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Practical Staged Implementation of Digital Field with Short Term Benefits

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Abstract

The digital oilfield technology is typically associated with high level of field automation and instrumentation, as well as advanced petroleum engineering modelling.

This paper discusses the application of digital oilfield to large brown fields based on real, but anonymous cases, where the level of instrumentation is low, production models might not be available, and the local expertise might be limited.

In such situation, the principles of digital oilfield need to be adapted. This paper presents a staged implementation methodology, where the benefits and costs can be evaluated at every step of the project, allowing to build a system with the right amount of functionality and complexity.

The first step focuses on improving data quality, even if the data is captured manually, through automated quality checks and raising awareness during the data capture process. The second step focuses on automating routine tasks, such as reporting, leading to efficiency improvement, but also increased accuracy and traceability of the reported figures. The third step focuses on developing a production monitoring platform, allowing to perform exception-based surveillance, particularly important for large fields, as well as providing a single point of access for different disciplines, hence acting as a collaborative environment. At last, the model-based more complex workflows are discussed, such as virtual metering, production optimization and short-term production forecasting.

The main conclusion of this paper is that the Digital Oilfield can deliver value for brown fields, even if they are close to their life end. The relatively low cost of these solutions, and the immediate benefits they can provide makes it meaningful, even in a short-term perspective. A staged implementation lowers both the project risks and the required initial investment, while easing the adoption process by the users.

The main differences with application to green fields is an increased focus on data quality improvement, and a lower focus on models and complex engineering workflows. The surveillance platform should also focus more intensively on exception based surveillance, allowing to pre-process large amounts of data, rather than providing extremely fine detail.

Introduction

The digital oilfield technology is typically associated with high level of field automation and instrumentation, as well as advanced petroleum engineering modelling.

The current paper discusses an approach based on real, but anonymous cases where the digital oilfield technology is applied on fields with lower levels of instrumentation, historically operated by large numbers of operators. It focuses on a step-by-step approach, gradually building the capability of the organization to operate more advanced systems by improving the overall level of surveillance allocation and optimization.

First, the data quality is enhanced through automatic quality check, data centralization, and appropriate portable tools for data capture.

Second, the integrated data is put in context through a surveillance platform, consisting of dashboards and events capture, leading to faster reaction time and decreasing the required work force for field monitoring.

Third, virtual metering is implemented to provide reliable rate estimates, which are the basis for more advanced workflows.

Fourth, the allocation process is enhanced and semi-automated by making use of the virtual metering.

At last, forecasting and optimization workflows are developed, based on the previous models, and tuned through accurate production figures.

The main observation of this paper is that the digital oilfield technology can add significant value to oil & gas operations, even in low instrumentation and automation scenario's, provided that its principles are adapted to the situation.

In such situations, improving the data quality and frequency is the most important step. The Digital Oilfield provides tools for doing live data quality check during data capture, reconciles redundant measurement sources, and serves the data to the user, along with uncertainty, leading to better choices.

The surveillance platform puts this data in context, and provides a single point of access for virtually all field data. It enables improvements in efficiency, but also provides a great amount of visibility and control over the operations. Regular reporting tasks can also be automated.

The virtual metering is a cost-effective alternative to physical measurement devices. Nevertheless, its output quality heavily depends on data quality and model quality. Therefore, it is essential to provide easy procedures and workflows to maintain the models in-line with reality.

Good data and good models allow for more advanced workflows, such as automated allocation, forecasting and optimization. Such workflows should not be implemented before the data and models are of satisfying quality.

The proposed approach allows companies to invest progressively, and to ensure that delivered functionality is fully utilized by the organization at every step of the process.

This paper is also focusing on initiatives leading to tangible and fast return on investment, by opposition to approaches more focused towards research and development, or focused on long term objectives, such as the enhancement of the ultimate recovery.

What are we really trying to achieve with Digital Oilfield?

Before diving into the implementation and details of digital oilfield, it is worth taking a step back, and re-assessing the goals of such initiatives, as well as their boundaries.

A high-level comparison with the downstream oil and gas industry provides good insights about the objectives of such program.

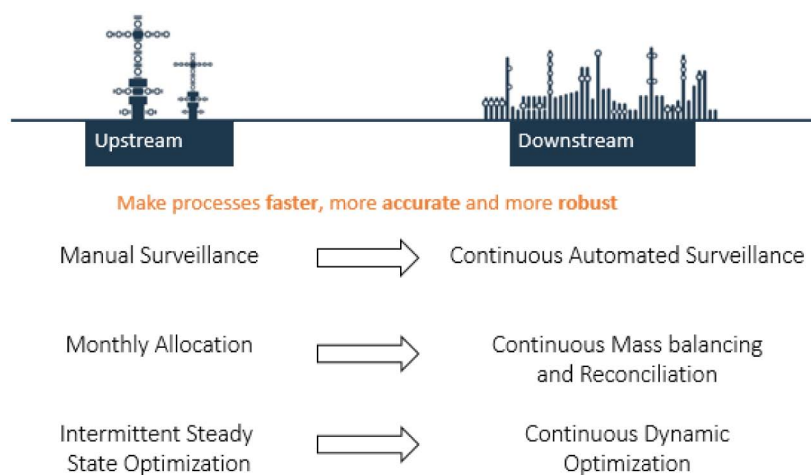


Figure 1—Comparison of key processes in upstream and downstream

Processes in the upstream and downstream oil and gas industry can be compared. For example, let's consider the processes of production surveillance, production allocation/production accounting and production optimization.

