Leakage Detection in a Gas Pipeline Using Artificial Neural Networks and Smart Alerting using Internet of Things

Chaithra- ckulal22@gmail.com
Deekshitha-sdeekshitha258@gmail.com
Department of Computer Science and Engineering
Alva's Institute of Engineering & Technology

***Abstract*— In this paper, a neural network-based method for leakage detection of a gas pipeline by using gas flow pattern is proposed. The pipe is divided in several segments and each segment is modelled by considering input/output pressure of the gas flow. The idea is to use a computer network based on Internet of Things (IOT) phenomena to gather all the required information for detection of the leakage point. In order to process the acquired data from the pipeline, a neural network is used and trained.Safety, the elementary concern of any project, has not been left untouched by IoT. Gas Leakages in open or closed areas can prove to be dangerous and lethal. The traditional Gas Leakage Detector Systems though have great precision, fail to acknowledge a few factors in the field of alerting the people about the leakage. Therefore,a Gas Leakage Detector having Smart Alerting technique is used which involves calling, sending text message and an e-mail to the concerned authority and an ability to predict hazardous situation so that people could be made aware in advance by performing data analytics on sensor readings.**

I. INTRODUCTION

Sixty percent of energy in the world is from oil and gas resources. So, to make transport independent and more reasonably priced, pipelines were adopted as a more economical means of transportation. Pipelines today transport a wide variety of materials including oil, crude oil, refined products, natural gases, condensate, process gases, as well as fresh and salt water. In many cases, due to the longer lengths and the difficult runs of remotely located pipelines, physical access may be limited. There exists the potential damage risk in gas pipeline such as impact of internal and environmental issues, the wave of pressure, fatigue cracks, tensile strength, material manufacturing errors, e.g. these potential damage risks can lead to pipeline leakage which can cause explosion in it. Therefore, conducting a monitoring exercise on gas pipeline is vital. Fault detection in the gas transmission pipeline in particular the leakage detection plays a major role not only in safety and protection of the environment but also in economy of the projects. Leakage detection systems must be sensitive, reliable, accurate, and robust.

Leakage detection systems can be categorized into two major types: continuous and non-continuous systems. The non-continuous systems include: Inspection by helicopter, smart pigging, and even tracking dogs. Three approaches are possible to avoid leakage over continues system:

The first, internal on the basis of physical mode such as mass or volume balance method, pressure point analysis, statistical system, Real Time Transient Model(RTTM) based systems and Extended RTTM.

Second, external implementation based on hardware such as sensors changing impedance, the volume of capacitor, fiber optic cable, acoustic sensor, infrared for image processing.

Third Hybrid, the combination of first and the second for example acoustic analysis and pressure by balancing mass and volume.

The breakage starts from a pin-sized hole which can easily be detected by the means of instrumentation. For instance smart pig sends inside the pipe to detect welding effect and cracks of the sides using magnetic flux features and ultrasounds waves. This system is not only capable of detecting the leakages and hence presence of excess amounts of harmful gases and alerting through audible alarms but also, with the help of IoT, alerting the concerned authority about the condition before any mishap takes place through a personal call and message using GSM module, an e-mail about the details of the area using an Ethernet Shield. The Gas Leakage Detector System also sends the sensor reading to cloud so that analytics could be carried out on the readings for increasing the precision of the system.

