Improving safety in Oil and Gas Pipelines and Offshore project using Wireless Sensors Networks

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Abstract
This paper presents a design architecture for wireless H2S remote monitoring system during the construction and drilling for Oil and Gas project. Because of the absence of wires and the nature of the construction activities while drilling (mobility of workers across the causeway is needed), the detection of the H2S gas needed to be mobile as well. Thus the wired solution was not possible except within the rig area’s sensor connectivity. Furthermore, the perimeters mobile sensors units, stationed around the mobile workers, were designed to operate in pairs for redundancy across wireless connectivity to the rig, H2S sensor redundancy, and the redundancy for the solar panel, beacon and horn. The perimeters mobile sensors units contains horns and beacon to alert the associated work group of the presence of any level of H2S. To further improve the reliability and availability of the connectivity between the rigs and ECC, VSAT and WiMax links were operated in redundant mode to achieve higher availability. Moreover, each group of workers are given a private mobile radio to communicate to the ECC the status of the H2S should an alarm be generated. The private mobile radio provides a second tier of redundancy for communicating emergency information to the ECC. The same infrastructure can be reused for the pipelines system to support remote monitoring system for H2S and pipelines Gas leak detection, Cathodic protection monitoring system, wireless CCTV and remote motion detection system.

I. Introduction

The Manifa Program has the prime objective of providing Arabian Heavy crude oil, sour gas and hydrocarbon condensate. One part of this project is construction of 41km of causeway (see Figures 1a and 1b) and 27 drilling islands in the shallow off-shore area, rough grading of 2,700,000 square meters for the construction of Saudi Aramco construction camp pad, Saudi Aramco and contractor office pads, construction contractor’s camp pad, and temporary sanitary facilities. It also includes new access roads, upgrade existing roads, construct four (4) bridges over the exiting nearby Highway, drill nine (9) permanent water wells, and provide temporary communication and electrical networks.

Furthermore, the scope of the project includes the installation of pipelines to transport gas, condensate, and crude oil produced from the Manifa Field to the Khursaniyah Gas Plant (KGP) and Ju’aymah Terminals. The project will install five new pipelines with related facilities to support the Manifa field development. The first one is a 48” diameter crude pipeline approximately 165 km long from the Manifa GOSP (Gas and Oil Separation Plant) to Ju’aymah
A Risk Assessment Study for simultaneous operations (Drilling & Construction) for the construction phase of Manifa Project was conducted. As part of the mitigation factors, the study recommends to install a temporary H2S monitoring system connected to the Emergency Control Centre (ECC) during the construction phase of the Manifa Project especially for the causeway construction. Currently there is no wiring between the drilling sites and any onshore sites and therefore wireless H2S monitoring system needs to be developed prior to the beginning of drilling and construction operation.

The main purpose of the wireless H2S monitoring system is to procure a temporary wireless H2S gas monitor system for Manifa project to support early alert for H2S gas presence in the area of the rigs and surrounding areas of the rigs under drilling. In addition, provide H2S readings to the Emergency Responder system to manage an emergency situation in case of any uncontrolled H2S release from Manifa Causeway Drilling operations, so that an Emergency Evacuation & Response Plan are initiated once the main Emergency Control Center is alerting.

Figure 1a: Ariel view of the causeway and drilling islands.
Each Drill Rig will have its own sensors installed on the Rig itself to monitor the H2S release during drilling. These drilling sensors are connected to its standalone Alarm system at the drilling site. In addition, the temporary wireless H2S gas monitoring system consisting of sixty four (64) mobile gas monitor units located on the causeway and another forty eight (48) gas monitoring units to be installed at the onshore drill sites. These units shall provide an early alert of H2S presence in and around the drilling rigs.

The wireless monitoring system shall be connected to the Emergency Control Center (ECC), and alarm at a setting ranging from low to high with the low alarm occurring at ten (10) parts of H2S per million (PPM) and the high alarm set at twenty (20) parts of H2S PPM. The locations of the sensors in the surrounding areas shall be determined by the onsite safety engineer, and relate directly to simultaneous drilling and causeway operations.

Once the drilling and construction is complete, the wireless remote monitoring network will be reused to support the operation in areas such as Remote monitoring system for H2S and pipelines Gas leak detection, Cathodic protection monitoring system, CCTV and Motion detection system.

It must be emphasized that the intent of this paper is not to recommend wireless as a mean for H2S detection system since the wired solution is much more reliable than the wireless solution. The objective of this paper is to provide a redundant wireless solutions and mechanisms to be used for offshore and onshore projects construction when the wired solution and power are not available. Certainly, having a wireless H2S system is better not having it at all.

The organization of this paper is as follow, section II will provide the challenges facing this project; section III will present the design architecture and solution integration, while section IV provides the conclusion and best practices.


II. Challenges

According to the risk assessment study, the release of H2S maybe occur affecting work areas; the availability of wireless remote monitoring system will provide an early detection for emergency response to respond. There were a number of challenges in this projects, main challenges are

- No Wired infrastructure or power in all of the site areas
- Construction Working staff are mobile depending on the work location
- Harsh environment and weather condition, temperature can reach up to 55 C and humidity can be 99 \%
- Wind effect & gas dispersion model will need to be factor in as part of the emergency plan.

