ABSTRACT

Pertamina Hulu Energi (PHE) Offshore Northwest Java Lima Field is experiencing continuous sea bed subsidence at a rate of 0.15 meter/year resulting in serious operational risk at Lima Flowstation. The subsidence has reduced the air gap between platform decks to sea level up to 3 meters from the original design. The subsidence also has affected a number of wellhead platforms in Lima Area. The immediate solution to mitigate the risk at the wellhead platforms was to relocate equipment from cellar decks to main decks. The focus of this paper is the complex task of synchronized raising of three platforms, interconnecting bridges and flare bridge of Lima Flowstation Complex.

Various studies were undertaken to return Lima Complex back to safe operations. It was concluded that a two stage solution would require the shortest period of Lima production shut down with acceptable levels of project costs. Two stages were required as the consequence of the limited air gap. First stage was to raise the objective structures 1 meter to give enough head room to install the second stage 4-meter raising jacks.

Project Management strategy was the key to successful execution of platform deck raising. It began with contracting strategy, engineering design including interface between Versabar as the designer and provider of the synchronized deck raising system and PT Timas Supplindo as the EPCIL Contractor for installation of the system, procurement and fabrication strategy, HSSE plan, quality plan and offshore execution strategy including commissioning and start up. All specifications were determined in the Project Execution Plan and Project Master Schedule.

The project summary was to raise three platforms, interconnecting bridges and flare bridge of Lima Complex at synchronized and controlled speed. It was achieved by controlling the pressure and hydraulic oil flow to each hydraulic jack. Elevation variance of each leg was monitored from the control room by means of string pot and certain levels were selected to stop raising operations for calibration.

Fifty-five days following shutdown the Lima Platform was back online; five days ahead of schedule. The first raising of approximately 1 meter was completed on September 4, 2013 and second raising of additional 3 meters on September 19, returning Lima Flowstation to safe operations and ensuring PHE ONWJ an additional 12-15 years of use.

INTRODUCTION

Pertamina Hulu Energi (PHE) Offshore Northwest Java (ONWJ), a subsidiary of PERTAMINA (National O&G Company) has operated Lima Field since taking over
ownership from BP West Java in July 2009. The first Production Sharing Contract (PSC) was originally operated by ARCO from 1971 - 2000.

PHE ONWJ Lima Field

PHE ONWJ Lima Field is situated in Java Sea approximately 45 nautical miles north from Tanjung Priok Port of Jakarta as shown in Figure 1. Lima Field commenced production from 1973. It has 19 wellhead platforms connected by subsea pipelines delivering the products to Lima Flowstation.

Figure 1 - PHE ONWJ Working Area and Lima Location

Lima Flowstation was built in 1973 with processing platform named LPRO and living quarters named LSER. Later in 1975, Compression Platform named LCOM was built at western side of LSER. Picture of Lima Flowstation is shown in Figure 2. Lima Flowstation is also a hub for delivering crude oil from KL field through LPRO, PERTAMINA EP Parigi Gas through LPRO, and West to East gas pipeline to deliver gas from west area to PHE ONWJ client served by east area.

Figure 2 - Lima Flowstation
Total daily production from this field currently is about 4,000 BOPD and 12 MMSCFD, or about 10% of total PHE ONWJ production. It is also a hub for KL production about 4,000 BOPD, West to East gas delivering 60 MMSCFD and PERTAMINA EP Parigi production about 70-75 MMSCFD.

**Lima Field Subsidence Phenomena**

Over the life of a production facility, reservoir pressure will reduce as oil and gas are extracted. This reduction in reservoir pressure may result in local compaction and consolidation of reservoir rock. Reservoir compaction may also lead to subsidence at the surface, or at the seabed in the case of an offshore platform. For a fixed offshore platform, a consequence of seabed subsidence is the reduction of the air gap between the average sea level and the underside of the topside increasing the potential for inundation of the deck in extreme storm conditions.

The subsidence phenomena at Lima Flowstation had been monitored half-yearly since it was identified. The subsidence rate currently is about 0.15 meter/year. This put the Flowstation at risk for structural failure under storm loading conditions. Consequently a permanent long term solution was planned. Various studies were conducted and concluded that raising of most critical platforms and facilities was the best option in terms of project schedule and budget. Further risk assessment was conducted in order to execute the project safely.

