NADAH: New Approach of Design Against Hydrates

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1. Context

Hydrates, solid crystals looking like compact snow, are formed of water and gas at high pressure and low temperature (Figure 1). These conditions are usually encountered during shutdowns and restart operations in deepwater environment.

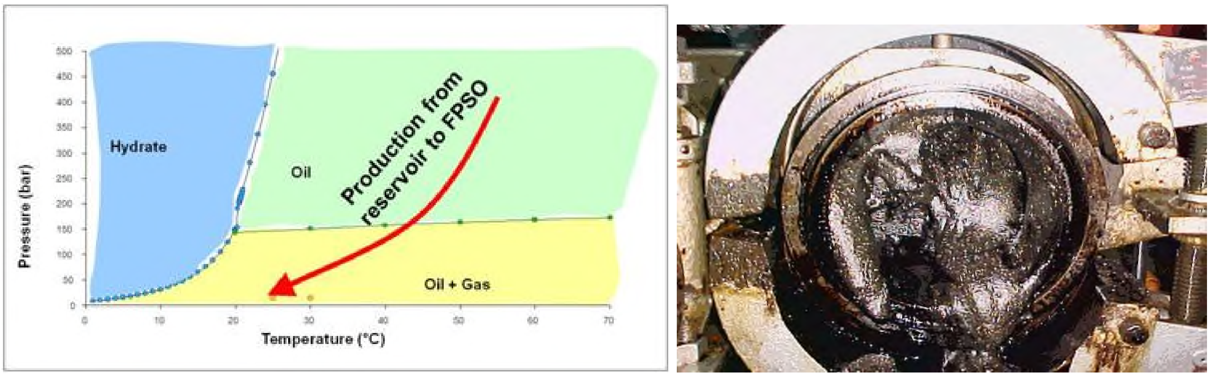

Figure 1 - Hydrates risks area & picture of a hydrates oil slurry recovered in pig trap

Considering the production shortfalls and the cost of offshore remediation means, line plugging due to hydrates formation is an undesirable outcome which must be avoided. One of the main constraints in deepwater development is therefore the management of hydrates in the production flowlines.

Current design approach of thermal insulation of deepwater field developments consists in staying free from hydrates region whatever the operations performed on site (restart, preservation, Etc.). Typical hydrate management philosophy for offshore oil fields can be summarized as follows:

- No continuous inhibition of the subsea system required in flowing conditions,
- No part of the fluid system is allowed to enter the hydrate risk zone during normal and shutdown conditions, including preservation sequence (Figure 2),
- During startup, the cold production fluid is inhibited at the wellhead (with methanol or glycols) until the production temperature reaches a temperature high enough to ensure sufficient cool-down time if another shutdown occurs.

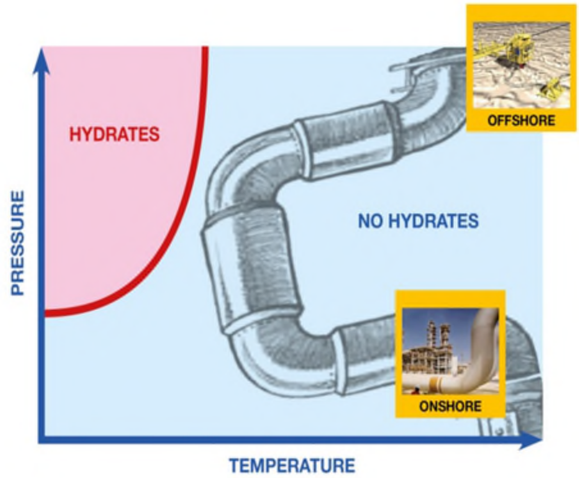

Figure 2 – Current design approach against hydrates – Stay free from hydrates thermodynamic region

The hydrate management for Deep Offshore oil dominated fields is typically based on adequate thermal insulation of the subsea network that guarantees sufficient steady state temperatures and provides acceptable cool-down duration to complete the preservation of the system after a shutdown. The figure 3 shows a typical preservation sequence,

1	2	3	4	5	6	7	8	9	10	11	12	13	14
No touch time				Depressurisation				Dead oil circulation					Margin
				MeOH injection									

Figure 3 – Typical preservation sequence for Deep offshore oil dominated fields (Timeline in hours)

To meet above design basis, very stringent thermal insulations have been implemented on our existing assets and thus having significant impact on the subsea CAPEX. Such design philosophy also imposes the implementation of “complex” operating procedures (dead oil circulation, hot oiling circulation, Etc.) as presented on figure above, therefore impacting OPEX and shortfalls.

