SIMULTANEOUS LEAK DETECTION WITH MAGNITUDE AT TWO POSITIONS FOR FLOW OF WATER IN PIPELINE USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT
Chemical process industries have complex structures comprising of equipments & network of pipelines carrying volatile, flammable & hazardous fluids. The timely detection of leak position & its magnitude is one of the challenging tasks. The present work is aimed at leak detection in a pipeline using artificial neural network models. Experimental runs are conducted & pressure drop for flow of water across the orifice meters placed in five sections is measured for normal conditions & with leak in one or two sections with varying magnitude. Part of the experimental data is used for developing two ANN models S & C having different topology. The validation is carried out using test data set. The trained networks are used for the prediction of these leak parameters. Based on the comparisons of the actual & predicted values of all the output parameters, it can be said that the present work is successful in developing models having high accuracy.

KEYWORDS: *Artificial neural network, leak detection in pipeline, pressure drop and multiple leakages.*

I. INTRODUCTION

Transportation of fluids through pipelines is one of the most important activities in process industry. Heavy losses are reported every year due to leakages from pipelines carrying fluids. It becomes a major task to minimize these losses by proper estimation of the position of leak & its magnitude & taking the corrective action. A leak in a pipeline is usually diagnosed by analyzing the change in the pressure drop across the point of leakage with the normal condition. The present work is aimed at estimation of leak detection parameters for pipeline carrying water by using Artificial Neural Network as a modeling tool.

The paper is presented in sections, starting with the introduction to Artificial Neural Network (ANN) followed by discussing the details of materials, methods & experimental procedure along with the details of ANN models developed. Result & discussion section gives the comparison of the predicted values obtained using ANN models developed in the present work with the experimental values at length. The paper concludes with the findings of the present work & mentioning the possible areas for future work that need to be explored.

II. ARTIFICIAL NEURAL NETWORKS

An Artificial Neural Network (ANN) is an interdisciplinary theme & finding applications in various fields of engineering, medical sciences, economics, meteorology, psychology, neurology, mathematics and many others. Neural networks exhibit many advantageous properties for solving complex problems of developing nonlinear multivariable correlation with speed & accuracy. They have the ability to generalize from training data to unseen data. It is influenced by & loosely modeled on the working principle of biological neural network. There are many types of artificial neural network, Multi Layer Perceptron (MLP) is one of them. It consists of input and output layers with hidden layers placed in between them. All the layers have number of processing elements or neurons or nodes present. The number of nodes or neurons present in input & output layers is same as the number of independent & dependent parameters respectively that are to be correlated. The independent & dependent parameters are referred as input & output parameters respectively. The number of hidden layers & the number of nodes in each hidden layer is decided by the complexity of the correlation to be developed [1].

Feed forward neural network is one of the most common type of ANN applied in situations related to modeling in which every node in each layer is connected with every node in the next layer. The signal leaving from every node of the input layer is altered by a multiplication factor called as connectionist constant or weight, which may vary from connection to connection. Every node in hidden & output layers, sums up several such input signals received into one, transforms the resultant signal by applying functions like sigmoid or hyperbolic & gives its own output signal. The power of ANN is in its training & error back propagation algorithm suggested by Rummelhart is popular in this regard [2].

The applications of ANN are many and varied in nature which include modeling of distillation column[3], modeling of packed column [4] , modeling of unsteady heat conduction in semi infinite solid[5], prediction of mass transfer coefficient in down flow jet loop reactor[6] , estimation of mass transfer coefficient for fast fluidized bed solids[7], detergent formulation[8], and similar other[9,10] are also reported. The ANN is also applied in areas of fault detection & diagnostics including leak detection in pipelines & some of the papers on the themes reported in literature include, an approach to fault diagnosis in chemical processes [11], fault diagnosis in complex chemical plants[12], incipient fault diagnosis of chemical process[13] and leak detection in liquefied gas pipeline[14],[15],[16],[17],[18].

