Hierarchic Organization of a Digital Oilfield System

Iakov S. KOROVIN and Maxim G. TKACHENKO

Southern Federal University, Scientific research Institute of Multiprocessor Computer Systems, (SRI MCS SFEDU), Taganrog, Russia

Keywords: Digital oilfield, Hierarchical model, Data mining methods, Multiagent technologies.

Abstract. Nowadays optimization of technological processes of oil production and treatment are a pressing issue. The most promising approach to solution of this problem is increasing of production volumes without any additional expensive equipment. It becomes possible, if we implement modern complex approaches to data processing which will cover all phases of hydrocarbons production [1].

Introduction

Control of large oilfields is a laborious process which requires on-the-fly decision making, fast reaction and adequate error correction. Effectiveness and precision of these solutions considerably depends on validity of the input information, its completeness, and the rate of control decision making. Implementation of intelligent methods of oilfield control, which cover all considerable technological processes, will be cost-effective. The approach requires implementation of tools and facilities called “a digital well”.

Digital Well Approach

Creation of adequate models of oil production complexes is a key component of the “digital well” systems, which allow organization of modern preventive procedures for reduction of equipment idle time [2]. At present these problems are the most pressing ones for organization of production control during the whole life of the well.

The most considerable advantages of such wells are:

- Systems of monitoring, control and self-diagnostic of technological equipment;
- Communication channels for data exchange concerning real-time condition of controlled objects;
- Adaptation of an advanced mathematical model of the well and auxiliary controlled equipment, such as pump equipment, and valves;
- Adaptation of advanced tools for prediction of changes of both internal condition of controlled objects, and external factors;
- Data mining tools which compensate inaccuracy of models of controlled objects;
- Possibility of off-line functioning when connection with control centres is lost.

Behavioral Model of a Digital Oilfield

So, we have developed and suggested a behavioral model of a digital oilfield based on continuous control of technological processes [3]. The general structure of the digital oilfield control system is given in Figure 1.
Figure 1. The general scheme of intellectual oilfield.

The model implies adaptation of a hierarchic oilfield control system. The model shows the most important units of the control system:

- The control system of pump equipment and computer-aided systems, which provides real-time analysis and control of current processes;
- The well control system, which provides modelling of technological processes, recognition, simulation, and analysis of internal condition of technological objects;
- The system of strategic control, based on smart approaches to data analysis and prediction, which provides estimation of occurrence of emergency situations, ways of their prevention and minimization of consequences, and making recommendations to personnel concerning preventive actions;
- Systems of user interface, installed on workstations of technologists, which reflect current condition of controlled objects and make recommendations concerning optimal control actions.

Challenges and Advantages

The suggested hierarchical approach to organization of the digital oilfield provides evolutionary implementation of intelligence systems. Implementation of the systems as stand-alone interacting nodes simplifies their independent modification and optimization.

As a tool of data processing we have used advanced approaches to digital data analysis based on a combination of the methodology of artificial neural networks, and probabilistic and temporal models for the problems of machine training [4][5][6] [7][8].

Such complex approach provides effective procedures of real-time monitoring, diagnostics, prediction and control in uncertain conditions, which are typical for modern oil-and-gas production. Our successful experience of implementation of projects for various purposes within the research area, and successful approval of the obtained scientific results by domestic and foreign scientific societies confirm correctness and validity of the approach and solvability of the problem.

Owing to the dynamic structure of control systems for digital oilfield, which unites data collection, storage and processing, it is possible to implements methods and tools of control on the base of a multi-agent approach.
Such solution provides effective interaction and evolutionary implementation of various systems of intellectualization of production processes based on neural networks, genetic algorithms, methods of regularities and abnormalities detection, and other modern approaches of artificial intelligence.

Besides advanced facilities of interaction between agents, applied solutions must remain adaptive, and be capable to optimize their own functions and change their own behavior, if both control systems and control centres of an upper level are changed.

The developed systems of data mining and monitoring are the base for a scientific and technological platform of a digital oilfield creation. Owing to modern data mining technologies it is possible to solve a number of pressing problems, such as simulation of control actions, detection of condition of equipment, detection of malfunctions, change of technological processes to obtain the most effective production rates. Owing to implementation of integrated systems of real-time monitoring, data mining and control of production processes, it will be possible to optimize the existing production processes, to increase target production rates and to prolong the life time of the oilfield.

Conclusion

Thus we have developed a novel model of a digital oilfield. The approach is relevant to all types of the oilfields (light and heavy ones). The basic idea is to represent all the stages of oil extraction process hierarchically in a single model. The other vital point is the application of modern data mining techniques (neural networks, evolutionary algorithms) together with the approach of multiagent information handling (“well agent”).

Acknowledgement

This paper is published due the financial support of the Russian Science Foundation (RSF) via the grant No 15-19-00196.

References

[1] V.D. Lysenko, Optimization of oilfield development. - Moscow: Nedra, 1991.
[2] V.D. Lysenko, Innovation development of oilfields. - Moscow: Ltd. Nedra-Business Centre, 2000. pp. 516.
[3] Y. Levin, D. Markelov, V. Zhiltso, A “digital well” for the oil company “YUKOS” // Scientific and technical herald of Yukos. 2003. № 6.
[4] Iakov S. Korovin, Igor A. Kalyaev, Modern Decision Support Systems in Oil Industry: Types, Approaches and Applications, International Conference on Test, Measurement and Computational Methods (TMCM) 2015, Chiang Mai, Thailand; Advances in Computer Science Research. ISBN 978-94-6252-132-2. ISSN 2352-538x, pp. 141-144.
[5] Iakov S. Korovin, The Importance of New Approaches Development and their Implementation in the Oil and Gas Industry in Russian Federation--the Current Situation Analysis, International Conference on Advances in Energy, Environment and Chemical Engineering (AEECE) 2015, Changsha, Peoples R China; Advances in Engineering Research. ISBN: 978-94-6252-109-4. ISSN: 2352-5401. Atlantis Press, Volume 23, 2015, p. 94-97.
[6] Iakov S. Korovin, Anatoly I. Kalyaev, Maksim V. Khisamutdinov, Data Mining Methods Application to the Problem of Handling Corporative Dataset on Heavy Oil Production, International Conference on Intelligent Control and Computer Application (ICCA), Zhengzhou, Peoples R China: JAN 16-17, 2016 Proceedings of the 2016 international conference on intelligent control and computer application, ACSR-Advances in Computer Science Research Volume 30, pp. 387-389.
[7] I.S. Korovin, M.V. Khisamutdinov, G. Schaefer, A. Kalyaev, Real-time diagnostics of oil production equipment using data mining, 2016 5th International Conference on Informatics, Electronics and Vision (ICIEV), 2016, pp. 1196 – 1172, DOI: 10.1109/ICIEV.2016.7760184.

[8] I.S. Korovin, M.V. Khisamutdinov, G. Schaefer, A. Kalyaev, Application of hybrid data mining methods to increase profitability of heavy oil production, 2016 5th International Conference on Informatics, Electronics and Vision (ICIEV), 2016, pp. 1149 - 1152, DOI: 10.1109/ICIEV.2016.7760179.