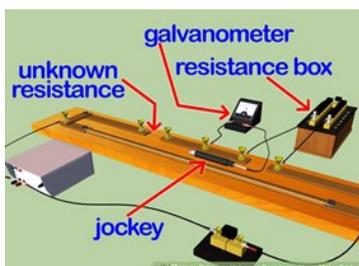**Figure-1 Circuit diagram of Wheatstone Bridge**

Figure-2 Laboratory arrangement to measure R

The unknown resistance Rx can be balanced against known resistances R1, R2 and R3 by adjusting their values until the galvanometer bridged across the parallel branches shows zero current. When the bridge is balanced there is no potential difference between points C and D. Hence,

$$\frac{Rx}{R3} = \frac{R1}{R2} \quad \text{hence,} \quad Rx = R3\frac{R1}{R2}$$

In the laboratory the resistances R1 and R2 take the form of a uniform resistance wire on which the position of contact determines the lengths comprising R1 and R2. Laboratory arrangement of wheatstone bridge is shown in figure-2. Since the resistance of a uniform wire is directly proportional to its length, we have

$$\frac{l1}{l2} = \frac{R1}{R2} \quad \text{hence,} \quad Rx = R3\frac{l1}{l2}$$

Wheatstone Bridge measures accurately resistances above 1 ohm to few Mega ohms as the resistance of connecting wires or terminals of the bridge is negligible as compared to the resistance value. For resistances less than 1 Ω the resistance of terminals or connecting wires becomes significant and so Wheatstone Bridge cannot measure low resistances directly. Hence, to make it suitable for low resistance measurements, it is necessary to deal with such undesirable resistances known as parasitic resistances. This requires some modification which is done in Projection Method. Here, the terminals of the Wheatstone Bridge are not connected to the bridge but are projected onto a four way key which offers much less resistance as compared to the terminals of the Wheatstone Bridge. The laboratory arrangement to measure low resistance by Projection Method is shown in figure-3.

Figure-3 Experimental Arrangement to measure R by Projection Method

EXPERIMENT AND CALCULATION:

The circuit was connected as shown in figure-3. For a known value of low resistance, null point lengths were obtained by placing the key in each of the four terminals of the four way key. These values were

recorded as 'a', 'b', 'c', and 'd'. The lengths corresponding to the resistances R1 and R2 were obtained as l1 = (b-a) and l2 = (d-c). The unknown resistance was calculated using the above formula of Rx. For each unknown resistor, ten observations were noted by varying the known resistance from 0.1 Ω to 1 Ω. The average value of unknown low resistance was found.

In order to understand the amount of variation or dispersion of set of data from the mean, Standard Deviation was calculated using the formula

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

It defines the way data is centred about the mean and shows how close or far the data points are from the mean. Low value of SD shows that the data is close to the mean while high value of SD shows that data is spread over a wider range of values. From the values of Standard Deviation, the Standard Error of mean were calculated using the formula $\frac{SD}{\sqrt{n}}$. Then the 95% confidence interval for the data was calculated using the formula: 95% confidence interval = mean ± 1.96 × standard error. The confidence interval states that if we use the same method to select different resistors and compute an interval estimate for each sample, we would expect the values to lie between the confidence interval 95% of the time.

RESULTS AND DISCUSSION:
The readings obtained by performing the experiment of Projection Method to measure low resistance are shown in table – 1

Table – 1 Experimental Observations of Projection Method

| Sr. No.	Value of Standard Resistance	Mean Value of Resistance Measured by Projection Method	Standard Deviation	Standard Error	Confidence Interval (95%)
1	0.1 Ω	0.136 Ω	0.00663	0.00208	0.132 – 0.140
2	0.2 Ω	0.232 Ω	0.01248	0.00394	0.224 – 0.240
3	0.3 Ω	0.312 Ω	0.016	0.00506	0.302 – 0.322
4	0.4 Ω	0.407 Ω	0.02002	0.00633	0.395 – 0.419
5	0.5 Ω	0.507 Ω	0.03195	0.0101	0.487 – 0.527
6	0.7 Ω	0.708 Ω	0.02959	0.00935	0.690 – 0.726
7	0.9 Ω	0.903 Ω	0.03436	0.01086	0.882 – 0.924
8	2 Ω	2.153 Ω	0.06436	0.02035	2.113 – 2.193
9	5 Ω	6.182 Ω	1.29731	0.41028	5.378 – 6.986
10	7 Ω	11.171 Ω	7.43132	2.35019	6.565 – 15.777
11	8 Ω	No Deflection on Both Sides			
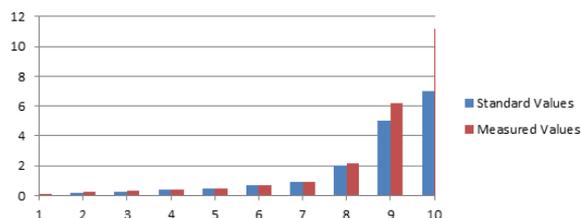
Figure-4

RESULTS AND DISCUSSION :
From the above table, it has been observed that Projection Method gives quite accurate results for unknown low resistances between 0.1 Ω to 0.9 Ω. The calculated value of resistances matches quite closely with the standard value. It has been observed that the null point length on the Wheatstone Bridge increases steadily with the increase in resistance, ie. the length corresponding to the resistor R1 increases steadily from 0.1 Ω to 8 Ω. As we move towards medium resistance range starting from 1 Ω we find that the calculated value begins to differ as compared to the standard value and as we move higher, this difference increases. This can be seen very clearly in figure-4. The

values of Standard Deviation also show a similar trend with very low values for low resistances and comparatively high values for medium resistances. The Standard Error is also found to be less for low resistances and as we move towards medium resistances, it increases steadily. The effect of Standard Error is also observed in the values of Confidence Interval. As we move from low to medium resistances, the confidence interval increases which shows that the calculated values begin to differ from standard values. This is observed upto resistance of 7 Ω for which the difference in both values is significantly high. For resistances of 8 Ω and higher, the galvanometer does not show deflection on both sides and hence, readings cannot be obtained using Projection Method.

CONCLUSION:
It can be concluded from the above discussion that Projection Method which is a modification of Wheatstone Bridge is a very simple and accurate method to measure low resistances. It is a well known fact that medium resistances can be measured very accurately using Wheatstone Bridge and now with this modification Wheatstone Bridge can be used for accurate measurements of low resistances also. Thus Wheatstone Bridge can be effectively used to measure low resistance by using Projection Method technique.