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Theory and Application of Probabilistic Method of Designing Customized Interval Control Valves Choke Trim for Multizone Intelligent Well Systems

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Abstract

This paper describes a stochastic approach to the design of interval control valve choke trims for an intelligent well system. The paper builds on the deterministic approach of specifying the Cv characteristics of a multi-position control valve. The probabilistic method considers reservoir uncertainties in productivity indices, zonal pressure drawdown, expected production (or injection) rates and field production operation philosophy.

This design approach allows the control valve to meet the expected control objectives and ensures that the design trim is applicable to a wide range of well performance. The probabilistic method is demonstrated using real data from field examples.

The probabilistic design methods described in this paper are applicable to all intelligent well systems using variable choking valves, on both production wells and injection wells. The methodology is also applicable to intelligent well systems targeting reservoirs with characteristics that are widely uncertain. This method will enable the engineers to design an interval control valve (ICV) that incorporates reservoir uncertainties with field control philosophy leading to an optimized well delivery system.

Introduction

Intelligent well downhole control valves are used for many purposes in different field applications. Downhole control valves can be used to control production commingled from multiple zones, to balance production between contributing zones and to implement field operating strategies. The number of intelligent well installations using variable flow control rather than binary (on/off) valves has increased to the point where variable flow control is the preferred solution in the majority of installations.

The use of intelligent well technology in field development has been addressed by several authors. Oberkircher[1] *et. al* presented a review of different applications and integration of intelligent and multi-lateral well systems. The authors highlighted benefits and drawbacks and potential solutions of selected applications.

Haugen[2] *et. al.* also discussed a field development that integrates intelligent well systems with multi-lateral technology in three horizontal subsea wells in the Gullfaks South Stratfjord field. The implementation resulted in estimated reserve increase to 5.4 MM Sm^3. The main attraction for using the technology was to provide required flexibility to control contribution from different branches of the multi-lateral wells. In a satellite offshore Malaysia field, Bogaert[3] *et. al.* described an integration of gas lift optimization with intelligent well systems for real-time flow estimation and remote process control. This application resulted in about 10% production gains and 2% additional reserves. In each of these applications, the performance of the downhole ICV is determined by the valve trim design. The trim is described by its valve coefficient, Cv, which quantifies the relationship between flow rate and pressure drop of the valve as a function of position.

In order for the ICV to provide the necessary degree of flow control required, it is necessary to incorporate information about the intended application and operating environment of the ICV in the design process of the trim Cv. This means information about the reservoir for which the ICV will be used to control production or injection needs to be used in the design process. The process of incorporating the reservoir performance with other engineering constraints results in an ICV with a customized choke trim design that meets the requirements of the particular application. A choke trim customization method involving the use of nodal analysis and engineering design constraints is given by Konopczynski and Ajayi[4]. This method can be used to customize downhole chokes for specific applications. The authors indicated that the objective of the customized design is to specify a choke trim that provides good flow control sensitivity across the range of valve positions based on the reservoir information. This design process challenges the engineers to consider the operating conditions for the IWC application.

The methodology described in reference 4 provides a deterministic approach to the design process. The methodology uses the “best guess” scenario of the zonal performance to arrive at the trim design parameters. This