In the present work, experimental runs are conducted for flow of water in a pipeline having five sections with and without leakage of varying magnitude. The pressure drop across the orifice meter provided between two sections of the pipeline carrying water is recorded. The data generated for normal & faulty conditions having leak at one or two positions of varying magnitude is used for training of artificial neural network (ANN). The trained ANN is then tested for its validity & accuracy in predicting the leak position and its magnitude.

III. MATERIALS & METHODS

The schematic of the experimental set up is shown in Figure 1.The details of various parts of the experimental set up are given in table 1 & details of operating parameters are given in table 2.

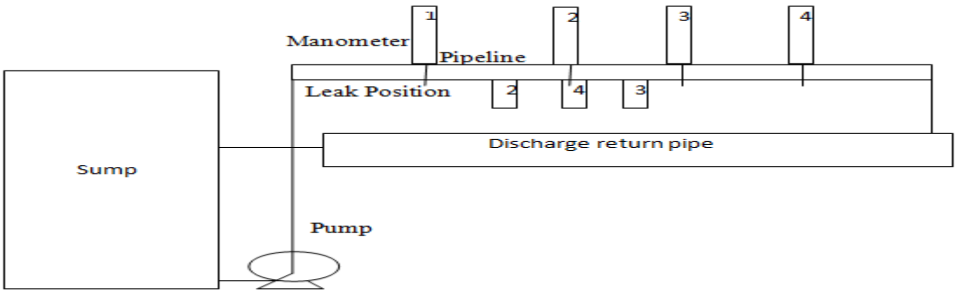

Figure 1: Schematic of the experimental set up

- Experimental set up is comprised of a pipeline having length of 7.3 m & dia of 1.5 inch
- The pipeline has five sections 1, 2, 3, 4 & 5 having length of 1.42, 1.52, 1.31, 1.42 & 1.52 m respectively.
- Sections are connected using a flange assembly. Every flange has an orifice plate & rubber gasket placed in between them. Four nut-bolts each of diameter 0.5" are used for each assembly. Two tapings are provided for manometer connection at appropriate locations across the flanges.
- Four inverted manometers are connected in each section to measure the pressure drop
- A sump of 5000 liter capacity is used.
- Water is forced into the pipeline using 1HP pump.

- Discharged water is re-circulated to the sump using 3” pipeline.
- Pressure drop across the orifice in each section is recorded by varying the flow-rates of water for normal conditions.
- Leak positions 2 & 3 are generated by creating a hole in the pipeline using a needle at 0.915 & 0.88 m from the first & second flanges respectively.
- Leak position 4 is created by loosening the nut and bolt assembly of the flange 2.

Procedure

i. The manometer readings across each section are noted down for constant flow conditions of water. The flow-rate is determined using digital weighing scale.
ii. Leak position 2 is generated & procedure mentioned in (i) is repeated. The magnitude of the leak is determined by collecting the water leaked out in a measuring jar for known interval of time
iii. The procedure in (i) & (ii) is repeated for leak positions 3 & 4 also.
iv. The procedure is repeated for simultaneous presence of leak positions 2 & 3.
v. The earlier holes created for leak positions are blocked using appropriated sealing agents.

Table 1: Experimental setup details

Part of the experimental set up	Details
Sump	5000 liter
Pump	Centrifugal Water Pump, 1 Hp
Suction & Discharge Sections	Flexi pipe
Total Length of Pipe	7.27 m
Pipe Diameter (Inside)	1.5”
Material of construction for pipe	PVC
Number of Pipe sections	5
Number of Orifice Plates used	4
Orifice diameter	0.5”
Number of flanges	8
Flange to flange assembly	4 nut(0.5”)-bolts for each assembly
Flange Material	Acrylic Sheet 8 mm thick
Flange diameter (outer)	4”
Gasket material	Rubber
Manometers	4 Inverted U-Tube Manometers

Table 2: Details of operating parameters

Experimental Fluid	Water
Manometer Fluid	Water
Flow Rate	0.307- 0.329 liters per sec
Temperature	30-35 ^{O}C
Leak position 2	0.915 m from 1st flange
Leak magnitude 2	1.1-1.85 ml per sec
Leak position 3	0.88 m from 2nd flange
Leak magnitude 3	0.55-0.6 ml per sec
Leak position 4	2nd flange assembly
Leak magnitude 4	1-1.35 ml per sec

IV. DEVELOPMENT OF ANN MODELS

The aim of the present work is to develop ANN model for estimation of leak position and its magnitude, for this the flow-rate & the four manometer readings are to be correlated with the leak position & its magnitudes. Thus there are five input parameters that are to be correlated with four output parameters. All the Artificial neural network models are developed using the experimental data generated [19] using elite-ANN© [20]. The typical schematic of architecture of artificial neural network is shown in figure 2.

