



Exploration & Production

GENERAL SPECIFICATION

SUBSEA SYSTEMS

GS SPS 020

Subsea control unit functional requirements
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1. Scope

This document describes the required functionality of the Subsea Control Unit (SCU), which is the Information Control and Safety System (ICSS) node interfacing the Subsea Production Control System (SPCS), thus the node controlling and monitoring the subsea wells through the ICSS Operator Station (OS). **The required functionality described in this document, is mainly as seen from the SPCS, i.e. there will be several aspects of the SCU functionality that are not covered by this document.**

The SCU part of the ICSS shall comply with specification **GS INS 134**.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
Not applicable	

Professional Documents

Reference	Title
Not applicable	

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	



Total General Specifications

Reference	Title
GS INS 134	Design and supply of information, control and safety system
GS SPS 001	Design and philosophy requirements for subsea stations

3. Introduction

3.1 Abbreviations

ACV	Annulus Circulation Valve
AMV	Annulus Master Valve
AWV	Annulus Wing Valve
CCR	Central Control Room
CIV	Chemical Injection Valve
CITV	Chemical Injection Throttle Valve
DHPT	Down Hole Pressure Transmitter
DHSV	Down Hole Safety Valve
DV	Manifold 3-Way Directional Valve
ESD	Emergency ShutDown
ETU	Electronic Test Unit
EV	Emergency Valve
HP	Hydraulic High Pressure
HPU	Hydraulic Power Unit
HV	Hand (manually initiated) driven Valve function code
ICSS	Information Control and Safety System
LIM	Line Insulation Monitoring
LIR	Local Instrument Room
LP	Hydraulic Low Pressure
MCM	Manifold Control Module
MCV	Manifold Circulation Valve
PCV	Production Choke Valve
PI	Pressure Indicating function code
PIGV	Manifold PIGging Valve
PMV	Production Master Valve
PSD	Process ShutDown

PV	Process Variable
PWV	Production Wing Valve
ROV	Remote Operated Vehicle
SCM	Subsea Control Module
SCU	Subsea Control Unit
SEM	Subsea Electronic Module
SPCU	Subsea Power and Communication Unit
SPCS	Subsea Production Control System
TI	Temperature Indicating function code
UPS	Uninterruptible Power Supply
UV	Multi-variable driven valve function code
VDU	Visual Display Unit
XOV	Crossover Valve

4. System description

4.1 Control system objectives

The purpose of the SCU is to:

- Gather and validate sensor readings, convert to engineering units, monitor for alarm limits and display and trend process variables
- Validate and execute operator commands
- Initiate shutdowns of the SPCS depending on the information coming from the subsea modules or from the topside installation
- Gather and monitor housekeeping data from subsea control modules and subsystems to ensure a safe and sound performance
- Store data as required for reservoir management, production allocation and system integrity monitoring
- Detect mechanical rupture subsea as well as other hydrocarbon leaks using rate of change of pressure sensors readings
- Provide an operator support tool for production optimisation
- Include maintenance tools for the SPCS.

4.2 Subsea process equipment overview

Subsea process items are remotely operated valves for well flow manipulation and safeguarding as well as pressure and temperature transmitters. The valves and sensors are located down hole, in the X-mas tree and at the subsea manifolds.

The following subsea process items shall be controlled and monitored by use of the SCU and OS. The relevant typical process items are listed in tables below.

The well tubing, wellhead, X-mas tree, subsea manifold, flowlines, risers and associated instrumentation are shown on subsea P&ID's.

The following typical valves shall be controlled by the subsea production control system:

Table 2.1.1 - Subsea valves

X-mas tree control functions	Function code
Production Wing Valve, PWV	EV
Production Master Valve, PMV	EV
Annulus Wing Valve, AWV	EV
Annulus Master Valve, AMV	EV
Scale Inhibitor Valve, SIV	EV
Crossover Valve, XOY	EV
Production Choke Valve, PCV (0 to 100%)	UV
Annulus Circulation Valve, ACV	EV
Annulus Ventilation Valve, AVV	EV
Down hole control functions	
Upper Down Hole Safety Valve, DHSV (U)	EV
Lower Down Hole Safety Valve, DHSV (L)	EV
Manifold control functions	
3-way Directional Valve or Isolation Valve	HV
Manifold Circulation Valve	HV
Manifold Pigging Valve	HV

