

GENERAL SPECIFICATION

Field operations

GS EP EXP 135

Full Control of Wells (FCW) specification
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1. Scope

1.1 Definition

FCW is a set of control algorithms implemented in the PCS part of the ICSS. Refer to [GS EP INS 134](#).

It aims at reproducing in a sequential, systematic and ideal way the well control operation.

It ensures the transition of the well from a closed state to a stable production state, in which it makes it possible to continuously ensure an optimal oil flow rate, while taking into account the reservoir constraints, the installation's capacities or the well's reactivity.

The data issued from various sensors are treated by **FCW**, which acts on different actuators according to preset parameters.

FCW is a control tool; because of that, and according to [GS EP SAF 261](#), it does not interfere with safety logics. Moreover it will be 'realigned' according to the different safety trip levels.

FCW exists for different types of well and for different means of activation: **naturally flowing, gas-lifted, ESP, PCP**. Several control algorithms are also adapted to gas injection and water injection.

1.2 Purpose of this General Specification

To provide a generic document introducing the **FCW** general and technical descriptions in all its allowed forms and to allow for each **FCW** project:

- The drafting of the **FCW** scope of work, specific to each project, in order to realize the functional analysis that will be given to the integrator.
- The definition of instrumentation and system requirements for the basic engineering.

The chapter « general technical specification » (cf. §3) deals with the implementation measures and principles to take into account in the scope of work.

The chapter "implementation" (cf. §4) deals with the requirements in terms of instrumentation, control system architecture, and the user interface to develop.

1.3 Application

This General Specification, for the **FCW** system implementation, is applicable to new developments and also to sites that are already producing. In either case, the purpose of the **FCW** system is to improve the control and the production of the installation.

The **FCW** system can be deployed on sites (offshore or onshore) producing oil, dry gas, or condensate, and whatever the site topology.

FCW can also be installed to optimize injection on several injector wells.

The **OCWR** (Overall Control of Wells and Risers) is the production optimization system for subsea production fields and is covered by the [GS EP EXP 137](#).

This document only describes the more common **FCW** applications. However, variants can be implemented to satisfy specific requirements of a given site.

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2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
Not applicable	

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP EXP 131	Design and installation of Process Data Server
GS EP EXP 137	OCWR specifications
GS EP INS 134	Design and supply of integrated control and safety system
GS EP INS 197	Process Standard Functions
GS EP SAF 226	Completed wells safety systems and safety rules
GS EP SAF 261	Emergency Shutdown and Emergency De-Pressurisation (ESD & EDP)

2.1 Abréviations

AHFR	Annulus Head Flow Rate (ESP)
AHP	Annulus Head Pressure
AMV	Annulus Master Valve
APCV	Annulus Pressure Control Valve (ESP)
BRS	Back Rotor Spinning (ESP)
BSW	Basic Sediment and Water
CCR	Central Control Room
CPU	Central Processing Unit
CTBP	Coiled Tubing Bottom Pressure
CTHP	Coiled Tubing Head Pressure
DCS	Distributed Control System
DHP	Down Hole Pressure
DHSV	Down Hole Safety Valve
DHT	Down Hole Temperature

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ESD	Emergency Shut Down System
ESD-0	Total Black Shut Down
ESD-1	Fire & Gas Emergency Shut Down
ESDV	Emergency Shut Down Valve
ESP	Electrical Submersible Pump (activation)
FCW	Full Control Of Wells
FGS	Fire and Gas System
FLP	Flow Line Pressure (downstream of production choke)
GL	Gas-Lift
GLFCV	Gas-Lift Flow Control Valve
GLFR	Gas-Lift Flow Rate (PID loop controller)
GLP	Gas-Lift Pressure (header)
GLR	Gas Liquid Ratio = Gas production / Oil + Water production
GLT	Gas-Lift Temperature (header)
GOR	Gas Oil Ratio = Gas production / Oil production
GTS	Gathering & Testing Station
HIPPS	High Integrity Pressure Protection System
HMI	Human Machine Interface
ICSS	Integrated Control and Safety System
PI	Productivity Index
IT	Intensity Transmitter (of a VSD)
MFM	Multi Flow Meter
MTTR	Mean Time To Repair
PCS	Process Control System
PDMS	Process Data Management System
PCP	Progressive Cavity Pump
PID	Proportional, Integral, Derivative
PSS	Process Safety System
PWV	Production Wing Valve
RCV	Production choke
ROV	Remote Operated Valve
RZT	Choke Position Transmitter
SD	Process ShutDown Shut Down
SD-2	Shut Down level 2
SD-3	Shut Down level 3
SDV	Shut Down Valve
SIL	Safety Integrity Level
SSV or UMV	Surface Safety Valve or Upper Master Valve
ST	Speed transmitter (of a VSD)
THDP	Tubing Head Delta Pressure
THP	Tubing Head Pressure

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THT	Tubing Head Temperature
TPS	Temporary Production Stop (FCW)
VSD	Variable Speed Drive
WHSIP	Wellhead shut-in pressure Shut-In-Pressure

2.2 Terminology

No-flowing well: Well that does not produce without activation. A well is considered to be "no-flowing" if no liquid or gas flow is observed on the surface after the activation system has been stopped, the tubing head pressure having been restored to atmospheric pressure and the well production having been stabilized beforehand.

Naturally flowing well: Wells that do not satisfy the "No-flowing well" criteria above are classed as "Naturally flowing".

Oil well: Well producing with a **GLR** lower than 500 (vol/vol).

Gas well: Well producing with a **GLR** higher than 500 (vol/vol).

Injection well: Well flowing from surface installations into the reservoir.

Production system: Set of production wells, producing on a same separation train or a same header. In most cases it is a satellite platform, a cluster or a "Gathering station".

Separation system: Liquids treatment in the production separators.

Gas evacuation system: Production gas treatment chain, toward the flare and the injection or export systems.

Gas-lift production system: Set of compressors, gas production wells and treatments ensuring the supply of the gas for GL activation.

Module: Software object implemented into the PCS and based on algorithmic, sequential or continuous functions that ensure the control of a process unit. In case of identical units the module can be duplicated as many times as needed.

Monowell: Module ensuring individual well management according to specific optimisation criteria.

Multiwell: Module ensuring the optimisation of production of a set of Monowells producing toward a same production system, by active monitoring of defined 'Process limitations'.

Multifield: Module ensuring the optimisation of production of a set of Multiwells producing toward a same central process system, by active monitoring of defined 'Process limitations' of the central process system.

Well testing: Module managing the automatic calculation of wells in test.

Monowell parameters: Set of readable and adjustable values that permit to adapt the FCW algorithm to each real well characteristic. These parameters are set points, thresholds, delays, limits...

Short Stop: When the well is stopped, the "short stop" is defined according to time and head temperature criteria. Short stop allows a faster well restart, and the possible use of a faster ramp up.

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Opening up: Control of the On/Off production valves or control of the reopening action of the valves if previously closed by **FCW**.

Process limitation: Specific process constraints on topside systems (separation, gas evacuation or gas-lift production...) which can lead to a safety trip if wells production is not temporary or permanently adjusted accordingly.

Load shedding: Strategy that is defined for Multiwell and Multifield. For Multiwell, it consists in reduction of either the gas lift consumption or reduction of the well production (or both). It is initiated by the Multiwell control module that is permanently monitoring the defined 'process limitations' to avoid a safety trip of the process, and so to minimize the production shortfalls. Two kinds of load shedding actions are identified:

- Partial = reduced production without stopping of wells.
- Total = closing of wells.

For Multifield, it will optimise the production of the field depending on the evolution of defined Process limitations of the central process system.

Different load shedding strategies can be defined.

Strategy table: table of readable and adjustable values (ranks, delays...) which permits to adapt Multiwell start-up and load shedding orders that are sent to the Monowells. Strategy tables are also defined to adapt Multifield start-up and load shedding orders that are sent to the Multiwells.