Production surveillance

Virtually all refineries in the world are equipped with surveillance systems allowing the operators to monitor continually the operations of the plant. Interactive process diagrams are available, displaying trends of real-time measurements in context. Laboratory data is accessible through dedicated laboratory databases and integrated into the surveillance systems. A vast number of alarms is configured for alerting the operators of any potential issues in the system. In fact, the number of configured alarms can be so great that supervisory systems are dismissing and merging alarms automatically for avoiding overloading the operators (Liu, Jun et al., 2001).

While the most advanced green fields feature similar levels of production monitoring, the situation in mature, brown fields can be very different. In many cases, obtaining the raw measurements remains a manual exercise, whereby the field operators are physically visiting the wells and taking measurements manually, which is sent back to the offices through mail, excel sheets, or fax.

The data tend not to be integrated, with several databases being disconnected and difficultly accessible by an end user (for example, cross checking production data with laboratory data and reservoir analysis requires advanced users to build complex excel files with queries to different databases).

Most of the production surveillance is done ad-hoc, most often through countless excel sheets developed by departments or individuals. There is a lack of an integrated and unique view on the operations, and therefore the communication between entities is made difficult, since there is no common ground.

Alarms may just not be defined, relying on expert interpretation of the numbers, or might not be centralized, leading to different departments reacting at different pace to the same events, or simply missing them.

Production allocation / production accounting

Modern refineries are equipped with systems continuously reconciling the production, and achieving real-time mass and energy balance (Soderstrom, T. A. et al., 2000) (Chiari, M. et al., 1997). This is made possible using flow meters and analyzers transmitting real-time values, and process models ensuring that the balances are closed several times per day, or even per hour. This reduces the uncertainty of production figures dramatically, and ensures perfect control of the products being consumed and produced.

Some advanced green fields are adopting similar strategy for their production allocation; the production is measured using multi-phase flow meters continually, as well as having fiscal export meters at the end of the process. Reservoir, wells, network and process models are available for distributing the imbalances as accurately as possible (Patel, P. et al., 2014) (Wu, X. et al., 2012).

Nevertheless, most often, the allocation process is still happening very infrequently (once a month), and is based on a straight extrapolation of the last measured well productivity during production well testing. The allocation factors obtained in this case (ratio between the sum of the production measured through well test and fiscal export figures) are often very far from a value of 1, which would mean a perfect match between the individual well production and the export meters.

The allocation of water production and gas production is often neglected in oil production systems, since these products are not easily valorized. An accurate allocation of these phases is nevertheless essential to a good understanding of the field performance.

Production optimization

Most refineries are equipped with real-time optimization systems, for example by using advanced process control technology. The production is continually analyzed, and operating modes altered to cope optimally on a second basis. Actuators are manipulated automatically in a closed-loop system, ensuring that production is maintained at its optimum 24h a day, 7 days a week (Howes, S. et al., 2014).

In upstream oil and gas, optimization processes are often the result of relatively long studies by a dedicated group of engineers. The implementation of the recommendations is also a lengthy process, which is better measured in days than hours. Closed loop control systems exist for the process side of upstream operations, but are virtually inexistent on the well side.

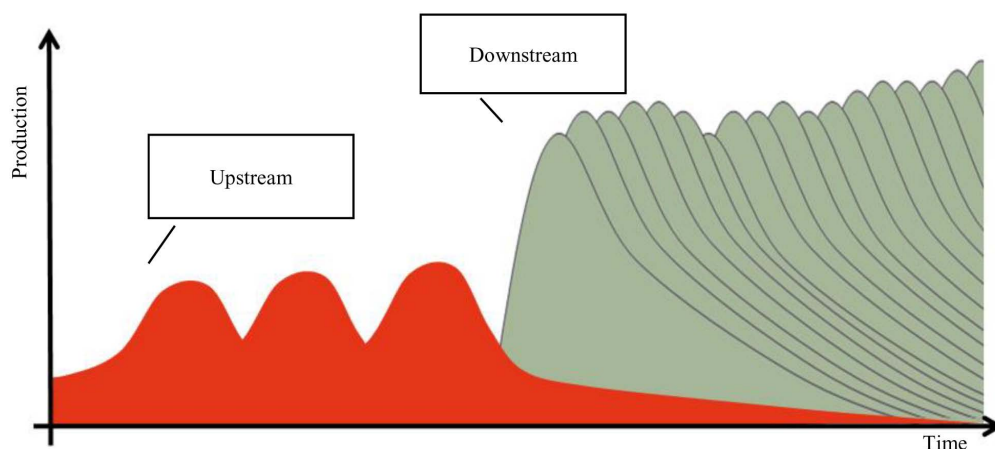


Figure 2—Optimization frequency in upstream and downstream

Why do such differences remain?

According to the authors, there are two main reasons for such differences to happen; higher technical challenges and uncertainties in the upstream operations, and historically less financial pressure on the upstream activities.

From a technical perspective, it is easy to understand that the upstream activity is subject to a lot more uncertainty and control challenges than the downstream. The reservoir is a complex entity, with constantly transient conditions, and will never be as well characterized than man-made equipment.

The produced fluids are also difficult to characterize, being multi-phasic, as well as more difficult to measure. All these reasons make the challenge of controlling the production a much more complex challenge.

From an economic perspective, refineries have long operated with profit margins being considerably tighter than the ones of upstream, leading to higher efforts for reaching production excellence and efficiency. The current downturn in the upstream oil and gas is certainly a trigger for applying new technology that allows more efficient operations by limiting the overhead, assist the operators better and enhance both production levels and ultimate recovery.

How to improve the situation for upstream?

