Wireless Sensing on Surface Hydrocarbon Production Systems

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Abstract. The use of wireless sensor networks for monitoring and optimising the performance of surface hydrocarbon production systems is reported. Wireless sensor networks are shown to be able to produce comprehensively instrumented XTs and other equipment that generate the data required by Intelligent Oilfield systems. The information produced by such systems information can be used for real-time operational control, production optimization and troubleshooting.

1. Introduction

The oil and gas industry faces continual demands for improvements in production efficiency, with the recent fluctuating oil and gas price providing yet more incentives for such improvements. Of equal importance is the potential for new systems and techniques to increase the amount of oil recovered. The industry also faces new challenges from increased environmental awareness and legislation. In general terms, operators wish to achieve enhanced asset awareness to maximize performance by allowing operation of their assets cost effectively, and at the technical limit of efficiency. A key technology in delivering these improvements is the Intelligent (or Digital) Oilfield, which relies on the flow of useful information from the hydrocarbon production equipment. This information can be in the form of pressures, temperature, flow rates, production fluid composition, or equipment status (e.g. choke and value positions, connector engagement). This information can be used for real-time operational control decisions to optimize production, or analysed retrospectively for troubleshooting, work over planning, and equipment reliability assessment.

The generation of accurate performance data from the production equipment is an essential component of Intelligent Oilfield systems. Effective production data generation will necessarily require the deployment of a comprehensive suite of sensors on production systems. The resultant data can then be utilised in data processing (condition performance monitoring) and modelling systems, (including models of discrete components of the overall production process such as; valves, flow lines and pumps) to produce intelligent hydrocarbon production systems capable of enhanced operation.

Important components within surface hydrocarbon production system are the XT and wellhead, as shown in figure 1. Various steel pipes (or casings) are situated within an oilwell, in order to support the borehole into the earth, and to transport produced fluid to surface oilfield equipment. The wellhead provides a means of suspending and aligning these casings, and a pressured connection between the
oilwell casings and the XT. An XT contains valves, access ports, and potentially a choke. These are used to control the flow of production fluid from the oilwell, and to provide access to the oilwell for maintenance and injected fluids.

Conventionally these devices have been fitted with only a small number of sensors. Major factors restricting the number of sensors deployed are the physical requirements, such as available space for cabling and associated infrastructure, ease of access for installation and repair, and costs of the cabling. In many applications, such cabling needs to be armoured both for security and to avoid problems with interference from electrical systems on the XT.

Figure 1: Photograph of XT installed on Wellhead (below grating) on an Offshore Platform

2. Wireless Sensing

An alternative approach to producing highly instrumented hydrocarbon production systems is to utilise wireless technology. Such an approach will immediately offer significant cost savings in relation to the cabling and installation, with estimated savings of between 25-90%, depending on the complexity of the installation\(^9\). The removal of the physical cabling requirement, combined with the associated reduction in cost, will make it far more practical and cost effective to deploy a far greater number of sensors. The potential benefits of wireless technology can be realised in both future developments and also legacy fields, where the cost effectiveness of wireless sensing may be particularly useful on remotely located installations. In such locations significant cost and safety benefits will be accrued from reduced visits for inspection and maintenance.
Wireless technology provides a flexible sensing solution with the option for the deployment of new wireless sensors, as well as the upgrading of existing hardwired sensors to transmit their information wirelessly. Wireless sensing installations are quickly and cheaply expandable, which is of particular benefit for temporary setups, such as during hydrocarbon production system installation or troubleshooting. Wireless sensors may also be deployed to augment the safety of operations, whilst the reduced requirements for wired infrastructure maintenance reduce personnel exposure to the dangerous environment surrounding production equipment.

In developing the wireless network for a hydrocarbon production system, it is important to take account of the complexity of the metal structures (of both the surroundings and equipment itself), and ensure that the wireless network design minimises the potential problems associated with interference and reflection. Due consideration should be given to data rate requirements for each instrument, in order to minimize the power consumption of the wireless sensor, and associated energy storage devices. As shown in Figure 2, high data rates are usually achieved at the expense of power consumption, with low power technologies, such as Near-field Magnetics or ZigBee, exhibiting power consumptions several orders of magnitude less than Ultra-Wide Band or Wi-Fi.

