

NEXT GENERATION INTELLIGENT COMPLETIONS FOR
MULTI-STACKED BROWNFIELD IN MALAYSIA

NUR FAIZAH BINTI P MOSAR

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Faculty of Engineering
Universiti Teknologi Malaysia

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To my beloved husband, dearest son,
dear parents, and family members,
especially my supervisor,
thank you for all your support, encouragement and guidance.

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ABSTRACT

Multi-stacked brownfield in Malaysia is known to have zonal contrast reservoir pressure and water cut. Commingled production without any flow control such as conventional on-off sliding sleeve will induce cross flow of production from a high pressure reservoir to lower pressure reservoir which disables optimum oil production. Having high zonal water cut contrast will cause early or excessive water production translates to deferred oil production. To pro-actively prevent these occurrences, adaptation of intelligent completion components such as Permanent Downhole Gauge (PDG) and surface-controlled Flow Control Valve (FCV) can be used. Downhole FCV choke is designed to cater for the dynamic changes of reservoir properties predicted over well life. In order to standardize the FCV choke sizing by well or by campaign, the choke sizing will be averaged to fit for all layers which is not the ultimate optimized design for maximum oil production. Latest in market today, electrical driven infinite position FCV is the solution to conventional hydraulic actuated FCV. Having infinite position enables optimized choke sizing for all reservoir layers and flexible to tackle uncertainties and dynamic changes of reservoir properties over time which enables the ultimate optimum oil production and water cut reduction. Besides choke sizing, deployment method and operating method also contribute to installation and operating efficiency. Conventional multi-position FCVs in market today are either fully hydraulic operated or electro-hydraulic operated which require hydraulic pump units at surface to enable pressuring up hydraulic control lines to change the position of FCV. It is also time consuming during deployment due to the requirement of electrical splicing, hydraulic splicing and FCV actuation sequence. Infinite position FCV is electrically operated using single downhole cable that can be multi-dropped to more than 25 FCV which reduces deployment time. With WellWatcher Advisor software that provides real time optimization features, operating efficiency is improved significantly with infinite position FCV as compared to conventional multi-position FCV and on-off sliding sleeve.

ABSTRAK

Medan matang yang berlapis di Malaysia mempunyai kontras tekanan reservoir dan potong air yang tinggi antara lapisan. Pengeluaran minyak secara bercampur tanpa alat kawalan aliran misalnya sarung gelongsor akan menyebabkan berlakunya aliran silang dari reservoir bertekanan tinggi ke reservoir bertekanan rendah, lalu menghalang pengeluaran secara optimum. Kontras potong air yang ketara mengakibatkan penghasilan air yang lebih awal lalu mengurangkan pengeluaran minyak. Untuk mencegah kejadian ini, komponen pelengkapan pintar seperti Tolok Kekal Bawah Lubang (PDG) dan Injap Kawalan Aliran (FCV) yang dikawal dari permukaan boleh diguna. FCV bawah lubang direka bentuk supaya sesuai dengan perubahan dinamik yang dialami reservoir. Saiz purata pencekik diguna pakai untuk semua lapisan bagi memaksimumkan pengeluaran minyak. Terkini di pasaran, FCV berposisi infiniti memberikan penyelesaian yang terbaik dengan pencekik bersaiz optimum boleh diguna pakai untuk semua lapisan reservoir demi mengoptimumkan pengeluaran minyak dan mengurangkan potong air. Selain saiz pembukaan, alat itu turut menyumbang kepada kecekapan pemasangan dan operasi. FCV konvensional pelbagai posisi beroperasi secara hidraulik atau elektro-hidraulik memerlukan pam hidraulik di permukaan. Alat itu memakan masa pemasangan berikutan kerja penyambungan tiub elektrik dan hidraulik serta aturan penggubahan posisi. FCV berposisi infiniti dikendalikan sepenuhnya secara elektrik menggunakan satu kabel elektrik dan boleh digunakan untuk lebih daripada 25 FCV yang sudah pasti mengurangkan masa pemasangan. Penggunaan perisian WellWatcher Advisor yang berciri pengoptimuman masa nyata berjaya meningkatkan kecekapan operasi FCV berposisi infiniti berbanding FCV konvensional pelbagai posisi dan sarung gelongsor.

