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Intelligent Transmitter : Analysis of Effective parameters on Sensor Response of Gas Transmitter to Enhancement Measurment Accuracy by Intelligent Corrective Model Based on Artificial Neural Network

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Abstract*— As we may know, H2S is a toxic and dangerous gas that mainly can be found in oil fields, drilling rigs, gas separators, petrochemicals etc. It is so dangerous that if it exceeds a specified amount, it will cause physical and respiratory complications or death in some cases. For the time being, a transmitter is used to detect and measure the concentration of H2S gas which the most significant part of it, is the gas sensor. We used an electrochemical sensor to construct the transmitter. Neural networks have been used to investigate the effect of environmental parameters such as temperature and humidity. The network consists of an input layer, a hidden layer and an output layer. The results show that the output of the neural network is well able to follow the actual output. Therefore, changes in temperature and humidity affect the response of the hydrogen sulfide gas transmitter, and this change reduces the accuracy measured by the device. Furthermore, high-precision hydrogen sulfide detection sensors are generally expensive. This finding has important implications for developing robust gas sensors. By using the achieved relationship and considering the effect of temperature and humidity changes, the accuracy of the low-cos sensors can be greatly increased and the cost of producing a hydrogen sulfide transmitter can be greatly reduced.

Keywords— Artificial Neural Network , Intelligent Transmitter, Sensor response, Temperature and Humidity Effect

I. INTRODUCTION

Hydrogen Sulfide is a toxic and dangerous gas which its mixture with air is flammable. It is so dangerous that if it exceeds a specified limit, it will cause respiratory disorders and death in some cases. Hydrogen Sulfide can be found in petrochemical industries, gas separators and deep or shallow wells. In oil fields, in different stage of well site, hydrogen sulfide can be found. In drilling stage, the source and manner of H2S is formation that have gases come with mud to above the ground and the leaking position is bell mouth and shale. In other stage, the source and manner of H2S is formation that have gases through finally cement casing and the leaking position is wellhead. In Testing stage, the source and manner of H2S is output fluid leaking and the leaking position is wellhead and extractor. In Production stage, the source and manner of H2S is chemical additive decaying and the leaking position is oil tank cover[1-3].

[1] In order to obtain the safety of work place, transmitters are used to measure and control the concentration of hydrogen sulfide gas. A gas detector is a device used to measure gases in the environment and is known as part of the workplace safety system. This device also measures gas leakage and transfers it to the control room to perform the required operations in the face of gases. Their function is to generate an alarm when the gas concentration exceeds a certain level and buying them time to evacuate. The reason for the importance of these devices is that some gases are toxic and dangerous and if they exceed a certain level, they are harmful to human health. These devices are widely used in industry such as drilling rigs. Gas detectors can be classified in terms of the sensors used in them as well as in terms of installation capability. semiconductors, oxidation, catalytic, photoionization, infrared, portable devices and fixed gas detectors are types of gas detectors. [1, 2] Figure 1 illustrate the location of transmitter installation.

Figure 1Location of transmitter installation

So far, a lot of work has been done to manufacture gas transmitters, and many companies have built this device. However, among the device produced, there have been little discussion about the influence of temperature and humidity on transmitter output response and there are few cases that consider the effect of environmental factors on the output response measured by the transmitter and sensor and it is a major problem with this kind of devices. However, research and experiments have shown that ambient parameters such as temperature and humidity affect the output of the sensors (depending on the type of sensor structure) and the output of the transmitters. Recently, researchers have shown an increased interest in this issue. This concept has recently been challenged by Nenova studies demonstrating the effect of ambient factors on sensor output response. In 2013, Nenova, et.al. studied the efficacy of temperature and humidity on the amount of methane gas with metal oxide gas sensors and concluded that ambient factors such as temperature and humidity have substantial impact on metal oxide gas sensor characteristics.[3] However, far too little attention has been paid to analysis the efficacy of T and RH on transmitter output response and the most studies have only been carried out in a small number of areas such as data communication and multi gas sensor. In 2018, pang et.al. analysis the efficacy of T and RH on output response of electrochemical gas sensors detecting CO, NO, NO2, OX. They concluded that the T and RH have changing effect on the response of sensor in active and reference electrode. For NO gas, a linear relationship was found between T and RH and reference electrode. while other sensors have lower effect from ambient parameters.[4] This paper will focus on and construct a hydrogen sulfide gas transmitter and to investigate the effect of temperature and humidity parameters on the hydrogen sulfide sensor response with artificial neural network.

