International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 5 Issue 5, May 2018

ISSN: 2394-4404

Alternative Approach To Reducing Unaccounted Petroleum Products In Pipeline Systems

D. I. Egu
Petroleum Department, Madonna University Nigeria

A. J. Ilozobhie
Physics Department, University of Calabar, Nigeria

***Abstract:** The menace of unaccounted petroleum products in our pipelines for downstream and upstream petroleum product transportation poses a huge challenge when it is ruptured due to corrosion, vandalism and human errors. The pipeline grid network in Nigeria poses even more serious challenges when they pass through lonely terrains vulnerable to vandalism such as vegetation covered areas, swamps, creeks, and so on. Existing monitoring procedures has failed as pipeline leakages is still continually on the increase. Painfully, these are evidences of inefficiency in the operation, monitoring and management of the nation's pipeline system. The aim of this study to systematically carry out a comprehensive economic and technical evaluation of two leakage detection systems (LDS) namely fiber optics and negative pressure wave (NPW) based on pipeline DPR breakage report from April to July, 2017. Results of some critical economic profit indicators showed that the net cash returns (NCR) gave N1,686,473,000 and N2,117,214,936 for fiber optics and NPW. The payout time (PO) was quicker for NPW at a period of 0.69 month as against a much longer period of 2.64 months for fiber optics. The present value per naira (PV/N) gave 2.81 and 37.81 for fiber optics and NPW. The present value at 15% discount rate gave N1,274,387,000 and N1,725,732,000 for fiber optics and NPW. As a result of this, NPW is economically considered and from a technical point of view, it is also selected since both devices are good but on a long run, NPW would perform better. It is recommended that new strategies be adopted to reduce the menace of unaccounted products in our pipeline network system.*

***Keywords:** downstream, upstream, corrosion, fiber and payout*

I. INTRODUCTION

Pipeline is an efficient means of transporting fluids over long distances, from production locations to the markets. The safe and continuous operation of hydrocarbon pipelines requires the pipeline operator to have the most up-to-date information to hand regarding the condition of his pipeline (Donald, 2008). It is clear from current research that pipeline distribution network in Nigeria has failed. The most common causes of the failure are sabotage or vandalism and poor maintenance. In locations where the pipeline is relatively inaccessible, the principle and theory of standby of visual inspection is not an easy option to implement, and great damage may go undetected for considerable periods of time. The continued operation of hydrocarbon pipelines in these often rather inaccessible locations requires the ability to monitor the line condition remotely (Jun et at., 2013). The main elements that constitute a pipeline system are the Initial Injection Station, Compressor/Pump Stations, Partial Delivery Station, Block Valve Stations, Regulator Stations and Final Delivery Station. In general, pipelines can be classified in three main categories depending on its main purpose, such as Gathering pipelines or Flow lines, Transportation Pipelines or cross country pipelines and Distribution Pipelines. All these facilities face several vandalization due to lack of proper protection system by the operating companies. Onigbinde, (2014)

The menace of unaccounted petroleum products in our pipelines for downstream and upstream petroleum product transportation poses a huge challenge when it is ruptured due to corrosion, vandalism and human errors. The pipeline grid network in Nigeria poses even more serious challenges when they pass through lonely terrains vulnerable to vandalism such as vegetation covered areas, swamps, creeks, and so on.

Existing monitoring procedures has failed as pipeline leakages is still continually on the increase. In addition, the country's mass media had, on many occasions, carried sad news relating to the victims of kerosene explosions and other related home accidents caused by petroleum products vandalism and subsequent sale to the public (Mohammed et al., 2014). All these are evidences of inefficiency in the operation, monitoring and management of the nation's pipeline system. Thus this research is solely to carry out a comprehensive economic and technical evaluation of two leakage detection systems (LDS) such as fiber optics and negative pressure wave (NPW) for both downstream and upstream pipeline networks.