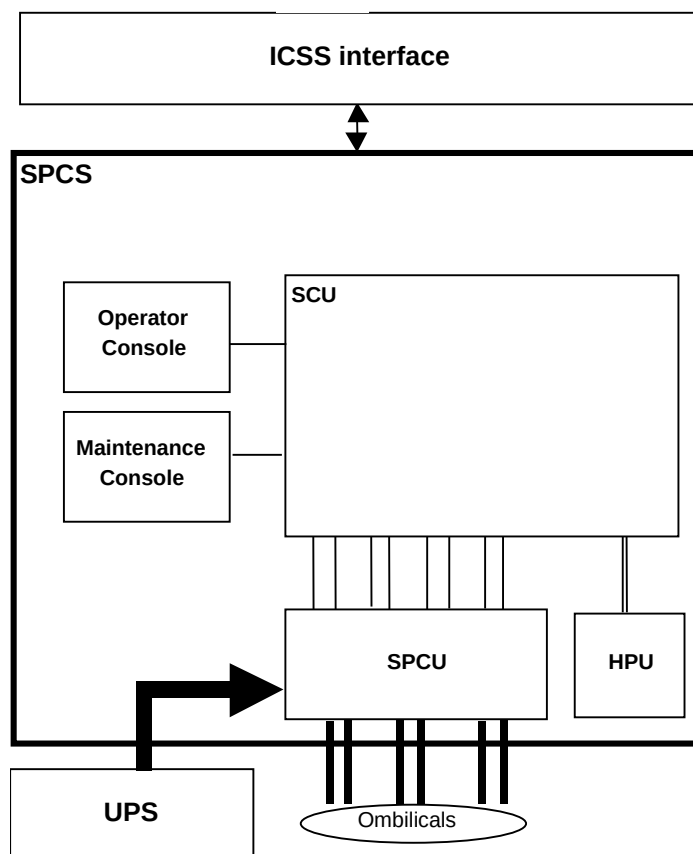
The following typical measurements shall be acquired by the SCU:

Table 2.1.2 - Subsea sensors

Measurement	Sensor location	Function code
Production wellhead pressure	Upstream choke	PZI
Production wellhead temperature	Upstream choke	TI
Production flowline pressure	Downstream choke	PZI
Production flowline temperature	Downstream choke	TI
Annulus pressure	Downstream AMV	PI
Valve position	Inferred from hydraulic pressure and flow measurements in SCM/MCM (pressure is primary indicator, wrong flow gives a warning)	
Control module internal monitoring	Each SCM/MCM	N/A
Choke position monitoring	Hydraulic step pulses as Primary, Back-up from True Position Sensor	
Choke differential pressure	Inferred from simultaneous measurement of upstream and downstream choke pressure sensors.	PDI
SMART WELL Pressure sensors		
SMART WELL Temperature sensors		
SMART WELL Unit internal monitoring		
Down hole pressure	Down hole Gauge	PI
Down hole temperature	Down hole Gauge	TI

5. System overview

5.1 General architecture



5.2 SCU architecture

The subsea control unit part of the ICSS is defined following the same architecture definition.

The SCU is divided in three functional sub-systems:

- The process control system
- The safety shutdown system
- The auxiliary controls.

5.2.1 Process control system

All actions to the subsea production system performed by the operator through the OS shall be performed by the PCS part of the SCU. Confirmation and status of commands shall be displayed at the operator stations.

5.2.2 Safety shutdown system

The safety control of the SPCS is performed by the SCU. There is no automatic shutdown performed by the SCM (SEM).



The safety actions are in accordance with the Safety Logic Diagram defined for a specific project.

There are two normal safety levels:

- The general production shutdown
- And the emergency shutdown.

The various valves to be closed in the above situations are described in the project safety logic diagram.

5.2.3 Auxiliary control

All actions not linked with production aspect as housekeeping, commissioning, configuration and maintenance related to the SPCS shall be performed through a dedicated operator station or an Engineering workstation protected by password.

5.3 Subsea Production Control System (SPCS)

Operator commands are issued by OS and are transmitted through the SCU and SPCU and via an umbilical to the SEMs. The SEMs may be located in SCMs or MCMS, dependent on system configuration.

The SCM control and monitor X-mas Tree valves and instrumentation and interface down hole equipment. The MCM control any remote control manifold valves and monitor any manifold mounted sensors.