2. Nature of this innovative design approach

Based on the improvement on our internal know-how on hydrates, it is now admitted that some crudes present interesting capabilities in delaying hydrates formation, in other words hydrates crystals will not form instantaneously and massively as soon as Pressure & Temperature conditions reach hydrates thermodynamic region. Such properties are named “induction” properties. As an example, Dalia crude offers an induction time of 72 hours for a subcooling (delta temperature compared to Hydrates Dissociation Temperature) of 6.5°C against Hydrates Dissociation curve.

The proposed innovative design approach therefore relies on the state of the art in hydrates physico-chemistry. The principle is basically to take into account the natural properties of the crudes in delaying hydrates formation when designing new installation, with the main objectives of unlocking reserves and projects.

This new approach also allows optimizing the operations of our existing assets.

Practically, it consists in operating the production line within the hydrates **thermodynamic** region but outside of the hydrates **formation** region (Figure 4).

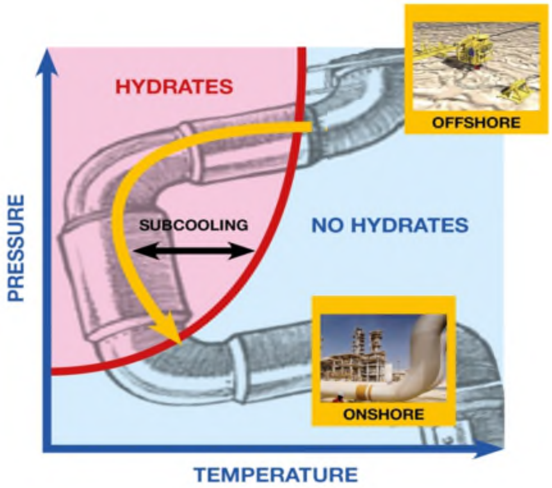

Figure 4 – Innovative design approach against hydrates – Operations inside hydrates thermodynamic region but outside hydrates forming conditions

Main expected benefits are:

- For future assets to
  - Avoid having too stringent thermal insulation specifications, which leads to significant CAPEX savings,
  - Minimize subsea equipments (CAPEX savings) with low degree of complexity (faster development),
- For existing assets (e.g. Block 17) to already simplify the operations on site by extending the No Touch Time period before any preservation operation is launched. This optimization participates in saving OPEX and reducing production shortfalls,

3. Methodology to evaluate the natural crude properties vs. hydrates

a. Introduction to hydrate formation

Hydrates do form at the interfaces between gas & water but much more predominantly at the interface between oil & water.

The presence of crude is a key element because it contains lots of dissolved gas (while the solubility of gas in water is very weak). The more crude is present, the more hydrates can possibly form; nevertheless hydrates may be more easily transported by the crude. The viscosity of the slurry is then a key element to get a plug.

When only gas and water are present in dynamic conditions, although a very short delay in hydrate formation is expected, the hydrate formation rate will remain very weak: consequently, it will take much more time to build a hydrate plug.

b. The Hydrate Induction Time method

Total has in the last decades been intensively involved in R&D on hydrates, both working in our own laboratories in CSTJF with notably the DSO/IP/EXP/PPF/TFA cells Pilots (Figure 5) and through JIPs with Herriott Watt (Edinburgh, UK) and in collaboration with other companies like STATOIL with main objectives to characterize the kinetics of hydrates formation. One of the main outcomes has been to map hydrate formation P&T zone depending on the induction time (Hydrate Induction Time of Crudes or HITC methodology) for various fluids with and without hydrate inhibitor use. For instance, a Rapid Growth Region (RGR) has been highlighted but also on the contrary P&T zones where hydrates formation can take several days!

Figure 5 – (Left): Schematic representation of one “hydrates cell” used to study hydrates up to 200 bara and which can work at either isochoric or isobaric conditions. (Right): photograph of the 4 cells set

Typical results of “hydrate mapping” obtained with this HITC methodology are illustrated in the figure 6.

