

# Measurement and Control System for Midstream Plant

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**Abstract:** The measurement and control system for a midstream plant differs from the downstream system. Flexible control and communication systems are required for the oil production wells in this type of plant. A specific measurement system is provided from the oil transfer pipeline, and complicated controls are required for the high-pressure gas re-injection process.

**Keywords:** oil well, oil gathering station, cascade gas compression, long distance communication.

## 1. General

JGC has completed a midstream oil process project successfully at an oil production field located in the North Africa desert area.

During the project execution, engineering design, construction and commissioning stages, we experienced the different culture of midstream vs. the downstream projects that we have executed previously. The characteristic measurement and control system for a midstream plant is to be focused on in this paper.

## 2. Process Introduction

### 2.1 Oil Production

This oil production field is length 20 km and width 15 km. The estimated nominal oil production rate is 230,000 barrels of oil per day (BOPD) for approximately 8 years, and then declines progressively to 20,000 BOPD at year 25 (field design life). Production crude oil is exported to the existing pipeline network after treatment.

Any accompanying gas is compressed and re-injected into the underground reservoir.

### 2.2 Ambient Condition

Plant location is the center of a desert area, and the nearest city is approximately 300 km.

Therefore, the ambient condition is very harsh. The absolute maximum temperature is 60 °C in summer season and the absolute minimum temperature is -2 °C in winter season. Solar radiation is intense. Therefore, we have to take care of field material selection of piping, tubing, cabling and panels. Basically, SUS316 is used for all of field materials wherever possible.

Additionally, sand storm occurs often, and stop the field work. This is a major risk on scheduling in desert. We also have to take care for sand itself. Very small diameter sand may intrude into the inside of instruments, and damage the electric circuit and sealing. Special tight sealing is required on the every field instruments.

Fig.1 shows the plant overview during sand storm.



Fig. 1 CPF Plant Overview in Sand Storm

### 2.3 Midstream Process Overview

The midstream process may be divided into three areas, oil production wells, oil gathering satellite stations and central production facility (CPF).

Crude oil is gathered to 6 satellite stations from 23 wells at the oil production field. Gathered oil is led from satellite station to CPF for treatment and storage. Treated oil is exported to the existing pipeline using high-pressure export pumps.

The high-compression facilities of accompanying gas re-injection are provided in the CPF also.

The overall process configuration is shown in Fig.2



Fig. 2. Overall Process Configuration.

### 2.4 Control System Overview

The control system for this project is called “Integrated Control System (ICS)” and consists of four levels as follows.

- 1) Process Control System (PCS)

It carries out regulatory control of flows, pressures, temperatures, etc., within pre-defined limits and sequence control.

2) Process Shutdown System (PSD)

It carries out low level shutdowns of process equipment in the event of minor excursions of process variables outside preset limits

3) Emergency Shutdown System (ESD)

It carries out shuts down part or all of the plant in the event of a more serious process upset condition or a specified Fire or Gas alarm condition, and relieves overpressure from process piping or equipment and disposes of the inventory safely

4) Fire and Gas Monitoring System (F&G)

It detects the fire or gas leakage from detectors mounted in field and buildings, and generates alarms. Those fire and gas detection status are transferred to ESD for shutdown triggers.

The philosophy of ICS is to centralize the control. All of process information, not only for CPF but also satellite and wells, can be seen at DCS display in Central Control Room (CCR) in CPF. Generally all operator action is performed in the CCR in normal operation period. The process control of the package systems is carried out by its Unit Control Panel (UCP) and major control information is transmitted to ICS via serial link.

### 3. Oil Production Wells

#### 3.1 Well Digging

The oil production well shall be installed by the drilling contractor. They are specialist for well preparation. Oil drilling is quite a risky business. It is quite difficult to determine the right position of well, even though underground survey was carried out several ways. It is often the case that only water or gas comes from a well in expected oil field.

When drilling contractor could reach the spouting, they set up the “Christmas Tree” at the well head. This should be a tie-in point between the drilling contractor and plant EPC contractor.

The “Christmas Tree” is the typical word for the wellhead. That is a complex of valves at well top. Fig 3 shows the picture of the Christmas tree.



