REVISIT A MATURE OIL FIELD'S FACILITIES TO EXTEND ITS ECONOMIC LIFE

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A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Petroleum)

School of Chemical and Energy Engineering
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JANUARY 2019

To my beloved husband who motivated me,
to my parents who prayed for me,
to my family and friends who supported me in completing this thesis.

ACKNOWLEDGEMENT

I would like to express my gratitude to my supervisor, Associate Professor Issham Ismail for his guidance and encouragement from the start until the completion of this research study. His ideas inspired me to expand the research study and his advice made it possible for me to finish the research in time.

I would like to thank my husband who stood by me all the time. His positive words really drove and inspired me in wanting to complete my master’s on time. A special thanks to my parents who endlessly pray for my success, to my family who supported me and everyone around me who encouraged my journey until the end. I am very grateful to have all of you in my life.

Thank you so much for your endless love and support.

ABSTRACT

Mature fields hold large volume of remaining hydrocarbon in reservoir. However, they are exposed to many challenges, for example increasing GOR, increasing water cut, and integrity issue of facilities which restrict the economic viability of the fields. The net operating cash flow is on a decreasing trend and the economic limit is approaching closer. Multidisciplinary approach which involves subsurface strategies and surface optimization are required to extend the economic life of mature fields. The purpose of this study is evaluate the impact of rejuvenation of mature fields by integrating subsurface optimization through infill wells and surface facilities optimization by converting a manned Central Processing Platform (CPP) to an unmanned Wellhead Platform (WHP) on the extension of mature fields' economic life. Isolation of rotating equipment and reduction of equipment count on the CPP are required to reduce the maintenance frequency and gives opportunity to unman the CPP. However, the additional gas production from the new infill wells introduces another challenge on the surface facilities' capacity limit of the platform. Process changes are required on the existing platform and were evaluated using hydraulic simulation tool, PIPESIM to determine the new operating condition at the existing platform after conversion of that CPP to WHP. Brownfield modifications required to accommodate high gas production from new infill wells were evaluated based on the results of adequacy check on existing equipment. CAPEX and OPEX required for the subsurface and surface optimization plan were estimated to evaluate the economics of the mature fields based on the new scenario. From the results, it is shown that conversion of the manned platform to unmanned platform can reduce the OPEX by 12% and economic limit is extended four years longer.

ABSTRAK

Medan minyak matang masih mempunyai baki isipadu hidrokarbon yang besar tertinggal di dalam reservoir. Walau bagaimanapun, medan tersebut berhadapan banyak cabaran, misalnya nisbah gas : minyak dan peratus potong air yang meningkat serta isu integriti kemudahan yang membatasi kewajaran ekonomik di medan terbabit. Aliran tunai bersih operasinya terus berkurang dan had ekonominya semakin genting. Pendekatan daripada pelbagai disiplin yang melibatkan strategi subpermukaan dan pengoptimuman kemudahan di permukaan adalah diperlukan bagi melanjutkan jangka hayat ekonomik medan yang matang. Kajian ini dilakukan bertujuan untuk mengkaji tentang kesan membangunkan semula medan matang dengan menyepadukan pengoptimuman subpermukaan menerusi penggerudian telaga sisip dan pengoptimuman kemudahan permukaan dengan menukar Pelantar Pusat Pemprosesan (CPP) berpenghuni kepada Pelantar Telaga Kepala (WHP) tanpa penghuni, terhadap pelanjutan hayat ekonomik medan matang. Pengasingan kelengkapan berputar dan pengurangan bilangan kelengkapan di CPP perlu dilaksana bagi mengurangkan kekerapan penyelenggaraan dan seterusnya membuka peluang untuk membolehkan pelantar berfungsi tanpa penghuni. Namun begitu, pengeluaran gas secara berlebihan dari telaga baharu mengetengahkan cabaran lain terhadap had muatan kemudahan pelantar. Perubahan proses diperlukan di pelantar sedia ada dan dinilai menggunakan perisian hidraulik, PIPESIM bagi menentukan parameter operasi yang baharu di pelantar terbabit. Pengubahsuaian yang diperlukan bagi mengendali kadar gas yang tinggi dari telaga baharu telah dikaji berdasarkan hasil pemeriksaan terhadap kelengkapan sedia ada. Perbelanjaan modal dan perbelanjaan operasi yang diperlukan untuk merealisasi pelan pengoptimumam subpermukaan dan permukaan telah dikira. Penukaran pelantar berpenghuni kepada pelantar tanpa penghuni telah dikira kosnya bagi menilai keputusan ekonomik medan matang terbabit berdasarkan scenario baharu. Keputusan kajian menunjukkan bahawa penukaran pelantar berpenghuni kepada pelantar tanpa penghuni boleh mungurangkan perbelanjaan operasi sebanyak 12% dengan hayat ekonomik boleh dilanjutkan selama empat tahun.