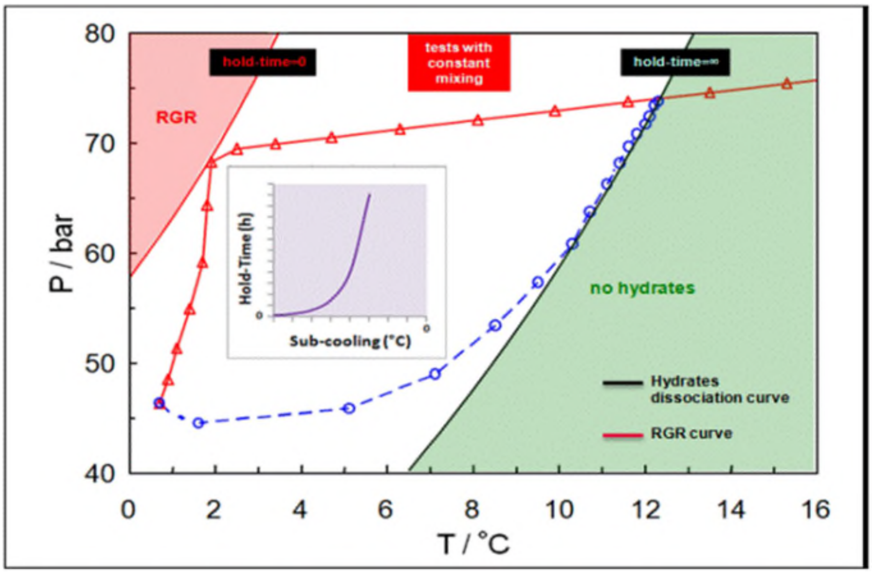

Figure 6 – Principles of HITC observed under constant mixing condition (RGR=Rapid Growth Region)

Every point in the green zone is outside the hydrate thermodynamics region. The red zone is the RGR. The white zone, located between the red and green zones is a region where hydrates will form after a given hold-time going from zero (on the red curve) up to infinity on the black curve (dissociation curve). Hold-time is presenting an exponential trend from the red curve (hold-time=0) up to the black curve (hold-time →∞). It is then possible to draw a curve corresponding to a given hold-time.

All of these hold-time curves are obtained experimentally using a constant high mixing (dynamic conditions after restart) of the present phases (gas, crude, water) to trigger hydrate formation.

It must be strengthened that there is no direct relation between the RGR and the risk of actually plugging the production lines with hydrates. Indeed plugging depends on the quantity of hydrates which is not considered at this stage and actually depends on the water content. Finally, the hydrates transportability has to be assessed as the crude may have the ability to transport them.

4. Plugging risk evaluation tool

In the frame of this innovative design approach, a dedicated Excel tool has been developed to evaluate the hydrates formation risks related to these innovative design and operations philosophies and to support the decision to relax the thermal insulation specifications. Practically, pressure and temperature conditions in the production network are compared to the Hydrates Dissociation curve and crude induction properties.

The principle of the method consists in filtering the results of multiphase flow software (Figure 7) such that even if the temperature observed during the production restart would trigger that the production line is within the hydrates thermodynamic region at some locations, the hydrates risk is deemed nil as long as the hydrates forming components (gas and water) are not present simultaneously or the exposure time to hydrates thermodynamic conditions is lower than hold-time of the crude for the associated subcooling (Delta Temperature compared to Hydrates dissociation temperature - DTHYD).

