A Gap Analysis for Subsea Control and Safety Philosophies on the Norwegian Continental Shelf

05.10.2016
HyungJu Kim
Mary Ann Lundteigen
Christian Holden
hyung-ju.kim@ntnu.no
Contents

1. Introduction
2. Background Knowledge
3. Presentation of Gaps
   1) Standards and Regulations
   2) Status and Gaps
4. Results and Discussion
1. Introduction
1. Introduction

• Some subsea control and safety requirements are based on topside systems
• This may result in overly complex and costly design solutions
• Tailor-made solutions for subsea control and safety need to be developed
• The first step is to investigate current status and identify gaps
2. Background Knowledge
## 2. Background Knowledge

### 2.1 Hazard, Hazardous Event, Consequence

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Hazardous event</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>External hazard</td>
<td>Topside blowout</td>
<td>Injury/fatality</td>
</tr>
<tr>
<td>Long-term hazard</td>
<td>Unintended hydrocarbon release</td>
<td>Large oil/gas spill to environment</td>
</tr>
<tr>
<td>Inherent hazard</td>
<td>Operations outside normal conditions</td>
<td>Subsea processing equipment damage</td>
</tr>
</tbody>
</table>
2. Background Knowledge

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Hazardous event</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>External hazard</td>
<td>Topside blowout</td>
<td>Injury/fatality</td>
</tr>
<tr>
<td></td>
<td>H.C. leak at riser</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H.C. leak at pipelines (safety zone)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H.C. leak at pipelines (to riser)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H.C. leak at processing facilities</td>
<td></td>
</tr>
<tr>
<td>Long-term hazard</td>
<td>H.C. leak at pipelines (to processing)</td>
<td>Large oil/gas spill to environment</td>
</tr>
<tr>
<td></td>
<td>H.C. leak at manifold</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H.C. leak at pipelines (to manifold)</td>
<td></td>
</tr>
<tr>
<td>Inherent hazard</td>
<td>H.C. leak at wellhead/ Xmas tree</td>
<td>Subsea processing equipment damage</td>
</tr>
<tr>
<td></td>
<td>Operations outside normal conditions</td>
<td></td>
</tr>
</tbody>
</table>
2. Background Knowledge

2.2 Subsea Hazardous Events

1) Human

- **Subsea Wellhead and Xmas Tree**
- **Manifold**
- **Subsea Processing**
- **Riser**
- **Safety Zone**

**Hydrocarbon leak**
- Topside blowout
- H.C. leak at riser
- H.C. leak at pipelines (safety zone)
2. Background Knowledge

2.2 Subsea Hazardous Events

2) Environment

- H.C. leak at wellhead/Xmas tree
- H.C. leak at pipelines (to manifold)
- H.C. leak at manifold
- H.C. leak at pipelines (to processing)
- H.C. leak at pipelines (to riser)
- H.C. leak at processing facilities

Hydrocarbon leak

Subsea Wellhead and Xmas Tree

Manifold

Subsea Processing

Riser

Safety Zone

Receiving Facility
2. Background Knowledge

2.2 Subsea Hazardous Events

3) Asset

Operations outside normal conditions
2. Background Knowledge

2.2 Subsea Hazardous Events

- H.C. leak at wellhead/Xmas tree
- H.C. leak at pipelines (to manifold)
- H.C. leak at manifold
- H.C. leak at pipelines (to processing)
- H.C. leak at pipelines (to riser)
- H.C. leak at riser
- Operations outside normal conditions
- H.C. leak at processing facilities
- Receiving Facility
- Riser
- Safety Zone
- Personnel
- Environment
- Asset
2. Background Knowledge

2.3 Subsea Safety System
2. Background Knowledge

2.3 Subsea Safety System

- H.C. leak at wellhead/Xmas tree
- H.C. leak at pipelines (to manifold)
- H.C. leak at manifold
- H.C. leak at pipelines (to processing)
- H.C. leak at pipelines (to riser)
- H.C. leak at riser