The goals can be summarized as making the processes described "faster, more accurate and more robust". This is essentially the mandate of digital oilfield.

Several tools, technologies and methodologies are available for reaching these goals; efficient, fast and scalable data management solutions, integrated production surveillance platforms, integrated asset models, automated engineering workflows, etc.

The following sections detail which of these techniques are most appropriate for brown fields, given their specific challenges.

Brown field specific challenges and objectives

Brown field specific challenges

The very first question is "Does it make sense to invest on such technology for a field which is close to the end of its life?".

This paper focuses on simple and relatively low-cost solutions that allow delivering quick wins at any stage of the field lifetime. Automated data management strategies and automated routine tasks lead to higher operational efficiency and lower overhead in a very short timeframe. Improved production surveillance (including efficient alarming schemes) leads to optimization opportunities and faster reaction time, decreasing significantly the production losses. Increased accuracy of the processes and increased data quality allow for better understanding of the reservoir and well performance, possibly leading to extended field lifetime. All of these activities translate in increased production and reduced OPEX for a low CAPEX investment, therefore making these solutions attractive in a short-term perspective.

The situation in brown fields is significantly different from the situation in green fields, and therefore, the digital oilfield solutions need to be adapted.

- Low level of instrumentation

Greenfields will typically be designed with a high level of instrumentation, including downhole gauges, multi-phase flow meters, possibly sand detectors, red-eye meters, etc. The same situation happens on the process side.

In brown fields, it is still often the case that well head sensors are not even transmitting real-time data to a centralized system. The choke valve positions are not measured continually, and the wells are tested very infrequently. The process side might also be very poorly instrumented, with some situations where fiscal-grade export meters are not available.

While the installation of additional, up-to-date hardware is often necessary, proper data management solutions can ensure that the available data is maximally leveraged, centralized, quality checked and readily available for improved decision capability and field surveillance.

- Large scale of operations

Brown fields are most often land-based, since the technology for operating such fields has been available for the longest time. With a depleted reservoir, the wells average productivity tends to be low, leading to a vast number of wells, spread on a large scale.

This situation calls for efficient means of monitoring the wells remotely.

- Legacy processes in place

In a green field, the main challenge is to define efficient processes and systems from the ground up. For brown field, the same challenge is there, with the additional difficulty of displacing legacy processes, leading to an additional change management effort, and pre-existing expectations.

- Limited on-site expertise

Highly specialized and qualified teams tend to be deployed on the flagship, newest developments of oil companies. Therefore, the available expertise on-site might be limited, leading to the need for robust and well-defined processes, allowing to exploit advanced tools in a simple manner.

With all the challenges mentioned above, it seems obvious that applying a text-book Digital Oilfield "recipe" is doomed to fail.

The dependency on high frequency, high quality data needs to be low.

The solutions should focus on giving an easy overview of the full field, highlighting quickly the main issues in large scale operations (exception-based surveillance), rather than providing very fine insights on the well performance.

The complexity of the models developed for supporting the key processes need to be limited to ensure appropriation and maintenance by the local asset personnel. Workflows involving the use of such models need to be well defined and guided, ensuring timely execution.

A focus should be given to capturing the current practices, and the newly designed processes should encompass the site requirements to ensure adoption of the new processes.

Objectives of Digital Oilfield for Brown fields

- Enhance the visibility, understanding and control over operations

There is no possible optimization of the production without a decent understanding of the field performance, nor the ability to follow-up on the optimization actions identified.

The digital oilfield should allow getting a quick overview of the current field performance, pinpoint issues, and provide transparency on the optimization initiatives and their results.

- Save time by automating routine tasks

The digital oilfield has the capability of reducing considerably the load of routine tasks. This does not only translate in reduced overhead, but also to increased capability of the field personnel to carry added-value activities, such as interpretation of the available data, identification of optimization opportunities, and further collaboration between different departments (Al-Jasmi, A. et al., 2013)

The automation of these tasks also ensures timely execution of the key processes, increased robustness and ability to audit the produced figures transparently.

- Enhance remote surveillance

Due to the large scale of operations, it is essential that the field personnel can monitor the key field parameters from their main workstation. A first analysis should not require a well inspection, which is extremely time consuming.

The availability of remote surveillance systems also allows specialists from elsewhere in the company to provide advice and expertise by looking at the same data as the field personnel. These solutions also allow higher management to constantly keep visibility on the key performance indicators of production.

- Increase predictability and reliability

Poor production figures always lead to inefficiency, and eventually, troubles in the operations. Wrongly reported production figures will turn into a costly issue with the partners or the customers, and possibly involve penalties. Failure to accurately predict the future production, or to meet the production targets is also a major issue, leading to poor financial performance.

Increasing the reliability of production figures, as well as the robustness of processes such as short-term forecast places the company in a much safer and controlling position.

- No non-sense approach, and quick benefits

Margins are tight, remaining field lifetime is short, investment budgets are limited, as well as the focus on applying new technologies. In this context, the Digital Oilfield needs to deliver immediate value, and require low investment. A staged implementation should also be preferred, whereby the added value of the initiative is re-assessed at every stage of the process, to determine how far the organization should take the initiative to contribute optimally to the field strategy.

A step-by-step approach

In the mindset of "no non-sense and quick benefits" approach, a framework has been defined, ensuring that the proper steps are taken, in the right order.

The authors have witnessed several initiatives failing, being considerably delayed or over-budget because of the wrong focus at different stages of a project.

For example, it is easy focusing on developing detailed production models, only to find out that they can't be accurately calibrated because of the lack of quality raw data.