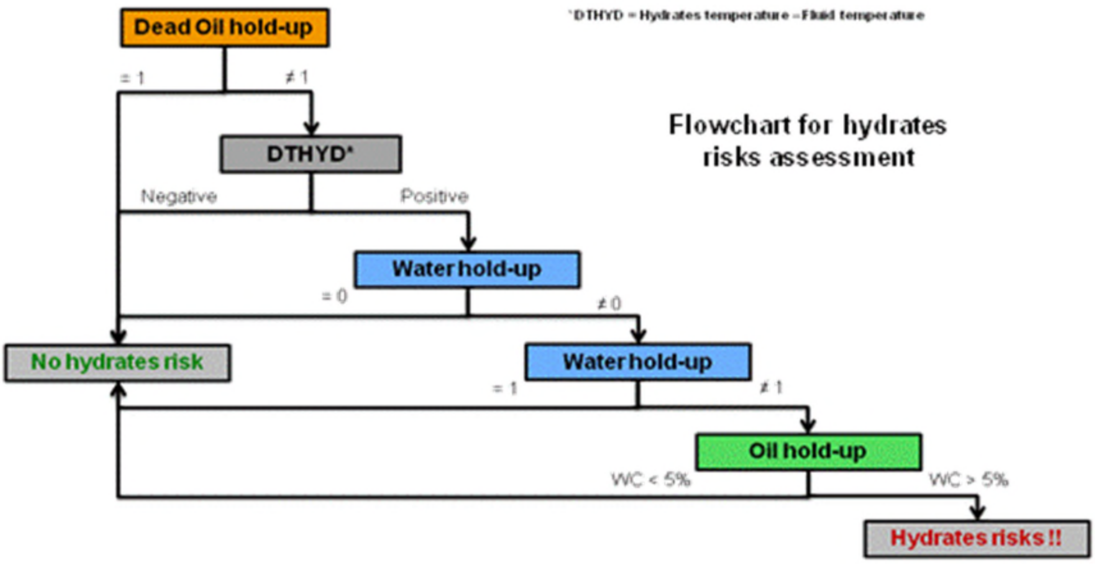

Figure 7 – Filtering method for the hydrates risks analysis

This advanced post-treatment of the key variables of multiphase flow software is performed at all location along the flowline for each time steps of the dynamic simulations. The in-house tool computes hydrates risks evaluation taking into account induction properties for all transient operations occurring in fields (i.e. preservation, restart, Do Nothing period).

Main results provided by the numerical tool are:

- Number of sections of the line exposed to hydrates risks (RGR, No oil meaning no induction time, Etc.) – Figure 8,

- Relevant information (Liquid Hold-Up, P, T) for advanced hydrate risks analysis (formed quantity, transportability, Etc.) – Figure 10,
- Dynamic overview of the hydrates risks and operating conditions in the production network with time – Figure 9.

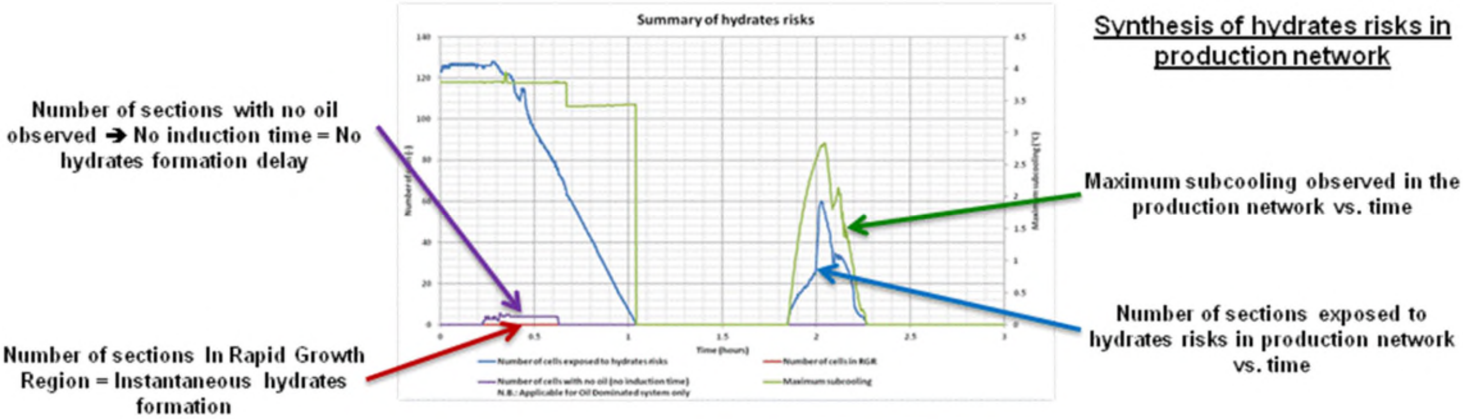

Figure 8 – Synthesis of the hydrates risks

The figures 9 and 10 show an example of a flowline production resume after a long duration shutdown. Inlet temperature rapidly increases above hydrate formation conditions while locations close to the outlet still remain in hydrate formation zone 2 hours after the restart.

