

Securing Nigeria's Crude Oil and Gas Pipelines – Change in Current Approach and Focus on the Future

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Abstract- The perennial bombardment of Nigerian pipelines by agitating militants has become an embarrassingly serious security threat; coupled with the unfettered crude oil bunkering that has defied solutions and caused huge negative impact on the most populous black nation's economy. Unfortunately, most of the country's pipeline protection techniques are still obsolete. Though new technologies like fiber-optic sensing, drones, infra-red capable satellites/GPS systems and SCADA techniques have become popular, but not being suited for Nigeria renders them ineffective.

A review of the most efficient pipeline burial technologies for Nigerian terrain was conducted while appropriate combination of these with modern intrusion, sensing and detection techniques all adapted to suit identified challenges were identified. Recommendations were proffered for more holistic approach to address the challenges of bunkering and incessant bombings, the use of modern networking as part of the pipeline intrusion detection and protection with attention paid to SCADA cyber security alongside everything else. Corruption being Nigeria's biggest problem called for mitigates that may not necessarily eliminate human sabotage.

Index Terms— Pipeline, Fiber-optic sensing, Burial technologies, Intrusion, sensing and detection techniques, SCADA cyber security.

I. INTRODUCTION

It has been a painful two years now for oil and gas companies and exporting countries. Of course it is a bit worse for some, more than others. In June 2014, the world market price of crude oil began a steady decline from \$115 per barrel to its low point of approximately \$43 per barrel in January 2015 (Voigt et al., 2015). For operating / producing companies, this has meant huge losses and negative balance sheets so crippling that more than a few of these companies have become insolvent and bankrupt. For crude oil and gas exporting countries, this has meant budget deficits, terrible economies leading to recession for most of them, devalued foreign exchange rates and increase in debt profiles.

For consumers of refined petroleum products, this has meant a respite from the previously prevalent high prices of fuel and other related products. According to Kate Deer, Amy Gilligan and Brian Parkin (2015), low prices are bad for exporters, but oil importers such as China and India are benefiting. Alternative energy providers, electric car manufacturers, etc. have also benefitted, but for the time being, there is a limit to how much of the oil and gas energy they can provide to an increasingly energy-hungry and speedily growing population. The biggest winners are countries who depend almost exclusively on imports from exporting countries for their oil and gas and other energy needs.

Operating companies have tried to cope with the low prices by cutting costs through; unburdening themselves of lots of employees (to reduce overheads), going from heavy reduction to complete elimination of cash demanding activities and operations, such as: exploration, drilling and completions, buying new fields, among others. They have focused instead on producing from already completed wells, selling off some of their fields along with other assets, plus completing and producing from DUCs (Drilled but Uncompleted) wells, and doing work-over on some wells that have been shut in for one reason or the other. Also, they have engaged almost all their 3rd party contractors and service companies to reduce their prices in line with the times.

Exporting countries have on their side mostly relied on increasing their production and exports as high as they can get it, to compensate for the lower revenues due to the much lower prices, and to make sure that they do not lose their market share (i.e. percentage of total sales among exporting countries), in the same way a business might lose customers to others in the same sector. Operating companies have also done the same in an attempt to further improve their balance sheets.

An unfortunate consequence of the exploration of crude on a large scale is the tendency for the countries involved to depend solely on it for revenue, as is the case with almost all (arguably 75%) of all crude exporting countries. Hence the crippling of the economies of such countries when prices stay low for long or massive sabotage and threats to this source of revenue occur. Nigeria is a case in point. Almost all these exporting countries (and companies) will have to, among other modes of export, rely heavily on the use of pipelines to transport or export their produced crude oil from one point to another, and from one country to another, depending on its location, costs and other factors. Tankers are also used for this, but they cannot only move much smaller amounts at a time and hence are less efficient, with their usage depending on circumstances.

Security for oil and gas operations has never been as much a source of concern at any time as it is now, with sustained terrorism all over the world especially in petroleum exporting countries, particularly targeting oil / gas facilities and installation. Tyagi SB (2016) says 'Critical Energy Infrastructures have been subjected to increasing terrorist threat which is correlated with the growing political and economic instability in oil and gas producing regions'. Some instances are the take-over of Ramalla, the biggest refinery in Iraq by Islamic extremists, and the bombings and bunkering in Nigeria and South America. There have even been attacks by the ISIL (or ISIS) militants on Libyan oilfields. Attacks on oil and gas infrastructures are now weapons adopted by international

terrorism irrespective of the political system and socio-economic boundary (Eze et. al., 2015).