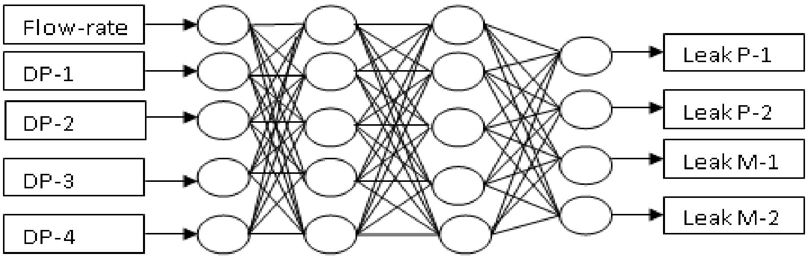

Figure 2: Schematic of Architecture of Neural network

The topology of ANN decides the arrangement of layers and the number of neurons in each layer. Since the accuracy of the ANN model depends upon the number of hidden layers and number of neurons in each layer, in present work two different topology of ANN are used in developing two ANN models Simple (S) & Complex (C). The details of the topology are given in table 3. The training data set comprising of 27 data points is used in developing the models whereas the validity of developed models is tested using 5 data points. The RMSE of models S & C is 0.3186 & 0.080 respectively. The comparison is carried out with the actual values and it can be said that both the models developed have excellent accuracy levels.

Table 3: Topology of the ANN model S & C

ANN model	No. of neurons				Data points		
	Input layer	1st Hidden layer	2nd Hidden Layer	Output layer	Train Set	Test Set	RMSE Train Set
ANN model Simple-S	5	5	5	4	27	5	0.3186
ANN model Complex-C	5	10	10	4	27	5	0.0800

V. RESULT AND DISCUSSION

Comparison between actual values of all the dependent parameters or output parameters and the predicted values obtained by using ANN models S & C is done for both the training as well as test data sets. Based on these comparisons of predicted values, the inference regarding the suitability of these models can be drawn.

Figures 3 to 6 show the graphs plotted between the actual & the predicted values obtained using ANN models S & C for training data set for output parameters; leak position1, leak position2, leak magnitude 1 & leak magnitude 2 respectively.

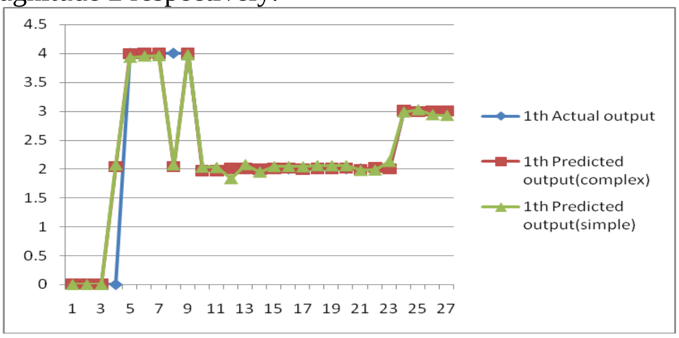

Figure 3: Comparison of predicted values for estimation of leak position 1 or output parameter 1 for training data set for C & S models with actual values