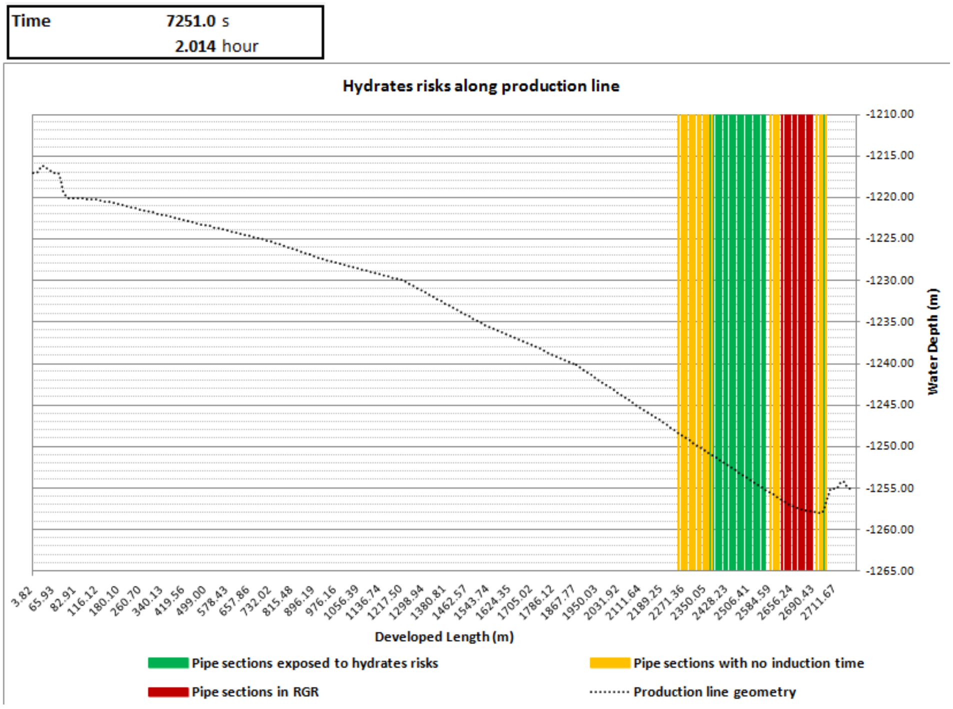

Figure 9 – Position of the sections in the production line potentially exposed to hydrates risks 2 hours after start-up – Not representative of real case

