“CLOV, valorization of technical expertise and commitment to local development”

IPTC “Excellence in project integration award”

INTRODUCTION

Located 140 kilometres from shore, CLOV is the fourth deep water development of the prolific Block 17 of Angola, with water depth ranging from 1,100 to 1,400 metres. CLOV came on stream in June 2014. It is operated by Total (40%) in partnership with Statoil (23.33%), Esso (20%), BP (13.67%) and Sonangol as concessionaire.

The production plateau of 160,000 barrels per day was reached only three months after first oil. This is contributing to block production, now up to 700,000 barrels per day and reaching 2 billion barrels produced in May 2015, confirming this as the most important production site for the Total Group.

As with its block 17 forerunners (Girassol, Dalia and Pazflor), CLOV is a mega project with major challenges. The four development areas (DA) are spread out over 29 by 25 kilometres (three times as long and twice as wide as Paris). Two oil types are produced simultaneously, from two separate reservoirs (Oligocene and Miocene) with differing temperatures, pressures and viscosities, all impacting flow characteristics. To compensate for this, subsea multiphase pumping was chosen to boost oil recovery as the reservoir pressures decrease. Summarizing, the CLOV concept is of a large integrated subsea production system, and an all electric FPSO with full gas export to liquefaction plant onshore thus enabling “Zero flaring” under normal operations.

CLOV fulfilled its promise of achieving project delivery inside 47 months as planned, and within the 8.4B$ budget (to First oil). CLOV has also laid a roadmap going forward with new milestone achievements in terms of local fabrication and assembly, and strengthening the sustainable partnership between Angola and Total. Lastly, CLOV paid close attention to safety with a strong presence of HSE teams and ongoing training to give CLOV a noteworthy safety performance (zero fatalities and 9 LTIs for 33 million man-hours).
PROJECT ELEMENTS

CLOV is the acronym of the four Development Areas (D-A), Cravo, Lirio, Orquidea and Violeta located in the northwest of Block 17 with water depths ranging from 1,100 to 1,400 metres. CLOV is a standalone development comprising 34 subsea wells (19 producers and 15 water injectors), 8 manifolds and a multiphase pump system, a 180 kilometer subsea pipe and riser network and at the surface, a Floating Production Storage and Offloading (FPSO) vessel associated with an Offloading Terminal.

A story begun in 1998

The first discoveries were Lirio in 1998 and Cravo in 1999, both promising Turbidite Oligocene reservoirs. Quickly, subsurface studies and reservoir models indicated larger than initially estimated reserves. Then Orquidea and Violeta (Miocene and Oligocene reservoirs) were discovered in 1999 and 2001 respectively. At this stage, the concept was of a hub based on Cravo-Lirio and future tie-back development of the two latter discoveries. Continuous efforts and drilling of exploration and appraisal wells on Orquidea and Violeta confirmed the combined reserves of 505 million barrels, justifying the CLOV standalone development chosen in 2007.

In 2008, the economic turmoil and the large increase of development costs led the Total team to pursue a strategy of cost saving: full gas export to the planned onshore liquefaction plant and a single production ring on Cravo-Lirio to replace the initial dual line. Basic engineering began at the end of 2008 along with the call for tenders’ process. Once again to contain cost, the contractual process included innovative strategies with a package breakdown to encourage competition between contractors. In July 2010, main contracts had been awarded and the execution phase began.

Major challenges for a project built worldwide

Turbidite Oligocene and Miocene reservoirs represent 381 km² of cumulative area. They present different characteristics of pressure and temperature and two oil types. The permeability of the unconsolidated Oligocene reservoirs is good (about 1 Darcy). They present good quality oil. Miocene reservoirs are less consolidated than Oligocene. They are in channel form and required producer and injector wells to optimize production. Moreover, the lack of vertical connectivity involves the use of selective completions. Miocene oil is more viscous and slower to “lift” from the seabed which led the project to install a Multi-phase pump system.