After completion of the construction phase, redesigning and re-engineering the system to be used in operation phase will be the main challenge.

III. Design and Integration

In each drilling rig, there will be a portable office for staff that includes small communication room. In that room wireless Ethernet Radio (gateway) with external antenna mounted on 6-meter pole will be installed. In addition, redundant wireless link will be used to connect each rig with the ECC. The redundant link consist of one wireless VSAT link and second link wireless WiMax link, both operated on a hot standby mode. The communication room includes an Ethernet switch for hot standby function purposes. Moreover, 2 fixed H2S sensor around the rig will be connected to the system for extra safety measure. Figure 2 provides the design architecture of the wireless monitoring system.

The Mobile Perimeter Unit consists of (see Figure 3):

- Integrated perimeters H2S sensor
- Wireless Ethernet Radio (Wi-Fi) & antenna
- Solar Power Unit with battery
- Horn & Beacon
- NEMA4X enclosure (IP66)
- Mobile infrastructure cabinet

The Monitoring System located at ECC includes the following components:

- PLC which is composed of a CPU with a Modbus TCP/IP card for communications to the Wireless Radio Interfaces.
- Network switch/firewall.
- WiMax wireless Ethernet bridge
- Wind direction indicator
- Server hosting software to map sensors number to locations
Figure 2: Wireless Architecture Solution.

Figure 3: Mobile Perimeter Unit hardware components.
Monitoring software sample screens:
There will be a desktop computer running the SCADA system software package. The SCADA
will be configured to display all of the alarms related to the H2S Monitoring system, graphic
pages will be provided displaying a visualization of each island and the alarms. The information
that will be available to the operator will depend upon the access level used to log in by the
operator. The application software allow the operator to track all the 27 drilling islands at the
same time, if an alarm happened due to a high reading of H2S or a communication disconnect
with one of the sensor then the island number will start flashing on the screen, see Figure 4.

Pressing on the specific island number will show all sensors (mobile and fixed) on that island
with the H2S level reading (green mean the reading still within the acceptable range), see
Figure 5. If any alarm happened in another island at a particular time, a red light message will
be display in the bottom of the page and an alarm sound will be there too, moreover pressing to
one of the sensor will take you to the configuration page of that sensor as showing in figure 6.
The configuration page will allow change of the H2S alarm level.

The alarm levels will be set at 10ppm (parts per million) and 20ppm for the H2S Sensors. The
beacon and horn will be activated at or above the 10ppm level via relays on the H2S sensors
themselves. If any of the detectors 1 to 6 (non drilling rig detectors) are activated then the
following will happen:

- Alarm at the H2S Monitoring System SCADA,
- Alarm at the Beacon and Horn adjacent to the sensor.

If either of the detectors 7 and 8 (at the drilling rig) is activated or if either of the detectors 7 and
8 goes into fault, then the following will happen:
• Alarm at the H2S Monitoring System SCADA.

If any of the detectors go into fault then the relevant fault code will be displayed on the screen and the relevant Gas Detector will go into fault on the Human Machine Interface (HMI).

**Figure 5:** Per drilling Island H2S Sensor information

**Figure 6:** Configuration information for H2S Sensor module alarm.
IV. Conclusions

The intent of this paper is not to recommend wireless as a mean for H2S detection system since the wired solution is much more reliable than the wireless solution. The objective of this paper is to provide a redundant wireless solutions and mechanisms to be used for offshore and onshore projects construction when the wired solution and power are not available. Certainly, having a wireless H2S system is better not having it at all.

Wireless was the only possible solution for the circumstances of this project to protect workers around the drilling rigs areas. Because of the nature of the construction activities while drilling, mobility of workers across the causeway is needed; subsequently the detection of the H2S leaks needed to be mobile as well. Thus the wired solution was not possible except within the rig area’s sensor connectivity.

Because satellite availability is in the order of 99.8% and WiMax availability degrades over / around sea, the combined availability of the two systems operating in redundant mode will provide acceptable level. Furthermore, the perimeters mobile sensors units were designed to operate in pairs for redundancy across wireless connectivity to the rig, H2S sensor redundancy, and the redundancy for the solar panel, beacon and horn. Moreover, each group of workers are given a private mobile radio to communicate to the ECC the status of the H2S should an alarm be generated. The private mobile radio provides a second tier of redundancy for communicating emergency information to the ECC.

The following best practices must be followed when such installation (or similar installation) is pursued:
- Antenna stationed on Mobile perimeter unit must be firmly fixed (not vibrating) to improved reception
- Remote management of devices are essential to the efficiency of this solution
- Good configuration will minimize lots of rework.
- Selection of standard interoperable devices minimize the integration, installation, and spare part management
- Equipment needs to be selected to withstand a maximum of ambient temperature of 55°C, 99% humidity, and strong dust.

The same infrastructure can be reused for the pipelines system once the drilling and construction is completed. The wireless remote monitoring network will be reused to support the operation in areas such as remote monitoring system for H2S and pipelines Gas leak detection, Cathodic protection monitoring system, wireless CCTV and remote motion detection system. In some of these applications, wireless will be used as primary communication, such as Cathodic protection monitoring system, wireless CCTV and remote motion detection; while in others, wireless will be used as the secondary communication media or secondary alerting such as remote H2S and pipelines Gas leak detection.