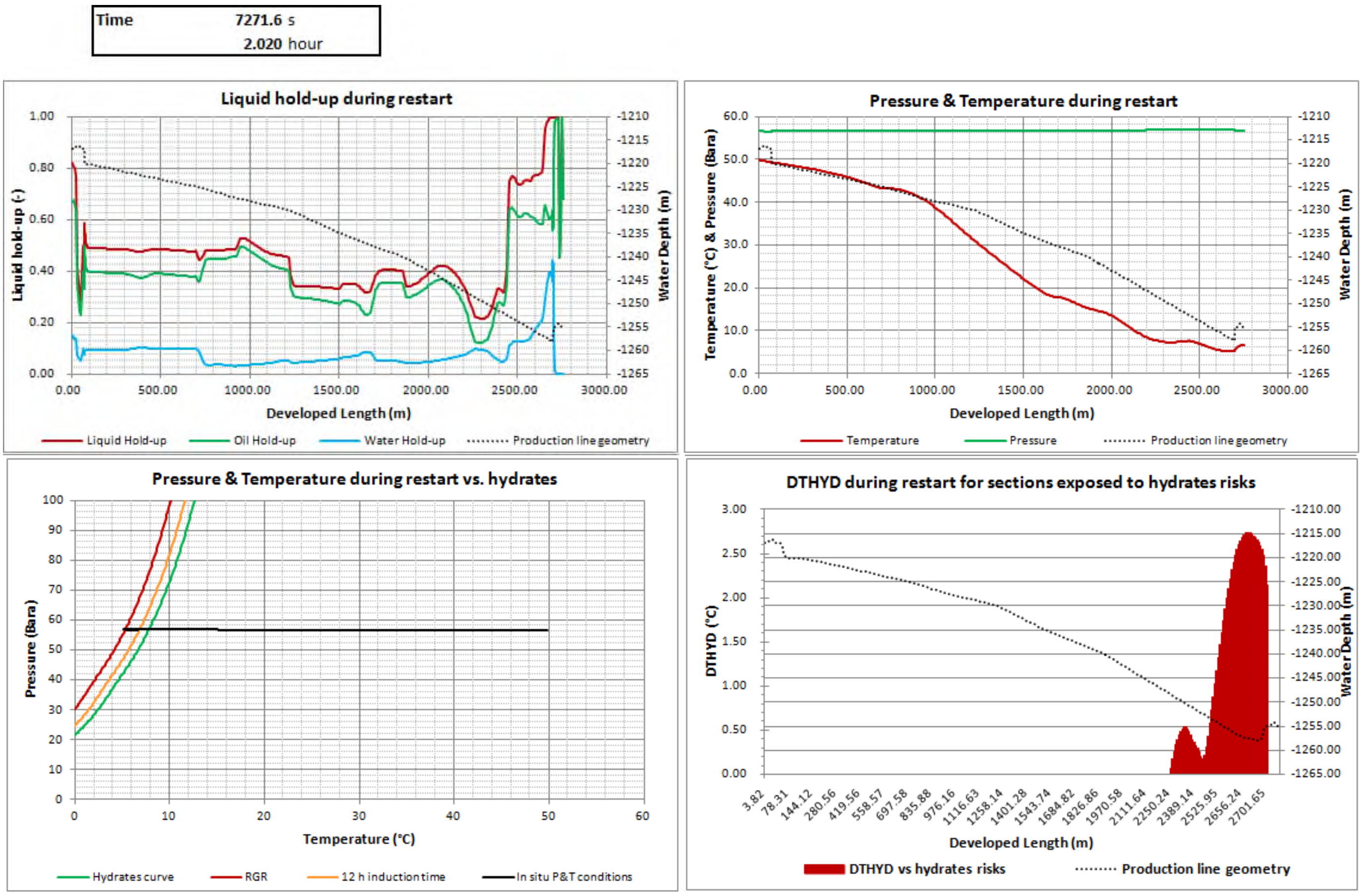

Figure 10 – Overview of flowing conditions in production line 2 hours after start-up – Not representative of a real case

5. Dalia Phase 3 – First application of this breakthrough in design phase

Dalia Phase 3 is a Brownfield project (currently in the FEED phase) on Block 17 Dalia asset (1300 m Water Depth). It consists in developing the Camelia North reservoir. After identification by Total E&P Angola of new reservoir targets and the impossibility to locate their wellheads within standard offset to existing drilling center due to the excessive step out required to reach reservoir target, an innovative subsea scheme has been proposed, taking on board the induction properties of Dalia crudes.

This subsea scheme consists in installing a 3 km single insulated production line to connect new drilling center to an existing manifold (Figure 11).