3. FCW general technical specification

3.1 FCW General Representation

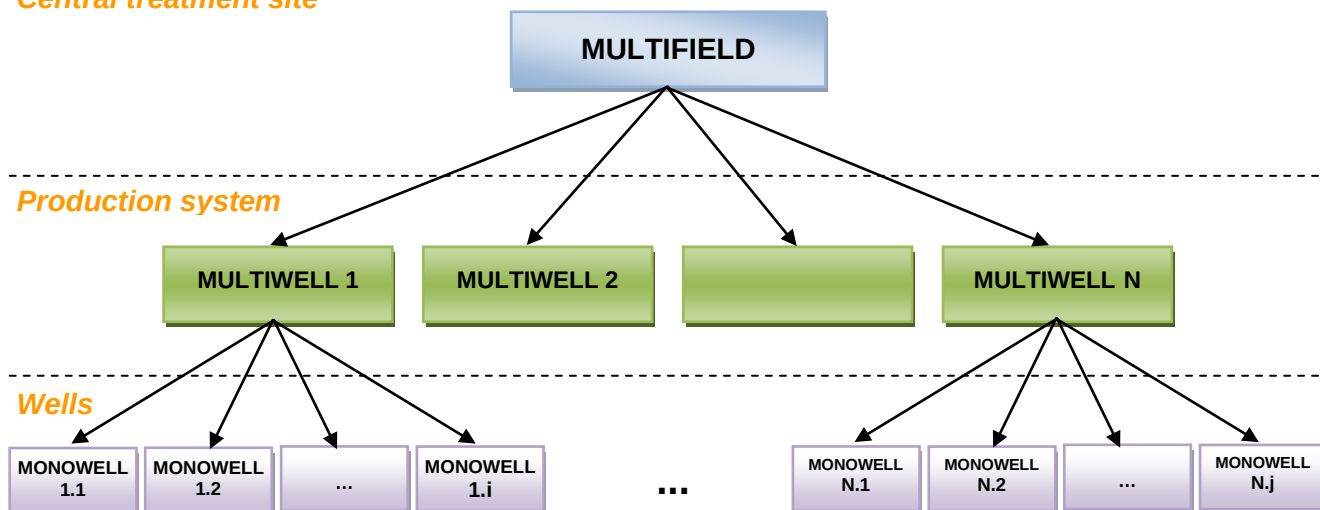
3.1.1 FCW Modules

FCW can have up to three different control levels:

- Monowell.
- Multiwell.
- Multifield.

These modules can be presented as follows:

Central treatment site



3.1.2 Monowell module

- The well is individually managed according to its own optimization criteria. It is independent from the separation / treatment system and of the gas-lift production / distribution system.
- Control valve commands and frequency set points are under **FCW** control. **PID** controllers are used in cascade and the operator cannot access individually to the valve commands or the set points.
- In Monowell control mode, the start-up order for each well is given by the control room operator on the well view. Once the order is given, the start-up stage is an automatic operation.

3.1.3 Multiwell module

- Wells are managed not only according to their own optimization criteria, but also and in priority according to treatment system or gas-lift production process limitations.
- The Multiwell general start-up order is given by the operator. Once given, Multiwell will tend to optimize production according to process status. Therefore, it will refer to the Multiwell start up table to send start up orders to Monowells while respecting ranks and delays as defined in this table.
- The Multiwell control module continuously monitors the process limitations and according to predefined scenario (quick level or pressure increase in a separator or in an export pipe) applies a liquid or gas production reduction strategy. The aim of this action is to prevent safety trips and so to avoid associated production shortfalls.
- For the gas-lifted wells, the Multiwell control module continuously monitors gas-lift availability. In case of a gas-lift network pressure decrease, it applies a consumption reduction strategy leading in priority to the closure of the less productive wells (high

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BSW). The aim of this action is to prevent a destabilization of all the wells requiring gas-lift supply.

- A well that was in Multiwell mode and has been stopped by a production system common stop (**TPS**, **SD-2** or higher) will stay in this mode in order to be restarted automatically.
- For each well, the control room operator has to select a production mode (Monowell or Multiwell). This choice can be done after well restart. Multiwell mode is the recommended mode for an optimization of the production. Monowell mode will be selected on specific occasions, during well test for example as the well must remain at a stabilized production target.

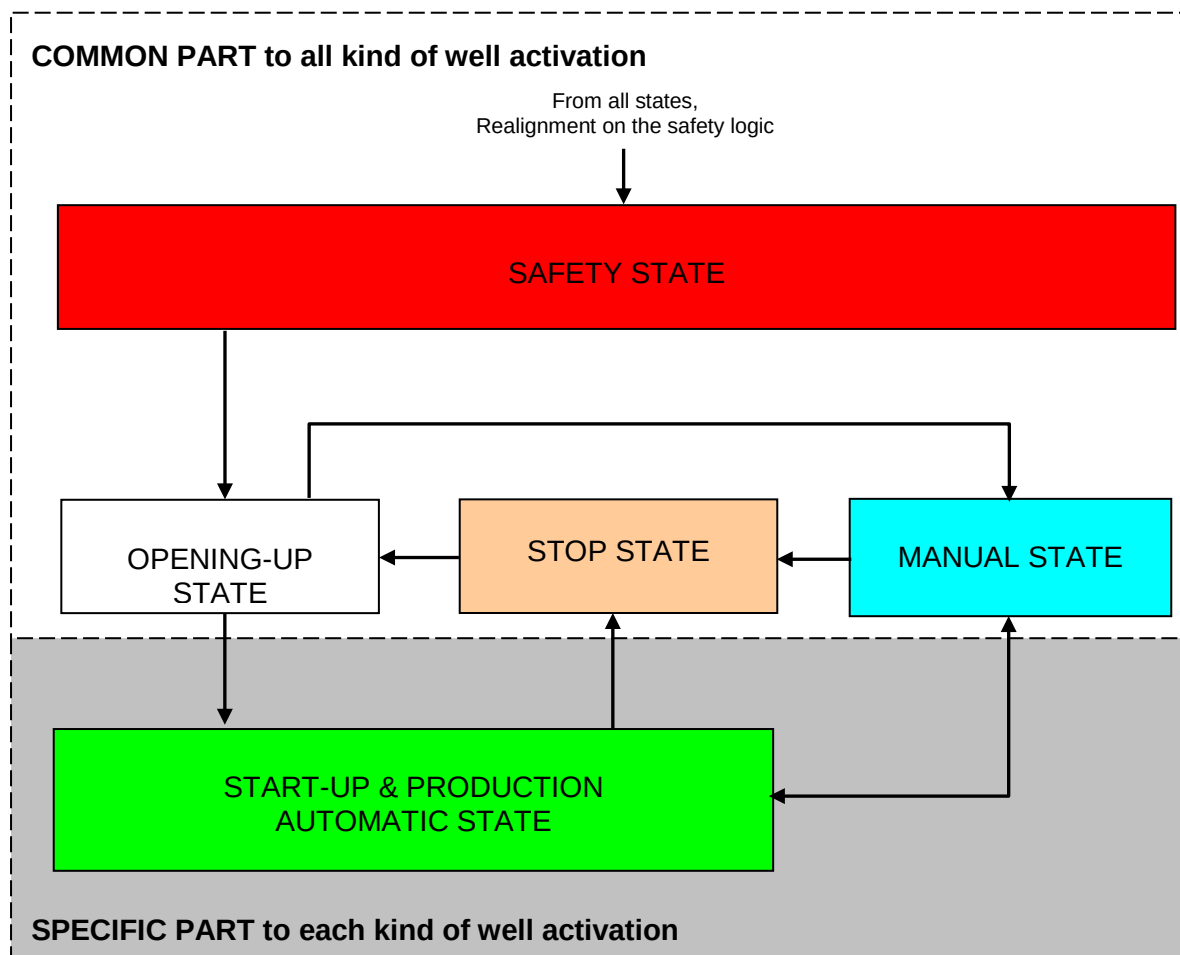
3.1.4 Multifield module

- Multifield control module only acts on wells that are switched in Multiwell control mode.
- Multifield control module manages the central treatment system process limitations, such as water treatment or flared gas...
- The Multifield control module continuously monitors the production and evacuation systems process limitations and according to predefined scenarios (high flaring, saturated water treatment), it applies a strategy to reduce the flow (or close) of selected wells.
- To ensure the uniqueness of the orders sent to the wells, the Multifield control module cannot directly act on the wells, but it does act on the Multiwell control modules required strategies.

3.2 MONOWELL module

Monowell module includes different states that are linked together in a specific sequence.

3.2.1 Wells main control sequences



COMMON PART: states are similar for all kind of well activation.

SPECIFIC PART: states are specific for one kind of well activation.

