Enabling the all subsea factory without compromising safety and efficiency

Dr. Alexandre Orth, Bosch Rexroth
The ALL Subsea Factory
User Demands

Safety
• Protection of people
• Protection of environment

Green
• Low CO2 / Low Power
• No Leakage of Control Fluids

Volatile
• Low Break-Even
• Standardization

Far Away
• Tie-back Oil: 50-100 km
• Tie-back Gas: 300-500 km

Deeper
• Water Depth up to 4.000 m
• High Pressure / High Temperature

=> Technology Requirements

@ Subsea
• No Topside Hydraulic Power Unit (HPU)
• Small Umbilical (without hydraulics)

Simple
• No hydraulic pipes & hydr. control system
• Only electric cabling (plug & play)

Efficient
• Downsize for commissioning equipment's
• Low power: simple electric infra-structure

Uptime
• Condition monitoring
• Smart, Connected, i4.0 / IoT ready...

Safe
• Fail-Safe emergency closure with high integrity level (availability, monitoring)
The ALL Subsea Factory

We are Bosch!

Our values – what we build on

Future and result focus
Responsibility and sustainability
Initiative and determination
Openness and trust
Fairness
Reliability, credibility, legality
Diversity

Responsibility and sustainability
We act responsibly in the interest of our company, also taking the social and ecological impact of our actions into consideration.
Our Purpose …

Our Vision …

… to make the exploration of the **SUBSEA WORLD** safe, green and efficient
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Safety Definitions

- **Machine safety**
  “The concept of safety of machinery considers the ability of a machine to perform its intended function(s) during its life cycle where risk has been adequately reduced.”
  [ISO 12100]

- **Safety and hazards**
  “Safety includes all operational, technical and emergency preparations significant for the protection of people, environment, installations and vessels present.”
  [ISO 13628-1: Petroleum and natural gas industries – Design and operation of subsea production systems – Part 1: General requirements and recommendations]
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Safety Definitions

Functional safety

- “Part of the safety of the machine and the machine control system which depends on the correct functioning of the SRECS, other technology safety related systems and external risk reduction facilities” [IEC 62061]

Safety-related Electrical Control System (SRECS)

- “Electrical control system of a machine whose failure can result in an immediate increase of the risk(s)” [IEC 62061]

➢ As soon as the safety of a machine depends on a correct function of the control system, it is therefore called “Functional Safety” with special requirements on the availability of the safety function.
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Designing a Safety Function

Fig. B-5.2: SRP/CS, consisting of three subsystems SRP/CS\textsubscript{a}, \textsubscript{b}, source BGIA Report 02/2008

Fig. B-5.3: Analysis of the circuit diagram for identifying the safety-related components, source BGIA Report 02/2008

Source: Handbook 10 Steps to Performance Level
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Safety Function in Subsea Hydraulic Control

Definition: Emergency Closure
„When the power supply is shut off (or lost), than the valve shall be moved back to its safe position (close or open)“. 

Safety-related components:
1. Fail-safe mechanic spring
2. Subsea hydraulic valves

Implementation:
Power off de-energizes the valves’ solenoids, releasing the pressure of the hydraulic cylinder where a field-proven mechanic spring moves back actuator

Support components:
1. Optional: sensors for monitoring
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Safety Function in Subsea Electric Control with Battery

- **Definition:** Emergency Closure
  "When the power supply is shut off (or lost), than the valve shall be moved back to its safe position (close or open)."

- **Implementation:**
  *Once the power off has been detected, the electric controls uses the energy in the battery to drive the electric motor to move back actuator*

- **Safety-related components:**
  1. Sensor (detecting power off)
  2. Electric controls (hardware)
  3. Software for the control system (safety logic)
  4. Electric Battery
  5. Electric Motor
  6. Mechanic Gear (or further transmissions)
  7. All electric cables and connectors
  8. Sensor for monitoring battery charge level
  9. Software for battery energy management
  10. Communication (noisy or disturbances)

- **Support components:**
  1. Subsea power supply, umbilical, ROV, ...
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Basic Safety Principles

- **De-energization principle (release of energy principle):**
  “The safe state is obtained by release of energy to all relevant devices. [...] Energy is supplied for starting the movement of a mechanism.” [ISO 13849-2]

- **This means:**
  - The system always starts from the safe position
  - Energy has to be provided to leave the safe state
  - By taking out the energy, the system returns automatically to the safe position.
  - If possible, this principle shall be followed.

- **States of a control system component:**

\[
\begin{align*}
\lambda &= \frac{1}{\text{MTTF}_d} + \frac{1}{\text{MTTF}_u} \\
\lambda_d &= \frac{1}{\text{MTTF}_d} \\
\lambda_u &= \frac{1}{\text{MTTF}_u} \\
\text{DC} &= \frac{\lambda_d + \lambda_u}{\text{MTTF}_d + \text{MTTF}_u}
\end{align*}
\]

- **States (C):**
  - Failure-free: C₀
  - Safe failure: Cₚₘₜₑ
  - Control system is defective however in safe position (no danger!)
  - Dangerous detected failure: Cₑₚ
  - Dangerous undetected failure: Cₑₚ₀

- **Events:**
  - \( \lambda_s \): Safe component failure
  - \( \lambda_c \): Component has been exchanged
  - \( \lambda_d \): Dangerous component failure and dangerous failure can be identified
  - \( \lambda_t \): Test rate (DC: failure has been identified)
  - \( \lambda_d \): Dangerous component failure and dangerous failure cannot be identified

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Our Way ... 

