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Support Vector Machine based Adaptive Calibration Technique for Resistance Temperature Detector

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Abstract: This paper proposes an adaptive calibration technique for temperature measurement using Resistance Temperature Detector (RTD) sensor based on Support Vector Machine (SVM). In practise, RTD has nonlinear response characteristics, and its output varies with variation in RTD. Support vector machine approach is used to design an adaptive calibration technique which (i) produces the output to have a linear mapping relationship to achieve RTD nonlinearity compensation, and (ii) to produce output adaptive to variations in temperature coefficients of RTD and reference resistance. The simulation results show that the proposed technique has fulfilled its set objectives. Since root mean square of percentage error is found to be 0.0015.

Keywords: Adaptation, Calibration, Optimization, Linearization, Resistance Temperature Detector, Support Vector Machine.

1. INTRODUCTION

Temperature measurement is required over a wide range of applications and under different atmospheric conditions, that too with high accuracy and precision. To cater these varied requirements, temperature sensors based on different principles have been developed. Among all these, RTD is a well-known and widely used sensor in the industry. Stable and precise outputs are the main characteristics of RTD which promotes its use over other temperature sensors. However in a RTD, the problems of non-linear response characteristics and dependency of output on temperature coefficients and reference resistance (R_o) have restricted the use of this sensor.

In practice this problem of nonlinearity is overcome by using some calibration techniques. The process of calibration is limited to a certain range, and the process of calibration is to be repeated every time whenever a RTD is replaced. It is time consuming and may demand for a change in hardware also. This increases the time requirement and effective cost of measurement system.

Shakeb A Khan et al (2003) discussed linearization of RTD using neural network, and its implementation on microcontroller**.** Calibration of RTD is achieved by using look up table in the form of transducer electronic datasheet was reported by Darold Wobschall et al (2004). Yi Gao et al (2006) used least square support vector machine to linearize RTD output. Vladimir V Gureyev et al (2007) discussed calibration for RTD using analogue circuits. Neural network algorithm is programmed to calibrate the temperature sensor used for compensation by Zhang yao-feng (2007). Yi Xianjun et al (2009) discussed polynomial for curve fitting is implemented on ARM processor for RTD. A look up table programmed on a FPGA is used for temperature linearization by T Nandha Kumar et al (2010). Calibration of RTD is done using a look up table implemented on micro-controller by Jiguang Liu et al (2010). Use of look up table created on visual basic software for calibration of RTD is reported by Najidah Hambali et al (2010) and Najidah Hambali et al (2011). A circuit for lead wire compensation is reported by S K Sen et al (2011), linearization of temperature sensor is achieved with the analogue circuits. Zhi Weng et al (2011) discussed calibration of RTD using the curve fit function of LabVIEW. Franceso Paolo et al (2012) and D Mrugala et al (2012) discussed linearization of temperature sensor using analogue circuits.

Literature review suggests that the above papers discussed methods of linearization, but most of the methods are restricted only to a portion of full scale. Moreover adaptation to variation in temperature coefficients and reference resistance is also not discussed, which means that the system needs to be repeatedly calibrated whenever RTD is changed. This paper aims at designing an adaptive calibration technique for RTD using SVM to overcome the restriction of the above discussed works.

The paper is organised as follows: After introduction in Section 1, a brief description on RTD and data conversion is given in Section 2. Section 3 deals with the problem statement followed by proposed solution in Section 4. Result and analysis is given in Section 5.

2. TEMPERATURE MEASUREMENT

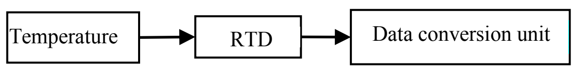

Fig. 1. Block diagram of temperature measuring technique

The block diagram representation of temperature measurement technique is given in Fig.1.

2.1 Resistance Temperature Detectors

Bela G Liptak (2003) and John P Bentley (2003) have reported Resistance temperature detectors or Resistive Thermal Devices (RTDs), are temperature sensors that exploit the predictable change in electrical resistance of some materials with change in temperature. The relation between temperature and resistance is given by the Callendar-Van Dusen equation as shown in (1) and (2).

for $-200^{o}\,C < t < 0^{o}\,C$

$$R_T = R_O(1 + at + bt^2 + c(t - 100)^3) \qquad (1)$$

for $0^{o}\,C < t < 650^{o}$

$$R_T = R_O(1 + at + bt^2) \qquad (2)$$

where

R_T – resistance at temperature T^{o} C
R_o – resistance at temperature 0^{o} C (reference resistance)
a, b, and c are temperature coefficients.