With a drilling campaign of more than 2,500 days, the wells team will have handled 34 wells of which 32 are horizontal and 2 deviated. While most of the wells on CLOV require light architecture (a standard for Block 17), 9 still need a heavy casing program. In addition, 12 out of 19 producers and all injectors have stand-alone screens (natural sand packing) and 7 producers include open-hole gravel packing (artificial packing) to control sand production. Lastly 7 wells have selective completions to improve production and gas management, particularly on the Lirio D-A because of a large gas cap. On Lirio there is water, then an oil layer about 100 metres thick, and then a major gas cap above it. Gas is more mobile than oil, so when a reservoir is produced, the gas gets to the well quicker than the oil. This means there are gas surges or breakthroughs, and an increasing proportion of gas coming up the well. If not controlled, the gas production could cause flow assurance problems. The solution is to control the amount of gas being produced, without compromising the recovery of oil. CLOV’s answer is selective completions, controlled from the FPSO, this allows Field Operations to select the layer or combination of layers traversed by the well that they want to produce from.

This mega project was built from four continents and required 33 millions man-hours to achieve first oil. At peak activity, more than five thousand people were mobilized between Total and its contractors. The management team was permanently on contractor sites to supervise construction and installation, to ensure the application of high Quality standards required by the Total Group and to promote a Safety culture. Safety on site was a daily priority on CLOV and the project benefitted with a good safety record.
Managing a project of such magnitude and to deliver it on time with reliable equipment as well as a good safety performance requires communication and positive cooperation between key stakeholders. Three months after first oil, the production plateau was reached, and following final commissioning of the gas compressors, routine flaring was stopped at the beginning of 2015.
PROJECT IMPACT

Total is the leading oil operator in the country and the contribution of CLOV through Block 17 strengthens Angola’s position as one of the top two oil producers in Africa along with Nigeria. With a 60 year presence in Angola, and a long history of local involvement the Angolan affiliate has developed decade by decade a local recruitment rate of 73%. 9,000 Angolans work on sites operated by Total, and Total’s presence is an important boost for local industry.

CLOV, a path forward

At early stages of the project, local content was integrated into the contractual strategy and was an important criterion in the bid analysis to select contractors. In terms of man-hours, 10 million (excluding drilling) were achieved in-country i.e three times more than the previous project. The fabrication and assembly executed in Angola represented 64,000 tonnes of material and drove local yards to undertake important upgrades in order to meet the CLOV requirements. Local Content for CLOV represented 25% of the entire project budget.

Five Angolan yards were used. Sonamet yard along with Angoflex located in Lobito (500 kilometres South of Luanda) were responsible of 50% of the subsea network and a part of the buoy (production and water injection flowlines, spools and jumpers, 3 Hybrid Riser Towers, a gas export line, 80 kilometres of umbilicals…) and a large part of the buoy. Seven out of eight manifolds were also fabricated at Sonamet. Even though Sonamet was the most experienced yard and also the one with the largest industrial capacity, upgrades were required such as the reconditioning of two assembly lines, the building of a new white room or the construction of a new crane. In Angoflex, the metamorphosis was also impressive as the fabrication yard area was extended from 17,000 to 53,000 square metres. The Helix machine capacity was doubled and two production and storage carousels were built. On average, 80% of the workforce was Angolan at the yards involved in CLOV.

In Luanda, a large number of the ”christmas trees” were assembled at FKIA yard (12 out 15 water injectors and 5 out 19 producers). At Petromar in Soyo, the Multiphase pumps foundation was manufactured. But the biggest transformation occurred at Paenal ship yard, a small facility located 250 kilometres south of Luanda.

Paenal, a new industrial centre in Angola

In three years, the Paenal ship yard was almost fully transformed. 7,700 tonnes of fabrication and assembly had to be completed with a major challenge: berth the first FPSO in Angola then lift and install a locally fabricated topside module. To accept the 305 metres FPSO arriving from Korea where she was mostly constructed, the quayside had to be extended from 80 to 480 metres, the yard built a crane with a 2,500 tonnes capacity, the biggest in Africa. In addition to these works, several workshops, offices, canteen and a clinic were built. The objective was to be ready for the CLOV FPSO in 2013. November 8th, early in the morning, the first docking operations of a FPSO in an Angolan harbour began and ran perfectly. Both Total and contractor teams were proud to attend this event. Two weeks later, the water treatment module was successfully lifted and installed by Jamba, the brand-new crane.