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**Figure 3 - Subsidence at Lima Field**
Contracting Strategy

Due to the complexity of the project, the general contract was divided into two major contracts. The first contract was for technical services of deck raising system design and delivery of the equipment. The second contract was for engineering, procurement, fabrication, construction and installation of the deck raising system and required platform modifications related to deck raising work.

The first contract was awarded to P.T. SAS International as local agent of Versabar, with experience in deck raising of two eight legged platforms in Gulf of Mexico (GoM). They provided the deck raising system design, platform legs modification design, layout of equipment, and manufacture and delivery of the deck raising system. Design of platform legs modification was conveyed to second contract for further engineering, verification of the applied load, and fabrication of deck leg sleeves.

The second contract was awarded to P.T. Timas Suplindo through an open tender process. They performed detail and installation engineering of platform modification for structural, piping, risers, and E&I modification impacted by deck raising. They procured all materials required for modification, and fabrication works, prepared adequate manpower and marine spreads to complete the work.

DESIGN / METHOD

Versabar’s patented deck raising technology was first developed in 2006 when a GoM operator needed to raise the topsides on two 8-legged drilling and production platforms. The technique was then developed to meet Lima Subsidence remediation requirements due to limited air gap and becoming proprietary of Versabuild.

The agreed solution was conducted in two stages: the first raising used split sleeves to encapsulate the legs throughout the raising process. This encapsulation provided a high degree of lateral stability during the raising operation and subsequently formed the permanent leg extension for the raised condition. Three platforms of LCOM, LSER and LPRO were raised together with their associated link bridges and flare bridges by jacking with multiple synchronized rams without removing the bridge connection between them. Only bridge connecting LPRO to LA well head platform was disconnected at LA side and lifted together with the others.

The deck raising system can be divided in several component and sub-systems. Those components and sub-systems are:

1. Lower & upper ram attachment points (lower and upper padeye);
2. Deck leg sleeves and bushings;
3. Bridge lift frames;
4. Storm safe pin-offs assembled in the pin trough;
5. Deck leg hydraulic rams;

6. Bridge support hydraulic rams;

7. Hydraulic Power Unit / Power System and its mounting structure;

8. Ram Synchronization and control system.

The lay-out of the system is shown in Figure 4.

![Deck Raising System lay-Out](image)

**Figure 4 - Deck Raising System lay-Out**

**Jack, HPU and Control System Design**

Two types of hydraulic rams were custom engineered to raise the platforms in two stages, and three types of rams were used to simultaneously raise the supporting bridge structures to the full 4 meters. The 1st stage rams were to raise the platforms about 1 meter height, and then leg pins were inserted. In the 2nd stage, dual-rod rams were used to raise the platforms about 2.7 meter height. After pinning off, the 2nd stage rams continue to raise the platforms to 4 meter height and then pin-off once more. The work schematic is shown in Figure 5.

Four hydraulic rams were arranged at each deck leg of platform, and two rams for each bridge leg. Hydraulic rams were designed so in case one ram in the cluster failed, the deck raising process still could continue. Each ram had a 500 kips rated capacity. The ram lugs had special bushing allowing certain degree vertical tolerance. This feature was required especially for installation at LPRO and LSER platform.
The custom engineered HPU (Hydraulic Power Units) that operate the rams incorporate a redundant design using two of everything where applicable, starting with the utilization of twin diesel engines and hydraulic pump arrangements, each with their own fuel supply and cooling capability. In the unlikely event of an engine or pump failure during the raising operation, the units were designed to be able to continue the raising process unaffected. The HPU’s also integrated failsafe design into the control scheme so that in the event of a lost control or hydraulic signal, all operations would automatically halt until the matter was resolved. One HPU unit serves one platform or one lift frame.

Core control system equipment includes:

- Control building – PLC, HMI, and PC equipment housing structure on LA platform
- 78 pressure transducers, one per hydraulic ram and retract manifold
- 36 position transducers (string pots, two per leg)
- One master control / monitoring station, located in the control building
- Six slave control / monitoring stations, located locally in each HPU
- Main PLC control panel, located in control building
- Six PLC remote I/O panels, located near each slave control at each HPU
- One PLC remote I/O rack inside control building
• Platform junction boxes, one at each leg or jacking point

• Interconnecting power and communication cabling.

The above control system arrangement was identical for the Stage-1 and Stage-2 raising.

Two modes of operation were available: Local (manual) and Remote. Remote control mode was the normal operation mode. The Operator at master control managed all legs / jacking points via the one joystick synchronously or controlled any single leg individually using the same controller but selecting different control configuration setting.

