INNOVATIVE SOLUTION FOR ASSESSING AND MONITORING UNDERGROUND PIPELINE SYSTEM BY SENSOR NETWORK

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ABSTRACT: Transportation of petroleum products like oil and gases for long distance is performed through pipeline for the economic and environmental reasons. In a pipeline based transportation, leakage and breakage are serious problems that cause material loss, economical loss, along with environmental pollution and loss human life. This The proposed work is presented in this paper is for the prevention of pipeline breakage not for the detection leakage; the system mainly enlighten the methodology of early warnings to predict the possibility of breakage or leakage might occurs in the gas lines by monitoring some line safety parameters. The early warning system could broadcast alert signals to the pipeline monitoring station which helps the nearby agency to take immediate preventive measures. There are many environmental factors that badly affect the underground pipeline system. The factors are corrosion, ground disorder, internal and external stress exerts on pipeline and soil displacement so forth. The proposed system utilizes attractive features of flexiforce force sensor technology as a monitoring tool, where, the comparison of measured force with the specified yield strength of the pipeline is the core work of the proposed system which can achieved by using an advanced platform of microcontroller.

Keywords – **Pipeline leakage detection techniques, early warning system, yield strength formula, force measurement, simulation.**

I.INTRODUCTION

The development of human civilization attained its space with various difficulties. The beginning from human civilization merchandize are intentionally transported. Transportation is considered as one the basic need of trade and exchange. Because many of the resources such as fuels, food items, raw materials are accessible on specific spots or plentiful only in few regions on earth. So dispersion and sharing of assets should essential for adjust the deficiency. For transportation, people who depends different modes according to better convenience, speed, safety, diminish labour, cost and so forth. The diverse mode of transport are air, water and land transport which incorporates rail, street and pipeline transport. The huge improvement occurs in the transportation and distribution network seeking the most secure and comfortable mode especially transporting product such as petroleum, gas and crude. For transporting products in a long distance one might adopt pipeline as a channel of transport. Also, while considering the nature of some product to be transported one mainly prefer underground pipeline due to some economic and safety reason. There are several factors that destructively affects underground pipeline which are leakage, breakage, corrosion so forth. The safety of the pipeline is very important and at the same time ensure the safety of the pipeline had face many challenges. Now a days, there are various techniques are implemented for monitoring the underground pipeline those are mainly put forwards sensor network based leakage detection.

II. LEAKAGE DETECTION SYSTEM

Leakage detection is the most common cause of pipeline accident. Now a days many systems are implemented and executed for the governance of underground pipeline safety , which are mainly comes under public sector some of them are comes under private sector. The government always take serious attention to ensure the safety of the pipeline transportation especially it deals with economically prior products such as gas, oil, petroleum so on. There are various techniques adopted for real time pipeline monitoring. Wireless sensors offers more advancement of technology in various fields, mainly, pipeline monitoring systems adopts the features of wireless sensor network instead of using wired sensors because it is more beneficial. Zhi Sun et al [1] introduced a wireless sensor network based underground pipeline monitoring system which works on the principle of magnetic induction. In the operational framework, sensors were placed both inside and outside of the pipeline to monitor the pipeline and localize the leakage. MISE-PIPE enhanced accurate detection and localization with effective cost. MISE-PIPE can gather the information such as acoustic, vibration measurements, flow pressure measurements and soil property measurements for detecting and localizing the leakage.

A pipeline monitoring framework was developed by Imad Jawhar et al [2] by using a wireless sensor network. The sensors collects the data from the environment and GPS mechanism embedded in the sensor locate the position of the leakage. The sensors are deployed for sense the various parameters such as pressure, temperature, chemical composition and acoustic signal, whereas, the communication is possible through different sensor nodes classified as basic sensor node (BSN), communication relay nodes (CRN) and data discharge nodes (DDN). The data discharge node is communicate with the network control center through satellite

