An Electro-Mechanical Actuator With Hydrostatic Drive to Improve Efficiency and Safety of Subsea Production

- **Abstract:**
  This work presents a novel approach for actuation of subsea valves, which combines the strengths of an electromechanical actuator with a hydrostatic transmission. The presentation will provide a concept of a hybrid actuator for subsea production based on successful industrial solutions.

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The evolution of the electro-hydraulic actuators in the industry

a) Hydraulic
- Constant motor speed hydraulic power unit
- Constant electrical drive power
- Hydraulic power distribution

b) Electro hydraulics
- Variable motor speed hydraulic power unit
- Electrical drive power on demand
- Hydraulic power distribution

c) Fully integrated solution
- Electro hydraulic axis, electro mechanic axis, hydro gear
- Power on demand, energy buffering and regeneration
- Electrical power distribution

Energy Efficiency
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Design concept of the novel Subsea Valve Actuator (SVA)

a) Subsea Valve Actuator – TRL 5 Concept
   - a redundant system inside one fixed enclosure

- Variant 1: basic functions as reference
- Variant 2: advanced functions and sensors

b) Actuator Control Module – TRL 2 Concept
   - a redundant system with two exchangeable enclosures

- Variant 1: basic functions as reference
- Variant 2: advanced Condition Monitoring
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System Architecture

Master Control Station (MCS) — MCS — Sea surface

Subsea Control Module — SCM — Seabed

Actuator Control Module

Subsea Valve Actuator

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Schematic Diagram

a) Cylinder module with fail-safe spring

b) Drive System (redundant)

c) Safety control module (release spring by power cut off)

d) Pressure compensation (redundant)

e) Manual override (API RP17H: class 4)
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Design optimization with system simulation

- Power consumption of a Subsea Valve Actuator for 2 1/16” Gate Valve (Var. 2)

Parameters:
- Well-pressure: 10 kpsi (690 bar)
- Actuator Stroke: 63 ± 0.2 [mm]
- Nominal stroke time open: 60 [s]
- Nominal stem force: 180 [kN]
- Scope: power consumption of the drive system (e.g. not incl. sensors)
- Fail-Safe spring considering worst case of all applicable modules
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Functional safety concept

SCM: Subsea Control Module; ACM: Actuator Control Module; SVA: Subsea Valve Actuator

SCM
- Input
- Emergency Signal
- Well Monitoring

ACM
- Logic
- Safety Relays S1A + S1B
- Safety relay S2A + S2B
- Electric Control

SVA
- Actuators
- DCV1
- DCV2
- DCV3
- DCV4
- Actuator Sensors
- Diagnostic Elements
- Channel 1
- Channel 2
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Design for reliability and system availability

a) Simplest System (State of Art)
   - no pressure difference = risk of sea water ingress

b) Improved System (State of Art)
   - Hydraulic overpressure

c) Subsea Valve Actuator – 1st Step

   - Integration in compact design:

   - Subsea Valve Actuator – 2nd Step
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Proof of concept using physical model tests (TRL 2)

a) Test principle
- hydraulic accumulator is used to simulate well and spring forces
- all component are emerged in hydraulic oil (tank simulates internal actuator enclosure)

b) Test implementation
- Hydraulic cylinder with same size/complexity
- All standard components selected for the SVA were tested in variant 1 and 2 functionalities
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Proof of concept using physical model tests (TRL 2)

- Durability validation test of the fail-safe spring module
- Energy efficiency test of the electric motor and pump drive
- Material compatibility test with different materials and fluids (with and without sea water contamination)
- Durability validation test of the pressure compensation module
Prototype Test (TRL 3 to TRL 5)

a) Interface for 2 1/16” Subsea Gate Valve - Bonnet (acc. to API 6A:2010 / ISO 10423:2009)
b) Modular design for operation up to 3.000 m depth with complete redundant drive and safety system
c) Energy efficiency system incl. hydraulic clamping of fail-safe spring package and low voltage components
d) Control system with SIL 3 functional safety inside incl. monitoring during emergency closure
e) Sensors integrated for Condition Monitoring
   a) Redundant Actuator Absolute Position
   b) Working Pressures
   c) Temperature
   d) Pressure-Compensation Volume
   e) Water Ingress Detection
f) Override for ROV class 4 Interface (emergency closure or opening) incl. position indicator
g) Redundant analog subsea electric interface
h) Redundant pressure compensation system with electric components protect against sea water ingress
Pj. Subsea Valve Actuator
Prototype Test (TRL 3 to TRL 5)

- Modular Design

![Diagram of subsea valve actuator components]

- Spindle drive and set of sensors
- Drive system
- Subsea internal cables
- Bonnet interface
- Control/ROV interface
- Safety control
- Pressure compensation
- Cylinder with fail-safe spring
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Prototype Test (TRL 3 to TRL 5)

- Standardized Interface
Comparison of economical aspects (CAPEX and OPEX)

Comparing to a **typical hydraulic systems**, it saves:

1. Topside Hydraulic Power Unit (CAPEX and footprint) with the regular refill of fluid (OPEX).
2. Avoid of umbilicals with hydraulic power lines, being operated with simple electric power.
3. Avoid of any piping work at the subsea trees or manifolds, saving material and also high commissioning costs.
4. No hydraulic maintenance is needed with complicated flushing and refilling at seabed.

Comparing to **all-electric systems**, it saves:

5. CAPEX costs due to extensive application of standard components and lean-manufacturing.
6. Up to 75% of electric peak and stand-by power with impact in OPEX but much more in CAPEX, when the infrastructure for subsea power distribution to all actuators are considered.
7. High safety levels, high system reliability and condition monitoring optimize the system availability (up time), increasing efficiency.