The objectives are:

- ✓ To carry out an economic and technical evaluation of both fiber optics and negative pressure waves.
- ✓ To carry out an economic comparative analysis of both fiber optics and negative pressure waves.
- ✓ Determination of critical economic indices as bases for choice of selection and suggesting possible technical reasons.
- ✓ To make appropriate recommendations were necessary.

II. STUDY LOCATION

In this report, the NNPC/PPMC pipeline system 2E between Port-Harcourt and Aba is considered as shown in figure 3.

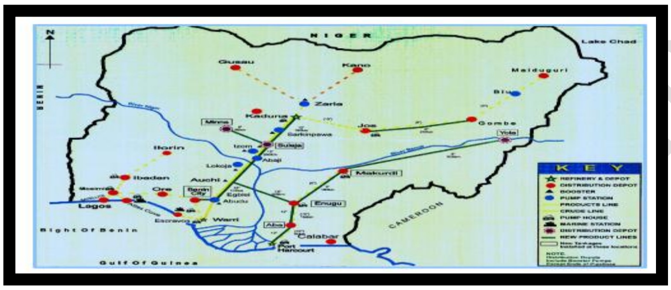


Figure 3: NNPC/PPMC pipeline system (Chukwuma et al., 2015)

NEGATIVE PRESSURE WAVE (NPW) SYSTEM

When a leak occurs in a pipeline, the pressure drops at the release location. This negative pressure wave propagates out from the location of the release in both directions and can be sensed by pressure meters at the ends or along the pipeline. The detection and confirmation of the negative pressure form the basis of this technology. Note that this technology is also (incorrectly) referred to as “acoustic” method (Chukwuma et al., 2015). As the initial pressure drop caused by a leak is short lived, it is necessary to sample the pressure data quickly e.g. 60 times per second. Thus dedicated data acquisition hardware is usually required.

There are two main negative pressure wave technologies in the market:

- ✓ The traditional technology derived in the early 80’s were hampered by bandwidth limitations for communications along the pipeline, thus a significant amount of processing was carried out locally. If a local processor detects a pressure drop larger than a preset threshold value, then an alarm event is sent to the master processor. By combining the different events and time stamps, a decision is made by the master processor about the presence of a leak. Since the threshold is often close to the normal noise level, a number of pressure drop events could be sent to the master processor when no leak is present. It results in either a lot of false alarms or significant desensitization by increasing the threshold.
- ✓ A new system was launched a few years ago. Capitalizing in the significantly improved pressure sensors and communication infra-structure, this technology samples pressure data at high frequencies e.g. 60 Hz and send them all to the central server for thorough analysis.

ADVANTAGES OF NEGATIVE PRESSURE WAVE (NPW)

- ✓ Cost effective to install.
- ✓ Not sensitive to flow measurement performance.
- ✓ Accurate leak location.
- ✓ Short detection time for all leak sizes.
- ✓ Largely insensitive to fluid properties such as viscosity and density.
- ✓ Unaffected by ambient conditions.
- ✓ Ability to detect thefts.

DISADVANTAGE OF NEGATIVE PRESSURE WAVE (NPW)

- ✓ False alarms if not tuned optimally.
- ✓ Normally requires custom hardware for high speed sampling and communication.
- ✓ Leak size is not a direct calculation.
- ✓ May miss a slowly developing leak.
- ✓ Pipeline equipment noise can result in higher leak thresholds in some pipelines

SYSTEM ARCHITECTURE & TYPICAL DEPLOYMENT CONFIGURATION

A Negative pressure wave system for a typical deployment of two parallel pipelines is shown in figure 2. In this simple example two pressure sensors are placed at each end of the pipeline and one pressure sensor is placed in the middle to create 2 segments. The length of each segment could range from 10 to 20 km, based on the fluid type and characteristics, and the operating conditions of the pipelines. The two sensors at each end are required to help the LDS system filter out noise arriving from outside the protected pipeline segments. Any field network can be used for the communication between the FSPs and the CC, and any communication network can be used for the communication between the CC, CMS, and the SCADA system. The Negative pressure wave system is built using the best-in-class industrial hardware and software components. The following is a description of each major component in the Negative pressure wave system. The length of pipeline segments varies from one project to another and depends on many parameters such as pipeline diameter, pressure, density, etc.

