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Economic Study of Offshore Marginal Oil Field Development

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Abstract

On the pass decade, development to find oil and gas sources seem an easy and not complicated, it was due to developed area had a high economic profile and determined risk level. But over the time, remaining reserves will have high level of difficulty, it would need high effort and special treatment to develop marginal field become an economical project. This paper will discussing on how to modelling development of offshore marginal oil field X as integrated solutions with source of gas from field Y for injection, lifting, make-up and fuel. First by set new design and operation philosophy starting from basic requirement, determining the parameters, assembling into a number of integrated options, continue with risk, technical and economic studies. Finally optimize the result with sensitivity parameters to be able to produce the most optimal and economic scenario. Spreadsheet use during analyzing for modelling input parameters, to optimize value of IRR, NPV, POT and to perform sensitivity analysis. The results of this optimization will provide a real picture for management as a guidance to take further direction. Finally, the project becomes economical to be carry out, give additional portfolio to Contractor, help to meet the needs of energy supply and contribute multiplier effect on the national economics.

Keywords: *Marginal field, philosophy, development, optimization, economics*

1. Introduction

In Indonesian legislative system, it is expressly stated that strategic commodity which is important and control livelihood of many people controlled by the state. Oil and Gas (O&G) are natural resources representing this condition, so the state must have a strategic and dominant role in control, exploration and exploitation of O&G sector. Production Sharing Contract (PSC) is a form of cooperation between Contractor and Government of Indonesia (GOI) as holder of sovereignty of oil and gas resources.

O&G exploration and production activities is profit-oriented business. Economic analysis must be carried out by considering some parameters to minimize a risk. The main problem for upstream O&G companies for development is high investment fund required to provide proven and experienced human resources, technology and equipment. O&G reserves located in reservoirs far below surface of the earth, so it can’t just be estimated only. Feasibility study of investment to calculate economic indicators such as CAPEX, OPEX, Internal Rate of Return (IRR), Net Present Value (NPV), and Pay Out Time (POT) shall be performed to determine whether development plan could be implemented or not.

Best approach solution to develop marginal field is to use of appropriate and targeted principles (fit-for-purpose), that was development scheme by changing applied new philosophy of design and operation to change an existing; starting from a minimum requirement while still maintaining quality and safety. Implementation of this scheme was proven to provide general savings, it is expected to be able to maintain Company's sustainability in face of crisis.

X is one of potential marginal oil field, a waxy oil field with a potential reserve of around 98 MMBO (P50). While Y is a gas field with a small reservoir reserve that is located near

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to field X. Integrated concept for both fields with new philosophy concept and optimizing the use of gas from Y field as injection gas, lift gas, make-up and fuel in the development of marginal oil field X will provide many benefits and added value.

2. Methodology

Research method presented explains sequence of steps that will be carried out to develop offshore marginal oil fields. Starting with a preliminary study, formulating problems and gathering data needed to establish concept of each parameter, then stringing these parameters into an integrated configuration. Risk, technical and economic analyses are carried out to review design concepts. Furthermore, optimization is done with sensitivity parameters of fuel, production rate and oil price. The result will be used as a basic guide for Company to develop through further engineering processes, flow diagram as shown in Figure 1.

Figure 1. Development's flow diagram

2.1. Determine Alternative of Development Concept

2.1.1. Reservoir Drain Concept: In general there are 3 (three) reservoir drainage schemes:

- Primary, is the way to drain reservoir using internal reservoir force mechanism.
- Secondary, is drainage using gas injection techniques that is provided to reservoir. This solution will be able to maintain stable reservoir pressure, so production period could be maintained.
- Tertiary, is apply EOR technology, by using an ESP pump, chemical, polymer or other. Not used in this study.

2.1.2. Wellhead Concept: Offshore development is divided into:

- Subsea where the wellhead will be located on seabed.
- Topside where the wellhead will be located at floating platform.

2.1.3. Production and Supporting Facility Concept: In this analysis used:

- Wellhead Platform (WHP)
- Wellhead platform and production processing as well, CPP
- Floating Production and/or Storage and Offloading (FSO/FPSO)

2.2. Set of Integrated Configuration

In general, architecture based on integrated surface / sea floor clusters of development. Consists of one gas injection well with five production wells, each equipped with gas lift facilities.