The CLOV project has brought new perspectives to the surrounding area. The yard needed to hire people coming from the Kwanza Zul region. The yard welding school reopened in 2010 and trained the qualified welders and pipe fitters required for the job. The strategy adopted by CLOV was to create sustainable development for Paenal and allow the Angolan yard to become an important player in Angolan industry offering Topside module fabrication and integration. With CLOV, the yard has reached 2,5 million of man-hours per year capacity and is now able to handle other big projects such N’Goma FPSO. Moreover, the local population has also benefitted from this development with shops, banks, hotels and restaurants opening over the past three years.

The major challenge for the CLOV Local Content was to deliver the equipment on time, within budget and in accordance with Total High HSEQ standards. Supervision by the CLOV management team on site was crucial to meeting project expectations.
Upstream certification for young Angolan Operators

If developing and building new industrial facilities is an important requirement, then education is essential to operate these facilities. In 2011 Total E&P Angola, (CLOV) in association with the French Institute of Petroleum* launched a long-term training program (21 months) for Operators. Young Angolans were recruited to follow this program. It alternated theoretical courses (English, math’s, design, instrumentation...) and practical work onboard FPSO’s to allow familiarization with the processes and the facilities. At the end of the 21 months, 36 trainees graduated with a level 2 diploma, the “Upstream certification” and they were hired by Total to become operators on Block 17 FPSOs. Twelve of them kept on with a specific training on a 3D tool called Immersive Training Simulator (ITS) dedicated to CLOV facilities. The ITS is an innovative tool based on an interactive video game which gives trainees and operators an almost real-life experience of being on offshore facilities and face HSE scenarios to improve safety onboard.

For CLOV, Total was involved once more on ever increasing scale in promoting both human and industrial capabilities in Angola and shared the oil and gas success by actively supporting the transfer of experience and know-how. This is a win-win strategy because the country will maintain its leading role in Africa as well as for Total which will need such skilled resources for the future.

*French Institute of Petroleum (in French: Institut français du pétrole, IFP) is a public research organization in France founded in 1944 as Institute of Oil, Fuels and Lubricants. The Institute is based at Rueil-Malmaison near Paris, and has sites near Lyon and at Pau. As of 2004, it had 1729 employees, a budget of 253 million euros, and was responsible for a post-graduate training centre, IFP School (also known as the École du Pétrole et des Moteurs), and an extensive industrial training program.
USE OF TECHNOLOGIES

Block 17 was one of the first deep offshore blocks to be licensed in Angola. Each previous development; Girassol, Dalia and Pazflor pushed the deep water technological boundaries. With this experience gained, CLOV followed the path of innovation.

Subsea multiphase pumps system

CLOV is Total’s first development to install subsea multiphase pumps at this depth (1,170 metres). The system consists of two helico axial pumps (one as back up) pumping to the FPSO a mixture of viscous fluid coming from low pressure Miocene reservoirs (Orquidea-Violeta) and lighter fluid from Oligocene reservoirs (Orquidea 11 West). In such an environment, the mixture is more difficult to transport to the surface (15 km on the seabed then 1,300 metres up to the surface). The multiphase pumps allow integrating low pressure reservoirs into a high pressure subsea production system. Moreover, the system will minimize production decrease due to falling reservoir pressure. The pumps are designed to handle liquid and gas at the same time, and can operate at different speeds depending on the composition of the fluid. They are customized to the CLOV reservoir conditions (about 40% gas).

Multiphase pumping is a technology which will be beneficial in producing in deep offshore environments and especially brown fields. It will help to lift fluids from very deep water, heavy fluids or fluids coming from wells far from the production unit. In addition, this type of pump helps to maintain a production plateau and improve oil recovery after several years of production when reservoir pressure falls.

