Humidity effect has been calculated for acetone sensor under 85-90%RH, created inside the chamber. The test results are shown in Figure 6. It is observed that there is an increase of 0.2V in high humidity sensing compared to the low humidity sensing. Artificial neural network was used to compensate these effects.

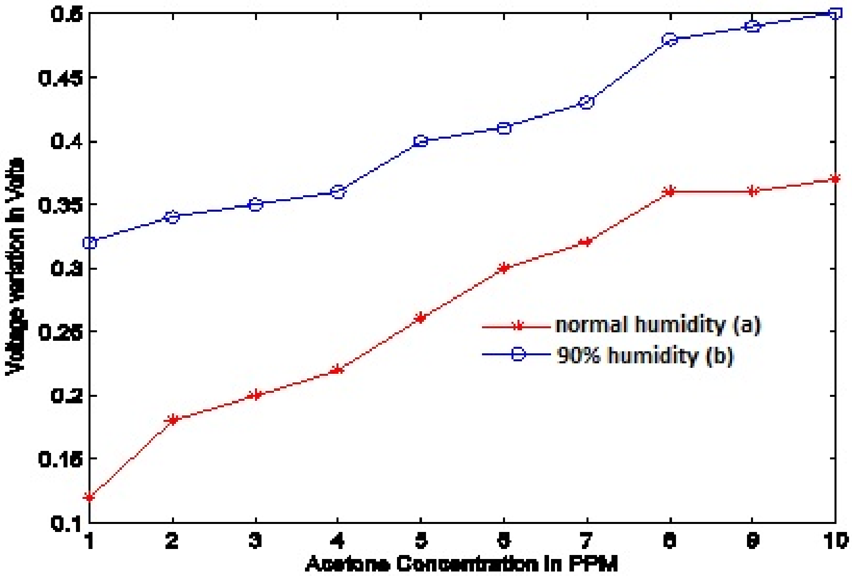

Figure 6. Acetone detection a). Under normal humidity b). Humidity=90% inside the chamber

The network is trained such that the MSE (Mean Square Error) is very low and Regression reaches 1. The trained network knowledge is stored in terms of weights and biases. The network is fixed with 180 I/O layer weights and 31 neuron biases. The trained network MSE is 2.75 x e^{-27} and the total regression ratio is 0.9962 as shown in Figure 7. The relation between the acetone concentration and sensor response with humidity effect is already explained and is modeled in ANN tool [14].

From the collected samples it is observed that different values of voltage, resistance, pressure, humidity and temperature have been recorded for every person depending on their glucose levels and flow rate.

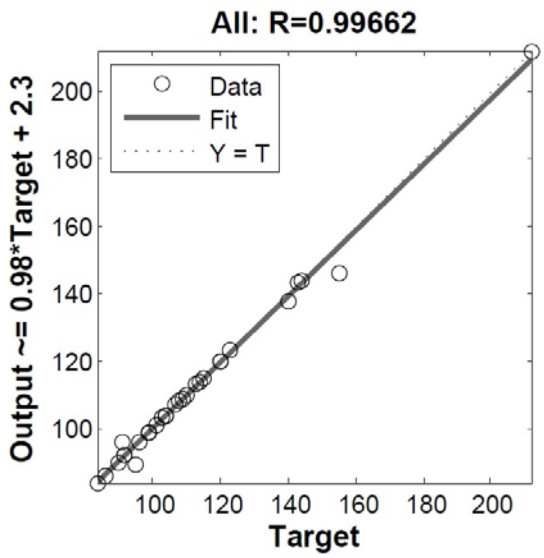

Figure 7. Network with R=0.99662

Figure 8 shows the network trained with regression coefficient R=1. Validation and Test results also show regression coefficient R=1 as shown in Figures 9 and 10. After training the network it has been tested with different breath inputs and the results compare closely with the actual glucose levels.

