LINEARIZATION OF RESISTANCE TEMPERATURE DETECTOR BY DIFFERENT APPROXIMATION TECHNIQUE

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ABSTRACT *: resistance temperature detectors (RTDs), is also known as Resistance thermometers, are types of sensors which are used for measuring the temperature. In general, the sensitivity of the RTD is basically zero and it has no linear characteristics, thus it is not convenient in the industry. Nonlinearity is the performance of a sensor, in which the output signal does not vary proportionally to the input signal. Applying the group average method and least square method , the nonlinearity of the RTD can be improved by varying the output voltage with respect to temperature.*

Keywords : Resistance Temperature Detector (RTD), Least Square Approximation method, Linearization, Group Average method, Callendar-Van Dusen equation.

I. INTRODUCTION:

A temperature sensor is a device, usually, a RTD[7], which is responsible for detection of response according to different external inputs. The inputs could be light, heat, motion, moisture, pressure, temperature etc. The output signal will be displayed at the sensor after processing over a network. Measuring temperature through an electrical signal. It contains two copper wires that are required to connect an RTD with an electrical circuit. As a physical quantity, temperature defines the amount of heat existing in a substance which are measured over a scale. In this industry this measure of temperature is used to record, analyze and study the properties of different devices. This measure is used for variation with respect to other physical quantities for studying device behavior. An RTD[8] is a temperature sensor which is used to detect the temperature by transmitting an electrical current through a metallic component located in vicinity where temperature is to be measured[5]. The resistance value of the RTD element is then measured by an instrument. This resistance value is then correlated to temperature based upon the known resistance characteristics of the RTD[10] element. An RTD works on a simple principle of relationship between temperature and metals. With the increase in metal temperature, the flow of electricity resistance is increased. In the same way, when the RTD[9] resistance temperature increases, the electrical resistance will also increase[5]. For rectification of the nonlinearity complications the Group average method and least square approximation method is applied to compare and get the standard value of the output during temperature detection.

II. NONLINEARITY MODELLING OF A SENSOR

Callendar-Van Dusen[11] equation defines the connection with the resistance and temperature. The Callendar-Van Dusen equation is given below:

$R_2 = R_1[1+x*t+y*t^2+z*t^3*(t-100)]$ …………(1)

Where

R_2 = resistance at temperature t(^{o} c)

R_1= resistance at temperature t. (where t=0^{o}c)

t = temperature in degrees Celsius

x, y, and z = Callendar-Van Dusen constants

Callendar-Van Dusen equation can be simplified below:

For Temperature: $0^o \le t \le 661^o$c ,

$R_2 = R_1[1+x*t+y*t^2+z*t^3]$; for $t \ge 0^o$c ……..…..(2)

$R_2 = R_1[1+x*t+y*t^2+z*t^3*(t-100)]$; for $t \le 0^o$c ......(3)

in this way the non-linearity problem is appeared in this equation which is used to match the transmitter sensor using effective RTD curve to get the value of temperature.

iii. SENSOR RESPONSE RECTIFICATION:

Here we uses two methods for rectification of Resistance Temperature Detector, i.e. Least Square Approximation method and Method of Group Average. These are describing in detail below

Least Square Approximation Method: The least square approximation method is a standard way in regression analysis which is used to solve the systems having more unknown equations. "Least squares" means that the solutions which minimize the square value of the sum for the residuals of all equation .The effective application of the value fitting is that the least-squares sense minimizes the residuals of the square[1],[8] value of sum i.e the inconsistency between a practical value and the fitted value[4].

Consider that the data set falls on this equation,

$p=c+mq+kq^2$ …………....(4)

To approximate the given data, (q1,p1),(q2,p2),……,(qn,pn) where n>=3, and the error of least square , is

$e = \sum^n_{i=1}[pi-f(q_i)]2$

$= \sum^n_{i=1}[pi-(c+mq_i+kq_i^2)]2$ …….(5)

$= \min$

where the c,m,n are unknown coefficients and q_i and p_i are given. To obtain the least square error, the unfamiliar coefficients c,m,n have to zero in first derivatives.

