Remote Operation of Oil and Gas production installations in the Niger Delta

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Abstract— **The current security challenges posed by the militancy in the Niger Delta region of Nigeria and the need by the International Oil and Gas Companies(IOC) operating in these areas to deploy both local and expatriates personnel for mandatory site visits both for operations, maintenance and upgrades make it necessary for the evolution of more effective operation strategies. The IOCs have resorted to the use of armed military escorts for staff to and from the sites and this has yielded some reduction in the risks but has still not totally eliminated it. This paper presents a robust communication configuration which is designed to enable remote operations, control, maintenance and upgrades by experts from a secure location away from the site. The system is implemented using appropriate sensors, communication links, topologies and plant operators. The advantages of this system include the reduction of staff exposure to the risks currently associated with traveling to these remote locations in the Niger delta region. It also ensures significant OPEX cost savings for the IOCs in terms of logistics costs and also allows for an increased effectiveness of the experts in terms of deployment time and the number of sites the can handle.**

Index Terms— **Communication, Kidnapping, Niger delta, Remote Operations.**

I. INTRODUCTION

Oil and gas production started in Nigeria with the first commercial find from Oloibiri in 1956 by SHELL(then known as Shell D'Arcy). The dominant role played by Shell continued till Nigeria joined the Organization of Petroleum exporting Countries (OPEC) in 1971. Nigeria currently has a number of international and indigenous oil and gas companies operation within her territories.[1][2]. By the year 2000, oil and gas exports accounted for more than 98% of the total export earnings and about 83% of federal government revenue, as well as generating more than 40% of its GDP. It also provides 95% of foreign, and about 65% of government budgetary revenues [2]. Nigeria's proven oil reserves are estimated by the U.S United states Energy Information Administration (EIA) at between 16 and 22 billion barrels (3.5×10^9 m^3),but other sources claim there could be as much as 35.3 billion barrels (5.61×10^9 m^3). Its reserves make Nigeria the tenth most petroleum-rich nation, and by the far the most affluent in Africa. In mid-2001 its crude oil production was averaging around 2.2 million barrels (350,000 m^3) per day with nearly all of the primary reserves in the Niger delta region. [2] Figure 1 shows the site map of the oil fields in the Niger delta. The most productive region of the nation is the coastal Niger Delta Basin in the Niger Delta or the South- South region. This region encompasses most of the oil fields. Most of Nigeria's oil fields are small and scattered, and as of 1990, these small unproductive fields accounted for 62.1% of all Nigerian production [2]. This scattered nature of the oil field locations necessitated the establishment of an extensive and well-developed pipeline network to transport the crude.

The impact of crude oil discovery and production has had both positive and negative impacts on the Nigerian Economy and environment. On the positive side, it has helped in the creation of employment opportunities and local expenditure on goods and services it also contributes to government revenues, to gross domestic product, to foreign exchange reserves and the supply of energy to industry and commerce. The impact of the negative effects of crude oil production is felt in the surrounding communities within which the oil wells are exploited. Some of these communities still suffer environmental degradation, which leads to deprivation of means of livelihood and other economic and social factors. This negative impact has led to a number of problems for the operators in the Niger delta ranging from kidnapping to vandalization of facilities. Production is disrupted intermittently by the protests of the Niger Delta's inhabitants, who are being exploited. [3][4]

II. CRUDE OIL PRODUCTION CHALLENGES IN NIGERIA

The most significant aim of the operator in the Oil and Gas industry is to maximize production at minimal costs. To achieve this, top of the range technology is usually developed and deployed to maximize the production from the wells. The impact of technology on the production process has always been significant but the current situation in the Niger Delta with restive youths vandalizing the facilities and kidnapping the personnel calls for a technology that reduces the effect of these vandalization on the production process[4]. The current solutions being deployed in solving this problems involve the deployment of armed military personnel to provide security for the operator's personnel when the go to work. This has brought some other complications as the security personnel are usually the first targets in the effect of an attack and again the company personnel can not be given 24hr cover all day and all week as kidnapping of these staff has been shown to take place

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during off work times and locations e.g during social visits.[5][6][7][8][9]

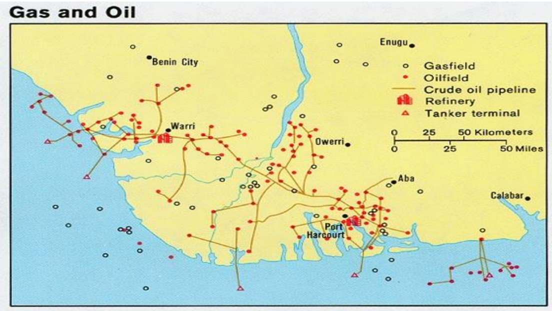

Figure 1 Site map of oil fields in the Niger Delta

The site map in Figure 1 shows the location of the oil fields in the Niger Delta and Figure 2 shows the Oil disruptions due to militant activities as at 2006.

