BEST PRACTICE FOR OFFSHORE PLATFORM DEFORMATION SURVEY USING GLOBAL NAVIGATION SATELLITE SYSTEM

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DEDICATION

To my beloved Mom and Dad, Wife and Kid and all the families..

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ABSTRACT

Offshore Platforms are one of the most important assets for Oil and Gas Company, and PETRONAS (Malaysia National Oil Company) is no exemption. Offshore platform started to be built around 1970s in the Malaysian waters and some of these platforms are still in production until today. Due to the age of some of these platforms that are already exceeding 30 years, there are issues with the structural integrity, thus the necessity for measurement and assessment have arisen. Pulai-A platform, one of PETRONAS platform located offshore Terengganu falls into this category. The method chosen in this research for the platform survey is Global Navigation Satellite System (GNSS), a highly precise solution to accurately demonstrate the real platform movement in three dimensions with a proven track record and rapid emergence of geodetic technologies and infrastructures in the global scale. The main objective of this research is to analyze in details the two different survey campaigns carried out using different GNSS methodology in 2006 and 2012. The research methodology used is by comparing the differences in the GNSS data acquisition, processing and results between these two epochs. There is also a study on project management impact for different GNSS technical approach, on how the new technique could save cost and time. After the analysis, results show that up to 80% cost-saving and 50% time-saving could be achieved by applying the new GNSS development into the survey process. The research concludes that application of improved GNSS methodology would certainly improve results and project quality. A best practice on how to use GNSS method to measure old and existing offshore platforms is proposed, based on the improvement applied in the 2012 campaign compared to the more conventional methodology in 2006. The proposed best practice is meant to be the pioneer in a more formal guidelines establishment for offshore platform survey using GNSS methodology in the future.

ABSTRAK

Pelantar luar pesisir adalah salah satu aset yang paling penting untuk Syarikat Minyak dan Gas, dan PETRONAS (Syarikat Minyak Nasional Malaysia) tidak terkecuali. Pelantar luar pesisir mula dibina sekitar tahun 1970-an di perairan Malaysia dan beberapa platform ini masih beroperasi sehingga hari ini. Oleh kerana usia beberapa platform ini sudah melebihi 30 tahun, terdapat isu dengan integriti struktur pada pelantar, oleh itu keperluan untuk pengukuran dan penilaian telah timbul. Pelantar Pulai-A adalah salah satu pelantar PETRONAS yang terletak di luar pesisir Terengganu termasuk dalam kategori ini. Kaedah yang dipilih untuk kajian ini adalah kaedah sistem navigasi satelit global (GNSS), iaitu penyelesaian yang sangat tepat untuk menunjukkan pergerakan sebenar sesebuah pelantar dalam tiga dimensi yang mempunyai rekod lepas yang terbukti, juga dipacu perkembangan pesat teknologi dan infrastruktur geodetik dalam skala global. Objektif utama kajian ini adalah untuk mengkaji secara terperinci dua kempen kaji selidik yang berbeza dilakukan dengan menggunakan kaedah GNSS pada tahun 2006 dan 2012. Kaedah penyelidikan yang digunakan adalah dengan membandingkan pengumpulan data GNSS diantara dua epok dari segi pemprosesan data dan keputusan. Terdapat juga kajian mengenai kesan pengurusan projek hasil pendekatan teknikal GNSS yang berbeza tentang bagaimana teknik baru dapat memberi penjimatan kos dan masa. Selepas analisis, keputusan menunjukkan penjimatan kos sebanyak 80% dan juga 50% dari segi penjimatan masa boleh di capai dengan menggunakan pembangunan GNSS yang baru ke dalam proses pengukuran. Kajian dapat disimpulkan bahawa dengan penggunaan kaedah GNSS terbaru, ianya akan meningkatkan kualiti keputusan pengukuran dan juga kualiti projek. Dicadangkan satu amalan terbaik penggunaan kaedah GNSS bagi tujuan mengukur pelantar luar pesisir yang lama dan sedia ada dengan mengambil kira perubahan yang diguna pakai dalam kempen tahun 2012 berbanding kaedah yang lebih konvensional pada tahun 2006. Cadangan amalan terbaik ini adalah bertujuan untuk menjadi perintis dalam penghasilan garis panduan yang teratur untuk kajian pelantar luar pesisir menggunakan kaedah GNSS pada masa akan datang.