Pipelines have always been one of the most difficult infrastructures to secure in the oil and gas industry. This is mainly because of the worth and flammability of what it contains/carries, and very importantly because it stretches for long distances, some of which are over terrain that is difficult to navigate or access with any level of regularity. Ease of access and navigation is necessary for patrol purposes. Oil and Gas field operators and exporting countries, to whose facilities these attacks have happened, have experienced huge losses in production for the duration of the threat, lost the time it took to complete repairs and get back to production. When these are added to the incalculable loss of lives, some of whom are the best at what they do, and the impact to the environment both in possible costs and time in effecting clean-up, it is easy to see how considerable the total losses are. A single pipeline incident can have devastating effects, causing property destruction, service interruptions, environmental damage and death – all of which can cost pipeline operators millions of dollars in financial losses. Further, incidents involving oil theft can have a significant economic impact by going unnoticed for long periods of time (Senstar, 2016).

Ifeanyi Okowa, the governor of Nigeria's delta state observes in *The News*, that 'our problem is further compounded by the recurring decimal of crude oil theft and pipeline vandalism which by most accounts, about 400,000 barrels of oil are stolen daily, accounting for trillions of naira loss to the economy and when we add the value of the gas condensate lost also, the figure becomes astronomical' (Ibeleke, 2016). As this is usually also the backbone of power supply in such countries, for example Nigeria, when major crude oil and gas pipelines are sabotaged, the unpleasantness of effect is far-reaching.

This article will focus on the threats currently experienced in the Nigeria's oil and gas sector pipelines area, particularly in the Niger Delta region. It will look at how we currently secure these crude oil and gas pipelines, the loop holes in the methods we currently adopt and offer alternative to better secure oil and gas pipelines in the country. Finally, it attempts to show how these new techniques will better secure these pipelines now and are better focused on also overcoming any future challenges, and how potential challenges with these new procedures may be overcome.

II. CURRENT PIPELINE SECURITY DEPLOYMENTS IN NIGERIA

When the going was good, the generally implemented security measures include the following; in-house security personnel employed directly by the operating companies themselves. These are usually mostly present in the company's offices and a little less at operation sites, both onshore and offshore. These security personnel usually do not carry serious arms and liaise with other parties to secure the company's interests. Vigilantes, comprising of locals who originally own, and in some cases still live near or around the area where operations take place, are also part of the security [paraphernalia](#). State (or country) security personnel, usually some form of joint task force (JTF), comprising the military, mobile police units, and for swamp / offshore locations, the navy, form the last member of the human security unit.

The company security provides information, and is responsible for communication, organization and coordination

of all the other parties. In the event of a security concern, they provide minimal first level engagement and SOS.

The local vigilante helps to look after company facilities, in this case pipelines, and help curb the participation of locals in threats like stealing, bunkering, violence, destruction, etc. They also provide intelligence on impending large-scale attacks if and when they are aware. They help when it comes to looking after long stretches of pipelines, particularly those passing through inaccessible locations, etc.

The military (JTF) provide the muscle in this unity and deliver protection in the use of force. They also repel certain type of attacks and prevent escalations in some instances. Lots of times, they are involved in the patrol of the length of the pipeline in SUVs / jeeps on land, and speed/gun boats in swamp and offshore locations. Depending on distances, they might make between 2 passes a day and 1 pass a week (sometimes cost is a factor in this regard, and determine how many teams are involved in the patrol and the distances each patrol has to cover).

The last part of this security technique is internal sensors usually mounted inside pipelines measuring the line pressure of the fluids (oil and / or gas). When pressure drops suddenly, there might be a leak in the pipeline and it can be located by the sensor that detected it and the closest valve to the sensor. In the occasion of this sudden pressure drop, the closest valve is closed remotely, and security dispatched with some engineers to confirm the cause of the fault, and in cases of breaches like bunkering or sabotage the security people intervene and clear or arrest the vandals or in the case of leaks, the technical people intervene.