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LIST OF ABBREVIATIONS AND SYMBOLS

bpd	-	barrel per day
CAPEX	-	Capital Expenditure
CPP	-	Central Processing Platform
EOR	-	Enhanced Oil Recovery
FWS	-	Full Well Stream
GOR	-	Gas Oil Ratio
H_2S	-	Hydrogen sulfide
MIC	-	Microbiologically Influenced Corrosion
MMboe	-	Million barrel equivalent
MMSCFD	-	Million standard cubic feet per day
MMstb	-	Million stock tank barrel
NPV	-	Net Present Value
OPEX	-	Operating Expenditure
PIR	-	Profit Investment Ratio
PSC	-	Production sharing contract
WHP	-	Wellhead Platform

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CHAPTER 1

INTRODUCTION

1.1 Background

Offshore developments in Malaysia have matured. Since 1961, petroleum activities in Malaysia have significantly expanded with the discovery of first offshore well in Temana field, offshore Sarawak (Woodmac, 2017(a)). The first offshore facilities in Malaysia water was installed in 1968, in West Lutong field, offshore Sarawak. Samarang field is the first oil field developed in offshore Sabah in 1975 under Sabah Shell PSC (Woodmac, 2017(b)). On the other hand, in offshore Peninsular Malaysia, Pulai and Bekok are the first developed oil fields with first production brought onstream in 1978 (Woodmac, 2017(c)). Since then, the number of mature fields and aging offshore facilities in Malaysia are increasing.

A mature field (also known as brown field) can be defined based on its surface and subsurface conditions, but it might be different from individual oil companies. TOTAL defines a field as mature when either one of subsurface and surface criteria for mature field is reached (Parshall, 2012). For subsurface, a field is considered mature when the cumulative production has reached 50% of the initial 2P (proved and probable) reserves. For the surface, the field is considered mature after 10 years of production results in aging of facilities (Heugas, 2012). In other definition, a mature field is a field that had produced more than 50% of its resources or field and has been producing more than 25 years (IHS Cambridge Energy, 2011).

Mature fields that have been producing more than 25 years, have posed many challenges, for example a sharp decline in production, high water cut, aging facilities which have been operated beyond the design life, etc. These challenges restrict the economic viability of mature fields (Khatib and Walsh, 2014) and approach the economic limit earlier. Fields have reached their economic limit when the production rate of the fields fall below which the net operating cash flow is negative (Petroleum Resources Management System, 2007). The mature fields will be assessed whenever they are approaching their economic limit, in which decision either to continue production by taking up rejuvenation methods or to plug and abandon the fields can be made. Economic strategies, for example, extending the field life and reusing of existing facilities are considered before abandonment decision is made to maximize the profits (Antia, 1994). Abandonment of fields requires decommissioning of the facilities and wells, which will be removed from the fields.

Oil companies are taking different measures to extend economic field life of mature fields longer than expected earlier. This is because mature fields hold opportunity to expand reserves volume with relatively low risk since the reserves have already been categorized as proved or probable with readily available data obtained from the production (Munisteri and Kotenev, 2013; Parshall, 2012). On top of that, existing facilities in the mature fields give opportunity for other new discoveries to tie-back to their facilities (Brandt and Mohd Sarif, 2013).