II. METHOD

A. Different Sensor Technologies

To date various methods have been developed and introduced to measure the amount of gas concentration. The more significant part of a transmitter is gas sensor which it plays a vital rule in transmitter designing. A variety of methods and sensors are used to detect gas concentration. Each has its advantage and drawbacks. Surface acoustic wave could be placed in harsh and rotating parts, detect nerve and blister agents and has a high response time. Catalytic gas sensor measures flammability of gases and requires air or oxygen to work. Optical gas sensors have a very wide monitoring area, easy operation in absence of oxygen and affected by ambient light interference. Thermal gas sensors have an easy operation in absence of oxygen and have reaction due to heating wire. Electrochemical gas Sensors have short response time, can measure toxic gases in relatively low concentrations and they can detect wide range of gases. Infrared gas sensors can be used in inert atmosphere but not all gases have IR absorption. Semiconductor gas sensors works well at constant high humidity condition and have an high response time.[1, 5-7]

Different studies have considered different sensors in a variety of ways. Considering the danger of hydrogen sulfide gas and the importance of its immediate detection, response time is the principle parameter in choosing a sensor. As shown in figure 4 and can be seen from table 1, electrochemical sensors has less response time compare to others.[8-10]

Table 1Comparison of all gas detection sensors

No	Sensor Type	Advantage	Disadvantage
1	Electrochemical	Short Response Time Measures toxic gases in relatively low concentrations. Wide range of gases can be detected	Advanced monitoring technique used
2	Infrared	Can be used in inert atmosphere	Not all gases have IR absorption.
3	Semiconductors	works well at constant high humidity condition.	Susceptible to contaminants and changes due to environmental conditions. High Response Time
4	Thermal	Robust but simple construction. Easy to operate in absence of oxygen.	Reaction due to heating wire.
5	Surface Acoustic Wave	Could be placed in harsh and rotating parts	High Response Time
6	Catalytic	measures flammability of gases low cost technology	Requires air or oxygen to work. Can be poisoned by lead, chlorine and silicones
7	Optical	Easy to operate in absence of oxygen. Not affected by electromagnetic interference	Affected by ambient light interference

Mainly, the use of gas detection sensors has brought so many opportunities to control infected environments. Nevertheless, there are serious issues about the quantity of the data acquired from sensors. Studies indicate that environmental parameters effect the output response gained from sensors and transmitters. Factors such as temperature and humidity effect the output response of sensors and transmitters and their measurement accuracy. This topic will be considering the efficacy of ambient factors such as T and RH on the output response of transmitter with hydrogen sulfide electrochemical sensor in variable circumstances and also on the measured concentration by the Sensor. [1, 11-14]

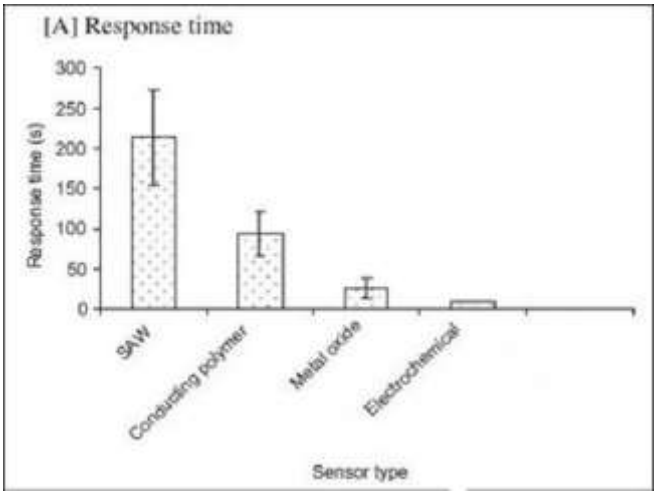

Figure 2 Comparison of response time of different electrochemical sensor

B. Electrochemical Sensor

The electrochemical sensor measures the gas concentration with oxidation reaction to generate positive or negative current through an external circuit. The main components of an electrochemical sensor include three electrodes which are: working, reference and counter. These components are combined with an electrolyte inside an electrochemical sensor. The upper part of the sensor has diffusion limiting hole through which the ambient air interacts with the sensor electrolyte. This results in electrochemical reaction. This reaction causes current to flow from "working" to "counter ". The value of this current is proportional to the amount of gas and is measured by an external electrochemical sensor circuit.

