An Investigation into the Use of Artificial Neural Network to Monitor and Detect Leakage Point(s) along a select Pipeline.

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ABSTRACT

The problem of incessant leakages in oil pipeline from intentional or natural accident with its untold results of pollution, loss of lives from fire outbreak, and reduction in production output, spurred the burning desire to proffer a novel solution with the use of artificial neural network as a tool to detect oil leakage, pin-point the leakage spot and provide useful communication link with the supervisory control and data acquisition (SCADA).

The data used for this work was obtained from Atlas Cove, Lagos, Nigeria under the NNPC-PPMC Mosinmi Area Depots. Pressure of oil flowing in pipelines between Atlas Cove Depot, Lagos and Mosinmi Area Depot in Ogun state, Nigeria were used for the training of artificial neural network.

The data was randomly picked and divided into training data (50 constants), validation data (50 constants), and testing data (50 constants) as contained in the neural network training algorithm. The best network architecture that is, a four layer neural network (20-20-15-10) obtained from trials for this model was used. The use of graphical user interface, a tool in MATLAB®, makes the analysis easy and interactive.

Artificial neural network (ANN) approach to solving this identified oil leakage problem gives satisfactory results as the error between the ANN output and the target is very tolerable being 0.000566069 with a goal of 0.01. This could be implemented physically as an artificial intelligence unit in the monitoring of oil pipeline networks.

(Keywords: pipeline leaks, pipeline right of way, oil flow pressure, artificial neural network, pipeline model)

INTRODUCTION

The most popular way of transporting petroleum products is by the use of pipelines. The use of pipelines eases the movement of petroleum products from one location to the other. The distances covered by these pipelines are in thousands of miles passing through cities and villages. Some pipelines are laid overhead when passing through frost prone areas. There is no denying the fact that pipelines have become indispensable occupants of especially dedicated land areas in Nigeria.

However, as beneficial as petroleum products are to us as man, damages often occur to pipeline networks as a result of factors ranging from lack of proper maintenance of the network, ageing of the pipeline networks, pipeline vandalization, and accidents. Once there is any damage to the pipeline(s) by any form, leakages often occur which usually cause harm to both humans, animals, and the environment.

In October 17, 1998 – a pipeline explosion occurred at Jesse in the Niger Delta region of Nigeria, killing about 1,200 villagers, some of whom were scavenging gasoline, so far the worst in the history of pipeline vandalization in Nigeria [1].

In May 12, 2006 – an oil pipeline vandalization or rupture occurred outside Lagos, Nigeria killing around 200 people. Year 2000 is the worst hit where three different pipelines vandalization led to explosion that killed hundreds of people [7]. Ijegun pipeline explosion occurred in May 16, 2008.

The loss of human lives, damages to the natural habitat of plants and animals due to pollution, developing a cheap model for pipeline monitoring, and inability of relevant authorities to respond fast to cases of pipeline vandalization due to manual methods of monitoring pipelines leak points in Nigeria are the motivating factors responsible for this research work.

The rest of the paper contains sections such as; description of the pipeline network, the existing technologies to protect pipeline, artificial neural network design, ANN layer explained, importance of Levenberg-Marquardt algorithm, results and discussion, conclusion, and recommendation.

DESCRIPTION OF THE PIPELINE NETWORK

The pipeline network segment under consideration is that which links Atlas Cove depot in Lagos state, Nigeria to Mosinmi depot in Ogun state, Nigeria under the NNPC/PPMC Mosinmi Area Depots. The pipeline covers a distance of 45.7km. The method presently being used in monitoring of this pipeline is manual as pipeline guards still patrol the network once there is a pressure drop in the flow of oil along the pipeline. The exact location of leak(s) cannot be ascertained because there are no installations of modern monitoring equipment along the pipeline. Security agents detailed to the monitoring of the pipeline usually rely on information from the surrounding communities as regards the state of the pipeline.

Millions of dollars' worth of petroleum products are being lost on a daily basis resulting chiefly from the activities of vandals who are so sophisticated in their operations in order to cover their tracks.