Local mode was selected if there was remote mode fault. Attending operators at each of the six slave control / HPU control panels controlled the travel and speed of the corresponding legs with feedback from local digital LED displays monitoring the displacements and audible input from the supervisor in charge of total operation.

Emergency Shutdown Switches also were available in the main control and each of the HPU, in case it was required to suddenly stop the raising operation at discretion of Operators.

The “Lead Leg” is the platform leg / jacking point that the other legs followed while in synchronized mode. It was the predicted heaviest leg load among the others, so it was considered as the slowest speed. The other legs speeds were controlled so not to exceed the maximum deviation allowed. The system alarm sounded if leg deviation reached 0.5inch and stopped operations at 1inch.

Hydraulic flow to each cluster of rams was controlled by a centralized PLC based control system. Flow was controlled via electronic flow control valves, one per leg cluster, with an infinitely variable flow range from 0% to 100% of maximum flow capacity. Vertical displacement of each leg during raising operations was continuously monitored by string extension potentiometers (string pots), two units per leg. The synchronization system for normal operations continuously controlled the hydraulic flow to each cluster of rams to ensure the relative displacement between legs did not exceed the specified tolerance. The control system monitored and reported key hydraulic power unit variables, i.e.: engine oil pressure, rpm, and hydraulic pump pressure.

Permanent Deck Leg Section Replacement Design

The permanent deck leg section replacement design is shown in Figure 5:

1. Leg bushing (red color)
2. Lower padeye (yellow color)
3. Upper padeye integrated with sleeve (green color)
4. Inner sleeve (orange color)
5. Outer sleeve (purple color)
The Stage-1 raising required installation of lower padeye, leg bushing, and upper padeye before stage-1 rams. For LCOM, lower padeye was installed first to give working table for the next operation. For LSER and LPRO, leg bushing and upper padeye were installed first because the lower padeye should be installed in batter section of deck leg, as consequence of limited length of deck leg.

Leg bushing was required to transfer the deck leg load at the crown section to the new sleeve section and to strengthen the leg prior to partial cutting, approximately 60% of the circumference, and pin hole cut out at the cutting window.

The upper padeye was integrated with the leg sleeve and attached to the bushing. Once the first three parts were installed, then four rams were installed and hooked-up. Next followed the pin trough assembly, camera and camera mount, and string pot ready for Stage-1 raising.

Once Stage-1 raising was completed, pin-off and welded, all four stage-1 rams in one cluster were removed and installation of Stage-2 parts was initiated. It consisted of an inner sleeve and outer sleeve. The inner sleeve was welded to bottom part of upper padeye ring. The outer sleeve fit loosely over the inner sleeve so the inner sleeve could slide freely before the pin holes aligned. Then followed the pin trough assembly at upper and lower pin holes, camera and camera mount, and string pot were ready for Stage-2 raising.

Each of the assemblies was custom made to fit each individual leg as they are unique. Special precautions were taken with LPRO and LSER lower padeyes as they had to be installed on the batter part of deck leg. Trial fitting during fabrication was essential to give assurance during offshore installation.

![Flare Bridge Lift Frame](image-url)
HPU Frame and Bridge Lift Frame Design

The lifting operations required rams and jacking structures to be installed on the LA platform (Figure 7), and both flare bridge tripods in order to successfully raise the Lima Flowstation. A lift frame was constructed to raise the linked bridge. The jacking frames each made use of four (4) rams to raise the bridges to the final 4 meter elevation, synchronized with the deck raising operation. Each was supported by two clusters of two (2) rams. The ram ports in each cluster were connected to each other by a common manifold. The common manifold caused each ram within the cluster to respond to the same pressure, in order for each ram to carry equivalent loads.

![Figure 7 - LA Bridge Lift Frame](image-url)

With insufficient space on flare bridge tripods, an HPU platform was integrated to the flare bridge lift frame. Then the HPU was placed to provide power to the hydraulic rams as shown in Figure 6.

Due to limited or restricted deck space, it was necessary to rest LSER and LPRO HPU on the link bridges throughout the duration of the project. The mounting structures were installed prior to installation of HPU units. The mounting structures incorporated fully circumferential walkways, dual egress ladders, and a lay down area for refueling, cable and hose hook-up.