The basic of this sensors works is that the gas reacts with the sensor. A counter electrode is used to make a balance for working basic performance and also to create an equivalent current that fits to the intended gas. Such as those used in this device - ME3-H2S - some sensors also contain reference which is used for keeping sensitivity for the intended gas. Electrochemical sensors have admissible linearity. Previous studies confirm that in different conditions, the electrochemical sensor outputs will face changes and such changes is due to parameters like temperature and humidity. [4, 15, 16]

C. Design of Experiment Method (DOE)

Today, there is a lot of research being done on the design, test and manufacture of various equipment and materials. In order to increase the accuracy of the experiments and increase the efficiency of the proposed methods, this method should be introduced that are based on mathematical calculations and with which the experiment can be designed and modeled. Design of experiment creates an optimal experiment by considering the effect of different parameters and modeling the experiment and desired design. This method can be used to predict the process of testing and results obtained as well as to reduce the number of tests in physical and electrochemical experiments. In order to analysis the effect of T and RH parameters on response of hydrogen sulfide sensor, DOE-General Factorial approach it have been used. The figure illustrate that the data used is standard. [15] Here, data related to hydrogen sulfide gas of South Pars unit have been used. Due to the dangerous and toxic nature of this gas, its concentration and leakage are always controlled. In this study, the number of data is 80, of which 30 have been used for network training and the other 50 for network testing. Here, using the design of experiment (DOE) and general factorial methods, two modes are considered, which are in terms of the effect of temperature and humidity and not considering the effect of temperature and humidity on the sensor output and the amount of concentration measured. [17, 18]

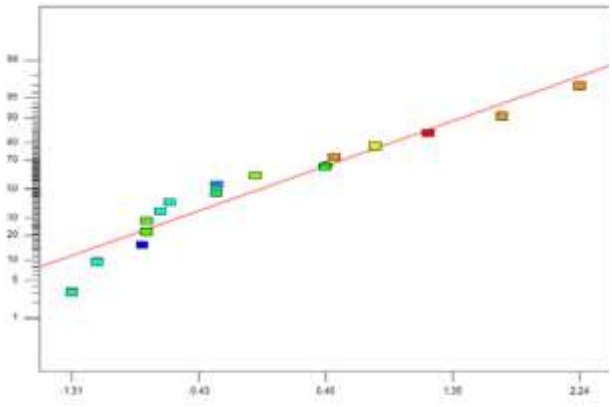

Figure 3Internally Studentized Residuals

D. Artificial Neural Network

Feed forward neural networks have been used to investigate the effect of environmental parameters such as temperature and humidity. This network consists of an input layer, a hidden layer and an output layer, the hidden layer of which consists of 6 neurons. The inputs of this network are the values of temperature, humidity and voltage of the sensor and its output is the value of the measured concentration. The total number of data is 80, of which 30 are used for training and 50 for testing. Data related to one of the wells in the oil-rich areas of South Pars.