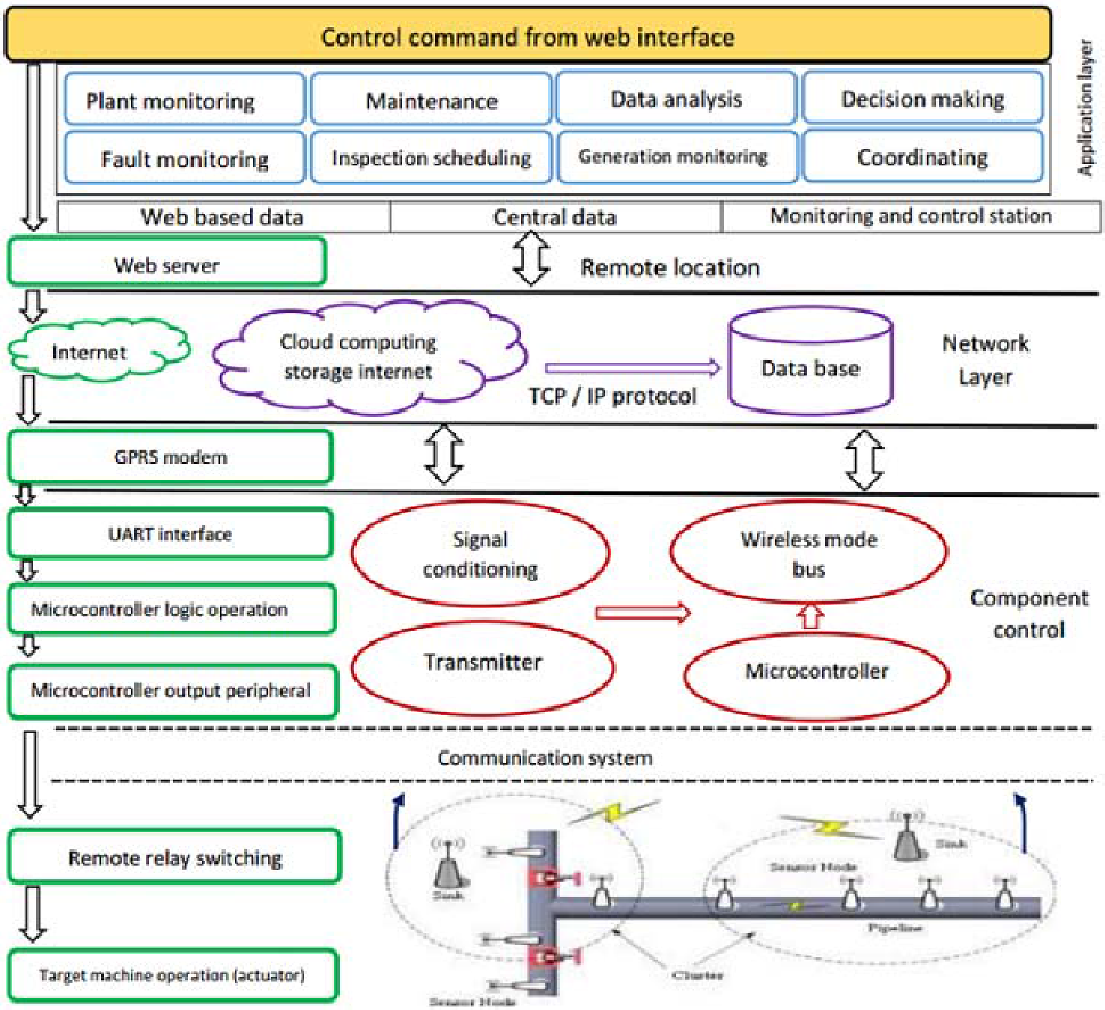

Figure 1. System architecture for leakage detection based on WSN and IOT

II. RELATED WORK

Gas Detectors have been in the market for a very long time and have been vastly used. They have wide range of applications and can be found in industrial plants, refineries, pharmaceutical manufacturing, paper pulp mills, aircraft and ship-building facilities, wastewater treatment facilities, vehicles, indoor air quality testing and homes. There is a plethora of devices available for matching the varying user requirements some of which are listed below:

A. Handheld EGD01

This Handheld EGD01 delivers high-sensitivity, and is easily adjustable for detecting a wide variety of combustible gases, including methane, propane, and butane. It is used by the building inspectors. As the name of the product suggests, it is a portable device and hence battery operated. It has both a sound and light alarm.

B. Amprobe GSD600 Gas Leak Detector

This is a portable gas detector for detecting gases such as methane and butane. It has a stainless steel probe. The probe allows the user to get into the hard to-reach places. It was designed for detecting gas within closed piping system and it has an audible alarm .

C. Analox Sensor Technology [5]

Safety of campus in terms of gas leakage detection in laboratory environment, canteens and other areas of possible gas leakage have been ensured by using of devices such as O2NE+, SAFE-OX+, A50, etc. provided by ANALOX Sensor Technology [5] and many more such devices by various other producers are used all around the world in all the campuses.