One can also develop extremely precise and accurate production models, but fail to get them maintained or used, because the complexity is too high, and the supporting workflows are also too complex.

Optimization and forecasting workflows sound very attractive, but they completely rely on accurate data and models, which is too often realized too late in the process.

The figure below provides a simple, yet effective way of visualizing a meaningful sequence for implementation of the different pieces of a digital oilfield solution.

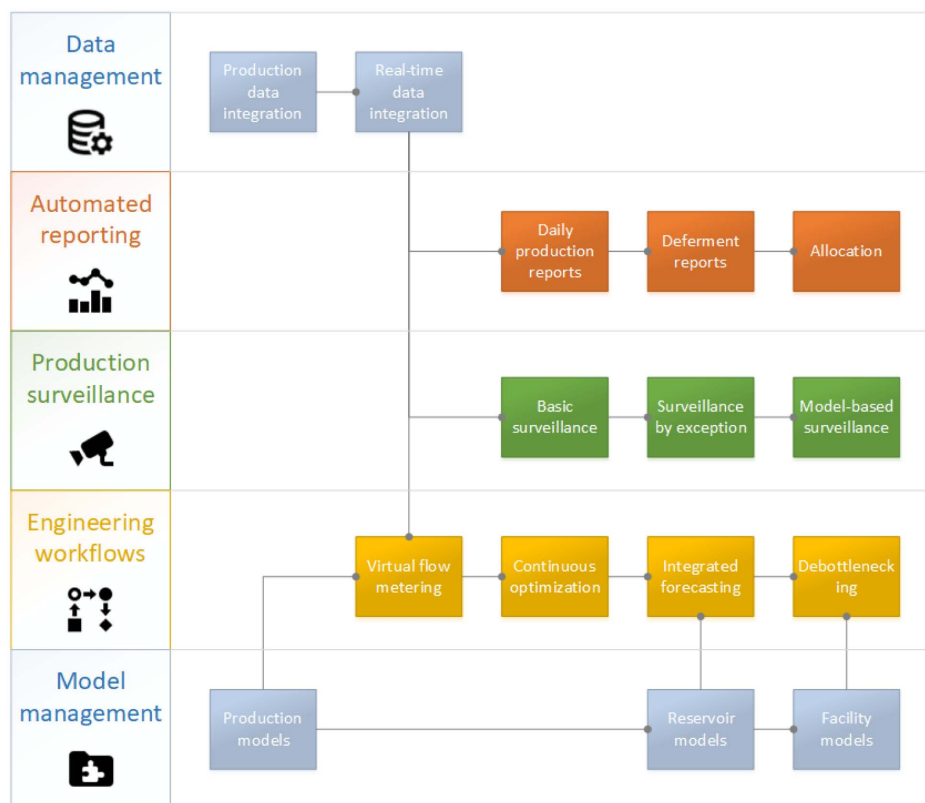


Figure 3—Staged implementation of Digital Oilfield for brown fields

Everything starts with data (data management)

All the other steps depend on the quality of the data captured; models, reports and workflows ("garbage in, garbage out").

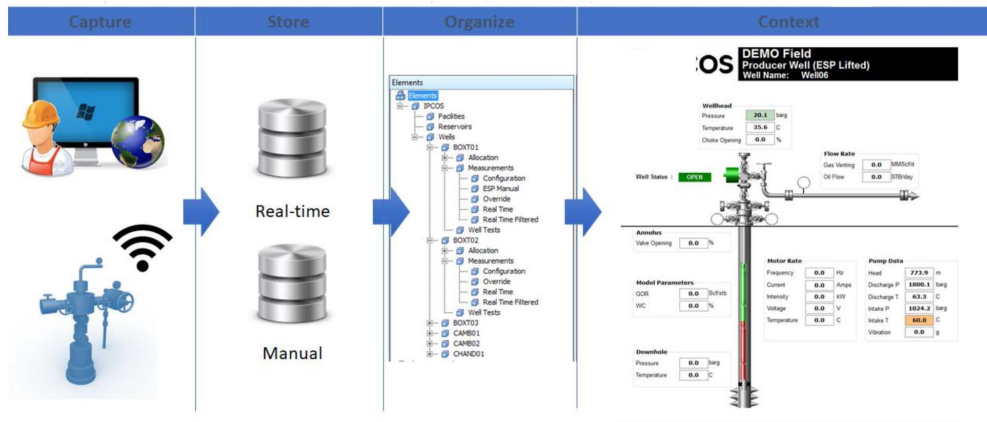


Figure 4—Data management process overview

Capture

As stated before, in a brownfield, a significant portion of the data is still manually or infrequently captured. Therefore, it makes a lot of sense to put efforts for increasing the quality and frequency of this data.

For enabling this, the proposed solution should:

- Provide the person who is capturing the data with context what was the latest captured figure? When was it captured? What is the trend of the evolution of this parameter? How does it compare with similar entities? Is there any special remark for a sensor?
- Perform automatic quality check. Is the value captured within reasonable bounds? Is this in-line with what is expected? Perform consistency check with value captured elsewhere in the system (is the well head pressure higher than the separator pressure?)
- Provide an overview of the complete data. Which well needs to be inspected next? How many wells are remaining for completing an allocation process?
- Shorten the data cycle from capture to storage. Connect directly to a database, and avoid people re-typing manually the figures, mistake in reading hand-writing, etc.
- Present the user with a fixed structure. The list of wells to be inherited from an official repository, avoiding typo's, the possible routing options must be constrained (well A can only flow to tank X and Y), etc.

