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I-Field Data Acquisition and Delivery Infrastructure: Case Study

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Abstract

Successful intelligent field (I-Field) implementation relies on a robust real time field to desktop data acquisition and delivery system. Such systems should have the bandwidth and the resilience to meet I-Field data acquisition and delivery requirements including data type, frequency, resolution, security, integrity, quality and reliability. The system must also have a design that safeguards against loss of data.

Saudi Aramco's earliest I-Field implementation projects were at Qatif and Haradh. These projects were instrumental in developing Saudi Aramco I-Field data acquisition and delivery requirements for reservoir and production engineers. The projects revealed limitations and challenges in the data acquisition and delivery infrastructure. Composed of several stages of interconnected systems supported by multiple organizations, these systems included surface and subsurface instrumentations, servers (data acquisition, control, database and applications) and various network protocols. System complexities and constraints dictated the need for developing an I-Field data acquisition and delivery infrastructure architecture that would meet Saudi Aramco's I-Field application requirements and overcome existing challenges and limitations.

This paper presents Saudi Aramco's experience and methodology of assessing field-to-desktop data acquisition and delivery infrastructure of the pilot project fields. It also highlights examples of some of the inherited challenges and implementation of the newly adopted data acquisition and delivery architecture. The adopted architecture, methodology, and subsequent experience gained in overcoming these challenges now serve as a guide to further intelligent field implementation in other Saudi Aramco fields.

Introduction

Field to desktop data acquisition and delivery infrastructure is the backbone component of Saudi Aramco's intelligent field (I-Field) surveillance layer, the first building block of Saudi Aramco I-Field architecture. Qatif and Haradh Increment-III fields (Al-Kaabi, et al., 2007; Saleri, et al., 2006) were the early I-Field implementations in Saudi Aramco. These two fields served as a pilot and test ground for capturing lessons learned and for re-defining users' and I-Field general requirements. The results of this experience led to the development of several I-Field guidelines and specifications and to the implementation of many components and elements of the surveillance layer (Al-Dhubaib et al., 2008).

This paper presents Saudi Aramco's experience and methodology of assessing field-to-desktop data acquisition and delivery infrastructure of the pilot projects' fields. The paper provides a brief overview of Qatif and Haradh Increment III fields and their level of instrumentation, describes the field's data acquisition and delivery infrastructure, and highlights encountered challenges and lessons learned. The paper also highlights examples of challenges encountered and discusses the implementation of the adopted field-to-desktop data acquisition and delivery architecture.

Methodology

To address the data acquisition and delivery challenges and to develop a robust I-Field data acquisition and delivery architecture, a Data Acquisition and Delivery Team comprised of subject matter expert representatives from all concerned departments was formed. The objectives of this team include:

- Define and document the I-Field data acquisition and delivery requirement.
- Define and document existing fields’ data acquisition and delivery infrastructure and support structure.
- Define and document existing fields' to regional and corporate database data acquisition and delivery infrastructure and support structure.
- Assess the current state of Qatif and Haradh Increment III fields’ data acquisition and delivery infrastructure and support structure for meeting I-Field requirement.
- Define an I-Field data acquisition and delivery infrastructure architecture leveraging existing infrastructure investments for upgrading existing fields.
- Resolve implementation and configuration issues in Qatif and Haradh-III data acquisition and delivery infrastructure.
- Incorporate I-Field architecture, specifications and guidelines into existing company engineering standards.
- Maintain developed architecture, specifications and guidelines.