Most of these pipelines will ideally/additionally have lots of other sensors, instrumentation and meters that are used for measurement, regulation and control of pigs. Pigs are used to clean pipelines as well as to confirm the internal integrity of the pipeline. The only detection then, focused on leaks and other internal concerns which were prevalent when the systems were installed (Eze et. al., 2015).

III. CHALLENGES WITH THE CURRENT PIPELINE SECURITY DEPLOYMENT

The current deployment is very reactive and not preventive. This is because almost all the earlier pipeline incidents were more of operational leaks and degradation; most devices installed have been mostly detection for internal concerns not external incursions (Eze et. al., 2015). The current set-up for securing pipelines in Nigeria has existed for over 20years now. Even though this system has been largely successful, especially during times of calm, lots of technologies employed then and still in use now, have become obsolete. Currently the SCADA technology has been adapted for pipeline security, unmanned drones and satellites can be utilized, and even fiber optic sensors are available. These are some of the technology now possible for use in pipeline security.

The second thing to note is that, every once in a while there is a political stalemate in the country, and these pipelines, especially the important high-volume ones, are used as a bargaining chip. A fresh instance is the current wave of bombings which have been going on nearly consistently for the past year and half at least. Maikanti Baru, an MD of the Nigerian National Petroleum Corporation has said that, 'Nigeria has lost over N2 trillion to militancy and pipeline vandalism since the beginning of the year' (The Nation, 2016).

Now, the underlying reason why this is not only possible but relatively easy for miscreant and militants to do, is that almost all the targeted pipelines have been surface pipelines. Only in just one instance has an underwater (note, not underground) pipeline had been bombed. This means that access to the pipelines have been relatively easy.

Similarly, bunkering has continuously gone on unabated for the better part of 15 years while companies' and the country's efforts to curb it have been largely unsuccessful. Again this is because the pipelines are on the surface and are relatively easy to access. However, most of these bunkering have been concentrated around swamps and land areas where the natural vegetation which have large trees that create shade/cover from the sky and prevents the perpetrators from being seen by helicopter flybys or even satellites without infrared capabilities.

This is also the case in areas difficult to access normally by road or boat. The consequence being that even when leaks and breaches are detected, the culprits would be long gone and have completed whatever they set out to do in the first place, before they can be apprehended or stopped.

Little wonder we keep hearing of the difficulty in eliminating illegal bunkering, and it has become virtually impossible for the JTF to secure / stop the still occurring bombing of pipelines, despite very heavy military presence accompanied by heavy artillery.

There are other dimensions to the problems with pipeline security in Nigeria, including violently divergent political views, need for incorporating indigenes in ownership of fields, etc. but while they might be mentioned in passing, the article will strictly focus on the technical side of things, and the option it provides would help to curb a lot of the issues irrespective of these other dimensions.

IV. AVAILABLE PIPELINE SECURITY TECHNOLOGIES FOR CONSIDERATION

Burial Technologies:

There are several technologies for laying pipeline in deep water, for example the J-lay, S-lay and the towed pipeline. However, the write-up will not be considering deepwater pipeline security as there have never been any attacks in this area, certainly due to difficulty for would-be attackers to access those. Nevertheless, the towed pipeline, which involves towing long stretches of jointed pipeline to the required location, might be a good consideration since it can be of assistance in swamp areas. Burial can sometimes be a challenge in some offshore and swamp locations, particularly when the water bottom or seabed is slanted, or at least not flat. Luckily, in Nigeria none of these are a major concern, and the swamp bottom though

with loose soft top soil is reasonably flat, making burial techniques easy to implement.

The three primary methods of pipeline burial in water are: Dredging, (through various methods) which mechanically cuts or digs a trench which can later be back filled; Jetting, using high pressure water and air or water educators to create a trench by fluidizing the seabed which is then dispersed into the water column to be carried away by the current; or Rock / Soil Dumping, a method of covering or "back filling" a pipeline that remains above ground on the seabed or below ground down in a trench (Bisso Marine, 2016).