cellular technology. In order to increase the reliability of the system, the sensor nodes are placed in a shorter distance than its actual transmission range and which also offers more protection in sensors node failures. M.I Mohamed et al [3] investigated the attractive features of wireless smart sensor technology to enact monitoring, tracking and control of water distribution system; whereas, a potential of power harvesting techniques is also favorably rooted to monitor the pipeline network. Ali M Sadeghioon et al [4] designed wireless sensor network for monitoring underground water pipeline; the system is efficient for detecting the leakage occurs along in the entire pipeline network. The sensor nodes have a data gathering and processing unit, then the signal is transmitted through a transmission unit where microcontroller unit gathering the values from the sensor and process the data. Before transmitting the data, the power management unit managing the power regime of the sensor nodes. The advantages of the ideal pipeline monitoring sensor are low power consumption, non-invasive to the pipe, easy to install gathering useful data without extensive data processing or high sampling rate. M. Jayalashmi et al [5] implemented an enhanced underground pipeline leakage monitoring and detection system using wireless sensor network. Where, the water pipeline system is monitored by flow sensors and data gathering and processing is controlled by AT Mega 8 microcontroller and the wireless transmission would possible through ZIGBEE module, the detection system works based on the relative pressure change profile in the pipe.

Riny Sulistyowati [6] implemented a wireless mobile sensor network for detect and monitor the LPG gas leakage in gas pipeline, in which, the control of the system is accomplished by Fuzzy logic. TGS2610 mobile sensor is capable to sense the presence of LPG and these metal oxide semiconductor sensor is also suitable for the detection of toxic and explosive gases. The electrical resistance of the sensor is decreased when contact with the LPG that means which has low conductivity in free air. F.A Batzias et al [7] framed a reliable leak bio-detection system for the natural gas pipelines. NG leakage surveillance can achieved through biosensors and the robust selection of the sensor was done by Fuzzy Multicriteria Analysis [FMCA]. This biosensor based leakage surveying approach is adopted in an NG pipeline network in Greece.

Qingmin Hou et al done an experimental work of leakage detection in gas pipelines using FBG strain sensor [8]. This work portrayed, FBG strain sensor that detect the pressure within the pipe by sensing the hoop strain. Where, the least square vector machine (LS-SVM) method was adopted to process the data which associate with leakage detection. A comparison of FBG strain sensor and conventional pressure sensor was successfully mentioned; comparing the signal from both sensors is helped to examine the sensing ability of the two sensor when both sensors met pressure wave. LS-SVM technique used as a classifier for distinguish the no-leakage and a leakage conditions. E. Tapanes et al proposed a fiber optic sensing solutions of real time pipeline integrity monitoring [9].The FOS technology offers high resolution and also it is not subjected to electromagnetic interference . The optical fibers have the ability to detect physical, chemical and mechanical parameters it is relevant for the pipeline monitoring includes stress and strain measurements, ground vibration monitoring, and, temperature and pressure measurements. An advanced Foptic^{TM} vibration sensor technology is depicted for measure dynamic and quasi-static strain levels. Daniele Inaudi et al [10] presented a long-range pipeline monitoring system based on distributed optical fibers where the sensing mechanism is corporates the theory of Brillouin and Raman scattering. The distributed fiber sensing offers to monitor 60 km of pipeline with a single instrument and its range is extended up to 300 km by optical amplifier. Different leakage detection technologies can successfully detect the leak occurs in the pipeline but the main drawback of the leakage detection techniques, is that, warning and control measures are taken only after the leak occurs. The proposing system is an early warning system measures the different factors that destructively affect the pipeline and predict the pipeline condition.

III. ASSESSING AND MONITORING THE SAFETY OF UNDERGROUND PIPELINE SYSTEM

3.1 Design of pipeline monitoring and early warning system

The proposed system is an early warning system it provide early warnings before chance of leakage or breakage occurs in the gas pipeline. The early warning system consists of monitoring sensor subsystem, data acquisition and transmission subsystem, data analyzing and warning unit. Underground pipeline disaster is normally happens due to variations in some environmental parameter and non-predictive incidents like corrosion, external force, pressure, ground vibration, landslide so forth. The proposed smart sensor system could continuously evaluating the security status of the pipeline by means of measuring acceleration of ground dislocations, forces exerted on pipeline and soil displacement.