3.2.2 Common part

3.2.2.1 Safety state

Refer to **GS EP SAF 226** for well safety management:

- Safety logics and the associated safety valves are managed by **ESD**, **PSS** and **FGS** and are **out of FCW**. Safety logics always have priority over **FCW**.
- In accordance with **GS EP SAF 261**, **PWV** and **SDV** are safety valves that may be remotely controlled by **FCW** if fitted with an additional specific solenoid independent from the safety trip circuits. This is to prevent a spurious reopening of these valves upon safety bar reset. In this case, the reopening of **PWV** and **SDV** is automatically managed by the **FCW** when the operator wants to restart the well.

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- **DHSV** and **SSV (or UMV)** safety valve position feedbacks are required by the **FCW** in order to manage the valves opening sequence during start-up.
- For **ESP** and **PCP**, the variable speed drive is equipped with safety shutdown command, managed by the **PSS**, and with a start/stop control command, managed by the **FCW**.

The Safety state is a realignment of the **FCW** sequence in case of safety trip.

When the safety bar of the well is tripped, **FCW** will immediately close control valves (**RCV**, **GLFCV**) and **PWV** and **SDV** (if fitted with a specific additional solenoid).

- Variable speed drives are stopped by the **FCW** using their “stop” control command.

3.2.2.2 Opening-up state

- This state is active after safety bars reset.
- The external operator reopens the **SSV** and - if needed - the **DHSV** at the well control panel.

FCW keeps the control valves closed, the control solenoid valves of the **SDV** and **PWV** closed and the variable speed drive control command on “stop”.

3.2.2.3 Manual state

- In most cases, this state is reserved for special operations (wire line servicing, safety valve leak testing, maintenance, etc...), or in case of dysfunction of the **ICSS** or of the instrumentation.
- As soon as the safety bars have been reset Manual control mode can always be activated by the operator.
- In this mode the operator can access all the control valve commands or all the frequency set points managed by the **FCW**, without any restriction. **PID** controllers can be operated either in **AUTO** or **MANU**.
- Safety logics are still active and they still have priority.
- Well can be switched back by the operator in Monowell control mode when in production state, on condition that valve configuration is consistent with the one required by **FCW** in this state, i.e. Safety valve actuators opened and control valves inside their adjustment ranges.

3.2.2.4 STOP state

- **FCW** includes a control Stop function implemented in the **PCS**. This is not a safety stop. It allows:
 - A smooth stop of the well when it is planned and preceded by a progressive closing of the chokes. This kind of stop is activated by the **Planned Stop** command (see §3.2.4).
 - A “clean and quick” stop of the well either when a well dysfunction is detected or when the operator wants to quickly stop the well. This kind of stop is activated by the **Stop** command (see §3.2.4).
- In both cases, **PWV** and **SDV** are closed last, after a temporization.

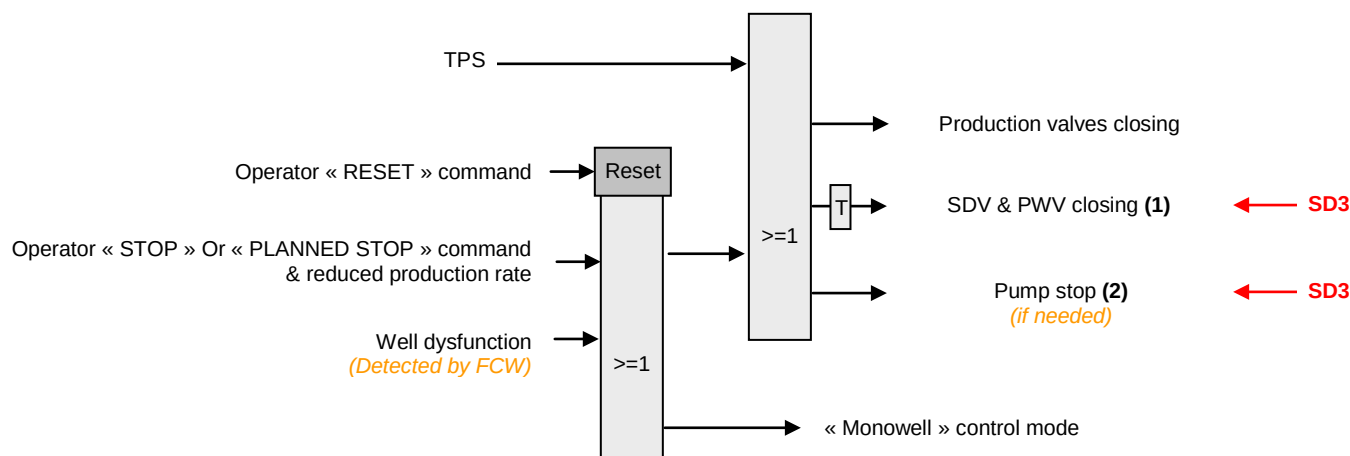
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- **FCW control STOP** function includes a **RESET** command in order to acknowledge it before start-up.



(1) Specific solenoid for control actions

(2) start/stop control command

3.2.3 Specific part

Start-up and production state:

Start-up state, the well is started by an operator order on the well DCS view that immediately opens the control solenoid valves of the **PWV** and **SDV**, activates the “start” command of the variable speed drive and directly launches the start-up phases.

Start-up sequences are different according to the different kind of activation but they have the same goal: to bring the well from a stop state to a stable (but not already optimized) production state.

Production states are different according to the different kind of activation. The aim of the production state is to reach a stable and optimized production target.

3.2.3.1 Naturally flowing wells specific part

Monowell control algorithm for naturally flowing wells is characterized by:

- A production target that can be estimated by one of the following means: a wellhead pressure, a delta-P measurement on the choke or a wellhead temperature or a bottom delta-P.
- A strict control of pressure variations (head & bottom) for the well bore formation interface and downstream installation protection during start-up and production.
- A slower start-up ramp-up that can last several hours according to the stop duration, the kind of well bore formation interface and the wellhead pressure variation.
- A stop following ramp-down, when programmed (different from the safety cases).

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- The possible regulation of a methanol injection valve upstream of the choke according to the upstream choke temperature in order to prevent hydrate formation.

Multiwell algorithm includes:

- A choke opening pause (of one or several wells) according to selected parameters on the separation/treatment system.

A production load shedding in two stages, partial and total, with a different strategy for the gas network and the oil system.

3.2.3.2 Gas-lifted wells specific part

Monowell algorithm for gas-lifted wells specificities:

- A single modification of well settings permits the algorithms to take into account the evolution of well life (1).
- Two kinds of start-up are possible: **Closed** (production choke is closed during the casing compression phase) and **Opened** (production choke is opened and tubing decompression is performed in parallel with casing compression) (2).
- Production flow rate can be estimated according to the wellhead temperature or the delta-P on the choke or the Down Hole Pressure (**DHP**). Gas-lift flow rate is estimated according to casing pressure gradient.
- Possibility to manage a short stop that allows a quick return to the previous production settings without going through some of the long start-up phases.
- During production stage: continuous optimization of the injected gas over production liquid rate ratio, at the same time maintaining well stability.
- A possible chemical injection valve regulation according to well state.

Multiwell algorithm includes (3):

- The possibility to boost the well by injecting more GL in case of gas-lift excess.
- Gas load shedding in case gas-lift is no more available.

(1) Three kinds of exploitation modes are accessible via the parameters setting:

Naturally flowing (without gas-lift), the well does not need GL - neither to start nor to get a steady maximum production.

Activated (by gas-lift), gas-lift injection is necessary both for start-up and production.

Specific or Unusual Gas Lift, are included in this type:

- Wells that are able to start without assistance (in order to deliver low pressure gas to the compressors) but that need gas-lift for a nominal production.
- Wells that need low casing pressure for start-up and production.
- Semi eruptive wells that need gas-lift injection for start-up but are able to produce without it.

(2) "Closed" start-up allows a high casing compression before start-up. In "opened" start-up, gas-lift injection and well start-up are performed in parallel.

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(3) Some functions of the Monowell algorithm are only activated when the well is in the Monowell mode.

Double string wells specific case

A module is dedicated to double completion gas-lifted wells with a production by the two strings.

For this kind of application, each string is independent; each one is managed by one **FCW** gas-lifted Monowell module that is linked with a double completion **FCW** module that ensures:

- Sequence synchronization between each string.
- Automatic start-up of both strings.
- Gas-lift flow rate set point calculation according to each string requirement.