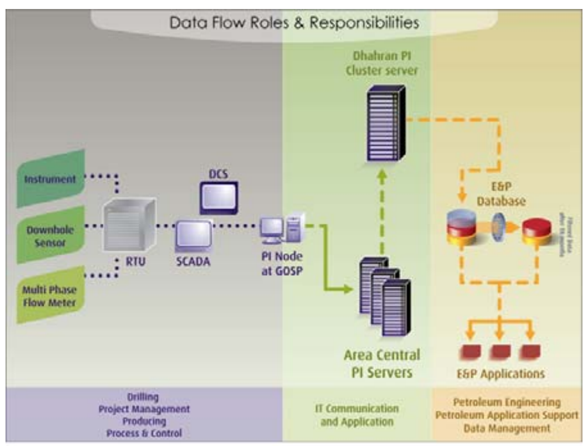

Fig. 1: Field to Desktop data flow

1 Overview of Qatif and Haradh-III Fields

1.1 Qatif Field

The Qatif field is located approximately 31 miles (50 kilometers) north of Dhahran. The field is a gently north-south trending anticline feature, which has two domes - one in the north and one in the south. Qatif measures 31 miles (50 kilometers) in length and 6 miles (10 kilometers) in width. The northern portion is offshore in water depths up to 41 ft. The major part of the field extends over onshore populated agricultural areas and major highways. About 15% of the field extends offshore. Qatif field was developed in 2001-2004 period to produce 500,000 barrels oil per calendar day (BOPCD) Arabian Light blend (33°-35° API) from different reservoirs utilizing horizontal and extended reach well technology.

Two gas-oil separation plants - 1 and 2 (GOSPs) were constructed by the north and south domes in 2004 to handle 300 and 200 MBCD respectively. In addition, two new water injection facilities (WIP-1 and 2) were constructed in the north and south domes to handle 650,000 barrels water per day (BWPD) and 500,000 BWD in north and south domes respectively, distributing Wasia injection water into four existing and four new flanks.

All of the Qatif well sites were equipped with state of art surface and subsurface instrumentation. A total of 102 producers and 92 injectors were put into production based on the concept well site work area where each area may support one to six wells. Designated numbers of wells in each well site work area were equipped with a Permanent Downhole Monitoring System; however, a multiphase flow meter (MPFM) is deployed to support all of the wells in each well site area. Table 1 provides a brief background of the project statistics and level of instrumentation.

Production, MBD	500	**MPFM**	20
Injection, MWBD	840	**GOSP**	2
Producers	102	**WIP**	2
Injectors	92	**On-stream date**	August 2004
EV/OBS	4	**Injection startup**	April 2004
PDHMS	42	**ICVs**	0

Table 1: Qatif Field Statistics

1.2 Haradh-III

Haradh Increment III (Haradh-III) is a 3-hour drive southeast of Dhahran. It is part of Ghawar field, the largest onshore oil field in the world. Its has a total oil production capacity of 300,000 bpd of Arabian Light crude oil and 140 million scfd of associated gas. Haradh-III GOSP has full automated well control and monitoring.

The Haradh-III project successfuly leveraged and integrated four technologies: MRCs; Intelligent Well completions (employing control valves for preventing premature water breakthrough); Geosteering for optimal well placement; and the I-Field concept enabling real-time surface and subsurface field monitoring and control (Al-Kaabi, et al., 2007).

Many of the oil wells are equipped with downhole valves to equalize withdrawal from individual laterals and Permanent Downhole Monitoring Systems (PDHMS) to measure downhole pressure and temperature. Each well is also equipped with surface transmitters for measuring wellhead pressure and temperature, annuli pressures, valve choke setting, downstream pressure and Cathodic Protection (CP) current. Moreover, every well is equipped with MPFM units with a Radio Active (RA) source that enables real-time measurements for oil, water and gas rates which eliminates the need for a test trap and test lines in Haradh-III. All of the acquired data is transmitted to Remote Terminal Units (RTUs) that are installed at each well site. RTUs transmit the data to the Haradh-III plant Supervisory Control and Data Acquisition (SCADA) through fiber optic cables. The SCADA at the plant allows data monitoring and control of the surface and downhole choke valves. The data is automatically transferred from the SCADA to the plant information (PI) server. Table 2 provides a brief background of the project statistics and level of instrumentation.