FLOW EQUATION

The equation for a typical steady state isothermal liquid flow in a pipeline is [11]:

$$Q_1 = C_1 \times x\, 10^6 \sqrt{\frac{1}{f}}\, d^{2.5}\, \frac{[P_i - P_d - C_2 G (h_i - h_d)]^{0.5}}{\Delta L G} \quad \textbf{(1)}$$

where, Q_1 = flow rate (turbulent region)

f = friction factor
d = pipe internal diameter
P_i = inlet or upstream pressure
P_d = downstream or outlet pressure
C_2 = Constant
G = specific gravity of fluid
h_i = upstream pressure
h_d = downstream elevation
ΔL = pipe segment length

EXISTING TECHNOLOGIES TO PROTECT PIPELINES

Some of the technologies involved in the protection of pipelines took the form of manual monitoring (that is walking the pipeline), satellite monitoring, and the use of security cameras. Modern technology that is commonly being used to protect pipelines is the one that uses computers [8]. This computer arrangement accepts information from the field related to pressures, flow rates, and temperatures to estimate the hydraulic behavior of the product being transported. Estimation is done, results compared to other field references to detect the presence of anomaly or unexpected situation, which may be related to a leak.

ARTIFICIAL NEURAL NETWORK DESIGN

Artificial neural network is a network developed to emulate biological neural networks. ANN is extremely simple abstractions of biological neurons, realized as elements in a program or perhaps as circuits made of silicon.

Networks of these artificial neurons do not have a fraction of the power of human brain, but they can be trained to perform useful functions [8].
Artificial neural network is a brain mesh network.

Neurons are believed to be the basic units used for computation in the brain. In neural networks, connections are important. Each neuron in the brain has the order of hundreds or thousands of connections to other neurons, making the total number around 10^{14} or 10^{15}. This is fewer than the number we would get if every neuron connected is considered in relation to the size of the brain, a neuron connects directly to only a small fraction of other neurons [2, 9].

<u>ANN layer explained</u>

A four-layer neural network was used for this work. After the input, the hidden layer consists of three layers. In the first layer, the transfer function was 'tansig'. The second layer transfer function was also 'tansig'. In the third layer ‘purelin’ function was used and in the fourth layer, ‘purelin’ was also used as the transfer function [5].

Neuron(s) Used

The neurons in the architecture were generated from the algorithm for the network. 20 neurons were applied in the first hidden layer.

20 neurons were also used in the second hidden layer. The third hidden layer consists of 15 neurons and the fourth layer has 10 neurons in its layer.

The type of training used was supervised learning and data fed is termed training set. The method used for adjusting the weights for this problem is “back-propagation” [3].

Data used were divided into; training data, test data, and validation data. During training a relationship is established between the actual past results which serve as the input data and the corresponding pipeline desired values that represent the targets data. For all these data, pressure in bar is considered throughout.

The input pressure data ranges from 40.8bar to 42.84bar while the target pressure ranges from 37.74bar to 40.8bar. These values were normalized to -1 and 1 for better neural network handling.

The network output is converted back to the normal input unit using a reverse function in the back-propagation algorithm.

