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A Mathematical Approach to Closed Loop Relative Humidity Controller

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ABSTRACT

This paper concerns mathematical calculation for RH controller. In industrial processes especially in textile industries the proper quality of a textile depends on moisture content or dryness of a cloth. Hygroscopic transducer is used for measuring RH, which results in change in its resistance. Any resistance change can be observed as voltage change at the output of Wheatstone bridge. The proposed mathematical approach is a closed loop control system for maintaining RH to the desired value. The generated bridge voltage is converted to current for controlling the coil, which in deed controls the operation of the valve to maintain the desired RH value during the process.

Keywords

RH-Relative Humidity, Hygrometer, Wheatstone bridge

INTRODUCTION

In past, there has been a tremendous need for closed loop control of relative humidity for certain industrial processes. For example in textile industry where moistening of textile is purely dependent on maintenance of relative humidity inside the chamber were the textile is being treated, so there is a strong need to control and maintain this relative humidity continuously. To make the textile moist, the relative humidity present inside the chamber gets varied very quickly and it can only be maintained continuously with the help of a closed loop control operation. It can be achieved with the help of proposed electronic system.

CONTROL OF RELATIVE HUMIDITY IN A TEXTILE MOISTENING PROCESS

In certain textile finishing processes, the moving textile strip is passed through a moistening chamber to be moistened and softened. The relative humidity in the chamber is maintained at a high leve1 by spraying water into a duct through which the chamber air recirculates. This system layout is illustrated in Figure 1.

The moving textile strip enters the moistening chamber through the wall on the left. It passes over several moving rolls as it moves through the chamber to where it exits through the wall on the right. The strip is dry when it enters the, chamber and, wet when it leaves the chamber, so it is constantly removing water vapour from the air. This loss of water vapour must be continually replenished to maintain the relative humidity at the proper value (about 80%).

The water vapour is replenished by sucking the chamber air into the recirculating duct on the right-hand side of Fig. As the air passes through the, recirculating duct, it encounters a battery of mist nozzles. It picks some of the water vapour from the mist and re-enters the moistening chamber on the left. The air re-enters much wetter than when it left the chamber.

The amount of water vapour that the air absorbs as it flows through the recirculating duct depends on the water flow admitted to the mist nozzles. This flow is controlled by the pneumatic diaphragm control valve in the water supply line. If the valve is further open, it allows a greater water flow to the mist nozzles, which then provide more vigorous misting.

The diaphragm control valve is the electro pneumatic type shown in Figure-1. The amount of valve opening is proportional to the amount of current through the electromagnet input coil which moves the balance beam. Therefore, the water flow rate and the amount of mist are determined by the amount of current delivered to the coil. The electro pneumatic apparatus is designed to respond to currents in the range of 2 to 10mA.That is if the coil current drops to 2 mA or less, the valve shuts completely off. If the current raises to10mA, the valve opens wide. For current values between 2 and 10 mA, the valve is somewhere in the throttling range between wide open and completely closed. The, sensing coil is driven, by an op amp voltage-to-current converter.

The electronic circuit which drives the sensing coil is shown in Figure-2. Here is how it works.

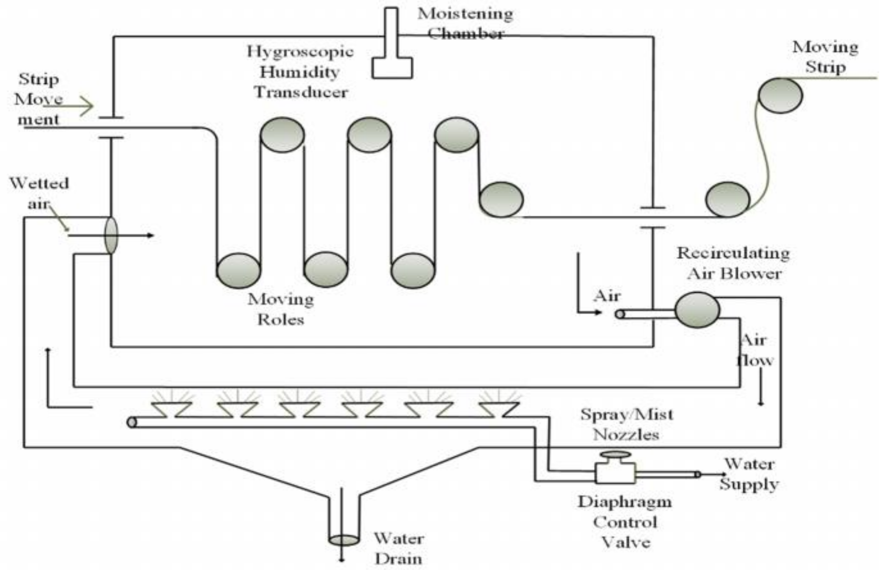

Figure: 1: Model of Textile Moistening Process.