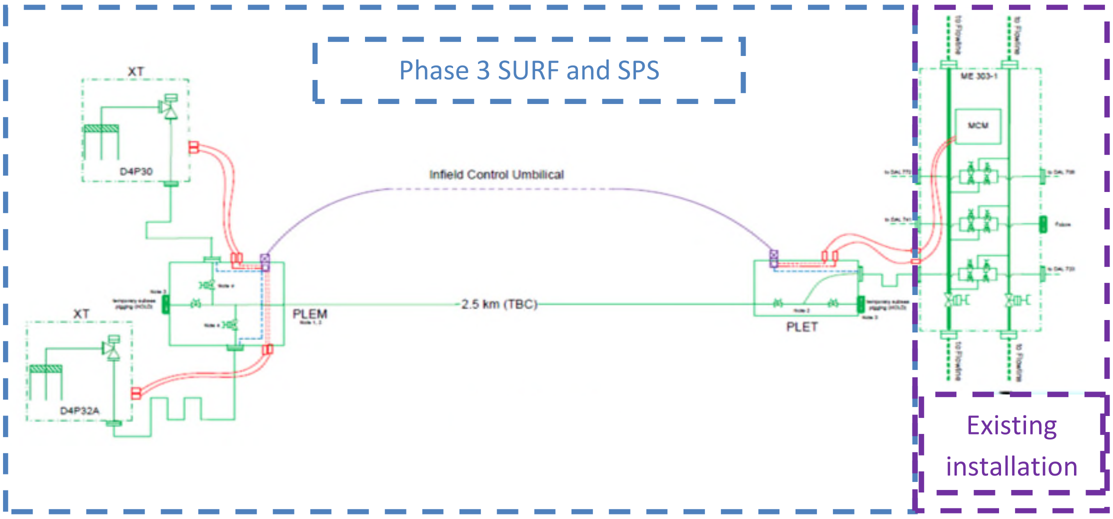

Figure 11 – Subsea Tie-in principle for Dalia Phase 3

In case of a production shutdown, and whatever the duration, a "Do Nothing Approach" will be applied to this long tie-in line and the hydrates risk mitigation will rely only on:

- The long hydrates induction capability of the Dalia crude (3 days for a 6.5°C subcooling),
- The downward bathymetry of the line from the new wells to the existing manifold (Figure 12). The objective is to take advantage of the liquid segregation naturally induced by gravity and leading to formation of an oil buffer layer between gas and water phases (Figure 13).

Indeed, during restart operations, the cold water will be progressively pushed into the hot main production flowline in a piston mode effect thus preventing mixing with cold gas.