Surface facility CPP / FSO / FPSO is provided for process needs and/or storage. Two stages of three phase separator are used to separate liquid into produced gas, oil and water. Produced gas is then compressed to reach pressure of 1,500 psig and go through a dehydration process to remove its water content. This gas is partly distributed as lift gas and partly enters the stage 2 compressor to reach pressure of 2,500 psig that will be used for gas injection into reservoir. Produced water will be treated by a water treatment unit to meet environmental standards, before it can be discharged overboard. Crude oil stored in hull of ship, metering system is provided to enable oil export activities through tanker.

Set of configuration is an integration of several basic development concept. Total five alternatives will be depth review in this paper, as explained in Figure 2.

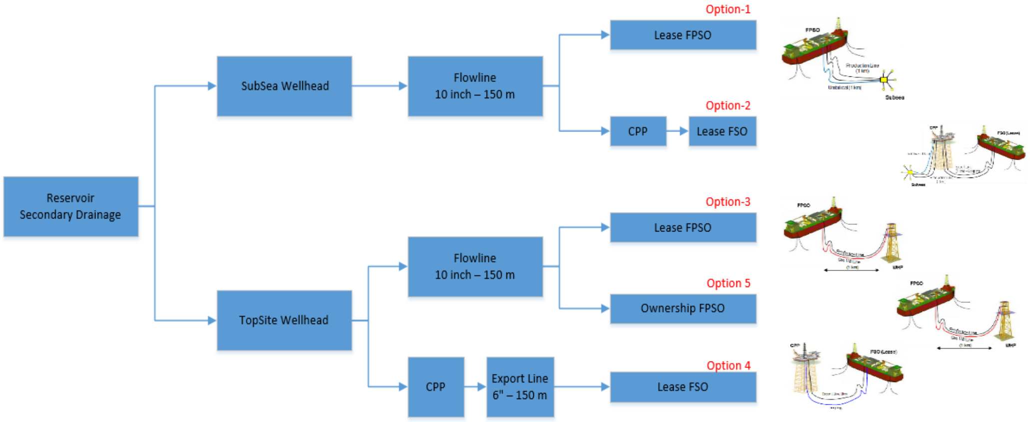

Figure 2. Set of standalone configuration alternatives

2.3. Technical Study

Technical assessment is be based on hydraulic and qualitative feasibility analysis of an ability of resources, equipment and technology needed while still can maintaining quality, safety standards and overall project schedule.

Pipeline hydraulic analysis is carried out to investigate feasibility of hydraulic to be able to accommodate product from field X as identified in terms of erosion velocity and back pressure to the well. Fluid velocity must not exceed an erosion velocity ratio (EVR) criteria of a certain pipe size, referring to the API RP 14E standard and also with back pressure that occurs in export multiphase pipe.

2.4. Economic Study

An economic assessment is based on an economic feasibility analysis of PSC term related to revenue, investment, operating costs, NPV, IRR and POT for certain production period. The most possible alternatives will be elaborated further in engineering implementation phase, based on financial benefits that are most attractive to Company. Basic assumption are:

- Field live time 10 (ten) years.
- DMO holiday for 60 months, tax 48 %.
- CAPEX costs include: oilfield drilling x, gas field Y drilling, seabed well investments, WHP or CPP investments, pipelines, FSO or FPSO conversions or FPSO purchase.
- OPEX costs include: FSO rent USD 20 MM/year or FPSO rent 65 K/day, well interventions USD 5–8 MM /year, O&M wells USD 11 MM /year, diesel price USD 14 MM /year, abonnement, O&M FPSO USD 10 MM /year.
- Amount of income includes: oil price of USD 65 /barrel.
- Contractor Margin Attractive Rate of Return (MARR) 10 %.

Formula that use to calculate economic analysis of project, including IRR, NPV, investment costs and O&M parameters as in Equation (1) and (2):

$$NPV = \sum_{t=0}^{T} \frac{Rt-Ct}{(1+IRR)^t} \quad (1)$$

$$NPV = -CF0 + \frac{R1-C1}{(1+IRR)} + \frac{R2-C2}{(1+IRR)^2} + \cdots + \frac{Rn-Cn}{(1+IRR)^n} \quad (2)$$

Wherein:

CF0: initial investment cost (capex)	IRR: discount level
Rt: cash-in on certain period	t: time period
Ct: cash-out on certain period	NPV: net present value

Sensitivity analysis is carried out to see an effect of main parameters to forming overall complexity of a project and to determine optimal level of these parameters. Main sensitivity parameter simulated here are capex, opex and oil price.