Production, MBD	300	**MPFM**	40
Injection, MBD	560	**GOSP**	1
Producers	32	**RTU/SCADA**	72
Injectors	28	**On-stream date**	February 2006
EV/OBS	13	**Injection startup**	September 2005
PDHMS	40	**ICVs**	87

Table 2: Haradh - III Field Statistics

2 Field-to-Desktop Data Acquisition and Delivery Infrastructure

2.1 Description

Field data in Saudi Aramco traverses multiple stages or zones of instrumentations, networks and PI servers before it reaches the corporate database and then to the engineers desktop as shown in Fig. 1. Each zone is managed by a different organization or multiple organizations as demonstrated by the color shaded areas in Fig. 1. The first level is the field level where surface and subsurface instrumentation data is collected and streamlined to the second level into the PI field's server through the SCADA network as show in Fig. 2. The second level is the local area, or regional, level where several fields' data is streamlined to the third level through area PI servers. The third level is where the data is collected from all area level networks and streamlined to the corporate database through a cluster of PI servers. Major parts of this structure were designed and built over the years to satisfy many of Saudi Aramco's operational objectives.

2.2 Field Instrumentations

There are several instrumentation subsystems at each well site supporting different functions. The primary instrumentations for the I-Field initiative are MPFM, surface pressure and temperature gauges, downhole pressure and temperature instruments, and surface data acquisition systems.

The downhole instruments and surface acquisition system constitute the PDHMS. Figure 2 outlines the connection between these different instruments and the RTU where the pressure, temperature and flow rate data is transmitted from the well site to the plant SCADA server. Further, control commands utilizing this infrastructure can be used to operate the Motor Operated Valve (MOV) as part of managing the oil well production.

2.2.1 PDHMS

Each PDHMS has a local Data Acquisition System (DAS), which is connected to the RTU using RS 485 multi-drop. Over 80 wells are equipped with PDHMS in both Qatif and Haradh-III fields.

2.2.2 MPFM

Each MPFM is connected to the RTU through an RS 422. A total of 20 MPFMs are installed at the Qatif field and 40 at Haradh-III. In the Qatif field, each MPFM is supporting several wells at the manifolds.

2.2.3 Other Well Site Instrumentation Systems

There are other important well site instrumentation systems that are connected directly to the RTU through hard-wired connections. These are: Sectionalizing Valves (SVs), Corrosion Inhibitor Skid, Scrapers, Shelter Fire Alarms, and uninterrupted power supply (UPS) alarms. Emergency Shut Down (ESD) System is a stand alone system with redundant reliable connections.

2.3 Field Process Automation Network

The process automation network connecting the instrumentation from the well sites to the GOSP SCADA servers consists of advanced instrumentation devices connected by a modbus (RS 485) to the RTU. The RTU is interfaced directly to an Optical Transport Network (OTN) that is linked to the SCADA terminal servers at the Central Control Room (CCR).

There are two different OTN rings supporting over 50 drilling sites, providing a self-healing process automation network between the instrumentation at the well site and the SCADA terminal server at the Qatif GOSP. The SCADA terminal server is connected via the CCR room Ethernet network to redundant SCADA servers. The SCADA servers are supported by a single threaded Network Attached Storage (NAS).

The Haradh-III process automation network started with one self-healing ring supporting over 50 different wells. Due to number of optical nodes, the self-healing ring formation encountered stability issues upon a node failure. This has resulted in a complete network blackout in several occasions. Hence, a two ring network redesign was implemented where the wells were distributed semi-equally. This has improved the overall performance of the process automation network.

2.4 Computer Control Room Servers

Each GOSP control room has PI scan node servers and SCADA servers.

2.4.1 PI Scan Node Servers

Field PI scan node servers are locally connected to SCADA servers through Saudi Aramco's Wide Area Network. The primary objective of the scan node servers is to exchange field SCADA application data with the local area and corporate Enterprise PI servers in Dhahran.

