Module structure

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  - Basic control systems
- Section 2 – Subsea control systems
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  - Commonly used terms
  - Methods of control
  - Choice of system
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  - Subsurface components
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  - Infield connections
  - Multi-bore connectors
  - Jumpers
  - Connectors and Penetrators
- Section 5 – Instrumentation
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  - Basic instrumentation
  - Advanced instrumentation
- Section 6 – Topside Control Systems
  - Offshore control systems
  - Where does it all fit in?
Learning objectives

By the end of this module you will be able to understand....

- What a subsea control system comprises
- What factors influence control system design
- How a subsea control system relates to other systems

Section 1 – Introduction to control systems

- Scope of control systems engineering
- Basic control systems
Scope of control systems engineering

Communications
Software
Electrical
Mechanical
Instrumentation
Interfaces
Fibre optics
Hydraulic

To name a few……..

Open loop control

Initiator
Automatic
Manual

Logic
Automatic
Pneumatic
Hydraulic
Manual

Actuator
Hydraulic
Electrical
Pneumatic

Process
Closed loop control – Actuator feedback

Initiator → Logic → Actuator → Process

Sensor

Closed loop control – Process feedback

Initiator → Logic → Actuator → Process

Sensor → Sensor
Powering the system

The power supply can be:
• Hydraulic
• Electrical
• Pneumatic

Section 2 – Subsea control systems

- Introduction
- Commonly used terms
- Methods of control
- Choice of system
Introduction

- What is the definition of a subsea control system?
  - ISO 13628-6 says........
    - “control system operating a subsea production system during operation”
  - More useful....
    - “To safely maintain the flow of hydrocarbons from a subsea facility”
- What are the main challenges for a subsea control system?
- What are a subsea control systems two primary requirements?

Subsea control systems

- Does a control system fulfil it’s primary requirements?
  - Safe operation
    - 2003 HSE Report into valve failures that resulted in a hydrocarbon release showed:
      - 43% of failures were from inadequate design, materials, etc
      - 0% from control systems
  - Availability
    - 2003 HSE Report into valve failures that resulted in downtime showed:
      - 43% of failures were from inadequate design, materials, etc
      - 24% of failures were from the control system
  - The cost per failure?
    - Average of 100 hours downtime
**Commonly used terms**

- **Closed hydraulic circuit**
  - Hydraulic fluid is returned to its point of supply

- **Open hydraulic circuit**
  - Hydraulic fluid is vented to sea or a recoverable subsea storage vessel

- **Directional control valve or valve**
  - Controls the flow of hydraulic fluid

- **Solenoid**
  - Electrical coil that controls the position of a control valve

**Supply**

**Return to tank**

**Function**

- **Fail safe**
  - Returns to a safe condition in a fault condition, can be fail open, fail close or fail as is.
  - Usually controlled by a mechanical spring

- **Hydraulic accumulator**
  - Pressure vessel used to store hydraulic fluid under pressure

- **Latched function**
  - A function where the control signal does not need to be continuously applied.

**Supply**

**Vent to sea**

**Function**
**Methods of control**

- **Direct Hydraulic**
  - Low tech solution
  - High level of reliability
  - Easy to understand
  - Easy to fault find
  - Easy to service
  - Cheap
  - Best suited to shallow water
  - Slow to respond
  - Large umbilical

- **Piloted Hydraulic**
  - Subsea accumulation
  - Mechanical or electrical pilot valve operation
  - Valve sequencing can be used
  - Not suited for ultra-deep water or long step outs
  - Slow to respond
  - Large umbilical
Methods of control

- Direct Electro Hydraulic
  - Smaller umbilical
  - Faster response
  - Simplified control pod
  - Not suited for ultra-deep water or long step outs
  - Increased number of subsea electrical connections
  - Requires separate electrical umbilical or multicore umbilical

- Electro Hydraulic Multiplexed
  - Long step out and deep water
  - Faster response
  - Simplified umbilical
  - Capable of complex control
  - Improved surveillance
  - Increased number of subsea electrical connections
  - Higher voltage connections
  - More complex subsea components
  - More difficult to support
Methods of control

- All Electric

- Ultra deep water and extremely long step outs
- Zero emissions
- Suitable for harsh environments
- Subsea processing
- Easily expandable
- More autonomous?
- Lower operating and maintenance costs?
- Complex electro-mechanical devices
- Power electronic devices subsea
- High voltage distribution systems
- Harder to control failure modes
- Greater level of technical support
- Higher Intervention costs?
- Installation costs?