Regarding internal leakage detection system Pressure point analysis is based on the evaluation of pressure drop or thepressure profile measured at individual points. As an impulsive leakage brings up a characteristic change in the pressure drop, you can check whether the measured pressure drop, DP within a time period DT exceeds set thresholds. In addition to an upper threshold, a lower threshold for the pressure is also determined and if either one of these events occurs; the system triggers a leak alarm.

Real Time Transient Model or RTTM systems can compensate for dynamic changes. To do this, they make use of basic physical laws which the pipeline must obey:

The conservation of mass principle, which includes the density ρ, the time t, the flow velocity v and the pipeline location coordinates s

The conservation of momentum principle, which includes the flow velocity v, the time t, the pressure P, the pipeline location coordinates s, and the pipeline friction fs

The conservation of energy principle, which includes the enthalpy h, the time t, the density ρ, the pressure P, and the specific loss performance L.

These physical principles precisely describe the stationary and transient activity of the flow in the pipeline. Using these equations flow, pressure, temperature and density can be calculated and integrated in real time for each point along the pipeline. These trends are also known as hydraulic profiles and accurately predict the true performance along the entire pipeline.

Artificial Neural Network (ANN) methods are used to model the pipeline in cases where generating mathematical and analytical models are complex. ANN is an appropriate candidate for leakage detection by using classification and estimation function. ANN is a robust method for facing noise which is suitable for real-time usage. There are different approaches for the detection of pipes leakage based on ANN. Authors in [2], have used acoustic sensor and analyze it by ANN. In a way acoustic sensors are sensitive on magnitude or velocity of wave (leak signal) due to characteristics of sound signals which are classified and trained with ANN and it is used as an ANN input and features of the signal from leakage analysis under the pipe pressure. Such signal after passing a filter is classified in several voltage signals by different frequencies and in output leakage is detected.

Technologically point of view, WSN and IOT have attracted the interest of researchers whereas many industrial branches with different applications are used in the industrial WSN. Structure of IOT are three layers. Sensors, voltage and current transducers are placed in the first layer. Microcontroller which is needed for the processing and wireless communication along with the servers also locate in this layer. The Second one is the network layer which consists of real-time processed-data and the database. The third is the application layer including suitable web services for the designed basis data collection which is illustrated on graphical display for monitoring of plant performance and exist control to reduce the decision making period. The structure illustrates in Fig.1.

This paper presents a leakage detection method for gas pipeline based on Dynamic ANNs. For this purpose, wireless sensor network majored measure gas flow pattern use as the input signals for ANN. Multi layers of perceptron topology (MLP) were used for learning rules and offline training ANN including adjusting weights. The ANN was trained based on the error back propagation algorithm with partial derivatives. The input signals are dynamic neuron with delay time (ATDNN). The output signal is a certain value of identifying leakage specification considered as the input for leakage classifier to show whether the signal is a leakage or not. Fluid mathematical model was obtained from experimental data in real life pipeline. A computer network based on Internet of Things (IOT) phenomena was installed to aggregate all the required data to detect leakage points.

III. MATHEMATICAL MODEL

The dynamic equation of fluid along the pipeline is as

follow:

$$\partial Q/\partial t + gA\ \partial H/\partial z + \mu|Q|Q = 0 \quad (1)$$

$$b^2\ \partial Q/\partial z + gA\ \partial H/\partial t = 0$$

Where:

H is the pressure head (m)

Q is the flow (m3/s)

z is the length coordinate (m)

t is the time coordinate (s)

g is the acceleration of the gravity (m2/s)

A is the cross-section area (m2)

D is the pipeline diameter (m)

b is the speed of sound (m/s)