Operations outside normal conditions

H.C. leak at processing facilities

Receiving Facility

Riser

Safety Zone

Downhole Safety Valve
2. Background Knowledge

2.3 Subsea Safety System

- H.C. leak at wellhead/Xmas tree
- H.C. leak at pipelines (to manifold)
- H.C. leak at manifold
- H.C. leak at pipelines (to processing)
- H.C. leak at pipelines (to riser)
- H.C. leak at riser
- Topside blowout
- Receiving Facility
- Subsea Wellhead and Xmas Tree
- Manifold
- Subsea Processing
- Operations outside normal conditions
- H.C. leak at pipelines (safety zone)
- Xmas Tree PMV/PWV
- Riser
- Safety Zone
2. Background Knowledge

2.3 Subsea Safety System

Subsea Wellhead and Xmas Tree

H.C. leak at wellhead/ Xmas tree

H.C. leak at pipelines (to manifold)

H.C. leak at manifold

Manifold

H.C. leak at pipelines (to processing)

H.C. leak at pipelines (to riser)

Subsea Processing

Riser

Safety Zone

Receiving Facility

Topside blowout

H.C. leak at pipelines (to riser)

Manifold valves

H.C. leak at processing facilities

Operations outside normal conditions

H.C. leak at pipelines (safety zone)
2. Background Knowledge

2.3 Subsea Safety System
2. Background Knowledge

2.3 Subsea Safety System

Subsea Wellhead and Xmas Tree

- H.C. leak at wellhead/ Xmas tree
- H.C. leak at pipelines (to manifold)
- H.C. leak at manifold
- H.C. leak at pipelines (to processing)
- H.C. leak at pipelines (to riser)

Manifold

- H.C. leak at pipelines (to processing)

Subsea Processing

- Operations outside normal conditions
- H.C. leak at pipelines (safety zone)

Receiving Facility

- Topside blowout
- H.C. leak at riser

Riser

- H.C. leak at pipelines

Safety Zone

- Subsea Isolation Valve
2. Background Knowledge

2.3 Subsea Safety System

Subsea Wellhead and Xmas Tree
Manifold
Subsea Processing

Trip and Isolate

Receiving Facility
Riser
Safety Zone

Xmas Tree PMV/PWV
Downhole Safety Valve
Manifold valves
Subsea Isolation Valve
2. Background Knowledge

- Topside blowout
- H.C. leak at riser
- H.C. leak at pipelines (safety zone)
- H.C. leak at pipelines (to riser)
- H.C. leak at processing facilities
- H.C. leak at pipelines (to processing)
- H.C. leak at manifold
- H.C. leak at pipelines (to manifold)
- H.C. leak at wellhead/Xmas tree
- Operations outside normal conditions
- DHSV
- X-mas PMV/PWV
- Manifold valves
- Trip/isolate processing
- SSIV
- Injury/fatality
- Large oil/gas spill to environment
- Subsea processing equipment damage
2. Background Knowledge

2.4 Subsea Control System

**TOPSIDE**
- Operator Control Stations
- Subsea Control Unit (SCU)
- Subsea Power and Control Unit (SPCU) / Electrical Power Unit (EPU)
- Hydraulic Power Unit (HPU)
- Chemical Injection System
- Topside Umbilical Termination Unit (TUTU)
- Pump Control Unit (PCU) / Compressor Control Unit (CCU)
- HV Power System
- Barrier Fluid (BF) Injection System

**SUBSEA**
- Umbilical Termination Assembly (UTA) / Subsea Distribution Unit (SDU)
- Subsea Control Module (SCM)
- Subsea Electronic Module (SEM)
- Subsea Control Module Mounting Base (SCM MB)
- Instruments, valves and chokes
- Process Equipment

**PCU / CCU controls:**
- the speed of the pumps / compressors by controlling the VSDs
- the minimum flow / anti-surge system
- the barrier fluid system
- planned sequences like startup and shutdown

**Green : Subsea Production**
**Red : Subsea Processing**
3. Presentation of Gaps
3. Presentation of Gaps

3.1 Standards and Regulations

- Subsea safety and control systems should be designed in accordance with regulations and standards.
3. Presentation of Gaps

