METHOD IN AN OIL AND/OR A GAS PRODUCTION SYSTEM

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ABSTRACT

A method in an oil and/or a gas production system including a plurality of oil and/or gas wells and parameter testers adapted for oil and/or gas production parameter testing. The method is adapted to compare a plurality of options related to the oil and/or gas throughput in the oil and/or gas production system. A plurality of parameter samples are drawn from a parameter distribution. A performance measure is generated for each parameter sample by using the parameter sample and a characterizer for each of the options. An aggregated performance measure is generated for each of the options by using the performance measures.
Fig. 4

Choosing the test giving highest total oil production

Calculating total oil production with information from each test

Generating samples

Obtaining well test data
METHOD IN AN OIL AND/OR A GAS PRODUCTION SYSTEM

FIELD OF THE INVENTION

The present invention relates to a method according to the preamble of the independent claim.

BACKGROUND OF THE INVENTION

This invention relates to a method for decision-making for oil and/or gas production systems. Specifically, the invention relates to production optimization of such systems.

Oil/gas well testing may be performed to support many decisions including ones related to production optimization. In production optimization information such as gas-oil ratio and water-oil ratio are used to decide on, for example, which wells to prioritize for choking back/opening so as to avoid over/underutilization of the production capacity. Since the reservoir properties change with time, uncertainties of estimates increase with time, and eventually a new well test will be required. As the uncertainty in an estimate grows, so does the risk for prioritizing the wrong well(s) giving lower oil production than necessary.

Production throughput is an important performance indicator in an oil and/or gas production system. Herein, production throughput is intended to mean the oil and/or gas production per time interval. The throughput depends on many different factors; some may be specific to each production system, others are more general. One important general factor is how the limited processing capacity of the production system is utilized.

By using a computer simulation or a mathematical optimization method, good operational strategies may be found. The accuracy of the computer simulations and mathematical optimization methods depend on the accuracy of the parameters used in their mathematical model. To ensure good accuracy of the simulation, parameters are measured by installing measurement devices, and experiments are performed to obtain values that may not easily be measured during normal operation.

The testing of wells is generally performed by routing an individual well to a dedicated test separator. The oil, water, and gas rates at the outlet of the separator are then measured. Thus, important properties including the gas-oil ratio and the water-oil ratio can then be calculated. A test may take several hours, thus constraining the frequency at which the wells can be tested. A policy is therefore required to decide the frequency to test each individual well. One simple strategy would be to test all wells at the same frequency. Another strategy may be to test some wells more than others. This may be due to higher uncertainty in some wells, or that some wells are more important than others (e.g. higher potential). Independent of the strategy used, the goal of the well test is usually to give information that will enhance oil production.

For an oil and/or gas production system, a well test is typically performed by routing the production from a single well (one of several wells in the system) 105, 106 or 127 (see FIG. 1) to a dedicated test separator 107. This allows for measuring of parameters from this single (specific) well. The values measured are typically the flow rates of oil, water, and gas, as well as test separator pressure and/or temperature, upstream downstream wellhead pressure, and temperature, and choke opening. From these tests, values such as the gas-oil ratio and the water-oil ratio are derived. These values are critical for the optimization of such production systems.

There is typically only one or a few such test separators 107 in each production system. Therefore, all wells in the system cannot continuously be monitored. The operation of an oil and/or gas production system therefore requires a way of choosing which well to test. Even if the test separator 107 may test all wells at a satisfactory frequency, there may be other uses for the test separator 107.

For production systems where the production separator 108 capacity is limiting the total oil production, the test separator 107 is often used in the same way as a production separator 108 when it is not used for testing wells 105, 106 or 127. Then, the oil/gas flow from the multiple wells in the system may be routed to the test separator 107 to fully utilize its processing capacity. However, the measured values are then for a mixture from the production of the wells, and not for each well. Thus, the measured values can then not be used as a well test for a specific well.

The currently used method for deciding which well to test is based on a schedule, where all wells are tested at the same frequency. When suspecting changes in one well, e.g. based on changes in measured values such as pressure or temperature, the test schedule is then typically modified in order to investigate this.

U.S. Pat. No. 6,978,210 discloses a method for automatically scheduling tests of automated measurements and control devices. According to the method, measurement data is automatically collected from automated measurement and control devices that are located in a hydrocarbon production system. The data that is collected is compared with data stored in a database. The comparison of data is used to automatically schedule test of the plurality of automated measurement and control devices.

