Assessment of Net Oil and Gas Reserves and Analysis of the Influencing Factors under Production Sharing Contracts

FA Gui-fang¹, ZOU Qian¹, YI Yanjing¹, LI Zhi-yu¹

¹ PetroChina Research Institute of Petroleum Exploration & Development, Beijing 100083, China
E-mail: fafang@petrochina.com.cn

Abstract. Production sharing contract (PSC) is one of the most commonly used contract type in international petroleum cooperation practices, under which, contractors obtain net reserves composed of in kind “cost oil” and “profit oil” by taking risks, bearing exploration, development and production costs, paying royalties, income taxes and other fees to the government of the resource country (the host government). The net reserves owned by a contractor refer to the remaining economic recoverable reserves that the contractor can obtain during the remaining contract period, which represent the real revenue the contractor can realize. Taking Project XX in Africa for example, this paper analyzed the methods for estimating net oil and gas reserves under PSCs, discussed the impacts of production, decline rate, plan, prices, costs, profit oil sharing and taxes on net reserves from four aspects including technique, economics, commerciality and engineering. In addition, the paper also made sensitivity analysis of the factors having significant influence on net reserves, such as the oil production, oil prices, operation expenses and investment, and put forward some recommendations for optimizing field development strategies to maximize contractors’ economic benefits.

1. Introduction
International petroleum investment contracts are the link between the host countries and the oil companies from other countries. They lay a legal foundation for oil companies to conduct exploration, development, and production activities in the host countries, and play an important role in the contemporary global economy and trade of petroleum. Currently, PSC is one of the most widely used contract type by the host countries of oil and gas resources such as China, Indonesia, the Philippines, Malaysia, Myanmar, Peru, Ecuador, Argentina, Venezuela, Brazil, Sudan, Angola, Niger, Nigeria, Azerbaijan, Turkmenistan, Libya, Syria and Oman[1-2]. This paper took Project A in Africa for example and combined the practices of net reserves assessment in recent years to analyze the contents and features of a PSC, the estimation methods and influencing factors of net reserves under a PSC. In addition, the paper also made sensitivity analysis of the factors having significant influence on net reserves, such as the oil production, oil prices, operation expenses and investment, and put forward some recommendations for optimizing field development strategies to maximize contractors’ economic benefits.

2. Contents and features of PSC
PSC means an oil company from another country (the contractor) signs a contract with the host government or the national oil company of the host country to conduct exploration, development and production activities within the contract area, with the ownership of the petroleum resources held by
the host country. Under a PSC, the contractor takes risks itself, and bear the exploration, development and production costs. The oil production is split into “cost oil” and “profit oil” – the former is for the contractor to pay the development and production expenses and the latter is shared by the host country and the contractor in line with the sharing rate specified in the contract. The host government or the national oil company of the host country normally has significant regulatory and supervisory power, while the contractor must pay income taxes for the profits it obtains [3-4]. An obvious feature of a PSC is that the oil company and the host country form a contract relationship, of which the core content is production sharing. PSCs combine risks and benefits together. Oil production, reserves, reservoir risks and oil prices are all relevant to the cost recovery and profit sharing of a PSC project, and ultimately determine the economic benefits of the contractor. The contractor can get excess profit brought about by quality reservoirs and efficient operation one the one hand, but also must take the risk of being unable to recover part or all the incurred costs due to lower than expected production or other factors.

The advantages of a PSC lie in the fact that the exploration risks in contract execution can be better managed, the profits can be reasonably allocated, and both the host country and the contractor have the opportunity to gain the value-added part. PSCs are of great adaptability and flexibility – under a PSC, the host country retains the legal regulatory right, while the contractor exercises the project control right in daily operation. Such adaptability and flexibility can help the contractor to obtain fair rate of return, and facilitate the host country to design a production sharing framework to increase its revenue share as the oil prices go up. More importantly, both sides have the chance to enjoy higher than expected production. Besides the advantages, PSCs also have some disadvantages, which are demonstrated in the complexity and variability of the contract framework and contents. To reach a production sharing agreement, multiple rounds of negotiations are normally needed. In addition, there are many uncertainties for the contractor to realize its revenue under a PSC, and the contractor needs to be very skillful in executing the PSC to gain more revenue.