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LIST OF ABBREVIATION

E&P	:	Exploration and Production
3D	:	Three Dimensional
AC	:	IGS Analysis Centers
AIUB	:	Astronomical Institute University of Berne
AME	:	PETRONAS Approved Medical Examiner
BOSET	:	Basic Offshore Safety Training
C/A-codes	:	GNSS Coarse Acquisition codes
cm	:	centimeter
CORS	:	Continuously Operated Reference System
CRP	:	common reference point
DoD	:	Department of Defense of United Stated
DoY	:	Day of Year
ERP	:	Earth Rotation Parameters
etc	:	etcetera
FPSO	:	Floating Production and Storage Offloading
ft	:	feet
GDC	:	IGS Global Data Center
GDM2000	:	Geocentric Datum of Malaysia 2000
GNSS	:	Global Navigation Satellite System
GPS	:	Global Positioning System
IAG	:	International Association of Geodesy
ICRF	:	International Celestial Reference Frame
IERS	:	International Earth Rotation and Reference Systems Service
IGS	:	International GNSS Service
IMCA	:	International Marine Contractor Association
InSAR	:	Interferometric Synthetic Aperture Radar
IPVPN	:	Internet Protocol Virtual Private Network
ITRF	:	International Terrestrial Reference Frame

ITRF2000	:	International Terrestrial Reference Frame 2000
ITRF2008	:	International Terrestrial Reference Frame 2008
ITRF88	:	International Terrestrial Reference Frame 1988
JUPEM	:	The Department of Survey and Mapping Malaysia
kilometer	:	km
LEO	:	Low Earth Orbiter
MASS	:	Malaysia Active GNSS System
mm/yr	:	milimeter per year
MOPU	:	Mobile Offshore Production Unit
MyRTKnet	:	Malaysian Real-Time Kinematic network
OGP	:	Oil & Gas Producers Association
P-codes	:	GNSS Precise codes
PCSB	:	PETRONAS Carigali Sdn Bhd
PMO PCSB	:	PCSB Peninsular Malaysia Operation
PPP	:	Precise Point Positioning
PTW	:	Permit to Work
QC	:	Quality Control
QIF	:	Quasi-Ionosphere-Free
RINEX	:	Receiver Independent Exchange Format
RM	:	Ringgit Malaysia
RMS	:	Root Mean Square
RTK	:	Real Time Kinematic
SA	:	Selective Availability
SIM	:	Structural Integrity Managements
SIO	:	Scripps Institute of Oceanography
SLR	:	Satellite Laser Ranging
SOW	:	Scope of Work
SSB	:	Sarawak SHELL Berhad
SV	:	space vehicles
TGO	:	Trimble Geomatic Office
TRC	:	Technical Review Committee
TTC	:	Trimble Total Control
UCSD	:	University of California, San Diego
UTM	:	University Teknologi Malaysia
VLBI	:	Very Long Baseline Interferometry

CHAPTER 1

INTRODUCTION

1.1 Chapter Overview

It is strongly recommended to start every chapter a little introduction and overview about what will be discussed within the chapter. This would provide the readers a little outlook on what to expect while browsing through each chapter while at the same time trying to understand to message that are tried to convey across. In this first chapter as commonly done in typical research thesis, we started off with a brief explanation of the research in the background of study. The elaboration of issues and problems to be solved were explained in problem statement part, before specifically categorizing the research aims and objective together with scope of study to determine the wideness of research. The chapter would be capped off with the significance of study to list down chain of peoples who would benefit once the study is completed.