2.4.2 SCADA Servers

The SCADA server architecture is based on redundant severs. RTU circuits are connected through the OTN nodes to terminal servers. The terminal server is used to switch between primary and secondary SCADA servers in case of failure. Both SCADA servers share one NAS.

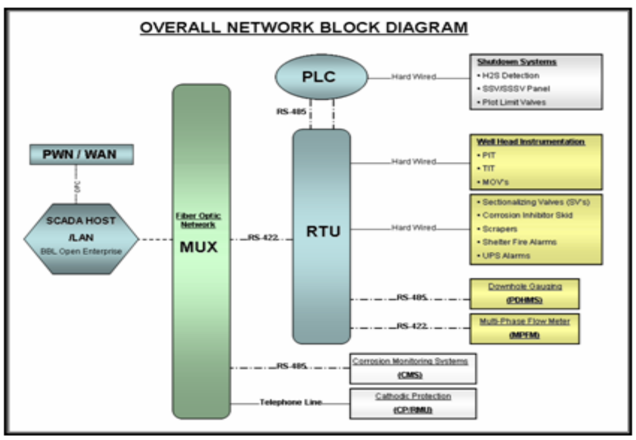

Fig 2: Typical Field Network Block Diagram

3 Defining I-Field Data Acquisition and Delivery Requirement

3.1 I-Field Data Requirement

Different field data types are required to be sampled at different frequencies, and certain data types are considered to be more critical for pressure and rate transient analyses. These will be sampled more frequently than others as shown below.

Data Type	Sampling Frequency
Bottom Hole Pressure	1 sec
Flow Rates (oil/water/gas)	15 sec
Wellhead Pressure	1 min
Temperature	5 min

Details of all other data types and their sampling recommended frequencies are shown in Table 3. The determination of the data type and associated sampling frequencies was developed through team consensus of representatives from various departments including production and reservoir management engineering.

3.2 System Requirements

- All real time data collection and delivery systems should be available 24 hours per day.
- Data sampling and collection frequency should meet I-Field requirements as per Table 3.
- The system should be 99% reliable.
- The system should safe against loss of data.
- The data availability should be 100%, i.e., no data loss.
- 7-day instrument data retention capacity in the fields.

Type	Data Type	Required Frequency (Seconds)
Vertical Producer	Gross rate	15
	Oil rate	15
	Water rate (or Water Cut)	15
	Gas rate (or GOR)	15
	Wellhead Pressure	60
	Wellhead temperature	300
	Wellhead Choke size, inches	86400
	Upstream choke pressure	300
	Upstream choke temperature	300
	Downstream choke pressure	300
	Downstream choke temperature	300
	Test date & Test time	900
	Test duration	900
	TCA Pressure	900
	SSSV position	300
	SSV/ESD Status (Open/Close)	300
	PURGE date start time	900
	PDHG bottom hole pressure	1
Horizontal or Multi-lateral With Smart Completion	Gross rate (MPFM)	15
	Oil rate (MPFM)	15
	Water rate (or WC) (MPFM)	15
	Gas rate (or GOR) (MPFM)	15
	Wellhead Pressure	60
	Wellhead temperature	300
	Wellhead Choke size, inches	86400
	Upstream choke pressure	300
	Upstream choke temperature	300
	Downstream choke pressure	300
	Downstream choke temperature	300
	Test date & Test start time	900
	Test duration	900
	BURGE date start time	900
	TCA Pressure	900
	SSSV position	300
	SSV/ESD Status (Open/Close)	300
	PDHG bottom hole pressure(1)	1
	PDHG bottom hole pressure(2)	1
	PDHG bottom hole pressure(3)	1
	PDHG bottom hole pressure(4)	1
	Downhole Flowmeter (1)	15
	Downhole Flowmeter (2)	15
	Downhole Flowmeter (3)	15
	Downhole Flowmeter (4)	15
	Downhole ICV Setting (1)	86400
	Downhole ICV Setting (2)	86400
	Downhole ICV Setting (3)	86400
	Downhole ICV Setting (4)	86400
	PDHG bottomhole Temp (1)	900
	PDHG bottomhole Temp(2)	900
	PDHG bottomhole Temp(3)	900
	PDHG bottomhole Temp(4)	900