Our Mission ... 

... is to enable the All Subsea Factory with innovative automation system solutions based on field-proven technology.
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Electrification of the hydraulics in the industry

- Hydraulic unit with constant motor speed
- Constant electrical drive performance
- Hydraulic power distribution

- Hydraulic unit with variable-speed drive
- Electrical drive performance on demand
- Hydraulic power distribution

- Electro-hydraulic, electro-mechanical actuators
- Electrical drive performance on demand
- Electrical power distribution

Energy Efficiency
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Different ways lead to the same goal...

- Choose for your case...
- the best technology:
  - Electro-Mechanic
  - Electro-Hydrostatic

- High precision and dynamics
- Large actuator forces
- Connectivity (digital bus)
- Robustness (long lifetime)
- Control and diagnosis
- Overload protection
- Plug and play (installation)
- Fail-safe spring
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Our Approach

Subsea Valve Actuator

System Simulation

Video @ https://youtu.be/FnmB8ZxnElI

Loads: max. 1,200 cycles in 25 years of operation.
# The ALL Subsea Factory Technology benchmark

## Conventional Hydraulics since 1950
- **Example of a Topside HPU**
  - Large: e.g. 12 x 3 x 3 m (+ redundancy)
  - Medium: 100 - 120 mm (reduced in 45%)
  - Small: 50 - 70 mm (reduced in 70%)

## Electro-Mechanic (EMC) since 2000
- **Example of Electro-Mechanic Actuator**
- **Subsea Valve Actuator (SVA)**
  - Large: saved FPSO / FLNG space
  - Medium: saved FPSO / FLNG space
  - Small: saved FPSO / FLNG space

## Electro-Hydrostatic (SVA) since 2018

### Criteria
- **Top Side HPU:**
  - Large: e.g. 12 x 3 x 3 m (+ redundancy)
  - Medium: saved FPSO / FLNG space
  - Small: saved FPSO / FLNG space

- **Umbilical:**
  - Large: Ø 150 - 250 mm (high costs: $$$)
  - Medium: Ø 100 - 120 mm (reduced in 45%)
  - Small: Ø 50 - 70 mm (reduced in 70%)

- **Subsea Control:**
  - Large: hydr. (acc...) + small elec. (400W)
  - Large: electric (15-25 kW)
  - Medium electric (4-6 kW)

- **Subsea Tree:**
  - Small: size actuators
  - Batteries → small or Springs → large

- **Safety:**
  - Emergency closure by springs (SIL 2)
  - Emergency closure: batteries or springs
  - Emergency closure by springs (SIL 2/3)

- **Availability:**
  - Low: hydr. flushing + no sensors
  - High: sensors for condition monitoring
  - High: sensors for condition monitoring

- **Environment:**
  - Leakage of hydr. fluids to sea
  - Friendly (leak-free)
  - Friendly (leak-free)

- **Application:**
  - Shallow water & Safety Critical
  - Deep Water & Safety NON Critical
  - Deep Water & Safety Critical

### Added Value
- **CAPEX Reference**
- **OPEX Reference**
- **CAPEX saving:** 5% to 10% significant
- **OPEX saving:** 10% to 20% significant

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## The ALL Subsea Factory

### Your Benefits @ System Life Cycle

<table>
<thead>
<tr>
<th>Engineering</th>
<th>Purchase</th>
<th>Manufacturing</th>
<th>Installation</th>
<th>Operation</th>
<th>Service</th>
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<tbody>
<tr>
<td>Low Space</td>
<td>No HPU</td>
<td>Plug &amp; Play</td>
<td>No HPU</td>
<td>Low Energy</td>
<td>Retrievable</td>
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<tr>
<td>SIL 2 or 3</td>
<td>Simpler Umbilical’s</td>
<td>Calibrated</td>
<td>No Flushing</td>
<td>Availability</td>
<td>Replace Hyd. Actuators</td>
</tr>
<tr>
<td>Low Energy</td>
<td>ww. Partner</td>
<td>No Piping</td>
<td>Monitoring</td>
<td>No Leakage</td>
<td>Plug &amp; Play</td>
</tr>
<tr>
<td>Override</td>
<td></td>
<td>No Flushing</td>
<td>Smart Set up</td>
<td>No Flushing</td>
<td></td>
</tr>
</tbody>
</table>

- **MODULAR**
- **LOW CAPEX**
- **EFFICIENCY**
- **EFFICIENCY**
- **LOW OPEX**
- **RETROFIT**

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**Electro-hydraulic actuator**

**Electro-mechanical actuator**

**Electro-mechanical actuator with hydrostatic gearbox**

**Subsea Valve Actuator from Bosch Rexroth**

**The best of both technologies together**
The ALL Subsea Factory
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Green

Volatile

Far Away

Deeper

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Efficient

Uptime

Safe

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State of the Art
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Why not?

Many thanks for your attention!

Further Questions?
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*Source: Presentation of Mr. Camerini (Petrobras) at IEPUC (BR)