Offshore development in Malaysia has been focusing on oil and gas fields in shallow water area which have less than 300 m water depth since the early development (Woodmac, 2017(d)). Today, many new discoveries in Malaysia have been explored in deep water and remote area. Stand-alone development for new discoveries, for example to install their own processing hub and to lay a long pipeline to shore, requires a large investment, which may result in negative economic scenario for the development plan. Alternatively, a concept to install a satellite platform and tie-back to the existing facilities can improve the economic value of deep water or remote area development. This has strengthened the need to extend the field life of mature fields. However, due to the challenge of aging facilities integrity, detailed economic assessment of new investment is required so that prior decision to extend the field life can be made.

Apart from that, oil companies have two options to extend the economic life of mature fields, either to reduce the operating cost or to revitalize the fields to increase production (Deng, 2013). Among the efforts to revitalize mature fields is secondary recovery, which aims to restrain the production decline and increase the production (Handayani and Simamora, 2012). Infill drilling is one of the secondary recovery methods that plays an important role to revitalize mature fields by accelerating recovery and adding new reserves (Sayyafzadeh *et al.*, 2010). The additional new reserves that can be recovered from infill wells depend on the number of infill wells and well locations to minimize the interference with the existing wells (Al-Mudhafer, 2013).

Multidisciplinary approach including reservoirs, wells and surface facilities engineering must be analyzed together. In addition to focusing on production enhancement from reservoir, revisiting surface facilities operation in reducing the operating cost can optimize cash flow of mature fields. The early development of offshore fields in Malaysia comprised a facilities complex including several satellite platforms, compression platforms, and processing platforms located in a field, due to large number of reserves to be recovered at that time. Central Processing Platform (CPP) receives full well stream (FWS) consists of oil, water and gas from satellite platform or Wellhead Platform (WHP). Oil CPP comprised two to three stages of crude separation system, oil export system and produced water treatment system, while gas CPP includes gas dehydration and compression system (Wan, 1988).

All of the equipment on top of the platform requires frequent inspection and maintenance to ensure they could function effectively. Therefore a manned operation, where people are routinely accommodated on the platform (PETRONAS Technical Standard, 2014), is required on the platform which results in high operational expenditures (OPEX) of the fields. In contrast, a WHP is designed as unmanned satellite platform with minimum facilities for unattended operation. Typical facilities on a WHP includes wellhead modules and utilities module (Wan, 1988). This research work focuses on mature oil fields in offshore Peninsular Malaysia which comprise three Central Processing Platforms (CPP) and two Wellhead Platforms (WHP) which are currently in operation. The platforms are located in a water depth ranging from 65 m to 75 m and have been in operation for 40 years.

1.2 Problem Statement

The main challenge of mature fields is to ensure attractive economic return of the fields within the terms and duration of the contract. Many mature fields in Malaysia have been going for improved oil recovery, for example infill drilling to increase recovery of the fields. A typical approach of rejuvenating the mature fields is often related to extending the remaining life of the existing facilities to accommodate the production until the end of PSC duration. However, revisiting existing surface facilities in mature fields to reduce the OPEX by converting a manned CPP to an unmanned WHP, while revitalizing the mature fields through infill drilling at the same time, is yet to be executed in Malaysia. To add more complexity to the approach to simplify the CPP, the new infill wells are high gas/oil ratio (GOR) wells, more than 220 m^3/m^3 which have exceeded the design capacity of the existing facilities. High GOR wells produce high volume of gas with relative to oil, which require bigger capacity of gas handling equipment, in particular separation system and compressor (Bothamley, 2004). In addition to that, the need to secure the integrity of the aging facilities demand for replacement of some equipment which are obsolete, will result in a significant capital expenditures (CAPEX) investment.

The oil fields of the research work are located in a water depth of 65 m to 75 m in offshore Peninsular Malaysia, which are named Field X and Field Y. Both fields were discovered in 1977 and started production in 1978 from five platforms which are X-A, X-B, X-C, Y-A and Y-B. X-A, X-C and Y-A platforms are central processing platforms, while X-B and Y-B are wellhead platforms. The processing platforms have rotating equipment, for example gas turbine compressors, gas turbine generators and pumps, which require frequent maintenance and manned operations. These have posed a high operating cost. Revisiting the surface facilities for the application of a manned operation to an unmanned central processing platform (CPP) can reduce the OPEX. Unmanned platforms have potential to operate at 25% of the OPEX of permanently manned platforms (Edwards and Gordon, 2015). Brown field modifications are required to be done on the CPP to operate based on unmanned operational model, which include reduction of equipment count, optimization of maintenance, and reduction of operational hours (Edwards and Gordon, 2015).