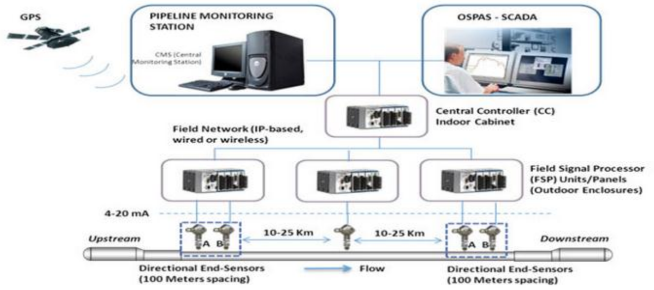


Figure 2: Typical Negative pressure wave Leak Detection System Configuration (Chukwuma et al., 2015)

OPERATING PRINCIPLE

It is widely known that the NPW (also known as acoustic) leak detection method is one of the latest and most powerful computational pipeline leak detection methods due to the fast response time (within a minute) and its ability to locate small and large leaks along the pipeline (Figure 3).

The operating principle for a negative-pressure/acoustic leak detection system is elegant and powerful. When a leak occurs, a drop in pressure will happen at the location of the leak. This causes pressure oscillations in the fluid which propagate as pressure wave signals at the speed of sound (and thus the term acoustic) through the fluid and away from the leak location in opposite directions. This system is obviously Pressure-based system and should not be confused with sonic/ultrasonic leak detection systems. It is referred to as acoustic since it is based on capturing and analyzing pressure waves traveling at the speed of sound.

By placing pressure sensors and associated communication equipment along the pipeline, the negative-pressure/acoustic leak detection system will detect the pressure transient wave associated with the pipeline leak. In the literature the traveling wave is often referred to as a "negative pressure" wave, or the "expansion" wave.

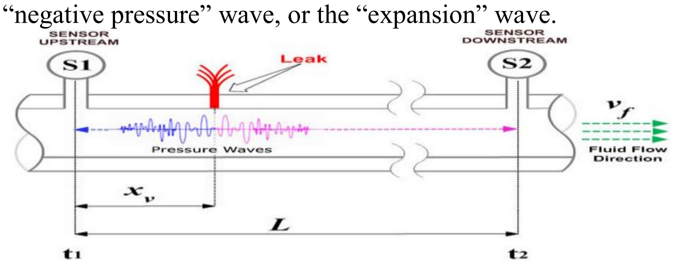


Figure 3: Basic Concept in a Negative-pressure Acoustic Leak Detection System (Donald, 2008)

As shown, when a leak occurs, the sudden drop in pressure at the leak location causes oscillations in the fluid pressure that propagate in both directions, upstream and downstream, at the speed of sound. Guided by the pipeline wall, High performance pressure sensors (designated as S1 and S2) installed at opposite ends of the protected pipeline segment will detect the drop in pressure and transmit the oscillating pressure signals to their corresponding Field Signal Processor (FSP) units/panels.

The FSP unit/panel is an integrated field-grade outdoor system which includes modules for data acquisition, signal conditioning, noise filtering, data processing and communication. The FSP unit first applies conditioning and filtering functions to separate leak signals from the background noise, and then applies advanced detection algorithms to determine if a leak "event" took place. The FSP units take into account fluid velocity (V_f), viscosity, pressure, and other pipeline specific parameters. Moreover, all leak events detected locally by the FSP units are time stamped using the GPS system.

The FSP units (two or more, based on pipeline length) then transmit the leak event(s) to the Central Controller (CC) unit, with the time stamp, which analyses events coming from the FSP units. By performing real-time computation and applying a variety of advanced algorithms, the CC declares if a leak has occurred or not, and it will then compute its location.