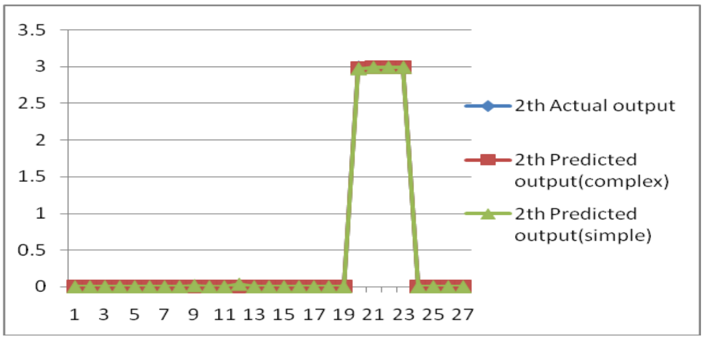

Figure 4: Comparison of predicted values for estimation of leak position 2 or output parameter 2 for training data set for C & S models with actual values

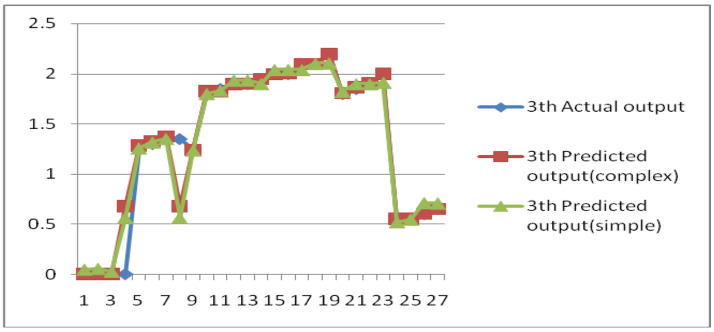

Figure 5: Comparison of predicted values for estimation of leak magnitude1 or output parameter 3 for training data set for C & S models with actual values

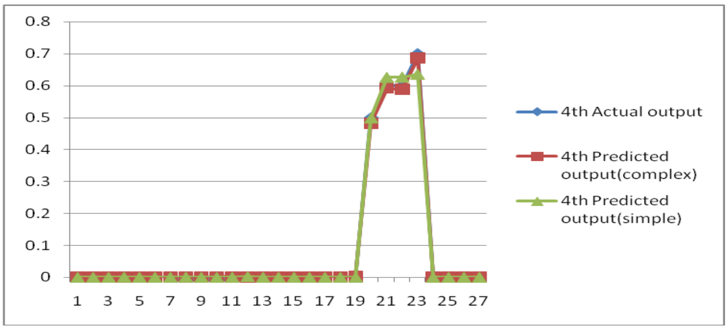

Figure 6: Comparison of predicted values for estimation of leak magnitude2 or output parameter 4 for training data set for C & S models with actual values

Similarly figures 7 to 10 show the graphs plotted between the actual experimental values & the ANN predicted values obtained using models S & C for test data set for output parameters; leak position 1, leak position2, leak magnitude 1 & leak magnitude 2 respectively.

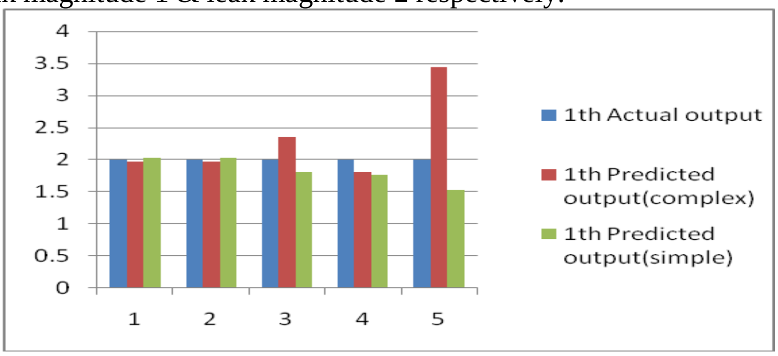

Figure 7: Comparison of predicted values for estimation of leak position 1 or output parameter 1 for test data set for C & S models with actual values