Interface with Multiwell module to ensure the consistency of the start-up or load shedding orders for each string.

Coiled tubing specific case

This module is dedicated to wells that are activated by coiled tubing which is a specific application of gas-lifted wells. In this application the gas-lift is directly injected at the bottom of the well through a small pipe located inside the tubing.

A Coiled Tubing Bottom Pressure (**CTBP**) is calculated according to the Coiled Tubing Head Pressure (**CTHP**) and the **GLFR** taking into account the gas column weight and the friction losses. This **CTBP** is related to the **DHP** and production flow rate can be estimated according to the **CTBP**.

The production target can be a well head temperature, a production flow rate, dual (**WHT** and production flow rate) or the **CTBP**.

3.2.3.3 ESP wells specific part

Monowell algorithm for **ESP** wells has the following specificities:

- Both naturally flowing phase and the ESP activated phase of the well can be managed. During well start-up, the FCW checks if the well is able to produce in naturally flowing mode (detection of a head temperature increase during tubing decompression) or if ESP activation is needed. During production, FCW is able to automatically switch the well to naturally flowing mode.
- According to the hardware configuration and the operator choice, the production target can be a pump frequency, a choke opening, the intake pressure or the wellhead temperature.
- The Monowell module mainly performs actions on the produced gas APCV, the "Start/Stop" command of the pump, the variable speed drive frequency set point and the PWV and AWW valves commands.
- Management of the variable speed drive set point is performed through speed-up and slow-down ramps. The frequency set point is calculated according to the selected production target and limiters state.
- Continuous monitoring of motor intensity consumption which is a stability criterion for the pump.

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- The more usual electrical limitations are taken into account: a limitation of the number of start-ups in the same hour, minimum time duration between two start-ups and back spin monitoring. Values given by the motor manufacturer are used for the setting.
- Vibrations measurements according to 3 axes X, Y, Z (and X', Y' and Z' if two sensors are available), intensity, wellhead pressure, motor temperature, Delta P across the RCV, annular gas flow, Bottom Hole Pressure and submergence level are used as motor speed limitations.
- Well bore formation interface is protected by minimizing fast pressure variations during decompression steps at start-up.
- Production flow rate is estimated using the bottom pressure and the PI of the well.
- A possible chemical injection valve regulation according to well state.

3.2.3.4 PCP wells specific part

Monowell algorithm for **PCP** wells has the following specificities:

- Production target can be either a fix speed or a wellhead temperature or a pump suction pressure or a submersion level.
- Management of the variable speed drive set point through speed-up and slow-down ramps.
- Continuous monitoring of the torque, the head pressure, the bottom pressure and the submergence level in order to ensure that the pump is kept in its working range.
- Start-up sequence process parameters checking.
- The more usual electrical limitations are taken into account: a limitation of the number of start-ups in the same hour, minimum time duration between two start-ups and back spin monitoring. Values given by the motor manufacturer are used for the setting.
- Vibrations measurements according to 3 axes X, Y, Z (and X', Y' and Z' if two sensors are available), are used as motor speed limitations.
- Production flow rate is estimated by using either the wellhead temperature or the motor speed or the bottom pressure and the PI of the well.
- A possible chemical injection valve regulation with injected flow rate optimization.

3.2.3.5 Operator commands

Preliminary notes

Command buttons are accessible from the control workstations.

Command button backgrounds shall be grayed-out on the **HMI** if they are not accessible.

« ON » command button

- In Monowell mode this command button initiates the well start-up sequence commencing with the opening of the PWV and gas-lift SDV.

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- In Multiwell mode this command button is not accessible to the operator. Start up order is sent by the Multiwell control module to each Monowell according to the Multiwell start up table.

« AUTO » command button

In Manual mode, the « **AUTO** » command button permit to switch the well in Monowell mode on condition that the well is already in a production state and the transition does not immediately affect actuators. i.e.: **PWV**, **SDV** opened, choke, gas-lift setting or frequency setting shall be in the Low-High range defined in the Monowell parameters.

« PLANNED STOP » and/or « STOP » command buttons

- These command buttons are always accessible whatever the control mode;
- « **PLANNED STOP** » command button allows a smooth stop of naturally flowing well by progressively closing the choke before activating the **FCW-STOP** function;
- « **STOP** » command button allows a “clean and quick” stop of the well by activating the **FCW-STOP** function. In case of **ESP** or **PCP** activated well the pump speed is progressively reduced;
- Well restart is possible after **FCW-STOP** function reset.

« MANUAL » command button:

Accessible as soon as the safety bars have been reset, this command button allows the operator to access the manual control mode from the operator workstation.

« MONOWELL » command button:

When in Multiwell, it allows the operator to switch the control mode to Monowell. Hence, the well is disconnected from the Multiwell logics.

« MULTIWELL » command button:

Allows the operator to switch control mode from Monowell to Multiwell. This command button is only accessible after the start-up of a well.

3.2.4 Settings of the Monowell module

The Monowell module includes around 50 parameters per gas-lifted well (15 for a naturally flowing well and 58 for **ESP** activated well) that can be gathered according to their types:

General parameters define the production mode, the type of start-up...

Delays in minutes or seconds.

Process values thresholds in physical units.

Set points and limits in physical units.

Coefficients, used for value calculations (flow rate, submersion level ...).

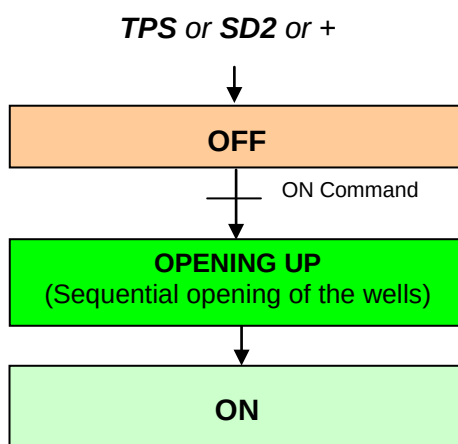
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3.3 MULTIWELL module

Multiwell algorithm includes:

- Management of all the types of wells (**naturally flowing, gas-lift, ESP and PCP**) on the same production system.
- Automatic start-up of all the wells according to a predefined ranking and delay without any intervention of the operator.
- Implementation of several predefined and user controlled strategies that are suited to each type of Process limitation (treatment or evacuation system saturation, shortage on the activation system). Depending on the type of Process limitation, it will initiate appropriate load shedding actions

3.3.1 Multiwell system main sequences



OFF

- Required production system stop following a safety trip or a **TPS**.
- After safety bars reset, the Multiwell state stays “OFF” until the operator sets the “ON” command.
- When the Multiwell state is “OFF”, it is impossible to start a well in Monowell mode. However switching this well to Manual mode and starting it is possible.

OPENING-UP

In this state, the control valves of wells under Multiwell control are reopened. This operation is performed sequentially, well by well, to limit hydraulic or pneumatic supply system requests.

ON

- Running state of the Multiwell system.
- Wells of the production system can be either in manual or Monowell or Multiwell mode. The Multiwell module only manages the wells that are in Multiwell mode.

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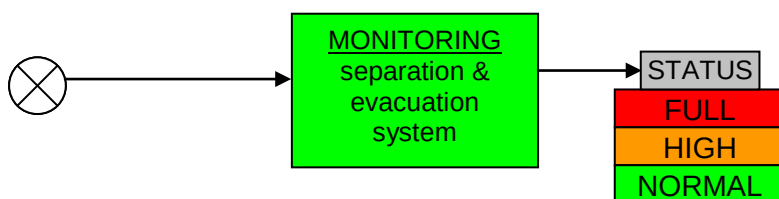
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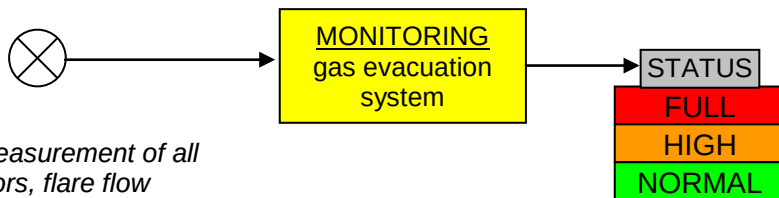
- As long as none of the process limitations are activated, the Multiwell module refers to the ranking of each Monowell in the start up table and sends start up orders accordingly. When receiving the start up order, each Monowell starts assigned well until reaching defined production target.