3.1 Standards and Regulations

- Facilities Regulations of The Petroleum Safety Authority Norway (PSA)
- OLF GL 070 of the Norwegian Oil and Gas Association
- NORSOK S-001, Technical Safety
- NORSOK I-002, Safety and automation system (SAS)
- NORSOK P-002, Process system design
- NORSOK U-001, Subsea Production Systems
- ISO 10418, Offshore production installations
- ISO 13628-1, Design and operation of subsea production systems - Part 1
- ISO 13628-6, Design and operation of subsea production systems - Part 6
### 3. Presentation of Gaps

#### 3.2 Status and Gaps

<table>
<thead>
<tr>
<th>1) Facilities Regulations – PSA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status</strong></td>
</tr>
<tr>
<td>• Commonly used for topside and subsea</td>
</tr>
<tr>
<td>• ESD should be independent (33)</td>
</tr>
<tr>
<td>• Facilities ... shall have a process safety system (34)</td>
</tr>
<tr>
<td>• The process safety system shall have two independent levels of safety (34)</td>
</tr>
</tbody>
</table>
# 3. Presentation of Gaps

## 3.2 Status and Gaps

### 3) NORSOK S-001

<table>
<thead>
<tr>
<th>Status</th>
<th>Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Commonly used for topside and subsea</td>
<td>• Most requirements are based on topside systems</td>
</tr>
<tr>
<td>• Two independent levels of protection shall be provided for process safety (9.4.1)</td>
<td>• May result in excessive redundancy</td>
</tr>
<tr>
<td>• PSD shall be independent from PCS (9.4.1)</td>
<td>• ESD node from topside. What if without topside, or topside being more remote?</td>
</tr>
<tr>
<td>• ESD functions shall be functionally and physically segregated from others (10.4.7)</td>
<td>• No specific time response requirement for subsea processing systems</td>
</tr>
<tr>
<td>• ESD hierarchy: APS – ESD1 – ESD2 (10.4.3)</td>
<td></td>
</tr>
<tr>
<td>• ESD response time ≤ 2 s/in (10.4.5)</td>
<td></td>
</tr>
</tbody>
</table>
## 3. Presentation of Gaps

### 3.2 Status and Gaps

<table>
<thead>
<tr>
<th>9) ISO 13628-6</th>
<th>Status</th>
<th>Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Subsea-specific requirement (production)</td>
<td>• No requirement for subsea processing</td>
</tr>
<tr>
<td></td>
<td>• Fail-safe philosophy (5.5.3)</td>
<td>• No specific time response requirement for subsea processing systems</td>
</tr>
<tr>
<td></td>
<td>• Response time (5.5.4)</td>
<td>• ESD node from topside. What if without topside, or topside being more remote?</td>
</tr>
<tr>
<td></td>
<td>• Subsea electrical distribution and hydraulic distribution shall be redundant or include spare (5.4.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ESD and optional PSD initiated from topside (7.4.9)</td>
<td></td>
</tr>
</tbody>
</table>
4. Results and Discussion
4. Results and Discussion

4.1 Results

• Few subsea production requirements
• No subsea processing requirement
• Common requirements are based on topside systems
• Topside based standards require independent control and safety systems
• ESD node from topside
4. Results and Discussion

4.2 Discussion

• Topside based standards require independent control and safety systems
• This may result in excessive redundancy

Source: SUBPRO Summary of Technical Information as provided by Aker Solutions
4. Results and Discussion

4.2 Discussion

• ESD node from topside. What if without topside, or topside being more remote?

  - Can we apply the same shutdown philosophy and simply exclude topside shutdown actions (e.g., shutdown of fans/heaters and bilge/ballast pumps)?
  - It may be required to establish a different type of shutdown philosophy
4. Results and Discussion

4.2 Discussion

- New processing units may introduce new hazards with potential to cause environmental leakages (e.g., subsea water treatment)

- Hydrate formation is not covered in this study

- Prevention and mitigation of hydrate formation is wholly different from the other hazardous events (closing valves vs. continuous monitoring and control)

- This hazardous event also needs to be further investigated
thank you