In Cramer, Moncur, and Berendschot, “Well-Test Optimization and Automation”, presentation at 2006 SPE Intelligent Energy Conference and Exhibition in Amsterdam, The Netherlands, 11-13 Apr. 2006, a method for scheduling of well tests is proposed. However, the proposed method uses a predetermined test schedule and the system does not calculate which well should be tested by itself.

A drawback of the known methods of scheduling the testing is that they do not use numerical optimization to find a test schedule. Another drawback is that the known methods do not use uncertainty distributions to find a test schedule.

The general object of the present invention is to optimize well testing in order to achieve the highest expected oil/gas production.

More specifically, it is an object of the present invention to provide an improved method for decision-making for oil and/or gas production systems, or a part thereof, in order to maximize production throughput.

SUMMARY OF THE INVENTION

According to the present invention, this above-identified object is achieved by a method having the features defined in the independent claim.

Preferred embodiments are set forth in the dependent claims 2-18.

According to the invention statistical analysis is preferably used of the possible outcomes of the well test, herein referred to as “options”, in order to calculate the value of getting more accurate information about a well. In particular, the method according to the present invention is adapted
to calculate how more accurate information will change or increase the oil and/or gas production rate because of better decisions.

[0019] The optimization is then achieved by choosing the option that preferably gives the most valuable information. Examples of options to choose from include “testing of a first well”, “testing of a second well”, or “installing a flow measurement device in an oil and/or gas production system”.

[0020] According to the present invention a method is developed to decide which well to test based on old test data and/or online measured and/or estimated data. The method is preferably implemented by a computer program that uses a Monte Carlo approach for identifying which well test is likely to result in the highest oil production rate after the well test information is utilized to optimize the production.

[0021] The method according to the present invention is preferably used to identify the next well to test in order to achieve the highest expected oil production. The method preferably assumes that the production from each well are independent and that the capacity constraint in the production can be described as single flow rate constraints in water, liquid, or gas. It is assumed that an estimate of the gas-oil ratio and/or water-oil ratio is available for each well.

SHORT DESCRIPTION OF THE APPENDED DRAWINGS

[0022] The accompanying drawings illustrate the present invention by way of examples and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to use the invention.

[0023] FIG. 1 is a schematic drawing of an oil and/or gas production system where an embodiment of the present invention is applied.

[0024] FIG. 2 is a schematic drawing of an oil and/or gas production system where an alternative embodiment of the present invention is applied.

[0025] FIG. 3 shows a flow diagram illustrating a method according to the present invention.

[0026] FIG. 4 shows an additional flow diagram illustrating a method according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0027] In FIG. 1 is shown a schematic drawing of an oil and/or a gas production system where the present invention may be applied.

[0028] The system comprises three wells 105, 106 and 127, a production separator 108 and a test separator 107. The invention may naturally be used in systems comprising two wells, or more than three wells.

[0029] 123 designates an upstream valve pressure of a valve 119 of well 105; 124 designates an upstream valve pressure of a valve 120 of well 106, and 125 designates an upstream valve pressure of a valve 126 for well 127. The term valve should herein be understood in a broad sense, i.e. to include a choke, a gate valve, a routing valve or a control valve.

[0030] 101, 102 and 128 designate routing valves for production separator 108 for the wells 105, 106 and 127, respectively.

[0031] 103, 104 and 129 designate routing valves for test separator 107 for the wells 105, 106 and 127, respectively.

[0032] 109 designates a flow rate measurement device for gas of production separator 108; 110 designates a flow rate measurement device for oil of production separator 108; and

[0033] 111 designates a flow rate measurement device for water of production separator 108. 115 designates a water level measurement device for production separator 108;

[0034] 117 designates an oil level measurement device for production separator 108; and

[0035] 121 designates a gas pressure measurement device for production separator 108.

[0036] 112 designates a flow rate measurement device for gas of test separator 107;

[0037] 113 designates a flow rate measurement device for oil of test separator 107; and

[0038] 114 designates a flow rate measurement device for water of test separator 107.

[0039] 116 designates a water level measurement device for test separator 107;

[0040] 118 designates an oil level measurement device for test separator 107; and

[0041] 122 designates a gas pressure measurement device for test separator 107.

[0042] The water-oil ratio for the well being tested is calculated by using flow measurement devices 113 and 114. The gas-oil ratio for the well being tested is calculated by using flow measurement devices 112 and 113.

[0043] The upstream valve pressures 123, and 124 and the valve positions 119 and 120 may be recorded in a data storage for later use.

[0044] This later use includes the generation of the parameters distributions, which is further discussed below.