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LIST OF SYMBOLS

<i>PDG</i>	- Permanent Downhole Gauge
<i>ICD</i>	- Inflow Control Device
<i>FCV</i>	- Flow Control Valve
<i>SGM</i>	- Solid Gauge Mandrel
<i>SAU</i>	- Surface Acquisition Unit
<i>HPU</i>	- Hydraulic Power Unit
<i>SCADA</i>	- Supervisory Control and Data Acquisition
<i>PDC</i>	- Permanent Downhole Cable
<i>SSD</i>	- Sliding Sleeve

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CHAPTER 1

INTRODUCTION

1.1 Background

Post drilling, a well must be completed safely and efficiently prior to initiating production. Completions system must be designed to withstand suspected loads throughout its life (PETRONAS, 2013). Numerous technologies today enable safe and efficient completions installation (Dyson *et al.*, 1999).

A well can be completed for a single reservoir or multi-stacked reservoir. As the associated cost for drilling a well in offshore environment is significantly high as compared to onshore, completing a well with multi-zone reservoirs can be a cost-effective solution for oil operators (Masoudi *et al.*, 2015). It also will enable operators to produce oil by commingling the production or selective sequential production from different layers.

One of the fundamental methodologies to enhance oil production in multi-zone completions is to incorporate reservoir

monitoring and control technologies as part of completions accessories (Schlumberger, 2015a; Pogoson and Cardona, 2013). Reservoir monitoring can be achieved by installing Permanent Downhole Gauge (PDG) that reads pressure and temperature data near reservoir and transmit the data real time to end user (Samuel *et al.*, 2014; Shestov *et al.*, 2015). Active reservoir control can be achieved by having surface controlled downhole flow control device near reservoir. This will enable proactive measure to optimize production throughout well life by delaying water and gas breakthrough and ultimately increasing oil production (Schlumberger, 2018a; Al-Amri *et al.*, 2013). Multi-zone completions can be completed in few configurations as shown in Figure 1.1.

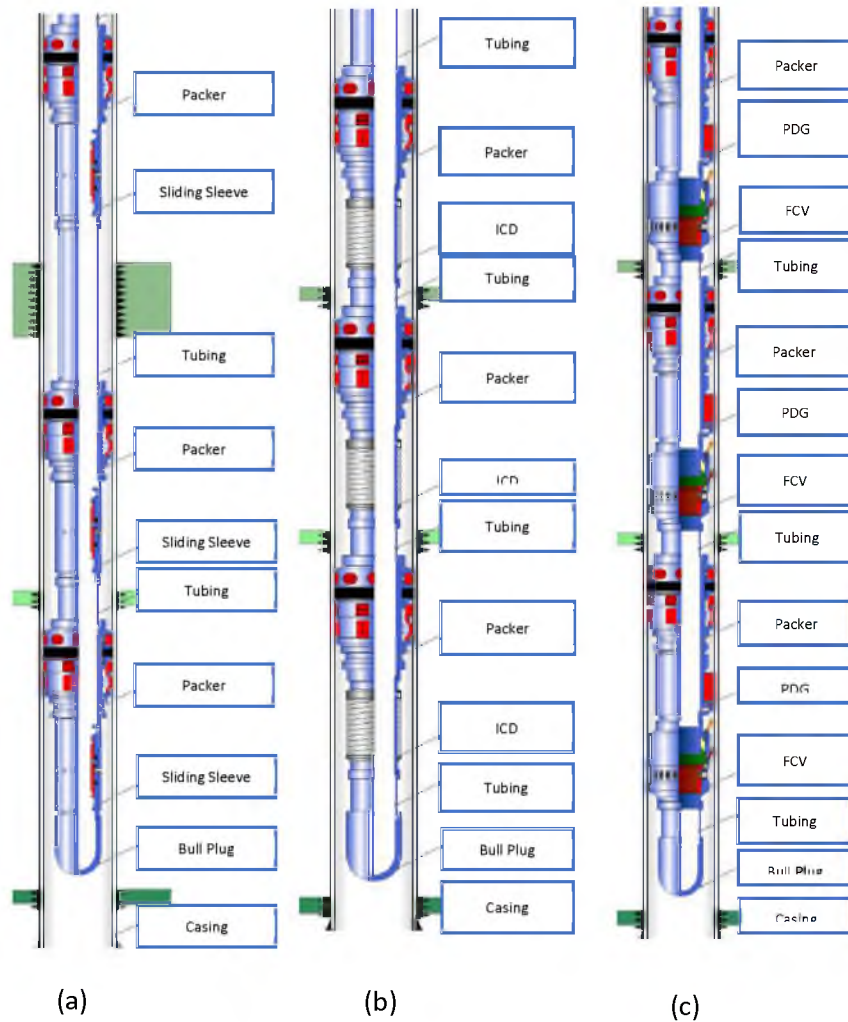


Figure 1.1 (a) Multi-zone with sliding sleeve, (b) Multi-zone with ICD, (c) Multi-zone with FCV and PDG