$\frac{\partial e}{\partial c} = 2\sum_{i=1}^{n}[p_i-(c+mq_i+kq_i^2)]=0$ ……......(6)

$\frac{\partial e}{\partial m} = 2\sum_{i=1}^{n} qi[p_i-(c+mq_i+kq_i^2)]=0$ …… .....(7)

$\frac{\partial e}{\partial k} = 2\sum_{i=1}^{n} q_i^2[p_i-(c+mq_i+kq_i^2)]=0$ ………. ..(8)

Increasing the above equations, we have

$$\sum_{i=1}^{n} p_i = c\sum_{i=1}^{n} 1 + m\sum_{i=1}^{n} q_i + k\sum_{i=1}^{n} q_i^2 \quad \ldots\ldots\ldots\ldots.(9)$$

$$\sum_{i=1}^{n} q_i p_i = c\sum_{i=1}^{n} q_i + m\sum_{i=1}^{n} q_i^2 + k\sum_{i=1}^{n} q_i^3 \quad \ldots\ldots\ldots\ldots.(10)$$

$$\sum_{i=1}^{n} q_i^2 p_i = c\sum_{i=1}^{n} q_i^2 + m\sum_{i=1}^{n} q_i^3 + k\sum_{i=1}^{n} q_i^4 \quad \ldots\ldots\ldots(11)$$

The unidentified coefficients c,m,n are acquired by solving the above linear equations which is known as normal equations[3],[6].When we put the values of this constants in equation 4 , we get the required curve of best fit.**Group Average Method:**

Consider a straight line p=mq+c ....(12)
there are n observations $(q_1,p_1),(q_2,p_2)\ldots\ldots,(q_n,p_n)$.
If q=q1, the value of p will be p1.
Now,

$p=mq_1+c$ ………………....(13)

$\text{error}, e_1= p_1-(c+q_1m)$, …………......(14)

$e_2=p_2-(c+q_2m)$,

$e_n=p_n-(c+q_nm)$ …………...(15)

The error can be positive or negative, but the sum of the error will be zero[2].
To find out the value of m and c, we need two expressions divided into two groups.
The first expression contains k observations

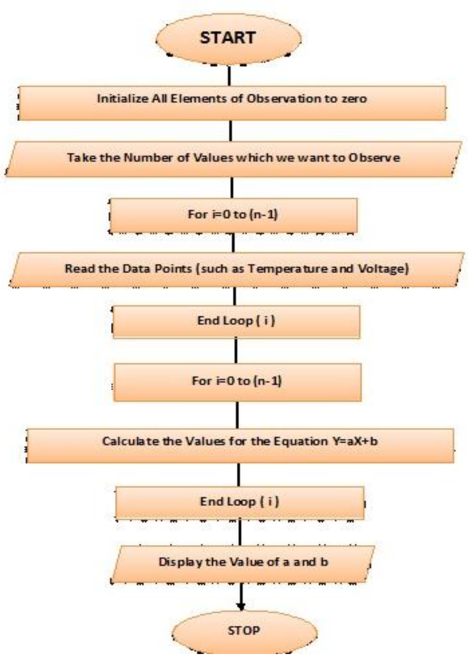

Figure 1: Flow Chart of LSM

SL. No.	Temperature(℃)	Output Voltage(V)
1	23.2	0.474
2	30	0.476
3	35	0.478
4	40	0.479
5	45	0.480
6	50	0.483
7	55	0.485
8	60	0.491
9	65	0.493
10	70	0.495
11	75	0.499
12	80	0.501
13	85	0.504
14	90	0.506
15	95	0.516
16	100	0.517