[0045] An alternative method for measuring the water-oil ratio and/or gas-oil ratio may be to close the level valves 135 and/or 134 of the test separator 107. The gas-oil ratio and the water-oil ratio may then be calculated using the level measurement devices 116 and 118 for at least two instances of time.

[0046] FIG. 2 is a schematic drawing of an oil and/or gas production system where an alternative embodiment of the present invention is applied.

[0047] According to this alternative implementation, the test separator 107 is replaced by a multiphase flow measurement device 130. After the stream has been measured, it is routed to the production separator 108.

[0048] In FIG. 2, 130 designates a multiphase flow rate measurement device. 131, 132 and 133 designate routing valves for the multiphase flow measuring device for wells 105, 106 and 127, respectively.

[0049] All other items in FIG. 2 are described above in connection with FIG. 1.

[0050] The inventive method in an oil and/or a gas production system comprises a plurality of oil and/or gas wells and means adapted for oil and/or gas parameter testing. The method is adapted to compare a plurality of options related to the oil and/or gas throughput in the oil and/or gas production system, and includes the steps of:

[0051] a) drawing a plurality of parameter samples from a parameter distribution;

[0052] b) generating, for each parameter sample, a performance measure by using said parameter sample and a characterizer for each of said options; and

[0053] c) generating an aggregated performance measure for each of said options by using said performance measures.
The parameter distribution is generated by using historical and/or online measured and/or estimated data obtained from the oil and/or gas production system.

Said data preferably includes at least oil flow rate, gas flow rate, water flow rate, liquid flow rate, gas-oil ratio, water-oil ratio, pressure, temperature, or fluid composition, or any combination thereof.

The method preferably includes the further step of:

generating at least one aggregation of said at least one aggregated performance measure.

The aggregation then comprises a reference to at least one option or characterizer.

The parameter distribution in step a) and b) is preferably obtained by a statistical analysis, preferably by a Monte Carlo simulation.

The aggregate performance measures determined for each of the options are used to select the optimal option which may be which well to test next or to install a multiphase flow meter.

According to a preferred embodiment the means adapted for oil and/or gas parameter testing is performed by using a test separator.

Alternatively, the testing may be performed by using a multiphase flow measurement device.

In the inventive method, at least one characterizer of the options comprises information that a specific well should be tested, and/or comprises information regarding the availability of a flow measurement device.

Furthermore, at least one characterizer of the options comprises information regarding use of a test separator, or measurement of flow rate, pressure, temperature, fluid composition, gas-oil ratio, or water-oil ratio.

The performance measure reflects the value associated with oil production rate, preferably the total oil production rate, oil production volume, preferably the total oil production volume, profit rate, profit or expenses (or any combination thereof) and the aggregated performance measure is generated by using the performance measures of each specific option characterizer. The aggregated performance measure is preferably generated by using the average value, or sum value, of said performance measures.

The present invention also relates to a computer program product loadable into the internal memory of a processing unit in a computer based system, such as an oil and/or gas production system server, comprising the software code portions for performing one or more of the method steps described above, when the computer program product is run on said system.

In addition the invention relates to a computer program product stored on a computer readable medium, comprising software code portions or a computer program for causing a processing unit in a computer based system, such as an oil and/or gas production system server, to control an execution of one or more of the method steps described above.

Thus, the method according to the present invention may be implemented as software, hardware, or a combination thereof. A computer program product implementing the method or a part thereof comprises software or computer program, run on a general purpose or specially adapted computer, processor or microprocessor. The software includes computer program code elements or software code portions that make the computer perform the method using at least one of the steps according to the inventive method.

The program may be stored in whole or part, on, or in, one or more suitable computer readable media or data storage means such as a magnetic disk, CD-ROM or DVD disc, hard drive, magneto-optical memory storage means, in RAM or volatile memory, in ROM or flash memory, as firmware, or on a data server.

A data flow of the inventive method is illustrated in FIG. 3. The method preferably comprises the following types of components: measured data 201, parameter distribution 211, parameter sample 212, 222, 223, 224, characterizer 231, 232, 233, performance measure 241, 242, 243, 244, aggregated performance measure 251, 252, and aggregation 261. In addition, the term option 271, 272 is used for grouping of a set of parameter samples; performance measures 241, 242, 243, 244; characterizer 231, 232, 233; and aggregated performance measure 251, 252, 253.