Environmental friendly FPSO

CLOV is also the result of a continuous improvement. CLOV is the second all electric FPSO for Total but the first to have extensive Variable Speed Drive implementation to optimize energy efficiency. This innovative concept is based on aero-derivative gas turbo-generators (3+1 of 28 MW each) for power generation associated to Variable Speed electric motors which feed all the large rotating machinery (gas compressors, water injection pumps and multiphase pumps). Operators can vary the frequency of the motors therefore their speed and hence adapt power demand which was previously impossible. Less energy is wasted reducing the environmental footprint. Capital and operating costs are saved and equipment availability due to longer maintenance intervals is improved. Additionally the equipment is deemed more reliable.

Total, as member of the Global Gas Flaring Reduction team, has had a no flaring policy since 2000 and has reduced flaring by 40% between 2005 and 2014 and CLOV is another demonstration with a Zero flaring policy under normal conditions of operations. Unlike conventional systems, there is no pilot flame on CLOV FPSO (close flare system). All the gas produced is either exported to Liquefaction plant onshore in Angola or sent to neighbouring FPSOs for reinjection. A small amount is used to run the power generation gas turbines.
The design of the CLOV surface and subsea facilities had to meet the specificities of the subsurface.

In terms of subsea layout definition, a significant number of interactions between SURF discipline (Subsea Umbilicals Risers and Flowlines), Geosciences specialists and Wells department were necessary in order to determine the optimal manifold and flowline locations on such a widespread development. The final layout represents surface locations of the wells allowing safety of drilling operations by maintaining sufficient clearance from shallow hazards. It allows us to reach appropriate reservoir targets to maximize recovery, and to reduce costs by minimizing flowline and umbilical lengths. This very much cross-functional activity, which is key for the project, requires good communication and a mutual understanding of the constraints between packages.

The subsea layout has also taken into account possible additional developments identified by the Geosciences team such as spare slots on production manifolds and water injection (In Line Tee) as well as spare capacity of the umbilical system and of control systems. This is particularly important in a Deep Offshore Development to integrate the prospective vision of additional resources at design stage as it enables marginal extra costs to allow further optimization of recovery.

Another example is the significantly high 6.5 Msm3/d gas compression capacity which was sized in order to accommodate the high production Gas Oil Ratio expected on Lirio field which holds a sizeable gas cap, likely to encroach towards the oil producers. Reservoir simulations were run in order to predict the magnitude and timing of the rise of Lirio production GOR and size the required gas compression for a sustained oil production plateau.

As the Miocene reservoirs are lower pressure, hold relatively heavier oil and are more prone for early water production, multi phase pumps have been integrated for flow assurance and are expected to boost Miocene production 2 years after first oil and increase the recovery by 4 Mb.

When addressing the subsea development of complex, distinct and widely spread fields, the integration of reservoir, well performance, flow assurance and topside constraints are absolutely essential, especially when the fields are aging (decrease of reservoir pressure, tri-phasic production). Coupled reservoir simulations have been used to orchestrate all those constraints and provide production profiles that allowed the confident sanctioning of the CLOV Project.
HSE

The Health Safety and Environment policy and management had covered all stages of the project, all facilities and of course all men and women involved. The performances achieved on the CLOV Project met the affiliate targets: 9 injuries were recorded while 33 million man-hours were executed. Even if every injury is one injury too many, none of the nine were live-threatening and everyone returned to work without permanent disability.

**Five major HSE Objectives and one credo “Safety first”**

- Ensure no harm comes to people or facilities
- Provide healthy and safe workplaces
- Take a systematic approach to risk reduction at all stages of the project
- Minimize any impact on the environment, particularly harmful emissions and discharge during operations
- Encourage all contractors and sub-contractors to apply similar high standards

Safety is not only the responsibility of the HSE team only but it is a shared concern. However, CLOV faced particular challenges in terms of HSE. There were three Angolan yards with a new workforce and new organization but the collaboration between the Total and contractors’ teams allowed exemplary performances. Moreover, a number of local inspectors working within the HSE team, both in Korea and in Angola, helped with their language skills to communicate effectively and fruitfully.