Type	Data Type	Required Frequency (Seconds)
PWI	Wellhead Pressure	1
	Wellhead temperature	300
	Wellhead Choke size, inches	86400
	Upstream choke pressure	300
	Upstream choke temperature	300
	Downstream choke pressure	300
	Downstream choke temp	300
	Injection Rate	15
	SSSV position	300
	SSV/ESD Status (Open/Close)	300
	TCA Pressure	900
	PDHG bottom hole pressure	1
OBS	Gross rate	15
	Oil rate	15
	Water rate (or Water Cut)	15
	Gas rate (or GOR)	15
	Wellhead Pressure	60
	Wellhead temperature	300
	Wellhead Choke size, inches	86400
	Upstream choke pressure	300
	Upstream choke temperature	300
	Downstream choke pressure	300
	Downstream choke temperature	300
	Test date & Test time	900
	Test duration	900
	SSSV position	300
	SSV/ESD Status (Open/Close)	300
	TCA Pressure	900
	PDHG bottom hole pressure	1
GOSP	Oil rate	900
	Water rate	900
	Gas rate	900
	Operating Pressure	900
	Disposal Wells Rate	900
	Disposal wells Injection Pressure	900
	MOV Inlet Pressure	900
ESP	Operating Current (AMS)	60
	Motor Speed	60
	Operating Frequency	60
	Intake pressure	1
	Discharge pressure	15
	Motor Temperature	60
	Motor vibration	60

Table 3: I-Field Data Types and Sampling Frequencies

4 Assessment

The Data Acquisition and Delivery Team conducted assessments on Qatif and Haradh-III data acquisition and delivery infrastructure from the fields to the corporate database and to the engineer's desktop in Dhahran. The objectives of the assessment include the following:

- Identify best practices and challenges of existing I-field data acquisition and delivery infrastructure implementations and support.
- Benchmark existing implementation against I-Field data delivery requirement.
- Develop I-Field specifications and guidelines that ensure the delivery of reliable quality real-time data from the fields to the engineer's desktop.
- Define and develop I-Field data acquisition and delivery infrastructure architecture.

The assessments resulted in identifying many performance issues and areas for improvement, highlighting the following:

1. Several well sites have system integration problems due to having a mix of different vendors' subsystems.

2. PDHMS issues:

   a. A few of the first installed systems had cabling connection problems between the downhole PDHM component and PDHM surface unit immediately after commissioning. This included electrical short circuits in the cable, loose connections with the downhole sensor, and/or malfunctioning downhole sensors.
   b. A few systems had connection problems and limitations with the RS-485 links between the PDHMS surface unit and the RTU. These systems were installed in a daisy chain network design topology, causing extended delays in the poll cycle and infecting network reliability issues and complicated maintenance and troubleshooting efforts.

   c. PDHM surface unit onboard memory was not sufficient to retain data for prolonged outages.
   d. Identified the need for PDHM Surface Unit Data Specification guidelines to address data retention capacity, data management, configuration and setup.
   e. Identified the need for battery backup to support data collection during power outages.

3. The design of the RTU implementation did not meet I-Field defined requirements due to:
   a. Number of wells served by a single RTU. An RTU failure may result in several wells and field's surface instrumentation data loss.
   b. Daisy chain connections of many wells' instrumentation result in a delayed polling cycle and inflexibility in troubleshooting and maintaining the connections.
   c. Limited or no memory to retain collected data during system failure.
   d. Lack of battery backup to support data collection in case of a power outage.

4. NAS performance degradation:
   a. Server disk capacity limitations and improper data management support.
   b. Communication problems with the data acquisition servers.
   c. Configuration files and outdated software releases.