List of wells coming from master structure

Well Name	Well Type	Path	Choke Size (in)	ESP (grip)	OST (deg C)	DSP (grip)	DST (deg C)	Annulus P (deg C)	Tabling T (deg C)	dp (grip)	Rate (t/T/day)	Comments
NF	T		177	100	52	63	44	85	100	37.00		
NF	A		175	46	108	90			66	-5.00		this well is flowing ever since.
ESP	T		175	88	48	60	120	81	74	28.00	1922.35	this well is flowing ever since.
NF	T		174	95	78	63	84	52	61	32.00		this well is flowing ever since.
NF	T + A		180	85	85	46	85	55	61	19.00		this well is flowing since 11/17
NF	T		115	85	62	40	84	52	64	25.00	2130.61	this well is flowing ever since.
NF	A		108	75	55	42	77	46	52	13.00		this well is flowing ever since.
ESP	T		100	82	63	63	55	86	71	19.00	1074.04	this well is flowing ever since.
NF	A		145	73	53	54	65	73	82	19.00		this well is flowing ever since.
NF	A		158	85	42	40	42	63	57	25.00		
NF	A		87	89	78	63	52	49	90	22.00	2245.29	
NF	A		99	80	67	57	49	85	38	23.00	1256.8	

Live data QA/QC

Validation on data type (list, numerical value, text, etc.)

Figure 5—Example of data capture web application with embedded quality checks

Implementing such solutions leads to dramatic data quality improvements, and is an extremely strong foundation for the other processes.

This process should be considered in parallel to installing new hardware, when possible. One should note that the installation of such sensors, and the infrastructure for transmitting data is changing quickly with the IoT (Internet of Things) technology, enabling the same results for a fraction of the cost (Mahdavi, M., 2017).

Store

It is important to setup databases which guarantee performance, scalability and easy maintenance. Typically, two types of databases co-exist; a real-time database (or data historian) and a production database (typically a relational database based on SQL or Oracle technologies).

While the implementation of these databases is mostly an IT exercise, and therefore will not be described in detail in this paper, it is important to understand the risks associated to failing to put in place proper storage solutions:

- Inability to obtain long term trend data
- Inability to trace back the raw data used for reporting and calculations
- Inability to easily extract the data
- Inability to centralize and integrate the data
- Inability to easily compute derived indicators (e.g. watercut = water rate/liquid rate)

The scalability and maintainability is also an important factor. For example, developing a bespoke solution might be a cheap exercise in the short term, but the total cost of ownership might explode in the medium term.

Organize

For enabling an efficient data analysis, but also easy data retrieval, it is essential to structure and organize the data. At this stage, it is also possible to integrate different data source into a single semantic model. The users do not have to know a tag name or a table name anymore for retrieving the data, they can query it and browse through it in a user-friendly structure, which, for example, lists the different wells and present the available data associated to them.

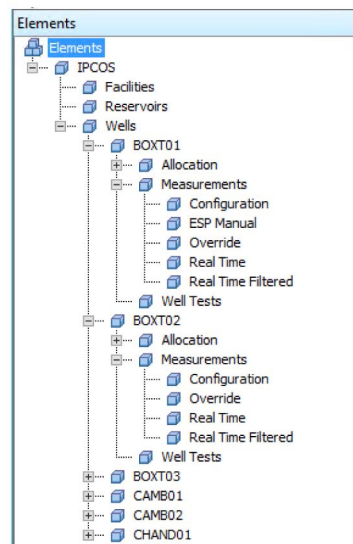


Figure 6—Example of semantic data model

Put data in context

The next step is to build user friendly views on the data. While this is scope belonging mostly to the surveillance platform, it is important to ensure that the users can easily assess the data quality (for example through color coding indicating old data, out of bounds data, frozen data, etc.), that trends can easily be accessed for a long time period, that the alarms are displayed next to the relevant data, etc.