The jetting method involves using a high pressure water and air or water educator jet sled. The jet sled is placed over a previously laid pipeline or in some instances operates simultaneously while pipeline is being laid. The jetting process cuts the seabed with high volume pressurized water "jetted out" through typically 100 or more nozzles at the leading edge of the sled and across the bottom of the trench while spoil is extracted from beneath the sled via the educator system, which then disperses the spoil into the water column. While jetting, gravity lowers the pipeline to the bottom of the jetted trench behind the sled (Bisso Marine, 2016).

The jetting method is limited to favorable soil compositions which can be fluidized and pass through the educator system. Jetting as a burial method is only commercially feasible when the backfill can occur via a natural seabed backfill process (Bisso Marine, 2016).

The rock and / or soil dumping is a method of covering a pipeline on the seabed that is above or partially above the surface of the seabed or as an alternative when the seabed is too hard to dredge or jet. Rock and / or soil dumping is also an effective yet costly (specific regulations can substantially increase the complexities and expenses of post lay seabed restoration) way to cover or back fill a pipeline which is exposed on the seabed or at the bottom of an open trench (Bisso Marine, 2016).

Swamp Regions:

In swamps areas, jetting is one of the most efficient techniques which saves time and cost but still achieves the burial depth suggested. However, to ensure that the burial depth sufficient for the security intended, the self-propelled track sled is suggested. This is because it can; (a) Bury Active Pipelines; (b) Is bi-directional and can travel at controllable speed; (c) Is designed for all types of unconsolidated and consolidated soils; (d) Can cater for pipe range between 4" and 30" outer diameter (inclusive of coating); and (e) Can achieve first pass depth up to 16 feet (4.88 meters) (Bisso Marine, 2016).



Pipeline Burial Plough (Bisso Marine, 2016).



Self Propelled Track Sled (Bisso Marine, 2016).

Land

The current technologies for laying buried pipeline on land like trenched or trenchless are quite sufficient and are pretty basic. However, the trenchless is suggested since it gets to the depth required. Auger boring and Horizontal Directional Drilling are also note worthy, but they might not allow simultaneous installation of fiber optic technology. Bulldozers are used for clearing trees and other obstacles, and then excavators are used to dig the ground and the pipeline added

joint by joint or in long chain of joints to another to save time. The major point here is to make sure that there are no pipelines laid on or above ground where they are an easy target.

Provisions can be made at certain areas where pipelines from different sources may be collated, commingled, temporarily stored or for exports. Again this is advised to be in areas without vegetation cover from above and in terrains easy for security operatives to access by ground and/or from the sky.



Buried Pipeline on Land. Recommended depth 16ft to 30feet.



Buried Pipeline (Senstar, 2016) Recommended depth 16ft to 30feet.

Control Centers

Where pipelines distances are very long, like from Port Harcourt to Kaduna, pipelines may be brought to the surface at certain very few points, over very short distances as are necessitated by need co-join crude oil/gas coming from different sources or where temporary storage or exportation is done. Some of these points may also be used when technical repairs and local monitoring are desired.

A key place to perhaps consider this would be areas where wireless signals or the fiber optic network would be interconnected and/or boosted for efficiency. The areas where these points are established should be manageably small, fenced off and reasonably secured. It should also be at places where re-enforcements will find it easy to access should the need for back-up human security be expedient.



Pipeline Security Operations Center (AIS security Solutions, 2013)

SCADA

SCADA stands for Supervisory Control and Data Acquisition - any device that gets data about a system in order to control that system is a SCADA application (DPS Telecom, 2016). In general, a SCADA application has three elements: The process/system/machine you want to monitor and control (in this case pipelines), a network of intelligent devices that interfaces with the first system through sensors, and are a means to control outputs. The network, which is the SCADA system, gives you the ability to measure and control specific elements of the first system (DPS Telecom, 2016).

A SCADA system performs four functions: (a) Data acquisition by sensors (digital or analog) and control relays, etc., (b) Networked data communication, (c) Data presentation and (d) Control (DPS Telecom, 2016). The networking may be

achieved using any installed fiber optic sensing by multiplexing.