μ = f/2DA where f is the Darcy-Weissbach friction coefficient

One leakage may cause discontinuity at point z_i :

$$Q\ z_i = \lambda i \sqrt{H}\ z_i \qquad (2)$$

In a way that λi > 0 depends on orifice aria / discharge coefficient. A pipeline with n-1 leakage have n pair of the “equations (1)” with marginal conditions between each section of pipe as follow:

$$Q_b\ |z_1 = Q_a\ |z_1 + Q\ |z_1 \qquad (3)$$

In a way that Qa|zl and Qb|zl are the previous and the later ones and by having specified length of pipeline L and by supposing that the leakage is distributed alongside Z equally (Δz = L/n). Estimated partial derivatives from pressure and the flow is in a variable zone as follow:

$$\partial H/\partial z \quad H_{i+1} - H_i/\Delta z$$

$$\partial Q/\partial z \quad Q_i - Q_{i-1}/\Delta z \qquad (4)$$

In which index i regarding the variables in the beginning of part

i and marginal conditions for every section it’s as:

$$Q_i = \lambda i \sqrt{H_i} \ (5)$$

With substituting “equation (4)” in “equation (1)” we have:

$$\partial Q_i / \partial z = a_1(H_i - H_{i+1}) - \mu |Q_i| Q_i \quad (6)$$

$$\partial H_i / \partial z = a_2(Q_{i-1} - Q_i) - (\lambda i\text{-}1 \sqrt{H_i}) u_{ti}$$

Where:

H1 = Hri and Hn+1 = Hro as system inputs parametric constants a1 = gπr2n/L and a2 = b2L/gπr2n with n = 4 Uti = u (t − ti) is the unit step function associated with the occurrence time ti of the leak i. In case there is no equal distribution, Δz is variable and parameters a1 and a2 are have equal pressures both at inlet and outlet affiliated to the gap between the leakages. In such a case H1 and H5 of a pipeline and Q1 and Q4 are measured flows all over the pipeline. Toward this four leakages in marginal condition is considered Fig.2.

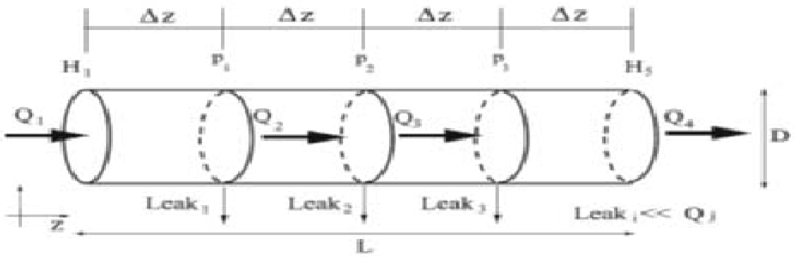

Figure 2.Distributed model of pipeline

IV. PROPOSED SCHEME

The proposed scheme of algorithm is illustrated in Fig.3. In the proposed method there is an ANN that identifies place of leakage along the pipeline. Time delay signals Q1 and Q4 are inputs of dynamic ANN which enhances the performance of ANN. The identification algorithm is divided into four parts.

Two wireless ultrasonic flow meters were installed on the beginning and at the end of the modelled pipe generating data for training the neural model. The measurement of the inlet and outlet flows with the delayed-time are provided which they are the inputs of dynamic ANN. Discontinued model of a pipeline with length L is illustrated in Fig.2. The modelled pipe is divided into n sections with install deterministic observers upper the pipeline. It is created 2^n operational states. The accuracy of identified leakage depends on to the number of divided sections of pipeline. The bigger n would be the more accuracy. The set of $\{F_1(K), F_2(K), F_3(K) \dots F_n(K)\}$ is the states of n discontinued sections of pipeline and output of ANN becomes activated by hyperbolic-tangent. The amount of F (K) is from 0 to 1 that’s why a binary filter is needed for making binary code and the estimation of binary fault. The set of $\{F_1(Z), F_2(Z), F_3(Z) \dots F_n(Z)\}$ is the output of binary filter which have extracted the amount of 0 and 1 which in one side the binary to decimal converter block on the basis of simple digital rule, binary codes convert into a number that is the characteristic of operational state of pipeline. In other words the binary code of output filter goes towards the leakage estimation block which is the algorithm of the equation of the fluid dynamic. A leakage causes the discontinuation of “equation (2)” at point i. In a way $\lambda i > 0$ is dependent on orifice aria and discharge coefficient and it’s connected to flow and pressure of pipeline. $\lambda i \neq 0$ defines the leakage which is estimated from the sample of binary operational states. By analysis the behaviour of the dynamic patterns, the difference of the operational states are observed. Then in the leakage block magnitude classifier allocate the