3.3.2 Multiwell monitoring systems

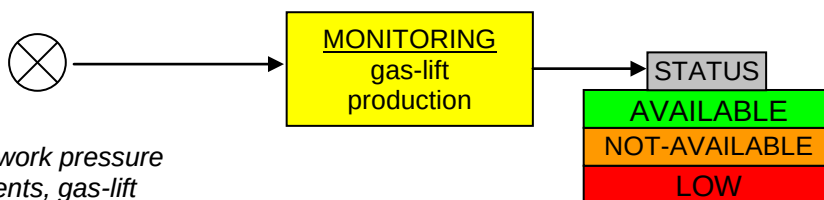
Systems monitoring



Oil (and interface) levels of all the separators, expedition pressure.



Pressure measurement of all the separators, flare flow rates, HP compressors state



Gas-lift network pressure measurements, gas-lift compressors state

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3.3.3 TPS (Temporary Production Stop) Function

TPS function performs a preventive temporary stop of a production system upon external causes in order to ensure a smooth remote restart of unmanned sites. It is not a safety function. **TPS** only closes control valves.

As for Multiwell load shedding operations, this function reduces the production loss (preventive stop of control valves by the **FCW**). **TPS** is active whatever the well control mode is.

The more usual **TPS** activation causes are the following:

- Downstream platform **SD2**.
- Electrical power loss (load shedding).
- Operator command.

3.3.4 Operator commands

Preliminary note: Wells managed in Multiwell mode are the only ones concerned.

« ON » command button

- This command button ensures wells restart.
 - Wells are started-up in two phases:
 1. reopening in sequence of the opening-up valves (**PWV** & **SDV**) of all the wells (1);
 2. start-up well by well in accordance with the strategy table that defines the wells rank and timing.
- (1) Valve opening orders are scheduled in order to take into account possible hydraulic / pneumatic limitations. In case of a bad opening of a valve during start-up, the sequence goes back into the STOP state.

« Process limitations activation » command button

Process limitations of the Multiwell can be temporarily disabled individually by an operator command in order to prevent load shedding actions according to this process limitation.

3.3.5 Settings

The Multiwell module manages around 12 parameters per gas-lifted well (10 for a naturally flowing well and 8 for **ESP** activated well) organized in a strategy table and two thresholds per process limitation.

They are gathered according to their type:

- Ranks define each well start-up and load shedding priority.
- Timers, in minutes; allow a time scheduling of the start-up and load shedding.
- Levels, compared with measurements: permit to define process limitations status.

For gas-lifted wells start-up and load shedding thresholds on GL network pressure condition the associated actions.

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3.4 MULTIFIELD module

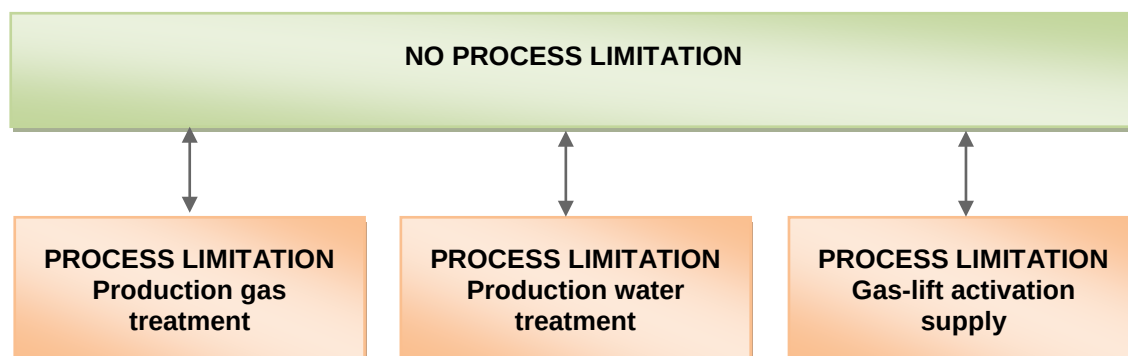
Multifield module monitors the process limitations of the central processing unit that manages several platforms or several production stations.

Multiwell algorithm includes:

- Monitoring of the identified process limitations that in most cases are:
 - Associated gas evacuation system: flare, injection, export.
 - Gas-lift General network : compressors pressure and status, when several production systems are using the same network (meshed network).
 - Oil treatment system on the central platform.
 - Production water treatment and evacuation system on the central platform.
 - General export from the central platform.
- Management of all the types of wells (**naturally flowing**, **gas-lift**, **ESP** and **PCP**), on several production systems.

Implementation of predefined and user controlled strategies that are suited to each kind of constraint.

3.4.1 Multifield system main sequence



No process limitations

- The Multifield module allows the Multiwell and Monowell modules of each production system reach their production targets.

“Production gas treatment” process limitation

- The Multifield module initiates the Multiwell module gas load shedding strategy for a predefined production system.

“Production water treatment” process limitation

- The Multifield module initiates the Multiwell module liquid load shedding strategy for a predefined production system.

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“Gas-lift activation supply” process limitation

- The Multifield module initiates the Multiwell module gas-lift load shedding strategy for a predefined production system.
- Multifield does not include an electrical load shedding (not used today).

3.5 Well testing module

The well testing module automatically launches a counting sequence for a well for a predefined duration.

Although this function is not an optimization function, it is usually included in the **FCW**. Indeed, the data issued from the counting makes it possible to improve well knowledge and so improve well control and production.

This chapter describes the minimum requirements for well testing.

Separator arrangement and well routing

- If the manifold routing valves of the well are remote controlled, the sequence ensures the automatic routing of the well on the test header.
- After well routing, the sequence waits for a minimum stabilization delay, not only to evacuate the previously tested well effluents but also to allow the stabilization of the separator temperature.
- During active counting phase, the algorithm calculates the mean value of each measurement and the cumulated flow rates.
- During the whole test procedure, the operator can reset the counters or stop the well test.

Results recording

- Results are available and automatically transferred to the **PDS**. All the results are recorded, whatever the cause of the test end. Then, it is the operator’s responsibility to validate the test or not.

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Test results table

Process	Measurement	Notes	Treatment
Well	THP		Moving average during the test.
	THT		
	AHP		
	RCV position		
	DHP	If transducer present	
	DHT		
	AHFR	ESP well	
	IT / ST	Intensity, frequency for ESP well	
	FLP		
	GLFR	GL well	Cumulated flow rate GS EP INS 197
Separator	Separator pressure		Moving average during the test.
	Separator temperature		
	Gas flow rate		Corrected and cumulated flow rate GS EP INS 197
	Hydrated oil temperature	According to the type of transducers used for liquid flow rate measurement	BSW, GOR calculation
	Hydrated oil flow rate		
	Dry oil flow rate		
	Water flow rate		
Calculations	Test duration	HH/MM/SS	Real time test duration calculation
	Start	YY/MM/DD HH/MM/SS	Test starting hour
	End	YY/MM/DD HH/MM/SS	Test ending hour

3.6 FCW control interface – HMI

3.6.1 FCW displays list

The following table gives a summary of the control and supervision displays with **FCW** or without **FCW**.

Important preliminary notes

The number of displays is given as an indication and can be modified according to the supervision control capabilities.

The “1/12” symbol means that a maximum number of 12 wells can be used on the display.

The “N” symbol means the number of wells in a Multiwell.

The “P” symbol means the number of Multiwell (platform) in a Multifield.

The “L” symbol means the number of load shedding system existing on the platform.

