Cable-less Downhole Monitoring and Flow Control for Remote Operation of Gas-lifted Wells

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Abstract

This paper describes the design, development and successful deployment of a relatively simple wireless electric gas lift valve system. Key functions offered by the system today include: wireless deployment, variable lift valve position, permanently installed real time downhole gas injection, pressure and temperature measurements, remote monitoring and control. The current version of the system has been deployed in a Middle East well and a well in the Far East. Performance, reliability and optimization data are currently being gathered from these deployments.

Introduction

Wireless down hole communication and control is an emerging technology, with numerous possible applications in the oil and gas industry. In late 1998, a research team within the Shell organization began looking at possible technical solutions to deliver wireless power and communications, and for initial applications of this technology. The research team conceived a method for powering, monitoring and controlling an electric gas lift valve in a “dry” annulus well. The proof of concept was demonstrated in a 600 feet deep test well at a Shell facility in Houston in October 1999. The prototype configuration was improved through further deployments in a test well in the UK in July 2000, followed by live well deployments in the Middle East in January 2001 and the Far East in August 2001. Fully functioning systems were then deployed in the Middle East in August 2002 and in the Far East in December 2002.

The most recent installations are currently being remotely monitored, in order to build a database of the system performance and reliability.

System Architecture and Functionality

In the current configuration, the tubing and casing are used as separate electrical conductors to create a current loop through which a power and data signal are transmitted to a down hole telemetry unit (figure 1). Power is taken off uniquely designed electrical chokes to drive the down-hole equipment. In this first application, the downhole telemetry device is controlling an electric gas-lift valve and is also interrogating several down hole pressure and temperature gauges (figure 2). Being multiplexed and multi-drop, the system is able to “power talk” (power–up and communicate) with several down hole units using communication technology developed and owned by Shell. Each downhole unit may individually perform different functions.
Since the current design uses the tubing and the casing as a coaxial cable, electrical isolation must be established and maintained between them. This is accomplished using non-conducting centralizers, the electrical choke, and dielectric fluids in the annulus. The Research Team selected the gas lift application as the first embodiment due to the ease of creating electrical isolation by evacuating the annulus with the gas lift gas.

The current design has been installed in two existing wells as part of normal re-completion operations. Sufficient power (100 – 300 watts) must be provided on the surface. A communications link from the well site to the office is desirable to take greatest advantage of the system (figure 3). A single conductor electrical feed-through in the tubing head and hanger is also required.

**System Functionality**

The current system design offers the following functionality:

- SCADA interface for
  - remote monitoring and control of the valve on demand
  - remote monitoring of downhole gas flow rates through the valve
  - remote monitoring of downhole pressure and temperature
- The valve may be opened or closed to any setting from 0 to 100%
- Gas flow through the valve at any setting can be calculated
- Wireless deployment

**Early Deployments**

Early system deployments were carried out as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 1999</td>
<td>Houston</td>
<td>Wireless power and communications concept proven in shallow test well.</td>
</tr>
<tr>
<td>August 2000</td>
<td>UK Land</td>
<td>Power and comms tested at depth</td>
</tr>
<tr>
<td>April 2001</td>
<td>Far East</td>
<td>Prototype Gas Lift Valve deployment in live well. Failed due to inadequate design. Learning carried forward.</td>
</tr>
<tr>
<td>August 2001</td>
<td>Middle East</td>
<td>Prototype Gas Lift Valve deployment in live well. Failed due to inadequate design. Learning carried forward.</td>
</tr>
<tr>
<td>H1 2002</td>
<td>Houston</td>
<td>Redesigned system run in test wells.</td>
</tr>
</tbody>
</table>
Middle East Deployment

In August 2002, a wireless gas lift system was successfully deployed in a Middle East well. The equipment, built and tested in the Shell lab in Houston Texas, was made up and tested in the Operating Company’s base workshop (figure 4). After testing, the equipment was delivered to site as plug and play assemblies ready to be run into the well. As it is essential in this design to insulate the tubing from the casing, insulating centralizers were fitted to the tubing. This was done while the tubing was lying on the pipe rack prior to running into the well to avoid any lost time while running the completion string. The equipment was installed into the completion string in the same way any completion assembly is installed and the only impact of running this equipment and a standard completion was an additional 30 minutes spent testing to ensure proper operation of the valves. The time taken for the completion from picking up the first Gas-lift assembly to finishing the pressure test on the X-mass tree was approximately 12 hours. After the flow and gas lift lines were hooked up and tested and the well was linked to the surface electronics and the system was ready to be commissioned.

One hour after the gas-lift gas was turned on the top unloading valve was uncovered. In this well it was not necessary to use the unloading valve to reach the lifting valve. After a further 30 minutes unloading the bottom lifting valve was uncovered and started communicating. The valve responded as designed, with the pressure, temperature and valve position indicator readings all functioning correctly. Communication with the well was then transferred to the Central Control Room in the Operator’s base and the well is now monitored and controlled from there (figure 5).

It should be noted that with 100% of the gas lift gas pressure available, and no concerns about cables on the tubing, on this installation, it was possible to set the lifting valve 150m (TVD) deeper than other installations in the field.

Far East Deployment

In December 2002 December the second cable-less gas lift system was deployed as part of a workover re-completion on a Far East well. The operations were carried out in the same way as the work done in the Middle East with the same small impact on the actual completion operation as seen there.

Gas lift pressure was limited during the commissioning of this system. It took five hours from the time the gas-lift gas was turned on to uncover the top unloading valve. Communication with the top valve was established and it was opened sufficiently to allow the well to be unloaded to the lifting valve. After a further three hours unloading, the bottom lifting valve was uncovered and started communicating. The bottom valve
responded as designed, with the pressure, temperature and valve position indicator readings all functioning correctly. After gaining control of the lifting valve the unloading valve was closed completely and the lifting valve was now controlling the well production. Communication with the well was then transferred to the Operator’s main office, and the well is now monitored and controlled from there.

**Impact**

With direct control on demand of the lifting valve and real time monitoring of down-hole conditions now available at the surface, it is possible to fine-tune the lifting valve setting to optimize the production rates and gas lift gas usage. The valve can be opened or closed to any setting from 0 –100% over the operating range and the gas flow through the valve calculated for each setting. Since unloading valves can be controlled from the surface, all of the available gas lift pressure can now be used for gas lift as there is no need to close pressure operated unloading valves. As a result the lifting valve can be set 200 – 500 ft. deeper in the well than traditional valves, which in turn increases the production rate and reduces the abandonment pressure. Also, as flow is now controlled and measured in the well, flow control is no longer required at the compressor station.

**Conclusions**

A functioning wireless power and communications system, suitable for use in “dry” annulus wells has been successfully developed.

The initial application of this technology in gas lift operations has the potential to significantly increase the market share of gas lift systems in the artificial lift market, provided the reliability of the system is demonstrated.
Figure 1
Cable-less electric Gas Lift Valve System Schematic

Figure 2
Downhole Pod Architecture

Electrical Choke: Voltage difference across choke drives Power & Comms module
P&C module: electronics housing and gauges
Electric gas lift valve: miniature choke
Check valve
Middle East Installation
Surface power supply & telemetry designed for 6 days continuous operation without sunlight.

Figure 3
Surface Power Generation and Remote Communications Link
Figure 4

Downhole system ready for dispatch to the wellsite.
Valve set point indicator (valve opening from downhole indicator) 
Valve opening is set by dragging bottom indicator to the desired position

Graphical (history) and digital display

Figure 5
Example View of Monitoring and Control Software Interface