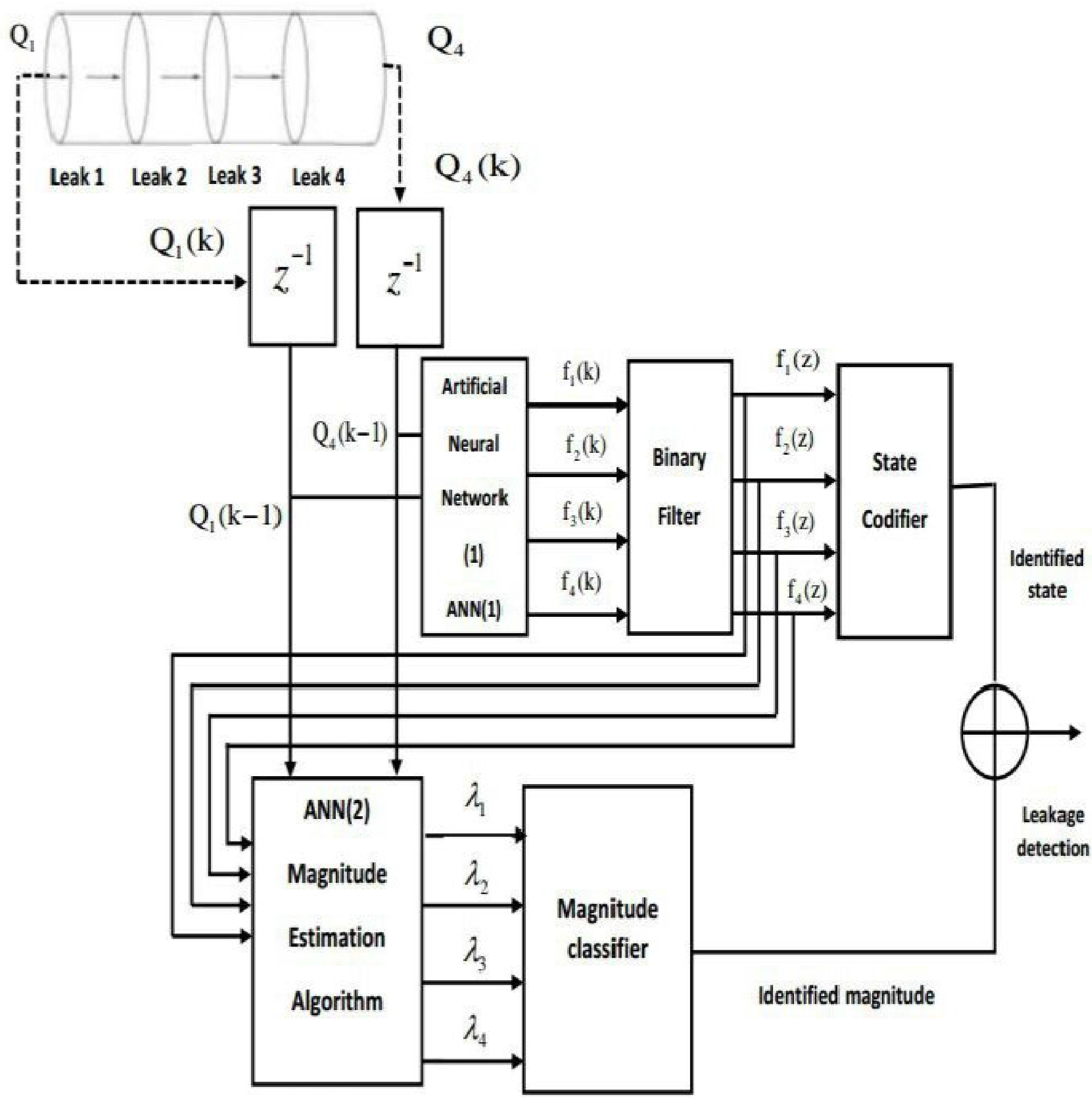

Figure.3. the structure of leakage detection scheme using ANN

amount of 0 and 1. As a result leakage and its place identify with combination of operational states and the magnitude of discharge coefficient The number of operational states that codes estimate depends on number of dividing sections of pipeline. Particularly, the pipeline is divided into four parts by the usage of two flow meters installed in inlet and outlet and three pressure gauge in the middle of modelled pipeline with 125 meters distance and there are sixteen operational states. Data transmits to microcontrollers by voltage and current transducers from the cluster heads which is equipped with GPRS/GSM module and internet protocol based on LEACH-TEEN routing algorithm which is event state because it is suitable for increasing the processors.