2.4.1. Production Rate: Production rate 12,500 BOPD is not considered as a sensitivity due to short of production's period - less than 6 months, so it will not be optimal in designing facilities. Sensitivity of production rate to be analyzed are: 10,000 BOPD; 7,500 BOPD and 5,000 BOPD.

2.4.2. Fuel: Fuel sources are very important part of economic analysis, used to provide source of energy in facilities. Two types of fuel source preferences that will be reviewed are:
Gas fuel will be provided from gas field Y, imported through an underwater export pipeline. Main parameter for economic analysis in this option is requirement to import gas with 10" underwater pipeline installation of ± 14 km to supply gas fuel from gas field Y to FPSO/CPP/WHP.
Diesel fuel shall be obtained from spot market, supplied by boat to meet energy needs of FPSO/CPP/WHP.

2.4.3. Crude Oil Price: Crude oil price is an important factor in carrying out economic analysis. Price used in this analysis is based on the predicted market price of ICP during the operating period in between 2021 – 2031.

2.5. Optimization

From various alternative configurations have been presented, then filtered into single selected option to be realized for development. These option is integrated configuration that meet with technical criteria and an able to provide the most optimum and economic benefits. This option will be optimized to reduce the risks in an implementation and operational processes.

3. Result and Discussion

Fluid characteristics of X field as waxy oil which has a fairly heavy density. Without advanced technology such as gas injection and gas lift, the well will not last long. To be able to extend the well's life and to maintain a constant production rate, pressure at reservoir must be maintained at around 2,500 psig and 1,000 psig at annulus in production pipeline. Two units gas compressor are provided to meet these needs. By utilizing gas, production profile can be maintained as simulation shown in Figure 3.

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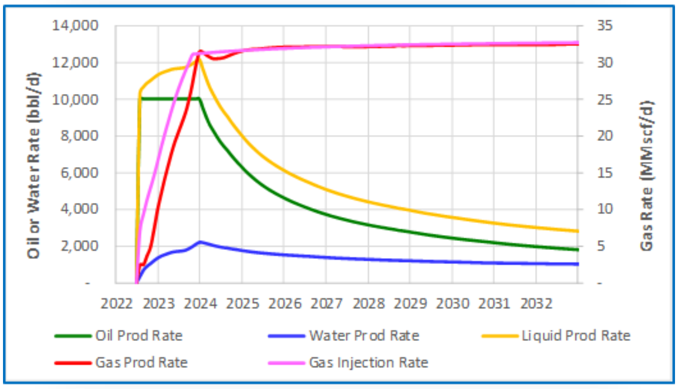

Figure 3. Production profile optimized

Topside wellhead control was chosen because it has high flexibility for operations (interference, maintenance) and requires lower investment and operational costs. Surface facilities are designed according to operating requirements in accordance to the philosophy adopted. Selected the simplest, easy to fabricate, to install and to operate and provide the most economic value. In general the design of wells and facilities can be illustrated through process flow diagram in Figure 4 below.