3. Methods for net reserves estimation and cash flow model under psc

3.1. Methods for estimation of net reserves

Net reserves refer to the share of gross reserves owned by the contractor as per its net economic interest specified in the contract. The contractor’s net reserves are related to various economic parameters such as the working interest, royalties, cost recovery and profits. The annual production corresponding to the production profile that constitutes the gross reserves is gross annual production (usually referred to as “operation production”). Similarly, the annual production corresponding to the production profile that constitutes the net reserves is net annual production. The process of net reserves estimation under a PSC varies depending on the complexity of the contract terms, and the formula is as below:

\[ R_{net} = \sum_{i=1}^{n} Q_{net,i} = \sum_{i=1}^{n} \left( \frac{Cost_{j} + Profit_{j} + Other\ Re_{v_{i}}}{P} \right) \]

Where,

- \( R_{net} \) – contractor’s net reserves,
- \( Q_{net,i} \) – net production in year \( i \), starting from the assessment year,
- \( n \) – effective period for economic evaluation, no longer than the contract period,
- \( Cost_{j} \) – the revenue realized by contractor’s cost oil in year \( i \), starting from the assessment year,
- \( Profit_{j} \) – the revenue realized by contractor’s profit oil in year \( i \), starting from the assessment year,
- \( Other\ Re_{v_{i}} \) – contractor’s other revenue than those realized by cost oil and profit oil in year \( i \).

For instance, the revenue realized by LMO and FTP, \( P \) – net back price. According to the new SEC
rules, it refers to the average of the trade prices on the first day of each month during the previous 12 months before the end of assessment. Under the circumstance where the PSC has specified the price, adopt the price in the PSC. For a project with local market oil (LMO) or first tranche petroleum (FTP) provisions, net back price is the average price obtained through dividing the gross production within the effective economic evaluation period. In other words, price equals to (revenue obtained by oil sales at the market prices + revenue realized by LMO or FTP sales) / gross oil production, out of which, a) the revenue realized by oil sales at market prices = the average of the trade prices on the first day of each month during the previous 12 months before the end of assessment × oil volume to be sold to the market within the effective economic evaluation period; b) the revenue realized by LMO or FTP sales equals to the average of the trade prices on the first day of each month during the previous 12 months before the end of assessment or the price specified in the contract × oil volume to be sold within the valid economic evaluation period; 3) the gross oil volume equals to the gross reserves within the valid economic evaluation period[5-8].

The above formula is appropriate for estimating the net reserves under a simple PSC, from which, it can be observed that the net reserves correspond to the total revenue obtained by the contractor, or the revenue realized by the contractor’s net production. There are complicated relations between the value of the net reserves and the contract terms. As a PSC contains many constraints, higher prices and higher production do not necessarily lead to more net reserves. Therefore, a detailed and sophisticated analysis process is required to understand the variation trend of net reserves under a PSC [9].

Some PSCs also contain, among other terms, royalties, FTP, LMO, and ring-fence terms. Under such circumstance, it is rather complicated to estimate net reserves. Nonetheless, there are still some rules to follow: if there are royalties to be paid in kind, the production corresponding to the royalties should be deducted before estimating the net reserves; if there are royalties to be paid in cash, it is not necessary to deduct the production corresponding to the royalties for estimating the net reserves, and the cash flow, rather than the net reserves, is influenced by the royalties; if there are FTP and LMO terms, the net reserves should be estimated pursuant to the above explanation of net back price; if there are ring-fence terms, models for estimating net reserves should be established separately for each concession area, as cost recovery and profit sharing are independent among different concession areas.

3.2. Cash flow model

The most distinct characteristics of PSCs are the restrictions on cost recovery and profit oil sharing. Fig. 1 illustrates the cash flows of the contractor and the host government under a PSC. Generally, the process of cost recovery and profit oil sharing can be divided into the following tiers:

![Fig.1 Cash Flow Model for Production Sharing Contract](image-url)

Tier 1: deduction of the royalties.
Tier 2: cost recovery. The host government allows the contractor to recover its costs from the net revenue. Most PSCs set an upper limit for the cost recovery. The upper limit of cost recovery in Fig.1 is 60% of the gross revenue, which means the contractor’s expenses beyond 60% of the gross revenue have to be recovered in the future.

Tier 3: profit oil sharing: the left revenue after deducting the royalties and the recovered costs are profit oil revenue, which is shared by the contractor and the host government in line with their respective interest proportions.

Tier 4: payment of income taxes. The contractor pays income taxes for the profit oil it gets, based on the stipulated tax rate. In Fig.1, the income tax rate is 50%.

4. Factors influencing assessment of net reserves and net present value
The net reserves assessment is an integrated task. Net reserves are not only related to technical factors such as field plans, development and production, but also dependent on other considerations including oil prices, costs, contract terms, transportation and marketing. The factors influencing net reserves can be classified into four categories, as analyzed in the following sections.

4.1. Technical factors

4.1.1. Five-year plan
The working plan in the next five years refers to the formal five-year drilling, new well commissioning, shut-in well resuming plan approved by the host government, together with the associated investment. Well location maps, structural maps and isopatch maps are also inevitable in the five-year plan. The detailedness and reliability of the data directly impact the assessment of PUD and PDNP.

4.1.2. Initial production
The initial production is the start point for predicting the future production profile. The historical data in the last few months of the assessment year exert huge influence on the start point of production forecast, which further affect the production profile in the next few years, even in the entire contract period[10].