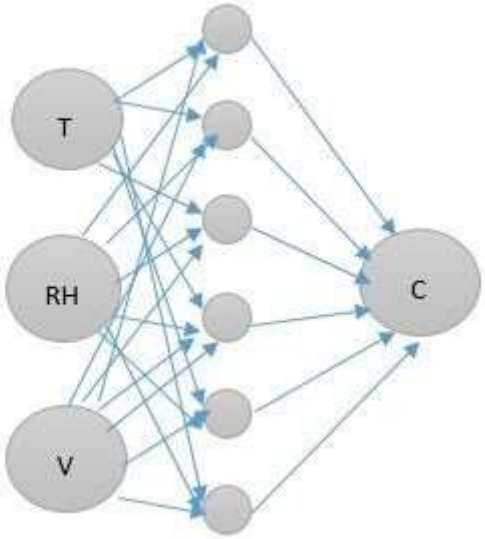

Figure 4 Structure of neural network

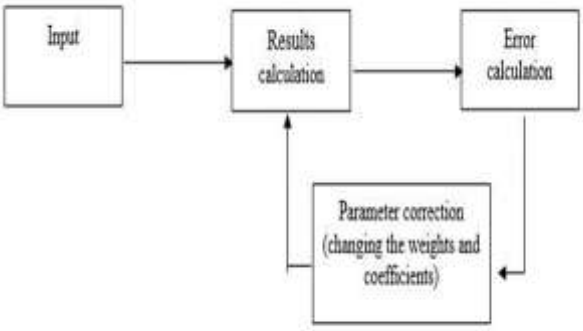

Figure 5Flowchart of training algorithm

III. Result and Discussion

By using this network, a model is obtained to correct measurement error due to environmental factors such as temperature and humidity. To acquire a model to forecast the process of the effect of the temperature and humidity on the output response of the transmitter, it was used quadratic polynomial curve fitting.

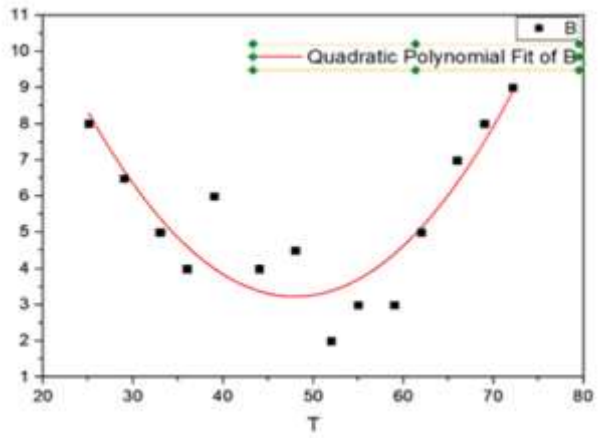

Figure 6H2S Sensor Response to the Change of Temperature

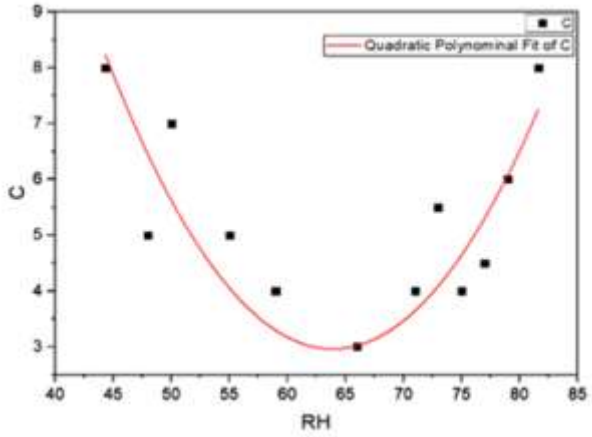

Figure 7 H2S Sensor Response to Change of Humidity Factor

$$Conc = (a*RH + b*T + k) * VAct$$

Table 2 sequential model sum of squares

Source	Sum of square	F-Value	P-Value
2FI vs Linear	0.18	0.043	0.8390
Quadratic vs 2FI	21.26	3.53	0.0690
Cubic vs Quadratic	9.32	0.67	0.6340

This formula of intelligent corrective model indicates that changes in each of the temperature and humidity factors have a parabolic relationship with the amount of response measured by the hydrogen sulfide transmitter.

Table 3 Analysis of variance

	Sum of squares	Mean of squares	P-Value	F-Value	Adeq Precision
Model	24.94	12.47	0.0325	4.51	5.668

The F-value of 4.51 point that the proposed model is significant. If the amount of P-value less than 0.05, the proposed model is significant. P-value indicate the error. As can been seen, the error is 3.25. Adeq precision measures the signal to noise ratio. If the obtained ratio is less than 4, the model is undesirable. As can been seen, the ratio is 5.668 and indicates an adequate signal.