BACKPROPAGATION ALGORITHM

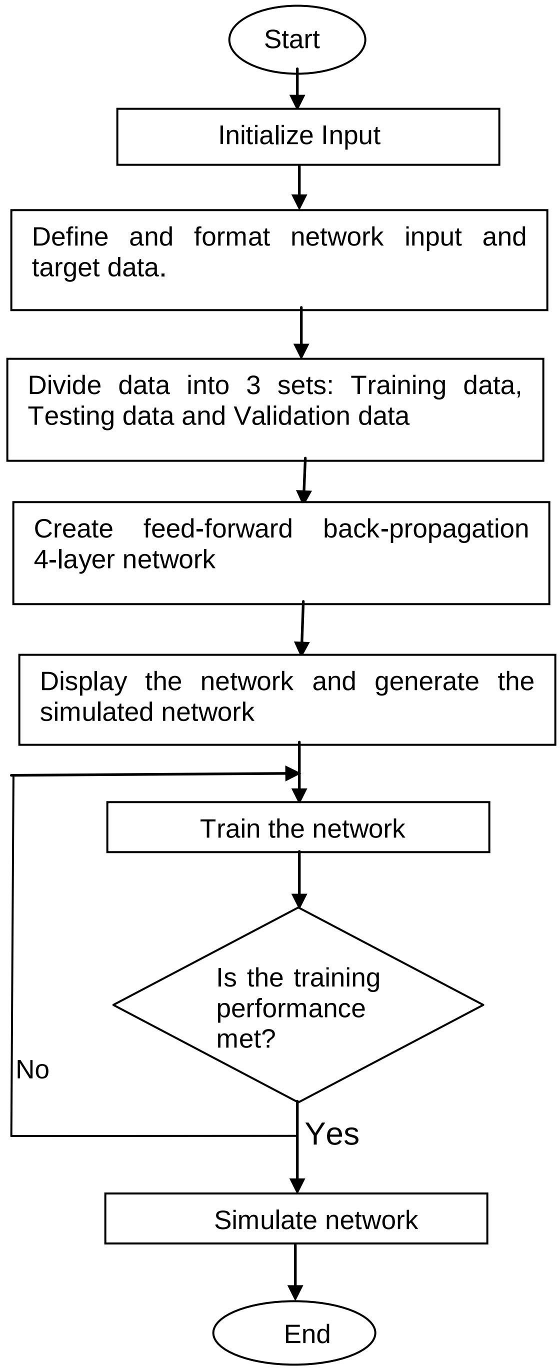

Figure 1: Artificial Neural Network Flowchart.

IMPORTANCE OF LEVENBERG-MARQUARDT ALGORITHM TO THIS WORK

Since the performance index of this work's neural network training is the mean squared error, Levenberg-Marquardt algorithm which is a variation of Newton's method that was designed for minimizing functions that are sums of squares of other nonlinear functions was used.

This algorithm appears to be the fastest method for training moderate-sized feed-forward neural networks as we have here. It also has a very efficient MATLAB implementation, because it has a built-in function for solution of matrix equation [3, 4].

RESULTS AND DISCUSSION

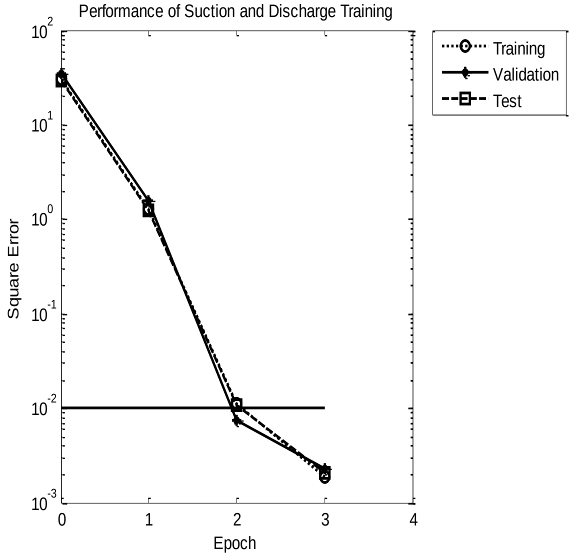

Figure 2: Training, Validation, Test Curves.

The iteration converges at the 3rd epoch indicating the uniqueness of the Levenberg-Marquardt training algorithm in terms of fastness. The performance goal was met at epoch 3 with a mean square error of 0.000566069 for a set goal of 0.01 as displayed in Matlab® R2007a version's window below:

TRAINLM-calcjx, Epoch 0/300, MSE 45.835/0.01, Gradient 85.4153/1e-010
TRAINLM-calcjx, Epoch 3/300, MSE 0.000566069/0.01, Gradient 0.220226/1e-010
TRAINLM, Performance goal met.

REGRESSION CURVE

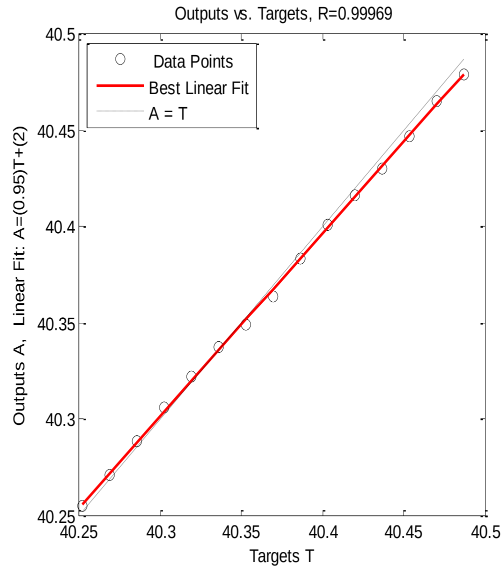

Figure 3: Regression Graph.

The regression curve above shows that the neural network output developed responded very well with the various output-target pairs (Table 1) during training. With 0.99969 regression value, it shows that the degree of association (relatedness) and corresponding changes of output-target pair is 99.9%, which is excellent. The sample of the output-target pair is shown in Table 1.