4.1.3. Decline rate
The decline rate is one of the key parameters in assessing reserves with performance methods such as decline curve analysis (DCA). It is mainly used in developed projects. Division of assessment units and determination of the decline type and the curve shape directly influence the proved developed reserves (PD). It is important to timely adjust the decline rate based on the actual development situation and production performance, particularly for the projects in ramp-up stage or without consistent decline trend.

4.1.4. Recovery factor
In assessment of reserves for the areas just put into production or about to be put into production, volumetric methods are generally used to calculate the OOIP, and the recovery factor (RF) is normally determined by analogy to the similar neighboring blocks or by pilot projects in the area. Then, EUR is estimated by OOIP and RF, before the P1 reserves are finally determined. Rigorous supportive data are required to determine the RF for P1 reserves. If secondary recovery has not been implemented yet, primary recovery is normally assumed.

4.2. Economic factors

4.2.1. Operating expenses and economic limit
The operating expenses include the costs for material supply, maintenance of well equipment, staff salaries, maintenance of surface facilities, and general administrative expenses, etc. The economic limit refers to the lowest production able to cover the operating expenses, capital investment and other spending. After determination of the total recoverable resources by static-data-based volumetric methods, dynamic-data-based production performance analysis or other approaches, economic evaluation should be run to determine the economic limit. To be recognized as reserves, the net revenue obtained from the asset should at least be equal to the operating expenses, capital investment and other spending paid for recovering the resources. The time at which the production rate makes the cash flow equal to zero is referred to as the economic limit. All the cash flows before the economic limit time are positive, and the corresponding resources are recognized as reserves. In contrast, the cash flows after the economic limit time are negative, and the corresponding recoverable resources cannot be recognized as reserves, which should not be included in the net reserves. Therefore, optimization of operating expenses via rational allocation and splitting can prolong the time of economic limit point, which is in favor of the net reserves estimate [11].

4.2.2. Oil prices
As what the contractor obtains under a PSC is the revenue realized by cost oil and profit oil, such revenue can be included in net reserves after being divided by oil prices. Therefore, the higher the oil prices, the lower the net reserves, if the revenue keeps unchanged. However, low oil prices are a double-edged sword: on the one hand, they might impact the economic limit time, and further impact the economics of the resources; on the other hand, as the net reserves are equal to \( \frac{(\text{cost oil} + \text{profit oil})}{\text{oil price}} \) or \( \frac{(\text{cost recovery} + \text{reward})}{\text{oil price}} \), low oil prices might even increase the reserves estimate.

4.2.3. Taxes and fees
The major taxes and fees in PSCs include royalties and income taxes. The royalties can be first deducted from the total revenue and paid to the host government either in kind or in cash. In many PSCs, the royalty rate changes with the oil production on a sliding scale. The contractor should pay income taxes for its profit share. The rate of income taxes is related to the contractor’s ultimate revenue and varies from country to country. In some countries, income taxes are even exempted, but the host government takes a very big profit share.

4.2.4. Cost recovery
Cost recovery means the contractor recovers the exploration, development and production expenditures from the total revenue. Most PSCs set some limit to the cost recovery amount that a contractor can take in a year, and carry over the uncovered costs to following years for the contractor to recover. The upper limit of cost recovery normally ranges from 30% to 60% of the gross revenue.

4.2.5. Profit oil sharing
After deducting the royalties and cost recovery from the gross revenue realized by oil/gas production, the remained revenue is allocated between the contractor and the host government. Before the costs are fully recovered, the upper limit of cost recovery stipulated in the contract applies. For instance, if the upper limit of cost recovery is 40%, of the gross revenue, the rest 60% is split between the contractor and the host government as profit oil. The rate of profit oil sharing exerts dramatic influence on the economics of a project. In many PSCs, the rate of profit oil sharing changes with the production on a sliding scale as well. The higher the daily oil production, the lower the profit share of the contractor, and the higher the profit share of the host government. The production start point of the sliding scale is determined based on the resource potential of the project. For projects with small resource potential, the production start point of the sliding scale is also low.
4.3. Commercial factors

4.3.1. Contract constraint
Constraint by contract period. Reserves are the aggregation of future production within the contract period and economic limit. If a contract approaches expiration and no extension is considered, the quantity after the contract expires cannot be recognized as reserves, even though the production performance is very good and the resource volume is huge. Therefore, for a project approaching contract expiration, whether or not the investment can be recovered within the contract period should be fully considered in preparing a new drilling plan [12].

4.3.2. Contract modification
Material contract modification will significantly influence the economics of resources. The plummet of oil prices in 2014-2015 directly caused some projects uneconomic and downgraded their reserves to contingent resources. If some contract terms can be changed through negotiating with the host government to respond to the low oil prices, some contingent resources may be upgraded to reserves, and some projects may become economic again.