- (1) Multi-zone with sliding sleeve – It requires slickline intervention to open and close the sliding sleeve.
- (2) Multi-zone with passive Inflow Control Device (ICD) – Multiple ICD with pre-designed choke size usually installed along the reservoir section.

- (3) Multi-zone with active Flow Control Valve (FCV) – Surface controlled flow control valves usually integrated with PDG (Rodriguez *et al.*, 2014; Mohammed Tawfik *et al.*, 2013).

Most FCVs in current market are available in two (Innes *et al.*, 2007), four (Rodriguez *et al.*, 2014; Mohammed Tawfik *et al.*, 2013), six, and eight (Masoudi *et al.*, 2015; Shestov *et al.*, 2015) positions. The FCV is operated with various means such as:

- (1) Hydraulic operated FCV (Jannise *et al.*, 2017) – Hydraulic operated FCV usually utilizes N+1 concept. N is referencing to number of FCV. One common line is shared between all FCVs. As example, if three FCVs are used for three zones, four hydraulic control lines are required to operate the FCV.
- (2) Electro-hydraulic operated FCV – Electro-hydraulic FCV utilizes one electrical cable and two hydraulic control lines to operate the FCV (Schlumberger, 2017b; Halliburton, 2015).
- (3) Electrical operated FCV – Electrical operated FCV utilizes one electrical cable to operate the FCV (Basak and Gurses, 2015).

Prior to deciding choke size for FCV, a reservoir simulation study would be done to achieve the most optimized design. Prior to commissioning at site, a detailed completion design and

planning is required to optimize rig time for complex installation of multi-zone FCV without jeopardizing safety nor quality.

1.2 Problem Statement

Multi-stacked reservoir in Malaysian brownfield is known to have great difference of reservoir pressure between the layers (Ceccarelli *et al.*, 2014). Commingled production without any choking capability such as sliding sleeve will induce cross flow between the zones (Hamid *et al.*, 2017).

Often, especially during oil crisis, completion design chosen is driven by cost. Multi-zone with sliding sleeve would be the cheapest option with regards to capital expenditure as compared to multi-zone with ICD or FCV. However, the setback of multi-zone with sliding sleeve would be higher operational expenditure as slickline intervention is required to open or close the sliding sleeve. In addition, as only open and close position is available with sliding sleeve, once the independent zone is not economical with excessive produced water or gas, there will be no capability to choke back water or gas production to produce remaining reserve. Hence, the sliding sleeve will be shut using slickline intervention.

Multi-zone completions with FCV require proper planning and tedious installation process. Control line termination at FCV, PDG cable termination at Solid Gauge Mandrel (SGM) and control lines splice at packer require longer installation time as compared to multi-zone completions with sliding sleeve. This translates to higher capital expenditure for multi-zone with FCV. However, on the other hand, the operational expenditure would be lower compared to multi-zone with sliding sleeve as FCV has multiple positions enable choking the production for the high water cut zone without intervention. This will permit the high water cut zone to still produce oil which directly translate in oil production incremental (Schlumberger, 2017a).

Hydraulic actuated FCV is operated using hydraulic pump while PDG is powered up by Surface Acquisition Unit (SAU) from surface which require space, instrument gas or air supply, and power allocation on the platform.

Conventional FCV is also limited by the number of positions. To design the choke size for these positions, a detailed study on the reservoir condition and production is required and simulation accuracy is extremely important. Sometime, the data available during design stage is limited which reduces the accuracy of the simulation. In addition, if the reservoir condition after drilling was found to be different as compared to simulated production, the actual production could be smaller than target.