Figure 2: Chart of typical data rates and power consumption for selected wireless technologies

Figure 3: Maximum range of wireless technologies, within context of surface oil & gas applications
The application of wireless communications technologies to enable wireless sensing on surface oil and gas equipment will not predicate a “one size fits all” approach. The suitability of wireless technologies to discreet applications is illustrated in Figure 3, where short range technologies could feasibly be applied for integrated equipment purposes, with the attendant benefits of low power consumption and longer range technologies providing facility-wide coverage.

3. Wireless Sensing on Hydrocarbon Production XT

The basic format of the FMC wireless sensor network for surface XTs is shown schematically in figure 4. As can be seen from the figure the system is made of a hub and a series of wireless enabled sensors. The hub contains the wireless base station that communicates with the on XT sensors. The hub also contains a local processor that performs first level screening and processing of the sensor data. As outlined above, to enable an operator to effectively monitor the equipment and production flow and to support intelligent oilfield systems, it is necessary to have a comprehensive suite of sensors distributed around the production equipment. Sensors that may typically be installed on the XT include those for pressure and temperature, fatigue monitoring, vibration, choke and valve positioning, hydrates during choke down, corrosion and environmental monitoring.

In designing wireless sensors for on XT applications it is essential that both the sensor devices and hubs comply with explosive atmosphere regulations. It is also highly desirable to ensure that the design allows ready installation of the sensors on the XT, new and retrofitting to existing XTs. An example of a single point 4/20mA self transmitting and self contained device is shown in Figure 4 b). This transmitter has a range of ¾ mile and has an operating temperature range of -20°C to +60°C. It is intrinsically safe with an Ex ia rating, and can therefore be used within zone 0 in the oil and gas industry. The units can be powered using a variety of methods including the use of batteries with reported 10 year lifetimes or energy harvesting schemes. The hub can be powered using similar methods.

![Diagram of FMC wireless sensor network](image)

**Figure 4 a): Wireless Sensing on an XT, b) self transmitting and self contained wireless device**
The system architecture approach which has been adopted for surface XT applications utilises high reliability, non line of sight wireless networking technology, ensuring that the signals get to where they need to go, regardless of changes which may influence other systems, such as structural alterations or environment conditions. The tool sets also allow easy interfacing to legacy infrastructure and can be quickly and easily installed and configured to interface with any production system. This ensures that the total monitoring system can be configured to work with all the systems available, providing the optimal solution to the operator.

As illustrated in figure 5 the surface XT wireless sensor network forms part of the overall integrated intelligent oil field system. In the FMC system, the hub can be used to service single or multiple XTs as well as auxiliary systems such as flow line chokes. The hub also contains the communications link with the operations control centre or other customer specified location. The nature of this communications link will depend on the locally available infrastructure, but may be land lines, via satellite, mobile phone or radio. Depending on the customer requirements and local conditions, the raw or processed sensor data may be transmitted to the remote base or operations centre. Within the operations control center the sensor data is further processed using condition performance monitoring systems and historical data sets to provide technical assessments and allow optimization of the production. From the control centre, key personal can be notified of alerts via mobile phone or laptop. The production data derived from the sensors may also be used in business application systems to assist in optimal commercial operation of the field.

4. Conclusions
Wireless sensor networks for surface hydrocarbon production systems offer a safe and cost effective route (with cost savings in relation to the cabling and installation of 25-90%) to developing comprehensively instrumented XTs and other equipment. Such instrumented systems will enable the equipment to integrate with Intelligent Oilfield systems that require the flow of useful information from the hydrocarbon production equipment. This information can be used for real-time operational control decisions to optimize production, or analysed retrospectively for troubleshooting, work over planning, and equipment reliability assessment.
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