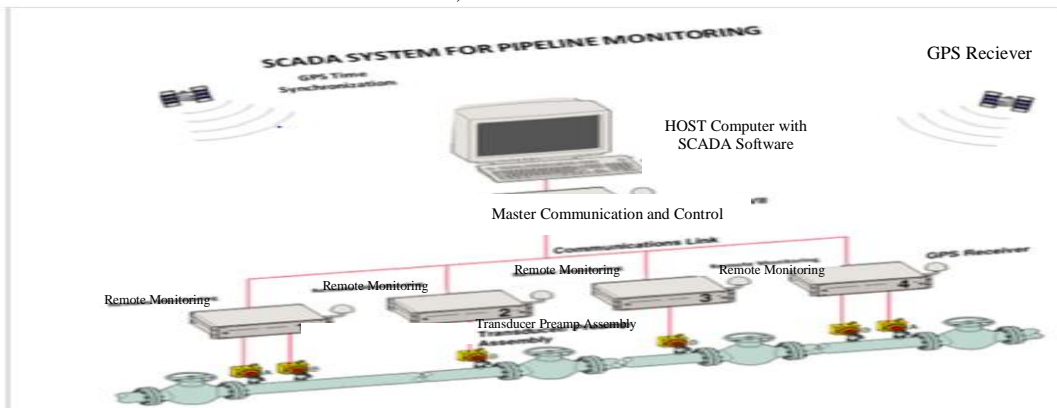
The pipeline SCADA system provides the common data collection interface where pipeline process information is gathered and displayed. Alarm management can be provided as well as visualization of the information generated by the leak detection and location systems (Gejger, Terrence, and Daniel, 2010). Video monitoring using cameras or even drones can be integrated into the pipeline SCADA system to provide the operator with additional information should process alarms occur. The same video monitoring system can be used for security purposes together with access control.

SCADA system uses a software platform that provides real-time control, optimizes security management systems and forms the backbone of a command, control and intelligence centre (AIS Security Solutions, 2013). The advantage of

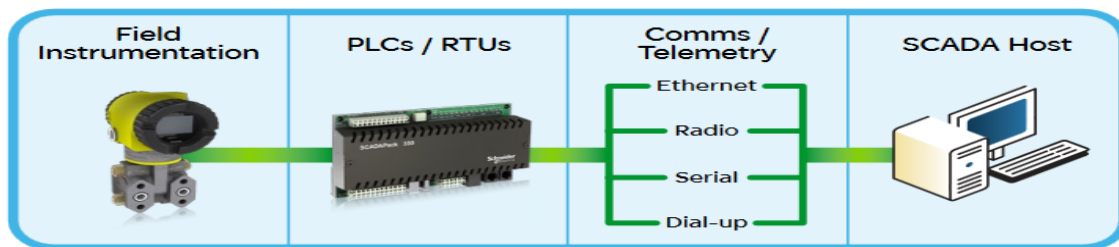
SCADA systems include; Reduce Maintenance Costs and Equipment Downtime; Increase Efficiency and Reduce Site Visits; Connect to Remote Human machine Interface (HMI) (ORBCOMM, 2016).

Finally, use of SCADA systems introduces cyber security concerns with a number of documented attacks. However, in

recent years there are open standard that have been produced to provide secure encrypted and authenticated data exchanges between remote assets and a SCADA host platform (Schneider Electric, 2016).



SCADA System for Pipeline Monitoring (AIS security Solutions, 2013)



SCADA System Overview (Schneider Electric, 2016)