Figure 2 Militant activities in the oil and gas industry

The oil fields are scattered around the Niger Delta. To effectively monitor the operations of these fields will require intensive deployment of both company core personnel and security personnel.[8] The current operational strategy requires the locations of onsite operators and regular visits by more experienced personnel from time to time either to provide corrective interventions and system upgrades This approach exposes these personnel to the risks and hazard associated with the site visits, it also has its attendant cost implications. The current approach aimed at reducing the incidence of kidnapping and its resultant effects on production involves the deployment of armed personnel to accompany the company personnel either during transportation to the different locations either by road or by water [10]. It also involves the location of military bases near these facilities for the purpose of providing security. This approach has its limitations part of which includes the fact that the soldiers are finite in number and experience has shown that the militants during attacks kill the military personnel as soon as the have the opportunity. This approach has provided a form of security but it does not prevent production shut in the event of an all out attack on the facility. Remote operations will lead to fewer site visits as it will enable fewer core personnel to handle more sites per time from a secure location.

III. COMMUNICATION SYSTEM ARCHITECTURE

Oil and gas production facilities are critical infrastructure and as such can be targets for sabotage and terrorist attacks. Recent advances in wireless sensors and communication systems can be deployed to provide monitoring and surveillance services for these facilities [11] and reduce the number of site visits and onsite personnel required for the their operations. Supervisory Control and Data Acquisition (SCADA) solutions provide a base for improved monitoring and management of oil and gas installations such as pipelines, production sites, valve installations, compressor stations and other remote sites.[12] The key components of a digital plant architecture include digital instrumentation, a control system, and an asset management system. As shown in the digital field architecture diagram in Figure 3

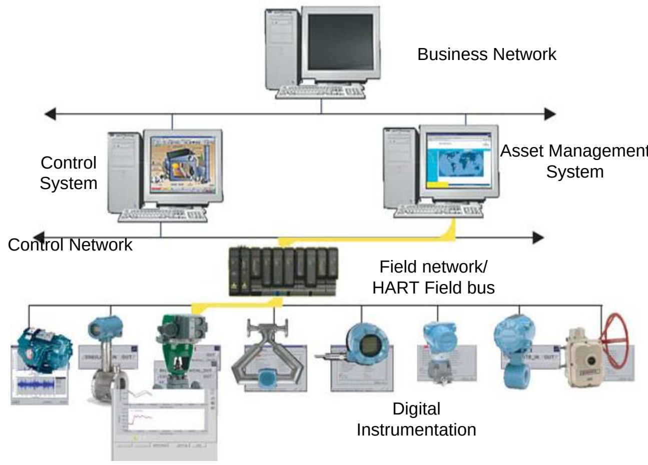

Figure 3 Digital Field Architecture

Digital instrumentation has become mainstream, replacing older instrument technology such as pneumatic and analog devices. Through the use of digital instrumentation, digital plant architecture has emerged to capitalize on the benefits of improved diagnostics and predictive intelligence to bring value to the end user. In digital instrumentation, a microprocessor handles converting a field signal (i.e., pressure, temperature, etc.) to a standard transmission format such as 4-20 mA analog, HART or Foundation Fieldbus (Figure 3). Using a microprocessor also brings the benefit of allowing additional valuable configuration information to be stored in the unit. Digital communications further increases the benefits since additional asset information may also be stored in the digital instrument. Examples include tag number, serial number, and construction materials–all of which are typically entered only once and then reside in the unit for future reference [13].

The communication block diagram for the remote operations architecture proposed in this work is shown in Figure 4.

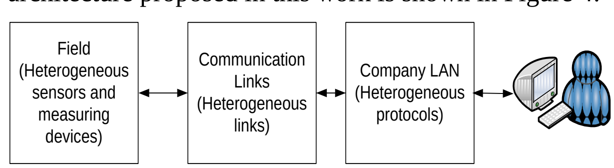

Figure 4: Communication block diagram for remote operations.