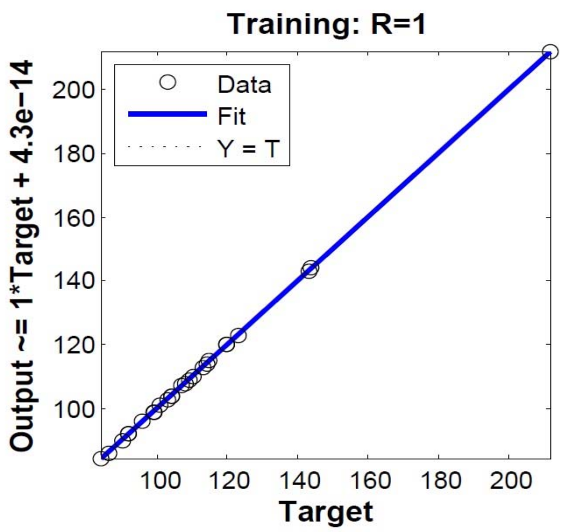

Figure 8. Trained network regression R=1

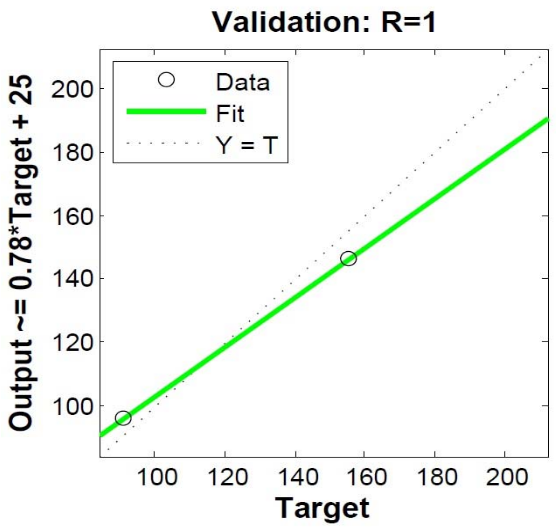

Figure 9. Network under validation R=1

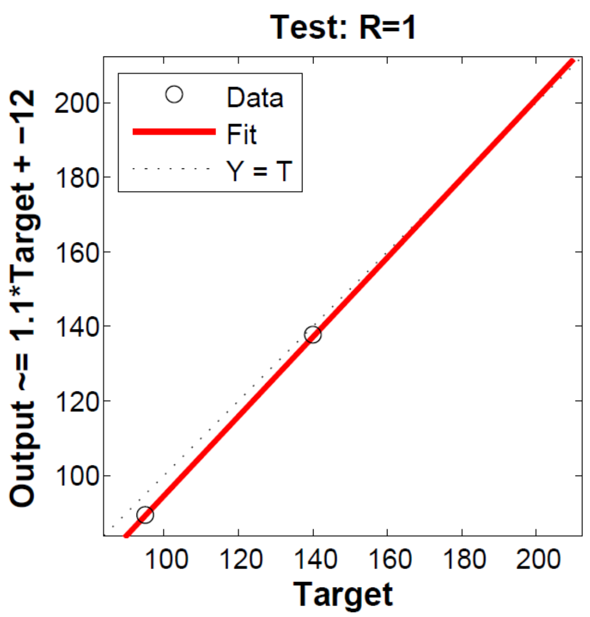

Figure 10. Network under test R=1

From the results it is observed that the voltage and resistance are playing important roles in measuring the glucose level non-invasively whereas the other parameters affect the measurements very little. The temperature effect is more compared to other two parameters, the relative humidity and pressure. The training data is collected from non-diabetic patients with glucose levels in between 80 mg/dL and 140 mg/dL and a few pre-diabetic patients with glucose levels in between 140 mg/dL and 180 mg/dL. Figure11 (a) shows the variation in concentration of actual blood glucose levels of a patient over time. Figures 11b to 11f show the variation in different parameters during the non-invasive monitoring of blood glucose over time.

