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Boosting economic efficiency of pads drilling projects. A comprehensive study of wells groupings and localization of the global maximum

A.V. Abramov [*], R.V. Bikbulatov, I.Yu. Kolesnik, A.N. Vinokurov, V.Kh. Mukhametshin

LLC "RN-UfaNIPIneft", Ufa, Russia

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ABSTRACT

The work demonstrates an approach to improve economic performance of well pads drilling projects by selecting an appropriate grouping of wells (wellheads). Scope of the work covers all thinkable groupings of a 24-well pad. We systematically enumerate groupings and estimate economic parameters of every grouping. Results of these calculations are represented in the form of NPV (Net Present Value) surfaces and NPV distributions which naturally locate global maxima for different starting flow rates. It is shown that traditionally used in oil industry groupings of wells do not provide the best economic efficiency of pads drilling projects. The top economic results could only be achieved by taking into account all available information on performance of wells. On basis of the study it is suggested to reconsider design of prospective well pads applying presented approach to boost economy of drilling.

The problem of finding optimal wells grouping could be defined in two ways: specific and general. The specific formulation implies equal (constant) number of wells in every group, whereas the general formulation admits having different number of wells in the groups. It is clear that computational complexity of the specific formulation is much smaller than that of the general. The total number of groupings in the specific case is bounded from above by the product of number of wells in every group and number of these groups, i.e. for a well pad of 24 wells the total number of possible groupings is less than 576. If the total number of wells in a pad is N then the number of groupings in the general case is 2ˆ(N-1), i.e. for a pad of 24 wells this gives 8,388,608 possible groupings. Having all these grouping options considered it is easy to show that the largest increase in NPV of a pad could be achieved with unequal (varying) number of wells in groups. Further analysis shows that NPV maximizing well pad configurations depend on characteristics of wells, especially the starting flow rate.

Economic performance of the optimal groupings is compared with that of the pad consisting of six groups each including four wells. NPV increase of the optimal groupings is exceeding 1% and in carefully chosen parameters of the economic model reaches few millions to tens of millions of Russian rubles. It is demonstrated that reasons for these gains are, in decreasing order of importance: (i) increased oil production accompanied with elevated CAPEX (Capital Expenditures); and (ii) decreased CAPEX accompanied with reduced oil production.

1. Introduction

Combining wells into pads has long been known as a method to make development of oil and gas fields with complicated surface conditions feasible (Bronzov, 1962; Permyakov, 1986). There are number of reasons to place wellheads within limited area ranging from swampy and wet territories to environmental and land property issues. While planning well pads development efforts have been dedicated to number of problems among which are the following.

Well spacing optimization with minimization of well interference was a major topic for quite a few works, just some of them are (Wilson, 2016; Suarez and Pichon, 2016; Gakhar et al., 2016; Schofield et al., 2015). Apart from that, organization of simultaneous pad operations was another key research direction. Complications of dealing with producing wells while drilling others are addressed in the wellhead monitoring system avoiding sub-surface well collisions (Stagg and Reiley, 1991). The system allows drilling to proceed without shutting-in already working wells.

Further significant push toward application and optimization of parallel pad jobs was giving by development of shale reservoirs.

* Corresponding author.
E-mail address: abramovav@ufanipi.ru (A.V. Abramov).

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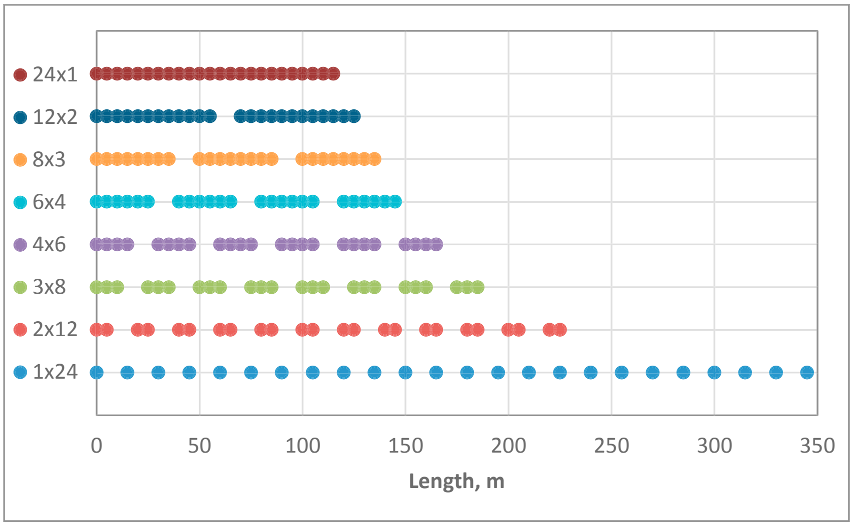

Fig. 1. Length of main part of a 24-well pad for different grouping options with constant number of wells in groups (dots represent wells, distance between wells is 5 m and distance between groups of wells is 15 m).