From the diagram in the Figure 4, the communication system for the remote operations comprise of the field segment made up of heterogeneous sensors for taking temperature, pressure, differential pressure, level and flow rate measurements. The communication links comprising of the transmission links from the sensors and measurement devices to the radio hut using a combination of wireless signal transmission and cables. The signals are transferred using point to point microwave links, optic fiber and other appropriate transmission media to move the signals into the company LAN. Within the company LAN the signals undergo a series of protocol conversions before the information contained is delivered to the final user in the appropriate format. The most critical part of this architecture is the field. This is due to the fact that it is remote and is prone to vandalization attacks.

IV. FIELD SEGMENT

The field segment comprises of sensors, measurement and control devices. The main functions carried out in the field location include:

A. System Monitoring

Much of oil and natural gas production occurs largely in remote areas far beyond the economic range of wired or terrestrially based wireless communication. Key to the operation of these production sites are production wells utilizing various pumps and recovery facilities that extract, collect, and transfer the oil and gas to transmission pipelines. The malfunction or failure of one of these key components is a critical event for the production operator [14] For system monitoring, appropriate sensors are used to measure the different parameters of interest. The acquired data can be transmitted to a central collation point using wires or wireless . The wireless technology in view of the fact that it eliminates wires and the costs and challenges associated with wired communication systems coupled with its ready availability is the technology of choice. These parameters and the required sensors includes the following.

(i) Pressure Measurement: The sensors are pressure transducers, pressure transmitters and indicators.
(ii) Temperature: Temperature transducers, temperature transmitters and indicators
(iii) Flow : Flow meters e.g turbine meters, ultrasonic flow meters
(iv) Density: Density meters
(v) Level : Level transmitters.

B. Surveillance

Surveillance can be implemented using wireless IP cameras installed at strategic locations such that the critical areas of the plant are covered. This video data is then transmitted to a central storage area from where the can be viewed. The use of IP camera with Pan/Tilt and Zoom capabilities makes it possible for individual cameras to be controlled from remote locations.

C. Remote Maintenance

The current impact and penetration of microprocessor based operation of plants and machinery and the use of SCADA systems in plant operation has given software a very critical role in plant operations. System upgrades now do not have to be hardware based as a change in software can bring about tremendous change in operation. This software upgrade and maintenance can be carried out by remote access to the plant system. This requires that the plant network be secured and protected from unauthorized access by the installation of the appropriate firewalls and associated protection systems.

D. Remote Control

The remote control of valves and switches are implemented via remote control such that each device can be controlled from specified remote locations. Emergency shut down procedures can be implemented from any of the specified offsite locations such that the control of the plant and any vital equipment can be controlled remotely in the event that onsite control becomes impossible.

V. THE COMMUNICATION LINK

In the domain of field monitoring, there is currently a dependency on cabled communications. The current preference for cabled (including copper and fiber optic cables) over wireless communications arises from their speed-of-light communications (particularly in safety critical systems), data throughput and ability to supply continuous power to sensors and associated hardware. However, the spatial distribution of wired sensors is often limited because of the cost of installing new sensors. Wireless sensor and communication systems allow the number of sensors to expand, although they suffer from lower data rates and, without energy scavenging capabilities, have a limited life expectancy.[15]

The communications links for remote operations is required to have the following characteristics

1. Very low latency
2. 100% availability and reliability
3. Very high security
4. 100% standby redundancy
5. High resistance to interference
6. High resistance to vandalization

The technologies available for these deployments include the Optic fiber and the microwave links. The optic fiber links have very high capacity and high resistance to interference but the challenges associated with laying optic fiber through built up areas, Right of Way acquisition and the ease of vandalization limits the use of the optic fiber to short spans where the incidence of vandalization is very limited. Microwave radios and links involve the construction of two towers one at the field base and another at the company base with microwave antennas mounted at specific locations on both towers to facilitate a line of sight between the two antennas. A microwave system includes an antenna, radio, multiplexers, waveguide (hollow metal conductor connecting the RF equipment to the antenna) and feed cables. Based on capacity and radio equipment, antenna size, tower heights and terrain elevation will play a major role in the planning and construction of the system. These four factors also will dictate system reliability, multi-path fading, fade margin calculations, Fresnel zone clearance, interference analysis, system diversity and long-distance specifications. Radios in the 2GHz to 6GHz frequencies can transmit over longer distances, which make them more suitable for rural areas. High-frequency radios are a better fit for suburban and urban environments. For example, a low-frequency radio could carry a signal for more than 20km, while a high-frequency radio, such as a 23GHz radio, could cover a path distance of about 5km.