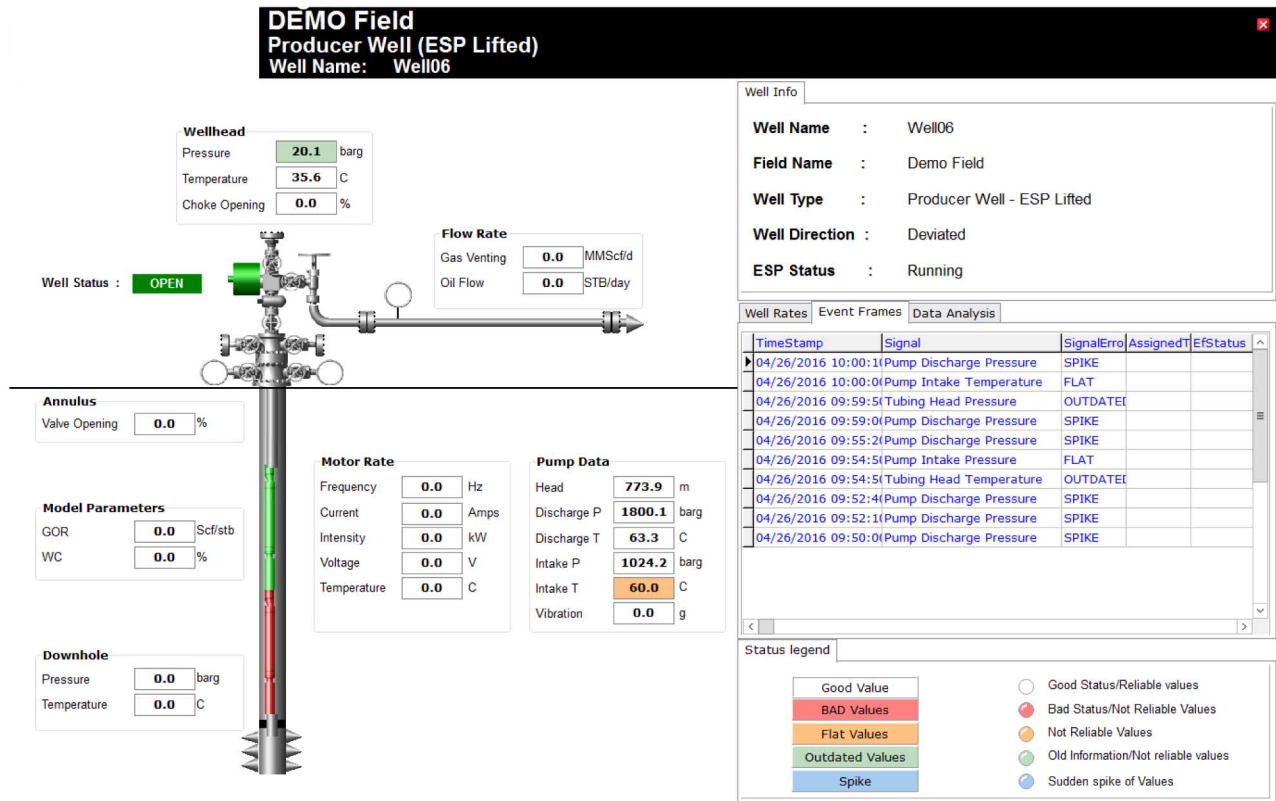


Figure 7—Example of data contextualization

Automate repetitive tasks and reporting

While there are many repetitive tasks occurring in the daily routine of field personnel, this section focuses solely on the automation of reporting.

Data management systems nowadays most often include the ability of generating report automatically. These reports can be for official purposes (daily production, monthly production, etc.) or technical purposes (failures over last week, wells uptime, losses, etc.). The data management solutions also often include the ability of performing simple calculations on the fly. Uptime of the wells can easily be computed based on a set of raw measurements. Losses can be automatically computed by cross-checking production figures with targets or forecast data.

The reports can either be automatically generated in a "hard" format (such as PDF) and distributed automatically through e-mail. A more modern approach consists in having web applications publishing these reports on-demand. The advantage of web applications is that they can be accessed from virtually anywhere, and any report can be generated on-the-fly, simply for information, or issued as a hard copy for official broadcasting.

As stated before, there are numerous advantages to automating these processes. Not only does it save precious time for the field personnel, it also guarantees timely issuing the reports, provides flexibility to generate the reports on-the-fly and ensures traceability of the figures.

Note that in numerous cases, these figures still need human correction. This capability can be implemented within the system, and can keep track of the changes applied, as well as the reason for which the changes applied, and the author of the changes.

Production surveillance

Implementing a production surveillance platform is key to the efficiency of the operations, as well as for guaranteeing a satisfactory level of understanding of the filed performance.

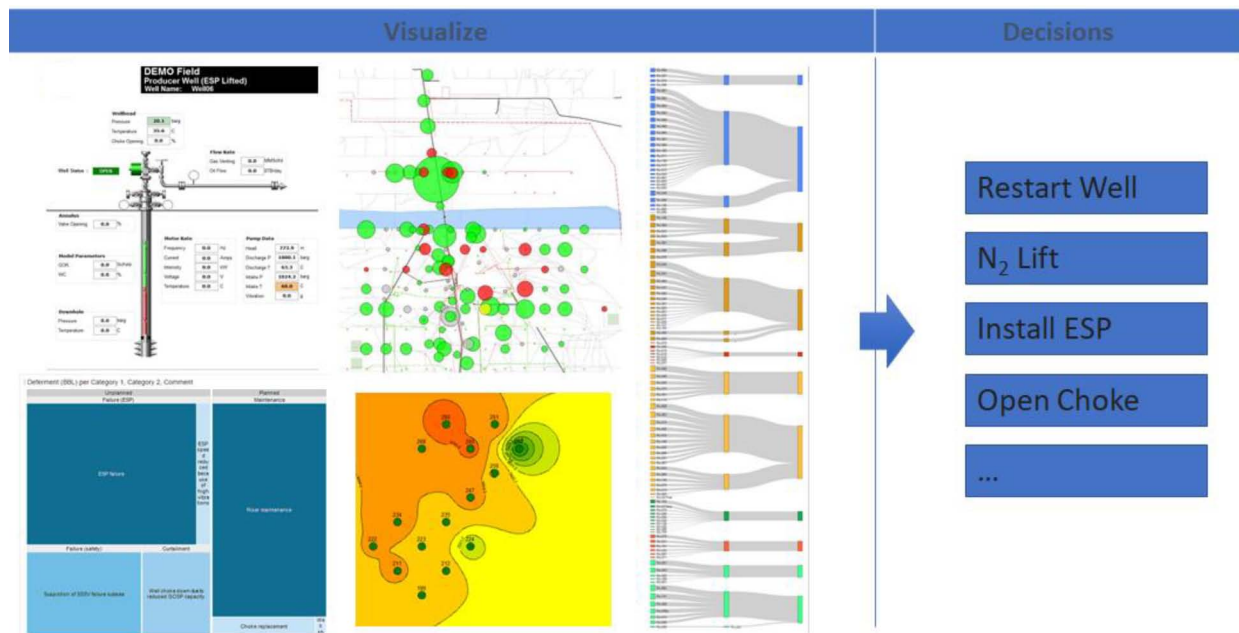


Figure 8—Examples of production surveillance visuals

The main objectives of a surveillance platform are as follows.