V. FIBER OPTIC TECHNOLOGIES FOR PIPELINE SECURITY -

1. Distributed Fiber Optic Sensing and Distributed Acoustic Sensing

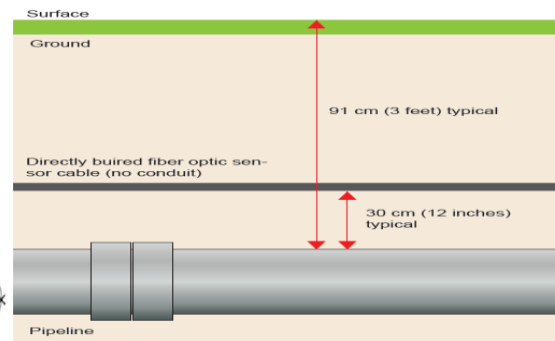
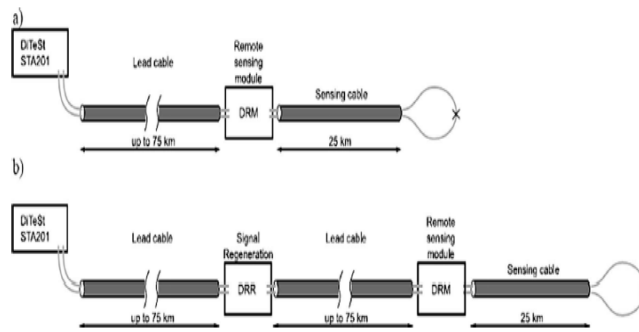
Though fiber optic technology has been in existence for telecommunications, and its application as sensors old, very new improvements in adaptations into DAS (Digital Acoustic sensing) have enable their use in pipeline surveillance, monitoring systems and security (Boman, 2015). DAS system converts a standard single-mode fiber-optic cable buried adjacent to a pipeline (often the same cable used for SCADA communications) into an array of virtual microphones (Hill, 2014). A laser that pulses up to 10,000 times a second is then passed through the system ‘listening’ to detect any disturbance’.

There are many forms in which it can be deployed, although most deployments require that an armored fiber optic cable be attached to, or be buried with the pipeline. They are so sensitive that they can detect, locate and classify activities such as personnel, manual and mechanical digging, tunneling, vehicles and even low-flying aircraft (Hill, 2014). Current

deployments can be made to work as proximity sensors to detect approach of non-desired elements. They can also be integrated with other kinds of sensors and types of security like remote cameras, and even unmanned drones (Senstar, 2016).

For very long pipelines it is possible to have junctions where one section is connected to the other (Glisic and Inaudi, 2010), or wireless technology is used to connect all the different section to each other and to the control center. For these places, if it is impossible to bury these connections, the pipelines may be brought to the surface in an easy to secure and guarded area where this can be achieved.

For most deployed fiber optic sensing systems, any damage to the fiber optics cable or system whether by accident or sabotage is quickly detected, and the place where the damage occurred is also pinpointed, this is called cable-cut immunity (Senstar, 2016). When this system is connected to a GPS (Global Positioning System) it is even easier to locate and resolve any ‘threats’ or damage. They have an additional advantage of being immune to electromagnetic interference (Boman, 2015), making them reliable and easy to secure.



Joining fiber optic sensors for long pipelines (Glisic B. and Inaudi D. 2010) Fiber Optic Digital Acoustic sensing for Pipelines (Senstar, 2016)

Modern Sensors

Sensors are Electrical/Electronic/Mechanical and Electromechanical devices mounted on and inside, in this case pipelines that are mostly used for measurement, communication/transmission, to aid 'state of the pipeline internal profile checks with pigs etc. Besides analog sensors, there are also digital ones. They are very useful, and most pipelines have a variety of them.

This article will recommend the continued use of the current fleet of sensors but in addition, this article is suggesting the addition of yet another sensory device for this category of pipelines to be buried. This new device would be mounted on the outside body of the pipeline, and would be the primary detector for points on the pipeline where breaches are imminent.

This would be a sensor a pressure (or weight) sensor, that will be calibrated to read normal values (or okay), when it sees the weight of sand that would normally cover the pipeline, but starts to send warning signals when it detects from 80% of that weight or less, with increasing alarm strength as that weight percentage reduces anywhere along the pipeline.

VI. OUTLINING THE WHOLE SUGGESTED TECHNOLOGY FOR NIGERIAN PIPELINE PROTECTION TO GO FORWARD

Assembling the above suggestions together to paint a clear picture, here is how the suggested consideration will work as one whole system.

1. Massive lengths of pipelines are assembled together and would have the usual protection techniques like cathodic protection to prevent corrosion, etc.
2. The current security personnel should be maintained albeit with better oversight, training, integration and routine rotations.
3. The usual fleet of sensors would also be mounted on and inside the pipeline, but additionally, a weight/pressure sensor would be mounted on the outside of the pipeline. This would monitor the weight of the sand above the pipeline after burial and trigger an electronic alarm when there is any excavation close to the pipeline which can then be checked out by a technical-security team combination. This will prevent easy access to the pipelines. This will essentially be a back-up system to the Fiber optic sensing (DAS) technology.
4. The pipeline is then buried to a depth range of 12 feet to 18 feet. This can be achieved either by trenching, or jetting in swamp and the usual way on land. This not only additionally prevents easy access to the pipeline,

but greatly reduces the impact of any bombs or dynamite detonated on the surface. Trenching using and sled is advised.