Typical factor to be considered in the setting up communication links and selecting the transmission frequency for the remote operations include:

1. The transmission range
2. The effect of vegetation on the signal
3. The effect of rain attenuation on the signal
4. The Polarization of the signal (rain affects horizontally polarized signals more)
5. Antenna type and gain
6. Pathloss and required fade margin
7. Government regulations on transmitter power
8. Power requirement of the transmitters at the different frequencies
9. Modulation scheme and encryption algorithms used
10 Channel capacity
11. Fresnel zone clearance

VI. CHALLENGES WITH REMOTE OPERATIONS

The increased reliance on equipment for plant operation, monitoring and control leads to situation where these equipment become very critical in plant operations and anything that affects them has an increased effect on the entire system. These equipment related challenges can be classified into three major categories with the most significant effect on these equipment being equipment vandalization. These categories are:

1. Equipment failures: This includes failure of the sensors, Remote Terminal Units (RTUs), power sources, associated cabling and devices and measurement transmitters. These failures are usually due to environmental factors and aging. These types of challenges don't occur very often as the equipments are usually subjected to factory acceptance test, system integration tests and have maintenance contract put in place to ensure timely maintenance and upgrade for these systems and devices.

2. Transmission challenges. These challenges arise from the fact that the surrounding vegetation can grow over time to cause the loss of the line of sight provisions establishing the communication links. The remedy for this involve controlling the vegetation growth by trimming or when trimming is impracticable the transmission routes can be changed to ensure continuous and reliable transmission of data to and from the remote well site.

3. Vandalization challenges. These constitute the greatest challenges currently being faced by operator in the Niger Delta regions of Nigeria. This is a situation where vandals come into these remote sites and remove equipment from the sites for sale and in some cases destroy the equipment they can't remove.

VII. STRATEGIES FOR REDUCING THE CASES OF VANDALIZATION

The devices at risk of Vandalization attacks if :

1 The are Independently existing e.g the solar panels, power sources

2 The Easily detachable and removable from the main systems e.g clamp-on meters, sensors, RTUs

3 Commercial viability is identified by the vandals e.g steel poles, poles used for mounting antennas which are being used to make jewelry.

4 The materials are attractive and stand out

The strategies for reducing these vandalization risks include the following

1. Camouflaging the devices with appropriate paints and colours to reduce their visibility and commercial viability and disguise them to hide their functionality.
2. Burying the devices In special compartments underground where possible to reduce their exposure
3. Integrating the materials into the oil processing equipment such as the well heads and encasing then in dummy pipes attached to the main pipelines to reduce their visibility.

VIII. ASSISTED REMOTE MAINTENANCE AND UPGRADE USING MOBILE FIELD DEPLOYABLE CAMERAS

The assisted remote maintenance and system upgrades using mobile field deployable cameras involves the use of onsite personnel to provide physical support to the remote based expert. The expert will use the support of the onsite operator do any physical activity needed to be done on site while the onsite operator uses a mobile field deployable IP camera to provide the video feedback to the expert located in a remote location.

IX. CONCLUSION

Remote operations provide the opportunity for the operation of devices on an oil and gas facility from a remote location using appropriate communication technologies and field devices. Remote operations control and software upgrade can be implemented from office domains using remote access to the field based. Remote maintenance and upgrades where physical devices are involved can be implemented using assisted remote maintenance and upgrade using mobile field deployable cameras and onsite operators. The current security instabilities in the Niger Delta region and the increased operational cost of oil production coupled with the instability in the price of crude oil on the international market make it necessary for operators to device means of reducing operational cost without any negative impact on production. Solutions that improve production efficiency and output are preferred. Remote operations provide a safe and cost effective alternative to plant maintenance and operation especially with respect to the use of expatriate and specialists in the oil and gas industry. It requires a robust architecture comprising of the field devices, the communication link and the office LAN. The most significant challenge with remote operations architecture is that of vandalization of the field devices. Strategies aimed at reducing the effect of this challenge have been listed and these strategies have a capacity to reducing vandalization attacks by either camouflaging the field devices, integrating them into the process equipment and dummy pipelines and even burying them where possible to conceal their identities.

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