6. System interfaces and requirements

6.1 Interface to ICSS

The Subsea Control Units (SCU) shall be connected to the ICSS data bus. The bus, and the SCU node connections to the bus, shall be dual redundant.

Shutdown signals from dedicated ICSS ESD/PSD nodes shall be transmitted to the SCU as for all other ICSS nodes.

6.2 Interface to the process data management system

The Process data management system (PDS) is a system used to analyse the production parameters and to record process data for historical purposes.

The PDS shall collect information from the SPCS directly in the ICSS as all other information available in the ICSS.

6.3 Interface to SPCS

All communication protocols used between SCU and SPCU shall be standard protocols widely used in the industry.

7. Operator interfaces

7.1 General Requirements

Operator interactions with the Subsea Production Control System fall in three categories:

- Process control and shutdown
- Subsea system “housekeeping”
- Subsea system configuration.

The purpose, function and access for each VDU picture are described in the following.

Operators shall access all subsea process objects by ICSS operator stations.

Subsea system housekeeping and configuration shall be performed via the ICSS maintenance console.

7.2 Subsea process and shutdown VDU pictures

ICSS subsea VDU pictures comprise all displays necessary for subsea process object monitoring and operation. The pictures shall be organised in a hierarchy with increasing level of detailed information:

- “Field overview picture” showing all templates and flowlines
- “Wellgroup overview picture” for each wellgroup
- “Well picture” presenting process control details for each well including down hole equipment.

If the field does not contain templates and manifolds, but only single wells, then “Field-” and “Wellgroup-” pictures will be merged to one level.

Associated process trend graphs, process variable details and tables shall be included at the different levels where required.

Process shutdown pictures shall be presented at the following levels following the Safety Logic Diagram:

- “Field overview picture” showing shutdown levels for all templates
- “Wellgroup overview picture” for each wellgroup showing shutdown levels for the wellgroup
- “Well picture” showing shutdown level for each well including valve status
- Valve position and status for all isolation and choke valves within the wellgroup
- Process variables for all process sensors within the wellgroup
- Alarms and blocked/suppressed objects.

7.3 Subsea housekeeping and configuration VDU pictures

All necessary displays for housekeeping and configuration of the Subsea Production Control System shall be presented at ICSS maintenance OS.

All maintenance tools shall be protected by password with several levels.



For each well, the following information regarding SCM Sensors, X-mas Tree Sensors, Additional Sensors, X-mas Tree valves and down hole/Smart Well equipment shall be available on a set of display pictures on ICSS maintenance OS.

Some of these informations shall be displayed on the Operator Station.

- Process sensor diagnostics, showing all process variables and SEMs measurements
- SEM Housekeeping diagnostics
- SCM and MCM hydraulic diagnostics, showing all hydraulic pressures and flows measured by SEMs
- Valves data log
- Details for each process sensor, including alarm limits, alarm hysteresis, engineering ranges and limits, process variable selection
- Details for each SCM sensor, including alarm limits, raw data, raw count ranges, alarm hysteresis, engineering ranges and limits, process variable selection
- Choke valve details for parameter setting and process variable selection
- Isolation valve details for parameter setting and process variable selection
- Remotely operated manifold valve details for parameter setting and process variable selection
- Calibration constants for all process sensors
- Calibration constants for all SCM sensors
- Configuration and monitoring of data communication
- Details of current status/availability for each SEM, each communication line, ISU LIM and SPCU power supplies
- Data communication failure statistics including all diagnostic data available in the communication protocol
- Subsea configuration including I/O board, modem, SEM address, ISU-line, HPU-line, etc.
- Subsea communication link overview
- Subsea well overview picture for enabling/disabling SEM's. Operator shall have access to both calibration constants currently in use by SCU and calibration constants to be downloaded/last downloaded to the SCU
- Smart Well data.

The various commands shall be invoked from a menu picture offering entries for all telegrams, housekeeping and other functions for configuration, parameter setting and background scanning for SEM data.