1.2 Background of Study

As widely known, the Exploration and Production (E&P) stage of oil and gas is a very costly activities economically and also a very time-consuming process. The operation, be it on land or offshore, must be planned thoroughly in making sure all the resources are utilized prudently, and failing that, one could lost fortune and even worse it could endanger assets and peoples life, as well as tarnishing a good reputation. In Malaysia, most of E&P activities are being done offshore. Therefore, a lot of offshore structure being built since the early 1970s to cater Production of oil and gas activities. These offshore structures include offshore platform, Mobile Offshore Production Unit (MOPU), Floating Production and Storage Offloading (FPSO) and subsea developments structure. In Malaysian waters alone, we have more than 200 offshore platforms to cater for extraction of oil and gas operation.

These offshore platforms are either built in clusters or stand-alone individual platform, manned and also unmanned. The biggest platform being built is 8 legged platforms, followed by 4 legged, 3 legged, and Mono-Port. Few platforms (normally 8 legged and 4 legged) connected to each other by bridges form a cluster. In a cluster or complex, the platform connected may have difference function such as Production Platform, Drilling platform, Gas platform, Living Quarters and few other uncommon functions.

Most offshore platforms, especially the one which was built on gas field, are prone to having subsidence and other movements. Even small deformation could cause damages since most platforms are being connected with pipelines, wells and also another platform. It is crucial to be able to measure these movements in order to ensure the integrity and reliability of the platform to avoid unwanted incidents and protecting the multi billion dollars of investments, as well as maintaining and maximizing productivities.

In this day and age, there are few different methods that have been used for the purpose of monitoring and measuring deformation of the offshore platforms. Among the tools and methods used are the Interferometric Synthetic Aperture Radar (InSAR), three dimensional (3D) laser scanning and water level sensors. These methodologies are commonly used onshore, but rarely has the testimony offshore, especially in measuring deformation which require highly accurate capabilities to detect such a small structural movements. Therefore, the most viable option we have to measure three dimensional movements of an offshore structure is using Global Navigation Satellite System (GNSS) technique, since the GNSS (since the beginning of Global Positioning System (GPS) days) has been proven to be the most feasible in getting the accurate and reliable subsidence value.

1.3 Problem Statement

Platform deformation and subsidence issue is one of the major issues concerning the offshore structural integrity, as it is not new in oil and gas industry worldwide. In Malaysia, Sarawak SHELL Berhad (SSB) and PETRONAS Carigali Sdn Bhd (PCSB) have had experiences in significant deformation occurred at their platforms in recent years, especially the old platforms and complex which has accumulated in excess of 30 years old in operational nature. Apart from general fatigue of these structures after long years in production, the type of reservoir and field also play a part in contributing subsidence proneness. As an example, gas field are more prone to subsidence compared to oil, and carbonate reservoir would result in more severe subsidence over long production years compared to the clastic reservoir (E.Kosa, 2012). These factors defining the pressing need for us to continuously monitor subsidence and deformation in delicate manner for us to make decisions on the structures and reservoir in the end.

The rates of deformation experienced in these platforms have been measured using various methods, with geodetic precise measurements being the most dominant routine to be used to determine subsidence. The reason Geodetic method became the most common and trusted method to detect subsidence and deformation of an offshore platform, is because the capability of achieving accuracies and detecting movements up to millimeter with the most cost-effective and workable manner. Other more complicated technique might also capable of achieving more or similar level of accuracy, but due to its costly nature as well as highly impracticable manner, it seems less favorable to become the solution. With the exciting developments of the Geodetics infrastructure in Malaysia on top of state-of-the-art already-available global Geodetics network, measuring deformation using GNSS always have the edge over any other technique, mainly due to the fact that GNSS present infrastructures is able to achieve millimeter accuracy in positioning works.

As deformation and subsidence are one of the main concerns of structural integrity, we need to also bear in mind that the South East Asia region is located on the Sunderland crustal plate, which is recently proving to be among the most seismically active plate in the world with at least 3 major earthquakes in the last 5 years (Jhonny et al. 2004). There have been quite a number of studies and researches being done to assess methodologies of measuring subsidence, but not one of these studies have taken into account the important factor such as the tectonic plate movement and Sundaland plate analysis into the whole equation.

