GATE KEEPER
A Technical Newsletter for the Oil & Gas Industry
JUNE 2018

Top of Line Corrosion Part 2: Risk Assessment & Mitigation

In the last GATEKEEPER, we determined the top of line corrosion (TOLC) rate along with the top of line water condensation rate. Now its time to assess the TOLC risk and the corresponding locations in the system where TOLC may occur. From there we can determine the appropriate mitigation and control strategies.

There are two main approaches for assessing critical variables for TOLC:

- Heuristic Approach (Rule of Thumb)
- System Component Analysis

Heuristic Approach (Rule of Thumb)

The heuristic approach involves using simplistic determinations of TOLC risk, such as the use of the bottom of line corrosion (BOLC) rates to indirectly assess the TOLC. Although they can provide a simple vetting assessment in the early stages of a project, these simplistic approaches produce misleading results and therefore do not give the complete picture of the risks. This can lead to faulty and costly decisions.

System Component Analysis

System Component Analysis (SCA) is a holistic approach analyzing the impact of individual components in the performance of the production system as a whole. The SCA is based on the risk analysis of every component and the impact it has on the downstream conditions. It is useful in determining the optimum mitigation strategy for TOLC for a given situation.

The advantage of the SCA methodology is that it accounts for all changes in the system and considers the locations of the components that will affect the performance of the system in the long term. SCA is suitable for complex systems that would otherwise be difficult to analyze. Figure 1 shows a risk assessment flowchart for the SCA approach.

System Component Analysis Approach

SCA involves the following list of steps:

1. Study the critical parameters which have major influences on the TOLC risk
2. Build a simulation model of the entire field, breaking the system into nodes
3. Evaluate the node for critical parameters
4. Repeat the process for each node

Once we have studied the critical parameters which have major influences on the TOLC risk, we can then build a simulation model of the entire field and logically divide the well and flowline network into nodes wherein each node has a tie-in point to the next node. For example, a typical node would encompass the well or set of wells and this will tie-in to the next node, be it a manifold or PLET. An example of such a system is provided in Figure 2.

Thermo-hydraulic analysis of the overall simulation model should be followed by the evaluation of the critical parameters for each of the logical nodes. The critical parameters include the pressure and temperature drop along the flowlines, the top of the line water condensation rate, the pH and partial pressure of CO_2 of the production flow, the liquid hold-up and the flow regime in each of the flowlines and the trunk lines. The results from the thermo-hydraulic simulations should also include the top of the line corrosion rate based on the IFE model.

Sensitivity studies will need to be performed to re-evaluate the temperature, top of the line water condensation rate and the corrosion rates for different sets of insulation thicknesses, line burial conditions, CO_2 content, well arrangements and line diameters. The results of the thermal-hydraulic studies and the sensitivity studies should be used to recommend the optimum well arrangement, line diameters, required insulation and burial conditions for the trunk line in the first node to make sure the top of the line water condensation rates and TOLC rates are within the manageable limits as the produced flow approaches the next node where the second well or set of wells tie-in.

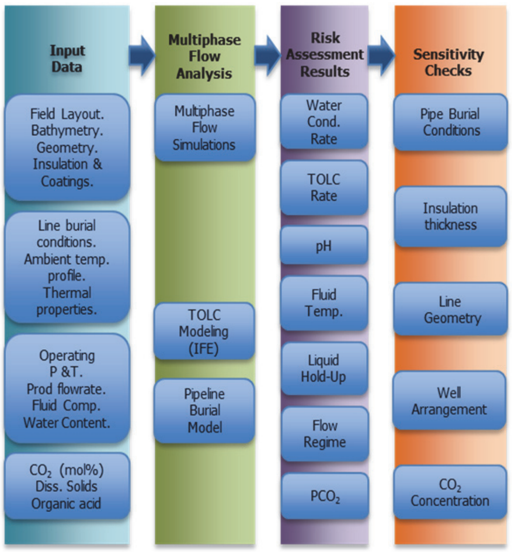

Figure 1: TOLC Risk Assessment Flowchart for the SCA Method

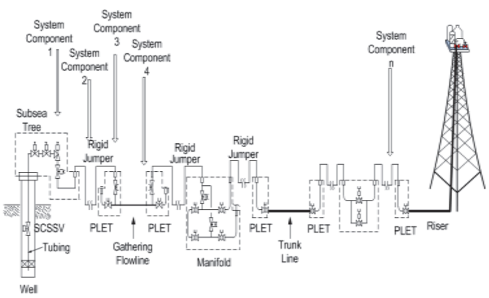

Figure 2: Field Layout Example

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GAT2004-GKP-2018.06

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The parameter evaluation and recommendation process followed for the first node will then need to be repeated for each of the subsequent nodes to complete the evaluation of the TOLC risk for the overall system and determine the strategy to mitigate the TOLC risk, as shown in Figure 3.