4.3.3. Sales contract
For the assessment of gas reserves, there must be a sales contract. Otherwise, even if the reserves are large, they cannot be recognized as P1 in reserves assessment. If the sales contract is signed for just one year, only the production in that year will be recognized as reserves, and none of the production from other years will be included in the reserves.

4.4. Engineering Factors
Engineering factors such as the integrity and in-service time of the surface facilities, pipelines and capacity of the processing plants impact the oil/gas transportation and the production capacity building, which further influence the realization of the production designed in the development plan, and ultimately affect the reserves estimate [13].

5. Sensitivity analysis of key factors
Take Project A in Africa for example to conduct sensitivity analysis of the key factors affecting net reserves and net present value (NPV).

The annual production of the project reaches 5000 MMB, and the remaining contract period is 15 years. The actual oil price of 40 US$/B in 2018 was adopted in assessment. The contractor’s interest is 50%, the royalty rate is 12.5% of the sales revenue, and the upper limit of cost recovery is 70% of the sales revenue after deducting the royalties. The profit oil is allocated between the contractor and the host government by Factor R, which is determined by the contractor’s net income/gross investment. When R ≤1, the contractor’s profit share is 60% and the host government’s profit share is 40%. When 1.0<R ≤1.5, the contractor’s profit share decreases to 55%, and the host government’s profit share increases to 45%. When 1.5<R≤2.0, both the contractor and the host government are allocated with 50% of the profit oil. When R >2, the contractor’s profit share further goes down to 45%, while the host government’s profit share goes up to 55%. The contractor’s net income is determined by deducting the operating expenses, investment, abandonment fees and various taxes from the contractor’s total revenue (realized by cost oil and profit oil). NPV is obtained by discounting the future net income at a 10% discount rate.

Select four key factors including the oil production, oil prices, operating expenses and capital investment, based on investigation of the indexes influencing the economics of the project, to conduct mono-factor sensitivity analysis via assuming each of them change by 10%, 20% and 30%, respectively, with other factors unchanged.

It can be seen from Fig.2 that variations in oil production and oil prices have significant impacts on the NPV of Project A, and there is a positive correlation between these two parameters and NPV.
Particularly, NPV is most sensitive to oil prices. When the oil prices change by ±10%, ±20% and ±30%, respectively, the NPV changes by 281-394 MM$, 214-437 MM$ and 148-477 MM$, respectively. The difference of the variation range is 113 MM$, 223 MM$ and 329 MM$, respectively. When the oil production changes by ±10%, ±20% and ±30%, respectively, the NPV changes by 308-376 MM$, 270-405 MM$ and 231-433 MM$, respectively. The difference of the variation range is 68 MM$, 135 MM$ and 202 MM$, respectively. The operating expenses are negatively correlated to NPV. When the operating expenses change by ±10%, ±20% and ±30%, respectively, the NPV changes by 319-365 MM$, 292-383 MM$ and 264-400 MM$, respectively. The difference of the variation range is 46MM$, 91MM$ and 136MM$, respectively. The capital investment is not a sensitive parameter, because Project A is in the mid-late period of its life time, when the present development is mature, and the future development does not need much investment. As a result, variations in investment does not significantly influence NPV. To sum up, besides oil prices, oil production and operating expenses are two major factors impacting NPV. Therefore, the economic value of the project can be maximized by increasing the oil production through enhancing the recovery efficiency and taking stimulation measures and rationally reducing the operating expenses.

6. Conclusions
PSC is one of the most commonly used contract type in international petroleum cooperation practices, under which, a contractor signs agreement with the host government, and obtains net reserves composed of “cost oil” and “profit oil” by taking risks, bearing exploration, development and production costs, paying royalties, income taxes and other fees to the host government. The tax type, cost recovery and profit oil sharing terms defer from country to country. Assessment of net oil and gas reserves is a comprehensive task integrating four factors including technique, economics, commerciality and engineering. Net reserves are influenced by the technical issues including the reservoir production capacity, recovery factor, development plan, and the non-technical issues such as the contract period, investment, operating expenses, oil prices, profit sharing, taxes, transportation and marketing. All the relevant parameters should be considered in the assessment process, and only when the key elements are determined accurately, the net reserves estimate can be objective and reliable.

Under a PSC, production, prices, operating expenses and capital investment influence the contractor’s NPV to different extents. Out of the four parameters, prices and production have the highest influence weight. The task of annual net reserves assessment is faced with various challenges because of the changes in oil/gas prices, host country’s policies, geographic locations of the assessed projects, local
environment, development efficiencies and production performances. It is important to make good
preparation analysis, sound development and assessment strategies prior to assessing the net reserves,
so as to maximize the net reserves and NPV of the assessed projects.

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