In order to extend the economic life of mature fields, both surface and subsurface approach should be revisited. The brown field modifications must be able to accommodate the high gas volume from the new infill wells to ensure maximum production and low operational cost can be achieved for longer economic life.

1.3 Objectives

The objectives of this research work are:

(1) To extend economic life of mature fields by converting a manned central processing platform (CPP) to an unmanned minimal facilities wellhead platform (WHP).

(2) To evaluate brown field modifications required at the field in order to maximize production from new infill wells with high gas production.

1.4 Hypotheses

There are four hypotheses outlined for this study:

(1) Integration of subsurface rejuvenation from infill wells and revisiting offshore facilities operation optimization at the same time will extend economic field life of mature fields longer and result in higher NPV.

(2) Converting manned processing platform to unmanned minimal facilities platform is feasible by isolating rotating equipment.

(3) Isolation of rotating equipment reduces OPEX in maintenance, inspection and logistic costs of the mature field.

(4) Optimization of processing system in brown field with new infill wells minimizes CAPEX investment.

1.5 Scope of Study

The scope of study are as follow:

(1) Evaluating process changes on the platform to be able to evacuate the hydrocarbon to other processing platform without any rotating equipment using flow assurance and hydraulic modelling by PIPESIM to determine the minimum departing pressure required.

(2) Performing capacity check on the existing surface facilities prior to introduction of high gas production from new infill wells by comparing the existing surface facilities capacity with the new production forecast.

(3) Estimating CAPEX and OPEX for brown field modifications to convert manned CPP to unmanned WHP by using an oil and gas cost estimation tool, Que$tor.

(4) Evaluating economic analysis to compare NPV and economic life of maintaining a manned central processing platform *vs.* converting to unmanned wellhead platform.

1.6 Significance of Study

The study is aimed to extend the economic life of mature fields, especially in Malaysia by optimizing the existing surface facilities to accommodate existing production, in addition to new productions from infill wells. The approach to convert the processing platform to minimal facilities wellhead platform could be used as a reference for other mature fields in Malaysia. This study highlights aspects of brown field modifications that need to be considered while having new infill wells of high gas production in order to minimize the number of equipment on the platform. The potential benefit of the study is an economically attractive cash flow of mature fields can be achieved via maximum recovery from new infill wells, in addition to the reduction of operating cost throughout the contract lifetime of the field. Production contract of the mature fields can be extended if the new economic life could go beyond the current PSC expiry date. The brown field modifications can be adopted in other mature fields including Sabah and Sarawak, in identifying area of concerns to focus on when changing the operating philosophy of a manned processing platform to an unmanned satellite platform. This approach can assist oil companies to realize the profitability in long term.

1.7 Chapter Summary

This chapter highlights the importance of extending economic life of mature fields as these fields hold many opportunities to expand reserves with readily available data. Mature fields provide opportunities for other marginal fields to tie-in their production to the existing facilities with optimum development CAPEX. Many considerations need to be focused on to ensure economically attractive return. Over time, as the production has declined and facilities have become underrated, revisiting of the surface facilities is very essential to maintain operation of the fields. The design of the facilities in mature fields was based on the production data available at that time. Infill drilling has now become a common approach to increase production of mature fields. However, a special attention must be given to produce from high GOR wells as the existing facilities might not be adequate to accommodate the high gas handling requirement. Another approach to simplify the processing system on top of the processing platform can reduce the OPEX and CAPEX as lesser equipment will be required for upgrading to receive the high gas production. The scope of the study are outlined to extend the mature fields' economic life by evaluating brown field modifications of the existing processing platform. The research can be adopted at other mature fields to allow operators to maximize the profit gain from the fields.

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