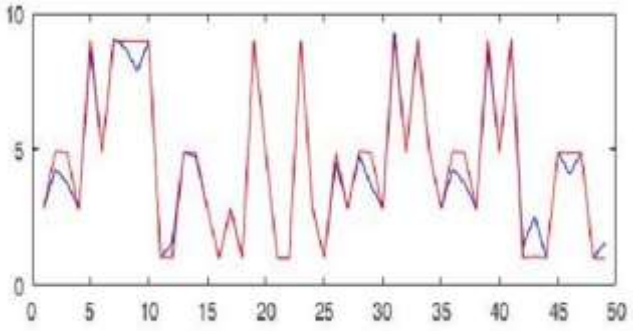

Figure 8 Result of intelligent corrective model

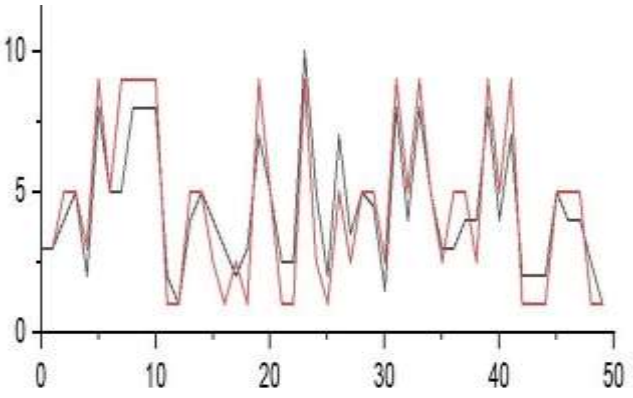

Figure 9Result without intelligent corrective model

By using this network, a model is obtained to correct measurement error due to environmental factors such as temperature and humidity. According to Figure 8, it can be seen that the obtained model has high accuracy than Figure 9. Its final prediction error is 0.16351 and the error in last iteration is 0.0066956 and three dimensional view of changes of T and RH are shown in figure 10. Axis X represents the number of test data and axis Y shows the amount of concentration. The red line represents the main data and the blue line also represents the model used.

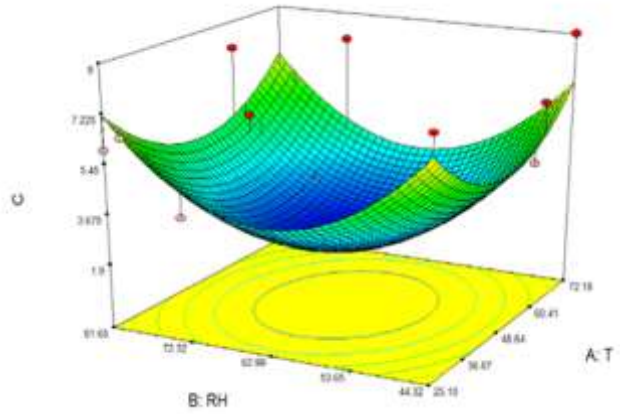

Figure 10 Three Dimension View of Effective Parameters

When considering the effect of temperature and humidity, it was observed that their changes affect the measured value. Therefore, using a neural network, intelligent corrective model was designed for it. In general, each sensor, according to the structural characteristics and the environmental condition in which it is located, has some changes in its output response. Using the proposed model and considering these changes, the output can be obtained with higher accuracy than the old fashioned sensors.

IV. Conclusion

In this study, the hydrogen sulfide transmitter performance under variable temperature and humidity conditions and its output response due to changes in the mentioned factors were investigated. This paper proposed an intelligent corrective model and the results of this model confirm many results of previous work in electrochemical gas sensors. This finding is in agreement with Wei (2018) findings which showed the effect of temperature and humidity on CO, NO and OX electrochemical gas sensor. According to the design of the experiment, it was observed that changes in temperature and humidity affect the working electrode of the sensor and as temperature and humidity change, the measured concentration also changes. Therefore, changes in temperature and humidity affect the response of the hydrogen sulfide gas transmitter, and this change reduces the accuracy measured by the device. Furthermore, high-precision hydrogen sulfide detection sensors are generally expensive. This finding has important implications for developing robust gas sensors. By using the achieved relationship and considering the effect of temperature and humidity changes, the accuracy of the low-cos sensors can be greatly increased and the cost of producing a hydrogen sulfide transmitter can be greatly reduced.

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