by using ANN on matlab is done by the following procedure:

As mentioned before, the wireless sensors were installed on the upper of the modelled pipeline aggregate changes in the flow and is being transmitted via Modbus TCP/IP to HMI interfaced Distribution Control System (DCS). Such data is taken from the location of South Pars Gas complex. Several tests are conducted.

First, there is no initial data in the ANN and new data is given to it and operational of ANN is observed.

Secondly, noise of “N” is added to the entering flow signal.

On the third attempt the changes of flow were increased in different sections of pipe and ANN with new data after changing in the discharge coefficient “λ” is trained again then the output is estimated the location of leakage accurately. In simulation the activity of leakage is displayed.

B. Simulation Results

Simulation results illustrate faults during train processing and ANN structure depends on delay of flow signal. The ANN which has excessive delay, performs better. As it was expected having too much data concerning dynamic characteristic helps to the ANN taking appropriate samples from patterns. Detection of fault index “Estimated fault states relative to all the real states” it is the sign of ANN performance. By using delay signal and existing dynamic in the train algorithm of transition respond there is no need to pipeline middle point’s data. In simulation more data will be obtained by dividing farther along the pipeline which improves the accuracy of leakage detection. In such approach estimation of leakage whereabouts is done by measurement of the input and output of flow and there is no need for the data of pressure and the amount of leakage. By analyzing the dynamic behaviour of patterns, the difference among states is identified. The ANN using time delay recognizes tiny faults and this peculiarity is effective on cost because it uses less time for training. Industrial IoT embedded device should be able to adapt to the measurement needs of the thing being monitored or controlled. The IoT can support continuous improvement and address previously unsolved problems to increase plant availability, safety, and reliability. By taking advantage of streaming data from sensors to quickly assess current conditions, recognize warning signs, deliver alerts and automatically trigger actions, Industrial IoT-based analytics solutions fundamentally transform identification and maintenance strategies.

VI. CONCLUSION

As can be seen there are different methods in leakage detection using ANN. The data analysis carried out by efficient neural network models could replace the human operator in the task of monitoring flow and pressure signal trends to warning the staff on the occurrence and inform the magnitude and location of the leakage. This methodology could be applied to monitor distribution networks of natural gas as well as industrial, commercial and residential gas pipelines in order to provide a safe operation and to avoid severe human health injuries caused by toxic gas leakages. Local control and monitoring is not economically reasonable for massive pipe transmission infrastructure. Thus using Wireless Sensor Network and Industrial Internet of Things are the most ideal and efficient approach for data aggregation and transmitting to control unit for the purpose of final decision making. A cloud-based control loop and Advanced Process Control (APC) monitoring system can be set up to monitor controls across the enterprise by an internal or external domain expert. With visibility and knowledge across sites, experts can alert and collaborate with site Subject Matter Experts (SMEs) and recommend actions when control benefit degradations are detected. Each site can benefit from earlier detection and faster resolution of problems afforded by a higher level of expertise focused on control performance. Approaches based upon remote and smart monitoring system in decision making with extensive, flexibility and automation in real-time architecture is the near future research to come.

REFERENCES

[1]Mohsen Rahmati , Honeyeh Yazdizadeh , and Alireza “Leakage Detection in a Gas Pipeline Using Artificial Neural Networks Based on Wireless Sensor Network and Internet of Things”, pp. 659–664, Springer-2009.

[2] Asmita Varma, Prabhakar S, Kayalvizhi Jayavel “Gas Leakage Detection and Smart Alerting and Prediction Using IoT ” SRM University, Kattankulathur, Chennai