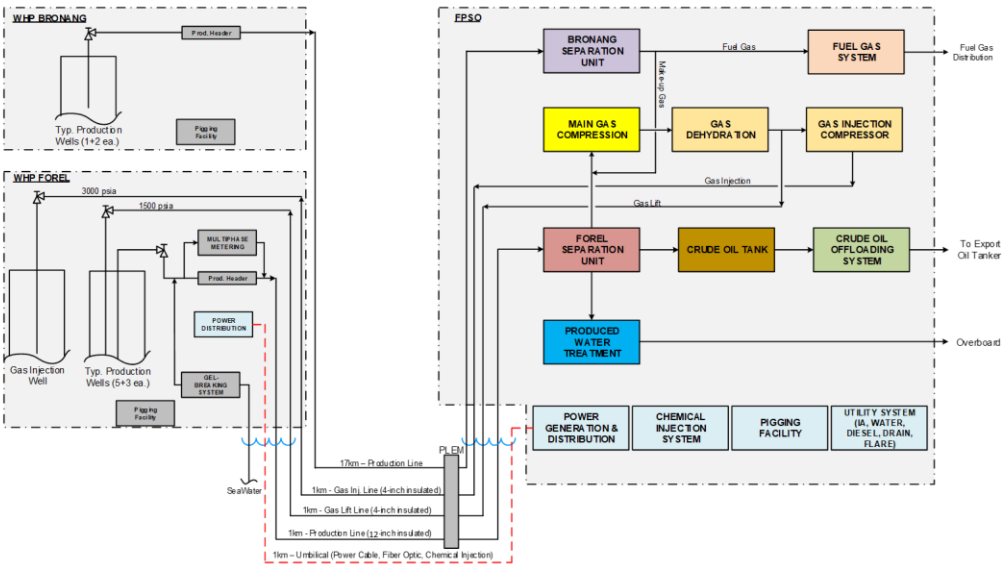

Figure 4. Process flow diagram

Hazard and Operability Study (HAZOPS) risk analysis is applied to examine process and design engineering related to potential failure of functions and their consequences as a whole. Assessment is based on existing protection/ control and severity based on final consequences, with a quantitative system of priority scale to help determine whether an identified hazards have sufficient attention, so additional protection is needed to reduce risk or require further analysis or it must accepted under current conditions / As Low As Reasonable Practicable (ALARP).

3.1. Economic Study

Standalone calculation cost on 5 alternative configurations give a conclusion that Option-3 worth the lowest capex, but with lightly higher opex.

Based on simulation been performed for 10 years operations, production rate 10,000 bopd will gift the highest gross revenue with total at about USD 1,068MM, while 7,500 bopd will be USD 832 MM and 5,000 bopd at USD 657 MM.
The use of diesel as fuel will be costly, it could consumed up to USD 140 MM to supply energy for operational and additional USD 2 MM to provide N2 bottles that were required for gas lift and gas injection. Diesel fuel only effective for short term. In this case it will not feasible since it make high of operational cost. Utilization of fuel gas from field Y will be the most economics solution for a long term development. Additional capex USD 50 MM is required to build minimum facility on Y field and laying subsea pipelines to export this free gas, but could generate efficiency of opex USD 130 MM.
Analysis with floating oil price give a solution that higher oil price will give better economic result both for Government or Contractor, but oil price is external parameter that can't to control.

3.2. Economics Indicator

Simulation of sensitivity parameters with spreadsheet show that production rate, fuel gas selection and oil price are dominant factor to forming the economics value. For this reason, development scheme must be encouraged to be able to produce 10,000 bopd, utilize gas from the Y field and forecast of moderate oil price USD 65/bbl as a basis. The higher oil price will be provides the more financial benefit for both Government and Contractor. Economic feasibility analysis based on PSC cost recovery term will produce a summary as shown on Figure 5 below.

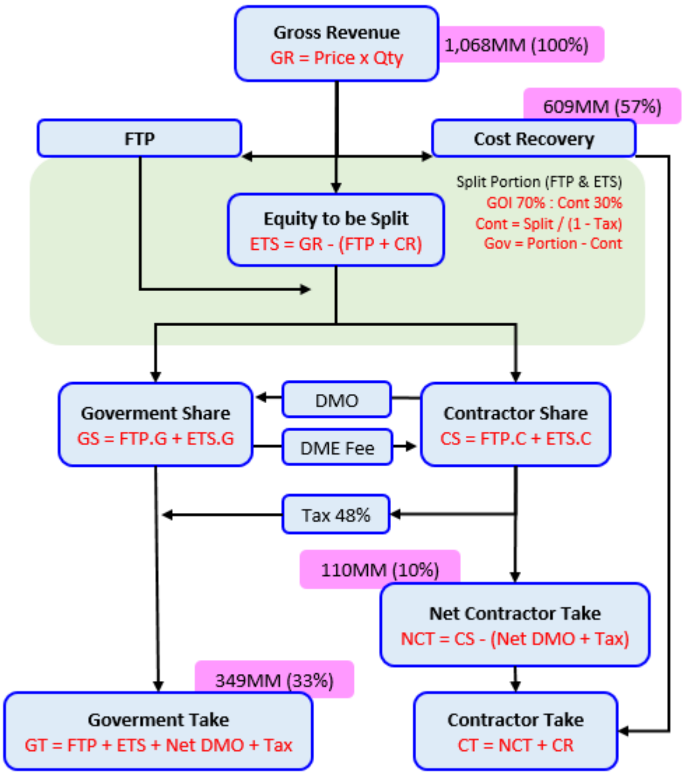

Figure 5. Economic analysis of PCS cost recovery

Details breakdown of each parameter and it related calculations could be illustrated as in Table 1 below.