Choice of system

<table>
<thead>
<tr>
<th>System Type</th>
<th>Cost</th>
<th>Maintenance /reliability</th>
<th>Flexibility</th>
<th>Step out</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Hydraulic</td>
<td>Low</td>
<td>Low technical threshold. Most components topside.</td>
<td>Limited</td>
<td>Short</td>
<td>Shallow</td>
</tr>
<tr>
<td>Piloted Hydraulic</td>
<td>Low</td>
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<td>Short</td>
<td>Shallow</td>
</tr>
<tr>
<td>Direct Electric</td>
<td>Low</td>
<td>Increased complexity.</td>
<td>Limited</td>
<td>Short</td>
<td>Shallow</td>
</tr>
<tr>
<td>Electro Hydraulic Multiplex</td>
<td>High</td>
<td>More complex, subsea equipment.</td>
<td>Expandable</td>
<td>Long</td>
<td>Deep</td>
</tr>
<tr>
<td>All Electric</td>
<td>High</td>
<td>More complex, subsea equipment.</td>
<td>Expandable</td>
<td>Very Long</td>
<td>Ultra Deep</td>
</tr>
</tbody>
</table>
Section 3 – Control system components

- Surface components
- Subsurface components
**Surface equipment**

- Typical surface components can include:
  - Topside Umbilical Termination Unit (TUTU)
  - Hydraulic Power Unit (HPU)
  - Electrical Power Unit (EPU)
  - Subsea Control Unit (SCU)
  - Master Control Station (MCS)

**Subsea control unit**

- Can act as a stand-alone control station or integrated into the PCS
- Interfaces to subsea equipment, HPU, EPU
- Provides operator and engineer access to the system
- Acts as a gateway for third party equipment
- Expandable
**Electrical power unit**

- Semi-conductor based power supply system
  - Variable voltage output
- Can house the communication on power modem
- Provides monitoring of the umbilical system.
  - Under and over voltage protection
  - Over current protection
  - Line insulation monitoring
- Communicates to the SCU

For Subsea to Shore developments this can be replaced by a high voltage transmission system comprising a high voltage step-up surface transformer connected by subsea distribution umbilicals to subsea high voltage stepdown transformers.

**Hydraulic power unit**

- Self contained unit provides high and low pressure hydraulic supplies for the subsea controls (sometimes HP hydraulics is derived from LP supply subsea)
- Provides surface accumulation
- Redundant motor pump sets
- PLC monitoring and control
- Interfaced to the SCU
**Topside umbilical termination unit**

- Hydraulic, electrical and fibre optic termination
- Electrical terminations in internal junction boxes
- Individual block and bleed valves for each hydraulic line
- Individual pressure gauge per hydraulic line

**Master control station**

- Operator and Engineering access to the system
- HMI graphical interface to the system
- Stand-alone system or
- Integrated into the distributed control system (DCS)
- Remote repeater stations
- Can be local or remote
Subsurface equipment

- Typical systems components can include:
  - Umbilical Termination Assembly (UTA)
  - Subsea Distribution Assembly (SDA)
  - Subsea Distribution Unit (SDU)
  - Communications Interface Unit (CIU)
  - Subsea Electrical Junction Box
  - Subsea Control Module (SCM)
  - Subsea Electronics Module (SEM)

Subsea termination assembly

- Terminates and distributes the umbilical
- Electrical, hydraulic and chemical distribution
- Multi-bore connectors
- ROV mateable jumpers
- Configurable arrangement using crossover caps and or jumpers
**Subsea distribution assembly / unit**

- Similar to UTA
- In-field distribution of hydraulic and electrical supplies and communication signals
- Subsea electrical junction box
- Local transformation of power supplies (step down transformers)
- Fibre to copper converters (CIU)

**Subsea control module**

- Can be installed on SDUs, SDAs, PLEM and XTs
- Controls and monitors subsea instrumentation and actuators (valves, etc)
- The SCM normally consist of:
  - Hydraulic and electric operated valves
  - Subsea Electronic Module
  - Couplers for electrical cables and hydraulic lines.
  - Valves contained in an oil filled pressure compensated housing
  - SEM in a one atmosphere pressure vessel
- Retrievable
Subsea electronics module

- One atmosphere pressure vessel
- Cards for control signal handling and communications
- Supports various communication protocols
- Power supplies for instrumentation and actuators
- Intelligent, able to perform local control

Section 4 – Connection systems

- Copper or fibre
- Umbilicals
- Infield connections
- Multi-bore connectors
- Jumpers
- Connectors and Penetrators
Copper or fibre

**Fibre**
- Pros...
  - High speed
  - Gigabits of information
  - Video and audio
  - Noise immune
  - Light weight
  - Sophisticated diagnostic tools
- Cons...
  - More fragile
  - Harder to terminate
  - More elaborate connectors, especially subsea
  - Expensive transmit and receive equipment

**Copper**
- Pros...
  - Cheaper modems
  - Easier terminations
  - Simpler connectors
- Cons...
  - Heavier umbilical
  - More expensive umbilical
  - Susceptible to noise
  - Lower data rates
  - Shorter distance

Ideally fibre optics should be used for all systems, however for simple shallow water applications it may be harder to justify.