Enable exception based surveillance

Typically, brown fields feature many wells. In this perspective, it is particularly inefficient to cycle through these wells for identifying issues. Not only is it a time-consuming process, but most importantly, the reaction time is very long when issues arise. It is not unusual to discover that wells are not producing anymore, that their performance has severely degraded, that a pump has severe damage due to extended operation outside its operating envelope, or, in the worst cases, that a producer has started injecting rather than producing due to poor back-pressure management.

The exception based surveillance system allows building priority lists for well inspection by automatically analyzing the sheer amount of data produced. The rules can be as complex as required. Examples include identifying well stopping producing, wells producing below target, pumps operating outside their range, etc.

An exception based surveillance system should also include the ability to track the remediation actions, and escalate issues to appropriate party, by using Business Process Management engines (Yero, J., 2010).

Alarms center

Having all the data at its disposal, the production surveillance platform is well positioned for generating different alarms, reducing the reaction time.

The typical alarms are generated instantly, based on thresholds (low and high bounds). While these types of alarms are a good first step, more advanced approaches are most suited to identify the real cause of a problem, and avoid overloading the users with useless alarms, which is a typical cause for ignoring them.

For example, the use of predictive analytics allows triggering alarms much earlier than the classical alarms. A model is used for predicting the expected behavior of a specific piece of equipment, and alarms are triggered if the actual measured behavior differs from the expected behavior by a certain threshold (Rawi, Z., 2010) (Gupta, S. et al., 2016).

Another example is to identify periods where a condition is met, rather than spot alarms. This allows much better analysis, as well as evaluation of the frequency and duration of events, leading to additional insights.

Integrate data and provide a single version of the truth

The data integration exercise happening in the data management phase should be leveraged through the production surveillance platform.

The production surveillance platform presents at the same time the official production figures, the raw measurement data, the production targets, the well history including past alarms, the reservoir data (such as reservoir pressures), etc.

This allows the engineers to obtain a complete overview of the data instantly, leading to better understanding, increased work efficiency and accuracy.

Single point of access for engineering analysis

By making such a system easily accessible (for example by using web applications), all engineering departments can access the system and extract data from it for their own calculations.

This also enables non-engineering departments to get an overview on the production, such as higher-level management.

Finally, this is an excellent way to promote collaboration between the different departments, but also between the assets and the specialized teams in headquarters. There are several publications detailing the operating mode between the expert center in the headquarters and the assets, highlighting the benefits associated to such an approach (Couput, J.-P., 2015).

Engineering workflows and model management

Production models

Production models are as essential to the complex engineering workflows as quality data is. While simple well models are sufficient for performing virtual metering and production allocation, more complex integrated models are necessary for performing meaningful production optimization, or short-term production forecasting.

One should keep in mind that building such models is only the first step. Maintaining these models in a ready-to-use state on the long term is usually a bigger challenge and requires significant effort, dedicated workflows for easing the updating process, and proper model management solutions for facilitating collaboration and versioning of these models.

If properly maintained, exploiting models unlocks great opportunities, such as production optimization, evaluation of well potentials, what-if scenarios for further field development, and so on. Extensive literature is available about the benefits of production models and integrated asset modeling (Rotondi, M. et al., 2008) (Shere, A. J. et al., 2010).

In a brown field situation, the ratio "cost over benefit" should be carefully evaluated though, and simple production models might be sufficient for easy applications.

Virtual meters and allocation process

Virtual metering is an interesting workflow for brown fields. It requires only simple well models (and not a fully integrated asset model), and provides a cost-effective alternative to physical flow meters, even though they will always be subject to higher uncertainty as their physical counterpart, and still requires accurate well test data for good calibration. For further information about the accuracy of virtual meters in different instrumentation conditions, please refer to "Evaluation of Commercially Available Virtual Flow Meters" (Amin, A., 2015)

Evaluation of the flow rates per phase for all the wells proves an extremely useful piece of information for multiple purposes; it is the base for proper allocation, it is a diagnosis of well performance, it is the base for losses management, and allows much finer diagnostics when analyzing field production variations than by relying solely on well test figures extrapolation. Accurate rates are also the basis for all reservoir characterization activities.

Once the rates are evaluated on a continuous basis, the allocation process can be automated relatively easily, by cross checking the sum of the rate estimates against the measured production at the system export point. Automating the back-allocation process, while still supervised by field personnel, enables significant time savings, as well as increased accuracy for reservoir characterization and diagnostic of well performance.

Advanced workflows: short term production forecasting and production optimization

Production optimization and forecasting workflows are extremely powerful tools, but also have heavy requirements for the underlying models.

A meaningful production optimization will require an integrated asset model. At the very least, the wells, network and basic facilities should be represented in a same model. The constraints also need to be accurately captured within this integrated model, or the optimization suggestions will be meaningless.

The optimization opportunities are significant in large brownfields though; proper management of production routing (distributing optimally the production between different gas and oil separation plants, and optimizing the back-pressures) alone might lead to significant improvements. Optimization of the artificial lift systems, such as electrical submersible pumps or gas lift, often encountered in brown fields, might also lead to significant improvements.

A short term (up to 90 days) forecasting workflow can significantly increase the accuracy of the production outlook, leading to lower risks in the operations, and better fulfillment of the contractual obligations. Such a workflow will require a reservoir description, coupled with the wells, network and facility models. Ideally, this workflow will take the maintenance planning activities into account as well.

These workflows are heavily relying on the success of the previous phases of the implementation of Digital Oilfield. It is important to consider these only once the organization has already adopted the basic elements of the program, such as data management practices and the production surveillance platform.