As an example, DSME completed 17 million man-hours without lost-time injuries both in Korea and in Angola. DSME and CLOV have been recognized by the Total Corporate Executive Committee with a Group Safety Award.

**Keys to success**

Through corporate methodology and experience, the CLOV Project team identified and established essential guidelines and behaviors to meet ambitious HSE objectives.

- Have clear rules and communicate with contractors and qualified personnel in contractor teams
- Construction safety specialists on site to verify compliance then advise and help if necessary
- Provide appropriate training to cover all aspects of the construction (work at height, work on scaffolding, confined space, electrical…)
- Monitor performances and incidents
- Make safety an ongoing dynamic: HSE developed Key Project Indicators for activities such as training, incident/near-missed reporting. CLOV promoted incentives to encourage improvement and team behaviour
- Get everyone involved
- Hazard management as a cornerstone of HSE management (supported by use of feedback both positive and negative from other projects)
PROJECT EXECUTION

2008, tormented by a global economic situation

It was in this climate that CLOV launched the tender process. The project had to face a cost increase and then an economic downturn. To bring prices down, Total chose a contractual strategy which encouraged more competition between contractors. For the FPSO, a Compensated Call For Tender (CCFT) based on design competition among four bidders, was launched to encourage them to look for and propose improvements and innovations. For the subsea network package, the scope of work was broken into smaller packages to reduce exposure of smaller players and encourage more firms to bid.

During the year of tender process, the world economic crisis created oil-price uncertainties. Therefore CLOV managers decided to disconnect technical and commercial bids usually submitted at the same time. This disconnection allowed extending the deadline for the commercial bids and CLOV took advantage of the falling market. In July 2010, the main contracts were awarded and the project execution phase began.

Target: First Oil

To achieve First Oil in the 47 months, CLOV adopted a risk-based approach. The objective was to mitigate any delays by re-sequencing activities or providing different options to meet planning expectations. Information on what happened on site facilitated planners and cost-controllers to anticipate and had helped management in decision-making.

On field, to ensure the quality and the reliability of CLOV equipment, a large team of quality-control inspectors conducted inspections continuously in order to check potential issues as early as possible and push for corrections and solutions immediately. This way, negative consequences on schedule and equipment readiness, such as rework, breakdown or repair, would be minimized.

A successful CLOV story

After one and a half years of production, a plateau reached in three months and a “No routine flaring” policy applied, CLOV is an industrial achievement and more especially a human one. More than the team spirit of the Group project helped to manage concerns and issues which could be faced during a mega project execution. What describes CLOV is the project team cohesion, the good relationship between stakeholders (concessionaire, partners, contractors and sub-contractors) and for people who worked on the project, it was an amazing and unforgettable experience. And CLOV still has 20 more years to go.
ACKNOWLEDGEMENTS

TOTAL would like to thank the concessionaire, SONANGOL, and its partners, Statoil, Esso and BP, for their support throughout the project.

TOTAL also want to thank the project contractors and sub-contractors, especially the Angolan yards for the work they achieved on CLOV and their effort to HSE objectives: mainly DSME and Paenal for FPSO; Subsea 7, Sonamet and Angoflex for the subsea pipeline and riser network; FMC, FKIA and Sonamet for the subsea production system; Framo and Petromar for the multiphase pump system; Bluewater, SBM and again Sonamet for the Oil Loading System, finally Ensco and Seadrill for drilling.
LOCAL CONTENT: CHALLENGES & SUCCESS

François BICHON

IPTC 2015 Doha – CLOV Project Session
60 years presence in Angola, on- and offshore

1/3 of Angolan oil production discovered and operated by TOTAL
- Block 17, the “Golden Block”, 1st producer in Angola (700 kbopd)

Pioneer in Angola’s deep offshore
- 4 large FPSOs: Girassol Dalia, Pazflor, CLOV
- PBF (Project Brown Fields)