The location of the leak is computed based on the pressure wave propagation velocity in the fluid, by examining the difference between wave arrival times (t_1 - t_2) at the two opposing sensors (S_1 and S_2), and the length of the pipeline segment, as shown in the equation below.

$$X_V = \frac{L_{PIPE}+(T_1-T_2)V}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,
Xv = Distance from segment end to leak location
L_{PIPE}= Length of this pipe segment
v = Sonic velocity in the fluid
t_1= Detection time at sensor S_1
t_2= Detection time at sensor S_2

It should be noted that not every pressure-based leak detection system is considered as an acoustic LDS system. In fact, many of the pressure sensors (and associated computing equipment) that are commonly used in traditional pressure-based leak detection systems (such as pressure point analysis, or PPA) do not qualify to be part a negative-pressure/acoustic LDS system due to their low sensitivity, slow sampling rate, and/or response time.

A leak event detected by the local processor (the FSP) unit represents a possible leak not a definite leak. Only the Central Controller (CC), after correlating readings from multiple FSPs and taking into account a variety of other factors, can declare a leak to the operator. (Mohammed, 2014)

III. MATERIALS

Research data was obtained in hard and soft copies from the directorate of petroleum resources (DPR). Data was acquired from information through inquiries from the pipeline companies in the Niger Delta.

IV. METHODS

- ✓ Comparison of downtime, expected time required to pump product through the line and number of breaks was done
- ✓ Assumed cash flow if LDS where applied, from data of previous months was tabulated
- ✓ Sensitivity analysis comparing NPW and Fibre optics using a table of assumed cash flow for the following economic parameters was done as follows;
  - NCR(Net Cash Recovery)

 ISSN: 2394-4404

- PO(pay out)
- PV/₦(present value per Naira)
- PV@15%(present value@ 15% discount rate)
- From the sensitivity analysis, the most feasible was chosen.

V. RESULTS

✓ COST (CAPEX AND OPEX) FOR NPW

According to a feasibility study of internal and external based system for pipeline leak detection in the upstream petroleum industry, approximately USD 350,000 (price includes hardware, software and engineering).

Converted to Naira: USD 350,000 = ₦ (350,000* 160) = ₦56,000,000

✓ COST (CAPEX AND OPEX) FOR FIBER OPTICS (DAS)

Approximately ₦ 601,121,280 was used for the economics analysis.

RESULTS OF FIELD DATA FROM PPMC FOR 2017

Results from PPMC area office from April to July 2017 indicates the maximum breaks in July with 45 while the least occurred in April with 17. These correspond to a downtime of 570.90hrs and 4344.60hrs for April and July respectively. Coincidentally, these breaks and downtime trends tallied with maximum volume pumped for PMS, DPK and AGO (Table 1 and Figure 4).

RESULT OF ASSUMED CASH FLOW FOR VARIOUS LDS SYSTEMS FOR 2017

Assumed cash flows after rigorous investigations gave N601,121,280 and N56,000,000 for fiber optics and NPW. The corresponding cash flows gave the least in April with N187,906,345 and N178,511,000 for fiber optics and NPW. The maximum cash flow for the comparative study was indicated in the month of July as N1,437,484,208 and N1,365,610,000 for fiber optics and NPW (Table 2 and Figure 5).

RESULTS OF SENSITIVITY ANALYSIS OF CRITICAL ECONOMIC PARAMETERS

Based on the estimated scenario of cash flows for fiber optics and NPW, the NPW with a maximum value of N2,117,214,936 is selected. The payout time (PO) was quite faster for NPW at 0.69 month as against a longer duration of the expected return on investment of 2.64 months for fiber optics. The present value per Naira (PV) was also higher for NPW with 37.81 while the present value at 15% discount rate gave a maximum value of N1,725,732,000 for NPW (Table 3, Figures 6 and 7).