As shown in FIG. 4, the first column of plots represents measured data 201, which are obtained from well tests. The second column of plots represents parameter distribution 211 and/or parameter sample 212, 222, 223, 224, which are obtained from said measured data 201. The third column of plots represents performance measure 241, 242, 243, 244, which are obtained from said parameter sample 212, 222, 223, 224. In this figure the performance measure is the total oil production rate for all wells in the oil and/or gas production system. The fourth column of plots represents the aggregation 261, which suggests which well should be tested. The aggregated performance measure 251, 252, 253 is represented on the line between the third and the forth column.

As mentioned above the parameter distribution and the generation of the performance measure are preferably obtained by a Monte Carlo simulation. Monte Carlo simulation is a powerful method for obtaining an approximate distribution of any dependent value of stochastic variables. The distributions of the stochastic variables are assumed to be known. Using these distributions, a finite number of samples of the stochastic variables are drawn. For each sample the dependent value is calculated. Important properties such as the standard deviation and average of the dependent variables calculated using Monte Carlo simulation will converge to the expected value. An illustrative data flow of the method used for testing two wells is shown in FIG. 4. In the preferred embodiment of the inventive method, the stochastic variable is the gas-oil ratio and/or the water-oil ratio of each well. The dependent variable is preferably the total oil production rate for the oil and/or gas production system.

The production optimization is normally based on estimates of parameters because the accurate value is not known, more specifically it is normally based on estimated gas-oil ratio and/or water-oil ratio text missing or illegible when filed. The estimate may be found using various techniques, but the simplest is perhaps the last well test. This is also the most commonly used technique. The uncertainty in the gas-oil ratio and/or water-oil ratio r_{i} for well i can be described by the distribution D_{i}. Methods for estimating the distribution D_{i} for each well will be discussed further below. Given these distributions, m samples \{r_{i, n}, K, r_{i, m}\} are drawn. Furthermore, if a test of well k is conducted, the estimate is updated. It is assumed that the well test is accurate, and thus,

\[ q_{ij} := \begin{cases} r_{ij} & i = k \\ \text{else,} \end{cases} \]

where text missing or illegible when filed is the estimate of the gas-oil ratio and/or water-oil ratio of well i after well k is tested using sample j.
For each such sample, the optimized oil production rate will be calculated. Furthermore, the oil production rate is calculated for each of the wells \( k \in K \) considered for testing. Because \( r_{i,k} \) is not known to the operator of the process, the inaccurate estimate \([text missing or illegible when filed]\) is used for well prioritization in the optimization. Let

\[
z_k = \sum_{j=1}^{n} z_{k,j},
\]

be the function returning the total oil production rate found in the calculation using the sample \( j \) and testing well \( k \), where \( q_i' \) is the oil production potential for well \( i \). The expected total oil production rate is given that well \( k \) is tested. The well to test can then be calculated by

\[
k^* = \arg\max_{k \in K} z_k.
\]

The described method draws a finite number of samples from a distribution, evaluates each of the samples using the same function \( f(\cdot) \). This means that \( n \) Monte Carlo simulations are conducted, one for each well test candidate. Monte Carlo simulation is a simple but powerful method. Most of the assumptions made here can easily be relaxed allowing other strategies to be used. Usually there is some inaccuracy in the well test performed, and this can easily be included by adjusting (1) to adding uncertainty for the case \( i=k \). Furthermore, the goal can easily be changed to e.g. maximize the profit instead of oil production rate by adjusting the function \( f(\cdot) \) accordingly. Risk may be accounted for by adjusting (3) to penalize for variance.

A calculation is required to evaluate the optimized oil production rate of the oil and/or gas production system for a given set of physical parameters, e.g. gas-oil ratio and/or water-oil ratio, and the corresponding estimates used for operation of the oil and/or gas production system. One simple and commonly used method is the swing producer based method, (Bieker, Slupphaug, Johansen, “Real Time Production Optimization of Offshore Oil and Gas Production Systems: A Technology Survey”, paper SPE 99446 presented at the 2006 SPE Intelligent Energy Conference and Exhibition, Amsterdam, The Netherlands, 2006). The method assumes that at most a single processing constraint is active and that each well has a maximal production rate. The goal is to maximize the oil production rate. The wells are controlled under the rule that the wells with the lowest (estimated) gas-oil ratio and/or water-oil ratio are opened at the expense of choking back wells with the highest gas-oil ratio and/or water-oil ratio. In the end, there will be one well partly choked back. The rest will be fully closed or opened.

In the following the steps according to the present invention are described in detail with references to FIGS. 1-4.

Generating a Characterizer

The characterizers 231 and 233 are preferably predetermined. They define the differences between the options 271 and 273 to be evaluated.
The aggregated performance measure may be at least one of the performance measures themselves. A person skilled in the art will understand that the performance measures may be scaled or transformed.