3.2 Force measurement using sensor subsystem

The specialty of the proposed work is the accomplishment of advanced pipeline monitoring and early warning technique with smart force sensor network. To identify and measure the dis-alignments developed in the pipeline, force sensor is used. In this work, a commercial sensor technology named Flexiforce sensor technology; Flexiforce sensors are ultra-thin and flexible printed circuits can be acts as force sensing resistor in an electrical circuit. Here, strong FlexiForce sensors are mounted on the pipeline to monitoring the force or pressure exerted on the pipeline. The figure.1 shown a Flexiforce sensors and are functioning on the principle of piezoresistive property. These sensors can measure force between any two surfaces and are durable enough to stand in unfavorable environments such as different temperature, humidity, moisture so on. When the force sensor is unloaded, the resistance of the sensor is very high. But when a force is applied to the sensor, the resistance of the sensor decreases with force. Flexiforce load sensor can manufactured in different shapes according to their application and these sensor carries many advantages including a superior linearity, high accuracy, output is not area- dependent, suitable for high temperature force measurements and user-friendly.

Fig.1 FlexiForce force sensors in different shape

These FlexiForce sensors can works in PSOC (Programmable embedded System-On-Chip) background. System-On-Chip is an integrated circuit that integrates all components of an electronic circuit in a single platform. These components includes digital, analog, mixed-signals, processor, memory, GUI, radio frequency functions and other application related options.

3.3 Yield strength of a pipeline

Pipeline transport is the transportation of materials or goods through pipe. Commercial underground pipelines are made of different materials such as steel, cement, cast iron and plastic. The selection of the pipeline materials varies with the date of the pipeline was placed in service, the characteristics of the local terrain, the diameter and the pressurization requirements of the pipeline. Transportation pipelines are made of different materials so the yield strength of the pipeline is differing with different material and with the difference in thickness. Yield strength is the material property defined as the stress at which the material begins to deform whereas yield point is the point where non-linear deformation begins. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible. According to Barlow formula shown in equation.1, the test pressure

$$P=2St/D \quad (1)$$

Where **P**-test pressure in psig, **D**-specified outside diameter of the pipe in inches, **t**-specified wall thickness of the pipe in inches, **S**-allowable stress in psi, which depends on the pressure being determined utilizing yield or tensile depending on what is trying to be determined. It is clear that the maximum tensile or hoop stress allowed in pipe is approximately yield strength "S" or the Specified Minimum yield Strength "SMYS" of the pipe.

3.4 Aanalysis

This proposed pipeline safety system uses PIC16f877a microcontroller to process the data from the sensor network along with these controller some necessary software is used.

3.5 Data acquisition and transmission system

The automatic collection and efficient transmission of data is essential in the pipeline safety system. The sensor subsystem communicate with the external world through wireless technology. With the fast developments of the communication field, 4G communication increase the speed and flexibility of communication anywhere in the world.

3.6 Data analyzing and warning units

The analyzing and processing of data from the sensor subsystem is the core of the pipeline safety system. Data analysis is carried out by the help of computer system in the base station on the basis of theoretical research. After the analysis, warnings are carried out with the help of sound and light alarm when the pipeline bearing body reaches the threshold value. An LCD display is used in the monitoring station for display the different sensor outputs which indicates the environmental parameters of the pipeline and additionally a data backup system is added which improve the functionality of the early warning system.

IV. SIMULATION RESULT

Proteus is one of the most prominent simulation tool in industry. Proteus design tool is used for schematic capture, simulation and PCB layout design which is works in Windows. Proteus can be purchased in various configuration according on the size the design being produced and requirements for microcontroller simulation. Proteus supports Microchip technologies such as

PIC10, PIC12, PIC16, PIC18, PIC24 and dsPIC33 microcontroller. The proposed gas pipeline monitoring and early warning system is simulated using Proteus 8.0 simulation suite shown in Fig.2, these design tool is very compactable which uses PIC16f877a IC with a platform of embedded C-compiler.