The results of the thermo-hydraulic studies and the sensitivity studies should be used to recommend the optimum well arrangement and field layout.

TOLC Mitigation Options Selection

Several mitigation options exist in order to control and minimize the risk of TOLC in subsea systems. Regardless of the mitigation option chosen, all options will have a certain degree of CAPEX impact on the project.

The goal is to design a system that is robust enough to handle the varying operating conditions and fluid compositions throughout the design life of the field, while trying to minimize the additional cost both from a CAPEX and OPEX perspective. Of these, the most common mitigations options are:

- Change of Metallurgy from Regular Carbon Steel to Corrosion Resistant Alloy (CRA) (Cladding)
- Addition of Insulation to Various Subsea Components
- Batch Treatment with Corrosion Inhibitors
- Subsea Field Layout Design Optimization
- Well Surface Location
- pH Control and Vapor Phase Corrosion Inhibitors
- Increase Wall Thickness for Corrosion Allowance Augmentation

Changes to Subsea Field Layout

Changes to the subsea field layout during the concept selection phase help identify and eliminate the spots prone to TOLC.

Increasing the Wall Thickness

The pipeline wall thickness can be increased to account for the TOLC rate over the life of the field. However, this method only suits those systems with very low TOLC rates.

Pigging

In export lines or looped flowline systems, TOLC can be mitigated by regular pigging and batch corrosion inhibitor treatment in addition to the continuous corrosion inhibitor injection used for BOLC mitigation.

Pipeline Cladding

For single flowline systems and systems with no provision for pigging, the only other viable option is to use CRA in those areas where water condensation occurs at a significant rate. In such cases it is common for CRA cladding to only be provided at the upstream end of the system where temperatures and condensation rates are highest.

Insulation

In pipelines where the top of line water condensation rates are high and localized, it is possible to minimize top of line water condensation rate and extend the length of the pipeline in which top of line condensation occurs by insulating or burying the pipeline. By controlling the heat transfer rate, top of line water condensation rate and TOLC rate can be controlled.

pH Control

The strategy to control pH and support the growth of an iron carbonate layer in sweet gas systems has been used effectively. However, the strategy is not suitable for systems with significant formation water production due to associated scaling risks.

Vapor Phase Corrosion Inhibitors

Application of vapor phase corrosion inhibitors for TOLC control is an emerging technology, with limited published field experience. As a result, it is still considered a higher risk control option in most instances.

Surveillance

In addition, there are surveillance options to ensure a system is meeting the design intent. These include:

- Intelligent Pigging and Inline Inspections (ILI)
- Continuous Corrosion Monitoring using In-line Piggable Corrosion Monitors
- Intermittent Corrosion Evaluation using External Non-Destructive Testing (requires vessel)

Pigging the system periodically using intelligent pigs (ILI), using inline piggable corrosion monitors and intermittent corrosion evaluation using a vessel would help in identifying the TOLC risk in advance and adopt a suitable mitigation strategy.

Conclusion

Assessing the subsea field layout during the concept selection phase can help identify and eliminate the spots prone to TOLC and decrease the need for mitigation in the future, leading to lower OPEX costs in the future.

It is clear that using heuristic methods, such as the BOLC assessment, will typically yield ultra-conservative results which can lead to unrealistic and more costly subsea designs. These designs may also impact another segment of the system that may actually in consequence be more susceptible to TOLC due to the excessively conservative upstream design.

Use of the System Component Analysis Method is strongly recommended. It allows engineers to take into account the entire system as a whole and ensure that there are no issues with TOLC for the design life of the system using the correct mitigation strategy. This will ultimately serve to minimize development costs from both a CAPEX and OPEX perspective.

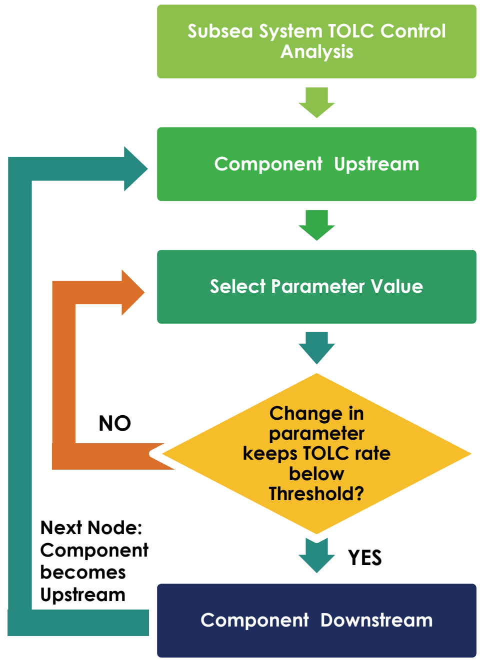

Figure 3: Nodal Analysis Flowchart of Critical Parameters with SCA Method