8. SCU software applications

8.1 Requirements

The following general requirements shall apply for the Subsea Control Units with respect to system integrity and configuration:

- Off-line SCU for Commissioning/Test/Training/Cold Standby shall be evaluated
- Failure in the control system for one well/wellgroup shall not affect the operation of other well/well groups
- Failure in the control system subsea for one well shall not affect the operation of other wells connected to the same Subsea Control Unit
- Failure in the control system for one of the two dual redundant SEM's in the MCM shall not affect distribution of hydraulic and electrical power and data communication to the SCM's within the same wellgroup
- Failure in the control system for power or communication with one of the two dual redundant SEM's shall not affect the other SEM
- For control of valves, both SEM's shall be configured to execute valve commands
- The SCU shall utilise the ICSS real time clock
- All alarms, events and other status changes in the system, both digital and analogue, shall be time stamped. Time stamp shall be generated as close as possible to the alarm source
- Trend functionality with configurable scanning frequency is required for every tag number including housekeeping values
- Operator shall be able to clear any warning or fault status.

8.2 SCU software configuration and well allocation

SCU software design shall facilitate easy configuration and reallocation of wells to the Subsea Production Control System using the ICSS maintenance OS.

All configuration data and sensor calibration data shall be entered as real engineering values (i.e. as will be understandable to the operator).

8.3 Subsea data communication

The SCU shall monitor the data communication between the SCU and each SEM and provide detailed communication statistics.

Loss of communication shall generate alarm. All communication errors shall be logged and presentable to operator with all error details available in the communication protocol.

8.4 Process sensors

Measurement of pressure and temperature upstream and downstream subsea choke as well as the annulus pressure are performed by the use of redundant pressure and temperature sensors.

The SCU shall gather data from the sensors via the SEM's and convert the raw data to engineering units according to a conversion algorithm and a unique set of calibration constants for each sensor.

SCU software design shall facilitate easy configuration and parameter setting for the sensors. All parameters and data required for the configuration of the sensors shall be defined in a configuration table in the SCU. The table shall be accessible from the ICSS maintenance OS.

8.5 Hydraulic pressure and flow sensors

The pressure and flow in the supply lines for hydraulic high pressure, low pressure and the return line is measured by the SEM. The pressure in each actuator line is also measured by the SEM.

The SCU shall convert raw data to engineering units according to a conversion formula and calibration factors.

The flow meter raw data shall be converted to litres (total actuator volume) and litres/min (leakage rate).

8.6 Valve commands and Valve position feedback

If only one SEM is available in the SCM or MCM (as applicable) due to failure or operational modes, then shutdowns, valve commands, and monitoring functions shall continue utilising the one SEM.

The SCU operates individual valves when commanded by the OS, and operates valves automatically on a detection of a shutdown condition.

Valve commands have the following priority:

- Automatic valve commands as part of a shutdown (safeguarding)
- Operator initiated valve commands
- Choke commands (manual or automatic).

If the actuator pressure transmitters are healthy, the valve position shall be determined by the differential pressure given by the hydraulic pressure for each valve actuator and the return line pressure. A correct pressure reading is necessary to confirm a valve open or closed. The flow measurement of hydraulic fluid shall be performed as a confirmation of valve operation and position.

The valve position shall be established as follows:

- Valve position **open**: the differential pressure is greater than “open limit”
- Valve position **closed**: the differential pressure is less than “closed limit”
- Valve position **unknown**: the differential pressure is between “closed” and “open limits”.

If the calculated position based on pressure readings is different from the commanded position, an alarm shall be given. The valve position indicated on the ICSS OS should be last position confirmed by pressure readings. An incorrect flow response after a valve operation shall give a warning to the operator.

If pressure transmitters are defective, the valve position shall be deduced from the hydraulic flow in the supply line (valve open) and return line (valve closed).

The Valve position shall then be established as follows:

- Valve position **open**: the supply flow is between valve open flow high and valve open flow low limit

- Valve position **closed**: the return flow is between valve close flow high and valve close flow low limit
- Valve position **unknown**: the flow is outside the limits above.

If the calculated position based on flow readings is different from the commanded position, an alarm shall be given. The valve position indicated on the ICSS OS should be the last position confirmed by the flow reading.

The valve open/close pressure and flow limit values for each valve shall be configurable parameters from the ICSS OS.

A "Clear fault" action for each valve, and "Clear fault all valves" per VDU picture shall be available from the ICSS Operator station.

This valve control logic shall apply for all valve operation regardless of the way it is actuated (operator initiated valve command or a valve command during a shutdown sequence).

If a valve is operated by ROV, hence the position is not known to the ICSS, this shall be indicated as a ROV-mode for this valve in the OS.