5. Frequent network connectivity failures between the remote sites and the data acquisition servers due to faulty fiber optic cables:
   a. Node failures.
   b. Fiber cuts (environmental).

6. Improper SCADA server data exchange to the PI servers:
   a. Data tags database configuration quality.
   b. Data storage limitations at the NAS SCADA server.
   c. Data exchange interface integrity due to lack of defined specifications that address I-Field requirements for data interface between RTU, SCADA, PI and Oracle databases.

7. Identified the need for and facilitated the deployment of I-Field field support teams.

8. Identified the need for service level agreements for support and response to the many involved systems.

9. Identified the need for Key Performance Indicators (KPIs) for benchmarking system connectivity.

10. Identified the need for a help desk call center to log, track and report connectivity problems.

11. Identified the need for field data change management process.

5 Specifications and Architecture Guidelines

The field assessment findings and the defined I-Field data acquisition and delivery requirements were instrumental in developing and providing input to new and existing specifications and guidelines which include but not limited to the following:

- Saudi Aramco Engineering Report 6114 (SAER 6114) for connecting application servers to remote sites for process automation.
- I-Field Data Acquisition and Delivery Infrastructure Architecture Guidelines.
- PDHM Surface Unit Data Specification Guidelines.
- Electrical Submersible Pump (ESP) Data Specification Guidelines.
- Input to I-Field Roles and Responsibilities Guidelines.
- Plant Information (PI) servers (field to central level) high availability recommendation guidelines.

6 Implementation

The developed architecture, specifications and guidelines were incorporated into action plans to mitigate and improve Qatif and Haradh-III data acquisition infrastructure. The developed architecture, specifications and guidelines provided feedback to ongoing field development projects and activities such as Abu Hadriya, Fadhili and Khursaniyah (AFK) projects (Pamer and Mukherjee, 2006). Additionally these specifications and guidelines are being incorporated into Saudi Aramco Engineering Standards and Functional Specification Documents (FSD) to ensure incorporation in new field development projects such as Khurais and Manifa (Pamer and Mukherjee, 2006).

This project provided the I-Field team an excellent opportunity to work with many of Saudi Aramco's organizations and their professionals to align many of the I-Field related development activities. As a result, Engineering standards are being updated; instrumentation data specifications have been developed, Function Specifications Documents (FSD) have been modified, and data acquisition and delivery monitoring tools and Key Performance Indicies (KPIs) are being developed. Additionally, service level agreements and services such as help desk and I-Field Support were identified and are being implemented. All of these developments form a key component in the development of the I-Field Surveillance Layer (Al-Dhubaib et al, 2008); building the foundation of Saudi Aramco's I-Field architecture.

7 Development Plans

Work is in progress on developing and rolling out an I-Field Master Plan that covers all of Saudi Aramco green and brown fields. The master plan development takes into consideration reservoir development and management objectives and priorities, fields' operation cost-effectiveness and the flexibility, robustness and cost-effectiveness of required data acquisition and delivery infrastructure.

The Data Acquisition and Delivery architecture as well as the all the components of the I-Field Surveillance Layer would need periodic update and ever greening process to incorporate related technology developments and advances, users' requirements and process and organizational development and changes. The I-Field Data Acquisition and Delivery team will ensure:

- Continual, exploration and evaluation of available and emerging data acquisition and delivery industry solution to enhance and optimize developed I-Field data acquisition and delivery infrastructure.
- Continual evaluation and integration of the data requirement for the I-Field Integration and Optimization Layers.
- Continual facilitation of in-house technical exchanges to communicate and integrate related I-Field technology and process development.
- Work with concerned organizations on updating and reflecting required changes in the developed I-Field specifications and guidelines.

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Nomenclature

GOSP	Gas Oil Separation Plant
MPFM	Multiphase Flow Meter
NAS	Network Attached Storage
OTN	Optical Transport Network
PDHMS	Permanent Downhole Monitoring System
PI	Plant Information
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
UPS	Uninterrupted Power Supply

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