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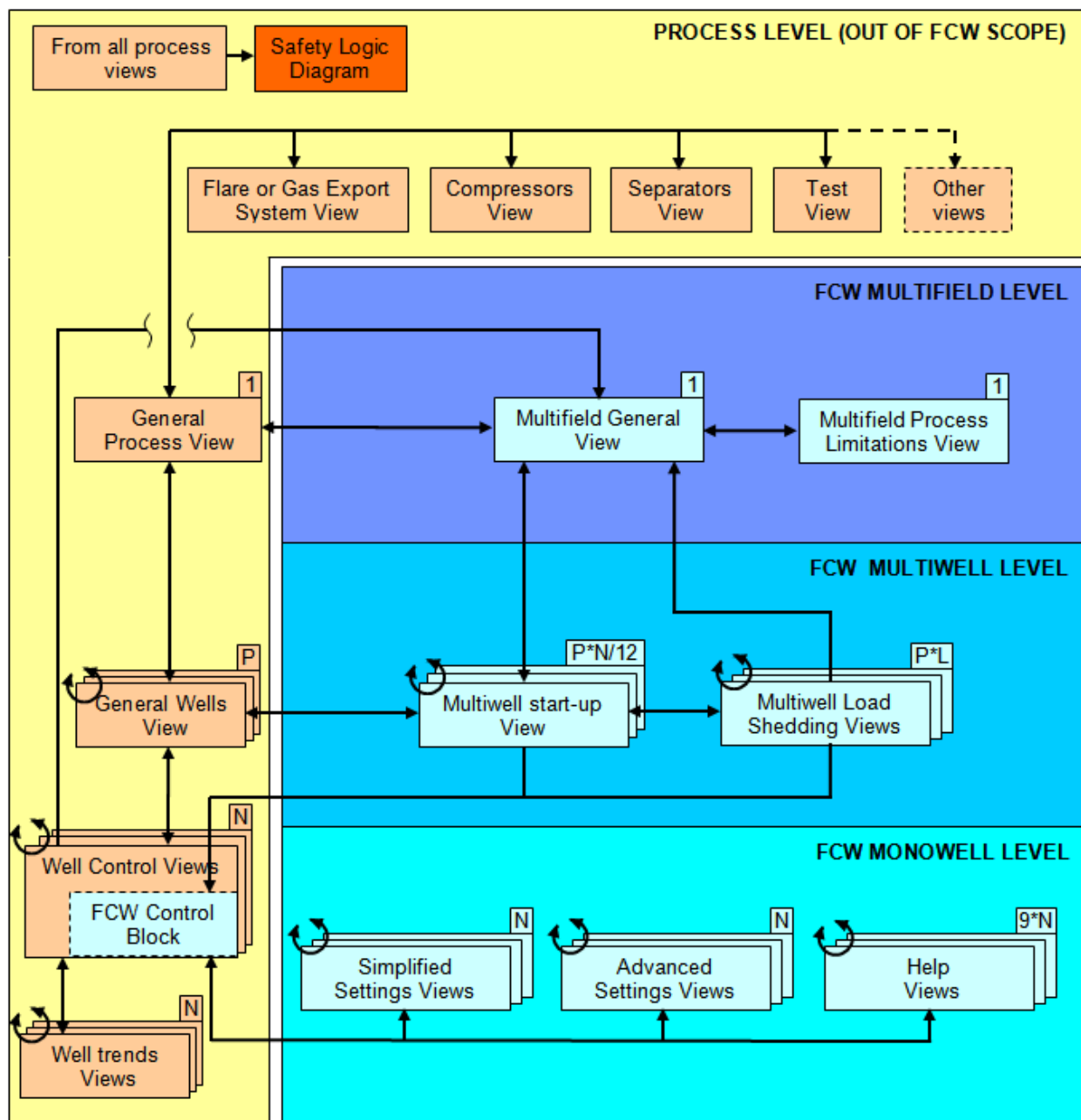
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Module	Display name	Description	With FCW	Without FCW
MULTIFIELD	Multifield general view	Process limitation strategy monitoring	1	0
	Multifield process limitations	Parameters setting for the field process limitations	1	0
MULTIWELL	Well general	Summarized table with all the wells measurements and status.	P	P
	Start-up	Priority start-up table and timers between each start-up.	P*N/12	0
	Load shedding	Priority load shedding table and timers between each load shedding.	P*L	0
MONOWELL	Well control	Well process and logigram	N	N
		FCW control block	N	0
	simplified settings	Well parameter setting	N	0
	Advanced settings	Advanced well parameter setting	N	0
	Help	Animated sequence view	9*N	0
	Trend	8 measurements in trends $Y=f(T)$	0	N
WELL TEST (1)	Separator process	Separator process view	1	1
	Last test results	Tests parameter setting and test launching view. Allows the real time monitoring of the results.	1	1
	Test historical	Table of the last test results for each well	1 or 2	1 or 2

(1) Well test is usually included in FCW but can also be present out of FCW.

3.6.2 FCW Displays architecture

The following architecture diagram gives a general view of the required displays for wells control under **FCW** and how to navigate between the different displays.



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N= number of well; P= number of platforms (Multiwells); L= number of load shedding systems.

3.6.3 Access levels

Different access levels are defined in [GS EP INS 134](#).

For **FCW** displays variables and as per [GS EP INS 134](#), three levels of access are required:

- **Visitor:** No accessible command.
- **Operator:** Normal process control and safety reset.
- **Maintenance/ Method / Engineer:** First level of intervention, Process parameters modifications, all system modifications including system configuration modifications.

The associated access levels are listed in the following table.

Level	Type of variable	Access levels according to GS EP INS 134		
		Visitor	Operator	Maintenance / Method / Engineer
MONOWELL	Operator commands		X	X
	Generic parameters			X
	Timers			X
	Process thresholds			X
	Divers Settings			X
	Coefficients		X	X
	Production targets		X	X
MULTIWELL	Operator commands		X	X
	Process thresholds			X
	Strategy table parameters			X
	Timers			X
MULTIFIELD	Process thresholds			X
	Strategy table parameters			X
	Timers			X

Legend: () read only access.

(X) read and write access.

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4. FCW implementation

4.1 Instrumentation

4.1.1 Well instrumentation

4.1.1.1 Sensors and actuators table

Location	Instrument	Instrument requirement according to the means of activation			
		Naturally flowing	Gas-lift	ESP	PCP
Completion	DHP		Suitable	R	R
	DHT			R	R
Production	THP	R	R	R	R
	THDP	Suitable (1)			N/A
	THT	R	R	R	R
	Production RCV	R	R	R	N/A
	RZT	R	R	R	N/A
Annulus	AHP		R	R	R
	AHFR		N/A	R	
	APCV		N/A	R	
Gas-Lift Activation	GLFR	N/A	R	N/A	N/A
	GLFCV		R		
	GLP		R		
Pump Activation	Vibration	N/A	N/A	R	R
	IT / ST			R	R
	BRS			R	R

Legend:

R = Required by FCW

N/A = not applicable

Nothing = Not required by FCW

Notes:

(1) For a cold well, the only means to estimate the production flow rate is the delta pressure and the position of the **production RCV**. In this case, these sensors become essential.

4.1.1.2 Interface with safety actuators

Actuators	Interface with FCW Monowell	Position status
DHSV	Valve position status shall be sent to FCW. It is estimated through service line pressure.	Optional
SSV	Valve position status shall be sent to FCW. It is estimated either through magnetic limit switches or through service line pressure. Because of vibrations and hostile environment, mechanical feedbacks shall be avoided.	R
PWV	Valve control circuit shall be fitted with a specific solenoid independent from the safety trip circuits in order allow FCW to remotely control it (please refer to GS EP SAF 261 , § 7.1.1.1.) Valve position status shall be sent to FCW as described above.	R
Annulus SDV	Same as above	R

Legend:

R = Re

4.1.1.3 Recommendation for instruments

In a general way, and for all the **FCW** modules (Monowell, Multiwell, Multifield) the instruments that are used by **FCW** will be distinct from safety ones.

Particular recommendations table

The precision of the instruments shall be + / - 0.5 %.

For the instruments that are not mentioned in the following table, there are no particular recommendations for **FCW**.

Instrument	Comment or particular recommendation
DHP	A very high resolution is required to follow reservoir evolutions
DHT	
THP	Relative pressure. It should be able to measure wellhead shut in pressure
THDP	Differential pressure. It should be able to accept wellhead shut in pressure

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THT	Temperature sensor PT100 (immersion into the fluid).
ProductionRCV / RZT	The choke valve is motorized (hydraulic, pneumatic or electric). It shall be equipped with a feedback device. Valve servomotor precision and repeatability shall be at least equal to 1%. For a step by step servo positioner, a good compromise should be applied between resolution and speed. This is only possible after an analysis of the application. As far as possible, the valve should be fail safe close, contrary to step by step systems that shall be fail safe as is. A not reliable choke servo positioner can make FCW inoperable.
GLFR	Orifice or vortex. Flow measurement is corrected.
GLFCV	Flow control valve, motorised, adjustable CV, fail safe close.
ESP	Equipped with a variable speed drive that is controlled by the PCS. Receives speed set point and START / STOP commands. Sends the following data: speed, intensity, faults, BRS. In some cases, the motor cable allows a transmission of down-hole pressure and temperature. When the variable speed drive does not deliver back spin data, speed sensor shall be able to deliver reverse rotations information. Data exchanges between the variable speed drive and the PCS is usually performed through hardwired signals. However, as the variable speed drive is able to support digital links (Profibus, DeviceNet, Modbus) such an option should be preferred.