Deck Leg Strengthening Design

In the event of one hydraulic ram failure during deck raising, an imbalanced load would create high bending moment to the deck leg. Structural analysis had shown that the deck leg would fail due to such a bending moment.
As mitigation, each deck leg was strengthened by welding stiffening plates between upper padeye ring and cellar deck beam. The strengthening also would act as stiffening for any seismic event.

**Operational Design Requirement**

The deck raising system was designed such that all raising system equipment failure modes resulted in a safe condition. For this system, a safe condition was defined as the clusters of rams remaining fully load bearing supporting the weight of topsides, but no longer moving. In all cases, failure of any of the components of the lift system would cause the control system to halt the raising operation. The rams would be able to remain fully loaded until the fault was rectified.

During any such event, the raising operation should be able to continue given the loss of any one major component (i.e. ram, hose, manifold, control valve, pump, or engine) on each platform either at reduced speed or after component replacement. The control system had a similar level of redundancy in power supply, computer and cabling / control umbilical.

The deck raising process was controlled through the continuous monitoring and management of vertical leg displacement (travelling), differential displacements between legs on a particular platform or bridge support structure, and average differential displacements between platforms and bridge support structures. Structural verification of the platform topsides determined acceptable ranges of differential vertical displacement between adjacent deck leg on single platform and between individual platforms and bridge support structures.

Raising operations considered weather restricted operations, and were limited to environmental conditions of the one year return storm for the calm weather season between May and October 2013.

**Assurance Process**

As part of assurance to deck raising system design, a System Integration Test (SIT) was conducted at Versabar facilities in Houston, mimicking the heaviest platform and one bridge as shown in Figure 8. It was conducted in two stages, first stage successfully completed 15 January 2013, and the second stage on 25 January 2013. Each stage of the raising was performed with split sleeves installed on the legs and leg pins inserted at each point of the raising operation as they would be offshore. The whole process was witnessed and certified by ABS, proving that raising synchronization was doing well and all failure modes were in place.

A Quantitative Risk Assessment and HAZID/HAZOP process were performed to see any failure possibility and the mitigation plan during design of the system and during offshore execution. It was shown that the deck raising system design is safe and the only high risk left was the welding design and execution. So the welding QA/QC was included as part of the assurance process to execute the project successfully.
OFFSHORE EXECUTION PHASE

The offshore execution phases can be grouped as pre-shutdown work, shutdown and post shutdown work as shown in Table-1. The green colored bar highlights when only supply boat was utilized, and blue colored bar when there were barges utilized.

**TABLE 1**

**OFFSHORE CAMPAIGN HIGH LEVEL SCHEDULE**

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<td><strong>Phase 6</strong></td>
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**Figure 8 - SIT of Deck Raising System at Versabar’s Facilities as Assurance**
Project Characteristics

The following project characteristics had to be taken into account during design of deck raising system and offshore planning:

1. A potential high risk had to be minimized;
2. Consideration of weather parameters;
3. Limited platforms pile and deck leg capacity lead to maximum allowable raising deviation;
4. Contingency case if one part of deck raising system broken;
5. Platform total shut down period limited, making most of preparation requiring hot work to be executed during live platform and quick reinstatement related to process;
6. Limitation of work space on platform;
7. Subsea pipeline configuration limiting barge anchor pattern.

Offshore Phase

Offshore execution was divided into seven phases, referring to the timing to arrival of raising equipment, shutdown schedule and the raising date, and the marine spread utilized. They were:

- **Phase-0**: early start for preparation of scaffolding, construction equipment transfer and hook-up, utilizing accommodation boat for contractor personnel. This phase commenced from 1 March 2013 until arrival of accommodation work barge on 28 May 2013.
- **Phase-1**: preparation and installation of deck raising materials assemblies, before arrival at site of Versabar’s deck raising equipment, utilizing one accommodation work barge.
- **Phase-2**: continue preparation and installation of deck raising materials assemblies, and installation of Versabar’s deck raising equipment including HPU and HPU platform on link bridges, LA lift frame before platform total shutdown, utilizing one accommodation work barge.
- **Phase-3**: continue preparation and installation of deck raising materials assemblies and equipment which could not be installed due to conflicts with existing features after platform total shutdown before Stage-1 deck raising, installation of flare bridge lift frames, disconnection of risers and any links between topside deck and jacket. Second barge was utilized and stationed northern side of platform as shown in Figure 9.
- **Phase-4**: removal of Stage-1 rams, installation of Stage-2 assemblies and rams after successful Stage-1 deck raising, before Stage-2.
- **Phase-5**: removal of Stage-2 rams and equipment, platform reinstatement and modification until ready to put back online.
- **Phase-6**: continue platform reinstatement after back online. On this phase, second barge was demobilized, leaving one barge stationed at southern side of platform.