Fig. 3 Christmas Tree

#### 3.2 Control System in Wellhead

The oil flow to the transfer pipeline is manually regulated by a choke valve at wellhead during normal operation. Therefore, no control loops are provided in the oil production well. Only some monitoring loops for temperature and pressure are provided in there.

Each oil production line at the wellhead is provided with three fail-safe, actuated shutdown valves, namely, sub-surface safety valve (SCSSV), surface controlled safety valve (SSV) and independent overpressure protection valve. In addition, lift gas lines will be provided with one shut-off valve. All shutdown valves shall incorporate a local manual reset mechanism and a test facility to enable the valves to be partially closed periodically to ensure correct operation of the shutdown systems.

A hydraulically operated wellhead control panel (WCP), which includes facilities for local well start-up is provided to each wellhead. Normal operation of the wellheads will be from the WCP, using manual hydraulic switch valves and local instrumentation. Shutdown logic is provided by hydraulic unit itself detecting extremely high pressure or low pressure at oil production line.

Shutdown valve command and status signals on hydraulic unit shall be connected to the simple programmable logic controller (PLC) in WCP and transmitted to the ICS through serial communication link. A single Modbus communication link via optical fiber is provided between the PLC at the well and the ICS in satellite station

The PLC also incorporates additional shutdown logic and monitoring loops in wellhead.

Fig.4 shows the function blocks in WCP.

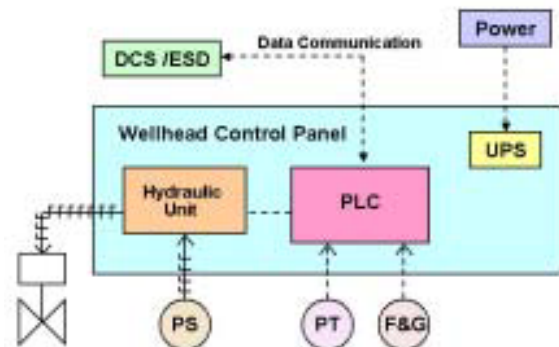


Fig. 4 WCP Function Blocks

The SSV should be closed either from the hydraulic logic, (following detection of high or low pressure in the flow-line, or manual pushbuttons), from the PLC, (gas leakage or fire detected, automatically from upper Stream via Satellite), or manual pushbuttons, (on the shutdown matrix in CCR). The SCSSV should be closed by hydraulic logic only.

The independent over-pressure protection valve is provided to oil transfer line to close on detection of a potential over-pressure situation detected by a flow-line pressure sensor integral with the valve actuator.

Fig.5 shows the overall image of oil flow and valves on wellhead.

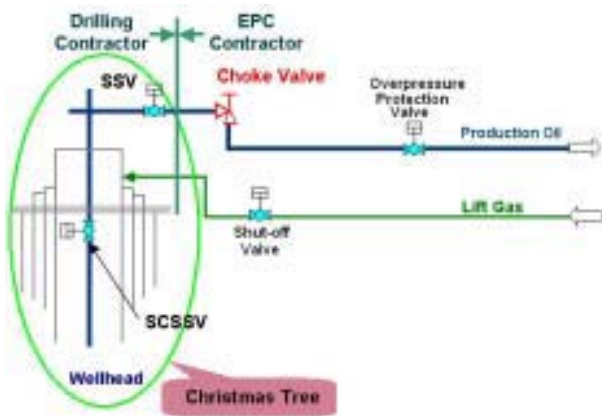


Fig. 5 Flow and valve location on wellhead

## 4. Control System in Satellite Station

### 4.1 Function of Satellite Station

Six satellite stations are provided to gather crude oil from several wells and to send it to the CPF.

PCS/PSD unit is installed for process measurement and control, and ESD unit is installed for process shutdown.

Incoming and outgoing oil lines between the satellite stations and wellheads and between the satellite stations and CPF are provided with manual isolation valves only. Actuated shutdown valves shall be provided in the oil transfer lines to and from the multi-phase flow meter (MPFM) to enable equipment isolation in the event of abnormal process conditions, and each lift gas line from CPF satellite.

Control, monitoring and shutdown of satellite stations are generally from the CCR via PCS/PSD unit.