Table 1. Economics indicator for production rate 10.000 bopd, fuel gas from Y field and oil price USD 65/bbl

Parameters	Unit	Opt-1	Opt-2	Opt-3	Opt-4	Opt-5
Field Live Time	Year	10	10	**10**	10	10
Crude Oil Volume	MMBOE	16.4	16.4	**16.4**	16.4	16.4
Average Oil Price	USD/bbl	65	65	**65**	65	65
Gross Revenue	MM USD	1,068	1,068	**1,068**	1,068	1,068
FTP	MM USD	213.6	213.6	**213.6**	213.6	213.6
FTP Contractor	MM USD	123.3	123.3	**123.3**	123.3	123.3
FTP Government	MM USD	90.4	90.4	**90.4**	90.4	90.4
Capital Cost	MM USD	277.1	459.8	**269.8**	362.1	552.8
Intangible	MM USD	170.7	215.4	**165.1**	196.6	234.3
Tangible	MM USD	106.4	244.4	**104.7**	165.5	318.5
Operational Cost	MM USD	339.6	317.3	**339.6**	317.3	127.3
Opex	MM USD	302.3	208.0	**302.3**	280.0	90.0
ASR	MM USD	27.3	27.3	**27.3**	27.3	27.3
Cost Recoverable	MM USD	616.7	777.1	**609.3**	679.4	680.1
(% of Gross Revenue)	%	58	73	**57**	64	64
Unrecoverable Cost	MM USD	0	0	**0**	0	0
ETS	MM USD	237.9	77.5	**245.2**	175.1	174.5
ETS Contractor	MM USD	137.3	44.7	**141.5**	101.0	100.6
ETS Government	MM USD	100.7	32.8	**103.8**	74.1	73.8
Contractor Profitable						
Net Contractor Take	MM USD	107.9	59.8	**110.1**	89.0	88.9
(% of Gross Revenue)	%	10	6	**10**	8	8
IRR 2022 Forward	%	10.7	3.4	**12.8**	6.6	3.8
NPV10 2022 Forward	MM USD	5.04	-79.4	**16.8**	-32.7	-99.7
POT	Year	5	7.5	**4.5**	5.8	8
Government Profitable						
Net DMO	MM USD	53.1	53.1	**53.1**	53.1	53.1
Tax	MM USD	99.6	55.2	**101.6**	82.2	82.0
Government Take	MM USD	343.7	231.4	**348.8**	299.7	299.3
(% of Gross Revenue)	%	32	22	**33**	28	28
PV10 2022 Forward	MM USD	233.0	156.9	**236.5**	203.2	202.9

Seem that Options-3 could provide the most attractive financial benefits for Contractor and Government. Capital that was invested could produce Government take USD 349MM (33%), Contractor take USD 110MM (10%), IRR 12.8% and POT for 4.5 years. IRR is higher than Contractor's MARR (10%) which has a meaning the project is profitable, total investment cost could be come back within 4.5 years and will generate positive cash flow forward up to end of field live.

3.3. Sensitivity

Sensitivity analysis performed to option-3 to see an effect of main parameter to economics indicator. Basic parameters as main contributor are capex (USD 269.8 MM), opex (USD 339.6 MM) and oil price (USD 65/bbl), with ± 20% of variance. Figure 6 show an effect to generate Contractor's IRR, while figure 7 show an effect to generate Contractor's NPV.