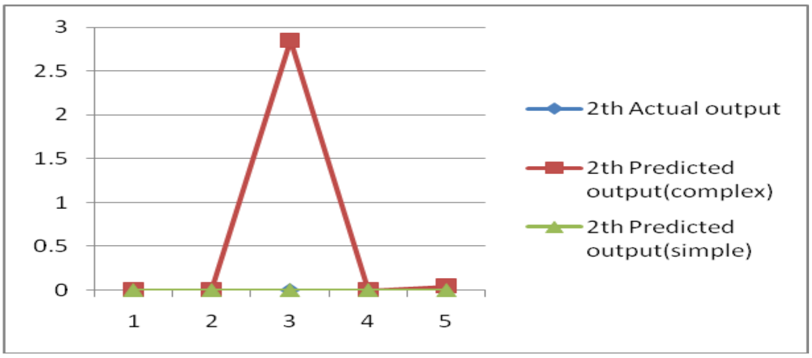

Figure 8: Comparison of predicted values for estimation of leak position 2 or output parameter 2 for test data set for C & S models with actual values

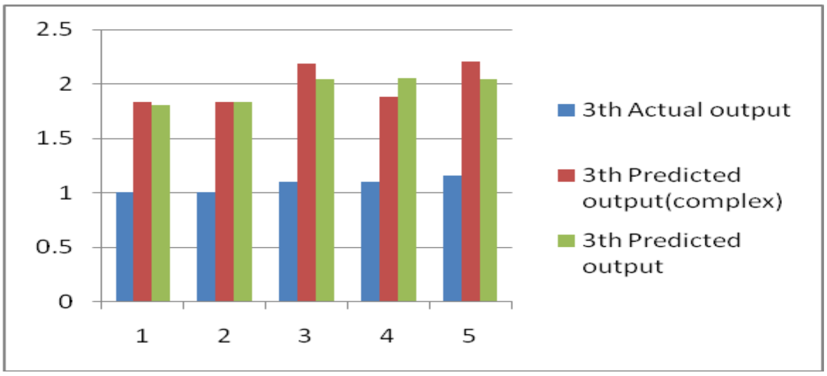

Figure 9: Comparison of predicted values for estimation of leak magnitude1 or output parameter 3 for training data set for C & S models with actual values

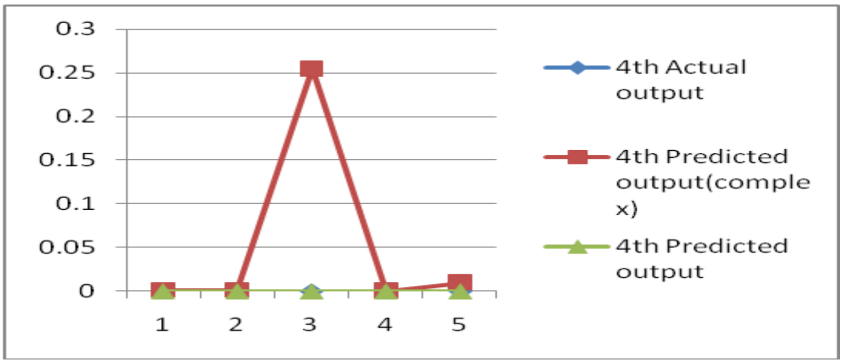

Figure 10: Comparison of predicted values for estimation of leak magnitude2 or output parameter 4 for training data set for C & S models with actual value

It can be seen from all these graphs of comparison for actual & predicted values that both the ANN models S & C developed in present work have good accuracy levels. It can also be seen from these graphs that the accuracy level of ANN model S is marginally better as compared to model C for test data set.

VI. Conclusion

The main objective of the present work was to explore the possible use of ANN in leak detection in pipelines transporting fluids. For this purpose, experimental data was generated for normal and leak conditions for flow of water in a pipeline. Holes were created artificially for generating leak conditions at three locations of the pipeline. Pressure drop across the orifice placed at four positions in the pipeline was recorded for these normal & leak conditions. ANN models S & C with different topologies were developed that correlated flow parameters like flow rate, pressure drop at four different locations with the leak position & its magnitude. The accuracy of prediction of these models were 0.3186 & 0.080 respectively. Based on the results and discussions, it can be said that both the ANN models developed in the present work are accurate in predicting leak parameters like position of the leak & magnitude of the leak, barring one or two situations. It can be thus concluded that, ANN can be effectively employed in developing models that can correlate the data which may be available for normal & faulty conditions.