TOTAL played major role developing yards in Angola
CLOV LOCAL CONTENT MAIN OBJECTIVES

- Step change in amount of work performed in country
- Coordinate target with Sonangol
- **10 million man-hours** in Angola (3 times > previous project)
- **25% of budget** for local fabrication and assembly
- 50% of Subsea Umbilical Riser and Flowlines package executed locally
- Large extension of Angolan yards
- **1st FPSO berthed** in Angola with **1st topside module integration**
- Nominate **Local Content Coordinator** to compile and follow up actual and potential local resources
- Provide **extra supervision** and **transfer know-how**
- Ensure **Safety on construction site** and promote safety culture
- Attract and support foreign contractors to set up local facilities
MAIN LOCAL FABRICATION AND ASSEMBLY

**Subsea Facilities**

- 5 out 19 Production XT assembled – FKIA, Luanda
- 12 out 15 Water Injection XT assembled – FKIA, Luanda
- Fabrication and assembly of production and water injection lines – Sonamet, Lobito
- Riser Towers fabrication – Sonamet, Lobito
- Gas export line – Sonamet, Lobito
- Fabrication of umbilicals – Angoflex, Lobito

**Surface Facilities**

- FPSO – Paenal, Porto Amboim
  - Fabrication suction anchor piles, riser and mooring protectors
  - Fabrication topside module
  - First topside module integration in Angola
- Oil Loading Terminal – Sonamet, Lobito
- 7 out 8 manifolds, 8 support structures & foundations – Sonamet, Lobito
- Multiphase pumps foundation – Petromar, Soyo
PAENAL, A NEW INDUSTRIAL POLE IN ANGOLA

FPSO, Porto Amboim
- 7,700 tonnes of fabrication and assembly
  - 1st FPSO berthed in Angola
  - 1st module integration
- 1.5 million of man-hours achieved without LTI

Yard upgrades
- Heavy lift crane for topsides module integration (2,500 tonnes)
- Quay extension from 80 to 480 m

Manpower
- Local workforce trained
- Yard capability doubled
SONAMET, THE MOST EXPERIENCED YARD

Subsea facilities and buoy, Lobito
- 23,000 tonnes of fabrication
  > 3 riser towers, piles, spools, jumpers
  > 7 out of 8 manifolds, Oil Loading Terminal
- 26,000 tonnes of assembly
  > Flowlines double jointing and pipe-in-pipe
- 4 million of man-hours achieved

Yard upgrades
- Reconditioning of riser assembly line, upgrade of double-jointing line, new white room

Manpower
- Welding school
- Local workforce up to 84%
CONCLUSION

- A necessity for Operating Companies
- Need careful and precise assessment of actual and potential resources
- Need early and larger involvement of Operator
  - Timely development of facilities
  - Transmission of know-how
  - Implementation of Safety culture
  - Importance of Quality
- Can be done
  - within Safety target
  - within Project Schedule
  - within Budget
The authors would like to thank Sociedade Nacional de Combustíveis de Angola (SONANGOL), Esso Exploration Angola (Block 17) Ltd., BP Exploration (Angola) Ltd., Statoil and Total for permission to present the information contained in this paper.
The TOTAL GROUP is defined as TOTAL S.A. and its affiliates and shall include the party making the presentation.

**Disclaimer**
This presentation may include forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995 with respect to the financial condition, results of operations, business, strategy and plans of Total that are subject to risk factors and uncertainties caused by changes in, without limitation, technological development and innovation, supply sources, legal framework, market conditions, political or economic events. Total does not assume any obligation to update publicly any forward-looking statement, whether as a result of new information, future events or otherwise. Further information on factors which could affect the company's financial results is provided in documents filed by the Group with the French Autorité des Marchés Financiers and the US Securities and Exchange Commission. Accordingly, no reliance may be placed on the accuracy or correctness of any such statements.

**Copyright**
All rights are reserved and all material in this presentation may not be reproduced without the express written permission of the Total Group.