Table 1: Output-Target Pair for Pressure Values between 40.0000bar and 40.1895bar.

Output-Target Pair	
ANN OUTPUT PRESSURE(bar)	**TARGET PRESSURE(bar)**
40.0001	40.0000
40.0132	40.0134
40.0273	40.0268
40.0410	40.0402
40.0549	40.0536
40.0691	40.0670
40.0824	40.0804
40.0951	40.0938
40.1097	40.1072
40.1260	40.1206
40.1372	40.1340
40.1474	40.1474
40.1626	40.1608
40.1773	40.1742
40.1894	40.1876

LEAK LOCATION DEMONSTRATION

Table 2: Leak Demonstration Data

LEAK DEMONSTRATION DATA		
INPUT PRESSURE (bar)	**ANN PRESSURE (bar)**	**DISTANCE (km)**
40.0001	40.0001	1
40.0132	40.0132	2
40.0273	40.0273	3
34.0410	40.0410	4
40.0549	40.0549	5
40.0691	40.0691	6
40.0824	40.0824	7
36.0951	40.0951	8
40.1097	40.1097	9
40.1260	40.1260	10
35.1372	40.1372	11
40.1474	40.1474	12
40.1626	40.1626	13
40.1773	40.1773	14
40.1894	40.1894	15

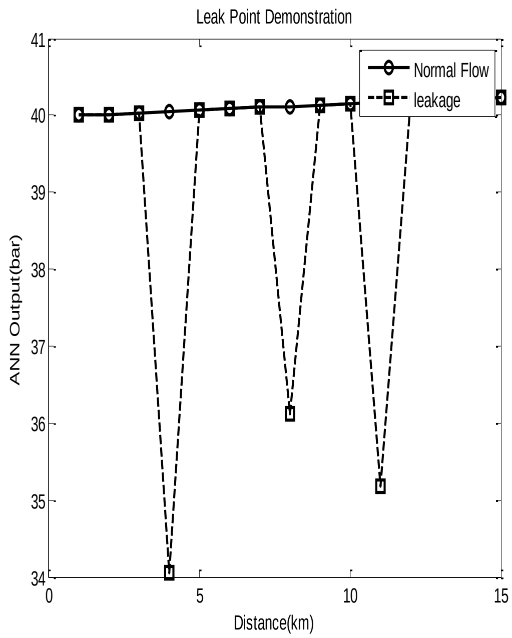

Figure 4: Leak Point and Magnitude Curve.

LEAK LOCATION DEMONSTRATION EXPLAINED

A good leak detection technology should be able to detect leak(s) of about 3 gallons of maximum flow within 15 minutes or less. Since 40bar is the maximum pressure at which premium motor spirit (PMS) is transported along the pipeline right of way, 8% of 40bar is 37bar.

Therefore, a pressure of 37bar is the critical pressure point used to determine leaks. That is, any pressure that is less or equal to 37bar indicates leakage condition along the pipeline transporting PMS for the present pipeline being considered.

The location of leak along the pipeline as well as the magnitude of the leak is displayed in the figure above. The artificial neural network output is compared with the pipeline pressure state each time oil flows in the pipeline.

For a PMS (Premium Motor Spirit) flow between Atlas Cove depot, Lagos and Mosinmi Depot in Ogun state, Nigeria, the pipeline length is 45.7km. This length is scaled to ratio 1:3.1 for better MATLAB® handling of the data. In other words, 1km on the graph translates to 3.1km on site. Now, once there is any pressure difference between the ANN output and the current flow pressure, the magnitude of the pressure as well as the exact point of pressure deviation is displayed as shown in Figure 4.

The pressure deviation which translates to leak points for the sample above occur at 4km (12.4km on site) with a magnitude of 34.0410bar , 8km(24.8km on site) with a magnitude of 36.0951bar and 11km(34.1km on site) with a magnitude of 35.1372bar, respectively.

CONCLUSION

Artificial Neural Network could be used to monitor pipeline, interpret the data and provide an important leak information as well as leak(s) exact location(s). ANN is fast with very small mean square error.

RECOMMENDATIONS

Artificial Neural Network should be incorporated as an integral part of pipeline monitoring system with Supervisory Control and Data Acquisition (SCADA). Further research work should consider pipeline that is subject to constantly changing temperature, multiple pipeline networks and effect of soil texture on leak detection.

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