For PCSB's platforms which all of them are located in the seismically-active Sundaland plate, understanding the plate movement characteristic quickly becoming an integral part in determining the final deformations and movement values for these platforms to ensure the final results would really represents the structural anomaly changes after the movement of the plate, which might or might not affect the deformation, was removed during the processing and analysis. The remote structures offshore are always in danger of being affected by these seismic plate movements and the integrity of these structures is always in question.

1.4 Objectives of Study

The way it is measuring deformation and movements of structures was just a small step in understanding the whole structural integrity issue for an offshore platform. However, in order to be relevant and fit for a master research project, the aim of the research was designed to propose the best practices of measuring deformation of an offshore platform using GNSS technique to be in line with the structural integrity monitoring as well as recent developments in Geodetics application & infrastructure.

In order to achieve this research aim, we formulate three main research objectives, which are:

a) **To Analyze the Previous and More Recent Deformation Survey Campaign at Offshore Platform using GNSS approach**
   - Analysis of the method used for the purpose of offshore platform deformation monitoring using GNSS in the past, how it was performed operationally, and results & data analysis complete with comparisons with more recent campaign to discuss the results in terms of technical as well as overall project management.

b) **To propose the best practices for offshore platform survey using GNSS technique based on latest GNSS development and Geodetic Infrastructure**
   - To provide the best practices for GNSS observation method for offshore platform deformation, taking into account its practicality, feasibility and data reliability.

1.5 Scope of Study

Scope of study is the focus of research where the subject being discussed. The scopes of the study for this investigation are:

a) The deformation monitoring methods that will be assessed in this research are Geodetic method using GNSS only.
   - There are various methods that could be used to determine offshore platform movements, but for this research purpose, only Geodetic method will be discussed since other method most probably do not have any relationship with all the Geodetics infrastructure development around this region.

b) These monitoring methods will only be applicable to monitor existing offshore platforms in Malaysian waters only.
   - The research design would be very much different with so many elements to consider if the GNSS methodology is to be applied since the very beginning of the platform design.

   - Pulai-A is the research subject for this topic, as it is the platform in Peninsular Malaysia water which has been in operation more than 30 years, and because of the historical evidence of deformation as well as legacy monitoring data availability.

1.6 Significances of Study

This research is important as for now, there is still no standard guidelines being established in PETRONAS as well as in Oil and Gas global practice, let alone methodology using GNSS with the purpose of monitoring deformation as well as ensuring the integrity of an offshore platform.

By completing the study, the benefits would have an impact on the overall business scale, where these advantages could be heeded:

a) The improved methodology would be useful as it would be the first of its kind in the industry that has been introduced to act as indicator for deformation of an installation, to inspect the overall platform integrity.

b) The improved methodology would be a useful assistance for Structural engineers to understand more about the trend of the structures, offshore platforms relationship with a moving plate underneath, as well as how the GNSS baseline processing method is important as the more structured and more cohesive way of measuring movements of the installation.

c) The improved methodology; which is some kind of a breakthrough in the surveying technologies and geo-dynamism science, would be the milestone for the Surveying and Geodetic people in oil and gas industry as the results of survey would be more convincing after elimination of most ambiguities, such as realization of global frame in relation with local network, determination of coordinates definition and velocity estimation for deformation analysis.

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1.7 Chapter Summary

The first chapter, Introduction, the discussion started off with the Background of Study where the discussion is about the important elements of offshore platforms in oil and gas business. Old platforms that have been operated more than 30 years could prove to be a challenge in maintaining productivity level, thus monitoring these old platforms became an integral part in ensuring the structural overall integrity. In the problem statement also there are remarks on the type of reservoir and fields, in which also could play a determining factor in platform deformation proneness.

After understanding issues, the Objective of Studies is designed to review, assess and evaluate two different survey campaigns to measure offshore platform deformation using GNSS technique. One being in 2006 and the more recent were done in 2012. The final objective is to propose the best practice for offshore platform deformation survey using GNSS technique. The chapter was capped off with a bit of list on the beneficial parties should the study be completed.

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