For brown fields with little remaining lifetime, it might be more appropriate to perform optimization and forecasting manually, since the implementation of automated workflows is likely to pay off only on the longer term.

Benefits at each stage of the project

In the introduction of this paper, it was claimed that a step-by-step approach was an appropriate way to implement digital oilfield for brown fields, and that each step would deliver value on its own, allowing for gradual investment, and evaluation of added value at every step.

The data management piece mainly increases the reliability and the robustness of the operations. It contributes to every other phase and enables efficiency gains through easy data access. This is arguably the most important step, and should always be the first step (Kingsley, I. et al, 2016).

The automated reporting increases the visibility on operations, the traceability of the figures, and allows for significant time gains (Ahmad, Z. I. B. et al., 2016).

The production surveillance system allows for faster reaction time, and hence decreased losses, time savings through instantaneous information availability, as well as increased collaboration and efficiency. This is a key component for enabling remote surveillance, and allow to exploit the expert centers in the headquarters (Van Den Berg, F. G. et al., 2012).

The engineering workflows are the most complex piece to put in place, but also the ones with the highest potential for production gains and optimized financial performance. Provided that the underlying models are maintained up-to-date, these unlock further optimization opportunities, improved accuracy, predictability, and longer-term reservoir management. Large brown fields, with complex network and artificial lift systems are good candidates for continuous optimization (Wee, T. et al., 2008).

Key human success factors

The success or failure of digital oilfield solutions still hinges heavily on the human factor. The human success factors in Digital Oilfield are not specific to the brown field, but remain applicable.

Start from the user requirements to design the platform, and not the other way around

It is easy to design a very advanced system from a remote location, and fail to tackle the actual issues faced by the field personnel, hence leading to rejection and obsolescence of the system.

While it is an economical solution to try and template a DOF solution into a "one size fits all", and deliver standard workflows or dashboards, this approach is unlikely to draw enough user acceptance.

A much more successful approach is to engage with the technical personnel directly to understand what is the bulk of their day-to-day job, and discuss with them the available solutions. This will steer the program into the right direction, and help staging the project according to priorities.

Involve all stakeholders from the start

No one likes to be forced into using or maintaining a system which one did not have any input with at the time of design. Therefore, it is very important to discuss with all stakeholders at the start of the project. The stakeholders having only a minor involvement in the project will naturally limit their involvement, and progressively, only the core team will emerge, hence allowing the meetings to remain efficient.

The typical stakeholders of a DOF project are the petroleum engineers, the reservoir engineers, the operators, the IT department, and the line management.

Develop in-house DOF champions

DOF systems need to be constantly promoted, without commercial agenda. For doing so, the most efficient method is to dedicate (at least part time) an engineer to the use, maintenance and promotion of these systems. Such "champions" can handle in-house training, provide a first point of contact for feature requests or technical questions, develop a roadmap for further developments and constantly evaluate the adequacy of the DOF system with the actual day-to-day job, which external personnel is unlikely to fully comprehend.

Developing in-house champions is probably the most important step in order to realize the full benefit of DOF.

Plan for appropriate training

Even though the greatest efforts are made into designing user friendly systems, not all capabilities are self-explanatory. Therefore, it is particularly important to plan the right trainings at the right time. Appropriate training does not necessarily mean a lot of training. A "train the trainer" approach, whereby the in-house champions are providing local training, has proven to be a cost-effective approach, which also greatly

simplifies the logistics, and ensure that the training is always focused on the actual challenges of the operations.

Invest in high quality support

DOF users will very quickly lose faith in the system if it goes offline regularly, or for extended periods of time. At the same time, they will also stop using the system in case of erroneous calculation, or missing critical feature.

It is very important to be able to respond to these issues quickly, and with the appropriate level of expertise. While local IT support is crucial for the first line support (troubleshooting of network issues, maintenance of the servers, etc.), it is often necessary to ensure a second and third line support, with higher level of expertise in DOF.

Keep DOF evolving

A living system is constantly evolving, and not progressing is going backwards with DOF systems. Users will inevitably bump into limitations, identify unfriendly behaviors and have additional requests when using the system. To promote the use of DOF systems, such requests should not remain unanswered, or the users will get frustrated and eventually revert back to a more flexible but unmaintainable solution, such as Excel.

There should be a budget provision for continuous evolution of the system, even small, to accommodate the feature requests of the most frequent users. They are more likely to turn into champions themselves, hence contributing to further use of the system.

Conclusion

The main conclusion of this paper is that Digital Oilfield can deliver value for brown fields, even if they are close to their life end, provided that a practical approach is adopted and its core principles are adapted. The relatively low cost of these solutions, and the immediate benefits they can provide makes it meaningful, even in a short-term perspective.

The main differences with application to green fields are an increased focus on data quality improvement, and a lower focus on models and complex engineering workflows, which require a higher investment and workforce for being built and maintained. The surveillance platform should also focus more intensively on exception based surveillance, allowing to pre-process large amounts of data, rather than providing extremely fine detail.

Another conclusion of this paper is that a gradual approach lowers both the project risks and the required initial investment, while easing the adoption process by the users. While this conclusion remains true for all digital oilfield projects, a brown field situation is ideal for such an implementation, since there is lower emergency and less strict deadlines than in a green field project.

Such an approach also allows to determine the required complexity and depth of the digital oilfield initiatives, based on tangible results. An evaluation of the benefits and costs after each phase allows the decision makers to make the most meaningful decisions regarding continuing the program, or maintaining the current implementation.

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