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Sensor Architecture for Open Hole Gravel Pack Completions

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Abstract

Measurements from permanent sandface sensors have been made in a dual-stage subsea well in the Bay of Bengal. Miniaturized temperature sensors were clamped to the exterior of sandscreens and transmitted their data across an inductive coupler back to the seabed by means of a downhole communication hub. The system has been permanently installed and was designed to provide interpretation data over the life of the reservoir. The completions hardware required to accomplish this was novel, but the implementation would not have been a success without attention to the overall instrumentation and controls architecture. Interface management was a key to the ontime deployment of the system.

The sensor data were transmitted in packed blocks that combined diagnostic information with raw temperature values. The communication hub merged those blocks with temperature and pressure values from above the production packer. Inductive coupling provided a wireless transmission of power and data between the upper and the lower completion. The combination was transferred to a subsea interface card in the tree which made the data available using a Modbus™ protocol. The Modbus data were transferred by subsea vendor protocols to a rack-mounted computer on the production platform. For the subsea vendor, there were essentially no differences between for sandface data versus for those wells with measurements only above the production packer. In particular, no additional or non-standard penetrations were required through the tree.

The sandface temperature data were transmitted in real-time during clean-up to the company headquarters in Mumbai, where they were staged onto an Oracle™ database. A thermal simulator has been configured to upload data from that database and provide an iterative inversion wherein reservoir properties are varied until simulated temperature data matches the measured data. Standard fluid modeling programs can then give a flow profile from those intepreted reservoir properties. The same thermal simulator will be used for production data, in which case the well data passes from the production platform to the same remote database using a redundant architecture.

Introduction

Reliance Industries Limited (RIL) has recently completed a deepwater subsea well in the D1-D3 gas fields in the KG-D6 block, offshore India, using a permanent sandface measurement system. Temperature sensors were deployed across the lower completion of a subsea, high-rate gas well. The data were transmitted real-time to shore during the well clean-up and will be used to continuously monitor the reservoir once production begins. Multiple vendors were involved in the communication change requiring extensive interface management. The implementation would not have been a success without attention to the overall system architecture and communication platform.

The completion hardware included a combination of sensors on both the upper and lower completion multi-dropped onto a single control line with a single penetration through the subsea tree. The sensors on the lower completion were clamped to the exterior of open-hole gravel-pack screens and passed their data to the upper completion via an inductive coupler as described by (Jaju, 2008). The same inductive coupler passed power from the upper completion to the lower. This novel use of inductive coupling solves a long-standing problem in permanent sensing on multi-stage completions. It requires no orientation, is immune from vibration and is tolerant to small amounts of debris in the wellbore. Because the sensors are on the exterior of the gravel-pack, there is no stinger in the flow that could otherwise restrict flow rate or compromise well control during deployment. The overall system provides a relatively large amount of data with a limit of 48 temperature sensors every minute. For this first KG-D6 deployment, 18 sensors were deployed along the lower completion, together with 2 quartz gauge sensors which updated their temperature and pressure every second. Data visualization is available on the control riser platform (CRP) as well as at the onshore processing facility. Redundant systems have been installed where needed.