DESIGN OF PROPOSED MODEL

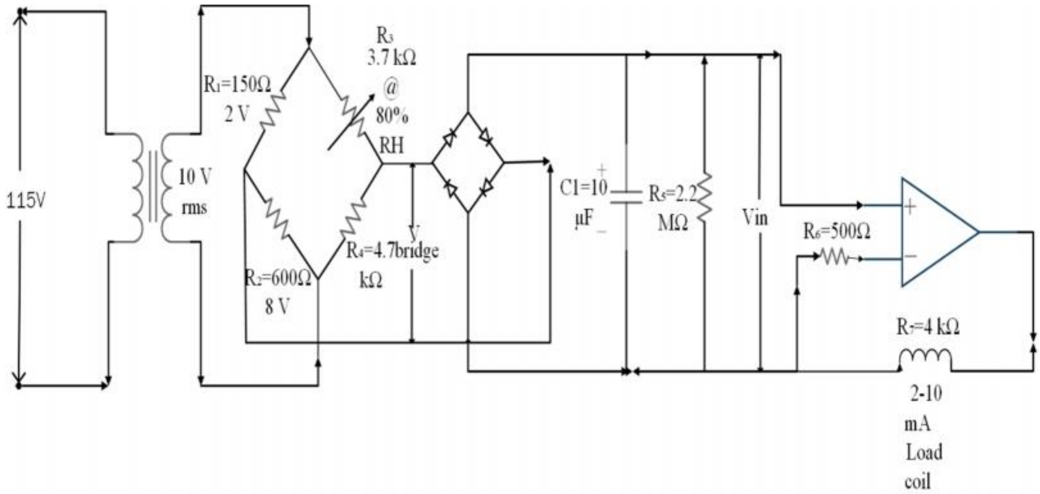

Figure: 2, The Proposed Closed Loop Circuit diagram for operating the Control Valve

The Wheatstone bridge is driven by a stable 10-V rms ac supply. A hygroscopic humidity transducer (hygrometer) is used for resistor R_3. A resistive hygrometer must be excited by ac voltage only. If the dc current passes through it for any length of time, it will become chemically polarized, and its characteristics will change. Therefore, it cannot be used in a dc Wheatstone bridge. This transducer has the resistance characteristics. The important data point from that graph that concerns us is

Relative Humidity	Resistance
80%	3.7 kΩ

Let us assume that the humidity in the textile moistening chamber is at 80% which is in the center of the acceptable range. The value of R_3 is then 3.7kΩ. The Wheatstone bridge ac output voltage, V_{bridge}, is equal to the difference between the voltage across R_2 and R_4.

$$Vb \quad = VR2 - VR4$$

V_{R2} can be calculated as

$$\frac{V_{R2}}{1\ \ Vr} = \frac{R_2}{R_2 + R_1} = \frac{6\quad \Omega}{6\quad \Omega + 1\quad \Omega}$$

$$VR2 = 8.0\ V\ r$$

When the relative humidity equals 80%, VR_4 is given by

$$V\ \ 4 = \frac{V_{R2}}{1\ \ Vr} = \frac{R_4}{R_4 + R_3} = \frac{4.7\ k\,\Omega}{4.7\ k\,\Omega + 3.7\ k\Omega}$$

$$VR4 = 5.6V\ r$$

Therefore, at 80% RH,

$$\text{Vbridge} = 8.0\ \text{V rms} - 5.6\ \text{V rms} = 2.4\ \text{V rms}$$

The peak voltage supplied to the ac terminals of the bridge rectifier is given by

$$Vp = (1.41)\ (Vb \qquad) = 1.421(2.4V) = 3.4\ V\ p$$

The bridge rectifier introduces a total voltage drop of 0.4V, since the applied voltage must overcome two germanium diodes at 0.2V each.

Therefore, the dc output voltage of rectifier acts as input voltage (V_{in}) to V to I converter is given by

$$V \quad = 3.4V\ p - 0.4V = 3.0V$$

The current through the load coil can be calculated from Eqn.

$$I = \frac{V_i}{R_6} = \frac{3.0\ V}{5\quad \Omega} = 6.0\text{mA}$$

Therefore, the sensing coil is carrying a current of 6.0mA when the relative humidity in the moistening chamber is 80%. The current of value 6.0 mA is the middle of the proportionate current range of the diaphragm-actuated control valve, so the control valve should be about 50% open and 50 % closed.