5. Above the buried pipeline, at a depth of about 15 to 30cm above the buried pipeline fiber optic sensing device should also be deployed. These are also modified to incorporate the ability to serve as motion sensing and proximity sensors up to a distance of 80feet.
6. Along the routes of the pipelines they may be brought to the surface at certain points. Here there is expected to be quite a number of pipelines, and the place could be for collation, collection, distribution, commingling, temporary storage, etc. These places could also be used as maintenance or local control centers. They must be small land areas and hence relatively easy to secure. They must additionally be easily accessible to land or air re-enforcements, and by drones should the need ever arise.
7. Finally, in order to limit the effect of bombings, companies should consider several considerable storages along pipelines. This will enable such companies meet their exportation agreements for some time, even when certain pipelines are destroyed or need repairs for any reason. Its effectiveness would depend of course on which pipelines are blown up.

VII. HOW THE SUGGESTED OPTIONS HELP ALLEVIATE CURRENT SECURITY PROBLEMS

1. It limits outside access to the pipelines very considerably. Hence cutting down opportunities for bunkerers or violent campaigners against to damage the pipelines or steal the product they carry.
2. Since the suggested system is proactive rather than reactive, it provides advance warning or threat to the pipeline before they threat is completed, hence more time to react, to prevent breaches before the occur.
3. In the above it saves tremendous time and money.

VIII. CHALLENGES AND LIMITATIONS OF THE SUGGESTED PIPELINE SECURITY IMPROVEMENT WITH ADVISED MITIGATIONS

Cost

Compared to the existing system of pipeline protection, the suggested approach is a bit expensive, especially having to bury all pipelines as deep as 12 to 18 feet. The additional sensor, while not hugely expensive, will be added cost as well.

The modern SCADA system, networked with fiber optics is not cheap either, and we have to factor in possible integration with satellite and/or drone flybys.

Again, it will be cheaper to implement for new pipelines yet to be installed, than for replacing pipelines which have already been deployed. This article suggests that companies and the government consider replacing the existing old systems with this new one, unless no serious threat is envisaged for a specific set of pipelines. But as no one can see the future, this is hardly a wise choice.

However, when this cost is weighed against the cost implications of the consequences of disrupted supply, of repairs, and time it requires to get things back to normal, it is not only well worth it, but cheaper for the company. Also for the country, the bigger implications of drop in revenue, lowered foreign exchange rates, and impact on the economy make this solution cost effective.

Implementation Timeline

This can be a concern since for new crude oil and gas production/transportation lines it will increase the time to start of operations and hence revenue. For already deployed pipelines to be buried, it might cause some disruptions to operations while the security systems are upgraded and then the pipeline buried. However, for swamp locations, there are burial technology available for active pipelines as discussed above which could be used.

Maintenance Concerns

One of the biggest concern with the suggested pipeline protection strategy, is the difficulty that would arise would arise should maintenance be needed since all the pipelines would mostly be buried. This is because access to the pipeline is difficult. However, if the best principles of pipeline protection are adopted, then there need for maintenance would be largely reduced, be less frequent and a lot farther between.

As a consequence of this, there are additional cost for excavating the pipeline to carry out the maintenance and the and the extra time this takes compared to if the pipelines were not buried.

Corruption

Another really big challenge the country has had in the fight to secure pipelines against bunkering, is human intervention, particularly where self interest is present. This concern is slightly reduced when the suggested pipeline security technique is adopted, compared to the status quo, but far is from eliminated. It is worthy of mention since it is still a weakness to the suggested option.

When leaks, breaches and other subterfuge are detected, the JTF and other force personnel sent to intervene could be

compromised and not tackle the perpetrators due to personal gains (bribes) that they are offered.