S/N	MONTHS	BREAKS	DOWNTIME (hrs.)	VOLUME PUMPED (m^3)		
				(PMS)	(HHK/DPK)	AGO
1.	April	17	570.90	5930.701	6052.893	513.409
2.	May	27	432.68	-	3394.961	9871.501
3.	June	34	549.43	3962	8037.649	9754.133
4.	July	45	4344.60	27950.62	15482.13	30850.87

Table 1: Field data from PPMC area office system 2E for 2017

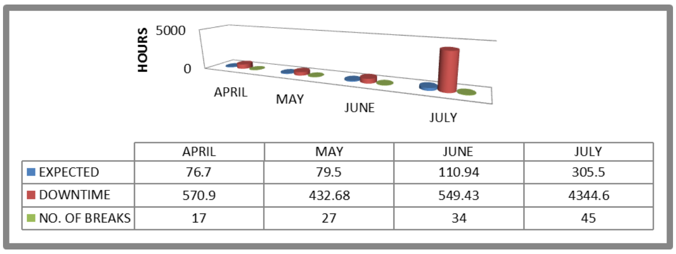


*Figure **Error! No text of specified style in document.**: Chart for comparing Expected time, Downtime, No. of Breaks experience during products transfer*

LDS/Months	Fibre Optics (₦)	NPW (₦)
(Installations)	601,121,280	56,000,000
April	187,906,345	178,511,000
May	270,865,634	257,322,400
June	391,338,482	371,771,600
July	1,437,484,208	1,365,610,000

Table 2: Assumed cash flow for various LDS systems for 2017

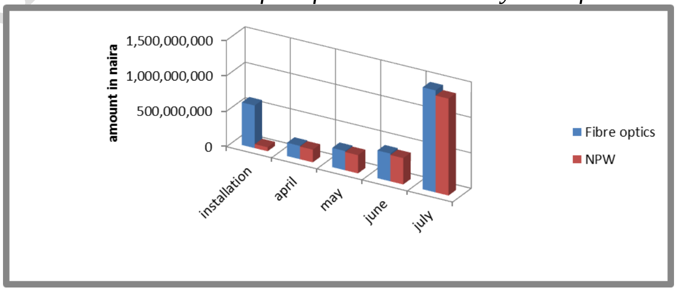
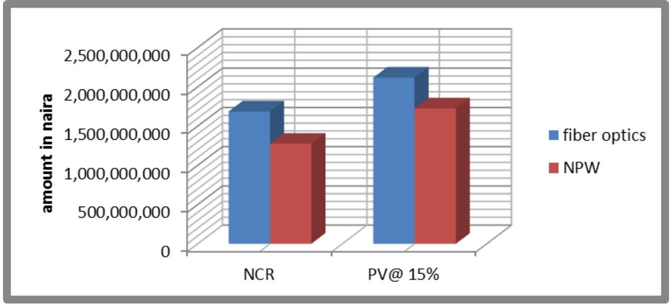


Figure 5: Assumed cash flow if various LDS systems where applied for previous months

LDS/Months	Fibre Optics (₦)	NPW (₦)	SELECTED
NCR(₦)	1,686,473,000	2,117,214,936	NPW
PO(months)	2.64	0.69	NPW
PV/ ₦	2.81	37.81	NPW
PV@15 %(₦)	1,274,387,000	1,725,732,000	NPW

Table 3: Selection of best from economic parameters from Sensitivity Analysis



 www.ijiras.com | Email: contact@ijiras.com

Figure 6: Selection of NCR and PV @ 15% from Sensitivity Analysis

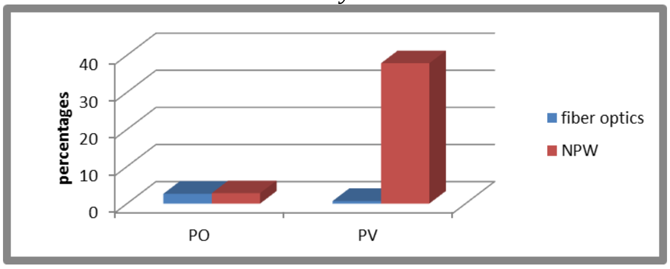


Figure 7: Selection of PO and PV from Sensitivity Analysis

VI. DISCUSSION OF RESULT

Approximate cost (CAPEX and OPEC) for the both methods were gotten:

NPW= ₦56,000,000 and FIBER (DAS) = ₦601,121,280. Table 2 shows Assumed cash flow if both LDS systems where applied before previous months and estimates the amount of money saved if both LDS are applied over the previous months and DAS was assumed to have a 100% product transfer due to its current zero pipeline leak incidents reputation (OGN, 2013), and NPW was assumed to have a 98% product transfer because vandalism had to occur before detection was made. Table 3: Sensitivity Analysis shows us comparison of both LDS with different economic parameters. The Net Cash Recovery is the subtraction of the installation cost from revenues made at intervals; and the NPW had a higher NCR. The time Interval for the company to get back returns on investment shows that the NPW had a better PO. The Present Value per Naira is a ratio of Net Cash Recovery to Investment and the NPW had a better PV/₦. The NCR at a discount of 15% showed that the NPW had a better PV@15%. From the feasibility study the Negative Pressure Wave LDS, proved to be more feasible than Fiber optics (DAS), LDS is recommended to be applied on the PPMC 2E pipeline system.

VII. CONCLUSION

Leak detection systems can be broken down into Personnel, Procedures and Technologies which are necessary for uninterrupted distribution of products in Nigeria. The results prove the feasibility of the Negative pressure wave system when applied on the PPMC system 2E system. Sensitivity Analysis to know the feasibility of the system with the following parameters; NCR (Net Cash Recovery), PO (Pay Out), PV/₦ (Present Value per Naira),PV@15% was carried out. Table 1 demonstrated the number of breaks, downtime and expected time for series of pipeline operation in four different months. A comparison was made between fiber optics cable system and Negative pressure wave system and the negative pressure Wave proved to be more feasible.

VIII. RECOMMENDATION

It's recommended that PPMC

- ✓ maintain standard procedures and codes of pipeline companies and personnel's should be fit for the job,
- ✓ The company must educated the communities along pipeline routes on the danger and disadvantages of pipeline vandalism,
- ✓ Proper investigation should also be carried out each time the act of vandalism occur to make an example of vandals and also their collaborators,
- ✓ Also the communities along the pipeline system should be favor by the pipeline companies.
- ✓ Patrol pipelines at areas of high risk (e.g. near villages or local criminals);
- ✓ Work with police to destroy the 'organized' crime (many of the thefts are for a criminal with an organization selling to customers). This will require special detective work.
- ✓ Review internal staffing (often criminals are working with pipeline staff).

ABBREVIATION

NNPC: Nigeria National Petroleum Company
PPMC: Pipeline and Product Marketing Company
DPK: Dual Purpose Kerosene
PMS: Premium Motor Spirit
AGO: Automobile Gasoline Oil
DTS: Distributed Temperature Sensor
DVS: Distributed Vibration Sensor
LDS: Leak Detection System

REFERENCES

[1] Chukwuma A., Okoli N. and Orinya S. (2015): Oil pipeline vandalism and Nigeria's security. Oil and gas summit proceedings of the NNPC, Abuja branch.

[2] Donald B. (2008): The Shake out scenario of pipeline premium, oil and gas pipelines, May edition.

[3] Jun Z., Andy H., Keefe M., John L. and Michael T. (2013). Review of Pipeline Leak Detection Technologies. ATMOS International journal, April edition.

[4] Mohammed F. (2014): Significance Of Pipeline Transportation In Nigeria – (A Case Study Of NNPC Enugu And Port. Petroleum Products, 5,pp7.

[5] Mohamed F. S., Faizal A., Hafiz J., Bukhari W., and Nasir M. F. (2014):A Feasibility Study of Internal and External Based System for Pipeline Leak Detection in Upstream Petroleum Industry, oil and pipeline journal, March edition.

[6] Onigbinde I. O.,(2014): Evaluation of Petroleum Products marketing in a Globalizing Economy: A Conceptual Evidence from Nigeria. British Journal of Marketing Studies Vol.2(2) pp.71-81.