Now if the humidity in the moistening chamber should drop below 80%, for some reason here is what would happen. The resistance of the hygrometer will rise causing a voltage drop across R_4. This will throw the bridge further out of balance, causing V_{bridge} to become larger. The greater V_{bridge} will result in a greater dc input circuit to the op amp circuit, causing a larger current to flow through the sensing coil. This opens the water supply valve further and tends to drive the humidity back up.

Let us try to calculate how far the relative humidity would have to drop inorder to open the water supply valve wide open.

To drive the valve wide open, a sensing coil current of 10mA is required. Therefore V_{in} is given by

$$Vi = (10m\quad)(500\Omega) = 5.0V$$

To have 5.0V delivered to the 10µF filter capacitor, the peak input voltage to the bridge rectifier must be 5.4V because 0.4V will be dropped across the diodes. Therefore the rms output voltage from the Wheatstone bridge must be

$$\text{Vbridge} = \frac{V_p}{1.41} = 3.9 \text{ V rms}$$

For the output voltage to be 3.9V rms, the voltage across R_4 must be

$$\text{VR4} = \text{VR2Vbridge} = 8.0 \text{ V} - 3.9 \text{ V} = 4.1 \text{ V rms}$$

If the voltage across R_4 equals 4.1 V rms, the voltage across R_3 is given by

$$\text{VR3} = 10.0 \text{ V} - 4.1 \text{ V} = 5.9\text{V rms}$$

Therefore we can find the resistance of R_3 from

$\frac{R_3}{R_4} = \frac{V_{R3}}{V_{R4}}$,,, therefore $\frac{R_3}{4.7\,k\Omega} = \frac{5.9\,V}{4.1\,V}$, R_3=6.8kΩ

This means that if the resistance of R_3 rises to 6.8kΩ, the sensing coil will cause the water valve to open wide. We find the relative humidity which would cause the transducer resistance to be 6.8kΩ. It appears to be about 70% RH. Therefore a drop in relative humidity to 70% is necessary to call for and produce full water flow to the mist nozzles.

Let us try to calculate how far the relative humidity would have to drop in order to close the water supply valve.

To drive the valve to close, a sensing coil current of 2mA is required. Therefore V_{in} is given by

$$\text{Vin} = (2\text{mA})(500\Omega) = 1.0\text{V}$$

To have 1.0V delivered to the 10µF filter capacitor, the peak input voltage to the bridge rectifier must be 1.4V because 0.4V will be dropped across the diodes. Therefore the rms output voltage from the Wheatstone bridge must be

$$\text{Vbridge} = \frac{V_p}{1.41} = 1.0 \text{ V rms}$$

For the output voltage to be 1.0V rms, the voltage across R_4 must be

$$\text{VR4} = \text{VR2Vbridge} = 8.0 \text{ V} - 1.0 \text{ V} = 7.0 \text{ V rms}$$

If the voltage across R_4 equals 7.0 V rms, the voltage across R_3 is given by

$$\text{VR3} = 10.0 \text{ V} - 7.0 \text{ V} = 3.0\text{V rms}$$

Therefore we can find the resistance of R_3 from

$\frac{R_3}{R_4} = \frac{V_{R3}}{V_{R4}}$,,, therefore $\frac{R_3}{4.7\,k\Omega} = \frac{3.0V}{7.0V}$, $\text{R3} = 2.01\text{k}\Omega$

This means that if the resistance of R_3 rises to 2.01kΩ, the sensing coil will cause the water valve to close. We find the relative humidity which would cause the transducer resistance to be 2.01kΩ. It appears to be about 70% RH. Therefore a drop in relative humidity to 70% is necessary for closure of the valve.

DISCUSSION OF RESULTS

The proposed designed circuit model is able to justify three conditions for the opening of valve based on the amount of current flowing through the coil of the valve. Table-1 shows clear values of currents with respect to amount of position opening of valve. The three conditions for which the calculations have been justified are noted to be as valve fully closed, partially closed and fully wide opened.

Table 1. Resistance or RH verses Valve Current/ Valve Position

Resistance(KΩ)	RH	I(mA)	Valve Position
2.01	40%	2	Closed
6.8	70%	6	Partially
3.7	80%	10	Widely open

Thus from the above values present in the table-1, it can be confirmed that the range of current of the coil used for maintaining the relative humidity is in the range of 2mA to 10mA.

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CONCLUSION

The proposed paper gives the mathematical computation of the required current for the operation of control valve to maintain desired RH value in textile moistening process.

REFERENCES

[1] Maloney Timothy, Industrial Solid State Electronics, Prentice Hall International, 1986.
[2] G.R. Mettam, L.B. Adams, in: B.S. Jones, R.Z. Smith (Eds.), Introduction to the Electronic Age, E-Publishing Inc., New York, 1999, pp. 281–304.