VII. FUTURE SCOPE

The present work has demonstrated the potential of the ANN which need to be explored further by conducting experiments with the data generated from a larger & complex network of pipeline like in industries. There are usually provisions in chemical process industries for measurement of the pressure drop across various sections of the pipeline network. There may be previously reported cases of leakages with their magnitudes & these data can also be used along with the data pertaining to normal flow conditions in developing ANN models, which can be effectively used for detection of leak that may occur in pipeline.

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REFERENCES

[1] Anderson, J.A. 1999. “An Introduction to Neural Networks (Prentice-Hall of India, Pvt. Ltd New Delhi),”
[2] Rumelhart, D.E. and McClleland, 1986. “Back Propagation Training Algorithm Processing,” M.I.T Press, Cambridge Massachusetts.
[3] Baratti, R., Vacca, G., Servida, A. 1995. “Neural networks modeling of distillation columns,” Hydrocarbon Processing, 35-38.
[4] Pandharipande, S. L., Mandavgane, S. A., 2004. “Modeling of packed column using artificial neural networks,” Indian J Chem Tech, 820-824.
[5] Pandharipande, S.L., Badhe, Y.P. 2003. “Unsteady state heat conduction in semi infinite solids artificial neural networks,” Chem Eng World, 82-84.
[6] Pandharipande, S.L., Badhe, Y.P. 2003. “Prediction of mass transfer coefficient in downflow jet loop reactor using artificial neural network,” Indian Chemical Engineer, 256-258.
[7] Zamankhan, P., Malinen, P., Lepomaki, H. 1997. “Application of neural networks to mass transfer predictions in a fast fluidized bed of fine solids,” AIChEJ, 1684-1690.
[8] Pandharipande, S. L., Agarwal, R.S., Gogte, B. B., Badhe, Y. P., 2003. “Detergent formulation by artificial neural network,” Chem Eng World, 78- 80.
[9] Pandharipande, S. L., Bhaise, A., Poharkar, A., 2004. “Steam tables: Using Artificial Neural Networks,” Chem Eng world, 50-54.
[10] Pandharipande, S.L., Badhe, Y.P. 2004. “Artificial neural networks for Gurney- Lurie and Heisler Charts,” J Inst Eng, 65-70.
[11] Fan, J.Y. Nikolau M. & White, R.E. 1993. “An approach to Fault diagnosis of chemical processes in Neural networks,” AIChE, 82-88.
[12] Hoskins, J.C. Kaliyur, K.M. & Himmelblau, D.M. 1991. “Fault diagnosis in complex chemical plants using artificial neural network,” AIChEJ, 137-141.
[13] Watanabe, K. M., Matsuura Abe, I., Kubota, M. and Himmelblau, D. M. 1989. “Incipient fault diagnosis of chemical processes via artificial neural networks,” AIChEJ, 1803-1812.
[14] Belsito, S. & Banerjee, S. 1998. “Leak detection in liquefied gas pipelines by Artificial neural networks,” AIChEJ, 2675-2688.
[15] Pandharipande, S. L. Badhe, Y.P. 2003. “ANN for leak detection in pipelines.” Chem Eng World, 70- 72.
[16] Ignacio, Barradas, Luis E Garza, Ruber Moralas-Menedez, Adrana Vargas-Martinez 2009. “Leak detection in a pipeline using ANN” CIARP pp. 637-644.
[17] Sukarno. P, Sidarto K A, Trisnobudi A, Setyoadi D I, Darmadi, Nor Hidayatullah. 2007. “Identification of oil pipeline leaks using ANN method”. Proceding symposium nasional IATMI. Pg. 25-28.
[18] Daoudi A, Benbrahim M & Benjelloun K. 2005. “Proceedings of world academy of science, engineering and tech”. Vol. 4 Pg. 1-3.

[19] Rai, Prashant. 2013. Project report submitted to Rashtrasant Tukdoji Maharaj, Nagpur University, Nagpur for award of B.Tech degree.
[20] Pandharipande, S.L., Badhe, Y.P. elite-ANN©. 2004; ROC No SW-1471 India.

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