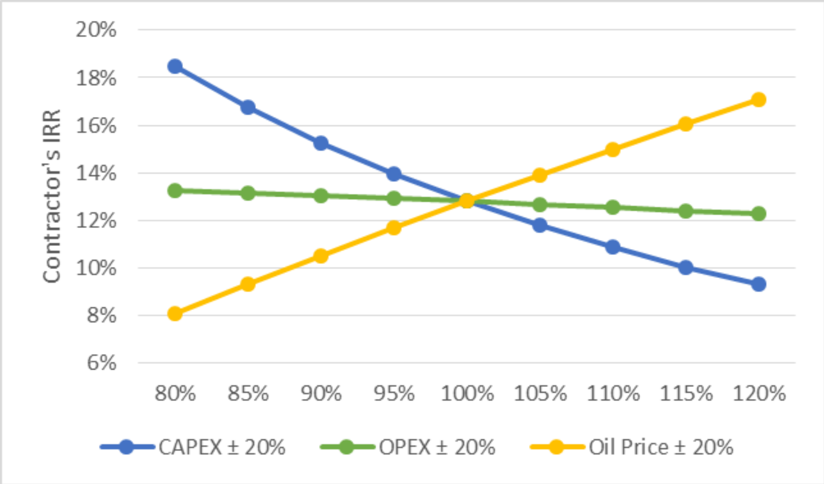

Figure 6. Sensitifity of contractor's IRR

IRR graph has a meaning:

- Capex: Smaller capex will generate bigger IRR and vice versa. Capex is high contributor to IRR. Maximum addition ± 15% (USD 310.2 MM), it will generate threshold value, where IRR ≅ MARR ≅ 10%.
- Opex: Smaller opex will generate bigger IRR and vice versa. Opex only can give small contribution to IRR, at range 12 - 14%,
- Oil price: Cheaper oil price will generate smaller IRR and vice versa. Oil price is high contributor to IRR. Maximum decrease ± 12% (USD 57.2 /bbl), will generate threshold value, where IRR ≅ MARR ≅ 10%.

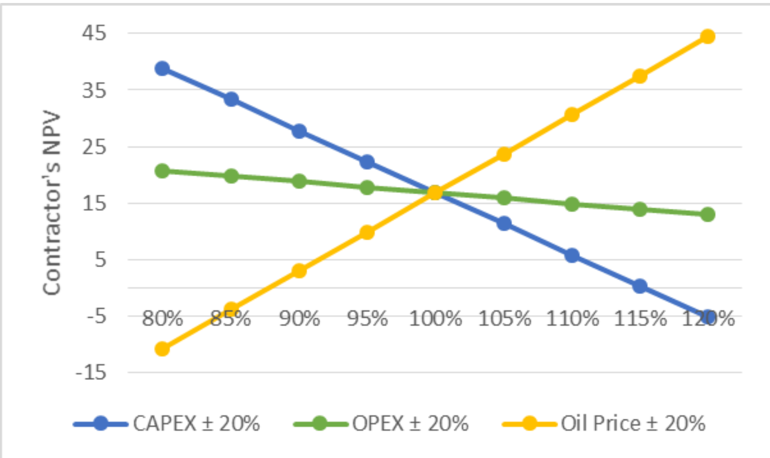

Figure 7. Sensitifity of contractor's NPV

NPV graph has a meaning:

- Capex: Smaller capex will generate bigger NPV and vice versa. Capex is high contributor to IRR. Maximum addition ± 15% (USD 310.2 MM), it will generate NPV at discount factor MARR, ≅ 0.
- Opex: Smaller opex will generate bigger NPV and vice versa. Opex only can give small contribution to NPV, at about USD 13 – 23 MM.
- Oil price: Cheaper oil price will generate smaller NPV and vice versa. Oil price is the highest contributor to NPV. Maximum decrease ± 12% (USD 57.2 /bbl), will generate NPV at discount factor MARR, ≅ 0.

3.4. Selected Option

Figure 8 shown share portion of the revenue between Cost Recoverable (CR), Government Take (GT) and Net Contractor Take (NCT), while Figure 9 shown POT and take profile for both Government and Contractor.