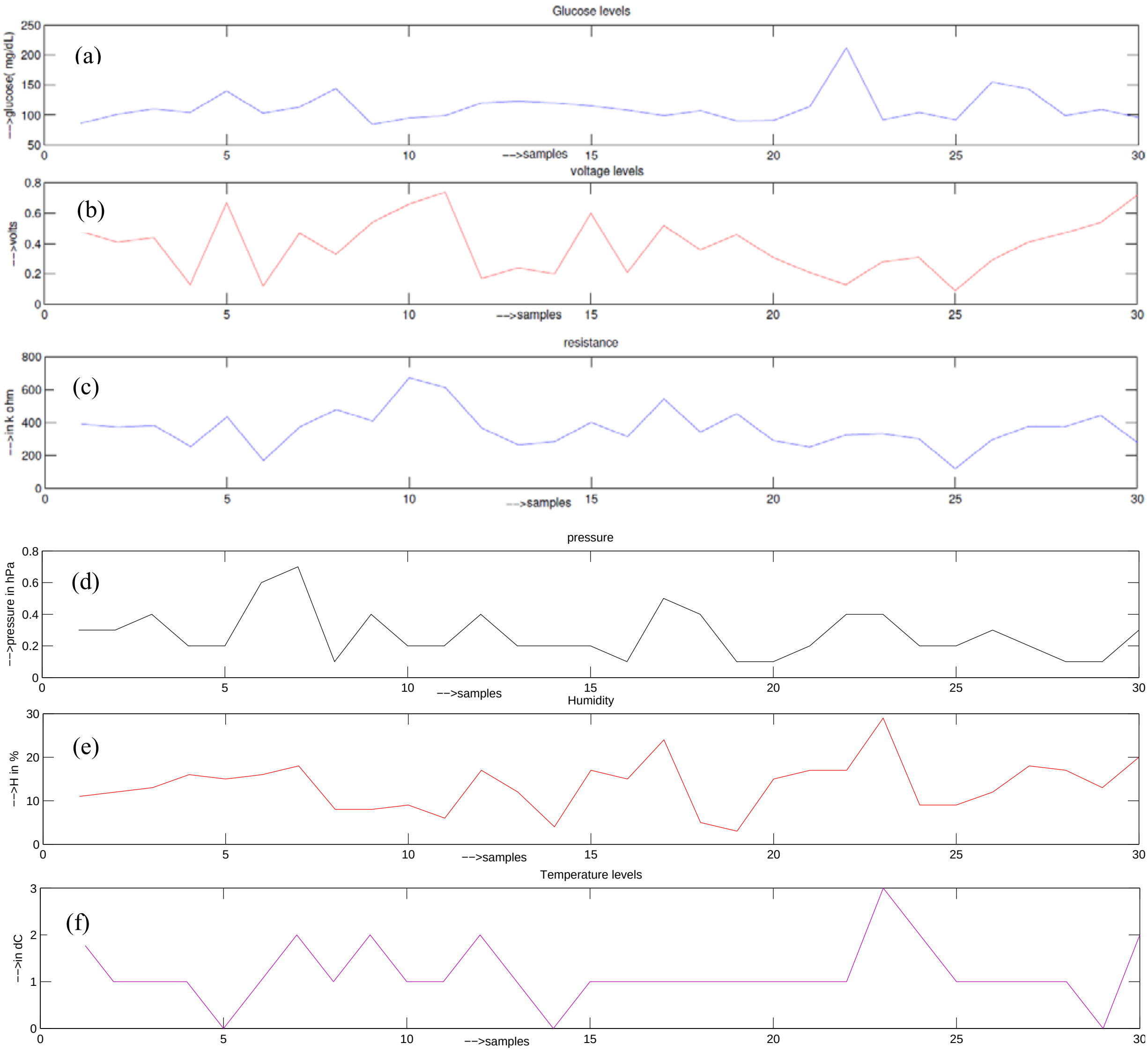

Figure 11. Variations in various parameters during monitoring of blood glucose levels over time: (a) actual concentration of blood glucose levels of a patient over time during invasive measurement; (b) voltage levels, (c) resistance, (d) pressure, (e) humidity and (f) temperature during non-invasive monitoring of blood glucose.

From the Figures 11 (a) to (f) it can be observed that if the glucose levels are high at some point the voltage will also be high and the resistance will go down and the other parameters are moderate. In some cases, albeit the glucose levels are high, voltage levels are low because of considerably low pressure, humidity and temperature levels, which indicate the person did not blow correctly into the mouth piece. These effects are minimized with the help of neural network tool.

V. CONCLUSIONS

In this study, the applicability of the breath acetone sensing method to the determination of glucose in human blood is demonstrated. We used acetone sensor for monitoring acetone levels in the exhaled breath and compared with actual blood glucose levels. We also considered the effects of the pressure, temperature and humidity parameters on the acetone sensing. This test involved studies of non-diabetic and pre-diabetic persons. We have also used Artificial Neural Network model for analyzing the data. The test results show that it is possible to measure the blood glucose levels via breath acetone sensing. The accuracy of the system can be improved with a large set of data.

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