In order to try to reduce the influence of this on pipeline security, it is suggested heavy consequence management be introduced for any personnel (security force or technical) found involved in any acts of sabotage or actively/passively aiding any such acts. Again, for JTF personnel, it is suggested that they are regularly rotated, with each personnel serving no longer than 4 months before being removed. This will fight complacency and any possible over-familiarization with sabotage perpetrators. They should also be paid well.

Cyber Security

Cyber security has been one of the biggest concerns in IT for a while, which has prompted the birth of firewalls, antivirus etc. If the SCADA system is deployed, the system could be vulnerable to hacking attempts. According to Alan Grau (2012), many legacy SCADA devices that were designed without security measures are now being connected to the Internet. A lot of these systems are now reasonably protected but concern in this area has increased recently and is worthy of mention.

To contain these sorts of threats, employing rehabilitated hackers have been suggested as the way to go. In Nigeria hacking has not quite been so much of an issue, and for the time being, this is not seen as a serious threat, but with focus on the future, the possible threat can be managed by having hackers or IT audit companies regularly evaluate the status of the SCADA cyber security and update the same accordingly.

IX. CONCLUSION

With all the issues surrounding the industry; lowered crude prices; the urgent need to keep safe all the country's oil and gas produce to make the money that is desperately required, for expenses like the National budget, as well as need to prop up the local currency for favorable FOREX (exchange rate), and the heightened attacks, bombings and bunkering, there is an obvious need to do things differently.

Even Emeka Okwuosa the group managing director of Oilserv Limited and Frazimex Limited, a pipeline and facilities repairs firm argues that a combination of different security measures and current technology will help in securing Nigeria's pipelines (Ugwuanyi, 2016). The solution suggested should be adopted such that they news of pipeline sabotage, bombings and so on for Nigeria and the producing companies here-in would be a lot less frequent, or even non-existent going forward. As also mentioned, scheduled upgrades need to program as required to keep the security continuously potent.



Exposed easily accessed and difficult to secure Oil Pipelines in the Niger Delta (Ibeleke, 2016 / Akinleye, 2016 / Faul, 2016)

X. RECOMMENDATIONS

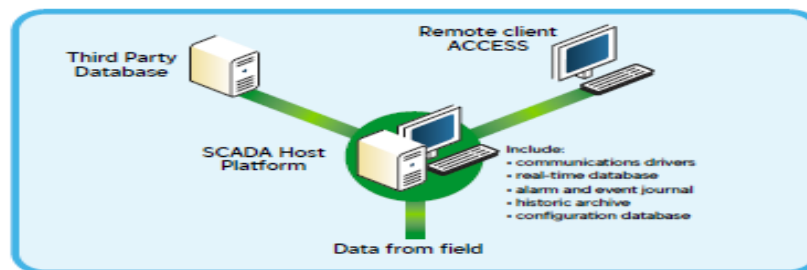
- If a pipeline must be covered or buried for security purposes, this is sometimes challenging. Let the

circumstances, cost and time be the driving factor for making the decision.

- It is recommended that the final depth of the pipeline be at least 12 feet or up to 18 feet. This should make access to pipelines in those areas quite difficult. It is advised that all pipelines in swamp areas be buried, and any collation, commingling, storage or export points between companies be moved to land locations where they can be secured.
- Though it might seem a bit of an overkill when fiber optic sensing have been deployed, this additional sensor will be an additional layer of security and can provide redundancy should the fiber optic be damaged, and be used until the primary detection security for the section whose fiber optic sensing is compromised, until normalcy is restored.
- Finally, large temporary storages are advised. They will serve as damage control, so as to limit the effects of pipeline explosions. It will however have no effect

on bunkering. These storages are also suggested in areas with good visibility and access, and most importantly secured.

- In order to drive down costs, companies whose pipeline fall in the same locality could combine technologies and hence cost and simply have login rights to a general SCADA mainframe, as shown in the picture below.
- Non-technical solutions that would enhance pipeline security which are also recommended include; officially involving the Government, introducing consequence management for communities where incidents occur, when such communities are part of the security system, increasing government's responsibility to the indigenes where these crude are acquired and the commitment of companies that they engage in development of the people there.



SCADA Host Platform (Schneider Electric, 2012)

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