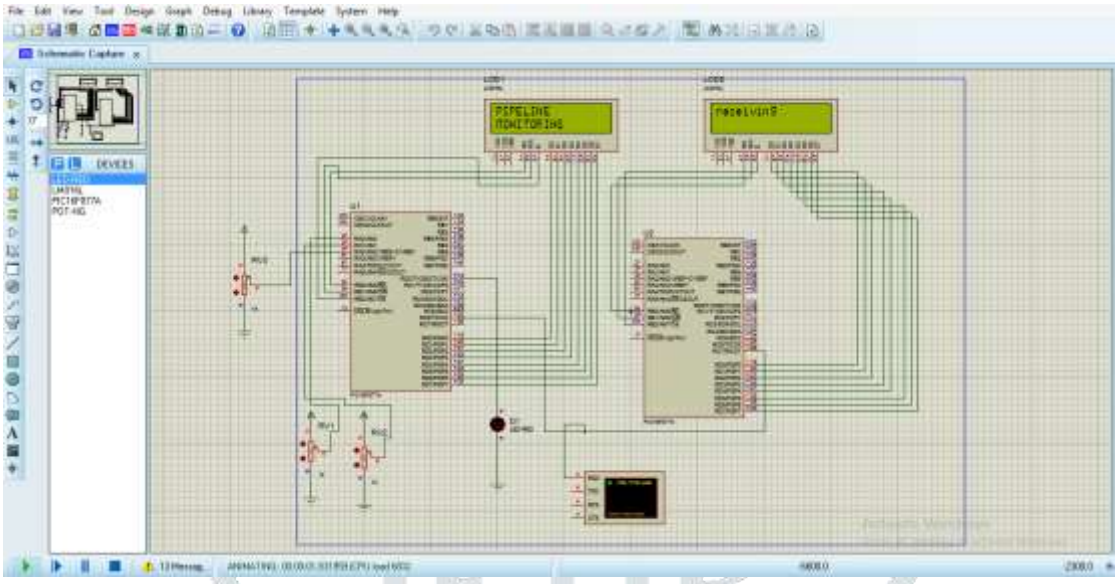

Fig.2. Schematic capture of a single pipeline monitoring unit

The proposed early warning pipeline security system was simulated using proteus software. When external force exerted on the pipeline is measured using force sensor network; the sensor output is replicated by potentiometer. Later the output from the sensor is transmitted through wireless network wirelessly transmitted to the receiving station; both the sensor unit and receiving unit is controlled by a microcontroller. In this work, a PIC16f877a microcontroller is used as processing device to manipulate the sensor data and its output is supplied to warning circuitry where different warning signals are generated. The controller also took backup of sensor data in necessary conditions. The backup system is a database, which records the range of force previously act on the pipeline in a particular location. The stored data is used to analyze the changes and damages that happen in future and able to produce necessary warning signal.

V. FINDINGS

- The Proposed pipeline security system predict the chance and force impact level of pipeline break with the help of sensor network.
- The main objective of the work is that, the system compared the exerted force act on the pipeline with the yield strength of the pipeline by formula.
- A backup system was introduced which improve the accuracy of the system by predict chance of breakage by adding the previous force impact level with the current force act on the pipe.

VI. CONCLUSION

A pipeline monitoring and early warning system is successfully simulated using Proteus 8.0 design suite. The specialness of this work is the projection of a smart sensor based network is named Flexiforce could introduced by Tekscan and these force sensor based monitoring system could exactly predict the chance of leakage or breakage in transportation pipeline. A most prominent PIC16f877a microcontroller and an embedded C-compiler are the programming platform of the proposed gas pipeline safety system. The sensor data backup and analyzing terms improve the accuracy of the early warnings and the entire system works on correlating the sensor output with the mathematical formula of yield strength of the pipe. The proposed system is not only used for gas line safety, it can be adopted for any pipeline system such as water pipeline, oil pipeline, sewage pipeline so forth.

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