Table 1: Temperature Vs Output Voltage Chart

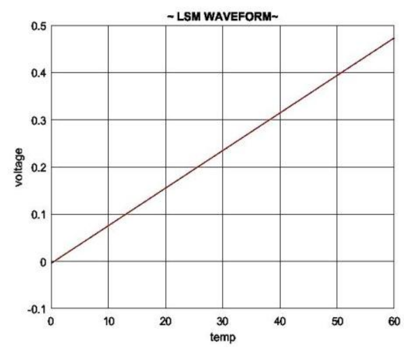

Figure 2: Temperature vs Voltage waveform of LSM

$(q_1,p_1),(q_2,p_2)\ldots\ldots,(q_k,p_k)$.
The second expression contains n-k observations $(q_{(k+1)},p_{(k+1)}),(q_{(k+2)},p_{(k+2)})\ldots\ldots$
The sum of two expressions assuming to be zero, we get
$\{p_1-(c+mq_1)\}+\{p_2-(c+mq_2)\}+\ldots..+\{p_k-(c+mq_k)\}=0$ ……......(16)
$\{p_{(k+1)}-(c+mq_{(k+1)})\}+\{p_{(k+2)}-(c+mq_{(k+2)})\}+\ldots\ldots..+\{p_n-(c+mq_n)\}=0$
simplifying this,
$(p_1+p_2+\ldots\ldots+p_k)/k=c+m(q_1+q_2+\ldots+q_k)/k$ ..... (17)
$(p_{(k+1)}+p_{(k+2)}+\ldots\ldots+p_n)/(n-k)=c+m(q_{(k+1)}+q_{(k+2)}+\ldots+q_n)/(n)$ ....(18)
From eq(17),
$1/k(q_1+q_2\ldots.q_k)$ and $1/k(p_1+p_2+\ldots.+p_k)$ denotes the mean values of q's and p's of the first groups[1].
Equations (17) and (18) are derived from eq(9) by changing q and p with their corresponding averages of both the groups.

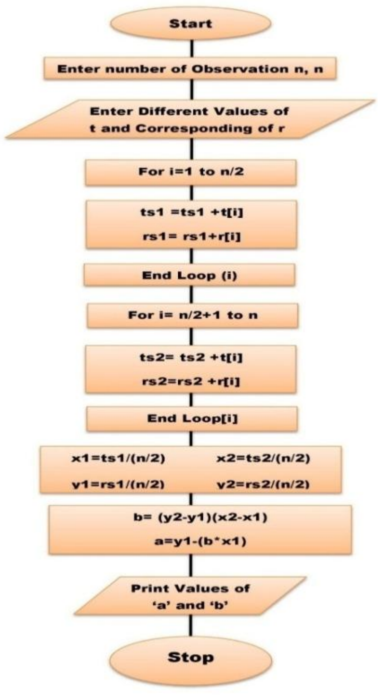

Figure 3: Flow Chart of GAM

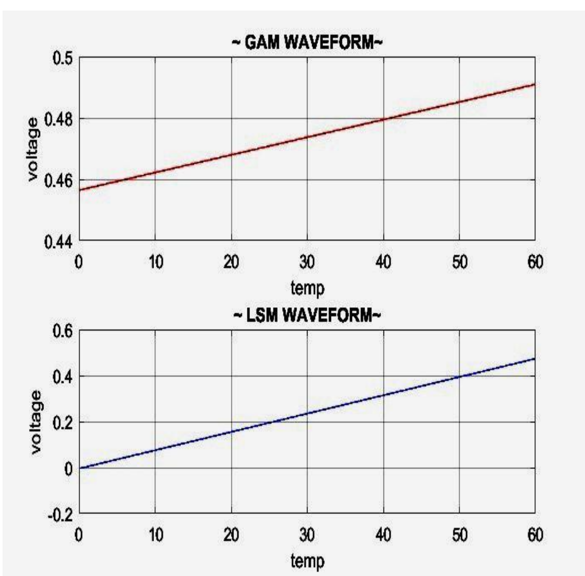

Figure 4 : Comparison of GAM and LSM Waveform

iv. COMPARISON BETWEEN LSM AND GAM :

Output from simulations are ploted, the curve, corresponding of those equations is shown below in theabove result.

By comparing the Group average method and Least square method, it can be observed that the simulated output of LSM is more linear than GAM output. So Least Square Approximation Method can be used to rectify the Resistance temperature detector, for achieving the linear value at the time of temperature detection for its linear characteristics. This properties are also shown below by using the MATLAB program, in which the linear and nonlinear characteristics of those methods are derived properly in the simulated output. As we put the value of constants and get the theoretical plot by the simulation.

V . CONCLUSION:

This work is based on the rectification of Resistance Temperature Detector. This proposed work is used to remove the nonlinearity error from the RTD by comparing the two methods i.e Least Square Approximation and Group average method. Through this process the nonlinearity of different temperature values can be optimized. The moto of this paper is to show how the nonlinearity of the sensor can be reduced using simple software simulation. The process of this technique has been illustrated in this paper .

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