8.7 Choke position feedback

The subsea choke feedback shall be provided by measurement of the choke actuator hydraulic pulses as position measurement.

The SCU shall convert the choke position measurement to "choke % open" for display on ICSS VDU.

Calculated Choke position shall be configurable from the ICSS OS.

8.8 Subsea sensor background scanning

Under normal operation the SCU shall automatically scan the subsea sensor values from the SCM and the MCM to maintain its database of pressures, temperatures, valve positions, etc. and hand this data off to the ICSS.

Process sensor. When this normal scanning scheme is interrupted, e.g. by a commanded valve operation, the SCU completes the current subsea monitoring command and reply sequence, performs the commanded operation and then returns to normal monitoring.

In order to monitor the subsea process as well as hydraulic power system, the SCU shall transmit command sequences to SCM and MCM at regular intervals.

The hydraulic power system in each SCM and MCM shall be monitored regularly. The SCU shall perform data acquisition, conversion of raw data and update the interface to ICSS for the following measurements:

- Hydraulic supply pressures (LP, HP)
- Hydraulic return pressure
- All valve actuator pressures
- Flow and leakage in hydraulic lines (LP, HP, return).

The process sensors in each X-mas tree shall be monitored minimum every 5 seconds.

The SCU shall perform data acquisition, conversion of raw data and update the interface to ICSS within this interval for the following measurements:

- Pressure upstream and downstream subsea choke
- Temperature upstream and downstream subsea choke
- Subsea choke position
- Annulus pressure.

The SCU shall provide alarms and warnings for subsea measurements per well according to the table below (all sensors shall have “Fault” and “Out of Range” alarms):

Table 6.9.1 - Typical Subsea sensor alarm matrix

Process variable	Warning low	Alarm low-low	Warning high	Alarm high-high
Down hole pressure	-	-	-	-
Down hole temperature	-	-	-	-
Upstream choke pressure	X	X	-	-
Downstream choke pressure	X	X	-	-
Annulus pressure	-	-	X	-
Upstream choke temperature	X	-	-	-
Downstream choke temperature	-	-	-	-
Annulus temperature	-	-	X	-
Hydraulic supply pressure, HP	X	X	-	-
Hydraulic supply pressure, LP	X	X	-	-
Hydraulic return pressure	-	-	X	-

8.9 Valve interlocks and blocked valve operations

The subsea control unit software shall include logic for blocking and suppressing of valve operations.

Actual interlocks will be decided on a project specific basis.

Valve operation shall be blocked in typical situations as listed below:

- Simultaneous operation of more than one valve in the same X-mas tree shall be inhibited by the SCU
- Operation of hydraulic valves on manifold and X-mas tree including choke shall be inhibited if the differential pressure between valve actuator supply line and return line is less than defined limits. The limits may be defined individually for each valve type
- Opening of the manifold diverter valves shall be inhibited if the pressure differential between the process fluids on each side is greater than a defined limit

- Opening of the manifold circulation valve/pigging valve shall be inhibited if the pressure differential between the process fluids on each side is greater than a defined limit
- Operation of the Choke valve shall be inhibited if operation of another valve in the same Xmas tree is in progress
- Opening of the PWV and PMV shall be inhibited when the PCV is open.

8.10 Choke operation

The subsea choke set point can be manually set by the operator or automatically controlled, i.e. well flow rate control in manual or automatic mode.

Operation of the choke valve shall be controlled by the SEM, which is configured as “active” from ICSS OS.

The SCU software design shall facilitate smooth (“bump less”) transfer between choke control modes.

When running the choke to fully open or fully close, the choke shall overstep a number of step, configurable for each choke and each end position from 0 to 10 steps.

Non confirmed steps during an operation shall cause a warning to the operator, but not initiate any additional steps.

Subsea choke operational modes are described below.

8.10.1 Manual

The operator selects choke Open/Close and enters the change to the choke position in the relevant ICSS VDU picture.

8.10.2 ICSS OS automatic

ICSS OS issues a new choke set point.

The SCU software detects the change and initiates a sequence of commands for choke movements to the SEM, which controls the choke.

The SCU software requests choke position, evaluates the feedback.

The ICSS OS VDU picture is updated.

8.11 Process shutdown

The shutdown levels and corresponding signals shall be identified on the safety logic diagram.

The SCU shall execute shutdown sequences based on the safety logic diagram.