Introduction and management of simultaneous (mostly occurring within a cluster of wells) and concurrent (mostly occurring within different clusters of wells) operations allowed successful implementation of drill-drill, complete-complete and drill-complete processes at once (Ogoke et al., 2014). These simultaneous and concurrent operations were found to be a cost effective way to speed up delivery of multi-well pads. Typical pad configurations considered in the work were 26 wells placed in clusters of six to eight.

Pad design evolution throughout field development to accommodate needs of different procedures required during construction, drilling and completion was a topic of (Demong et al., 2013). Gained experience and knowledge of practical aspects of shale pad development made it possible to leap from 6-well pad design to possible in the future 20-well pad design.

Several works have been devoted to stimulations of low permeability reservoirs and pad completion techniques aiming, among other goals, to minimize time to the first oil (Schofield et al., 2015; Rafiee et al., 2012; Roussel and Sharma, 2011).

An attempt to view a multi-well pad as a single system and devise an optimum pad development strategy has been undertaken for the Eagle Ford formation (Gakhar et al., 2016). Varying vertical conductivity and reservoir conditions, performances of two well configurations have been estimated and recommendations were given as to which should be applied and when.

An integrated approach combining simplified reservoir simulations and hydraulic calculations with placing of platforms (read “pads”) and layouts of pipelines under umbrella of linear programming was recently proposed and studied (Rosa et al., 2018). The approach is useful for NPV maximization with respect to number of design parameters for both green and brown fields, on- and offshore.

To avoid ambiguity it is necessary to emphasize that Russian speaking and English speaking authors use slightly different terminology when it comes to well pads. We encountered “well groups” and “well clusters“/ ”drilling clusters”, “pad drilling” and “batch drilling”. The meaning of terms is not confusing and self-explanatory but in our work we predominantly use the former terms.

From available out there literature it is not hard to notice a disproportion between well pads optimization from the reservoir engineering point of view and from the surface infrastructure perspective, with reservoir engineering dominating the agenda. Construction and development of pad layouts on the surface are usually regulated by some national standards, codes and norms, demands for safety. With oil companies being busy with complying with those standards and at the same time seeking for larger profits it is somewhat surprising how little has been done to optimize groupings of wells (wellheads) within a pad. There are reports analyzing very limited number of already used in drilling practice grouping options, no more than ten (Explanatory note, 2015). These few options do not even attempt to vary number of wells in groups, which leaves vast space of wells grouping possibilities untouched and economic benefits of optimal groupings remain to be unleashed.

To establish ground rules and to set certain parameters of drilling projects we use some national standards, which by no means compromises generality of results and conclusions of present work, but instead provides a practical baseline for the analysis. One of the regulating documents defining guidelines for well pads development projects in Russia is “The norms of process design of facilities for gathering, transport and treatment of oil, gas and water of oil fields”, also known as the VNTP 3-85 (VNTP 3-85, 1985). These norms are used in conjunction with the “Safety regulations for oil and gas industry” (The federal norms and regulations in industrial safety, 2013). The norms VNTP 3-85 demand to allocate wells in a pad along straight line and limit total number of wells to 24. The document requires the distances between wells and groups of wells to be 5 and 15 m, respectively (for Western Siberia). Number of wells in groups is limited to no more than four. Requirements that are set in such a way leave plenty of room for optimization of economic performance of field development projects by properly selecting wells groupings. On the one hand, grouping of wells reduces space between wellheads, which in turn reduces size of a pad and necessary landfilling (or land area), see Fig. 1 (in this figure and further on we use notation “number of wells” x “number of groups”). On the other hand, safety concerns delay production until drilling of the whole group is finished. Interplay and competition between these two factors result in convex shape of dependence of NPV on possible groupings with clear and prominent maximum. At the same time, as the influence of the delayed production is going to be stronger with larger starting flow rate, the NPV maximizing groupings are going to be different for different starting flow rates.

The problem of searching for optimal in terms of NPV wells grouping could be defined in two ways: specific and general. The specific form implies constant number of wells in every group, whereas the general form allows having different number of wells in the groups. It is clear that the computational complexity of the specific case is far smaller than that of the general. Number of possible groupings in the specific case is bounded from above by the product of number of groups and number of wells in every group. Groupings where overall number of wells is greater than number of wells in a pad must be discarded. Assuming maximum number of groups and maximum number of wells in those groups to be 24, one may calculate number of possible groupings for a pad of 24 wells