Each satellite station will incorporate production, test and lift gas manifolds, MPFM with individual metering of oil, gas and water, shutdown valves, control valves and local instrumentation.

Lift gas manifolds shall incorporate individual flow control loops for each oil production wellhead with associated flow controllers integrated in the local ICS controller node. Flow controller setpoints are remotely adjustable from the CCR.

### 4.2 Communication Methods

Single optical communication with Modbus protocol is provided for data transmission between satellite PCS and wellhead PLC. Multi-core fiber optical cable is used and shared with the telecommunication system

The single mode optical fiber cable laid beside the pipeline is used for the extension of the DCS data highway, instead of using a separate Supervisory Control And Data Acquisition (SCADA) system. This communication link philosophy makes system configuration simpler and easier, because all data transmission can be handled by the system

internal communication of DCS/ESD, and do not need a SCADA interface.

ICS system communication network philosophy is shown in Fig.6.

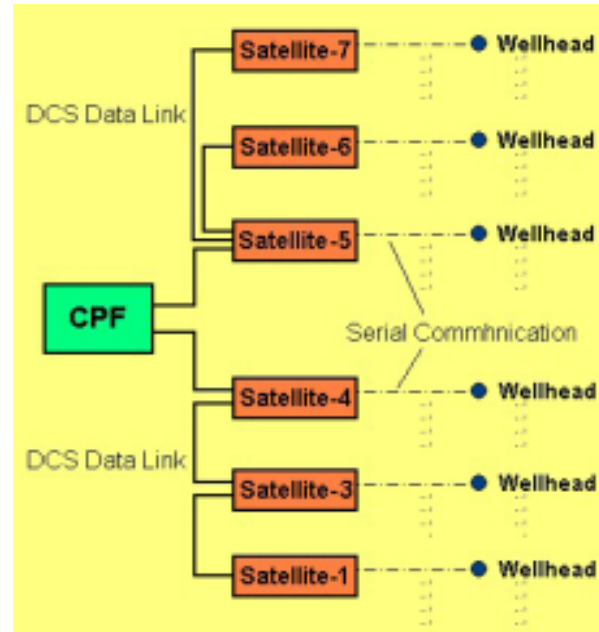


Fig. 6 ICS System Communication Philosophy

### 4.3 Multi-phase Flow Meter

Each well crude flow should typically be tested on a twice monthly basis of its oil flow contents by routing the selected well.

The test oil separator has been used for this test, previously. However, a Multi-phase Flow Meter, MPFM is provided for this test purpose in this project.

This flow meter consists of a venturi tube with flow, pressure and temperature sensor, microwave system and radioactive source with counter. The outline of MPFM is shown in Fig.7.



Fig. 7 MPFM Outline

The crude oil consists of three phases, oil, gas and water. The MPFM measures the total flow, total fluid density and permittivity. Then ratio of liquid-gas and ratio of oil-water and each phase flow are calculated.

The measurement data, pressures, temperatures and each flow, is sent to the satellite PCS by serial link and displayed in the CCR

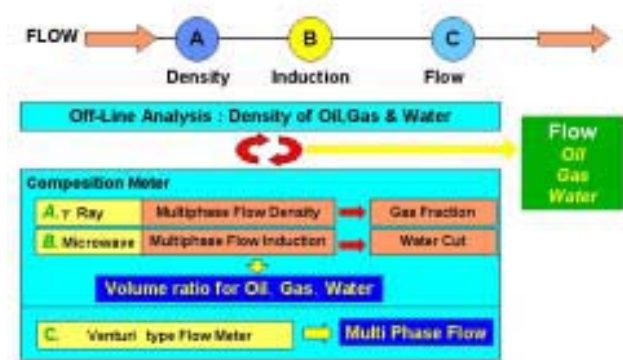


Fig. 8 MPFM Function Blocks

## 5. Central Processing Facility

### 5.1 Function of Oil Treatment

Three trains of crude oil treatment process are provided in CPF. Each process train consists of slug catcher, separators, desalters, heating furnaces, stripper columns and crude oil storage tanks. The process is not complicated and does not require automatic start-up. Therefore the train control system is not particularly difficult.