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4.1.2 FCW Multiwell process instrumentation

Instrumentation requirements for the production system (cluster or satellite platform)

Equipment	Measure	Requirement	Comment
Separation system	Liquid level (all stages)	R	Level controllers measurement
	Separator pressure	R	Pressure controller measurement
Export pipe	Liquid export pipe pressure	R	Another sensor than HIPPS should be set up
	Liquid export flow rate	Optional	
GL activation network (if existing)	Gas-lift header pressure	R	Allows GL availability calculation

Legend:

R = Required by FCW

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4.1.3 FCW Multifield process instrumentation

Note:

Multifield instrumentation strongly depends on the process limitations that have been defined. This involves a specific analysis of the application. The following table only mentions the more often used data.

Allocation	Measure	Comment
Separation / liquid treatment system	Oil level (all stages)	Level controllers measurement
	Pressure (all stages)	Process sensor required (not safety sensor)
	Water level (all stages)	Level controllers measurement
	Water flow rate toward treatment	Only if it is a process limitation
Gas treatment system	Pressure	Only in case of LP gas backflow to central platform
	Flared flow rate	It can be a calculation of a gas material balance
	Flare temperature	If radiation is critical
	1st stage separation gas compressors status	To anticipate a flare flow rate excess in case of gas injection compressors stop
Export system	Export pipe pressure	A sensor other than HIPPS must be set up
	Export flow rate	If it is necessary to limit production (quotas or other)
Production gas-lift system (if existing)	Compressors state	In case a fast action is required upon partial stop of GL compression
	GL HP network pressure	On GL distribution header

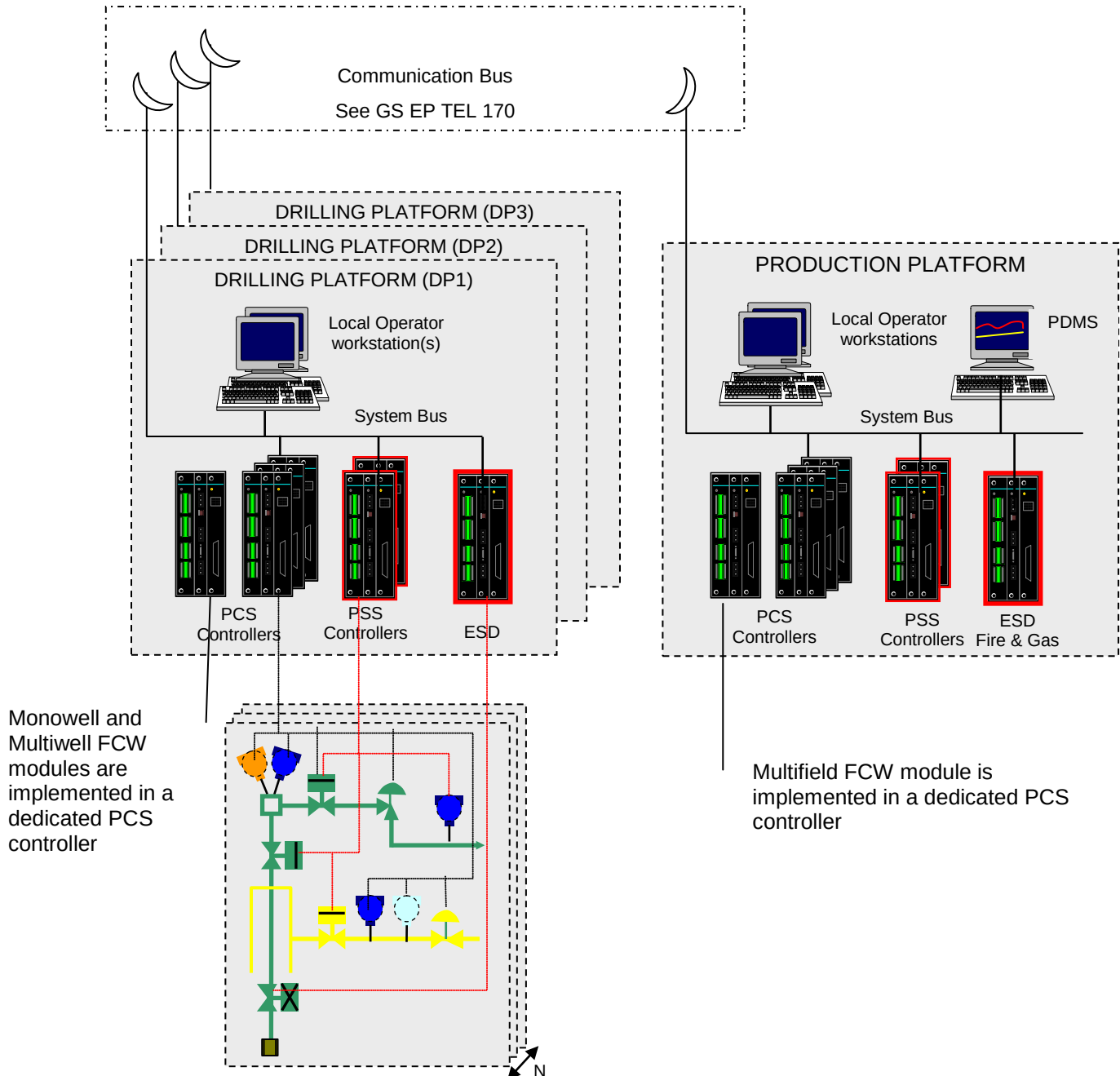
4.2 FCW implementation into the ICSS

FCW is completely integrated into the **ICSS** both at the programming level and at the user interface level. In most cases it does not require additional hardware.

However **FCW** uses **PCS** additional resources in term of number of displays, database size and calculation capability of the controllers.

This chapter lists the additional resources required for **FCW** implementation into the **PCS**.

4.2.1 ICSS classical architecture diagram



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Site	Subsystem	Impact of the FCW for the subsystem
On the central production platform	ESD	None
	PSS	None
	PCS	FCW Multifield algorithm
	HMI	Control views and parameters setting views for : - All the satellite platforms Monowell. - All the satellite platforms Multiwell. - Multifield displays. According to the tables given on the following paragraphs.
	PDMS	None
On the satellite platform	ESD	<u>Forwarded to the FCW :</u> - the DHSV status - the ESD bar status
	PSS	<u>Forwarded to the FCW :</u> - the SSV and SDV header gas-lift status. - the SD bar status - manage the Wing Valve and the SDV gas-lift safety command
	PCS	FCW Monowell algorithm FCW Multiwell algorithm FCW TPS function
	HMI	Control displays and parameters setting displays for - All the satellite platforms Monowell. - All the satellite platforms Multiwell. - Multifield displays.

4.2.2 Functions splitting by subsystems

4.2.3 FCW modules sizing

4.2.3.1 Supervision and control views

The number of views required for the **FCW** control of wells is estimated according to the table given in §3.6.1 (views per module).

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4.2.3.2 System database sizing

FCW implementation involves the creation of all the following parameters.

Table of the supervised variables for the Monowell modules:

Type of well	Parameters		Commands	Status	Alarms	Total
	Real	Integer				
Naturally flowing	15	3	11	5	5	39
Gas-lifted	50	5	10	5	5	75
ESP	58	4	10	5	33	110
PCP	55	7	8	6	20	96
Read/write	Read and Write		Read only			

Table of the supervised variables for the Multiwell modules:

Type of well	Parameters		Commands	Status	Alarms	Total
	Real	Integer				
Naturally flowing	10	8*N	5	11	6	32+8*N
Gas-lift	12	10*N	5	13	8	38+8*N
ESP	8	1+7*N	1	9	6	25+7*N
PCP	8	1+7*N	1	9	6	25+7*N
Read/write	Read and Write		Read only			

N= number of wells in the Multiwell

4.2.4 Requirements

4.2.4.1 ICSS performances requirements

The following table defines the ICSS cycle and response time for **FCW** algorithms treatment.