Conventional FCV installation is normally integrated with Pressure and Temperature PDG across each zone. The real-time data transmission every second can be configured to be sent to town for reservoir monitoring capability. Proactive measure to diligently monitor the real-time data and also the performance of the production is crucial. If changing to different choke size is required, production surveillance will need to be present at the platform physically to monitor the valve cycling operation with Hydraulic Power Unit (HPU) to ensure operations are completed successfully. Physical monitoring is required as valve cycling requires pressuring up control lines to actuate the FCV. Fluid return can be monitored to confirm downhole choke position.

Latest electrical operated FCV technology in market that has infinite position and embedded with sensors enable real time monitoring such as zonal pressure, temperature, flow rate and water cut will enhance fast loop decision making to optimize production over well life (Basak and Gurses, 2015; Almadi, 2014). The fact that more than 10 zones can be multi-dropped with one cable to actuate FCV will simplify offshore installation and surface commissioning significantly as compared to conventional FCV and PDG installation (Schlumberger, 2015b). The infinite position FCV will greatly increase the flexibility to tackle uncertainties and dynamic changes over time of multi-stacked reservoir properties to enable maximum oil production.

1.3 Objectives

The objectives of this study are as follow:

- (1) To evaluate infinite position FCV in improving oil production and reducing water cut as compared to on/off sliding sleeve in high zonal contrast of water cut and pressure.
- (2) To compare and prove adaption of infinite position FCV will improve installation time comparing to conventional multi-position FCV.
- (3) To compare and prove improved operating efficiency of infinite position FCV as compared to on-off sliding sleeve and conventional multi-position FCV.

1.4 Hypothesis

The hypothesis of this study are as follow:

- (1) By having an infinite FCV that is flexible to cater dynamic changes of reservoir over well life, the oil production will significantly increase and water production will decrease as compared to on-off sliding sleeve application.
- (2) One cable connected from downhole to surface to operate infinite FCV will simplify and reduce risk for downhole installation, surface installation and save significant amount of rig time as compared to conventional FCV.
- (3) Having real time optimizer WellWatcher Advisor software fed with real time data such as pressure, temperature, flow rate and water cut will facilitate a proactive measure to ensure full well potential achieved for oil production.
- (4) By simplifying method of operating infinite FCV by sending command from software, faster response time is achievable as compared to conventional FCV and sliding sleeve application in multi-zone commingled oil production.

1.5 Research Scope

The scope of research are as follow:

- (1) The study used common brownfield multi-stacked reservoir condition in Malaysia as an input into the flow simulations. The main idea was to understand the impact of reservoir properties contrast of multi-stacked brownfield reservoir such as the pressure and water cut difference between the reservoir layers towards oil and water production. Using these data, multiphase flow simulation was done using PIPESIM and WellWatcher Advisor software to compare oil and water production for multi-zone completions with sliding sleeve and infinite position FCV.
- (2) The installation and post installation operating efficiency was compared between sliding sleeve, conventional multi-position FCV and infinite FCV in multi-zone commingled production.

1.6 Significance of Study

High zonal reservoir properties contrast in multi-stacked brownfield oil reservoir is common in Malaysia. In addition, almost all wells in Malaysia are drilled from offshore platforms which incur high capital and operating cost as compared to onshore wells development. This study has proven significant incremental in oil production and reduction in water cut by having infinite position downhole flow control to cater for dynamic changes of reservoir properties over time. This study has provided lots of information for future consideration of adapting multi-zone Intelligent Completions with infinite position FCV.

1.7 Chapter Summary

Completing wells in multi-stacked brownfield reservoir is common in Malaysia to reduce overall cost by drilling fewer wells. It is known to have high contrast reservoir properties between reservoir layers such as pressure and water cut. Without the capability of controlling zonal production, commingled multi-zone oil production optimization is impossible due to cross flow from high pressure zone to low pressure zone and due to water production. Besides, with FCV, water and gas breakthrough can be delayed for maximizing oil production. By adapting downhole

monitoring and controlling device, commingled production enables maximum well potential for oil production. However, it is essential for downhole flow control to be flexible to cater for the dynamic change and uncertainty of reservoir properties over well life (Ghosh, *et al.*, 2013). Simplifying operating method for valve actuation using WellWatcher Advisor software aided with real time data such as zonal pressure, temperature, flow rate and water cut enables faster response time for valve optimization without the need of well intervention (Abuahmad *et al.*, 2016; Saeed *et al.*, 2015).

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