Direct hydraulic umbilicals

- Older design
- Large cross section
- Lots of hydraulic lines (one per function)
- Limited electrical connections
- Difficult to handle and terminate
Multiplexed electro-hydraulic umbilicals

- Smaller cross section
- Steel tubes
- Common hydraulic supply
- Chemical injection lines
- Fibre optic and copper signal conductors
- Power conductors

Infield connections

- Multi-bore connectors
- Jumpers
  - Hydraulic
  - Optical fibre
  - Electrical
- Couplers
- Connectors
- Penetrators
**Multi-bore connectors**

- Used to make the in field connections from the UTA to the SDAs and SDUs
- Electrical connections
- Fluid connections
  - Hydraulic control
  - Chemical
- Fibre optics
- Production flowlines

![FMC multi-bore connectors (collet type)](image)

**Jumpers**

- Used to distribute electrical, optical and hydraulic signals and supplies
- Oil filled pressure compensated hose
- Terminated with either a wet mateable connector, coupler or penetrator
- ROV installable
- Can be used to reconfigure the system

![ODI electrical jumpers](image)
**Couplers**

- ROV or diver operable, quick release style connector
- Wet mateable – poppet mechanism seals on release

**Electrical connectors**

- Wet and dry mate subsea
- Low voltage for signal
- High voltage for power supplies
  - 12KV Tyrihans
  - 36KV Ormen Lange
- Can be very problematic
**Fibre optic connectors**

- Wet mateable
- ROV or diver operable
- Limited number of mates and demates
- Fine tolerance

**Penetrators**

- Fibre optic or power (very high voltages)
- More reliable than connectors
- Made up dry and they are not serviceable subsea
- Usually used to terminate one end of a power cable
- Can be used as a barrier between oil and water, gas and oil and gas and water
Section 5 – Instrumentation

- Introduction
- Basic instrumentation
- Advanced instrumentation

Instrumentation

The subsea control system will generally include the following:

- Subsea and downhole transducers measuring temperature, pressure, valve position, sand production, multiphase flow, well parameters and the condition of the subsea control system equipment
- Control system variables and housekeeping parameters such as hydraulic fluid pressures, communications status and system voltages are also recorded for analysis at the surface
- Other parameters which can be monitored include:
  - Corrosion
  - Vibration
  - Strain
  - Movement (riser monitoring)
  - Ocean Current (riser monitoring)
- In a modern system almost any variable in the control system can be made available to the Process Control System
**Instrumentation - basic**

- Temperature (TT)
- Pressure (PT)
- The pressure and temperature transmitters can be combined into a single instrument called a PTT
- Both temperature transmitters (TT) and Pressure transmitters (PT) can be used to monitor either the process or the control system.
- Sand
  - Intrusive type measures the erosion on a probe inserted into the process flow
  - Non-intrusive are based on acoustic devices
- Valve position
  - Continuous measurement by LVDT or similar
  - Discrete measurement by proximity switch
  - Inferred from other measurements

**Instrumentation - advanced**

- Corrosion
  - Intrusive sensors penetrating the process flow, usually at the well head
  - Non-intrusive, normally fabricated as a section of pipeline
- Hydrocarbon
  - Capacitive sensor
- Flow meters
  - Normally mounted in-line
- Multiphase flow meters
  - In-line ROV retrievable devices
  - Measuring the fractions of gas, oil and water in the process stream.
  - Older subsea systems were not very accurate (~20%), newer systems more complex promise better results
  - Also measure, density, salinity, mass and volumetric flow rate, pressure and temperature
Section 6 – Topside control systems

- Offshore control systems
- Where does it all fit in?

Offshore control system

- Platform /Process Control System
  - DCS System
- Safety Systems
  - Fire and Gas System
  - Process Shutdown System (PSD)
  - Emergency Shutdown System (ESD)
- Subsea Production Control System
Where does it all fit in?

- Hydraulic Power Unit
- Process Control System
- Master Control Station
- Hydraulic Power Unit
- Chemical Injection Unit
- Electrical Power Unit
- TUTU
- Christmas Tree
- Downhole
- In-field Umbilical (Hydraulic, Electrical Power and Fibre Optic)
- Subsea Umbilical (Hydraulic, Electrical Power and Fibre Optic)
- Subsea Distribution
- Subsea Control Module
- Umbilical Termination
- Electrical and hydraulic jumpers
- Electrical jumpers, hydraulic hard piping

Future developments

- All electric field
- Sub-ice operations
- Increased sophistication of subsea processing units
  - Faster, more complex control loops
  - Increased instrumentation (process and condition monitoring)
- Remote and integrated operations
- Greater use of information
  - E-field systems
- Increased Complexity
  - Harder to test
- Increased attention to software quality systems, security and systems integration
  - TickIT, CMMI
  - Requirements engineering
Production Control System

**Key takeaways:**

- Safe operation
- Availability
- "Simple" and robust
- Electro-hydraulic
- All electric
- Increased amount of information
- Obsolescence