Level	Response time	Value
Monowell	Time for measurements update in the controllers.	≤ 1 S
	Cycle time for the execution of the algorithms off all the wells.	≤ 1 S
	Time for sequences realignment upon safety trip.	≤ 2 S

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Multiwell	Cycle time for the execution of the algorithm	≤ 10 S
	Response time between a process limitation high threshold detection and the first load shedding.	≤ 20 S
	Minimum time between two load shedding.	≤ 10 S
Multifield	Response time between a process limitation high threshold detection and the first action	≤ 30 S
Displays	Control or strategy display refreshment time including the update of all the displayed variables.	≤ 10 S

4.2.4.2 Functionalities

Historization server or PDS

All the measurements of all the wells with the following minimal characteristics shall be recorded and recovered in a trend form $Y = f(T)$ on a PI OSIsoft server:

- Number of trends per display: 6 minimum (for a good analysis of the process).
- Sampling frequency: 30 to 60 seconds.
- Recording duration: 30 days.
- Trend usual time range: 12 hours.
- Mobile marker allowing an easy reading of a value at a given time.
- Time scale backward and forward scan, backward scan to a specified date.
- Forward and backward zoom for both scales (time and Y), Y Auto scale.
- Color printing of the trends shall be possible without a saturation of the background.
- FCW statuses have to be registered (FCW general status, Mode, states, thresholds, setpoints, Monowell – Multiwell – Multifield parameters).

For more information about the PDS server, please refer to [GS EP EXP 131](#).

Help

Help views shall be provided for the **FCW** sequences and shall display:

- The current active **FCW** step.
- The blocking condition to transit to the next step including operator actions, current transmitters values and associated thresholds that need to be fulfilled, transmitter validity and/or inhibition...

These views can be displayed as animated graphcet or other means (table, contextual text...). The help view displayed upon operator request shall be the one corresponding to the current FCW sequence step.

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Alarms

If the ICSS is fitted with an alarm management system, **FCW** alarms shall be registered in the ICSS and specifically identified in order to easily sort the **FCW** specific alarms.

4.2.4.3 Data Management

Data Safety

- **FCW** settings shall be backed-up into the controller memory with a long live time battery or other means. **FCW** settings are not back-up in the workstation (neither client nor server).
- A file back-up of the **FCW** controller memory shall be performed on regular basis and used in case of replacement of the controller processing unit card.

Import / Export

The system should allow import / export of the **FCW** settings into a commercial available file standard (ex: Excel). The aim is to be able to treat these data on a desktop (or laptop) computer.

4.2.4.4 Safety integrity level and Availability

As defined in the **GS EP INS 134**:

- Safety level of the PCS controller where FCW is implemented: no SIL level required.
- Availability of the PCS controller where FCW is implemented: at least 99.95% based on an MTTR (Mean Time To Repair) of 4 hours, unless otherwise specified in the project specifications.

4.2.4.5 Loss of communication

If the **FCW** is implemented in a dedicated controller of the **PCS**, a communication loss detection system (watchdog) shall be implemented between the **FCW** controller and the others **PCS** controllers. In case of communication loss, the **FCW** shall automatically switch into manual mode in order to avoid any conflict when the communication is set back.

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Bibliography

GS EP INS 101	Instrumentation engineering, supply and construction general requirements
GS EP INS 102	Instrumentation identification
GS EP INS 107	Design and installation of instrumentation links
GS EP INS 135	Cyber Security requirements for design and supply of ICSS and Package Systems
GS EP INS 147	Design and supply of wellhead control panels
GS EP INS 150	Design method for system configuration – standard functions
GS EP INS 196	Input and Output Standard Functions
GS EP ELE 261	Solar Power System
GS EP EXP 153	Exigences pour la réalisation des Manuels Opératoires d'Exploitation
GS EP SAF 216	Area classification
GS EP TEL 170	Design and installation of Communications Network

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Appendix 1

Appendix 1 Additional

ADDITIONAL USEFUL INPUTS FOR THE SPECIFICATION OF A FCW

Field overview for the FCW architecture definition

		Central treatment facility	Production site N°1	Production site N°2	Production site N°....
Site name					
Site location (Onshore/offshore)					
Nbr. of production wells	Not activated				
	Gas-Lifted				
	ESP activated				
	PCP activated				
Nbr. of injection wells	Water injection				
	Gas injection				
Separation	Nbr of train				
	Nbr of stages				
Oil export	Gathering station name				
	Nbr of phases (1/2/3)				
	Nbr of pumps				
	Pressure				
Gas export	Gathering station name				
	Nbr of pumps				
	Pressure				
Gas treatment	Flare / injection				
Well test	Test separator				
	MPFM				
ICSS	PCS Manufacturer				
	PCS Type				
	Supervision Manufacturer				
	Supervision type				
	Local console (y/n)				
ICSS network	CCR location				
	Link with CCR (Fiber / radio)				
	Protocol (serial, Ethernet, other)				

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Appendix 1
Wells related inputs for the MONOWELL specification
Gas-lifted well
Completion type : ☐ Single completion OR ☐ Double completion

Activation type : ☐ Annulus Gas-lift OR ☐ Concentric Gas-lift

Additional instruments : ☐ DHP
 ☐ THDP

Process values :

Gas-lift manifold pressure _____ bar

Production header pressure _____ bar

Estimated tubing head pressure _____ bar

Estimated tubing head temperature _____ °C

Ambient temperature variations (according to day / night cycle and seasons)

☐ Low (<= 10°C) ☐ Medium (10°C to 20°C) ☐ High (> 20°C)

Constraints :

- ☐ Methanol injection
- ☐ Chemical injection
- ☐ Other exploitation constraints and hazards (GOR or BSW discontinuity, cyclic production, ...)

Description :

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Appendix 1
ESP activated well
Pump motor type : ☐ Fixed frequency OR ☐ Variable speed drive

Pump type : ☐ Single ESP OR ☐ Dual ESP

Casing ventilation : ☐ APCV OR ☐ Manual

Additional instruments : ☐ THDP
 ☐ other _____

Process values :

Production header pressure _____ bar

Estimated tubing head pressure _____ bar

Estimated tubing head temperature _____ °C

Ambient temperature variations (according to day / night cycle and seasons)

☐ Low (<= 10°C) ☐ Medium (10°C to 20°C) ☐ High (> 20°C)

Constraints :

- ☐ Methanol injection
- ☐ Chemical injection
- ☐ Other exploitation constraints and hazards (GOR or BSW discontinuity, cyclic production, ...)

Description :

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Appendix 1
PCP activated well
Casing ventilation : ☐ APCV OR ☐ Manual

Diluent injection : ☐ In the well bottom OR ☐ In the well head OR ☐ No injection

Diluent flow rate regulation : ☐ YES OR ☐ NO

Additional instruments : _____

Process values :

Production header pressure _____ bar

Estimated tubing head pressure _____ bar

Estimated tubing head temperature _____ °C

Ambient temperature variations (according to day / night cycle and seasons)

☐ Low ($\leq 10^{\circ}\text{C}$) ☐ Medium (10°C to 20°C) ☐ High ($> 20^{\circ}\text{C}$)

Constraints :

- ☐ Other chemical injection
- ☐ Other exploitation constraints and hazards (GOR or BSW discontinuity, cyclic production, ...)

Description :

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Appendix 1
Multiwell specifications
Multiwell production platform
Platform name :

Type of well	Number of wells under Multiwell control
Naturally flowing well	
Gas-lifted well	
ESP activated well	
PCP activated well	

Shortage or constraint :

- ☐ Gas-lift network
Gas-lift import or Gas-lift manifold transmitter tag :
Other significant transmitter tag :
- ☐ Oil production system
Oil export pressure transmitter tag :
Oil separator(s) level transmitter(s) tag(s) :
Other significant transmitter tag :
- ☐ Gas treatment system
Separator(s) pressure transmitter(s) tag(s) :
Flare and/or injection flow rate transmitter(s) tag(s) :
Other significant transmitter tag :
- ☐ Water treatment system
Water flow rate transmitter(s) tag(s) :
Other significant transmitter tag :
- ☐ Others _____

Process values :

Oil export pressure _____ bar
Gas-lift import pressure _____ bar
Gas export pressure _____ bar
Water export pressure _____ bar
Separators pressure _____ bar