2.2 Data conversion unit

Resistance variation of RTD can be measured by a bridge, or directly by volt-ampere method. But the major constraint is the contribution of lead wires in overall resistance measured. Compensation can be achieved by using three wires RTD is shown in Fig.2 as reported by Saibal Pradham et al (1999) and Omega (1988). The outputs V_1 and V_2 of the amplifiers A_1 and A_2 respectively are given by

$$V_1 = I_o(R_T + 2R_1) \qquad (3)$$

$$V_2 = 2.I_o(R_T + R_1) \qquad (4)$$

Differential amplifier A_3 gives the difference between these two signals V_2 and V_1 to produce an output $V_o = I_oR_T$, which is dependent only on the sensor resistance.

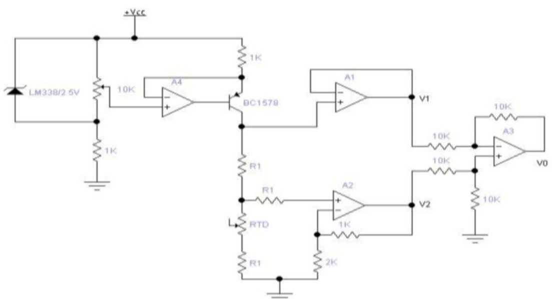

Fig. 2. Data conversion unit for RTD

3. PROBLEM STATEMENT

In this section, characteristics of RTD are simulated to understand the difficulties associated with available measuring scheme. For this purpose, simulation is carried out with three different values of R_o. These are R_o = 100, 300 and 500. Three different values of a = $2x10^{-3}$, $4x10^{-3}$, and $6x10^{-3}$, b = $-5x10^{-7}$, $-6x10^{-7}$ and $-7x10^{-7}$, c = $-2x10^{-12}$, $-4x10^{-12}$, and $-6x10^{-12}$, are used to find the output resistance of RTD. These output resistance are used as inputs of data conversion circuit. The MATLAB environment is used for simulation of characteristics.

Fig. 3, Fig. 4, Fig. 5, and Fig.6 show the variation of voltage with respect to change in input temperature considering different values of R_o, a, b, and c.

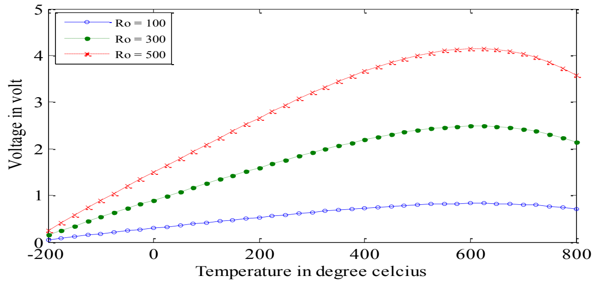

Fig. 3.Output voltage for variation of temperature and R_o, for a = $2x10^{-3}$, b = $-5x10^{-7}$ and c = $-2x10^{-12}$

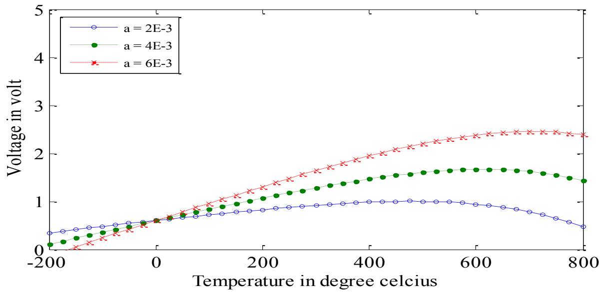

Fig. 4.Output voltage for variation of temperature and a, for R_o = 300, b = $-5x10^{-7}$ and c = $-2x10^{-12}$

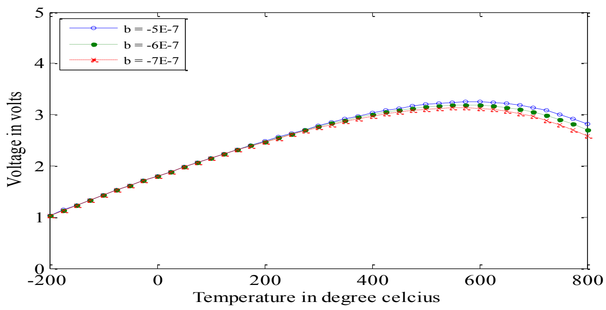

Fig. 5.Output voltage for variation of temperature and b, for R_o = 100, a = $4x10^{-3}$ and c = $-2x10^{-12}$

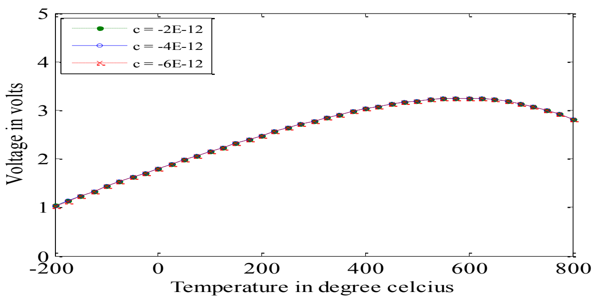

Fig. 6.Output voltage for variation of temperature and c, for R_o = 100, a = $4x10^{-3}$ and b = $-6x10^{-7}$