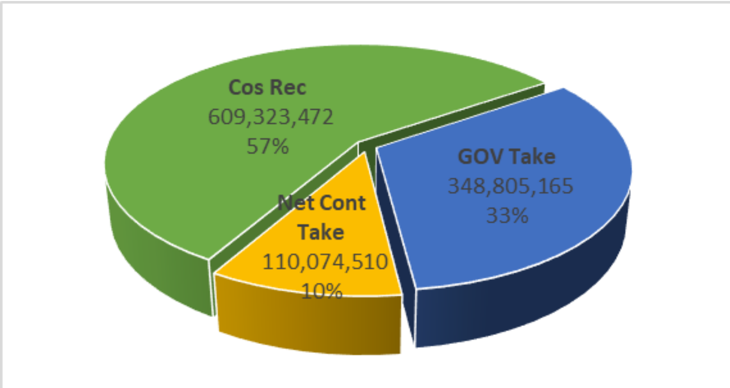

Figure 8. Pie chart of share portion

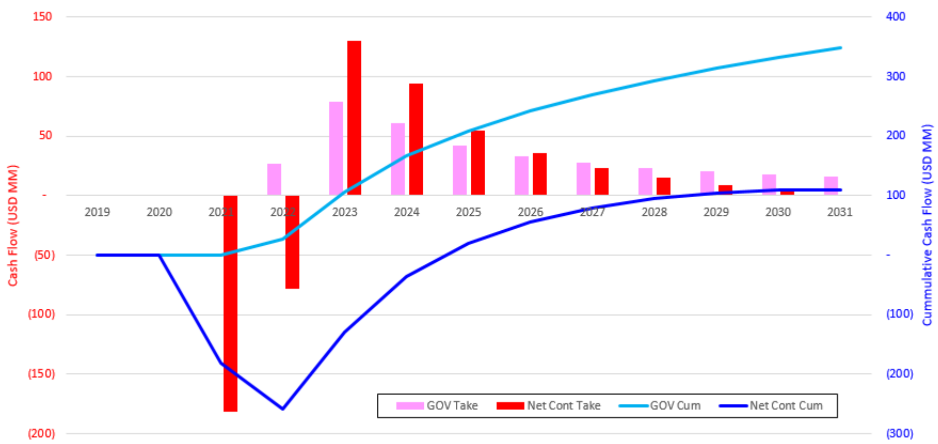

Figure 9. Profile of NPV contractor and Gov take

From entire alternatives been presented, it shown that options 3; which consist of secondary well drainage, topside wellhead with a minimum WHP, lease FPSO as process and storage facilities with oil production rate of 10,000 BOPD and utilizing gas from Y field for gas injection, gas lift and source of fuel, will provide the most attractive financial benefits for both parties. This alternative is most feasible concept to be implemented for the development of marginal oil field X, as illustrated in Figure 10 below.

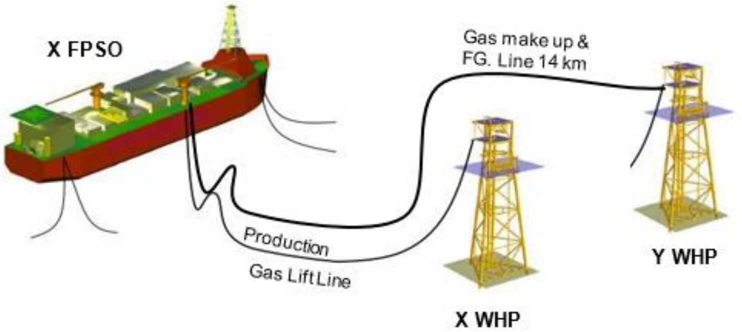

Figure 10. Integrated development selected

4. Conclusion & Suggestion

4.1. Conclusion

From series of data, analysis and discussion that has been performed, at least we could take a summary as follows:

- Development of marginal field X requires gradual steps to overhaul existing conventional standards, by adoption new philosophy of designs and operations that can embrace teachings, starting from minimum requirement. Implementation of philosophy, technical study and risk management are very important to select option of each parameter, used to assembly become set of integrated configuration.
- Economics study utilized to get big picture of economics indicator, as a basic lead to select an options which embedded with standard technical performance, optimum cash flow and could give most attractive business value both for Government and Contractor.
- Risk management through HAZOPS and HAZID workshop is effective to identify any possibility of failure, it severity and to select additional control required.

Final resume shown the most optimum solution to development offshore marginal oil field X is option 3 integrated with gas field Y, to utilize gas source as gas lift, gas injection, make-up and free fuel during an operation.

4.2. Suggestion

Revenue, capex and opex are internal parameters which can be controlled by Company and have big contribution to economic indicator. For such reason, development shall be directed to full fill those aim, through below steps:

- Maximize revenue by optimize and maintain production level, by utilizing technology of gas lift and and gas injection.
- Minimize budget spending (capex and opex), by well organizing new fit for purpose philosophy during engineering phase / project and operation.
- Optimizing other opportunity, by utilize field Y as source of free fuel for operation.

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