### 5.2 Gas Compression

The accompanying gas from crude oil should be compressed to high-pressure and re-injected to underground for both environment protection and efficient oil production. A multi cascade gas compressor system is provided for this purpose. The gas pressure must be increased step by step in each compression stage. In addition to anti-surge control system at each compressor, a pressure balance control of suction and discharge, and tight interlocks between machines and complicated start-up sequence are required for this multi cascade compressor system. Therefore, cross communication between compressor control panels (UCP) and PCS is required.

### 5.3 Oil Export

Treated oil is high-pressurized by cascade export pumps and exported to existing oil pipeline network. An oil leak detection system is provided for the crude export pipeline. Based on measurement of the pressure, temperature, flow and density at both ends, any leak point in pipeline can be calculated by pipeline modeling on occurrence.

## 6. Specific Requirement to ICS

### 6.1 Overall Integrated System

In addition of PCS, PSD, ESD and F&G, Management Information System (MIS), Training Simulator and all of system communication ways are part of ICS. In this integrated system, operating action, data handling

format, communication protocol are standardized for easy data transfer and operation.

### 6.2 Long Distance Communication Network

Long distance communication is mandatory required for midstream process. The set of single mode optical fiber and optical communication unit can transmit the data signal more than 5 km without electric and magnetic noise affect. Therefore, redundant optical communication is used for control data and shutdown data link instead of previous radio link communication.

A failure in a single branch of the communications network shall not affect the control of any loop. In the event of two coincident failures of redundant communications network branches, links between controller modules and the operator's interface in CCR will be lost but process control shall be maintained.

### 6.3 Flexible System

To determine the production well location is very difficult. In this project, only 50 % of well location had been fixed at the time of the control system shipping. Therefore, the control system configuration, especially for wells, must be very flexible.

### 6.4 Single Window Operation

All of PCS, PSD ESD and F&G process data and operation status are required to be displayed on the ICS display with graphic images and color modification.

PCS interfaces modules to the ESD and F&G are designed to ensure that the integrity of these systems is not compromised by any fault in the PCS.

All motor start and stop operations are executed on the ICS displays in addition to motor status monitoring. Therefore, a lot of data communication is required between Motor Control Center (MCC) and PCS.

### 6.5 Central Operation

It is required to minimize the local control within CPF due to harsh ambient condition. No operator is in the satellite stations nor wells in normal operating situation.

All process data monitoring and control action to process facilities can be done from CCR with ICS display.

### 6.6 Subsystem Communication

Packaged process and utility plant units are either directly controlled by the ICS, or may be supplied with separate control systems (Package UCP). Control and monitoring variables from the UCP are re-transmitted to the ICS via Modbus serial link or hard-wired as appropriate.

Detailed diagnostic facilities, e.g. machine monitoring, are provided at the UCP and overview information repeated to the CCR. Where the UCP is PLC based and large amounts of data are required within the CCR, a serial link is used to transmit information to the ICS.

PCS interfaces to other control systems, e.g. UCP, shall be designed to ensure that the PCS is fully protected from corruption and invalid commands emanating from such systems.

In order to reduce the quantity of hard wired signals, and associated cabling costs, extensive use of serial interfaces is

employed. Serial interfaces is generally used between the major process Package UCP and other heavy interface signal systems, e.g. Motor Control Centers (MCC) and electrical distribution system status signals.

The serial interfaces are standardized on a single protocol for commonality, e.g. RS485 using Modbus RTU protocol.

### **6.6 Typical Function Engineering**

Many of standardized software modules are defined for PCS, PSD, ESD and F&G functions. In the early engineering stage, typical functions should be defined, configured and tested. These approved typical functions are then copied for actual control loops for easy function engineering.

## **7. Conclusion**

The major points for design of mid stream process control are summarized as follows.

- (1) Material selection for field instruments against harsh ambient condition is important.
- (2) Well drilling is risky exercise and a flexible system is required.
- (3) Multi-phase flow meter is useful for crude oil contents flow measurement.
- (4) Long distance communication is necessary. Single mode optical communication system is suitable for this purpose.
- (5) Integrated control system with subsystem communication as single window operation is recommended.

## **References**

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