Generating Aggregation

The aggregation is preferably generated by using the aggregated performance measures for the different options. A preferred way of generating the aggregation is to choose that option resulting in the maximum, or minimum, aggregated performance measure. Alternatively, the aggregation may be an ordered list of options or characterizers.

In an alternative embodiment, the aggregation is generated as a visualization of the aggregated performance measures. Preferably, the visualization is ordered such that the aggregated performance measures are sorted in some way.

The method according to the present invention was implemented for choosing which well to test based on real well test data from an offshore oil production system in the North Sea. The simulation included 21 wells, and the total liquid production was restricted to 10000 Sm³/D in liquid production. The length of the simulation was 180 days.

Each well was modelled in the simulation as a producer of oil and water. The well model consisted of an oil production potential and a water-oil ratio. The oil production potential for each well was defined by an interpolation of the oil potential found in the well test data, making it time variant. To ensure a reasonable interpolation, it was restricted to zero from below. The water-oil ratio was defined as an interpolation of the water-oil ratios found in the well test data, but restricted to zero from below.

The present invention is not limited to the above-described preferred embodiments. Various alternatives, modifications and equivalents may be used. Therefore, the above embodiments should not be taken as limiting the scope of the invention, which is defined by the appending claims.

1. A method in an oil and/or a gas production system comprising a plurality of oil and/or gas wells and parameter testers adapted for oil and/or gas production parameter testing, wherein said method is adapted to compare a plurality of options related to the oil and/or gas throughput in the oil and/or gas production system, said method comprising:
   1.1. drawing a plurality of parameter samples from a parameter distribution;
   1.2. generating, for each parameter sample, a performance measure by using said parameter sample and a characterization for each of said options, and
   1.3. generating an aggregated performance measure for each of said options by using said performance measure, said parameter distribution is generated by using historical and/or online measured and/or estimated data obtained from the oil and/or gas production system.
2. The method according to claim 1, wherein said parameter distribution and the generation of the performance measure are obtained by a statistical analysis.
3. The method according to claim 1, wherein said aggregated performance measure for each of said options is used to select an optimal option.
4. The method according to claim 1, further comprising: generating at least one aggregation of said at least one aggregated performance measure.
5. The method according to claim 4, wherein said aggregation comprises a reference to at least one option or characterizer.
6. The method according to claim 5, wherein a routing valve is manipulated using said reference to at least one option or characterizer.
7. The method according to claim 1, wherein said parameter testers adapted for oil and/or gas parameter testing comprise a test separator.
8. The method according to claim 1, wherein at least one characterizer of said options comprises information that a specific well should be tested.
9. The method according to claim 1, wherein at least one characterizer of said options comprises information on the availability of a flow measurement device.
10. The method according to claim 1, wherein at least one characterizer of said options comprises information on using of a test separator, or measurement of flow rate, pressure, temperature, fluid composition, gas-oil ratio, or water-oil ratio.
11. The method according to claim 1, wherein said performance measure reflects the value associated with the oil production rate, oil production volume, profit rate, profit or expenses, or any combination thereof.
12. The method according to claim 1, wherein said aggregated performance measure is generated using the average value of a plurality of performance measures for said option or characterizer.
13. The method according to claim 1, wherein said aggregated performance measure is generated using the average or sum value of said performance measures.
14. The method according to claim 1, wherein a testing of a well obtains information of the content of water, oil and/or gas.
15. The method according to claim 1, wherein a reference to at least one option or characterizer is presented to the user.
16. The method according to claim 1, wherein said parameter testers adapted for oil and/or gas parameter testing comprise a multiphase flow measurement device.
17. A computer program product, comprising:
   17.1. a computer readable medium; and
   17.2. computer program instructions recorded on the computer readable medium and executable by a processing unit in a computer based system, for carrying out a method in an oil and/or a gas production system comprising a plurality of oil and/or gas wells and parameter testers adapted for oil and/or gas production parameter testing, wherein said method is adapted to compare a plurality of options related to the oil and/or gas throughput in the oil and/or gas production system, said method comprising:
   17.2.1. drawing a plurality of parameter samples from a parameter distribution;
   17.2.2. generating, for each parameter sample, a performance measure by using said parameter sample and a characterization for each of said options, and
   17.2.3. generating an aggregated performance measure for each of said options by using said performance measure, said parameter distribution is generated by using historical and/or online measured and/or estimated data obtained from the oil and/or gas production system.