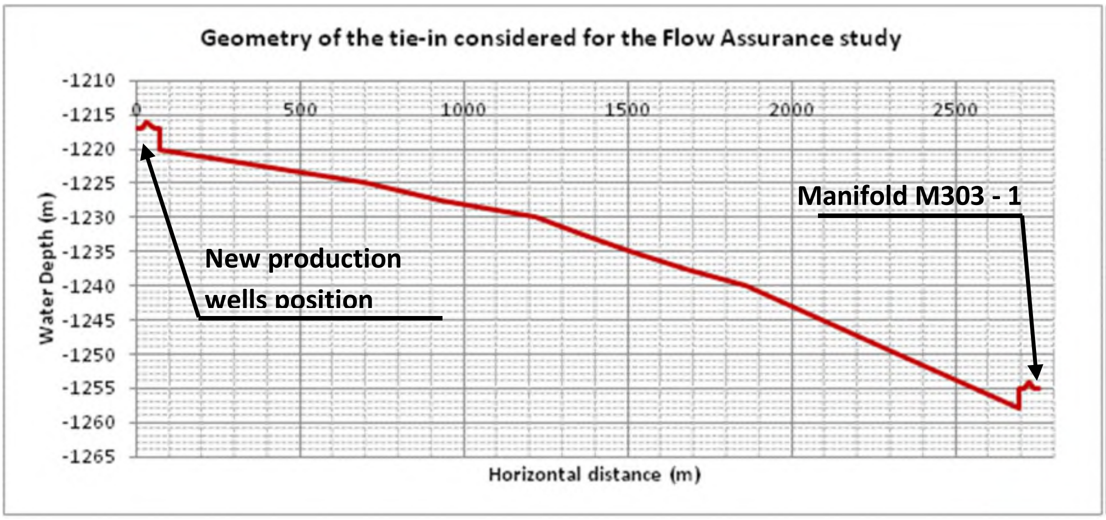

Figure 12 – Tie-in bathymetry

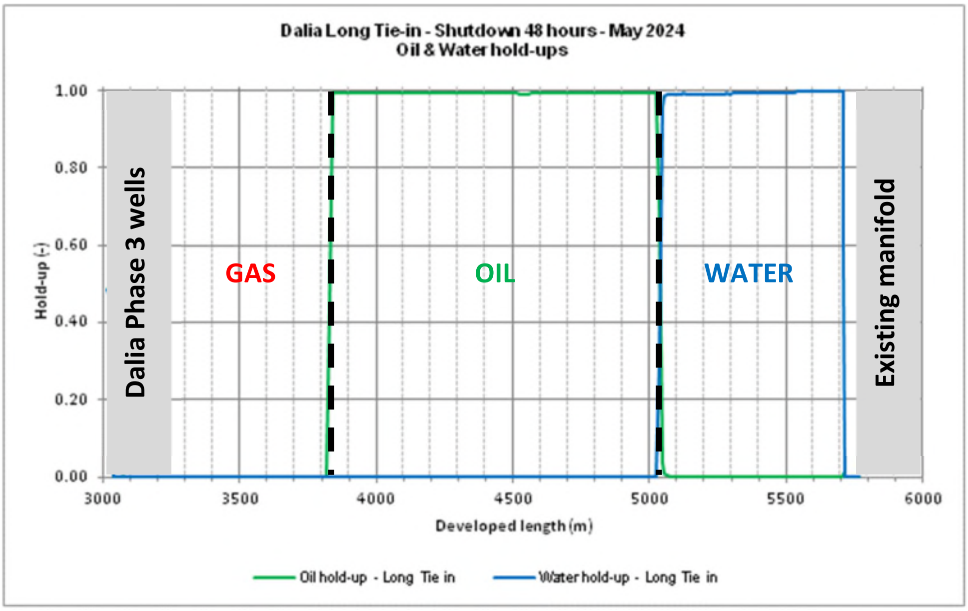

Figure 13 – Benefits of the downward bathymetry on fluid segregation and hydrates mitigation

Hence, the hydrate risks will be negligible as long as the tie-in line presents a downward bathymetry (maximum 2.5°C subcooling during 1 hour) – Figure 14.

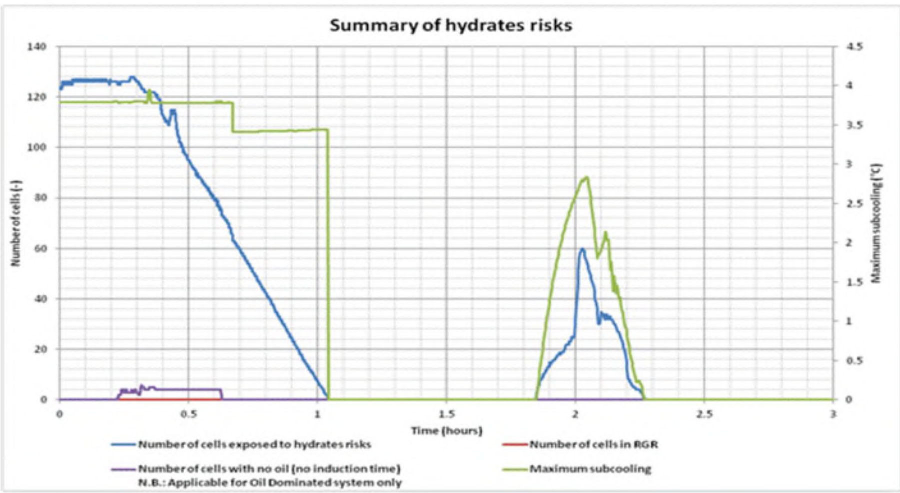

Figure 14 – Hydrates risks during a cold restart on Dalia Phase 3

6. Conclusion

The ***N**ew **A**pproach of **D**esign **A**gainst **H**ydrates* consists in an audacious change in the design and operating philosophy of our subsea facilities authorizing mastered incursions of the production fluid pressure and temperature couple in the hydrates thermodynamic region.

This has been made possible thanks to the development of our internal know-how on hydrates using our laboratory facilities, the development of specific hydrate risk evaluation tool and a collaborative spirit between affiliates and HQ specialists.

This breakthrough innovation is only supported by TOTAL, which alone is mastering the design and operational constraints associated to operations in Flow Assurance issues window.

Many future projects (Preowei, Begonia, Etc.), not only limited to Deepwater, could rely on this new hydrates management strategy. By reducing CAPEX, this approach will allow the development of new resources.

Dalia Phase 3 is a good illustration of the savings brought by this new open minded design approach. The proposed long tie-in architecture allowed reducing significantly the subsea and topsides scopes compared to conventional approach (almost 50% CAPEX savings on Flowline scope), making the project profitable and, for TOTAL, the first deepwater single production line where no preservation is implemented at shut-down and taking full advantages of Dalia crude induction properties.

A preliminary Dalia revisited cost exercise also highlighted that changing Pipe-In-Pipe to wet insulation allows saving about 200 – 250 M$.

As an additional result, this new and innovative approach also allows simplifying the operations on sites, by extending the No Touch Time Period and delaying the Dead Oil circulation phase with significant OPEX savings and shortfalls reduction on top. Thanks to this new hydrate management strategy, most of the SIMOPS that impose a shutdown of the production can now be achieved without preserving the line, which represents 10,000 – 25,000 barrel of oil saving per shutdown.