The pre-shutdown work was completed in three months after mobilization, no later than planned shutdown on 15 August 2013.
The shutdown sequence began on 15 August 2013 from wellhead platform shut-in, and completed in three days. The second barge named SS3 arrived and stationed at northern side of Lima Platform on 17 August 2013 when the flare was off. SS3 was stationed there to install flare bridge lift frames and HPU, weight approximately 50 metric tonnes in total as shown in Figure 9.

![Figure 9 - Barge Arrangement during Shutdown Duration](image)

At the peak of the project there were about 500 contractor personnel working offshore, stationed on two barges. At each shift, about 250 personnel worked on platform spreading from main deck down to jacket walkway area at all platforms and flare bridge tripods.

The Stage-1 deck raising was successfully executed 4 September 2013, raising the platforms and bridges about 1 meter, while the Stage-2 deck raising was completed 19 September 2013.

Main activities after the Stage-2 success were to reinstate platform conditions until ready for back online, focusing on process related work such as piping, risers, shutdown system, and disposal caissons. Project completion was scheduled no later than 15 October 2013. Lima Flowstation was back online on 10 October 2013, five days ahead of schedule or 55 days from the planned 60 days shutdown duration.

**KEY SUCCESS SUMMARY AND CONCLUSION**

The deck raising project was not impossible in any sense nor was it rocket science. The successful performance of the project execution was due to some key factors:

1. Dare to take new challenge, as this was a new project in the region;
2. Treat all Contractors as partners at the same level;
3. Collaboration within PHE ONWJ department to support the project;
4. Tight assurance process by conducting SIT, QRA, leg dimensional check, and fabrication trial fit;
5. Close monitoring of Contractor’s performance through interface meetings, communications and reporting;
6. Risk identification through HAZID and HAZOP process;
7. Tight QA/QC especially for welding quality;
8. Continuous Management support.

Stage-1 raising was an important step to validate the predicted load, since during engineering work the data used was the best estimate made by weight verification study. It was shown that LSER and LPRO platform weight were increased about 60 to 80 tons. Quick verification was made prior to Stage-2 and found that the weld design was fine.

The project required more than 1 million man-hours working from engineering stage, fabrication up to offshore execution, and was carried-out without any LTI.

Figure 10 - Stage-1 Raising
Figure 11 - Platform View after Stage-1

Figure 12 - Stage-2 Raising
Figure 13 - Flare Bridge Stage-2 Raising
About Authors

Oto Gurnita, PMP
Indonesia

Oto Gurnita has been more than 20 years’ experiences in Oil & Gas Projects with specialization in Project Management, inclusive of Engineering, Procurement, Fabrication, Construction/Installation, and QHSSE. Various onshore and offshore projects have been completed (e.g. Fixed Platforms, Floating facility and Subsea Completion). He has worked for various O&G Companies, starting in 1992 with ARCO Indonesia, BP Indonesia, EMP Kangean Ltd, Star Energy Ltd and currently working for Pertamina Hulu Energi (PHE) ONWJ since 2011. He was assigned in PHE ONWJ as Project Manager for Lima Subsidence Remediation project completed in 2013 and then UL Field Development project completed in 2014. Currently he is Project Manager for Fire & Gas Upgrade of Bravo Complex project and Oscar Field Development project. He has completed a number of both Offshore and Onshore Projects. He can be contacted at oto.gurnita@pertamina.com

Asning Suryo Nindyanto
Indonesia

Asning Suryo Nindyanto graduated from the Institute of Technology Bandung, Indonesia with a degree in Mechanical Engineering in 2001. He started his career in PT. Pillar Pradhana Dwitama as Project Engineer for Single Point Mooring activities. He then joined BP West Java Ltd. and later PT. PERTAMINA Hulu Energi ONWJ in 2009. He has an extensive experience in various projects: onshore, offshore, fixed platforms and floating facilities. Asning was assigned as Senior Project Engineer for the Lima Subsidence Remediation Project that was completed in 2013. Currently he is a project Leader for a New Terminal project. asning.suryo@pertamina.com